Water Quality Trends
Ohio River And Its Tributaries

ORSANCO

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Ohio River Valley Water Sanitation Commission

Water Quality Trends
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Statistical analyses of data resulting from
water quality monitoring conducted by ORSANCO

Water Quality Assessment Program

Ohio River Valley Water Sanitation Commission
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TABLE OF CONTENTS

INTRODUCTION 1
    Requirements for Tests of Trend 1
    Objective 1

DATA AVAILABILITY 2
    Commission Monitoring Activities 2
    Parameters Investigated 3
    Manual Monitoring System Stations 4
    Record Length 4
    Sample Collection Techniques 6

SEASONAL KENDALL TEST 6
    Problems Using Tests of Trend 6
    Description of the Seasonal Kendall Test 6
    Advantages to Using Seasonal Kendall Test 8
    Limitation of the Seasonal Kendall Test 9
    Seasonal Kendall Slope Estimator 9

RESULTS 9
    Total Suspended Solids 11
    Total Dissolved Solids 16
    Hardness 16
    Sulfate 16
    Total Phosphorous 16
    Ammonia Nitrogen 17
    Total Kjeldahl Nitrogen 17
    Nitrate/Nitrite Nitrogen 17
    Total Nitrogen 17
    Phenolics 18
    Copper 18
    Iron 18
    Lead 18
    Mercury 18
    Zinc 19

DISCUSSION 19
    Overall Observations 19
    Explanation of Trend Assessments 22

CONCLUSION 24

LITERATURE CITED 26

TABLES

Table 1 Manual Monitoring Stations Used for Trend Assessment 5

Table 2 Sampling Techniques Used for Collecting Manual Monitoring Data 7

Table 3 Seasonal Kendall Test on Flow-Adjusted Concentration 10

Table 4 Seasonal Kendall Slope Estimator Test on Flow-Adjusted Concentration 12

Table 5 Trend Category Counts and Weighted Values 13

Table 6 Number of Comparisons on Flow-Adjusted Concentration 20

Table 7 Dischargers on the Ohio River with Permit Limits for the Study Parameters 21

FIGURES

Figure 1 Difference Between Seasonal Kendall Test and Kendall's Tau 8

Figure 2 Map of Total Suspended Solids 14

Figure 3 Bar Charts of Total Suspended Solids - Trend Assessment Slope Estimator 15

APPENDICES

Appendix A Quality Assurance Plan for Manual Sampling

Appendix B Seasonal Kendall Test Methodology and Formulas

Appendix C Sample Pages of Residuals Analyses for Three Models

Appendix D Annual Mean of Concentration for Each Station

Appendix E Z-Statistic Table

Appendix F Trend Direction Maps and Slope Magnitude Bar Charts

PREFACE

The Seasonal Kendall Test has been used for evaluating trends in water quality data by several government agencies including the United States Geological Survey, Pennsylvania Department of Environmental Resources and Maryland Department of the Environment. The evaluation of trends of Ohio River water quality was based on the U.S. Geological Survey paper, "A Study of Trends in Total Phosphorus Measurements at NASQAN Stations," written by Richard A. Smith, Robert M. Hirsch and James R. Slack (1982). Information regarding the appropriate use of the Seasonal Kendall Test was derived from this paper. Software used for the evaluation was a LOTUS123® macro originally developed by Rod Kime of the Pennsylvania Department of Environmental Resources. Modifications to the macro were required to accommodate our study design. Permission to use the LOTUS123® macro is greatly appreciated. J. Shermer Garrison from Maryland Department of the Environment generously shared computer programs of his trends assessment study methodology and some of his experiences with the Seasonal Kendall Test.

INTRODUCTION

Trend studies are undertaken to determine the effectiveness of water pollution control efforts. This is an important question for agencies like the Ohio River Valley Water Sanitation Commission (ORSANCO). Large amounts of money have been spent on water pollution control efforts in the Ohio River Basin and ORSANCO is responsible for many standards which dischargers to the Ohio River must meet. Being able to statistically quantify improvements in water quality is a means of measuring the benefit of the money spent on water pollution control.

Applying the Seasonal Kendall Test to monthly monitoring data collected by the Commission establishes if trends in water quality exist in the Ohio River based on statistical tests. The test also determines if those trends are decreasing or increasing trends. A trend has been defined as a steady increase or decrease in data observations over time (Bauer et al., 1984).

Requirements for Tests of Trend

Assessment of long-term trends testing requires a consistent data set over time and a testing method which accounts for water quality parameters that vary seasonally and with stream flow. The Commission's Manual Monitoring System has produced a substantial data set resulting from the analysis of samples. The samples are collected monthly in a consistent manner which provides a database suitable to test for trends.

The Seasonal Kendall Test provides methods which screen out any variations of a parameter concentration due to flow. This makes the test superior to other trend assessment methods.

Objective

The objective of the long term trends program is to identify quantifiable trends in the Ohio River Basin water quality over time. This allows an identification of successes in water quality improvement and of problems yet to be addressed. The Seasonal Kendall Test was selected to establish trends for Ohio River Basin water quality. The results of the Seasonal Kendall Test indicate the statistical probability of a trend at a particular station for a specific parameter and the direction of that trend.

DATA AVAILABILITY

Commission Monitoring Activities

The Commission operates several water quality monitoring systems, including a Water Users Network, Electronic Monitors, Organic Detection System (ODS), Manual Monitoring System (MMS), Fish Population survey and Fish Tissue Contaminant monitoring. Unfortunately, because a consistent and sufficient data base is required for doing trends assessments, the MMS data is best suited for analysis of trends using the Seasonal Kendall Test.

The Water Users Network has provided data from as early as 1908, but due to the voluntary nature of the program the data are not consistent in terms of parameters and monitoring frequency. Because of inconsistencies and gaps in the data set, the Water Users data cannot be used for the assessment of trends.

The Electronic Monitors measured temperature, specific conductivity, pH, and dissolved oxygen from 1960 to 1986. The data set is extensive but gaps exist. Several changes in the location of stations also contribute to inconsistencies in the data set. The Electronic Monitors data is not easily accessible and is not considered the best candidate for trend assessment at this time.

The ODS was initiated in 1978 and provides data on selected organic parameters. The size of the data set would be sufficient, but most of the values are below the detection limit. Eventually ODS data could be used for long term trends assessment. A statistically valid means of addressing such data sets must be identified in order to apply trends analysis to the ODS results.

Fish Population data and Fish Tissue Contaminant data are not currently available for long term trends assessment. These are being entered into a data base, and are being subjected to quality assurance checks. At some point in the future the data may be suitable for trend analysis.

The MMS has been in operation since 1975. The system consists of monthly collection of data for many conventional parameters. There are sufficient detections for several of the parameters which give an indication of water quality. The data base is easily accessible and there is confidence in the quality of the MMS data. The Quality Assurance Plan for Manual Sampling is attached as Appendix A. A fixed-sampling schedule, like that of the Commission's MMS, is particularly well suited for seeing variability in the data and for detecting trends (Smith et al., 1982).

Parameters Investigated

The Commission measures several parameters in its monthly MMS using United States Environmental Protection Agency (U.S. EPA) methods and stores the resulting data in the STORET data base. STORET is a storage (STO) and retrieval (RET) system available to ORSANCO through U.S. EPA. Those parameters for which sufficient data was collected for use in the Seasonal Kendall Test are included in this study. They are as follows:

1. Total Suspended Solids (TSS)
2. Total Dissolved Solids (TDS is calculated from Conductivity)
3. Hardness
4. Sulfate
5. Total Phosphorus
6. Ammonia-Nitrogen
7. Total Kjeldahl Nitrogen (TKN)
8. Nitrate/Nitrite Nitrogen (N/N)
9. Total Nitrogen (sum of N/N and TKN)
10. Phenolics
11. Copper
12. Iron
13. Lead
14. Mercury
15. Zinc

Total dissolved solids is calculated from conductivity values using the formula:

TDS (in mg/l) = 0.625 * measured conductivity (in umhos/cm).

This equation is based on regression analysis of Ohio River water column samples. Total nitrogen is simply the sum of nitrate/ nitrite nitrogen and total Kjeldahl nitrogen. All other values are actual measured concentrations from STORET.

The Seasonal Kendall Test is applied to the calculated flow-adjusted concentrations of monitoring data (transformed data). The flow-adjusted values are derived using an equation model describing the relationship between flow and concentration, then removing the influence of this relationship from actual concentrations. The relationship between flow and concentration is estimated and used to provide a conditional expected value of concentration. Flow adjusted concentration is defined as the actual concentration minus the estimated conditional expected concentration (Smith, et. al., 1982) resulting in a residual.

The rationale for using residuals in trend analysis is to look for a trend in whatever remains once the relationship between flow and concentration has been removed. Theoretically, if there is no other influence on concentration, the residuals that remain should fluctuate randomly about zero. If there is another influence on concentration, it will result in a positive or negative trend according to the Seasonal Kendall Test.

Manual Monitoring System Stations

There are thirty-five stations at which monthly samples were taken for each parameter used in the analysis. The monitoring stations at which data are collected are listed in Table 1. Because sampling of the nutrient parameters was not performed year-round at thirteen sampling stations, the resulting data set is incomplete and cannot be included in the calculations. The five nutrient parameters are total phosphorus, ammonia, total Kjeldahl nitrogen, nitrate/nitrite nitrogen , and total nitrogen. Two other stations, at the Cumberland River and Tennessee River lack flow data.

Record Length

The record length chosen in this study is eleven years of data for all stations except Smithland Lock and Dam, which has only six years of data. In October 1986, four stations were moved. In these cases data sets from the old and new locations were combined in order to provide eleven years of data. The combined stations are indicated on Table 1 with an asterisk. The station at Oakmont Water Works (WW) on the Allegheny River was moved 5.9 miles downstream to Pittsburgh WW on the Allegheny River. The combined data set for the Allegheny River contains January 1977 to September 1986 from the Oakmont WW and October 1986 to December 1987 from the Pittsburgh WW. The station at Pike Island Lock and Dam on the Ohio River was moved 2.6 miles downstream to Wheeling WW. The combined data set for Wheeling contains January 1977 to September 1986 from Pike Island Lock and Dam and October 1986 to December 1987 from Wheeling WW. Two dischargers are located between these two sampling stations. The station at Greenup Lock and Dam on the Ohio River was moved 9.7 miles downstream to Portsmouth. The combined data set for Portsmouth WW contains January 1977 to September 1986 from Greenup Lock and Dam and October 1986 to December 1987 from Portsmouth WW. Four major dischargers are located between these two sampling stations. The station at Meldahl Lock and Dam on the Ohio River was moved 27.7 miles upstream to Maysville WW. The combined data set for Maysville contains January 1977 to September 1986 from Meldahl Lock and Dam and October 1986 to December 1987 from Maysville WW. Five major dischargers are located between these two sampling stations.

TABLE 1

MANUAL MONITORING STATIONS USED FOR TREND ASSESSMENT

	STATION	OHIO RIVER MP	TRIBUTARY MP #
1.	Monongahela River at South Pittsburgh	0.0	4.5
*2.	Allegheny River at Pittsburgh WW/	0.0	7.4
	Allegheny River at Oakmont WW	0.0	3.3
3.	South Heights	15.2	
4.	Beaver Falls on Beaver River	25.4	5.3
5.	East Liverpool L&D	40.2	
*6.	Pike Island L&D/Wheeling WW	84.2/86.8	
7.	Hannibal L&D	126.4	
8.	Willow Island L&D	161.8	
9.	Muskingum River at Muskingum L&D	172.2	5.8
10.	Belleville L&D	203.9	
11.	Addison–Kyger Creek	260.0	
12.	Kanawha River at Winfield L&D	265.7	31.1
13.	Gallipolis L&D	279.2	
14.	Huntington WW	306.9	
15.	Big Sandy River at Louisa	317.1	20.3
*16.	Portsmouth WW/Greenup L&D	350.7/341.0	
17.	Scioto River at Lucasville	356.5	15.0
*18.	Maysville WW/Meldahl L&D	408.5/436.2	
19.	Cincinnati WW	462.8	
20.	Little Miami River at Newtown	464.1	7.5
21.	Licking River at Covington	470.2	4.5
22.	North Bend	490.2	
23.	Great Miami River at Elizabethtown	491.1	5.5
24.	Markland L&D	531.5	
25.	Louisville WW	600.6	
26.	West Point	625.9	
27.	Cannelton L&D	720.7	
28.	Green River at Sebree	784.2	41.3
29.	Evansville WW	791.5	
30.	Uniontown L&D	846.0	
31.	Wabash River at New Harmony	848.0	51.5
32.	Smithland L&D	918.5	
33.	Cumberland River at Barkley Dam	920.4	30.6
34.	Tennessee River at Paducah	934.5	6.0
35.	Joppa	952.3	

* Refers to stations that were combined
L&D is Lock and Dam
WW is Water Works Plant
MP is mile point
From point of confluence with Ohio River

Sample Collection Techniques

When combining data sets, there is a slight possibility of undetected discrepancies within a data set due to sampling techniques. The Commission employs various sampling techniques in collecting MMS data depending on the location of the station. For instance, most of the samples taken at water works were tapped from an intake water line. At other stations, such as tributaries or dams, a grab sample is taken directly from the river. Table 2 describes sampling techniques used at each station.

SEASONAL KENDALL TEST

Problems Using Tests of Trend

Problems associated with using tests of trend are seasonality, skewness, and serial correlation (Smith et al., 1982). Not addressing any one of these problems could render the trend testing invalid. Seasonality refers to a season to season cyclical pattern in the data. The problem emerges when a test of trend tries to compare data collected in one month with data collected in a different month. Skewness refers to the lack of symmetry in underlying frequency distribution of the data. It is often due to season or stream flow dependence. If the test of trend chosen is a parametric test, which usually assumes a normal probability distribution of the data, the test will have the problems associated with skewness. Serial correlation refers to natural successive variation in the data over time. Two data points taken close to each other in time will be more similar than two data points taken farther apart.

Description of the Seasonal Kendall Test

The Seasonal Kendall Test is a revised version of Kendall's Tau testing for randomness against trend. Only certain kinds of comparisons are considered acceptable in the Seasonal Kendall Test. The Seasonal Kendall Test permits comparison of data points only within the same month. Kendall's Tau allows comparisons of data points in different months. As a result, fewer comparisons are made using the Seasonal Kendall Test than with Kendall's Tau. Figure 1 shows the basic difference between the two tests. When comparing two data points, the Seasonal Kendall Test determines if the later value is higher, lower or identical to the earlier value and keeps a running tally. A non-parametric test does not consider magnitudes of difference between two data points, simply that there is a difference (Smith et al., 1982). In this way, changes in water quality are recorded.

TABLE 2

SAMPLING TECHNIQUES USED FOR COLLECTING MANUAL MONITORING DATA

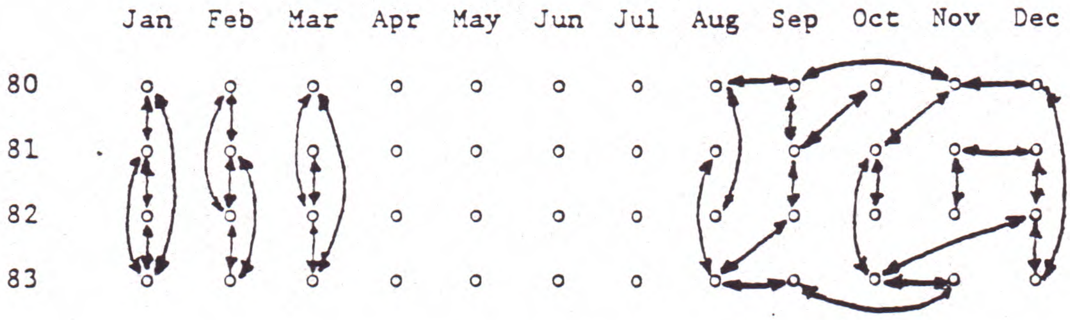
	Station	Technique
1.	Monongahela River at South Pittsburgh	1
*2.	Allegheny River at Pittsburgh WW/	1
	Allegheny River at Oakmont WW	1
3.	South Heights	1
4.	Beaver Falls on Beaver River	1
5.	East Liverpool L&D	1
*6.	Pike Island L&D/Wheeling WW	6/1
7.	Hannibal L&D	6
8.	Willow Island L&D	6
9.	Muskingum River at Muskingum L&D	6
10.	Belleville L&D	6
11.	Addison–Kyger Creek	1
12.	Kanawha River at Winfield L&D	2
13.	Gallipolis L&D	3
14.	Huntington WW	1
15.	Big Sandy River at Louisa	1
*16.	Portsmouth WW/Greenup L&D	1/6
17.	Scioto River at Lucasville	5
*18.	Maysville WW/Meldahl L&D	1/6
19.	Cincinnati WW	1
20.	Little Miami River at Newtown	5
21.	Licking River at Covington	1
22.	North Bend	1
23.	Great Miami River at Elizabethtown	5
24.	Markland L&D	2
25.	Louisville WW	1
26.	West Point	1
27.	Cannelton L&D	3
28.	Green River at Sebree	4
29.	Evansville WW	1
30.	Uniontown L&D	6
31.	Wabash River at New Harmony	5
32.	Smithland L&D	6
33.	Cumberland River at Barkley Dam	2
34.	Tennessee River at Paducah	5
35.	Joppa	1

Technique 1: Tap on intake water line from pumping station
Technique 2: Tap in turbine channel in dam
Technique 3: Collect sample from submersible pump
Technique 4: Grab sample from river near intake structure
Technique 5: Grab sample mid–channel (usually from a bridge)
Technique 6: Grab sample from upstream end of a guidewall to locks

The tally results are used to calculate a monthly statistic and a monthly variance. The sum of the monthly statistics and the monthly variances are used to calculate the z-statistic. The significance of the z-statistic then determines the presence or absence of a trend. The method is described in more detail in Appendix B.

FIGURE 1

DIFFERENCE BETWEEN SEASONAL KENDALL TEST AND KENDALL'S TAU



Seasonal Kendall Test permits comparison of data points only within the same month.

Kendall's Tau permits comparison of any two data points, even between months.

Advantages to Using Seasonal Kendall Test

The Seasonal Kendall Test accounts for seasonality, skewness and serial correlation of the data. Seasonality is removed by comparing data within the same month. For each month, the Seasonal Kendall Test compares data in earlier years to data in later years. The sum of higher, lower and tied comparisons is determined. The Seasonal Kendall Test accounts for skewness because it is a non-parametric test. A non-parametric test does not make assumptions about the underlying distribution of the data (Smith et al., 1982). Skewed water quality data will not affect a non-parametric test. Since the Seasonal Kendall Test does not detect the magnitude of difference between two data points under comparison, the fact that water quality data is serially correlated is unimportant.

Limitation of the Seasonal Kendall Test

Determining the correct record length and having sufficient data available for each parameter under investigation is the greatest limitation to the Seasonal Kendall Test. Record length refers to the number of years included in a data set. A record which is too long can mask the presence of a current trend and a record which is too short will not contain enough data points to distinguish a trend from natural variability in the data. While the choice of record length is essentially arbitrary, Smith et al. (1982) recommend a record length of five to ten years. ORSANCO's MMS data begins in 1975 and continues to the present. The usable data base available for trends assessment is the eleven years from 1977 to 1987.

Only parameters with sufficient data can be used in the Seasonal Kendall Test. Missing values may constitute up to 50% of the observations without diminishing the power of the test (Garrison, 1988).

Seasonal Kendall Slope Estimator

When it has been determined that a parameter exhibits a trend, it may be desirable to estimate the magnitude of the trend. The Seasonal Kendall Slope Estimator was chosen to perform this task. This method expresses the magnitude as a slope (change per unit time). However, this does not imply that a linear trend is assumed.

The Seasonal Kendall Slope Estimator is defined to be the median of the differences of the ordered pairs of data values that are compared in the Seasonal Kendall Test (Smith et. al., 1982). The difference divided by the number of years separating the data is recorded. The median of these differences is then converted to a slope (change per unit time). This process is described in more detail in Appendix B.

RESULTS

The results of the Seasonal Kendall Test of Trend are found in Table 3, Seasonal Kendall Test Results of Flow-Adjusted Concentration. This table contains the evaluation of trends based on the z-statistic. A table showing the z-statistic obtained when applying the Seasonal Kendall Test is found in Appendix E.

TABLE 3

SEASONAL KENDALL TEST ON FLOW-ADJUSTED CONCENTRATION

OHIO MP	STATION	TRIB RM	TSS	TDS	HARDNES	SULFATE	TOTAL PHOS	AMMONIA	TKN	NITRATE/ NITRITE	TOTAL NITRO	PHENOL	COPPER	IRON	LEAD	MERCURY	ZINC
0.0	MONONGAHELA R	4.5	dec	DEC	DEC	DEC	DEC	DEC	DEC	dec	DEC	O	DEC	O	DEC	O	DEC
0.0	ALLEGHENY R	7.4	O	DEC	O	DEC	dec	DEC	DEC	O	DEC	O	DEC	O	O	O	DEC
15.2	SOUTH HEIGHTS		dec	DEC	dec	dec	DEC	DEC	DEC	DEC	DEC	DEC	DEC	DEC	DEC	O	DEC
25.4	BEAVER R	5.3	INC	DEC	dec	DEC	O	DEC	DEC	O	DEC	DEC	DEC	O	DEC	O	DEC
40.2	EAST LIVERPOOL WW		O	DEC	O	DEC	DEC	DEC	DEC	O	DEC	DEC	DEC	DEC	DEC	O	DEC
86.8	WHEELING WTP		O	O	O	O	DEC	DEC	DEC	O	DEC	O	O	O	DEC	O	DEC
126.4	HANNIBAL L&D		O	O	O	O	dec	DEC	DEC	DEC	DEC	DEC	DEC	O	DEC	O	DEC
161.8	WILLOW ISLAND L&D		DEC	O	DEC	O	O	DEC	DEC	DEC	DEC	dec	DEC	O	DEC	O	DEC
172.2	MUSKINGUM R	5.8	O	DEC	DEC	O	:INS:	:INS:	:INS:	:INS:	:INS:	O	DEC	O	DEC	DEC	O
203.9	BELLEVILLE L&D		DEC	O	DEC	O	DEC	DEC	DEC	dec	DEC	O	DEC	O	DEC	O	DEC
260.0	ADDISON-KYGER CR		DEC	dec	DEC	O	DEC	DEC	DEC	O	DEC	DEC	DEC	DEC	DEC	O	DEC
265.7	KANAWHA R	31.1	DEC	DEC	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	DEC	DEC	O	O	O	DEC
279.2	GALLIPOLIS L&D		DEC	DEC	DEC	O	DEC	DEC	DEC	dec	DEC	O	DEC	O	DEC	O	DEC
306.9	HUNTINGTON WATER CO		DEC	O	O	O	O	DEC	DEC	O	DEC	DEC	DEC	DEC	DEC	O	O
317.1	BIG SANDY R	20.3	DEC	INC	inc	O	DEC	DEC	DEC	O	DEC	DEC	O	DEC	DEC	O	DEC
350.7	PORTSMOUTH		O	O	DEC	O	DEC	DEC	DEC	O	DEC	O	DEC	O	DEC	O	O
356.5	SCIOTO R	15.0	O	O	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	O	DEC	O	DEC	O	DEC
408.5	MAYSVILLE WW		O	O	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	O	O	O	DEC	O	O
462.8	CINCINNATI WW		O	O	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	O	O	O	DEC	O	DEC
464.1	LITTLE MIAMI R	7.5	O	INC	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	dec	DEC	O	DEC	O	DEC
470.2	LICKING R	4.5	O	INC	O	inc	DEC	DEC	DEC	O	DEC	DEC	DEC	O	DEC	O	DEC
490.0	NORTH BEND		O	O	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	DEC	DEC	O	DEC	O	dec
491.1	GREAT MIAMI R	5.5	O	O	DEC	O	:INS:	:INS:	:INS:	:INS:	:INS:	DEC	DEC	O	DEC	O	DEC
531.5	MARKLAND L&D		O	O	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	DEC	O	O	DEC	O	DEC
600.6	LOUISVILLE WATER CO		O	O	DEC	O	DEC	DEC	O	O	O	O	O	O	DEC	O	DEC
625.9	WEST POINT		DEC	O	DEC	O	DEC	O	DEC	O	O	O	DEC	DEC	DEC	O	DEC
720.7	CANNELTON L&D		O	O	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	dec	DEC	O	DEC	DEC	O
784.2	GREEN R	41.3	O	INC	inc	INC	DEC	O	O	inc	inc	O	DEC	O	DEC	dec	DEC
791.5	EVANSVILLE WW		DEC	O	O	DEC	DEC	DEC	DEC	O	O	O	DEC	DEC	O	DEC	DEC
846.0	UNIONTOWN L&D		O	DEC	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	O	O	O	DEC	O	O
848.0	WABASH R	51.5	O	O	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	O	dec	O	O	O	O
918.5	SMITHLAND L&D		O	O	DEC	O	:INS:	:INS:	:INS:	:INS:	:INS:	DEC	O	O	O	dec	O
920.4	CUMBERLAND R	30.6	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:
934.5	TENNESSEE R	6.0	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:
952.3	JOPPA		DEC	O	dec	O	DEC	DEC	dec	O	O	O	O	O	O	O	O

INC Strong Significant Increasing Trend; Probability < 5%
Inc Significant Increasing Trend; 5% < Probability < 10%
O No Significant Trend; Probability > 10%
dec Significant Decreasing Trend; 5% < Probability < 10%
DEC Strong Significant Decreasing Trend; Probability < 5%
:INS: Insufficient data available

The flow-adjusted concentration results (Table 3) are plotted on Ohio River maps. The maps give a feeling for spatial arrangement of the results found in Table 3. They also allow for the identification of localized effects. The Ohio River is often divided into three sections: upper, middle and lower. The upper Ohio River is defined as being between river mile 0.0 and 265.7. The middle Ohio River is between river mile 265.7 and 545.8. The lower Ohio River is between river mile 545.8 and 981.0.

Table 4 shows the results of the Seasonal Kendall Slope Estimator Test. The outcome of the test displays the slope of the trend for each parameter at all stations. The slope is shown as change in units of concentration per year. The results of the test were utilized to plot bar charts of the slope magnitude for a single parameter at each station.

Table 5 gives the number of stations for each parameter in each trend category: "DEC" for strong decreasing trend, "dec" for slight decreasing trend, "O" for no trend, "inc" for slight increasing trend and "INC" for strong increasing trend. An evaluation of trends for each parameter basinwide is found by using these trend category counts. Table 5 assigns weighted values for each station and calculates an average weighted value to indicate the strength of an overall trend for each parameter. Each result category is given a value, -2 for "DEC", -1 for "dec", 0 for "O", +1 for "inc" and +2 for "INC". An average weighted value is calculated for each parameter according to the number of stations it has in each result category. An analysis of "strong decreasing trend overall" requires an average weighted value of less than "-1.50". An analysis of "trend in a decreasing direction" requires an average weighted value between -1.00 and -1.50. An analysis of "no trend" requires an average weighted value of -1.00 to +1.00.

Total Suspended Solids

The flow-adjusted concentration values at twelve stations indicate strong decreasing trends. Refer to the map in Figure 2. The strongest decreasing trend occurs at mile point 306.9 with a slope of -12.7 mg/L/year. Refer to the bar chart in Figure 3. There is one strong increasing trend that occurs on the Beaver River with a slope of +2.22 mg/L/year (see Tables 3 and 4). The earlier data at this station may be the cause for the increasing trend.

There is essentially no overall trend, noting an average weighted value of -0.61 from Table 5. Therefore, an analysis of "no trend" is assigned to total suspended solids since the average weighted value is between -1.00 and +1.00.

The maps and bar charts for the remaining parameter analyses can be found in Appendix F.

TABLE 4

SEASONAL KENDALL SLOPE ESTIMATOR TEST ON FLOW-ADJUSTED CONCENTRATION

OHIO MP	STATION	TRIB RM	TSS (mg/l/yr)	TDS (mg/l/yr)	HARDNES (mg/l/yr)	SULFATE (mg/l/yr)	TOTAL PHOS (mg/l/yr)	AMMONIA (mg/l/yr)	TKN (mg/l/yr)	NITRATE/ NITRITE (mg/l/yr)	TOTAL NITRO (mg/l/yr)	PHENOL (ug/l/yr)	COPPER (ug/l/yr)	IRON (ug/l/yr)	LEAD (ug/l/yr)	MERCURY (ug/l/yr)	ZINC (ug/l/yr)
0.0	MONONGAHELA R	4.5	-1.57	-3.30	-1.22	-2.68	-0.008	-0.027	-0.059	-0.009	-0.067	-0.136	-1.28	O	-0.710	O	-5.30
0.0	ALLEGHENY R	7.4	O	-1.80	O	-2.09	-0.002	-0.010	-0.032	O	-0.033	O	-0.62	O	O	O	-1.70
15.2	SOUTH HEIGHTS		-1.42	-1.90	-1.31	-1.81	-0.011	-0.031	-0.073	-0.016	-0.089	-0.419	-1.33	-58.6	-0.437	O	-0.50
25.4	BEAVER R	5.3	2.22	-5.50	-1.13	-1.11	O	-0.055	-0.069	O	-0.079	-0.322	-1.71	O	-0.862	O	-2.80
40.2	EAST LIVERPOOL WW		-2.58	-1.90	O	-1.76	-0.012	-0.034	-0.074	-0.010	-0.088	-0.220	-2.43	-113.4	-0.966	O	-5.80
86.8	WHEELING WTP		O	-1.40	O	O	-0.004	-0.024	-0.047	-0.010	-0.060	-0.114	O	O	-0.634	O	-1.80
126.4	HANNIBAL L&D		O	O	-1.02	O	-0.004	-0.024	-0.028	-0.035	-0.074	-0.233	-1.32	O	-0.348	O	-1.80
161.8	WILLOW ISLAND L&D		-1.11	O	-1.25	-1.53	-0.005	-0.027	-0.049	-0.023	-0.082	-0.160	-1.74	-23.2	-1.009	-0.006	-2.30
172.2	MUSKINGUM R	5.8	O	-5.60	-2.09	-9.24	:INS:	:INS:	:INS:	:INS:	:INS:	O	-1.39	O	-1.252	-0.004	O
203.9	BELLEVILLE L&D		-2.80	-2.10	-2.24	O	-0.008	-0.016	-0.055	-0.055	-0.073	O	-1.58	O	-0.412	O	-1.90
260.0	ADDISON-KYGER CR		-4.82	-2.40	-2.23	O	-0.015	-0.023	-0.056	-0.008	-0.066	-0.367	-4.08	-131.0	-1.082	O	-0.50
265.7	KANAWHA R	31.1	-4.23	-2.70	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	-0.365	-2.41	-52.1	-0.442	O	-3.60
279.2	GALLIPOLIS L&D		-3.31	-3.90	-1.68	-0.84	-0.012	-0.022	-0.050	-0.010	-0.064	O	-2.41	O	-0.530	O	-3.30
306.9	HUNTINGTON WATER CO		-12.71	O	-0.56	O	O	-0.020	-0.090	O	-0.072	0.170	-14.16	-580.7	-1.102	O	O
317.1	BIG SANDY R	20.3	-12.07	2.40	1.14	O	-0.025	-0.014	-0.074	O	-0.066	-0.238	-4.04	-213.0	-1.251	O	-2.90
350.7	PORTSMOUTH		-2.06	-1.90	-0.95	1.02	-0.012	-0.008	-0.045	O	-0.032	O	-1.24	O	-0.551	O	O
356.5	SCIOTO R	15.0	O	O	-2.04	O	:INS:	:INS:	:INS:	:INS:	:INS:	O	-1.65	O	-1.057	O	-2.60
408.5	MAYSVILLE WW		O	O	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	-0.111	O	-52.0	-1.041	O	-1.80
462.8	CINCINNATI WW		O	-1.40	-1.02	O	:INS:	:INS:	:INS:	:INS:	:INS:	-0.154	O	O	-0.522	O	-3.10
464.1	LITTLE MIAMI R	7.5	O	4.90	-2.03	O	:INS:	:INS:	:INS:	:INS:	:INS:	-0.227	-1.24	O	-1.032	O	-3.50
470.2	LICKING R	4.5	O	5.70	O	0.82	-0.018	-0.008	-0.056	O	-0.054	-0.195	-1.03	O	-0.390	O	-12.20
490.0	NORTH BEND		-1.82	O	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	-0.378	-0.88	O	-0.884	0.020	-1.20
491.1	GREAT MIAMI R	5.5	-2.47	O	-3.26	O	:INS:	:INS:	:INS:	:INS:	:INS:	-0.363	-0.57	O	-1.646	0.002	-4.40
531.5	MARKLAND L&D		O	O	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	-0.490	O	O	-1.448	O	-1.60
600.6	LOUISVILLE WATER CO		O	O	-1.52	-0.67	-0.012	-0.009	-0.012	0.013	O	O	O	O	-0.865	O	-1.90
625.9	WEST POINT		-6.38	O	-1.57	O	-0.019	O	-0.022	0.013	O	O	-0.74	-166.9	-1.116	O	-4.40
720.7	CANNELTON L&D		O	O	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	-0.052	-1.11	O	-0.269	-0.021	-0.90
784.2	GREEN R	41.3	O	2.80	1.55	1.73	-0.012	O	O	0.022	0.027	-0.125	-0.38	O	-1.386	-0.011	-1.00
791.5	EVANSVILLE WW		-10.43	O	O	-1.00	-0.020	-0.009	-0.016	O	O	O	-2.78	-182.3	O	-0.003	-5.00
846.0	UNIONTOWN L&D		O	-2.10	O	O	:INS:	:INS:	:INS:	:INS:	:INS:	-0.014	O	O	-0.515	-0.011	O
848.0	WABASH R	51.5	O	-2.00	1.85	O	:INS:	:INS:	:INS:	:INS:	:INS:	O	-0.44	O	O	O	O
918.5	SMITHLAND L&D		-6.55	O	-2.98	O	:INS:	:INS:	:INS:	:INS:	:INS:	-0.664	-0.32	O	O	-0.013	-3.20
920.4	CUMBERLAND R	30.6	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:
934.5	TENNESSEE R	6.0	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:
952.3	JOPPA		-4.64	O	-1.56	O	-0.017	-0.008	-0.014	O	O	O	O	-57.9	O	O	O

O No Significant Correlation; Probability < 90%

:INS: Insufficient data available

TABLE 5

TREND CATEGORY COUNTS AND WEIGHTED VALUES

	DEC	dec	O	inc	INC	Total Avail.	DEC	dec	O	inc	INC	Sum	Avg. * Value
TOTAL SUSPENDED SOLIDS	10	2	20	0	1	33	-20	-2	0	0	2	-20	-0.61
TOTAL DISSOLVED SOLIDS	9	1	19	0	4	33	-18	-1	0	0	8	-11	-0.33
HARDNESS	11	3	17	2	0	33	-22	-3	0	2	0	-23	-0.70
SULFATE	5	1	25	1	1	33	-10	-1	0	1	2	-8	-0.24
TOTAL PHOSPHORUS	15	2	3	0	0	20	-30	-2	0	0	0	-32	-1.60
AMMONIA-N	18	0	2	0	0	20	-36	0	0	0	0	-36	-1.80
TOTAL KJELDAHL NITROGEN	17	1	2	0	0	20	-34	-1	0	0	0	-35	-1.75
NITRATE/NITRITE	3	3	13	1	0	20	-6	-3	0	1	0	-8	-0.40
TOTAL NITROGEN	15	0	4	1	0	20	-30	0	0	1	0	-29	-1.45
PHENOLICS	13	3	17	0	0	33	-26	-3	0	0	0	-29	-0.88
COPPER	23	1	9	0	0	33	-46	-1	0	0	0	-47	-1.42
IRON	7	0	26	0	0	33	-14	0	0	0	0	-14	-0.42
LEAD	27	0	6	0	0	33	-54	0	0	0	0	-54	-1.64
MERCURY	3	2	28	0	0	33	-6	-2	0	0	0	-8	-0.24
ZINC	23	1	9	0	0	33	-46	-1	0	0	0	-47	-1.42

DEC = -2 each
dec = -1 each
O = 0 each
inc = 1 each
INC = 2 each

* - AVERAGE VALUE	
> +1.50	Strong Increasing Trend
+1.50 to +1.00	Increasing Trend
+1.00 to -1.00	No Trend
-1.00 to -1.50	Decreasing Trend
< -1.50	Strong Decreasing Trend

FIGURE 2 - MAP OF TOTAL SUSPENDED SOLIDS

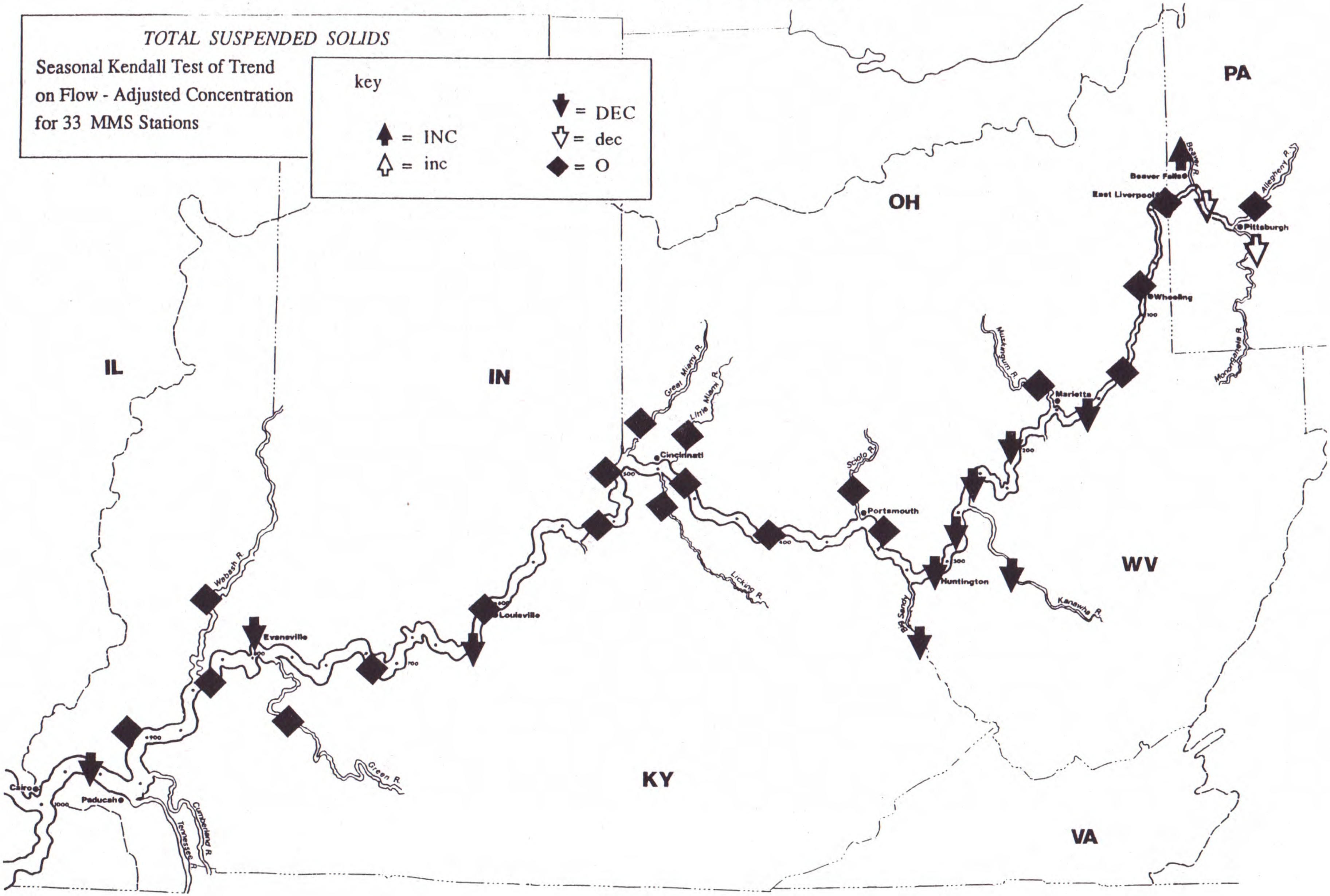
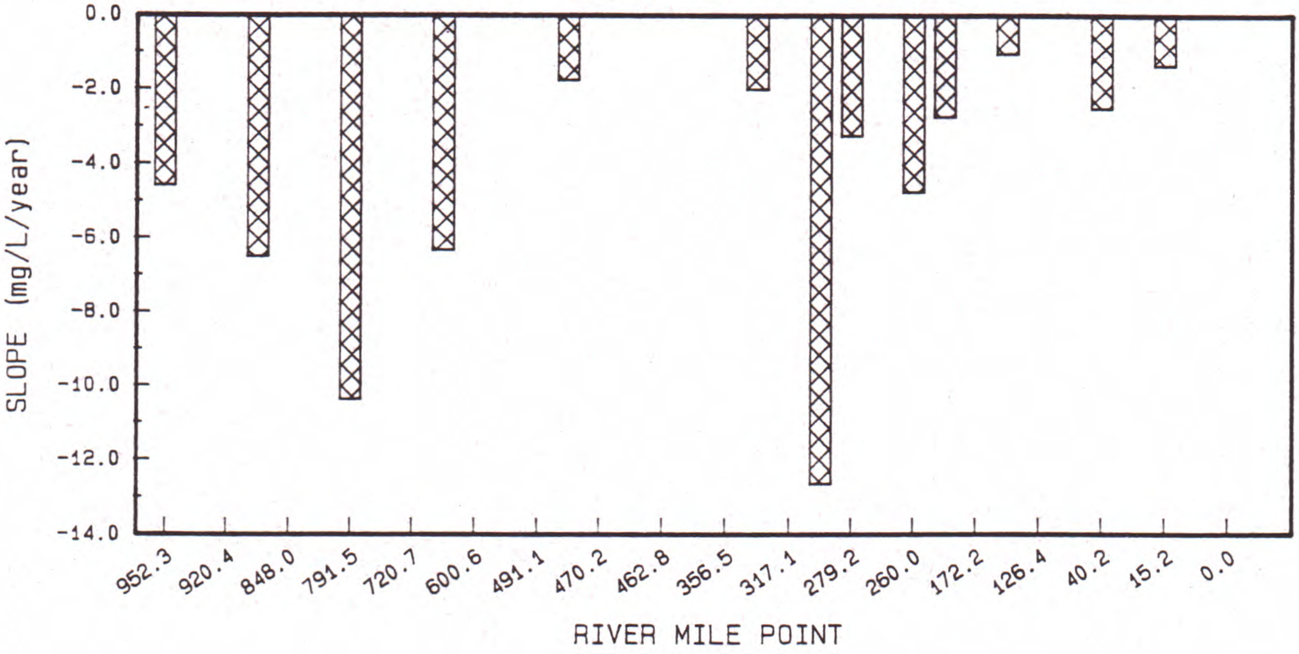


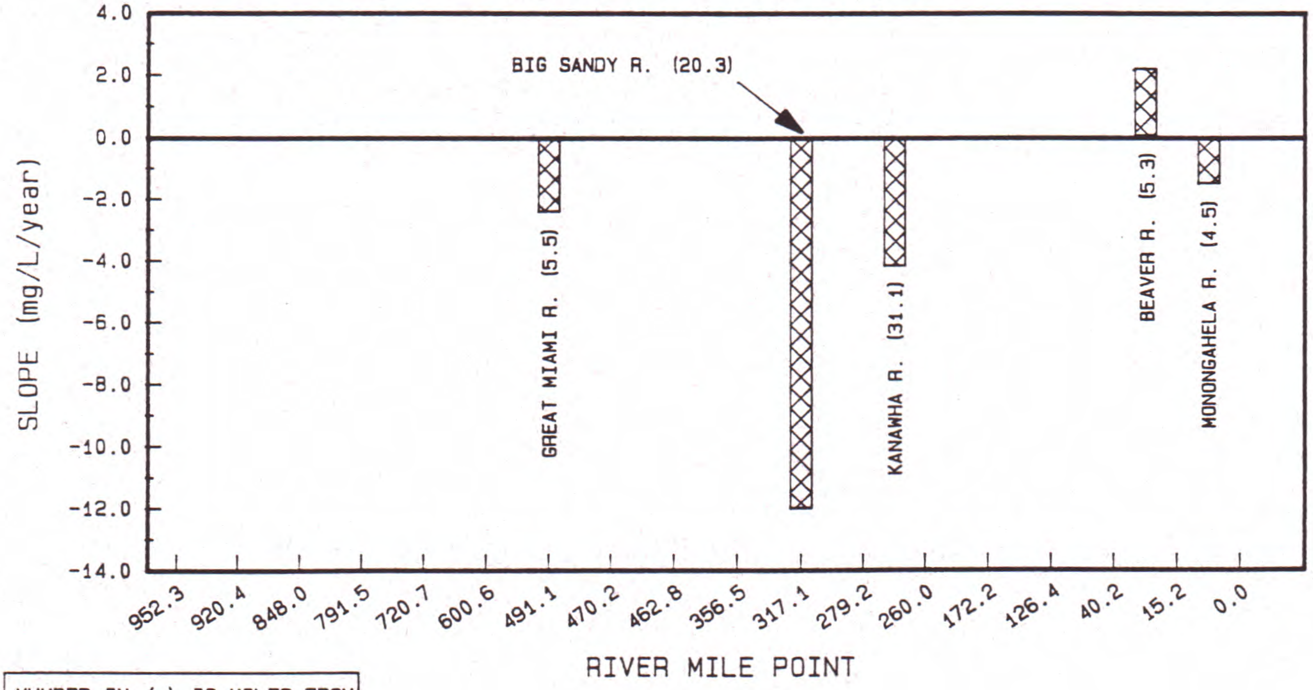
FIGURE 3 - BAR CHARTS OF TOTAL SUSPENDED SOLIDS

TREND ASSESSMENT SLOPE ESTIMATOR

Total Suspended Solids (Main Stem)



Total Suspended Solids (Tributaries)



NUMBER IN ( ) IS MILES FROM
CONFLUENCE WITH OHIO RIVER

Total Dissolved Solids

The analysis of the flow-adjusted concentration displays strong decreasing trends at nine locations and strong increasing trends at four locations. The two strongest decreasing trends occur at the Beaver and Muskingum Rivers with slopes of -5.50 and -5.60 mg/L/year respectively (see Tables 3 and 4). The strong increasing trends take place on the Big Sandy, Little Miami, Licking and Green Rivers. Three of these are Kentucky tributaries and the analysis shows declining water quality with respect to total dissolved solids in these areas. A majority of the stations demonstrate no trend at all which is reflected in the average weighted value of -0.33 (see Table 5). Based on this value, total dissolved solids displays "no trend".

Hardness

Eleven stations display strong decreasing trends and seventeen stations no trend. The strongest decreasing trend occurs on the Great Miami River with a slope value of -2.98 mg/L/year (see Tables 3 and 4). All increasing trends occur at tributary stations located on the Wabash, Big Sandy and Green Rivers. Hardness is evaluated as having "no trend" because of the average weighted value of -0.70 from Table 5.

Sulfate

Trends are shown both increasing and decreasing along the Ohio River for sulfate (see Tables 3 and 4). There are 25 stations that indicate no trend for sulfate which lead to the average weighted value of -0.24 from Table 5. Based on the average weighted value, sulfate is concluded as displaying "no trend". The strongest increasing trends occurred on the Green River and at Portsmouth with slopes of +1.73 and +1.02 respectively.

Total Phosphorous

The flow-adjusted concentration results indicate an overall decreasing trend for total phosphorus. Only three stations show no trend and the remaining stations all display decreasing trends (see Tables 3 and 4). The decreasing trend with the steepest slope of -0.025 mg/L/year occurs at the Big Sandy River monitoring station (see Tables 4 and 5). These decreasing trends lead to an average weighted value of -1.60 from Table 5. Total phosphorus is classified as showing a "strong decreasing trend."

Ammonia Nitrogen

An overall decreasing trend is observed for ammonia. Eighteen stations indicate a strong decreasing trend while only two stations show no trend (see Tables 3 and 4). The steepest slope occurs on the Beaver River with a value of -0.055 mg/L/year. The two stations exhibiting no trend are West Point (625.9) and Green River. The average weighted value for ammonia is -1.80 from Table 5. From this value, ammonia is classified as displaying a "strong decreasing trend." The values may be escalated due to the fact that ammonia does not show a significant correlation with flow. When the influence of flow is removed the resulting residual is magnified.

Total Kjeldahl Nitrogen

Seventeen stations display a decreasing trend while only two show none. The greatest slope magnitude occurs at mile point 306.9 with a value of -0.09 mg/L/year (see Tables 3 and 4). The average weighted value from Table 5 is -1.75 which indicates a "strong decreasing trend." The station showing no trend for total Kjeldahl nitrogen is Green River.

Nitrate/Nitrite Nitrogen

Three stations indicate a decreasing trend and 13 stations show no trend. The station with the greatest magnitude in the decreasing direction is mile point 203.9 (Belleville L&D) with a value of -0.055 mg/L/year (see Tables 3 and 4). From these evaluations the average weighted value was computed to be -0.40. This value (see Table 5) represents "no trend" for nitrate/nitrite nitrogen.

Total Nitrogen

Most stations show a strong decreasing trend for upper and middle Ohio River stations (see Table 3). The decreasing trend with the greatest slope magnitude occurs at South Heights (M.P. 15.2) with a value of -0.089 mg/L/year. Only four stations show no trend for total nitrogen. Since total nitrogen is the sum of total Kjeldahl nitrogen and nitrate/nitrite nitrogen, it is not surprising that Green River station is the only station indicating an increasing trend. The Green River station does not show a negative trend for nitrogen parameters, where most other stations do. This may mark the presence of a problem area. Total nitrogen has an average weighted value of -1.45 (from Table 5) which is classified as a "slight decreasing trend."

Phenolics

Thirteen stations show strong decreasing trends while 17 show none. The strongest decreasing trend takes place at Smithland L&D (M.P. 918.5) with a slope value of -0.664 ug/L/year (see Tables 3 and 4). The average weighted value for phenolics is -0.88 (see Table 5). This value leads to a condition of "no trend."

Copper

The flow-adjusted concentration results indicate 23 stations show decreasing trends while nine show no trend. The decreasing trend with the steepest slope occurs at mile point 306.9 with a value of -14.16 ug/L/year (see Tables 3 and 4). The average weighted value from Table 5 is -1.42. This value indicates a "decreasing trend" for copper.

Iron

Twenty-six stations show no trend for iron, seven displaying decreasing trends and none showing increasing trends. The strongest decreasing trend takes place at mile point 306.9 with a slope magnitude of -580.7 ug/L/year (See Tables 3 and 4 for these values) From Table 5 the average weighted value is -0.42 which indicates "no trend."

Lead

Twenty-seven stations showed decreasing trends and six showed no trend. The Green River was the site of the strongest decreasing trend with a slope magnitude of -1.65 ug/L/year (see Tables 3 and 4). The average weighted value from Table 5 is -1.64 which indicates a "strong decreasing trend" for lead.

Mercury

The majority of the stations show no trend for mercury, five have decreasing trends and none have increasing trends. The largest decreasing trend occurs at mile point 720.7 and has a slope of -0.021 ug/L/year (refer to Tables 3 and 4). The average weighted value from Table 5 is -0.24 which indicates "no trend" for mercury.

Zinc

Twenty-three stations indicate a decreasing trend while nine show no trend for zinc. The Licking River is the site of the largest decreasing trend with a slope of -12.20 ug/L/year (see Tables 3 and 4). The average weighted value is -1.42 which indicates a "decreasing trend" (see Table 5).

DISCUSSION

Overall Observations

The flow-adjusted concentration accounts for the influence of stream flow on concentration and removes this influence from consideration. Reductions in sources of these parameters should result in decreasing trends at many stations for flow-adjusted concentration results. In trying to identify changes in the potential sources of the fifteen parameters, it is only necessary to consider the results of flow-adjusted concentration. Explanations in changes of potential sources are offered as speculations.

Number of Comparisons

The number of comparisons made by the Seasonal Kendall Test is one means of determining the strength of the results. Table 6 shows the number of comparisons made out of a possible 660 at each station of all investigated parameters. By this standard, the results of hardness, phenolics, lead and mercury are relatively weak. The least confidence is held in the results for these parameters. The lower number of comparisons for hardness is due to inconsistent or no monitoring of hardness in 1977 and 1978. The number of comparisons for the other parameters may be higher if concentrations below detection levels were included in the methodology.

NPDES Permit Limits

The Clean Water Act requires dischargers to obtain National Pollutant Discharge Elimination System (NPDES) permits. As shown in Table 7, parameters that are heavily regulated within NPDES permits are total suspended solids, ammonia, copper, iron, lead and zinc. For those parameters that were regulated prior to the study period, the effects of point source controls might not be reflected in the trends unless major control technologies became available. Detailed analysis of permit histories are needed to fully define the relationship between point source controls and in-stream trends.

TABLE 6

NUMBER OF COMPARISONS ON FLOW-ADJUSTED CONCENTRATION

TOTAL POSSIBLE IS 660

OHIO MP	STATION	TRIB RM	TSS (sum)	TDS (sum)	HARDNES (sum)	SULFATE (sum)	TOTAL PHOS (sum)	AMMONIA (sum)	TKN (sum)	NITRATE/ NITRITE (sum)	TOT NITRO (sum)	PHENOL (sum)	COPPER (sum)	IRON (sum)	LEAD (sum)	MERCURY (sum)	ZINC (sum)
0.0	MONONGAHELA R	4.5	574	591	392	611	620	620	591	610	581	292	546	611	195	78	601
0.0	ALLEGHENY R	7.4	554	556	369	482	545	533	545	572	545	248	506	582	125	85	553
15.2	SOUTH HEIGHTS		611	601	385	620	630	630	610	630	610	320	561	630	244	99	621
25.4	BEAVER R	5.3	591	582	376	601	610	610	582	601	573	427	541	600	315	71	610
40.2	EAST LIVERPOOL WW		610	592	384	610	620	620	601	620	601	335	551	620	358	94	611
86.8	WHEELING WTP		640	631	400	640	611	630	611	630	611	358	600	640	261	104	631
126.4	HANNIBAL L&D		515	543	387	543	515	524	517	534	517	224	498	533	171	97	516
161.8	WILLOW ISLAND L&D		591	620	393	610	591	581	592	610	592	300	600	620	262	108	581
172.2	MUSKINGUM R	5.8	620	620	474	650	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	350	610	630	342	117	581
203.9	BELLEVILLE L&D		620	640	408	630	620	610	612	620	602	286	611	640	260	119	610
260.0	ADDISON-KYGER CR		620	650	408	630	620	562	601	620	601	291	630	630	259	110	601
265.7	KANAWHA R	31.1	581	630	432	592	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	247	582	611	150	51	508
279.2	GALLIPOLIS L&D		630	660	416	630	660	630	611	650	621	313	601	630	250	89	591
306.9	HUNTINGTON WATER CO		562	650	416	610	620	454	591	620	591	217	630	641	226	159	199
317.1	BIG SANDY R	20.3	581	591	426	581	580	398	554	574	537	161	580	600	222	82	483
350.7	PORTSMOUTH		505	543	378	505	508	502	516	526	516	237	506	515	175	70	464
356.5	SCIOTO R	15.0	572	573	426	553	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	378	572	582	344	138	512
408.5	MAYSVILLE WW		592	602	385	592	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	257	581	581	258	94	553
462.8	CINCINNATI WW		620	660	409	610	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	274	631	640	283	72	573
464.1	LITTLE MIAMI R	7.5	583	571	433	555	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	350	574	593	349	98	478
470.2	LICKING R	4.5	601	640	435	543	600	529	601	581	562	282	602	631	171	62	439
490.0	NORTH BEND		591	610	379	591	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	191	572	620	294	86	562
491.1	GREAT MIAMI R	5.5	564	620	420	582	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	259	533	594	303	79	563
531.5	MARKLAND L&D		572	601	350	565	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	181	484	538	248	160	436
600.6	LOUISVILLE WATER CO		533	621	409	621	621	525	610	630	610	62	481	620	243	83	439
625.9	WEST POINT		610	620	410	630	620	621	630	630	630	99	409	630	367	95	526
720.7	CANNELTON L&D		583	610	418	630	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	85	365	610	267	101	544
784.2	GREEN R	41.3	612	574	425	621	554	481	631	631	631	81	356	610	267	101	544
791.5	EVANSVILLE WW		620	630	418	650	631	544	650	660	650	114	473	640	319	89	553
846.0	UNIONTOWN L&D		582	585	416	621	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	126	365	641	266	128	464
848.0	WABASH R	51.5	630	620	434	650	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	187	374	640	318	91	519
918.5	SMITHLAND L&D		180	175	175	175	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	19	141	180	86	8	136
920.4	CUMBERLAND R	30.6	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::
934.5	TENNESSEE R	6.0	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::	:::INS:::
952.3	JOPPA		640	660	450	620	562	571	660	660	660	93	453	660	241	49	460
Average Comparisons per Station:			578	596	401	586	597	560	596	610	592	232	519	599	257	92	515

::INS:: Insufficient data available

TABLE 7

DISCHARGERS ON THE OHIO RIVER WITH PERMIT LIMITS FOR THE STUDY PARAMETERS

(Data from ORSANCO's NPDES permit files)

Parameter	
Total Suspended Solids	485 of 574 permits = 84%
Total Dissolved Solids	10 of 574 permits = 2%
Hardness (or Conductivity)	3 of 574 permits = <1%
Sulfate	10 of 574 permits = 2%
Phosphorus	10 of 574 permits = 2%
Ammonia	105 of 574 permits = 18%
Total Kjeldahl Nitrogen	44 of 574 permits = 8%
Nitrate/Nitrite	7 of 574 permits = 1%
Nitrogen	6 of 574 permits = 1%
Phenolics	47 of 574 permits = 8%
Copper	74 of 574 permits = 13%
Iron	100 of 574 permits = 17%
Lead	62 of 574 permits = 11%
Mercury	26 of 574 permits = 5%
Zinc	100 of 574 permits = 17%

Explanation of Trend Assessments

Total Suspended Solids

Total suspended solids have decreasing trends at all stations between Marietta near river mile 175 and Portsmouth near river mile 350. This is especially evident in Figure 2. Localized decreasing trends could be a result of the activities of coal mining in that area. West Virginia and southern Ohio are active coal mining areas. Tighter controls on these operations may be a possible explanation for this localized occurrence. Basinwide, flow-adjusted concentrations for total suspended solids indicate no change in sources during the study period (see summary on Table 5).

Total Dissolved Solids and Hardness

Total dissolved solids and hardness do not display any overall trend. Total dissolved solids and hardness are influenced primarily by natural factors. Localized strong decreasing trends at stations may be due to a short term influence. Groundwater can influence the Ohio River at any point in the basin during low flow conditions. Low flows give higher concentrations of total dissolved solids and hardness, of which would only be seen seasonally.

Sulfate

Overall, sulfate does not display a trend in either direction. However, sulfate does show strong decreasing trends in the upper Ohio River region. This area had a strong steel industry which is now diminishing, and the closing of steel mills may explain the localized effect. Basinwide, flow-adjusted concentrations for sulfate are unchanged (see Table 5), indicating little change in sources.

Total Phosphorus

Flow-adjusted concentrations of total phosphorus are decreasing basinwide (see Table 5). This trend can be attributed to the decrease of phosphates in detergents. Years ago, phosphates from detergents were considered a major factor of in-stream total phosphorus concentrations. Phosphates were banned in laundry detergents by a few Great Lakes States. In recent years, manufacturers changed their products by offering reduced phosphate and phosphate-free detergents. The Ohio River is benefitting from this manufacturing change.

Nitrogen Parameters

Flow-adjusted concentrations of ammonia-nitrogen, total Kjeldahl nitrogen and total nitrogen concentrations are decreasing basin-wide (see Table 5). This is attributed to the improved status of waste water treatment plants since 1977. Based on the Commission's 1978 Annual Report, 47% of waste water treatment plants in the Ohio River basin provided an acceptable level of control. The 1988 Annual Report boasts that 90% of Ohio River Valley communities have secondary treatment in place. During secondary treatment, Kjeldahl nitrogen is converted into ammonia. In the stream, bacteria convert ammonia to nitrate/nitrite nitrogen, which are the appropriate forms for uptake by plants. As might be expected, nitrate/nitrite nitrogen is the only nutrient parameter that remains unchanged.

Phenolics

Phenolics shows a substantial decreasing trend at many locations along the Ohio River, particularly in the upper 260 miles (see the phenolics map in Appendix F). The results of a study conducted by Roy F. Weston, Inc. (1986), links in-stream phenolics concentrations with permitted dischargers along the river. Weston, Inc. (1986) also reports a decrease in phenolics concentrations from the late 1970s to the late 1980s, which corresponds with a decrease in phenolics loadings from permitted dischargers. The decreasing trends of flow-adjusted concentrations for phenolics in the upper Ohio River could be due to the closing of steel mills and better treatment of effluent from those mills that remain open.

Copper

Copper shows a decreasing trend basinwide for flow-adjusted concentrations (see Table 5). It is possible that copper loadings are being reduced in waste water treatment plants as a side effect of treating for other parameters. Since pretreatment requirements for effluent discharged to waste water treatment plants have become more stringent during the study period, increased pretreatment requirements is also a possible explanation.

Iron

The flow adjusted concentrations indicate no trend for iron. Iron is considered a naturally occurring element, therefore control of point source discharges should not change in-stream iron concentrations.

Lead

Lead shows an overall decrease in flow adjusted concentrations. Lead has caused much concern in the past. Many industrial processes no longer use lead, such as in automotive fuels. Limitations for lead in discharge permits have existed even before the Commission's sampling program (see Table 7). Overall decrease is considered principally due to the switch to unleaded fuels.

Mercury

Overall, mercury shows no trend, however one area on the Ohio River indicates a strong decreasing trend for mercury (see mercury map in Appendix F). The area is from Cannelton Lock and Dam to the Wabash River station. Nonpoint source pollution is a major influence in this area. Many years ago, mercury was used as a fungicide on seeds. This practice is now outlawed. Possible explanation is that eliminating the usage of mercury as a fungicide on seeds has removed this nonpoint source influence on the Ohio River. This possibility needs to be confirmed by pesticide manufacturers. Most Ohio River stations indicate no trend in mercury during the study period (see Table 3). The mercury data base contains many missing values and concentrations below detection levels. The number of comparisons made by the Seasonal Kendall Test is one means of determining the strength of a trend assessment. Mercury contains the least number of comparisons for flow-adjusted values in Table 6. By this standard mercury results rate very weak.

Zinc

Zinc displays an overall decreasing trend for flow adjusted concentrations. Zinc is used industrially in galvanized steel. The steel industry and metals industry can easily remove zinc from their effluent through precipitation processes. Besides a failing steel industry, another explanation for decreasing trends in zinc is the stringent pretreatment requirements of publicly-owned treatment works on dischargers. Pretreatment is now the responsibility of the discharger as opposed to the receiving facility. Ohio River water quality is benefitting from this practice.

CONCLUSION

The intent of determining these trends is to identify changes in water quality and identify possible areas of concern in the Ohio River Valley. A non-parametric test, such as the Seasonal Kendall Test, indicates if there is a trend in water quality. For the Ohio River Basin, improvements (decreasing trends) are seen for several parameters. Overall decreasing trends are indicated for total phosphorus, ammonia, Kjeldahl nitrogen, total nitrogen, copper, lead and zinc during the study period. Several factors contribute to these water quality trends, including improvements in the status of waste water treatment plants, stringent permit requirements on dischargers, and reduced use of certain products contributing to nonpoint source pollution. Parameters that remain unchanged are total suspended solids, total dissolved solids, hardness, sulfate, nitrate/nitrite, iron, phenolics, and mercury.

The trend results generally appear to be favorable and document the effectiveness of past efforts of improving water quality on the Ohio River.

By incorporating the Seasonal Kendall Slope Estimator, the magnitude of the trends is estimated. The magnitude gives an idea of the change in concentration per year. The reader may be more interested in the magnitude of trends as opposed to simply the existence of a trend. Knowing trend magnitudes allows a better visual perspective on the rate of trend development.

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APPENDIX A: QUALITY ASSURANCE PLAN FOR MANUAL SAMPLING

QUALITY ASSURANCE WORK PLAN
FOR
MANUAL SAMPLING NETWORK

Ohio River Valley Water Sanitation Commission
49 E. Fourth Street, Suite 300
Cincinnati, OH 45202

December 1988

PROGRAM NAME: Manual Sampling Network

PROGRAM INITIATION: 1975 (last revised August 1986)

PROGRAM OBJECTIVE: To provide data on certain chemical and physical parameters for water quality assessments.

PROGRAM DESCRIPTION:

The Manual Sampling Network consists of monthly collection and analysis of river water samples at 36 locations on the Ohio River and the lower reaches of the major tributaries. The analytical parameters selected and the frequency of sampling are designed to provide information needed to appraise water quality conditions at each location and for general assessment of the river as a whole. Most parameters are analyzed monthly except for the nutrient parameters which are omitted at fifteen stations from November through April. Certain metals are analyzed quarterly. Laboratory analyses are obtained on a contract basis with state agency and commercial laboratories certified by US EPA.

MONITORING NETWORK DESIGN:

Manual sampling locations, parameters and sampling frequency are reviewed annually by the Monitoring Strategy Subcommittee to assure the program is responsive to the water quality data needs of the participating agencies. Sampling locations are selected to provide coverage:

- Upstream and downstream of major population and/or industrial centers on the Ohio River.
- In high water use areas such as public water supply intakes and recreational areas.
- At or near the point of confluence of major tributaries and interstate boundaries.

Since flow measurements are essential to accurately assess water quality impacts, stations are also sited where flow data is available. Descriptions of the current Manual Sampling stations are provided in Attachment A, Table 1.

MONITORING PARAMETERS AND FREQUENCY:

Water samples are collected each month as grab samples at the designated site. If access to the site is not available, the sample is taken at the nearest convenient point and duly noted on the sample report form. Samples are collected so as to arrive at the laboratory on a weekday (Monday through Friday) and within 24 hours. Parameter analysis schedules are listed for each station in Attachment A, Table 2.

PROGRAM ORGANIZATION AND RESPONSIBILITY

The following is a list of key program personnel and their corresponding responsibilities:

Part-time Field Investigators	- sampling operations
Coordinator of Field Operations	- sampling QC - performance and system audits - overall program coordination
West Virginia DNR Laboratory	- laboratory analysis/QC
Computer Operator	- data processing activities/QC
Monitoring Programs Manager	- data quality review - overall QA

PARAMETER TABLE:

PARAMETER	NUMBER OF SAMPLES	SAMPLE MATRIX	ANALYTICAL METHOD	SAMPLE PRESERV.	HOLDING TIME
Temp	432	Water	STD Method 212	none	Field Test
pH	432	"	EPA 150.1	none	Field Test
DO	432	"	EPA 360.1	none	Field Test
Sp. Cond.	432	"	EPA 120.1	Cool 4°C	28 days
Susp. Solids	432	"	STD Method 209	Cool 4°C	7 days
Alkalinity	432	"	STD Method 403	Cool 4°C	14 days
BOD	342	"	STD Method 507	Cool 4°C	48 hours
Sulfate	432	"	STD Method 426	Cool 4°C	28 days
Chloride	168	"	STD Method 407	Cool 4°C	28 days
Hardness	432	"	STD Method 314	Fix pH<2 HNO3	6 months
Cyanide	432	"	EPA 335.2	Fix pH>12 NaOH	14 days
Phenolics	432	"	STD Method 510	Fix pH<2 H2SO4	28 days
P (TOT)	342	"	EPA 365.2	Fix pH<2 H2SO4	28 days
ortho-P	342	"	EPA 365.1	Cool 4°C	48 hours
TKN	342	"	STD Method 420	Fix pH<2 H2SO4	28 days
Ammonia	342	"	STD Method 417	Fix pH<2 H2SO4	28 days
NO3-NO2	342	"	STD Method 418	Cool 4°C	28 days
Aluminum	432	"	EPA 202.1	Fix pH<2 HNO3	6 months
Arsenic	432	"	EPA 206.3	Fix pH<2 HNO3	6 months
Barium	144	"	EPA 208.1	Fix pH<2 HNO3	6 months

PARAMETER	NUMBER OF SAMPLES	SAMPLE MATRIX	ANALYTICAL METHOD	SAMPLE PRESERV.	HOLDING TIME
Cadmium	432	"	EPA 213.2	Fix pH<2 HNO3	6 months
Chromium	144	"	EPA 218.2	Fix pH<2 HNO3	6 months
Copper	432	"	EPA 220.2	Fix pH<2 HNO3	6 months
Iron	432	"	EPA 236.2	Fix pH<2 HNO3	6 months
Lead	432	"	EPA 239.2	Fix pH<2 HNO3	6 months
Magnesium	432	"	EPA 242.1	Fix pH<2 HNO3	6 months
Manganese	432	"	EPA 243.2	Fix pH<2 HNO3	6 months
Mercury	432	"	EPA 245.1	Fix pH<2 HNO3	28 days
Nickel	144	"	EPA 249.2	Fix pH<2 HNO3	6 months
Selenium	144	"	EPA 270.3	Fix pH<2 HNO3	6 months
Silver	144	"	EPA 272.2	Fix pH<2 HNO3	6 months
Zinc	432	"	EPA 289.2	Fix pH<2 HNO3	6 months

DATA QUALITY OBJECTIVES AND ASSESSMENT

Data quality requirements are parameter specific and shall conform to those stated in US EPA approved analytical methods. The quality assurance protocols at West Virginia DNR laboratories includes the following:

- duplicates run at 10% of sample load to determine precision
- spiked samples run at 5% of sample load to determine accuracy
- quarterly analysis of EPA prepared "knowns"
- annual participation in EPA Performance Evaluation Studies

The laboratory employs the Shewhart technique (EPA 600-4/79-019) for preparing precision and accuracy control charts.

PARAMETER	TARGET DETECTION LIMIT	ESTIMATED ACCURACY	ESTIMATED PRECISION	QA PROTOCOL
Temperature	1°C	1%		NBS Thermometer
pH	0.1	±0.2 units		pH 4 and 7 buffer checks daily
DO	0.05-0.1	1%	±0.05	Air calibration daily
Sp. Cond.	10µS	2%	±10µS	NaCl calibration check
Susp. Solids	1 mg/L	*	*	as stated in paragraph above
Alkalinity	1 mg/L	*	*	"
BOD	2 mg/L	*	*	"
Sulfate	2 mg/L	*	*	"
Chloride	2 mg/L	*	*	"
Hardness	2 mg/L	*	*	"
Cyanide	1 ug/L	*	*	"
Phenolics	2 ug/L	*	*	"
Phosphorus	0.02 mg/L	*	*	"
ortho-phosphate	0.08 mg/L	*	*	"
TKN	0.02 mg/L	*	*	"
Ammonia	0.02 mg/L	*	*	"
Nitrate-Nitrite	0.02 mg/L	*	*	"
Aluminum	200 ug/L	*	*	"
Arsenic	0.5 ug/L	*	*	"
Barium	100 ug/L	*	*	"
Cadmium	5 ug/L	*	*	"
Chromium	10 ug/L	*	*	"

PARAMETER	TARGET DETECTION LIMIT	ESTIMATED ACCURACY	ESTIMATED PRECISION	QA PROTOCOL
Copper	10 ug/L	*	*	"
Iron	50 ug/L	*	*	"
Lead	10 ug/L	*	*	"
Magnesium	10 ug/L	*	*	"
Manganese	20 ug/L	*	*	"
Mercury	0.1 ug/L	*	*	"
Nickel	10 ug/L	*	*	"
Selenium	1 ug/L	*	*	"
Silver	5 ug/L	*	*	"
Zinc	5 ug/L	*	*	"

* See West Virginia DNR Laboratory QA Plan

DATA REPRESENTATIVENESS, COMPARABILITY, AND COMPLETENESS

As an ambient "fixed station" network, the manual sampling program is designed to provide a overview of water quality conditions and trends at a specific location and across the entire Ohio River. The majority of sampling locations have been sampled repeatedly over the last 13 years, initially at a frequency of three times per month. Sampling frequencies of one to three times per month were found to provide an adequate number of data observations to establish long-term trends on the Ohio River. The period of record for the manual sampling network is shown by station in Attachment A, Table 3. During the water years 1986-87, data completeness was 95% - 100%.

Measures taken to assure data comparability and completeness include: standardized written field/analytical procedures (SOPs); standardized data recordkeeping; uniformity in sampling equipment; periodic field blanks, spikes, and duplicates. River cross-section surveys are also performed each year to insure representative sampling at each station in the network.

INTERNAL QUALITY CONTROL CHECKS

Sample blanks, duplicates, matrix spikes and comparison samples are submitted to the contract laboratory on a quarterly basis. Field blanks serve as a check on the sampling method, and any contamination from sample bottles and preservatives. Field spikes and duplicate samples serve as a check on laboratory accuracy and precision. Spikes are prepared using EPA Quality Control Samples available from the Environmental Monitoring and

Support Laboratory in Cincinnati. Comparison samples are collected from an alternate sample point at the same location to screen for potential problems in samples obtained from intake lines.

All manual sampling stations are checked on a periodic schedule to determine if the water sample collected from a particular site is representative of the river at that point. This is done by cross-sectional sampling of the river at various depths at the mid-point and quarter points and comparing the results to that obtained at the routine sampling point. First priority is given to those sites where potential problems may exist as well as new monitoring sites which have not been studied previously. Measurements of pH, temperature, conductivity and dissolved oxygen are taken in the field during cross-sectioning. Vertical composite samples may also be collected for other parameters such as metals, nutrients, and inorganics based on site-specific conditions.

SAMPLING PROCEDURES

Detailed sampling procedures for the Manual Sampling Network are contained in the Standard Operating Procedures, Part III. A general summary of these procedures is as follows:

River water samples are collected from raw water intake lines, off lockchamber guide walls, or bridges. To sample from outside structures, a weighted aluminum bucket is used with sufficient nylon rope attached to traverse the distance to the river surface. Grab samples are collected at a depth of one and one-half meters. For in-river depth integrated sampling such as for cross-section surveys, the Kemmerer water sampler is used. This device permits representative sampling of the water column at specified depths. To sample from intake lines, the sample tap valve is opened, flushed for 2-3 minutes and the sample collected in a 2-liter plastic carboy.

The appropriate aliquot of sample is distributed to the sample bottles, preservative agent added if required and the solution mixed thoroughly. Samples are placed in crushed ice within an insulated cooler for shipment to the laboratory. Field tests for temperature, dissolved oxygen, pH, and conductivity are performed on suitable aliquots of the sample. All field data and observations are recorded on the Water Quality Report form. Three copies of the report accompany the samples to the laboratory while a fourth copy is submitted to ORSANCO.

SAMPLE CUSTODY

Water samples collected in the field are identified by date, time, location, station ID code and are accompanied by a Water Quality Report form. The sample collector attests to the validity of the sample by signature on the bottles and the report form. The samples are delivered by the sample collector to the authorized carrier for shipment to the laboratory.

CALIBRATION PROCEDURES AND PREVENTIVE MAINTENANCE

See the Standard Operating Procedures for Ambient Water Quality Monitoring, Part III of the Quality Assurance Manual.

ANALYTICAL PROCEDURES

See Standard Operating Procedures, for Ambient Water Quality Monitoring, Part III of the Quality Assurance Manual.

DATA REDUCTION, VALIDATION, REPORTING

Field data and laboratory data are recorded on the Water Quality Report form. The data is received 4-5 weeks after sample collection, reviewed for completeness according to the monthly parameter schedule, and checked for outlying values. Any questionable data is verified with the laboratory manager and/or the field investigator. The data is then entered in ORSANCO's computer database, retrieved, verified against the source document and edited before transmittal to US EPA STORET system. A copy of the Water Quality Reports are bound by year and kept on file for ten years. Summary reports are produced for distribution to member states and for publication in the Quality Monitor.

DATA USAGE

The physical\chemical data generated by the manual sampling program is used to:

- assess general water quality conditions and identify problem areas

- evaluate point, non-point and tributary impacts to the Ohio River

- identify long-term trends in improvement or degradation in the Ohio River

- support water quality management decisions

Basic statistical tests are performed on the data to characterize water quality by station. These values are compared to the Commission's stream criteria and combined with other monitoring data for 305b assessments.

The seasonal Kendall test is applied to historical data to assess long-term trends in water quality.

PERFORMANCE AND SYSTEM AUDITS

The Coordinator of Field Operations checks for adherence to sampling protocols, resolves schedule conflicts and provides on-site training for the field investigators. The analytical services contract is updated and renewed each year with the laboratory. Since the laboratory is required to be US EPA certified, documentation and submittal of QC data is a prerequisite. The laboratory's quality control procedures are reviewed as necessary to assure the generation of valid data.

CORRECTIVE ACTION

Corrective action in field procedures consists of immediate follow-up with the field investigators to review the sampling protocol and provide additional training if necessary. Corrective action in the laboratory is the responsibility of the laboratory manager who informs ORSANCO when a problem occurs and the steps taken to resolve it.

REPORTS

Quality assurance reports for the Manual Sampling Network will be prepared periodically to present results of EPA performance tests and river cross-section surveys. Water quality data for all stations is reported quarterly in the Quality Monitor. Trend assessment results are published biennially in 305b report for the Ohio River.

ATTACHMENT A

MANUAL SAMPLING NETWORK

TABLE 1. MANUAL SAMPLING LOCATIONS/DESCRIPTION

STATION #	FLOW STATION	STATION NAME	MILE POINT	STATION DESCRIPTION (Sample Location)
1234	Acmetonia	Allegheny R. at Pittsburgh	7.4	Pittsburgh Waterworks intake (Submersible pump in intake structure building)
1237	Braddock	Monongahela R. at South Pittsburgh	4.5	Western Pennsylvania Water Co. intake Beck's Run (raw water tap in pumping station)
1201	Dashields	Ohio R. at South Heights	15.2	Duquesne Light Power Plant (intake structure at river bank)
1242	Beaver Falls	Beaver R. at Beaver Falls	5.3	Beaver Falls Waterworks intake (inlet chamber in the treatment building)
1500	E. Liverpool	Ohio R. at East Liverpool	40.2	East Liverpool Waterworks intake (tap in raw water line from pumping station to treatment plant)
1406	Wheeling	Ohio R. at Wheeling	86.8	Wheeling Water Department intake (raw water tap at plant)
1423	Moundsville	Ohio R. at Hannibal	126.4	Hannibal Lock and Dam near Hannibal, OH (outside up-stream guide wall)
1408	Willow Island	Ohio R. at Willow Island, OH	161.8	Willow Island Lock and Dam near Newell Run, OH (outside up-stream guide wall)
1531	Marietta	Muskingum R. at L&D #2	5.8	Lock and Dam #2 near Devola, OH (outside up-stream guide wall)
1421	Parkersburg	Ohio R. at Belleville	203.9	Belleville Lock and Dam near Reedsville, OH (outside up-stream guide wall)
1510	Pomeroy	Ohio R. at Addison	260.0	Kyger Creek Power Plant near Addison, OH (raw water tap near intake structure)
1450	Winfield	Kanawha R. at Winfield	31.1	Hydroelectric plant on west side of Winfield L&D (concrete structure above dam and hydroelectric facility)
1422	Gallipolis	Ohio R. at Gallipolis	279.2	Gallipolis Lock and Dam near Gallipolis Ferry, WV (outside up-stream guide wall)
1412	Greenup	Ohio R. at Huntington	306.0	Huntington Water Corporation intake on 24th Street in Huntington, WV (raw water tap in basement of building)
1610	Ashland	Ohio R. at Ashland	319.7	Ashland Waterworks in Ashland, KY (raw water line in basement)
1630	Louisa	Big Sandy R. at Louisa	20.3	Kentucky Power Co. plant on US 23 near Louisa, KY, (raw water tap in intake structure)

TABLE 1. MANUAL SAMPLING LOCATIONS/DESCRIPTION

STATION #	FLOW STATION	STATION NAME	MILE POINT	STATION DESCRIPTION (Sample Location)
1526	Greenup	Ohio R. at Portsmouth	350.7	Portsmouth Water Treatment Plant intake New Boston, OH (raw water line in basement of plant)
1538	Lucasville	Scioto R. at Lucasville	15.0	State Highway Bridge Rt. 348 crossing Scioto R. near Lucasville, OH (from center of bridge)
1611	Meldahl	Ohio R. At Maysville	408.5	Maysville Waterworks intake (raw water line in plant)
1504	California	Ohio R. at Cincinnati	462.8	Cincinnati Waterworks intake near California (raw water line in the basement of the round building)
1571	Little Miami	Little Miami R. at Newtown	7.5	Newtown Road bridge crossing L. Miami (as close to mid-channel as possible from bridge or below bridge according to safety practices)
1634	Covington	Licking R. at Covington	4.5	Kenton County Waterworks intake, (raw Water tap in basement of plant)
1508	Covington	Ohio R. at North Bend	490.0	Cincinnati Gas & Electric Co., Miami Fort intake (raw water tap in condenser pit of plant)
1551	Cincinnati	Great Miami R. at Elizabethtown	5.5	Lost Bridge crossing G. Miami R. near Elizabethtown, OH (mid-stream from bridge)
1600	Markland	Ohio R. at Markland	531.5	Public Service of Indiana hydroelectric plant intake (raw water line near electronic monitor)
1601	McAlpine-Up	Ohio R. at Louisville	600.6	Louisville Water Co. pumping station on Zorn Avenue (raw water line at station near electronic monitor)
1622	McAlpine-Low	Ohio R. at West Point	625.9	Louisville Gas and Electric Co. Mill Creek Plant (raw water line in the basement of the plant near electronic monitor)
1721	Cannelton-Up	Ohio R. at Cannelton	720.7	Cannelton Lock and Dam near Cannelton, IN (outside up-stream guide wall)
1656	Spottsville	Green R. at Sebree	41.3	Big Rivers Electric Plant near Sebree, KY (intake structure outside walkway)

TABLE 1. MANUAL SAMPLING LOCATIONS/DESCRIPTION

STATION #	FLOW STATION	STATION NAME	MILE POINT	STATION DESCRIPTION (Sample Location)
1703	Evansville	Ohio R. at Evansville	791.5	Evansville Waterworks Filtration Plant (raw water tap in basement)
1722	Uniontown	Ohio R. at Uniontown	846.0	Uniontown Lock and Dam near Hovey, IN (outside up-stream guide wall)
1741	New Harmony	Wabash R. at New Harmony	51.5	White Co. Bridge Commission Toll Bridge at New Harmony (middle bridge-pier beneath roadway)
1640	None	Cumberland R. at Pinkneyville, KY	16.0	Critteden-Livingston Water Plan (raw water line in lower level of building)
1650	None	Tennessee R. at Paducah	6.0	Ashland Oil Terminal on Highway 62 east of Paducah, KY (barge unloading dock at terminal)
1820	Shawneetown	Ohio R. at Smithland	918.5	Smithland Lock and Dam near Hamletsburg, IL (outside up-stream guide wall)
1821	Joppa	Ohio R. at Joppa	952.3	Electric Energy Inc. power plant near Joppa, IL (raw water tap in intake structure near electronic monitor)

TABLE 2. MANUAL SAMPLING SCHEDULE

MONTHLY PARAMETER SCHEDULE

STATION	ID CODE	(JAN., APR., JUL., OCT.)		(FEB., MAR., MAY, JUNE, AUG., SEPT., NOV., DEC.)	
		21CTA		**11CTA**	
PITTSBURGH	1234	SUSP. SOLIDS	CADMIUM	SUSP. SOLIDS	CADMIUM
SO. PITTSBURGH	1237	ALKALINITY	COPPER	ALKALINITY	COPPER
BEAVER FALLS	1242	SULFATE	IRON	SULFATE	IRON
		CHLORIDE	MANGANESE	CHLORIDE	MANGANESE
		TOTAL P	MERCURY	TOTAL P	MERCURY
		TKN	ARSENIC	TKN	ZINC
		AMMONIA	CHROMIUM	AMMONIA	ARSENIC
		NITRATE/NITRITE	NICKEL	NITRATE/NITRITE	ALUMINUM
		ORTHO P	SELENIUM	ORTHO P	
		BOD	SILVER	BOD	
		MAGNESIUM	ZINC	MAGNESIUM	
		PHENOLICS	ALUMINUM	PHENOLICS	
		CYANIDE		CYANIDE	
		21CA		**11CA**	
SO. HEIGHTS	1201	SUSP. SOLIDS	CADMIUM	SUSP. SOLIDS	CADMIUM
EAST LIVERPOOL	1500	ALKALINITY	COPPER	ALKALINITY	COPPER
		SULFATE	IRON	SULFATE	IRON
		HARDNESS	LEAD	HARDNESS	LEAD
		TOTAL P	MANGANESE	TOTAL P	MANGANESE
		TKN	MERCURY	TKN	MERCURY
		AMMONIA	ARSENIC	AMMONIA	ARSENIC
		NITRATE/NITRITE	BARIUM	NITRATE/NITRITE	ALUMINUM
		ORTHO P	NICKEL	ORTHO P	ZINC
		BOD	SELENIUM	BOD	
		MAGNESIUM	SILVER	MAGNESIUM	
		PHENOLICS	ZINC	PHENOLICS	
		CYANIDE	ALUMINUM	CYANIDE	
			CHROMIUM		

TABLE 2. MANUAL SAMPLING SCHEDULE

		MONTHLY PARAMETER SCHEDULE			
STATION	ID CODE	(JAN., APR., JUL., OCT.)		(FEB., MAR., MAY, JUNE, AUG., SEPT., NOV., DEC.)	
		21C		11C	
WHEELING	1406	SUSP. SOLIDS	CADMIUM	SUSP. SOLIDS	CADMIUM
HANNIBAL	1423	SULFATE	COPPER	SULFATE	COPPER
WILLOW ISLAND	1408	HARDNESS	IRON	HARDNESS	IRON
BELLEVILLE	1421	TOTAL P	LEAD	TOTAL P	LEAD
ADDISON	1510	TKN	MANGANESE	TKN	MANGANESE
GALLIPOLIS	1422	AMMONIA	MERCURY	AMMONIA	MERCURY
HUNTINGTON	1412	NITRATE/NITRITE	ARSENIC	NITRATE/NITRITE	ZINC
PORTSMOUTH	1526	ORTHO P	BARIUM	ORTHO P	ALUMINUM
LOUISVILLE	1601	BOD	NICKEL	BOD	ARSENIC
WEST POINT	1622	MAGNESIUM	SELENIUM	MAGNESIUM	
EVANSVILLE	1703	PHENOLICS	SILVER	PHENOLICS	
JOPPA	1821	CYANIDE	ZINC	CYANIDE	
		CHROMIUM	ALUMINUM		
		21CT		11CT	
LOUISA	1630	SUSP. SOLIDS	CADMIUM	SUSP. SOLIDS	CADMIUM
COVINGTON	1634	SULFATE	COPPER	SULFATE	COPPER
SEEBREE	1556	HARDNESS	IRON	HARDNESS	IRON
PADUCAH	1650	CHLORIDE	LEAD	CHLORIDE	LEAD
		TOTAL P	MANGANESE	TOTAL P	MANGANESE
		TKN	MERCURY	TKN	MERCURY
		AMMONIA	ARSENIC	AMMONIA	ARSENIC
		NITRATE/NITRITE	NICKEL	NITRATE/NITRITE	ZINC
		ORTHO P	SELENIUM	ORTHO P	ALUMINUM
		BOD	SILVER	BOD	
		MAGNESIUM	ZINC	MAGNESIUM	
		PHENOLICS	ALUMINUM	CYANIDE	
		CYANIDE		PHENOLICS	
		CHROMIUM			

TABLE 2. MANUAL SAMPLING SCHEDULE

		MONTHLY PARAMETER SCHEDULE			
STATION	**ID CODE**	**(JAN., APR.)** 21T	**(FEB., MAR., NOV., DEC.)** 11T	**(JULY, OCT.)** 21CT	**(MAY, JUNE, AUG., SEPT.)** 11CT
MUSKINGUM	1531	SUSP. SOLIDS	SUSP. SOLIDS	SUSP. SOLIDS	SUSP. SOLIDS
WINFIELD	1450	SULFATE	SULFATE	SULFATE	SULFATE
LUCASVILLE	1538	HARDNESS	HARDNESS	HARDNESS	HARDNESS
NEWTON	1571	CHLORIDE	CHLORIDE	CHLORIDE	CHLORIDE
ELIZABETHTOWN	1551	MAGNESIUM	MAGNESIUM	TOTAL P	TOTAL P
NEW HARMONY	1741	PHENOLICS	PHENOLICS	TKN	TKN
BARKLEY DAM	1645	CYANIDE	CYANIDE	AMMONIA	AMMONIA
		CADMIUM	CADMIUM	NITRATE/NITRITE	NITRATE/NITRITE
		COPPER	COPPER	ORTHO P	ORTHO P
		IRON	IRON	BOD	BOD
		LEAD	LEAD	MAGNESIUM	MAGNESIUM
		MANGANESE	MANGANESE	PHENOLICS	PHENOLICS
		MERCURY	MERCURY	CYANIDE	CYANIDE
		ZINC	ARSENIC	CADMIUM	CADMIUM
		ARSENIC	ZINC	COPPER	COPPER
		CHROMIUM	ALUMINUM	IRON	IRON
		NICKEL		LEAD	LEAD
		SELENIUM		MANGANESE	MANGANESE
		SILVER		MERCURY	MERCURY
		ALUMINUM		ZINC	ARSENIC
				CHROMIUM	ALUMINUM
				ARSENIC	ZINC
				CHROMIUM	
				NICKEL	
				SELENIUM	
				SILVER	
				ALUMINUM	

TABLE 2. MANUAL SAMPLING SCHEDULE

		MONTHLY PARAMETER SCHEDULE			
STATION	ID CODE	(JAN., APR.)	(FEB., MAR., NOV., DEC.)	(JULY, OCT.)	(MAY, JUNE, AUG., SEPT.)
		21	11	21C	11C
ASHLAND	1610	SUSP. SOLIDS	SUSP. SOLIDS	SUSP. SOLIDS	SUSP. SOLIDS
MAYSVILLE	1611	SULFATE	SULFATE	SULFATE	SULFATE
CINCINNATI	1504	HARDNESS	HARDNESS	HARDNESS	HARDNESS
NORTH BEND	1508	MAGNESIUM	MAGNESIUM	TOTAL P	TOTAL P
MARKLAND	1600	PHENOLICS	PHENOLICS	TKN	TKN
CANNELTON	1721	CYANIDE	CYANIDE	AMMONIA	AMMONIA
UNIONTOWN	1722	CADMIUM	CADMIUM	NITRATE/NITRITE	NITRATE/NITRITE
SMITHLAND	1820	COPPER	COPPER	ORTHO P	ORTHO P
		IRON	IRON	BOD	BOD
		LEAD	LEAD	MAGNESIUM	MAGNESIUM
		MANGANESE	MANGANESE	PHENOLICS	PHENOLICS
		MERCURY	MERCURY	CYANIDE	CYANIDE
		ZINC	ARSENIC	CADMIUM	CADMIUM
		ARSENIC	ZINC	COPPER	COPPER
		BARIUM	ALUMINUM	IRON	IRON
		CHROMIUM		LEAD	LEAD
		NICKEL		MANGANESE	MANGANESE
		SELENIUM		MERCURY	MERCURY
		SILVER		ZINC	ARSENIC
		ALUMINUM		ARSENIC	ZINC
				BARIUM	ALUMINUM
				CHROMIUM	
				NICKEL	
				SELENIUM	
				SILVER	
				ALUMINUM	

Table 3

STATION DATA BASE: MANUAL MONITORING SYSTEM

OHIO RIVER MILE POINT	STATION NAME	RIVER	STORET#	WATERBODY ID	WATERBODY NAME	BD	ED
0.0	PITTSBURGH WATER WORKS	ALLEGHENY	AR7.4M		ALLEGHENY	7/15/86	CURRENT
0.0	OAKMONT WATER WORKS	ALLEGHENY	AR13.3M		ALLEGHENY	7/15/75	9/3/86
0.0	SOUTH PITTSBURGH	MONONGAHELA	MR-4.5M		MONONGAHELA	11/3/75	CURRENT
15.2	SOUTH HEIGHTS	OHIO	OR9658M	ORWB03	DASHIELDS - BEAVER	11/3/75	CURRENT
25.4	BEAVER FALLS	BEAVER	BR-5.3M		BEAVER	11/12/75	CURRENT
40.2	EAST LIVERPOOL WATER WORKS	OHIO	OR9408M	ORWB06	PA STATE LINE - NEW CUMBERLAND	12/11/75	CURRENT
84.2	PIKE ISLAND L&D	OHIO	OR8968M	ORWB07	NEW CUMBERLAND - PIKE ISLAND	4/11/75	9/22/86
86.8	WHEELING WATER TREATMENT PLANT	OHIO	OR894.2M	ORWB08	PIKE ISLAND - HANNIBAL	12/15/75	CURRENT
102.4	SHADYSIDE	OHIO	OR8786M	ORWB08	PIKE ISLAND - HANNIBAL	11/18/75	9/22/86
126.4	HANNIBAL L&D	OHIO	OR8546M	ORWB08	PIKE ISLAND - HANNIBAL	9/26/77	CURRENT
161.8	WILLOW ISLAND L&D	OHIO	OR8192M	ORWB09	HANNIBAL - WILLOW ISLAND	11/19/75	CURRENT
172.2	MUSKINGUM L&D #2	MUSKINGUM	MU-5.5M		MUSKINGUM	11/19/75	CURRENT
203.9	BELLEVILLE L&D	OHIO	OR7771M	ORWB11	MUSKINGUM - BELLEVILLE	11/11/75	CURRENT
260.0	ADDISON - KYGER CREEK	OHIO	OR7210M	ORWB13	RACINE - KANAWHA	11/11/75	CURRENT
265.7	WINFIELD L&D	KANAWHA	KR31.1M		KANAWHA	11/11/75	CURRENT
279.2	GALLIPOLIS L&D	OHIO	OR7018M	ORWB14	KANAWHA - GALLIPOLIS	11/11/75	CURRENT
306.9	HUNTINGTON WATER CORPORATION	OHIO	OR6741M	ORWB15	GALLIPOLIS - BIG SANDY	11/11/75	CURRENT
315.8	KENOVA	OHIO	OR6652M	ORWB15	GALLIPOLIS - BIG SANDY	11/11/75	9/9/86
317.1	LOUISA	BIG SANDY	SR20.3M		BIG SANDY	11/10/75	CURRENT
319.7	ASHLAND WATER WORKS	OHIO	OR661.3M	ORWB16	BIG SANDY - GREENUP	7/9/86	CURRENT
341.0	GREENUP L&D	OHIO	OR6400M	ORWB16	BIG SANDY - GREENUP	11/12/75	9/9/86
350.7	PORTSMOUTH WATER TREATMENT PLANT	OHIO	OR630.3M	ORWB17	GREENUP - SCIOTO	10/23/86	CURRENT
356.5	LUCASVILLE	SCIOTO	SC15.0M		SCIOTO	11/12/75	CURRENT
408.5	MAYSVILLE WATER WORKS	OHIO	OR572.5M	ORWB18	SCIOTO - MELDAHL	7/8/86	CURRENT
436.2	MELDAHL L&D	OHIO	OR5448M	ORWB18	SCIOTO - MELDAHL	11/12/75	9/23/86
462.8	CINCINNATI WATER WORKS	OHIO	OR5182M	ORWB20	LITTLE MIAMI - LICKING	11/7/75	CURRENT
464.1	NEWTOWN	LITTLE MIAMI	LM-7.5M		LITTLE MIAMI	7/6/76	CURRENT
470.2	COVINGTON	LICKING	LR-4.5M		LICKING	11/18/75	CURRENT

Table 3

STATION DATA BASE: MANUAL MONITORING SYSTEM

OHIO RIVER MILE POINT	STATION NAME	RIVER	STORET#	WATERBODY ID	WATERBODY NAME	BD	
490.0	NORTH BEND	OHIO	OR4910M	ORWB21	LICKING - GREAT MIAMI	11/17/75	C
491.1	ELIZABETHTOWN	GREAT MIAMI	GM-5.5M		GREAT MIAMI	11/10/75	C
531.5	MARKLAND L&D	OHIO	OR4495M	ORWB22	GREAT MIAMI - MARKLAND	11/17/75	C
600.6	LOUISVILLE WATER COMPANY	OHIO	OR3804M	ORWB24	KENTUCKY - MCALPINE	11/10/75	C
625.9	WEST POINT	OHIO	OR3551M	ORWB25	MCALPINE - SALT	11/10/75	C
720.7	CANNELTON L&D	OHIO	OR2603M	ORWB26	SALT - CANNELTON	11/13/75	C
784.2	SEEBREE	GREEEN RIVER	GR41.3M		GREEN	11/14/75	C
791.5	EVANSVILLE WATER WORKS	OHIO	OR1895M	ORWB29	GREEN - UNIONTOWN	11/3/75	C
846.0	UNIONTOWN L&D	OHIO	OR1350M	ORWB29	GREEN - UNIONTOWN	11/11/75	C
848.0	NEW HARMONY	WABASH	WA9295M		WABASH	11/11/75	C
918.5	SMITHLAND L&D	OHIO	OR62.5M	ORWB31	WABASH - SMITHLAND	1/19/82	CL
920.4	BARKLEY DAM	CUMBERLAND	CR30.6M		CUMBERLAND	11/17/75	CL
934.5	PADUCAH	TENNESSEE	TR-6.0M		TENNESSEE	11/17/75	CL
935.5	PADUCAH WATER WORKS	OHIO	OR45.5M	ORWB34	TENNESSEE - CAIRO	7/10/84	CL
952.3	JOPPA	OHIO	OR28.7M	ORWB34	TENNESSEE - CAIRO	11/17/75	CL

APPENDIX B: SEASONAL KENDALL TEST METHODOLOGY AND FORMULAS

METHODOLOGY

In order to perform the trend assessments, several steps had to be taken. These included:

1) Selection of stations and parameters for analysis.
2) Selection of an appropriate model for determining the flow adjusted concentration values.
3) Retrieval and preparation of the data sets.
4) Statistical analysis of the data sets using the Seasonal Kendall Test.

Selection of Stations and Parameters for Analysis

Many missing values in a data set, like that of mercury or phenolics, decrease the reliability of the results. The Seasonal Kendall Test requires at least five data points in each month over the eleven year interval. The thirteen stations that do not monitor for nutrients year-round were excluded for this reason.

Values below the detection levels were censored and converted to missing values. "Because the Seasonal Kendall Test is nonparametric, outliers, missing values, or values defined as "less than" the laboratory detection limit present no computational or technical problem in its application." (Smith, et.al., Water Quality Trends in the Nation's Rivers, 1987).

Choosing a Model for Flow-Adjusted Concentration Values

Flow-adjusted values are derived from: (1) describing the relationship between flow and concentration using a statistical model and (2) determining the difference between the value predicted by the model and the actual value. This difference is the residual. The experience of J. Shermer Garrison of the Maryland Department of the Environment is that after testing several models at several locations, a LOG-LOG model (as defined in the table below) was often chosen as the best-fit relationship. A best-fit relationship is the model which best meets various requirements in four areas:

1) Analysis of Variance Table (ANOVA Table)
2) Plots of Predicted and Observed values versus Flow
3) Residual plots
4) Univariate table consisting of Normal Probability plot, Boxplot, and Stem-and-Leaf diagram.

The ANOVA table should have a low Mean Squared Error (MSE), a high F-value, a low P-value (probability of being wrong) and a high R-squared. If these numbers are similar for two different models, the model with the highest F-value is favorable. The plot of predicted and observed values versus flow should show a close association of observed values to the predicted line. A good model would simulate closely actual observations. Residuals are used to indicate a bias in the model. The residuals plot should indicate randomness. The residuals when plotted, should tend to fall in a horizontal band centered around zero. If a pattern emerges in the residuals plot, a departure of actual conditions from those predicted in the model exist. The univariate table is used to analyze the randomness of the residuals using a normal probability plot, a boxplot and a stem and leaf diagram. Randomness is indicated by a straight line probability plot, a standard boxplot and a bell shaped stem and leaf diagram. A uniform distribution indicates the model appropriately simulates actual conditions. The models tested in this study are found in the table below.

MODELS EVALUATED FOR USE IN
FLOW-ADJUSTED CONCENTRATION RELATIONSHIP
(Using TSS as an example parameter)

LINEAR	$TSS = \beta_0 + \beta_1 * FLOW$
LOG-LOG	$\mathrm{ln}(TSS) = \beta_0 + \beta_1 * \mathrm{ln}(FLOW)$
LINEAR-HYPERBOLIC	$TSS = \beta_0 + \beta_1 * [1 / (1 + 10^{(-2.5 - BETA)} * FLOW)]$ where beta = interger of log10(meanFLOW)
LINEAR-INVERSE	$TSS = \beta_0 + \beta_1(1 / FLOW)$
LINEAR-QUADRATIC	$TSS = \beta_0 + \beta_1 * FLOW + \beta_2 * FLOW^2$
LOG-QUADRATIC	$\log(TSS) = \beta_0 + \beta_1 * \log(FLOW) + \beta_2 * [\log(FLOW)]^2$

For the evaluation, total suspended solids and total dissolved solids were considered to be representative parameters in the Ohio River Basin. These parameters had the least missing values in their data sets and were tested consistently over the years. Residuals analysis for all models in Table 3 are run on both parameters at all stations to establish the appropriate relationship between flow and concentration.

The LOG-LOG model was determined to provide the best-fit relationship for both total suspended solids and total dissolved solids. Appendix C contains sample pages of the ANOVA table, the Predicted and Observed plots and the Univariate table for three models at the Cincinnati station on the Ohio River. It includes both total suspended solids and total dissolved solids for the LOG-LOG model, the LOG-QUADRATIC model and the LINEAR model.

Since the LOG-LOG and LOG-QUADRATIC models gave similar results, the Univariate tables of each model at the same station are similar for total suspended solids. The Predicted and Observed plots at most stations follow the same pattern for both models. The Residuals plot for the two models are similar at most stations and are either both randomly scattered or both display a similar pattern. In the ANOVA table, the MSE and the R-Square are often close in value between models. The deciding factor at all stations is the F-value in the ANOVA table. The model with the highest F-value and the lowest P-value is chosen as the best-fit model. Also, convention requires that if two models are very close, the simpler version is to be used. In this case, the simpler model is the LOG-LOG model.

In the case of total suspended solids, those stations that do have a better fit with the LOG-QUADRATIC model are the stations with fewer years of data. The fact that these stations have a better-fit relationship with the LOG-QUADRATIC model may have something to do with the size of their data sets. Total dissolved solids followed much the same pattern as total suspended solids did. Both relationships, LOG-LOG and LOG-QUADRATIC models, had overlapping patterns for Predicted and Observed plots and randomly scattered Residual plots. The biggest difference between models is usually in the F-value of the ANOVA table. Many times, all other numbers being similar, the F-value of the LOG-LOG model is twice as large as the LOG-QUADRATIC model.

Retrieving and Preparing Data Sets

The entire untransformed data set is in STORET including flow values, which are required for several calculations. Because the entire data set is too large to print here, Appendix D is a printout of the annual mean for each parameter in STORET. Stations with incomplete data sets for that parameter are marked with an asterisk. The parameters under investigation are retrieved from STORET and calculations are done for total dissolved solids, total nitrogen and loadings. For the flow-adjusted values, the LOG-LOG model is applied to the flow and concentration of each parameter at each station. The chosen model generates a predicted concentration for every flow value. The predicted values are then subtracted from the actual observed concentrations, resulting in residuals. These residuals comprise the flow-adjusted concentration data set. Each data set, one at each station for all parameters, is manipulated into a usable format.

Seasonal Kendall Test of Trend

The Seasonal Kendall Test is applied using a macro written in LOTUS123®. The test is designed to (1) compare each data point within a month with all earlier data points, (2) keep a running tally of the comparisons, (3) make adjustments in variability if two data points are identical, (4) calculate a monthly statistic and monthly variance and (5) calculate a z-statistic. For each form of the monitoring data, the Seasonal Kendall Test is applied to the data set of each station for each parameter. The z-statistic is used to test the null hypothesis. The null hypothesis is rejected if z indicates a $p<.10$. The resulting z-statistic determines the probability of a trend, and whether that trend is increasing or decreasing. An increasing trend indicates that parameter concentrations are increasing in the Ohio River water column over time, suggesting deteriorating water quality. A decreasing trend indicates that parameter concentrations are decreasing over time, suggesting an improvement in water quality. Between 10% and 5% probability is considered a slight trend, either increasing or decreasing. Less than 5% probability is considered a strong trend, either increasing or decreasing. Greater than 10% probability is considered no significant trend in the data.

Seasonal Kendall Test Formulas

For the Seasonal Kendall Test, only data within the same month is compared. In each comparison, an earlier data point is compared to a later data point. If the later value in time is higher, then a plus is scored (K+). If the later value is lower, then a minus is scored (K-). If the values are identical, then a tie is scored (t). The Seasonal Kendall Test obtains a monthly statistic of the data set by subtracting the minuses from the pluses (Bauer et al., 1984): $K_i = (K+) - (K-)$. The ties are used in the calculation of the variance for each monthly statistic. The actual formula for monthly variance (var) is given by Smith et al. (1982) as:

$$var = \frac{n(n-1)(2n+5) - \sum_{i=1}^{n} t_i(t_i-1)(2t_i+5)}{18}$$

where n = number of years in the data set

The sum of the monthly statistics [$K = \Sigma K_i$] and the sum of the monthly variances {$VAR = \Sigma var(K_i)$} are used to calculate a z-statistic (Bauer et al., 1984). The z-statistic formulas are shown below:

$$if\ K > 0\ then\ Z = \frac{K-1}{\sqrt{var}}$$

$$if\ K < 0\ then\ Z = \frac{K+1}{\sqrt{var}}$$

$$if\, K = 0\ then\ Z = 0$$

The significance of z-statistic then determines the presence of a trend.

If there is no trend in the data, then there is an equal chance that a given value is higher or lower than any other value in another year that same month (Smith et al., 1982). It will possess an almost equal number of pluses as minuses and will have a z-statistic of nearly zero. A positive or increasing trend will have more pluses than minuses and will have a large positive z-statistic (Smith et al., 1982). A negative or decreasing trend will have more minuses and a large negative z-statistic (Smith et al., 1982).

Seasonal Kendall Slope Estimator

The Seasonal Kendall Slope Estimator is employed using a macro written in LOTUS123®. The test compares each data point within a month with all earlier data points and stores the percent change for each comparison. Once all possible comparisons are made and stored they are sorted. After sorting, the median is determined and this value is recorded as the percent change at that station. The slope in units/year is then calculated as follows:

X = percent change (from LOTUS123® macro)

M = mean of actual concentration

Slope(units/yr.) = $(e^x-1)*M$

The slope magnitude can then be compared with the trend direction at that station. This allows for determining how fast a trend is increasing or decreasing. A positive slope correlates with an increasing trend, implying a deterioration in water quality. Conversely, a negative slope indicates a decreasing trend, suggesting an improvement in water quality.

APPENDIX C: SAMPLE PAGES OF RESIDUALS ANALYSIS FOR THREE MODELS

LOG-LOG MODEL OF TSS AT CINCINNATI WW

ANOVA TABLE

```
                                          ANALYSIS OF VARIANCE

                                       SUM OF        MEAN
                     SOURCE   DF      SQUARES      SQUARE     F VALUE       PROB>F

                     MODEL     1  95.25685942 95.25685942     129.281       0.0001
                     ERROR   127  93.57644993  0.73682244
                     C TOTAL 128    188.83331

                         ROOT MSE   0.8583836    R-SQUARE      0.5044
                         DEP MEAN    3.882651    ADJ R-SQ      0.5005
                         C.V.        22.10818

                                          PARAMETER ESTIMATES

                                PARAMETER       STANDARD     T FOR H0:
               VARIABLE  DF      ESTIMATE          ERROR    PARAMETER=0      PROB > |T|

               INTERCEP   1   -7.17607602     0.97554125         -7.356          0.0001
               LFLOW      1    0.99394527     0.08741697         11.370          0.0001


                      PREDICT    STD ERR                STD ERR    STUDENT                        COOK'S
OBS        ACTUAL       VALUE    PREDICT   RESIDUAL    RESIDUAL   RESIDUAL     -2-1-0 1 2               D

      1    2.1595      1.6747     0.2084     0.4848      0.8327     0.5821    |      |*    |        0.011
      2    1.8971      3.1591     0.0988    -1.2620      0.8527    -1.4801    |    **|     |        0.015
      3    4.6052      4.5786     0.0973     0.0266      0.8529     0.0312    |      |     |        0.000
      4    5.0876      5.0036     0.1242     0.0840      0.8493     0.0988    |      |     |        0.000
      5    4.9675      4.8596     0.1144     0.1079      0.8507     0.1268    |      |     |        0.000
      6    2.8526      4.0086     0.0764    -1.1560      0.8550    -1.3521    |    **|     |        0.007
      7    2.6391      3.3966     0.0868    -0.7575      0.8540    -0.8870    |     *|     |        0.004
      8    5.6870      3.1757     0.0979     2.5113      0.8528     2.9448    |      |*****|        0.057
      9    4.3175      3.4910     0.0831     0.8265      0.8544     0.9674    |      |*    |        0.004
     10    3.0204      3.0160     0.1073   .0044426      0.8516   .0052164    |      |     |        0.000
     11    4.0662      4.1036     0.0780    -0.0374      0.8548    -0.0437    |      |     |        0.000
     12    3.8850      4.1015     0.0780    -0.2165      0.8548    -0.2533    |      |     |        0.000
     13    5.7961      4.3858     0.0876     1.4102      0.8539     1.6515    |      |***  |        0.014
     14    4.6250      4.5102     0.0936     0.1148      0.8533     0.1345    |      |     |        0.000
     15    3.8067      4.6496     0.1013    -0.8430      0.8524    -0.9889    |     *|     |        0.007
     16    5.8319      5.6399     0.1720     0.1919      0.8410     0.2282    |      |     |        0.001
     17    4.8598      4.6368     0.1006     0.2230      0.8525     0.2616    |      |     |        0.000
     18    5.4220      4.7965     0.1103     0.6255      0.8513     0.7348    |      |*    |        0.005
     19    4.7449      3.9701     0.0760     0.7748      0.8550     0.9062    |      |*    |        0.003
     20    3.2055      3.5755     0.0803    -0.3701      0.8546    -0.4330    |      |     |        0.001
     21    3.6889      3.8026     0.0759    -0.1138      0.8550    -0.1330    |      |     |        0.000
     22    2.8904      3.0803     0.1034    -0.1900      0.8521    -0.2229    |      |     |        0.000
```

ANOVA TABLE

LOG-QUADRATIC MODEL OF TSS AT CINCINNATI WW

```
                                 ANALYSIS OF VARIANCE

                            SUM OF         MEAN
           SOURCE     DF   SQUARES        SQUARE        F VALUE       PROB>F

           MODEL       2  99.11129693  49.55564847       69.593       0.0001
           ERROR     126  89.72201242   0.71207946
           C TOTAL   128    188.83331

              ROOT MSE      0.843848      R-SQUARE       0.5249
              DEP MEAN      3.882651      ADJ R-SQ       0.5173
              C.V.          21.73381

                                 PARAMETER ESTIMATES

                          PARAMETER        STANDARD     T FOR H0:
       VARIABLE  DF        ESTIMATE           ERROR    PARAMETER=0      PROB > |T|

       INTERCEP   1      0.02779729      1.11329669          0.025          0.9801
       FLOW       1    .00000420653    .00000242306          1.736          0.0850
       L22        1      0.02766239      0.01066102          2.595          0.0106


                   PREDICT    STD ERR               STD ERR    STUDENT                      COOK'S
OBS      ACTUAL      VALUE    PREDICT   RESIDUAL   RESIDUAL   RESIDUAL     -2-1-0 1 2          D

  1      2.1595     2.2522     0.2991    -0.0928     0.7891    -0.1176    |      |      |   0.001
  2      1.8971     3.1567     0.0978    -1.2596     0.8382    -1.5028    |   ***|      |   0.010
  3      4.6052     4.4721     0.1106     0.1330     0.8366     0.1590    |      |      |   0.000
  4      5.0876     5.0641     0.1247     0.0235     0.8346     0.0282    |      |      |   0.000
  5      4.9675     4.8474     0.1140     0.1201     0.8361     0.1437    |      |      |   0.000
  6      2.8526     3.8549     0.1024    -1.0023     0.8376    -1.1966    |    **|      |   0.007
  7      2.6391     3.3329     0.0890    -0.6939     0.8391    -0.8269    |     *|      |   0.003
  8      5.6870     3.1686     0.0968     2.5184     0.8383     3.0042    |      |******|   0.040
  9      4.3175     3.4065     0.0886     0.9110     0.8392     1.0855    |      |**    |   0.004
 10      3.0204     3.0559     0.1084    -0.0355     0.8369    -0.0424    |      |      |   0.000
 11      4.0662     3.9471     0.1053     0.1191     0.8373     0.1422    |      |      |   0.000
 12      3.8850     3.9451     0.1052    -0.0601     0.8373    -0.0718    |      |      |   0.000
 13      5.7961     4.2448     0.1103     1.5512     0.8366     1.8542    |      |***   |   0.020
 14      4.6250     4.3889     0.1107     0.2360     0.8366     0.2821    |      |      |   0.000
 15      3.8067     4.5617     0.1106    -0.7550     0.8366    -0.9025    |     *|      |   0.005
 16      5.8319     6.3009     0.3599    -0.4690     0.7632    -0.6145    |     *|      |   0.028
 17      4.8598     4.5452     0.1106     0.3146     0.8366     0.3760    |      |      |   0.001
 18      5.4220     4.7580     0.1120     0.6640     0.8364     0.7940    |      |*     |   0.004
 19      4.7449     3.8185     0.1012     0.9265     0.8378     1.1059    |      |**    |   0.006
 20      3.2055     3.4743     0.0894    -0.2689     0.8391    -0.3204    |      |      |   0.000
 21      3.6889     3.6664     0.0954     0.0225     0.8384     0.0269    |      |      |   0.000
```

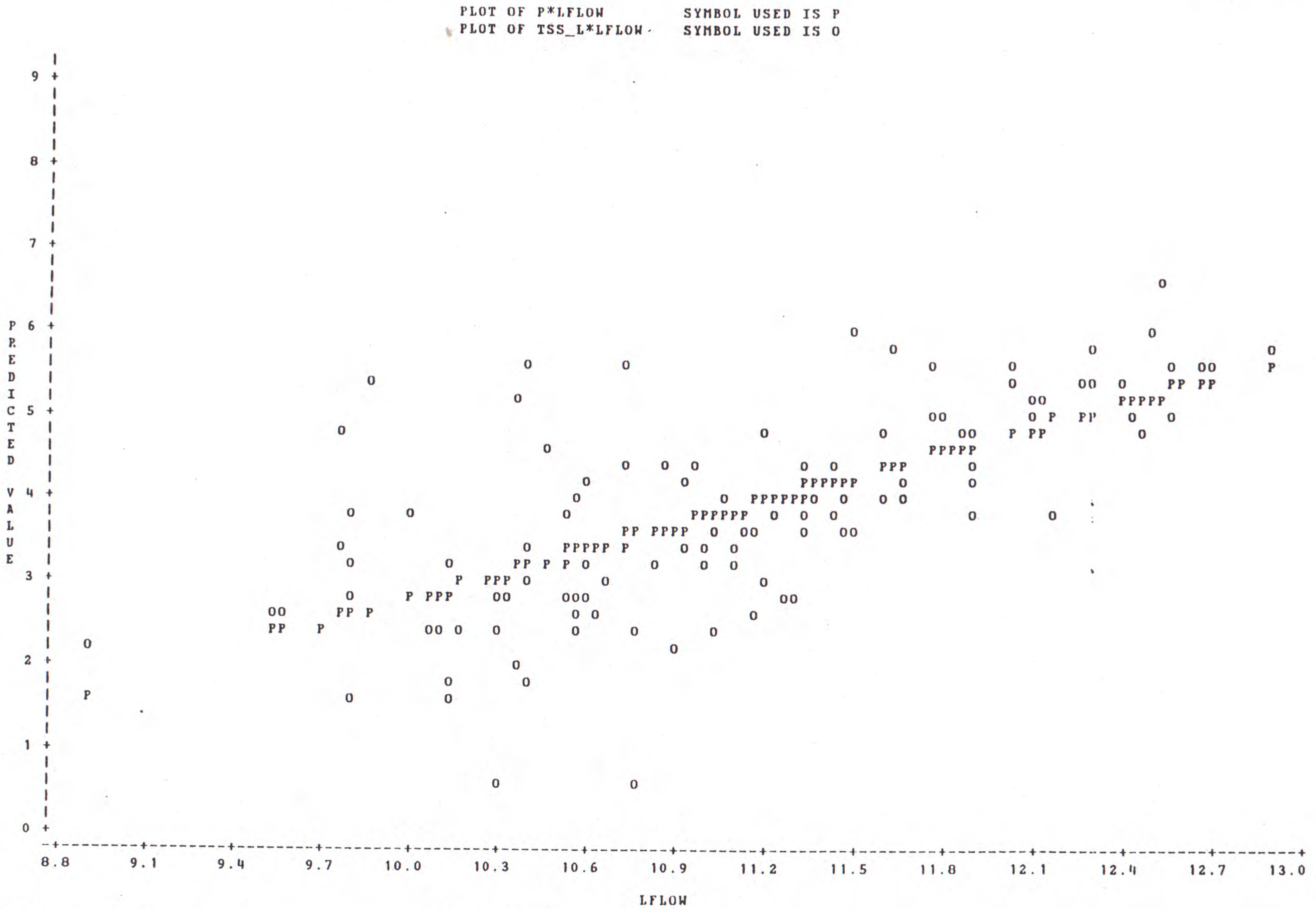
LINEAR MODEL OF TSS AT CINCINNATI WW

ANOVA TABLE

```
                                   ANALYSIS OF VARIANCE

                             SUM OF          MEAN
          SOURCE      DF    SQUARES        SQUARE       F VALUE      PROB>F

          MODEL        1   767591.84    767591.84       105.812      0.0001
          ERROR      127   921292.09   7254.26842
          C TOTAL    128  1688883.93

              ROOT MSE      85.17199       R-SQUARE       0.4545
              DEP MEAN      93.95995       ADJ R-SQ       0.4502
              C.V.          90.64713

                                  PARAMETER ESTIMATES

                            PARAMETER        STANDARD     T FOR H0:
         VARIABLE   DF       ESTIMATE           ERROR   PARAMETER=0      PROB > |T|

         INTERCEP    1     5.45213297     11.41349366         0.478          0.6337
         FLOW        1    0.000908402     0.000088310        10.287          0.0001


                      PREDICT      STD ERR                 STD ERR     STUDENT                        COOK'S
  OBS       ACTUAL      VALUE      PREDICT     RESIDUAL    RESIDUAL    RESIDUAL    -2-1-0 1 2              D

       1    8.6667    12.1440      10.9314      -3.4774     84.4676     -0.0412    |      |      |        0.000
       2    6.6667    35.2477       9.4240     -28.5811     84.6490     -0.3376    |      |      |        0.001
       3     100.0      129.7       8.2657     -29.7215     84.7700     -0.3506    |      |      |        0.001
       4     162.0      196.0      12.4380     -34.0349     84.2589     -0.4039    |      |      |        0.002
       5     143.7      170.3      10.5523     -26.6605     84.5158     -0.3154    |      |      |        0.001
       6   17.3333    75.4899       7.7109     -58.1566     84.8222     -0.6856    |     *|      |        0.002
       7   14.0000    43.2871       8.9723     -29.2871     84.6981     -0.3458    |      |      |        0.001
       8     295.0    35.7473       9.3947        259.3     84.6523      3.0626    |      |******|        0.058
       9   75.0000    47.0570       8.7764      27.9430     84.7186      0.3298    |      |      |        0.001
      10   20.5000    31.2508       9.6643     -10.7508     84.6219     -0.1270    |      |      |        0.000
      11   58.3333    82.5073       7.5812     -24.1740     84.8339     -0.2850    |      |      |        0.000
      12   48.6667    82.3484       7.5835     -33.6817     84.8337     -0.3970    |      |      |        0.001
      13     329.0      107.8       7.6190        221.2     84.8305      2.6074    |      |***** |        0.027
      14     102.0      121.5       7.9611     -19.4551     84.7991     -0.2294    |      |      |        0.000
      15   45.0000      138.9       8.6801     -93.9267     84.7285     -1.1086    |    **|      |        0.006
      16     341.0      367.0      27.5778     -25.9508     80.5837     -0.3220    |      |      |        0.006
      17     129.0      137.2       8.5975      -8.2159     84.7370     -0.0970    |      |      |        0.000
      18     226.3      160.2       9.8834      66.1500     84.5966      0.7819    |      |*     |        0.004
      19     115.0    72.8253       7.7753      42.1747     84.8163      0.4972    |      |      |        0.001
      20   24.6667    50.7511       8.5953     -26.0845     84.7372     -0.3078    |      |      |        0.000
      21   40.0000    62.3787       8.1031     -22.3787     84.7857     -0.2639    |      |      |        0.000
      22   18.0000    32.9767       9.5594     -14.9767     84.6338     -0.1770    |      |      |        0.000
```

LOG-LOG MODEL OF TSS AT CINCINNATI WW

PREDICTED AND OBSERVED PLOT

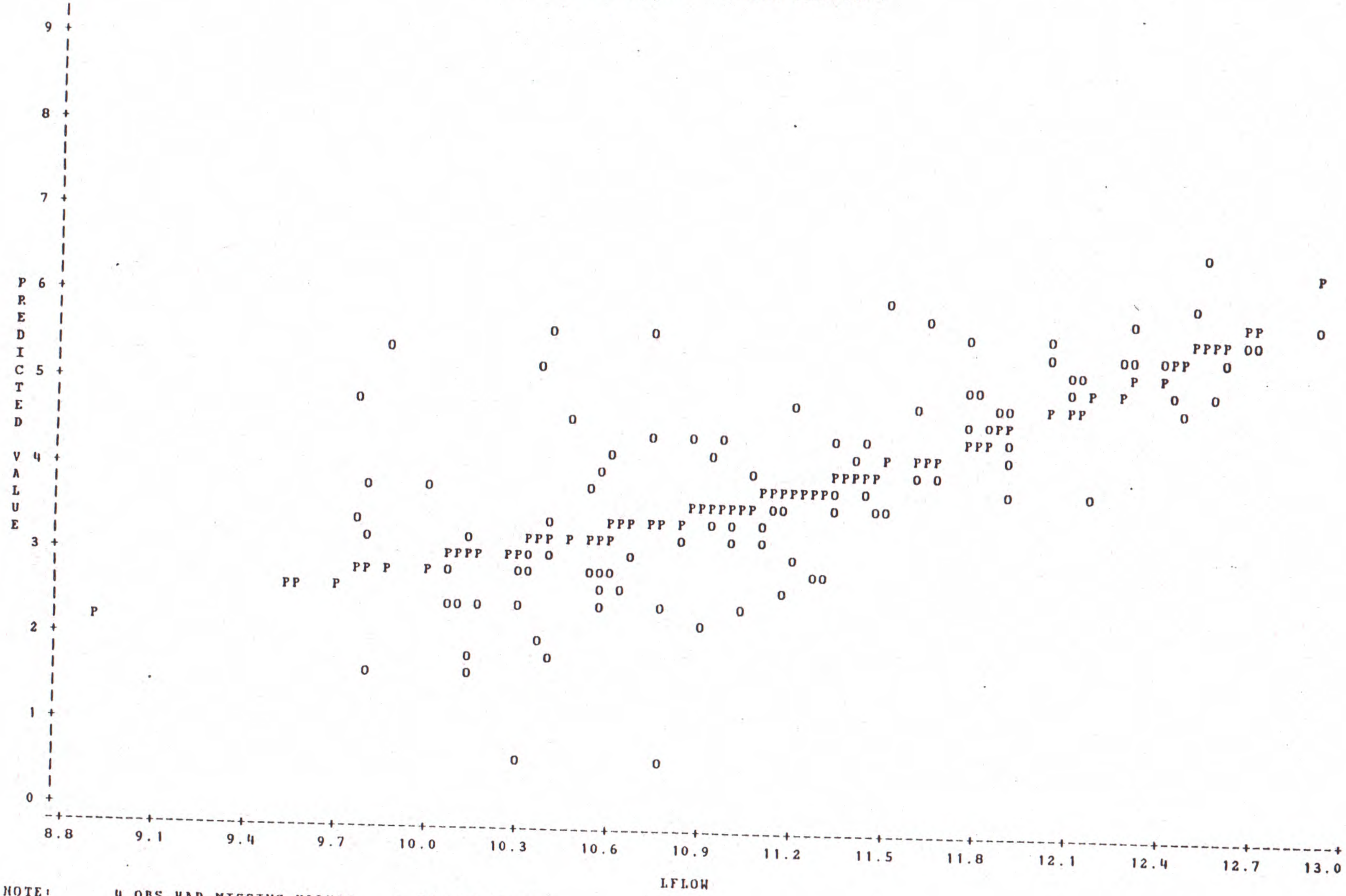


NOTE: 4 OBS HAD MISSING VALUES 70 OBS HIDDEN

LOG-QUADRATIC MODEL OF TSS AT CINCINNATI WW

PREDICTED AND OBSERVED PLOT

PLOT OF P*LFLOW   SYMBOL USED IS P
PLOT OF TSS_L*LFLOW   SYMBOL USED IS O

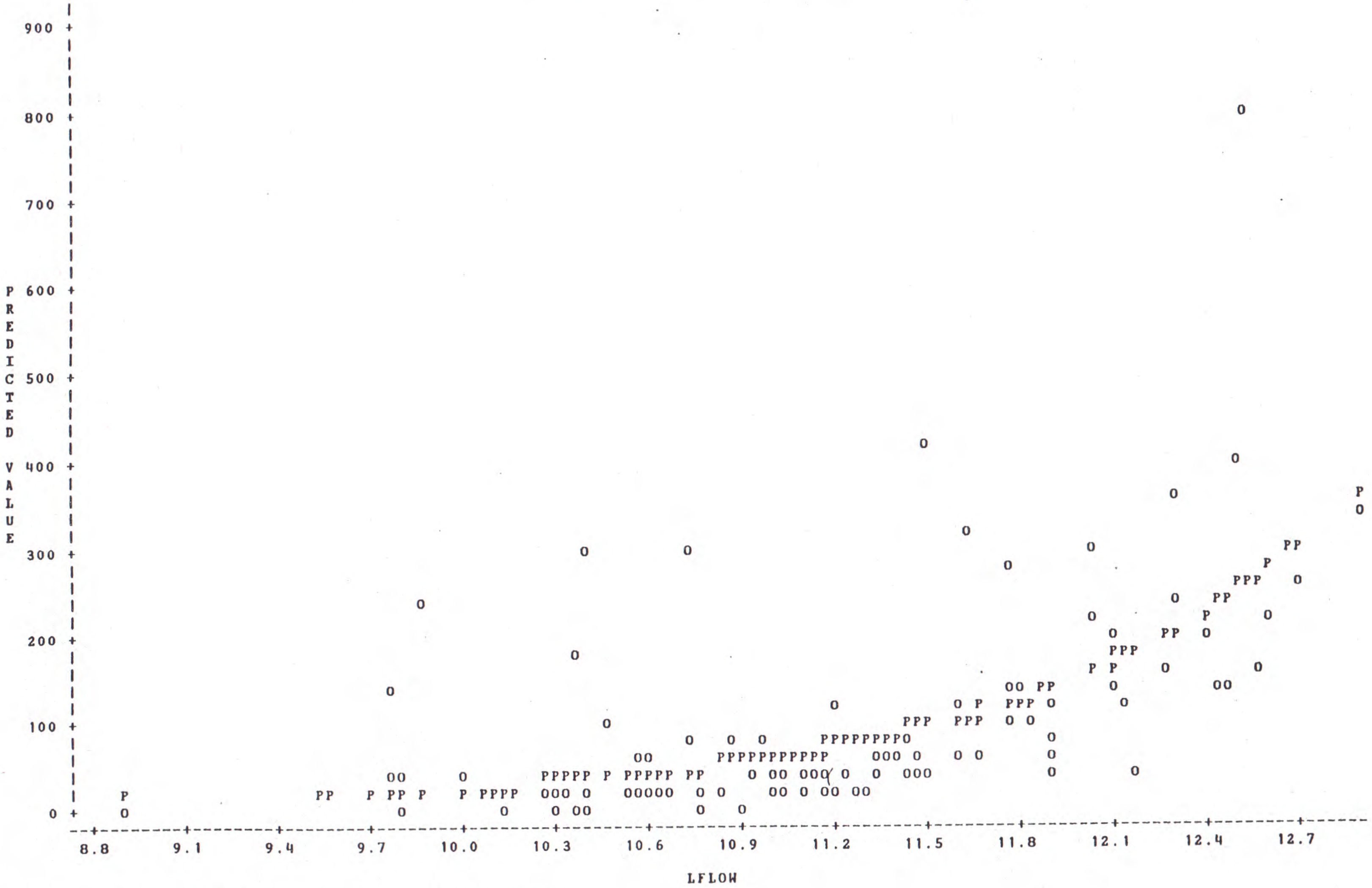


NOTE: 4 OBS HAD MISSING VALUES   72 OBS HIDDEN

LINEAR MODEL OF TSS AT CINCINNATI WW

PREDICTED AND OBSERVED PLOT

```
PLOT OF P*LFLOW   .  SYMBOL USED IS P
PLOT OF TSS*LFLOW    SYMBOL USED IS O
```



```
NOTE:     4 OBS HAD MISSING VALUES     79 OBS HIDDEN
```

LOG-LOG MODEL OF TSS AT CINCINNATI WW

UNIVARIATE TABLE

```
                                                            UNIVARIATE
VARIABLE=R              RESIDUALS

                 MOMENTS                                           QUANTILES(DEF=4)                                 EXTREMES

N                129 SUM WGTS         129              100% MAX     2.8379     99%      2.73992                   LOWEST    HIGHEST
MEAN      -6.723E-15 SUM       -8.673E-13               75% Q3    0.350159     95%      1.58597                 -2.82354    2.09873
STD DEV     0.855024 VARIANCE    0.731066               50% MED -.00879609     90%     0.892883                 -2.35723    2.19532
SKEWNESS    0.400081 KURTOSIS     2.06816               25% Q1   -0.417294     10%     -1.09425                 -1.44449    2.34864
USS          93.5764 CSS          93.5764                0% MIN   -2.82354      5%     -1.26692                 -1.37631     2.5113
CV            -99999 STD MEAN   0.0752807                                       1%     -2.68365                 -1.36736     2.8379
T:MEAN=0  -8.931E-14 PROB>|T|           1               RANGE      5.66145
SGN RANK      -223.5 PROB>|S|    0.600142               Q3-Q1     0.767453
NUM ¬= 0         129                                    MODE      -2.82354
D:NORMAL    0.103908 PROB>D          <.01

                                                       MISSING VALUE        .
                                                               COUNT        4
                                                        % COUNT/NOBS     3.01

STEM LEAF                                         #       BOXPLOT                             NORMAL PROBABILITY PLOT
   2 58                                           2          0             2.75+                                               *  *
   2 123                                          3          0                 |                                           ***   ++
   1 8                                            1          0                 |                                          *++++++
   1 112344                                       6          |                 |                                     +****+
   0 556667888888899                             15          |                 |                               +++*****
   0 1111111112222222233333333344444             31       +--+--+              |                         *********
  -0 44444443333333333332222222221110000000000   41       *-----*              |                  ********
  -0 9988777766665555                            16          |                 |             ******+
  -1 444332221110                                12          |                 |     ********+
  -1                                                                           |  ++++++
  -2 4                                            1          0                 |++ *
  -2 8                                            1          *            -2.75+*
     ----+----+----+----+----+----+----+----+-                                  +----+----+----+----+----+----+----+----+----+----+
                                                                                    -2        -1         0        +1        +2
```

LOG-QUADRATIC MODEL OF TSS AT CINCINNATI WW

UNIVARIATE TABLE

```
                                                              UNIVARIATE

VARIABLE=R              RESIDUALS

                 MOMENTS                                             QUANTILES(DEF=4)                                  EXTREMES

N                129  SUM WGTS         129               100% MAX    2.66351     99%      2.61998                    LOWEST     HIGHEST
MEAN       6.737E-15  SUM        8.691E-13                75% Q3    0.366955     95%      1.73262                  -2.73379     2.09509
STD DEV     0.837229  VARIANCE    0.700953                50% MED -0.0526812     90%      0.93104                  -2.38662     2.14131
SKEWNESS    0.433888  KURTOSIS     2.06724                25% Q1   -0.436613     10%     -1.03577                  -1.35492     2.28202
USS           89.722  CSS           89.722                 0% MIN   -2.73379      5%     -1.23096                  -1.33152      2.5184
CV             99999  STD MEAN   0.0737139                                        1%     -2.62964                  -1.25957     2.66351
T:MEAN=0   9.139E-14  PROB>|T|           1                RANGE      5.39731
SGN RANK      -320.5  PROB>|S|    0.451925                Q3-Q1     0.803568
NUM -= 0         129                                      MODE      -2.73379
D:NORMAL   0.0982982  PROB>D          <.01

                                                         MISSING VALUE         .
                                                                 COUNT         4
                                                          % COUNT/NOBS      3.01

STEM LEAF                       #                 BOXPLOT                                       NORMAL PROBABILITY PLOT
  26 6                          1                    0                        2.7+                                                  *
  24 2                          1                    0                           |                                               *
  22 8                          1                    0                           |                                             *
  20 04                         2                    0                        2.1+                                           **    ++
  18 1                          1                    0                           |                                          *    ++
  16                                                                             |                                             ++
  14 5                          1                    |                        1.5+                                         *+++
  12 25                         2                    |                           |                                        **
  10 34                         2                    |                           |                                     ++*
   8 23912338                   8                    |                        0.9+                                   +***
   6 01562                      5                    |                           |                                 +**
   4 68890                      5                    |                           |                              +++**
   2 0446912246788             13                 +-----+                     0.3+                            ++***
   0 22236890223567            14                 |  +  |                        |                         ++***
  -0 9777543219976554443322    22                 *-----*                        |                      ******
  -2 99722188877763221         17                 |     |                    -0.3+                   ****
  -4 9776552197430             13                 +-----+                        |               ****++
  -6 50095                      5                    |                           |             ***++
  -8 80                         2                    |                       -0.9+             *++
 -10 840640                     6                    |                           |         ****+
 -12 536420                     6                    |                           |     *****+
 -14                                                                         -1.5+      +++
 -16                                                                             |    ++
 -18                                                                             |  ++
 -20                                                                         -2.1+++
 -22 9                          1                    0                           |   *
 -24                                                                             |
 -26 3                          1                    0                       -2.7+*
     ----+----+----+----+--                                                       +----+----+----+----+----+----+----+----+----+----+
  MULTIPLY STEM.LEAF BY 10**-01                                                       -2        -1         0        +1        +2
```

LINEAR MODEL OF TSS AT CINCINNATI WW

UNIVARIATE TABLE

```
                                                             UNIVARIATE

VARIABLE=R              RESIDUALS

                 MOMENTS                                            QUANTILES(DEF=4)                                  EXTREMES

N                 129 SUM WGTS          129             100% MAX     541.558     99%       474.484                   LOWEST    HIGHEST
MEAN       -9.915E-16 SUM        -1.279E-13              75% Q3      5.38672     95%       184.236                 -132.322    221.186
STD DEV       84.8386 VARIANCE      7197.59              50% MED    -17.7072     90%         66.15                 -111.706    250.489
SKEWNESS      3.25266 KURTOSIS      14.7535              25% Q1     -34.0868     10%      -55.8275                 -110.999    259.253
USS            921292 CSS            921292               0% MIN    -132.322      5%      -82.9959                  -110.53     317.98
CV             -99999 STD MEAN      7.46963                                       1%      -126.137                 -93.9267    541.558
T:MEAN=0   -1.327E-16 PROB>|T|            1              RANGE        673.88
SGN RANK      -1693.5 PROB>|S|       0.0001              Q3-Q1       39.4735
NUM ¬= 0          129                                    MODE       -132.322
D:NORMAL     0.248685 PROB>D            <.01

                                                        MISSING VALUE         .
                                                                COUNT         4
                                                         % COUNT/NOBS      3.01
```

```
                     HISTOGRAM                     #       BOXPLOT                              NORMAL PROBABILITY PLOT
    525+*                                          1           *              525+                                                  *
       .                                                                         |
       .                                                                         |
       .                                                                         |
       .*                                          1           *                 |                                               *
       .*                                          2           *                 |                                            **
       .*                                          2           *                 |                                          **     ++
       .*                                          2           *                 |                                         * ++++++
       .**                                         4           0                 |                                     +***++
       .*                                          2           0                 |                               ++++++ *
       .**********                                20        +--+--+              |                         ++++++*******
       .**************************************    76        *-----*              |               *****************
       .********                                  15           0                 |       ********+++++
   -125+**                                         4           0             -125+*  * ** ++++++
        ----+----+----+----+----+----+----+---                                    +----+----+----+----+----+----+----+----+----+----+
        * MAY REPRESENT UP TO 2 COUNTS                                                -2        -1         0        +1        +2
```

LOG-LOG MODEL OF TDS AT CINCINNATI WW

ANOVA TABLE

```
                                  ANALYSIS OF VARIANCE

                              SUM OF         MEAN
         SOURCE     DF       SQUARES       SQUARE       F VALUE      PROB>F

         MODEL       1    1.96724152   1.96724152        66.434      0.0001
         ERROR     131    3.87918898   0.02961213
         C TOTAL   132    5.84643050

             ROOT MSE      0.1720818     R-SQUARE       0.3365
             DEP MEAN        5.29367     ADJ R-SQ       0.3314
             C.V.           3.250708

                                  PARAMETER ESTIMATES

                          PARAMETER         STANDARD       T FOR H0:
      VARIABLE   DF        ESTIMATE            ERROR     PARAMETER=0      PROB > |T|

      INTERCEP    1      6.84670420       0.19112373          35.823          0.0001
      LFLOW       1     -0.13980243       0.01715223          -8.151          0.0001


                        PREDICT     STD ERR                  STD ERR      STUDENT                           COOK'S
OBS           ACTUAL      VALUE     PREDICT     RESIDUAL     RESIDUAL     RESIDUAL     -2-1-0 1 2                  D

      1       5.3138     5.6018      0.0406      -0.2880       0.1672      -1.7222     |    ***|      |         0.088
      2       5.3658     5.3930      0.0193      -0.0272       0.1710      -0.1592     |       |      |         0.000
      3       5.3879     5.1934      0.0193       0.1946       0.1710       1.1379     |       |**    |         0.008
      4       5.0210     5.1336      0.0247      -0.1126       0.1703      -0.6610     |      *|      |         0.005
      5       5.1648     5.1538      0.0227       0.0110       0.1706       0.0642     |       |      |         0.000
      6       5.3391     5.2735      0.0151       0.0656       0.1714       0.3828     |       |      |         0.001
      7       5.6503     5.3596      0.0170       0.2907       0.1712       1.6975     |       |***   |         0.014
      8       5.7141     5.3907      0.0191       0.3235       0.1710       1.8913     |       |***   |         0.022
      9       5.4702     5.3463      0.0163       0.1238       0.1713       0.7228     |       |*     |         0.002
     10       5.3291     5.4131      0.0209      -0.0841       0.1708      -0.4921     |       |      |         0.002
     11       5.3391     5.2602      0.0155       0.0790       0.1714       0.4607     |       |      |         0.001
     12       5.1528     5.2605      0.0155      -0.1077       0.1714      -0.6282     |      *|      |         0.002
     13       5.1160     5.2205      0.0174      -0.1045       0.1712      -0.6103     |      *|      |         0.002
     14       5.0830     5.2030      0.0186      -0.1200       0.1711      -0.7016     |      *|      |         0.003
     15       5.2079     5.1834      0.0201       0.0245       0.1709       0.1435     |       |      |         0.000
     16       4.9896     5.0441      0.0341      -0.0545       0.1687      -0.3231     |       |      |         0.002
     17       5.2503     5.1852      0.0200       0.0651       0.1709       0.3811     |       |      |         0.001
     18       5.0380     5.1627      0.0219      -0.1247       0.1707      -0.7305     |      *|      |         0.004
     19       5.2612     5.2789      0.0150      -0.0178       0.1714      -0.1037     |       |      |         0.000
     20       5.4919     5.3344      0.0157       0.1574       0.1714       0.9186     |       |*     |         0.004
     21       5.3687     5.3025      0.0150       0.0662       0.1714       0.3861     |       |      |         0.001
     22       5.4569     5.4041      0.0202       0.0528       0.1709       0.3091     |       |      |         0.001
```

LOG-QUADRATIC MODEL OF TDS AT CINCINNATI WW

ANOVA TABLE

```
                                    ANALYSIS OF VARIANCE

                              SUM OF          MEAN
          SOURCE      DF     SQUARES         SQUARE       F VALUE        PROB>F

          MODEL        2  2.00823408     1.00411704        34.010        0.0001
          ERROR      130  3.83819642     0.02952459
          C TOTAL    132  5.84643050

              ROOT MSE     0.1718272       R-SQUARE        0.3435
              DEP MEAN       5.29367       ADJ R-SQ        0.3334
              C.V.          3.245899

                                    PARAMETER ESTIMATES

                            PARAMETER        STANDARD     T FOR HO:
       VARIABLE  DF          ESTIMATE           ERROR   PARAMETER=0        PROB > |T|

       INTERCEP   1        5.96975884      0.21960494        27.184            0.0001
       FLOW       1      -2.67955E-07     4.84976E-07        -0.553            0.5815
       LQ2        1      -0.005237701     0.002109102        -2.483            0.0143


                           PREDICT     STD ERR                  STD ERR    STUDENT                          COOK'S
  OBS          ACTUAL        VALUE     PREDICT     RESIDUAL    RESIDUAL   RESIDUAL      -2-1-0 1 2               D

     1         5.3138       5.5525      0.0587      -0.2386      0.1615    -1.4776      |     **|         |      0.096
     2         5.3658       5.3947      0.0194      -0.0289      0.1707    -0.1691      |       |         |      0.000
     3         5.3879       5.2006      0.0222       0.1874      0.1704     1.0997      |       |**       |      0.007
     4         5.0210       5.1271      0.0252      -0.1061      0.1700    -0.6240      |      *|         |      0.003
     5         5.1648       5.1531      0.0230       0.0117      0.1703     0.0684      |       |         |      0.000
     6         5.3391       5.2859      0.0206       0.0533      0.1706     0.3123      |       |         |      0.000
     7         5.6503       5.3660      0.0178       0.2843      0.1709     1.6637      |       |***      |      0.010
     8         5.7141       5.3927      0.0192       0.3214      0.1708     1.8825      |       |***      |      0.015
     9         5.4702       5.3542      0.0178       0.1159      0.1709     0.6784      |       |*        |      0.002
    10         5.3291       5.4114      0.0213      -0.0823      0.1705    -0.4829      |       |         |      0.001
    11         5.3391       5.2725      0.0211       0.0666      0.1705     0.3908      |       |         |      0.001
    12         5.1528       5.2728      0.0211      -0.1200      0.1705    -0.7036      |      *|         |      0.003
    13         5.1160       5.2308      0.0221      -0.1148      0.1704    -0.6740      |      *|         |      0.003
    14         5.0830       5.2115      0.0222      -0.1285      0.1704    -0.7544      |      *|         |      0.003
    15         5.2079       5.1890      0.0222       0.0189      0.1704     0.1111      |       |         |      0.000
    16         4.9896       4.9923      0.0730     -.002738      0.1556    -0.0176      |       |         |      0.000
    17         5.2503       5.1911      0.0222       0.0592      0.1704     0.3477      |       |         |      0.001
    18         5.0380       5.1642      0.0225      -0.1261      0.1703    -0.7404      |      *|         |      0.003
    19         5.2612       5.2912      0.0203      -0.0300      0.1706    -0.1761      |       |         |      0.000
    20         5.4919       5.3435      0.0180       0.1483      0.1709     0.8680      |       |*        |      0.003
    21         5.3687       5.3139      0.0192       0.0548      0.1708     0.3207      |       |         |      0.000
```

LINEAR MODEL OF TDS AT CINCINNATI WW

ANOVA TABLE

```
                              ANALYSIS OF VARIANCE

                            SUM OF          MEAN
         SOURCE      DF    SQUARES         SQUARE       F VALUE       PROB>F

         MODEL        1  70202.75151   70202.75151       49.087       0.0001
         ERROR      131    184349.68    1407.24946
         C TOTAL    132    254552.43

             ROOT MSE       37.51332       R-SQUARE       0.2758
             DEP MEAN       203.5542       ADJ R-SQ       0.2703
             C.V.           18.42916

                              PARAMETER ESTIMATES

                        PARAMETER        STANDARD      T FOR H0:
      VARIABLE  DF       ESTIMATE           ERROR    PARAMETER=0      PROB > |T|

      INTERCEP   1      229.75320      4.93353945          46.570          0.0001
      FLOW       1   -0.000272450     0.000038574          -7.063          0.0001


                      PREDICT     STD ERR                  STD ERR    STUDENT                              COOK'S
  OBS      ACTUAL      VALUE     PREDICT    RESIDUAL     RESIDUAL    RESIDUAL       -2-1-0 1 2                 D

     1      203.1      227.7      4.7236    -24.6212      37.2147     -0.6616      |     *|     |         0.004
     2      214.0      220.8      4.0687     -6.8585      37.2920     -0.1839      |      |     |         0.000
     3      218.8      192.5      3.6109     26.2680      37.3391      0.7035      |      |*    |         0.002
     4      151.6      172.6      5.4586    -21.0307      37.1141     -0.5667      |     *|     |         0.003
     5      175.0      180.3      4.6279     -5.3035      37.2268     -0.1425      |      |     |         0.000
     6      208.3      208.7      3.3349     -0.4140      37.3648     -0.0111      |      |     |         0.000
     7      284.4      218.4      3.8733     65.9693      37.3128      1.7680      |      |***  |         0.017
     8      303.1      220.7      4.0560     82.4580      37.2934      2.2111      |      |**** |         0.029
     9      237.5      217.3      3.7887     20.2250      37.3215      0.5419      |      |*    |         0.002
    10      206.3      222.0      4.1729    -15.7656      37.2805     -0.4229      |      |     |         0.001
    11      208.3      206.6      3.2821      1.6907      37.3695      0.0452      |      |     |         0.000
    12      172.9      206.7      3.2830    -33.7736      37.3694     -0.9038      |     *|     |         0.003
    13      166.7      199.1      3.3147    -32.3860      37.3666     -0.8667      |     *|     |         0.003
    14      161.3      195.0      3.4729    -33.7113      37.3522     -0.9025      |     *|     |         0.004
    15      182.7      189.7      3.7969     -7.0129      37.3207     -0.1879      |      |     |         0.000
    16      146.9      121.3     12.0872     25.5433      35.5127      0.7193      |      |*    |         0.030
    17      190.6      190.2      3.7600      0.3907      37.3244      0.0105      |      |     |         0.000
    18      154.2      183.3      4.3321    -29.1792      37.2623     -0.7831      |     *|     |         0.004
    19      192.7      209.5      3.3616    -16.8382      37.3624     -0.4507      |      |     |         0.001
    20      242.7      216.2      3.7108     26.5413      37.3293      0.7110      |      |*    |         0.002
    21      214.6      212.7      3.5000      1.9037      37.3497      0.0510      |      |     |         0.000
    22      234.4      221.5      4.1274     12.8770      37.2856      0.3454      |      |     |         0.001
```

LOG-LOG MODEL OF TDS AT CINCINNATI WW

PREDICTED AND OBSERVED PLOT

```
PLOT OF P*LFLOW       SYMBOL USED IS P
PLOT OF TDS_L*LFLOW   SYMBOL USED IS O
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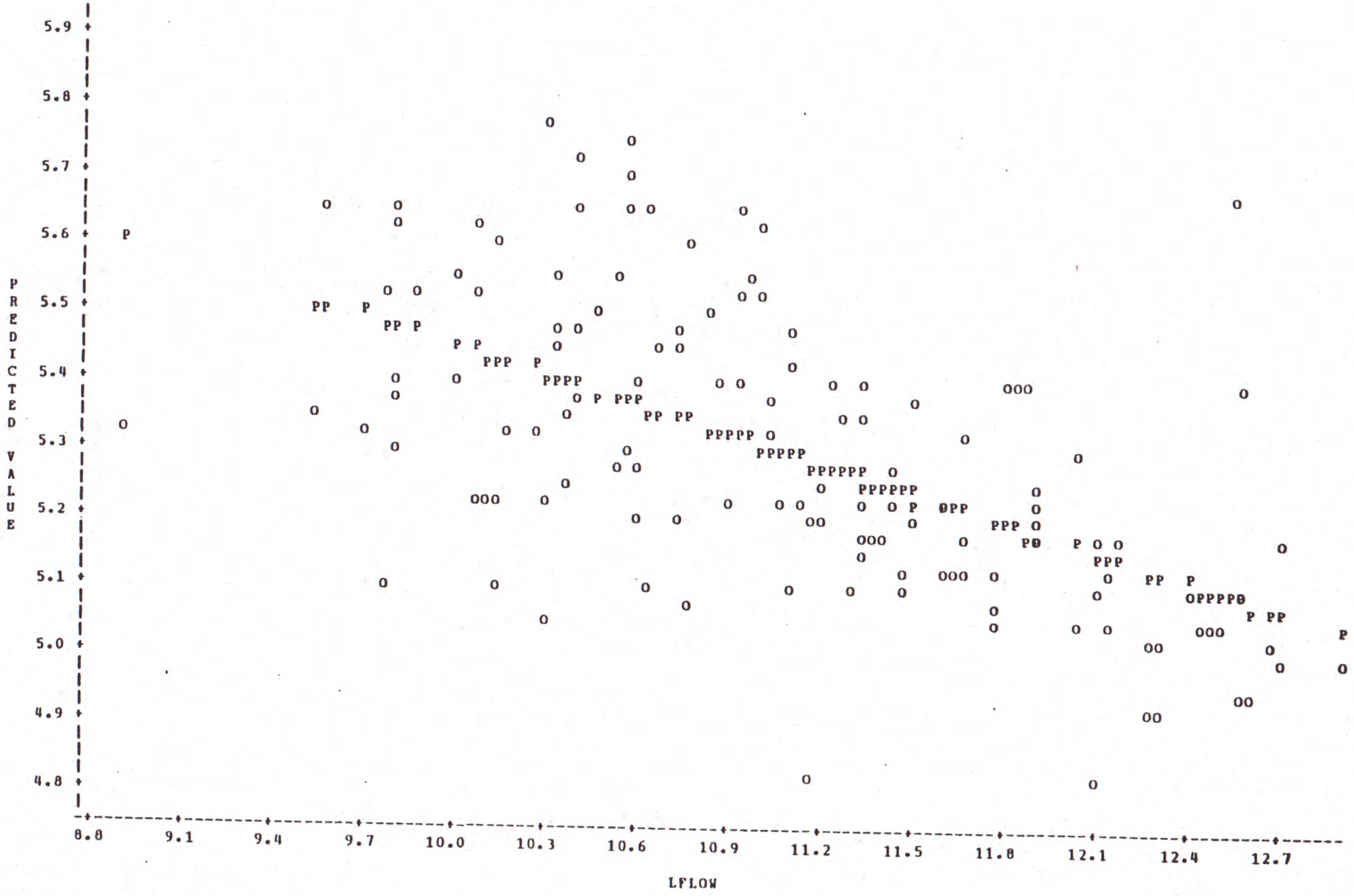
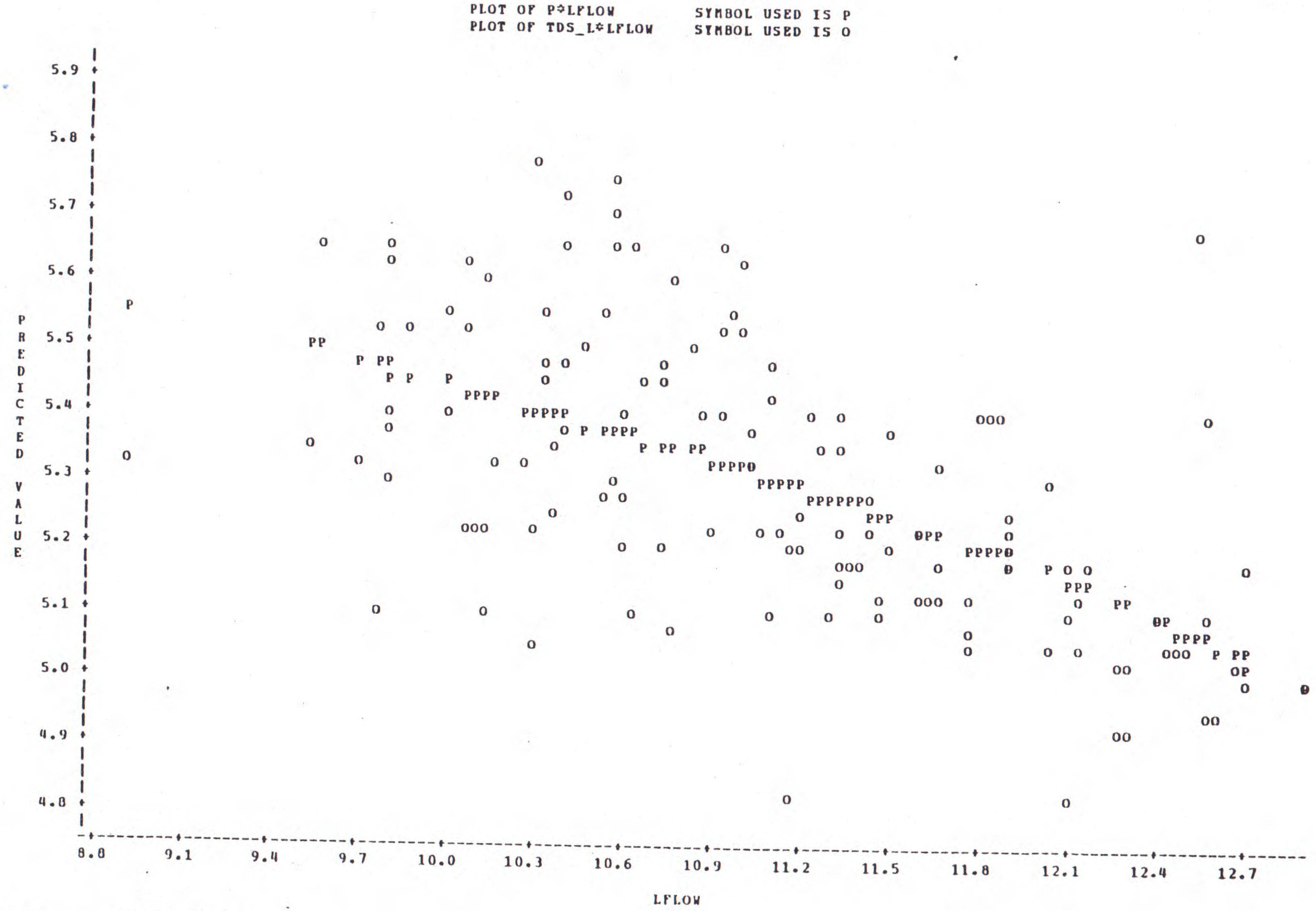


NOTE: 64 OBS HIDDEN

LOG-QUADRATIC MODEL OF TDS AT CINCINNATI WW

PREDICTED AND OBSERVED PLOT

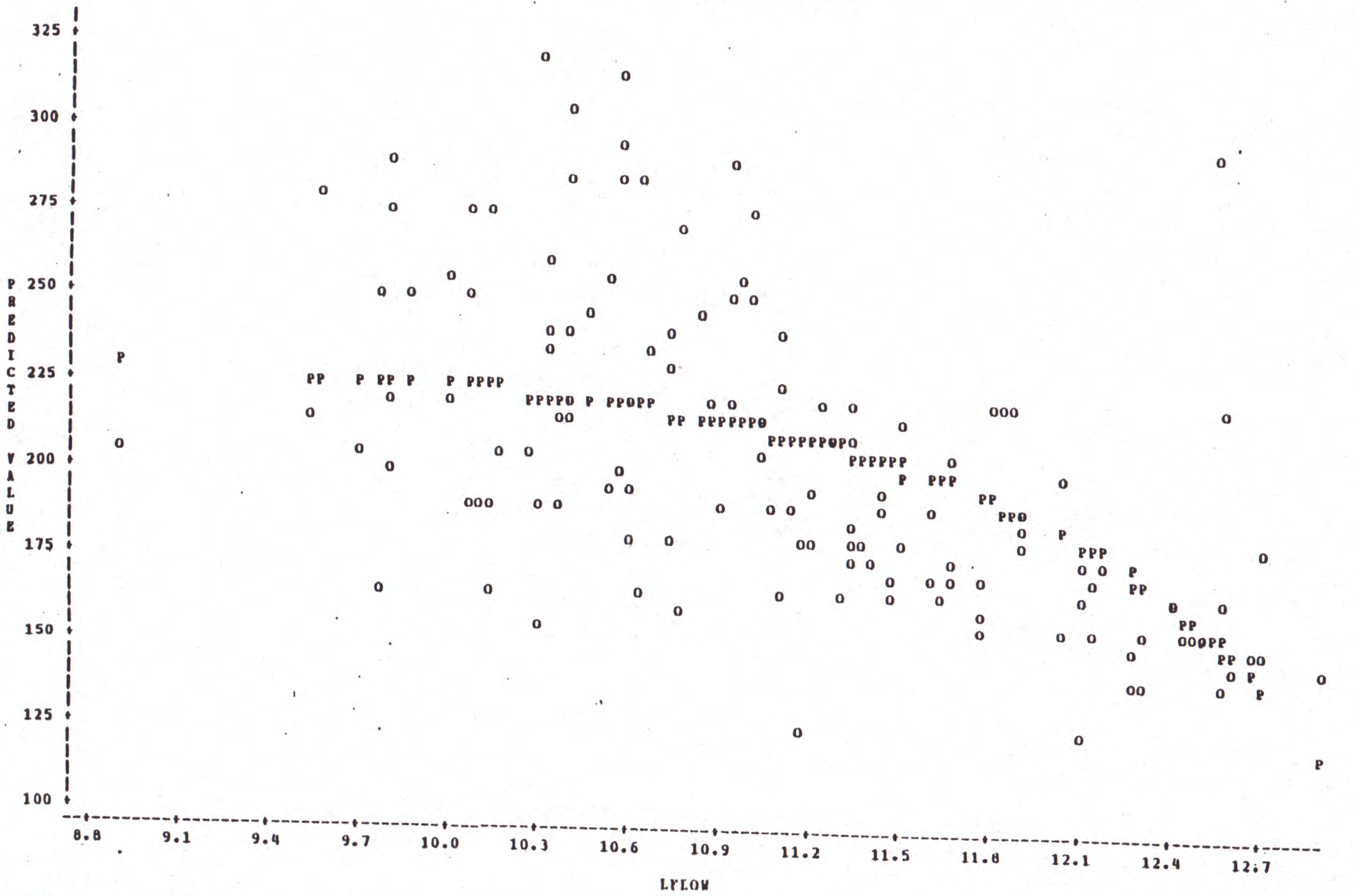


NOTE: 63 OBS HIDDEN

LINEAR MODEL OF TDS AT CINCINNATI WW

PREDICTED AND OBSERVED PLOT

PLOT OF P*LFLOW   SYMBOL USED IS P
PLOT OF TDS*LFLOW   SYMBOL USED IS O



NOTE: 64 OBS HIDDEN

LOG-LOG MODEL OF TDS AT CINCINNATI WW

UNIVARIATE TABLE

```
                                           UNIVARIATE

VARIABLE=R          RESIDUALS

               MOMENTS                                 QUANTILES(DEF=4)                              EXTREMES

N                 133  SUM WGTS          133    100% MAX    0.588752      99%     0.515734        LOWEST     HIGHEST
MEAN        2.264E-14  SUM         3.011E-12     75% Q3     0.114129      95%     0.310734     -0.455951    0.323457
STD DEV      0.171429  VARIANCE    0.0293878     50% MED -0.0283795      90%      0.22355     -0.371194    0.342243
SKEWNESS     0.320304  KURTOSIS     0.528328     25% Q1    -0.105544      10%     -0.19879     -0.356855     0.35892
USS           3.87919  CSS           3.87919      0% MIN   -0.455951       5%    -0.276419     -0.341421    0.373992
CV              99999  STD MEAN    0.0148648                                1%    -0.427134      -0.32707    0.588752
T:MEAN=0    1.523E-12  PROB>|T|            1     RANGE         1.0447
SGN RANK       -137.5  PROB>|S|      0.75833     Q3-Q1       0.219673
NUM ¬= 0          133                            MODE       -0.455951
D:NORMAL    0.0815316  PROB>D          0.029

STEM LEAF                                #
   5 9                                   1
   5
   4
   4
   3 67                                  2
   3 01224                               5
   2 5699                                4
   2 0013                                4
   1 667788899                           9
   1 00001112233444                     14
   0 555677778888                       12
   0 111222224                           9
  -0 4443321110                         10
  -0 9999999888777776666655555          25
  -1 444222111100000                    15
  -1 877665555                           9
  -2 110000                              6
  -2 977                                 3
  -3 43                                  2
  -3 76                                  2
  -4
  -4 6                                   1
     ----+----+----+----+----+
  MULTIPLY STEM.LEAF BY 10**-01
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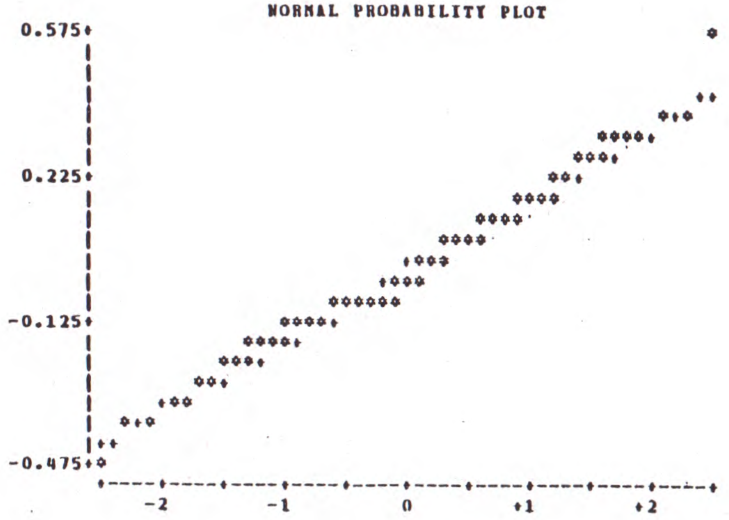

LOG-QUADRATIC MODEL OF TDS AT CINCINNATI WW

UNIVARIATE TABLE

```
                                          UNIVARIATE
VARIABLE=R              RESIDUALS

                MOMENTS                                   QUANTILES(DEF=4)                                    EXTREMES

N                 133  SUM WGTS          133    100% MAX    0.610861       99%       0.520649          LOWEST     HIGHEST
MEAN        2.147E-14  SUM         2.855E-12     75% Q3     0.109619       95%       0.317698       -0.468102    0.321447
STD DEV      0.170521  VARIANCE    0.0290772     50% MED -0.0249193       90%       0.212724       -0.355969    0.331851
SKEWNESS     0.355531  KURTOSIS     0.718371     25% Q1    -0.105795       10%      -0.193443       -0.355455    0.359321
USS            3.8382  CSS            3.8382      0% MIN   -0.468102        5%      -0.277763       -0.336168    0.369061
CV              99999  STD MEAN     0.014786                                1%      -0.429977       -0.326758    0.610861
T:MEAN=0    1.452E-12  PROB>|T|            1     RANGE       1.07896
SGN RANK       -166.5  PROB>|S|     0.709295     Q3-Q1      0.215414
NUM ¬= 0          133                            MODE      -0.468102
D:NORMAL    0.0731924  PROB>D           0.08

STEM LEAF                       #
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   5
   5
   4
   4
   3 67                         2
   3 02223                      5
   2 588                        3
   2 0024                       4
   1 555667889999              12
   1 0011112234                10
   0 5555556667788999          16
   0 11222                      5
  -0 4433333222110000          16
  -0 99998888877666555         17
  -1 444333322111100000000     21
  -1 997776665                  9
  -2 42000                      5
  -2 88                         2
  -3 43                         2
  -3 66                         2
  -4
  -4 7                          1
     ----+----+----+----+-
  MULTIPLY STEM.LEAF BY 10**-01
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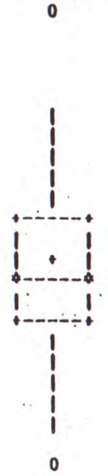
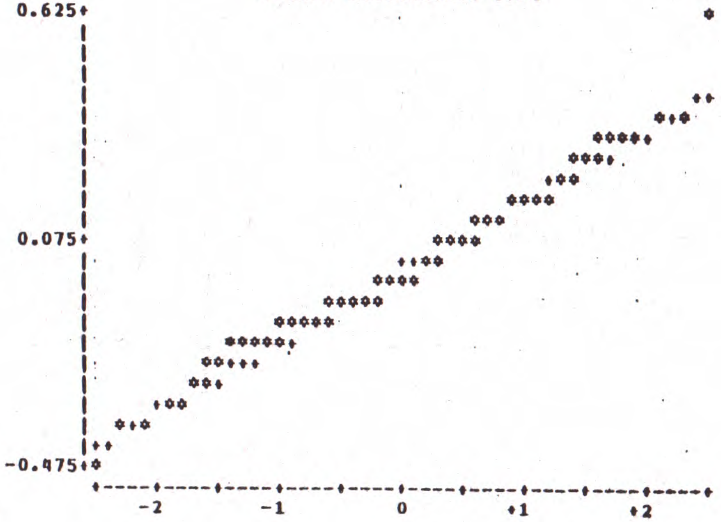
BOXPLOT



NORMAL PROBABILITY PLOT



LINEAR MODEL OF TDS AT CINCINNATI WW

UNIVARIATE TABLE

```
                                                    UNIVARIATE

VARIABLE=R            RESIDUALS

                    MOMENTS                                       QUANTILES(DEF=4)                              EXTREMES

N                 133  SUM WGTS          133      100% MAX     139.874      99%     125.355           LOWEST    HIGHEST
MEAN        1.779E-14  SUM         2.366E-12       75% Q3      24.3826      95%     68.8623         -85.3003    77.5294
STD DEV        37.371  VARIANCE      1396.59       50% MED    -6.12635      90%     53.9674         -65.4932     82.458
SKEWNESS     0.818372  KURTOSIS     0.957855       25% Q1     -27.7602      10%    -35.9342         -60.4964    93.2361
USS            184350  CSS            184350        0% MIN    -85.3003       5%    -55.9105         -59.3631    97.1703
CV              99999  STD MEAN      3.24047                                 1%    -78.5658          -57.573    139.874
T:MEAN=0    5.490E-15  PROB>|T|            1      RANGE        225.174
SGN RANK       -396.5  PROB>|S|     0.373821      Q3-Q1        52.1428
NUM ¬= 0          133                             MODE        -85.3003
D:NORMAL     0.096226  PROB>D           <.01

STEM LEAF                #
  14 0                   1
  13
  12
  11
  10
   9 37                  2
   8 2                   1
   7 38                  2
   6 133667              6
   5 01225               5
   4 2                   1
   3 257778              6
   2 04556666778        11
   1 012333456779       12
   0 1223469             7
  -0 87776555533220000  17
  -1 9987777653322100   16
  -2 9999988665555433211 19
  -3 88666655444432100  17
  -4 921                 3
  -5 9866                4
  -6 50                  2
  -7
  -8 5                   1
     ----+----+----+----+
 MULTIPLY STEM.LEAF BY 10**+01
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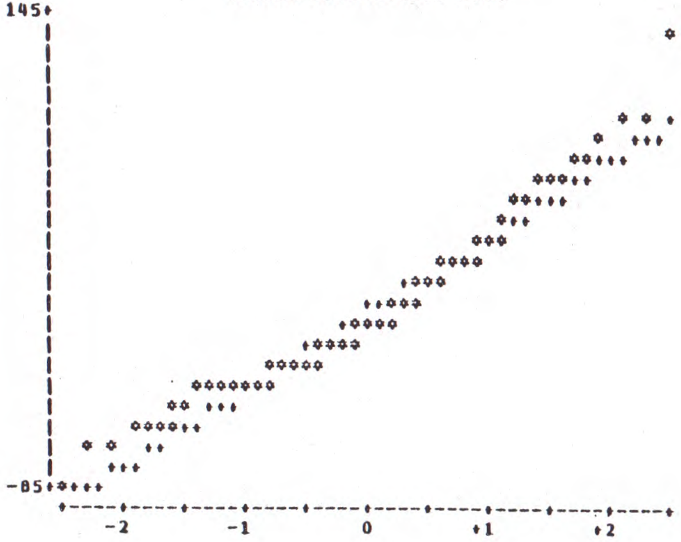
BOXPLOT

NORMAL PROBABILITY PLOT



APPENDIX D: ANNUAL MEAN OF CONCENTRATION FOR EACH STATION

ANNUAL MEAN OF TOTAL SUSPENDED SOLIDS (MG/L)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	43.2	29.5	60.9	52.6	22.3	32.3	22.1	14.0	42.1	15.3	15.0
0.0 MONOGA R	31.6	40.9	37.8	63.9	48.5	26.5	30.4	20.0	42.2	19.1	26.1
15.2 S HEIGHTS	33.9	44.8	42.2	46.5	45.8	32.3	27.8	26.0	46.2	26.2	34.6
25.4 BEAVER R	21.5	34.5	35.8	103.8	33.2	22.7	29.8	27.8	32.7	19.9	54.6
40.2 E LIVERPL	33.2	32.6	74.5	97.3	93.1	75.3	160.0	44.3	39.6	18.3	20.4
86.8 WHEELING	39.2	38.6	68.6	62.2	28.3	66.9	35.0	32.8	37.7	19.3	21.4
126.4 HANNIBAL	23.4	16.1	21.4	34.1	30.5	29.2	22.7	24.1	23.8	18.6	13.3
161.8 WILLOW IS	27.9	29.6	42.8	22.8	21.5	38.8	37.3	24.2	17.4	16.4	15.8
172.2 MUSKGM R	58.5	64.5	68.4	76.5	125.1	70.9	87.3	54.0	68.1	40.7	36.4
203.9 BELLEVL	33.5	45.4	49.8	90.2	120.0	57.6	51.8	25.2	29.0	33.2	14.9
260.0 ADDISON	58.7	102.9	64.7	59.8	88.4	64.3	44.4	38.1	83.0	64.1	20.7
265.7 KANAWA R	37.4	49.4	115.1	53.2	36.4	99.3	42.7	38.9	17.9	29.9	13.1
279.2 GALLIPOL	49.9	62.6	92.0	65.8	66.3	56.2	50.3	27.1	51.1	50.0	18.3
306.9 HUNTING	85.5	110.8	136.1	48.3	98.8	10.1	23.0	7.0	29.5	30.7	9.3
317.1 BIG SANDY	136.8	273.4	163.5	64.4	164.9	123.1	33.8	130.1	62.3	55.1	17.4
350.7 PORTSM	70.3	92.4	47.4	38.4	66.8	80.3	41.7	80.5	88.8	64.3	22.6
356.5 SCIOTO R	98.6	126.1	59.3	88.8	106.7	97.8	83.0	72.7	86.6	71.3	33.8
408.5 MAYSVILLE	54.2	46.0	54.0	63.4	55.8	58.7	87.5	63.6	115.6	49.6	26.2

ANNUAL MEAN OF TOTAL SUSPENDED SOLIDS (MG/L)

(CONTINUED)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
462.8 CINCINN	96.6	106.9	91.7	105.3	82.9	73.3	111.2	59.9	200.9	86.2	34.6
464.1 LIL MIAMI	132.7	94.8	30.3	110.0	87.9	49.3	94.7	100.6	58.0	130.0	35.0
470.2 LICKING R	107.4	130.0	72.3	55.0	61.5	100.2	56.6	84.9	51.4	85.7	65.6
490.0 N BEND	62.3	101.0	69.1	38.7	82.7	95.0	500.5	41.2	55.1	53.1	31.8
491.1 GR MIAMI	96.5	100.0	71.4	305.3	72.5	120.3	158.1	59.3	61.1	109.1	87.0
531.5 MARKLAND	45.3	50.9	47.9	40.9	72.9	100.1	30.4	33.7	226.1	56.5	31.5
600.6 LOUISVL	111.5	81.3	88.2	33.3	70.9	104.0	55.2	73.9	56.9	40.1	34.7
625.9 W POINT	103.9	210.6	298.3	52.7	127.3	135.0	79.6	50.3	74.8	54.8	52.5
720.7 CANNELTN	76.7	113.5	84.6	54.9	52.1	163.5	76.1	68.7	95.3	56.8	22.2
784.2 GREEN R	65.8	96.8	86.2	38.2	76.1	153.8	60.2	59.9	54.5	66.5	54.4
791.5 EVANSVL	122.0	356.0	405.3	606.3	85.5	159.7	85.1	99.8	162.9	102.1	78.4
846.0 UNIONTOWN	61.3	73.3	142.8	58.9	44.5	79.6	64.0	62.8	120.2	94.4	58.3
848.0 WABASH R	119.4	174.5	229.7	170.2	125.7	321.6	115.5	111.9	117.8	150.8	92.3
918.5 SMITHLAND	.	.	.	.	.	86.3	44.3	52.6	71.7	62.5	23.3
920.4 CUMBRLD R	25.6	28.7	37.2	18.0	26.6	28.5	17.8	12.4	10.7	12.2	13.8
934.5 TENNESS R	22.0	18.3	28.8	21.0	30.3	32.2	17.9	14.8	10.0	11.8	14.4
952.3 JOPPA	82.2	84.5	139.4	86.6	95.3	108.2	46.4	57.3	66.0	80.2	39.1

ANNUAL MEAN OF TOTAL DISSOLVED SOLIDS (MG/L)

	YY										
STATION	77	78	79	80	81	82	83	84	85	86	87
0.0 ALLEGY R	157.0	182.5	142.9	150.1	134.8	149.2	148.3	163.4	169.8	148.6	153.9
0.0 MONOGA R	226.2	225.0	220.3	230.0	214.2	214.1	236.9	202.9	182.4	209.4	223.0
15.2 S HEIGHTS	192.8	203.7	207.6	195.2	216.5	229.7	195.5	193.8	200.1	188.0	183.6
25.4 BEAVER R	271.7	253.1	270.3	239.6	243.6	253.4	231.3	224.8	248.3	227.7	231.8
40.2 E LIVERPL	202.1	207.3	208.2	196.6	179.0	187.2	189.9	182.0	198.6	185.9	207.3
86.8 WHEELING	212.1	235.1	216.5	216.3	213.1	220.6	226.0	206.0	222.7	211.9	208.0
126.4 HANNIBAL	182.2	238.2	234.0	230.0	222.7	231.5	258.1	212.2	227.9	218.5	214.7
161.8 WILLOW IS	216.3	228.5	224.7	237.0	211.5	220.3	251.6	216.1	231.5	207.6	216.4
172.2 MUSKGM R	420.5	360.9	305.3	359.4	360.4	387.8	377.8	355.2	375.0	359.6	390.6
203.9 BELLEVL	244.6	247.5	233.6	237.1	224.7	257.8	255.5	224.5	246.1	222.4	239.8
260.0 ADDISON	224.9	244.3	269.6	249.1	223.5	231.8	241.1	237.3	228.5	204.2	242.1
265.7 KANAWA R	154.2	134.5	118.8	126.6	121.3	108.6	119.1	107.0	111.4	110.7	131.3
279.2 GALLIPOL	202.6	205.8	228.7	232.1	221.7	213.8	214.3	192.4	192.3	176.3	210.9
306.9 HUNTING	189.7	200.4	209.1	198.7	206.6	214.1	220.1	199.2	191.8	177.9	232.8
317.1 BIG SANDY	216.1	218.1	228.8	259.1	259.9	233.1	270.6	251.7	253.0	277.8	321.0
350.7 PORTSM	211.5	207.8	197.7	243.6	231.5	208.8	242.8	188.3	220.8	187.5	220.5
356.5 SCIOTO R	387.6	321.9	347.7	332.4	378.4	354.9	417.9	397.2	390.1	358.3	422.7
408.5 MAYSVILLE	225.5	216.8	188.9	217.9	223.2	211.4	224.1	193.0	245.8	227.1	199.6

ANNUAL MEAN OF TOTAL DISSOLVED SOLIDS (MG/L)

(CONTINUED)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
462.8 CINCINN	209.5	199.2	194.4	210.2	208.7	201.8	198.5	193.0	208.4	219.5	188.1
464.1 LIL MIAMI	381.9	341.9	296.9	325.3	352.8	340.1	398.0	442.2	444.0	388.8	365.7
470.2 LICKING R	171.0	161.1	159.5	187.9	168.6	172.4	228.0	212.5	229.8	226.6	169.3
490.0 N BEND	229.2	216.6	209.6	247.4	237.5	210.9	235.5	215.6	241.2	226.8	206.0
491.1 GR MIAMI	468.3	415.6	368.0	411.5	461.2	395.3	430.7	441.4	444.3	402.9	389.7
531.5 MARKLAND	234.9	232.9	209.2	232.3	246.6	219.3	230.2	206.8	233.4	240.1	209.8
600.6 LOUISVL	211.9	223.5	200.0	240.3	242.5	220.1	229.2	216.4	233.3	235.2	204.4
625.9 W POINT	222.3	230.8	205.2	250.4	247.3	225.3	232.3	219.5	234.6	246.3	219.2
720.7 CANNELTN	234.0	233.0	198.4	228.7	227.2	211.5	233.2	218.8	216.1	224.8	216.3
784.2 GREEN R	182.9	195.9	165.1	217.4	192.6	175.9	195.3	221.1	230.4	253.4	217.9
791.5 EVANSVL	217.4	227.4	202.1	235.3	254.6	208.1	224.5	209.9	222.1	226.3	210.6
846.0 UNIONTOWN	227.9	232.3	203.1	247.7	249.2	208.5	219.3	218.2	218.2	217.9	229.7
848.0 WABASH R	323.6	292.0	295.1	324.4	359.0	299.2	315.4	289.1	287.0	287.6	287.6
918.5 SMITHLAND	.	.	.	.	.	225.6	246.9	227.9	237.2	250.3	146.0
920.4 CUMBRLD R	120.7	129.6	119.8	132.6	145.2	128.9	127.6	134.6	134.1	139.3	109.0
934.5 TENNESS R	101.8	109.9	97.9	113.3	132.4	105.2	97.4	113.3	115.6	127.1	97.9
952.3 JOPPA	212.1	214.8	199.3	238.1	257.1	233.3	215.6	213.2	221.9	242.4	137.0

ANNUAL MEAN OF HARDNESS (MG/L)

	YY										
STATION	77	78	79	80	81	82	83	84	85	86	87
0.0 ALLEGY R	.	.	92.5	101.0	88.7	97.1	92.1	87.7	103.7	89.6	94.5
0.0 MONOGA R	.	.	130.9	129.3	134.3	117.3	125.0	111.7	106.7	119.0	130.3
15.2 S HEIGHTS	.	.	120.7	121.8	115.3	110.2	112.3	93.8	115.5	105.3	111.8
25.4 BEAVER R	.	.	147.9	150.6	152.3	146.7	137.3	125.3	153.0	142.5	142.5
40.2 E LIVERPL	.	.	125.8	115.1	117.9	115.3	109.3	103.9	123.0	118.0	131.5
86.8 WHEELING	.	.	127.1	131.0	146.0	122.1	128.4	124.8	130.0	126.3	111.8
126.4 HANNIBAL	.	.	124.4	134.3	130.7	125.2	140.6	130.3	131.0	123.3	115.3
161.8 WILLOW IS	.	.	129.4	137.2	125.3	123.8	136.1	124.8	132.0	117.5	111.3
172.2 MUSKGM R	243.0	265.3	226.7	238.6	222.5	242.4	231.9	230.5	211.5	242.4	248.7
203.9 BELLEVL	.	.	145.5	155.7	135.6	145.0	153.7	137.7	138.2	133.3	123.3
260.0 ADDISON	.	.	141.2	150.1	145.8	134.7	146.8	135.2	131.1	132.5	146.0
265.7 KANAWA R	82.5	83.0	61.5	87.4	63.0	70.6	66.1	65.5	73.1	71.1	69.5
279.2 GALLIPOL	.	.	110.6	123.9	123.5	123.3	117.3	109.2	112.4	107.8	106.5
306.9 HUNTING	.	96.0	112.7	135.3	126.6	133.9	122.1	118.5	122.4	114.3	124.8
317.1 BIG SANDY	142.0	147.0	117.1	142.9	128.1	130.5	146.8	143.2	139.2	148.9	154.2
350.7 PORTSM	192.0	.	124.5	121.0	126.7	118.6	127.9	113.8	132.7	123.0	111.3
356.5 SCIOTO R	267.3	293.8	263.8	254.3	251.9	223.5	241.5	241.6	258.2	245.8	286.2
408.5 MAYSVILLE	.	111.0	124.1	135.8	137.1	124.3	134.9	163.5	154.8	122.4	128.2

ANNUAL MEAN OF HARDNESS (MG/L)

(CONTINUED)

	YY										
STATION	77	78	79	80	81	82	83	84	85	86	87
462.8 CINCINN	.	155.0	119.7	141.7	140.0	125.0	132.1	128.8	133.0	118.9	117.2
464.1 LIL MIAMI	298.7	253.5	253.2	245.5	256.4	251.1	238.2	198.5	226.8	254.2	270.2
470.2 LICKING R	124.0	118.6	122.0	129.7	148.8	133.5	152.3	159.7	120.8	132.2	124.0
490.0 N BEND	.	208.0	129.3	147.4	144.0	126.3	140.8	135.3	154.6	128.5	129.2
491.1 GR MIAMI	301.0	279.9	323.4	312.0	315.2	283.6	318.6	321.7	292.4	272.2	291.5
531.5 MARKLAND	.	207.0	136.1	158.2	141.4	141.3	152.7	140.3	164.3	145.6	147.4
600.6 LOUISVL	.	182.0	118.4	158.9	146.2	143.3	137.8	136.9	141.9	140.3	131.8
625.9 W POINT	.	183.5	124.2	157.3	150.4	140.8	144.2	142.2	135.4	145.5	131.2
720.7 CANNELTN	.	151.0	137.5	134.3	139.0	131.8	122.0	137.3	134.1	139.0	133.8
784.2 GREEN R	.	125.0	118.2	166.7	122.5	122.8	148.4	160.3	164.9	187.2	157.5
791.5 EVANSVL	.	96.5	128.6	159.0	156.2	137.3	140.6	147.3	139.4	160.3	139.7
846.0 UNIONTOWN	.	216.5	124.9	161.2	161.1	129.4	137.5	135.5	146.5	146.4	138.2
848.0 WABASH R	.	285.0	212.1	210.7	193.4	208.5	222.7	255.6	220.6	237.3	253.3
918.5 SMITHLAND	.	.	.	.	.	153.2	164.0	158.8	151.6	151.3	114.3
920.4 CUMBRLD R	.	147.0	82.7	103.0	98.2	98.8	100.5	91.7	106.2	107.0	89.7
934.5 TENNESS R	.	78.0	64.2	73.5	72.1	74.9	67.3	71.3	75.4	79.0	72.7
952.3 JOPPA	.	180.5	161.1	159.5	154.9	157.0	143.8	149.4	152.2	159.3	111.8

ANNUAL MEAN OF SULFATE (MG/L)

					YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	71.3	85.5	72.8	66.3	64.2	67.5	69.0	68.7	69.3	61.6	57.7
0.0 MONOGA R	116.3	110.0	111.8	109.2	124.6	104.5	121.3	99.9	90.0	98.2	110.5
15.2 S HEIGHTS	89.7	95.8	93.5	102.8	87.6	88.7	91.9	85.8	87.5	77.7	77.7
25.4 BEAVER R	87.7	74.1	65.1	72.7	77.4	68.3	70.9	64.7	69.8	62.8	57.0
40.2 E LIVERPL	86.1	89.4	78.4	89.9	83.5	76.0	81.9	76.2	82.8	74.3	81.7
86.8 WHEELING	94.5	101.6	93.3	95.3	94.2	86.5	77.3	86.3	95.1	82.5	59.4
126.4 HANNIBAL	69.3	95.9	89.2	93.0	87.6	87.3	85.5	90.1	93.8	79.8	68.4
161.8 WILLOW IS	98.3	89.5	85.6	105.2	93.4	90.0	115.8	87.3	97.2	91.9	60.1
172.2 MUSKGM R	126.1	104.4	97.8	112.8	122.2	122.0	131.7	120.6	115.4	120.3	103.0
203.9 BELLEVL	90.3	91.4	88.0	100.0	91.3	86.2	101.5	87.3	86.8	85.8	68.3
260.0 ADDISON	95.9	86.3	85.1	95.2	89.3	86.5	104.2	84.8	82.8	75.7	77.8
265.7 KANAWA R	43.1	31.3	26.8	30.3	32.6	24.3	35.8	23.5	32.6	28.3	24.7
279.2 GALLIPOL	77.6	69.3	74.2	71.5	88.1	63.8	82.5	60.3	70.7	60.1	54.6
306.9 HUNTING	74.0	74.6	68.0	85.5	85.9	81.6	101.1	72.8	80.9	69.9	64.3
317.1 BIG SANDY	89.7	92.0	85.7	95.0	113.4	92.5	119.3	101.9	100.4	107.4	110.7
350.7 PORTSM	76.8	73.5	60.1	79.1	79.2	63.3	87.0	58.6	80.0	68.5	63.3
356.5 SCIOTO R	84.5	63.5	45.0	58.2	79.7	67.7	81.6	68.5	79.0	79.0	79.3
408.5 MAYSVILLE	80.8	73.1	55.4	73.1	85.8	64.9	87.9	57.3	69.3	69.0	59.0

ANNUAL MEAN OF SULFATE (MG/L)

(CONTINUED)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
462.8 CINCINN	72.5	73.0	56.9	76.4	81.8	59.3	86.2	55.0	63.8	60.8	57.8
464.1 LIL MIAMI	50.6	34.8	29.9	34.9	45.4	40.4	50.8	44.4	42.0	37.5	34.8
470.2 LICKING R	36.8	23.8	19.3	25.3	30.3	23.8	33.5	37.4	27.0	45.8	38.8
490.0 N BEND	78.5	69.9	62.2	76.3	77.5	60.8	77.6	73.2	78.0	64.0	59.3
491.1 GR MIAMI	75.4	59.9	52.3	48.2	66.4	54.8	70.4	65.5	59.9	52.3	52.3
531.5 MARKLAND	78.1	68.8	54.3	68.3	82.4	54.8	76.3	71.8	76.6	62.1	55.8
600.6 LOUISVL	77.4	103.7	70.9	71.6	72.8	58.2	65.3	66.4	64.8	69.9	53.8
625.9 W POINT	80.4	78.4	70.5	73.7	74.9	60.3	68.4	66.7	70.7	66.3	52.2
720.7 CANNELTN	80.3	71.5	63.5	92.1	80.2	53.0	72.3	68.8	64.7	56.9	57.8
784.2 GREEN R	57.2	59.8	53.3	73.1	74.3	54.5	57.6	76.5	79.8	85.0	48.7
791.5 EVANSVL	77.1	107.5	63.8	73.6	81.5	53.3	66.0	67.8	67.4	64.7	53.6
846.0 UNIONTOWN	75.9	76.6	70.8	69.2	71.8	55.0	67.6	65.2	68.3	60.0	53.3
848.0 WABASH R	76.3	59.6	61.9	61.9	64.5	50.3	65.3	70.7	54.9	41.8	53.9
918.5 SMITHLAND	.	.	.	.	.	60.2	69.4	63.2	64.1	58.7	27.4
920.4 CUMBRLD R	18.1	19.0	17.8	18.4	27.6	28.5	25.8	18.1	19.5	23.2	18.2
934.5 TENNESS R	15.0	12.9	23.4	13.0	18.1	10.0	14.5	13.6	14.2	17.9	14.6
952.3 JOPPA	70.1	65.7	60.9	67.3	63.0	43.8	57.6	60.3	57.3	44.3	29.1

ANNUAL MEAN OF TOTAL PHOSPHORUS (MG/L)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0
0.0 MONOGA R	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1
15.2 S HEIGHTS	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1
25.4 BEAVER R	0.2	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.3
40.2 E LIVERPL	0.2	0.2	0.2	0.5	0.3	0.2	0.3	0.1	0.2	0.1	0.1
86.8 WHEELING	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1
126.4 HANNIBAL	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
161.8 WILLOW IS	0.1	0.1	0.3	0.3	0.2	0.1	0.2	0.1	0.1	0.2	0.1
* 172.2 MUSKGM R	0.2	0.2	0.9	0.3	0.2	0.2	0.1	0.1	0.1	0.4	0.1
203.9 BELLEVL	0.2	0.3	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1
260.0 ADDISON	0.2	0.3	0.3	1.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1
* 265.7 KANAWA R	0.2	0.3	0.6	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1
279.2 GALLIPOL	0.2	0.2	0.4	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.1
306.9 HUNTING	0.2	0.3	0.2	0.1	0.2	0.0	0.1	0.2	0.2	0.6	0.6
317.1 BIG SANDY	0.3	0.3	0.3	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.0
350.7 PORTSM	0.3	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2
* 356.5 SCIOTO R	0.8	0.5	0.5	0.6	0.4	0.4	0.3	0.2	0.3	0.3	0.4
* 408.5 MAYSVILLE	0.3	0.2	0.1	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.1

* INCOMPLETE DATA SETS

ANNUAL MEAN OF TOTAL PHOSPHORUS (MG/L)

(CONTINUED)

	YY										
STATION	77	78	79	80	81	82	83	84	85	86	87
* 462.8 CINCINN	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.4	0.2	0.1
* 464.1 LIL MIAMI	0.7	0.6	0.4	0.5	0.5	0.4	0.3	0.4	0.5	0.7	1.8
470.2 LICKING R	0.3	0.4	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.3	0.5
* 490.0 N BEND	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
* 491.1 GR MIAMI	0.5	0.5	0.3	0.5	0.5	0.5	0.4	0.4	0.3	0.7	0.5
* 531.5 MARKLAND	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.3	0.1
600.6 LOUISVL	0.6	0.4	0.3	0.1	0.2	0.2	0.2	0.1	0.3	0.2	0.1
625.9 W POINT	0.6	0.7	0.4	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2
* 720.7 CANNELTN	0.4	0.5	0.2	0.1	0.2	0.3	0.2	0.1	0.1	0.7	0.1
784.2 GREEN R	0.3	0.3	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1
791.5 EVANSVL	0.5	0.8	0.3	0.5	0.4	0.2	0.2	0.2	0.2	0.2	0.2
* 846.0 UNIONTOWN	0.3	0.5	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1
* 848.0 WABASH R	0.4	0.6	0.2	0.3	0.3	0.4	0.2	0.2	0.2	0.4	0.1
* 918.5 SMITHLAND	.	.	.	.	.	0.2	0.1	0.1	0.1	0.1	0.1
920.4 CUMBRLD R	0.2	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
934.5 TENNESS R	0.2	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
952.3 JOPPA	0.3	0.7	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.1

* INCOMPLETE DATA SETS

ANNUAL MEAN OF AMMONIA (MG/L)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1
0.0 MONOGA R	0.5	0.3	0.2	0.2	0.2	0.1	0.4	0.2	0.2	0.2	0.1
15.2 S-HEIGHTS	0.5	0.4	0.3	0.3	0.4	0.2	0.4	0.2	0.2	0.2	0.1
25.4 BEAVER R	0.9	0.6	0.5	0.6	0.6	0.4	0.4	0.3	0.3	0.3	0.3
40.2 E LIVERPL	0.5	0.4	0.3	0.3	0.3	0.2	0.6	0.2	0.2	0.2	0.2
86.8 WHEELING	0.5	0.4	0.3	0.3	0.3	0.2	0.7	0.2	0.2	0.2	0.1
126.4 HANNIBAL	0.3	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.2
161.8 WILLOW IS	0.5	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.2
* 172.2 MUSKGM R	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
203.9 BELLEVL	0.4	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
260.0 ADDISON	0.5	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1
* 265.7 KANAWA R	0.4	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.3	0.1	0.1
279.2 GALLIPOL	0.5	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1
306.9 HUNTING	0.3	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.0	0.0
317.1 BIG SANDY	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
350.7 PORTSM	0.5	0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1
* 356.5 SCIOTO R	0.5	0.2	0.2	0.2	0.3	0.1	0.2	0.1	0.2	0.1	0.0
* 408.5 MAYSVILLE	0.5	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

* INCOMPLETE DATA SETS

ANNUAL MEAN OF AMMONIA (MG/L)

(CONTINUED)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
* 462.8 CINCINN	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
* 464.1 LIL MIAMI	0.4	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.1
470.2 LICKING R	0.3	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
* 490.0 N BEND	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.1
* 491.1 GR MIAMI	0.7	0.4	0.3	0.3	0.4	0.2	0.3	0.1	0.1	0.2	0.1
* 531.5 MARKLAND	0.4	0.2	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.0
600.6 LOUISVL	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.1
625.9 W POINT	0.3	0.2	0.2	0.3	0.3	0.3	0.2	0.3	0.2	0.3	0.3
* 720.7 CANNELTN	0.3	0.2	0.1	0.2	0.2	0.3	0.1	0.1	0.1	0.1	0.0
784.2 GREEN R	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
791.5 EVANSVL	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1
* 846.0 UNIONTOWN	0.2	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.0
* 848.0 WABASH R	0.2	0.2	0.2	0.1	0.2	0.3	0.1	0.1	0.1	0.1	0.0
* 918.5 SMITHLAND	.	.	.	.	.	0.1	0.1	0.1	0.1	0.1	0.0
920.4 CUMBRLD R	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
934.5 TENNESS R	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
952.3 JOPPA	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1

* INCOMPLETE DATA SETS

ANNUAL MEAN OF TOTAL KJELDAHL NITROGEN (MG/L)

	YY										
STATION	77	78	79	80	81	82	83	84	85	86	87
0.0 ALLEGY R	1.3	0.5	0.5	0.5	0.8	0.7	0.5	0.4	0.4	0.3	0.3
0.0 MONOGA R	1.7	0.7	0.7	0.7	0.8	0.7	0.7	0.4	0.5	0.4	0.5
15.2 S HEIGHTS	1.5	0.8	0.7	0.8	0.9	0.9	0.8	0.5	0.6	0.4	0.4
25.4 BEAVER R	2.1	1.2	1.2	1.3	1.3	1.7	1.1	0.9	1.1	0.8	1.1
40.2 E LIVERPL	1.5	0.8	0.8	1.1	1.0	1.0	1.7	0.7	0.6	0.5	0.6
86.8 WHEELING	1.6	0.8	0.8	0.8	0.8	1.0	1.2	0.5	0.6	0.5	0.5
126.4 HANNIBAL	0.8	0.7	0.7	0.7	0.8	0.9	0.4	0.4	0.5	0.4	0.5
161.8 WILLOW IS	1.5	0.7	1.1	0.8	0.7	0.9	0.5	0.5	0.5	0.6	0.5
* 172.2 MUSKGM R	1.6	0.8	1.1	1.5	1.1	1.1	0.5	0.8	1.0	0.8	0.8
203.9 BELLEVL	1.5	0.7	1.0	0.8	1.0	1.1	0.6	0.6	0.7	0.6	0.5
260.0 ADDISON	1.6	0.7	0.9	0.8	0.8	0.9	0.5	0.5	0.5	0.7	0.5
* 265.7 KANAWA R	1.5	0.8	1.0	0.8	0.7	1.0	0.4	0.5	0.8	0.6	0.5
279.2 GALLIPOL	1.6	0.6	0.8	0.8	0.8	0.8	0.5	0.5	0.6	0.6	0.5
306.9 HUNTING	1.5	0.6	0.7	0.6	0.8	0.5	0.4	0.2	0.2	0.3	0.2
317.1 BIG SANDY	1.6	0.9	0.9	0.5	0.8	0.8	0.4	0.5	0.4	0.3	0.2
350.7 PORTSM	3.9	0.9	0.8	0.8	0.7	1.0	0.4	0.6	0.6	0.5	0.4
* 356.5 SCIOTO R	3.6	1.1	1.2	1.1	6.8	1.9	0.7	1.4	1.6	1.1	1.2
* 408.5 MAYSVILLE	3.6	0.9	0.5	1.3	0.7	1.0	0.6	0.4	0.5	0.4	0.4

* INCOMPLETE DATA SETS

ANNUAL MEAN OF TOTAL KJELDAHL NITROGEN (MG/L)

(CONTINUED)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
* 462.8 CINCINN	1.3	0.6	0.6	0.8	0.7	1.0	0.6	0.4	0.6	0.6	0.3
* 464.1 LIL MIAMI	2.1	1.2	0.8	1.1	1.0	1.5	0.7	1.0	1.0	0.9	1.0
470.2 LICKING R	1.8	0.8	0.6	0.7	0.8	1.0	0.5	0.8	0.4	0.6	0.5
* 490.0 N BEND	1.5	0.7	0.7	0.6	0.8	1.1	0.7	0.6	0.6	0.7	0.5
* 491.1 GR MIAMI	2.3	1.5	1.1	1.2	1.3	1.7	1.0	1.0	1.2	1.3	1.5
* 531.5 MARKLAND	1.7	0.6	0.6	0.7	1.2	0.9	0.5	0.5	0.7	0.6	0.5
600.6 LOUISVL	0.6	0.6	0.6	0.4	0.6	0.9	0.5	0.6	0.5	0.5	0.4
625.9 W POINT	0.9	1.1	1.0	0.8	0.9	1.4	0.7	0.7	0.6	0.8	0.8
* 720.7 CANNELTN	0.6	0.7	0.7	0.4	0.7	1.1	0.5	0.5	0.4	0.5	0.4
784.2 GREEN R	0.5	0.7	0.5	0.4	0.6	0.9	0.5	0.5	0.5	0.5	0.6
791.5 EVANSVL	0.7	1.0	0.8	0.5	1.2	1.1	0.6	0.6	0.6	0.5	0.6
* 846.0 UNIONTOWN	0.6	0.7	0.7	0.5	0.8	0.9	0.5	0.5	0.5	0.5	0.4
* 848.0 WABASH R	1.1	1.2	1.1	1.0	1.1	1.7	1.0	1.1	1.0	1.3	1.4
* 918.5 SMITHLAND	.	.	.	.	.	1.0	0.5	0.4	0.5	0.6	0.4
920.4 CUMBRLD R	0.4	0.5	0.5	0.4	0.6	0.7	0.4	0.5	0.4	0.4	0.4
934.5 TENNESS R	0.3	0.5	0.4	0.3	0.6	0.7	0.3	0.3	0.4	0.4	0.4
952.3 JOPPA	0.6	1.0	0.7	0.5	0.7	1.0	0.5	0.6	0.6	0.7	0.5

* INCOMPLETE DATA SETS

ANNUAL MEAN OF NITRATE/NITRITES (MG/L)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	0.6	0.8	0.6	0.7	0.7	0.6	0.7	1.0	0.7	0.6	0.6
0.0 MONOGA R	0.9	1.0	0.8	0.9	0.9	0.8	1.0	0.9	0.9	0.8	0.8
15.2 S HEIGHTS	0.7	0.9	1.0	0.9	0.9	0.8	0.9	0.8	0.9	0.7	0.7
25.4 BEAVER R	1.2	1.4	1.6	1.1	1.3	1.2	1.2	1.2	1.5	1.1	1.1
40.2 E LIVERPL	0.9	1.2	1.1	1.1	1.0	0.9	0.9	0.9	0.9	0.9	0.9
86.8 WHEELING	0.8	1.2	1.0	1.1	1.0	1.0	0.9	0.8	1.0	1.1	0.8
126.4 HANNIBAL	0.8	1.3	1.1	1.1	1.1	1.0	1.0	0.9	1.0	0.8	0.7
161.8 WILLOW IS	0.9	1.2	1.2	1.1	1.0	0.9	1.0	0.9	1.1	0.8	0.7
* 172.2 MUSKGM R	1.1	1.4	1.5	1.2	1.5	1.4	0.7	1.1	1.4	0.9	1.0
203.9 BELLEVL	0.9	1.2	1.1	1.3	1.1	1.0	1.0	1.0	1.1	1.0	0.8
260.0 ADDISON	1.0	1.1	1.2	1.2	1.2	1.0	1.1	0.9	1.2	1.2	0.9
* 265.7 KANAWA R	0.5	0.7	0.6	0.8	0.7	0.7	0.7	0.7	0.6	0.5	0.6
279.2 GALLIPOL	0.9	1.0	1.0	1.2	1.0	0.9	1.0	0.9	1.1	0.8	0.8
306.9 HUNTING	0.7	0.9	0.9	1.0	1.0	0.9	0.9	0.9	1.1	0.8	0.8
317.1 BIG SANDY	0.4	0.5	0.4	0.4	0.5	4.1	0.4	0.4	0.4	0.5	0.3
350.7 PORTSM	0.8	1.0	1.0	1.5	1.0	0.9	0.9	0.8	1.2	1.1	0.8
* 356.5 SCIOTO R	2.1	2.1	3.5	2.6	2.9	2.3	2.7	1.9	1.8	2.4	2.6
* 408.5 MAYSVILLE	1.0	1.2	1.1	1.1	1.1	0.9	1.0	0.5	1.2	0.7	0.9

* INCOMPLETE DATA SETS

ANNUAL MEAN OF NITRATE/NITRITES (MG/L)

(CONTINUED)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
* 462.8 CINCINN	1.0	1.2	1.0	1.2	1.2	0.9	1.0	0.5	1.2	0.8	0.9
* 464.1 LIL MIAMI	1.7	2.2	3.0	2.8	2.4	2.5	2.3	1.6	2.9	2.1	2.8
470.2 LICKING R	0.7	1.0	0.7	0.6	0.6	0.9	1.0	1.1	0.9	0.7	0.6
* 490.0 N BEND	1.0	1.3	1.4	1.3	1.3	1.1	1.1	1.2	1.3	0.7	1.1
* 491.1 GR MIAMI	2.6	3.3	3.8	4.8	4.5	3.8	4.2	3.7	2.1	3.4	2.7
* 531.5 MARKLAND	1.1	1.4	1.3	1.3	1.4	1.3	1.2	1.1	1.5	0.9	1.2
600.6 LOUISVL	1.1	1.2	1.2	1.3	1.4	1.3	1.4	1.5	1.3	1.3	1.2
625.9 W POINT	1.1	1.3	1.2	1.4	1.4	1.3	1.4	1.3	1.3	1.3	1.2
* 720.7 CANNELTN	1.1	1.3	1.2	1.2	1.4	1.2	1.2	1.2	1.4	1.2	1.4
784.2 GREEN R	0.8	1.0	0.9	1.3	1.2	1.0	0.9	5.6	1.0	1.2	0.7
791.5 EVANSVL	1.1	1.3	1.2	1.2	1.5	1.2	1.2	1.8	1.3	1.3	1.1
* 846.0 UNIONTOWN	1.2	1.3	1.3	1.4	1.8	1.3	1.1	1.2	1.3	1.1	1.1
* 848.0 WABASH R	2.0	2.2	2.0	1.4	3.3	2.6	2.2	2.4	2.0	2.7	1.1
* 918.5 SMITHLAND	.	.	.	.	.	1.6	1.2	1.3	1.4	1.6	0.4
920.4 CUMBRLD R	0.4	0.5	0.5	0.2	0.3	0.5	0.5	0.3	0.1	0.1	0.1
934.5 TENNESS R	0.4	0.4	0.4	0.3	0.2	0.3	0.5	0.4	0.2	0.2	0.2
952.3 JOPPA	1.0	1.5	1.4	1.3	1.9	1.7	1.4	1.5	1.5	1.6	0.7

* INCOMPLETE DATA SETS

ANNUAL MEAN OF TOTAL NITROGEN (MG/L)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	1.9	1.3	1.2	1.2	1.5	1.3	1.2	1.5	1.1	0.9	0.9
0.0 MONOGA R	2.6	1.7	1.5	1.6	1.7	1.6	1.6	1.4	1.4	1.2	1.2
15.2 S HEIGHTS	2.2	1.8	1.6	1.7	1.8	1.7	1.7	1.2	1.5	1.2	1.1
25.4 BEAVER R	3.2	2.6	2.8	2.5	2.7	2.9	2.2	2.0	2.6	2.0	2.2
40.2 E LIVERPL	2.4	2.0	1.9	2.2	2.1	1.9	2.6	1.6	1.5	1.4	1.5
86.8 WHEELING	2.4	2.0	1.8	1.9	1.8	2.0	2.1	1.3	1.7	1.6	1.3
126.4 HANNIBAL	1.6	2.0	1.8	1.3	1.9	1.9	1.5	1.3	1.6	1.3	1.2
161.8 WILLOW IS	2.4	1.8	2.2	1.8	1.8	1.8	1.5	1.4	1.5	1.4	1.2
* 172.2 MUSKGM R	2.7	2.1	2.6	2.3	2.6	2.5	1.2	1.9	2.4	1.7	1.8
203.9 BELLEVL	2.3	1.9	2.1	2.0	2.1	2.1	1.6	1.5	1.8	1.6	1.3
260.0 ADDISON	2.6	1.8	2.1	1.9	2.0	1.9	1.6	1.5	1.7	1.9	1.4
* 265.7 KANAWA R	2.0	1.5	1.6	1.6	1.4	1.7	1.1	1.2	1.4	1.2	1.1
279.2 GALLIPOL	2.5	1.6	1.8	2.0	1.8	1.7	1.5	1.4	1.6	1.4	1.3
306.9 HUNTING	2.2	1.6	1.5	1.6	1.8	1.4	1.4	1.1	1.3	1.1	1.0
317.1 BIG SANDY	2.0	1.4	1.3	1.0	1.2	5.0	0.7	0.9	0.8	0.8	0.5
350.7 PORTSM	4.7	1.9	1.8	2.3	1.7	1.9	1.3	1.3	1.8	1.7	1.3
* 356.5 SCIOTO R	5.8	3.2	4.7	3.7	9.7	4.1	3.4	3.3	3.4	3.5	3.9
* 408.5 MAYSVILLE	4.6	2.1	1.7	2.4	1.7	1.9	1.6	0.9	1.7	1.1	1.3

* INCOMPLETE DATA SETS

ANNUAL MEAN OF TOTAL NITROGEN (MG/L)

(CONTINUED)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
* 462.8 CINCINN	2.3	1.8	1.6	1.9	2.0	1.8	1.6	0.9	1.8	1.4	1.2
* 464.1 LIL MIAMI	3.8	3.4	3.8	3.9	3.5	3.9	3.0	2.6	3.9	3.0	3.8
470.2 LICKING R	2.5	1.7	1.3	1.3	1.4	1.9	1.4	1.7	1.3	1.3	1.0
* 490.0 N BEND	2.6	2.0	2.1	1.9	2.1	2.2	1.8	1.7	1.9	1.4	1.6
* 491.1 GR MIAMI	5.0	4.8	4.9	5.9	5.8	5.5	5.2	4.8	3.3	4.7	4.2
* 531.5 MARKLAND	2.8	2.1	1.9	2.0	2.7	2.2	1.6	1.6	2.2	1.6	1.7
600.6 LOUISVL	1.7	1.8	1.8	1.8	2.1	2.2	1.8	2.0	1.8	1.8	1.6
625.9 W POINT	2.0	2.4	2.2	2.1	2.3	2.7	2.1	2.0	1.9	2.0	2.0
* 720.7 CANNELTN	1.6	2.0	1.9	1.6	2.1	2.3	1.7	1.7	1.8	1.7	1.8
784.2 GREEN R	1.3	1.6	1.4	1.6	1.8	2.0	1.3	6.1	1.4	1.6	1.3
791.5 EVANSVL	1.8	2.3	2.0	1.7	2.7	2.3	1.9	2.3	1.9	1.8	1.7
* 846.0 UNIONTOWN	1.8	2.0	2.0	1.9	2.7	2.2	1.6	1.7	1.8	1.5	1.5
* 848.0 WABASH R	3.2	3.4	3.1	2.5	4.3	4.3	3.2	3.4	3.1	3.9	2.5
* 918.5 SMITHLAND	.	.	.	.	.	2.6	1.8	1.7	1.9	2.2	0.8
920.4 CUMBRLD R	0.7	0.9	0.9	0.6	0.9	1.1	0.9	0.7	0.5	0.5	0.4
934.5 TENNESS R	0.7	0.9	0.8	0.6	0.8	1.1	0.8	0.7	0.6	0.6	0.6
952.3 JOPPA	1.7	2.5	2.1	1.8	2.5	2.7	1.9	2.1	2.1	2.3	1.1

* INCOMPLETE DATA SETS

ANNUAL MEAN OF PHENOLICS (UG/L)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	8.5	4.6	3.3	6.5	7.5	5.0	.	4.1	2.6	8.4	2.0
0.0 MONOGA R	7.2	5.5	6.9	6.7	5.6	4.0	10.0	6.9	3.1	8.8	3.7
15.2 S HEIGHTS	11.0	8.7	5.7	9.3	4.2	3.5	8.5	11.6	3.5	8.2	2.3
25.4 BEAVER R	9.4	13.4	6.5	7.9	5.2	17.0	2.6	13.3	6.0	8.8	3.1
40.2 E LIVERPL	13.7	7.2	5.5	5.8	4.5	6.5	2.5	4.3	4.5	7.3	2.8
86.8 WHEELING	14.1	8.0	4.4	8.1	5.6	11.0	1.5	3.9	4.4	9.7	2.9
126.4 HANNIBAL	79.3	6.2	4.6	6.6	8.9	7.0	1.5	2.4	3.4	5.8	3.0
161.8 WILLOW IS	7.2	5.2	6.1	5.2	7.2	4.0	1.3	2.6	3.4	7.0	2.4
172.2 MUSKGM R	6.9	4.7	4.7	5.2	5.3	5.0	1.7	3.6	5.3	8.4	3.1
203.9 BELLEVL	6.3	5.0	3.9	3.1	3.5	4.0	2.5	2.2	5.4	7.1	2.4
260.0 ADDISON	11.4	5.7	15.8	3.4	11.1	2.5	2.0	2.4	3.9	6.8	3.0
265.7 KANAWA R	11.9	6.8	11.1	3.7	4.9	2.0	1.3	1.8	2.5	7.3	2.5
279.2 GALLIPOL	5.5	6.3	8.0	5.8	4.1	6.0	1.8	2.3	3.0	6.0	4.7
306.9 HUNTING	8.1	13.6	4.0	4.5	34.6	4.0	2.0	2.2	2.8	3.6	2.6
317.1 BIG SANDY	10.4	8.5	3.1	4.6	12.0	.	1.0	1.4	2.3	7.5	2.0
350.7 PORTSM	8.4	4.5	4.8	11.0	18.5	3.5	1.5	3.5	3.8	5.3	2.3
356.5 SCIOTO R	19.5	5.4	6.3	4.4	3.9	7.0	2.2	5.5	8.3	8.7	7.3
408.5 MAYSVILLE	10.2	9.0	6.1	4.6	4.0	3.0	2.3	3.1	3.9	4.1	3.0

ANNUAL MEAN OF PHENOLICS (UG/L)

(CONTINUED)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
462.8 CINCINN	10.4	11.1	3.8	3.1	11.4	2.0	1.8	2.8	3.5	3.7	2.8
464.1 LIL MIAMI	8.4	7.1	16.2	3.1	9.2	7.0	2.1	4.2	5.0	6.1	3.9
470.2 LICKING R	7.0	15.1	8.9	7.3	10.2	7.0	1.7	4.0	3.6	4.0	3.6
490.0 N BEND	10.8	14.3	3.4	9.5	11.1	15.0	19.0	.	4.7	4.0	2.8
491.1 GR MIAMI	25.0	9.6	4.2	5.2	11.8	11.5	16.0	10.0	9.7	5.9	5.0
531.5 MARKLAND	11.2	19.7	2.4	4.3	20.6	6.5	10.0	.	4.7	3.3	3.0
600.6 LOUISVL	6.2	4.8	3.3	14.0	12.0	5.0	16.0	18.0	4.0	4.4	2.3
625.9 W POINT	5.5	5.6	3.0	2.9	17.7	5.0	6.5	14.0	3.7	4.4	2.3
720.7 CANNELTN	6.1	4.7	2.5	11.0	18.9	3.5	.	11.0	4.0	3.1	2.0
784.2 GREEN R	7.3	4.0	2.0	6.2	8.9	3.5	10.0	.	4.2	3.0	2.8
791.5 EVANSVL	6.4	5.3	2.7	5.8	5.1	5.0	18.0	10.5	3.8	3.6	2.4
846.0 UNIONTOWN	10.9	4.6	2.5	4.1	3.0	2.5	17.0	.	3.2	2.9	2.4
848.0 WABASH R	11.4	5.1	4.1	4.6	7.5	3.5	6.3	10.5	4.8	3.0	3.4
918.5 SMITHLAND	.	.	.	.	.	8.0	9.5	10.0	4.2	3.9	2.4
920.4 CUMBRLD R	13.9	3.3	2.3	3.5	3.3	4.0	2.0	.	2.5	3.3	2.2
934.5 TENNESS R	5.6	3.0	2.0	5.3	2.7	9.0	12.0	15.0	2.5	3.5	2.2
952.3 JOPPA	6.4	4.8	2.0	5.6	7.4	3.0	13.5	12.0	4.0	3.3	2.7

ANNUAL MEAN OF COPPER (UG/L)

YY

STATION	77	78	79	80	81	82	83	84	85	86	87
0.0 ALLEGY R	11.3	26.2	16.2	30.2	26.6	14.2	18.0	6.1	5.1	8.5	6.7
0.0 MONOGA R	13.1	16.2	19.7	23.3	20.8	14.2	14.7	8.0	54.0	7.0	5.5
15.2 S HEIGHTS	15.1	22.5	14.8	31.1	26.2	8.0	13.5	7.3	6.4	5.1	23.3
25.4 BEAVER R	20.8	18.3	16.7	76.8	23.4	9.8	17.8	9.9	6.4	8.9	6.9
40.2 E LIVERPL	40.0	15.5	17.0	28.6	23.0	15.2	23.8	16.9	82.8	9.9	3.5
86.8 WHEELING	10.8	20.7	16.2	84.7	33.0	12.7	36.9	27.5	8.4	12.8	20.3
126.4 HANNIBAL	11.3	13.3	25.3	23.7	39.0	10.5	7.7	5.9	6.5	13.9	4.5
161.8 WILLOW IS	9.8	14.3	22.0	48.4	60.7	14.0	8.3	5.8	6.2	12.8	3.8
172.2 MUSKGM R	16.2	17.3	21.4	48.5	34.8	12.8	14.2	7.9	8.8	13.6	6.8
203.9 BELLEVL	11.2	24.2	25.7	42.5	34.8	13.8	8.3	8.1	6.6	11.4	3.8
260.0 ADDISON	24.0	45.7	138.3	127.8	45.1	20.0	11.8	11.6	17.8	15.0	37.0
265.7 KANAWA R	24.9	20.8	54.4	14.8	23.3	11.6	9.7	5.6	4.1	28.2	3.5
279.2 GALLIPOL	15.2	35.2	32.9	69.0	21.8	9.8	9.5	7.0	11.1	7.7	6.3
306.9 HUNTING	290.0	136.8	84.9	78.8	69.3	13.4	8.5	8.7	14.2	54.0	18.5
317.1 BIG SANDY	36.7	95.7	27.4	120.0	19.3	11.1	8.8	11.7	8.9	15.7	6.4
350.7 PORTSM	20.5	40.9	31.8	67.2	10.2	12.5	17.0	8.7	8.9	12.8	7.3
356.5 SCIOTO R	20.0	34.7	21.7	150.5	39.8	17.5	10.6	7.3	7.4	12.8	5.7
408.5 MAYSVILLE	53.1	19.3	8.8	81.8	33.3	20.3	17.5	83.9	210.6	23.1	26.6

ANNUAL MEAN OF COPPER (UG/L)

(CONTINUED)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
462.8 CINCINN	35.7	21.4	158.5	118.1	244.2	11.8	17.2	69.8	318.3	419.5	61.5
464.1 LIL MIAMI	34.6	20.1	7.0	21.5	10.9	9.1	11.6	48.8	8.7	11.3	4.7
470.2 LICKING R	24.4	13.8	5.5	118.3	13.3	9.8	8.8	117.9	4.8	35.5	12.8
490.0 N BEND	25.5	35.8	15.5	15.3	13.2	11.3	18.4	26.7	17.0	8.9	39.5
491.1 GR MIAMI	21.5	16.4	17.0	15.0	15.0	11.0	11.3	13.6	21.1	14.2	9.5
531.5 MARKLAND	39.6	14.7	10.7	22.5	24.8	16.0	14.8	55.8	17.7	19.8	12.8
600.6 LOUISVL	33.3	59.3	64.7	16.3	44.3	19.5	23.9	26.3	26.4	32.7	26.8
625.9 W POINT	30.0	41.0	14.3	14.5	15.2	17.5	22.1	13.5	11.4	7.5	6.9
720.7 CANNELTN	.	20.0	27.0	14.9	13.5	67.0	16.2	57.1	12.3	7.6	13.6
784.2 GREEN R	.	29.6	8.7	16.5	12.2	8.0	10.0	12.5	10.0	5.6	6.5
791.5 EVANSVL	68.9	94.6	26.0	17.8	27.1	12.2	13.7	16.1	16.1	8.5	10.3
846.0 UNIONTOWN	.	22.8	11.8	22.3	14.7	9.2	13.1	13.6	12.1	7.6	9.2
848.0 WABASH R	.	17.3	24.3	12.0	13.3	26.7	15.4	24.3	12.2	12.3	19.9
918.5 SMITHLAND	.	.	.	.	.	9.7	17.4	14.4	8.8	6.8	16.8
920.4 CUMBRLD R	.	38.3	21.8	24.0	9.6	10.4	15.3	15.6	17.4	13.6	65.6
934.5 TENNESS R	190.0	17.5	7.5	6.0	6.5	5.9	6.4	12.5	4.3	3.6	8.9
952.3 JOPPA	.	33.0	18.7	14.4	19.3	13.7	25.1	15.5	13.0	30.2	17.6

ANNUAL MEAN OF IRON (UG/L)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	1566.7	1250.0	2465.8	1950.8	1525.6	1439.2	1398.3	1060.9	1701.7	1314.2	950.5
0.0 MONOGA R	1291.7	2531.8	2093.3	2346.7	2455.8	1311.7	1384.2	1475.0	2491.7	1280.8	1358.3
15.2 S HEIGHTS	2011.7	2916.7	1673.3	2266.9	2725.8	1703.3	1215.5	1644.2	2305.8	1355.8	1588.3
25.4 BEAVER R	1526.7	2600.0	1852.5	2492.7	1903.1	1342.5	1388.2	1764.2	1633.3	1305.8	2431.7
40.2 E LIVERPL	2474.2	1766.7	3233.3	4325.8	5521.7	2894.2	5249.1	2370.8	2230.0	1500.8	710.8
86.8 WHEELING	1700.0	4166.7	2852.5	2726.7	1514.2	2535.8	1633.3	1357.5	2275.0	1281.7	1306.7
126.4 HANNIBAL	993.3	1031.3	1111.7	1352.5	1000.0	1360.8	866.5	868.7	1325.0	1050.8	801.2
161.8 WILLOW IS	1040.8	1341.7	1942.5	1183.8	1129.2	1768.3	1964.7	940.8	1072.5	922.5	898.2
172.2 MUSKGM R	1676.7	1858.3	2921.7	2417.5	3931.7	2370.8	3240.8	1341.7	2296.7	1579.8	1345.5
203.9 BELLEVL	1262.9	1452.1	2317.5	1540.8	4180.8	2277.5	2167.5	1349.3	1550.0	1818.3	908.8
260.0 ADDISON	1672.7	3300.0	2833.3	2009.2	4198.2	2085.8	1663.3	2087.2	3870.0	2480.7	1074.2
265.7 KANAWA R	756.8	2283.3	3359.1	1458.0	1301.7	2453.3	1148.7	1572.8	851.7	1491.0	587.5
279.2 GALLIPOL	850.0	2361.5	2635.8	2316.7	3089.1	1971.7	2045.5	1879.2	2483.3	3013.3	940.0
306.9 HUNTING	3663.3	4670.8	3725.9	1950.8	3193.3	330.0	702.5	253.8	934.8	1031.0	86.5
317.1 BIG SANDY	5963.6	7591.7	6697.0	2712.9	5841.8	4076.7	1558.0	5412.2	2482.5	3098.0	1115.0
350.7 PORTSM	2280.0	3719.2	1858.3	1338.0	2546.9	2783.3	2614.0	3429.2	3281.7	2692.5	1331.7
356.5 SCIOTO R	2450.0	3077.3	1922.5	2478.3	2910.8	3116.7	2900.0	1413.6	2737.5	2631.8	1544.2
408.5 MAYSVILLE	2322.7	1545.5	1915.8	2190.8	2240.0	1981.7	3570.2	2548.3	4389.2	2136.7	1585.5

ANNUAL MEAN OF IRON (UG/L)

(CONTINUED)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
462.8 CINCINN	3453.8	3388.5	3137.5	2706.7	3188.3	2612.5	3425.0	2669.2	6700.0	3311.7	1482.7
464.1 LIL MIAMI	3744.2	1163.6	1370.8	2498.3	2943.6	1332.5	2322.5	2828.3	1925.8	3582.5	1267.3
470.2 LICKING R	3365.4	3316.7	2326.7	1955.0	2200.0	2905.8	2410.9	3230.8	2187.5	3369.2	2649.1
490.0 N BEND	2391.4	5370.8	2938.3	1523.8	3074.2	3806.7	2878.2	2165.8	1989.0	2002.5	1440.8
491.1 GR MIAMI	3286.2	2854.5	2212.5	3180.8	1729.2	3915.5	1969.0	1841.8	2553.0	3140.0	2428.3
531.5 MARKLAND	931.1	2604.2	2342.5	1420.8	2401.2	3759.2	1322.0	2019.1	5786.0	2370.8	1250.8
600.6 LOUISVL	4411.7	2695.3	2750.0	1330.8	2624.2	3692.5	2180.4	2408.3	2697.5	1824.2	1340.8
625.9 W POINT	4882.5	6733.3	5208.3	1626.3	3305.0	4755.8	4125.1	2170.0	3239.2	2427.3	2004.2
720.7 CANNELTN	2230.0	2927.3	3235.8	1926.7	1716.2	5101.8	3014.4	2525.8	3877.9	2626.7	928.3
784.2 GREEN R	2171.7	4941.8	3162.5	1360.8	2054.5	3070.8	2192.5	2716.7	2558.3	2254.2	2108.3
791.5 EVANSVL	4701.7	5642.7	9716.7	7743.3	4323.1	4305.0	3933.3	3650.8	6331.8	3701.5	3023.3
846.0 UNIONTOWN	2681.7	3069.2	4207.5	2426.7	2707.5	2761.7	2118.3	2491.7	4619.2	3915.8	2174.2
848.0 WABASH R	4091.7	3883.6	6477.5	3233.6	4018.6	7942.5	4122.5	3675.8	4405.0	5960.0	2933.3
918.5 SMITHLAND	.	.	.	.	.	2715.8	1627.5	2980.8	3414.2	2638.3	1287.5
920.4 CUMBRLD R	942.5	858.8	1145.0	379.2	329.1	410.8	769.0	492.5	470.0	516.0	453.3
934.5 TENNESS R	971.7	756.0	859.2	629.2	466.4	650.8	725.5	626.7	524.2	682.8	367.5
952.3 JOPPA	2873.3	3870.8	3863.3	2586.2	3058.3	3575.8	2458.3	2667.5	3046.7	3325.0	1441.7

ANNUAL MEAN OF LEAD (UG/L)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	17.5	19.4	13.8	10.0	22.0	14.0	12.3	24.7	13.1	13.0	10.0
0.0 MONOGA R	25.4	27.7	15.8	14.4	18.0	10.0	14.1	25.4	14.7	12.9	12.5
15.2 S HEIGHTS	18.1	28.5	15.1	12.7	83.8	12.0	11.4	24.9	13.5	10.0	12.3
25.4 BEAVER R	28.1	38.3	19.2	18.4	14.8	12.0	16.7	25.6	13.1	13.5	17.4
40.2 E LIVERPL	28.5	25.4	18.2	20.0	21.1	16.5	28.4	16.6	16.0	14.0	12.0
86.8 WHEELING	30.4	31.9	17.8	16.4	14.0	16.0	15.9	20.8	15.2	11.5	11.5
126.4 HANNIBAL	16.0	20.2	14.2	15.3	10.0	20.0	15.4	29.0	12.0	10.0	10.2
161.8 WILLOW IS	22.3	22.5	17.6	20.4	100.7	82.0	14.5	23.4	12.4	10.3	10.5
172.2 MUSKGM R	31.4	27.3	55.2	40.7	12.0	14.0	16.2	26.9	18.7	16.3	16.0
203.9 BELLEVL	19.8	19.6	15.5	20.8	13.5	17.0	16.8	17.3	12.5	14.4	10.3
260.0 ADDISON	28.6	45.2	18.2	14.8	16.0	14.0	12.3	20.2	15.9	14.0	11.8
265.7 KANAWA R	31.9	37.3	17.1	10.7	22.0	10.0	22.5	23.7	10.0	15.3	24.2
279.2 GALLIPOL	31.5	41.5	18.4	14.4	15.0	.	12.0	20.7	14.3	12.9	27.0
306.9 HUNTING	40.5	26.9	20.5	17.0	11.3	24.0	16.7	26.3	12.7	14.7	10.7
317.1 BIG SANDY	35.0	33.3	17.8	15.0	28.0	17.0	38.4	23.8	12.0	14.0	11.0
350.7 PORTSM	41.0	36.1	15.5	22.0	14.5	18.0	14.3	19.6	14.6	13.7	11.6
356.5 SCIOTO R	45.5	36.4	31.5	23.3	17.6	12.0	21.9	23.1	16.2	17.1	33.0
408.5 MAYSVILLE	41.8	36.5	30.2	19.5	12.0	12.0	17.9	17.6	19.1	12.0	12.0

ANNUAL MEAN OF LEAD (UG/L)

(CONTINUED)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
462.8 CINCINN	32.5	24.8	14.0	12.3	33.0	18.0	14.7	16.4	31.8	13.3	12.4
464.1 LIL MIAMI	44.6	41.9	17.3	15.3	16.3	.	19.6	22.2	16.2	17.0	16.4
470.2 LICKING R	25.5	20.9	15.8	6.0	10.0	.	14.6	16.8	14.7	11.4	11.1
490.0 N BEND	23.0	26.8	21.1	21.0	19.5	16.0	16.4	4.3	8.0	12.0	11.0
491.1 GR MIAMI	51.7	37.5	28.8	42.3	25.0	12.0	66.0	3.7	17.4	18.8	20.8
531.5 MARKLAND	23.3	31.1	52.0	14.0	14.0	14.0	53.3	4.3	19.0	12.0	10.8
600.6 LOUISVL	15.1	20.6	44.8	30.2	12.7	11.0	15.0	4.9	8.9	11.0	11.5
625.9 W POINT	22.3	28.7	32.5	23.0	14.3	14.7	13.5	5.8	9.8	12.4	11.8
720.7 CANNELTN	16.2	20.6	64.4	20.3	18.0	18.0	268.1	7.6	10.9	14.0	15.0
784.2 GREEN R	23.4	19.4	47.3	35.6	24.7	13.0	51.7	3.3	9.2	12.8	12.2
791.5 EVANSVL	14.9	21.2	48.7	33.0	24.0	13.3	38.1	5.6	14.1	14.8	13.2
846.0 UNIONTOWN	22.0	16.6	37.6	48.8	10.7	.	7.4	6.4	12.9	14.9	11.6
848.0 WABASH R	18.0	16.0	74.7	45.4	21.3	19.0	67.9	4.1	9.5	18.5	19.5
918.5 SMITHLAND	.	.	.	.	.	67.6	55.7	4.5	7.6	12.5	12.3
920.4 CUMBRLD R	11.2	20.9	38.0	36.0	100.0	10.0	100.0	2.0	7.5	11.0	11.3
934.5 TENNESS R	20.3	17.4	47.3	24.9	20.0	20.2	42.9	5.0	7.6	12.0	10.4
952.3 JOPPA	11.1	21.9	43.3	81.0	10.0	16.0	9.7	4.5	6.4	14.6	11.3

ANNUAL MEAN OF MERCURY (UG/L)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	0.8	0.2	0.1	0.1	0.1	0.3	0.4	0.2	0.2	0.3	0.1
0.0 MONOGA R	.	1.1	0.1	0.2	0.1	0.2	0.3	0.1	0.4	0.1	0.2
15.2 S HEIGHTS	.	0.3	0.1	0.2	0.1	0.2	0.5	0.7	0.3	0.2	0.2
25.4 BEAVER R	.	0.2	0.1	0.1	0.7	0.2	0.2	.	0.2	0.2	0.2
40.2 E LIVERPL	.	0.2	0.1	0.2	0.2	.	0.4	.	0.3	0.2	0.1
86.8 WHEELING	1.0	0.8	0.1	0.2	0.2	0.2	0.5	0.1	0.3	0.2	0.1
126.4 HANNIBAL	.	0.3	0.2	0.1	0.2	0.3	0.4	0.1	0.3	0.2	0.1
161.8 WILLOW IS	0.8	0.3	0.6	0.4	0.2	0.5	0.2	0.1	0.1	0.1	0.2
172.2 MUSKGM R	0.6	0.2	0.7	0.5	0.3	0.2	0.5	0.2	0.1	0.1	0.1
203.9 BELLEVL	0.8	0.3	0.7	0.5	0.1	0.5	0.2	.	0.3	0.1	0.2
260.0 ADDISON	.	0.2	0.8	0.2	0.2	0.3	0.3	0.2	0.2	0.3	0.2
265.7 KANAWA R	.	0.1	0.7	0.2	0.1	0.2	0.3	0.1	1.0	0.1	0.1
279.2 GALLIPOL	.	0.1	0.6	0.3	0.1	0.2	0.2	.	0.2	0.3	0.2
306.9 HUNTING	.	0.2	0.1	0.2	0.1	0.3	0.5	0.4	0.7	0.3	0.2
317.1 BIG SANDY	.	0.2	0.4	0.2	0.4	0.2	0.2	0.1	0.1	0.1	0.1
350.7 PORTSM	.	0.2	0.6	0.2	0.1	0.4	0.3	0.2	0.2	2.3	0.2
356.5 SCIOTO R	.	0.2	0.7	0.3	0.2	0.2	0.3	0.2	0.1	0.4	0.1
408.5 MAYSVILLE	.	0.2	0.1	0.2	0.2	0.3	0.4	0.3	0.1	0.2	0.1

ANNUAL MEAN OF MERCURY (UG/L)

(CONTINUED)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
462.8 CINCINN	0.7	0.1	0.1	0.2	0.4	0.3	16.5	0.3	0.2	0.1	0.1
464.1 LIL MIAMI	.	0.1	0.1	0.2	0.1	0.3	1.8	1.4	0.2	0.1	0.1
470.2 LICKING R	.	0.1	0.1	0.2	0.2	0.4	0.3	0.3	0.1	0.1	0.1
490.0 N BEND	.	0.1	0.2	0.4	1.3	0.3	.	.	0.1	0.1	0.2
491.1 GR MIAMI	.	0.1	0.2	0.4	0.3	0.3	0.2	.	0.2	0.2	0.2
531.5 MARKLAND	.	0.2	0.3	0.6	0.8	0.4	0.5	0.3	0.1	0.2	0.1
600.6 LOUISVL	.	0.1	0.3	0.2	0.4	0.3	0.4	.	0.2	0.1	0.2
625.9 W POINT	.	0.4	0.2	0.2	0.3	0.3	0.2	.	0.3	0.1	0.2
720.7 CANNELTN	.	1.7	0.6	0.4	0.4	0.2	0.2	.	0.1	0.2	0.1
784.2 GREEN R	.	1.0	0.3	0.2	0.3	0.3	.	.	0.2	0.1	0.1
791.5 EVANSVL	.	0.4	0.4	0.2	0.2	0.2	.	0.6	0.2	0.2	0.2
846.0 UNIONTOWN	.	2.8	0.3	0.4	0.2	0.4	0.2	.	0.2	0.1	0.2
848.0 WABASH R	.	0.3	1.1	0.2	0.3	0.2	0.3	0.2	0.4	0.1	0.1
918.5 SMITHLAND	.	.	.	.	.	2.8	0.4	0.3	0.1	0.1	0.2
920.4 CUMBRLD R	0.5	0.2	0.3	0.2	0.2	0.4	0.2	.	0.1	0.1	0.1
934.5 TENNESS R	1.4	0.3	0.4	0.2	0.5	0.3	0.6	.	0.1	0.2	0.2
952.3 JOPPA	0.8	0.3	0.3	0.3	0.2	0.4	.	.	0.1	0.1	0.2

ANNUAL MEAN OF ZINC (UG/L)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	68.3	53.8	41.8	35.8	32.0	24.2	39.2	39.3	33.6	31.3	29.3
0.0 MONOGA R	123.3	76.4	57.5	55.8	54.8	29.3	35.0	42.6	45.9	27.1	24.8
15.2 S HEIGHTS	86.7	81.7	55.5	49.2	55.8	27.3	34.2	41.2	35.6	29.3	25.1
25.4 BEAVER R	88.3	118.3	75.8	83.3	70.6	50.8	74.2	67.0	57.1	56.8	69.1
40.2 E LIVERPL	91.7	65.0	74.5	93.8	101.8	53.5	115.0	88.4	48.3	37.2	36.6
86.8 WHEELING	68.3	91.7	57.5	70.0	39.2	45.0	38.3	40.3	45.2	38.7	32.3
126.4 HANNIBAL	33.3	50.6	40.8	48.3	40.3	34.0	20.9	43.8	26.3	29.7	57.4
161.8 WILLOW IS	64.2	40.8	45.8	40.9	37.3	38.8	27.1	24.5	24.4	32.8	25.4
172.2 MUSKGM R	39.2	24.2	38.3	35.8	33.6	25.0	29.3	22.2	26.2	31.5	19.4
203.9 BELLEVL	69.2	47.5	47.5	38.3	50.7	41.1	28.0	25.6	38.5	32.4	29.1
260.0 ADDISON	59.1	70.8	115.0	47.3	52.7	32.7	95.7	32.3	45.9	43.7	22.8
265.7 KANAWA R	70.9	64.5	46.0	23.3	27.0	28.2	15.5	15.6	10.9	35.6	10.7
279.2 GALLIPOL	54.0	65.8	189.2	50.0	46.7	23.6	29.1	33.5	29.7	29.7	22.4
306.9 HUNTING	105.0	57.5	44.5	28.2	41.2	27.2	.	.	.	30.9	275.8
317.1 BIG SANDY	74.5	60.0	54.4	50.0	43.1	28.4	15.7	29.8	17.8	21.3	24.8
350.7 PORTSM	74.0	59.0	35.8	45.0	41.3	37.6	41.0	35.8	38.3	37.6	14.0
356.5 SCIOTO R	64.5	56.7	33.3	101.8	49.5	56.5	28.0	20.8	28.3	29.3	21.6
408.5 MAYSVILLE	80.0	46.0	28.3	79.1	38.0	34.7	54.6	64.7	45.2	42.9	20.6

ANNUAL MEAN OF ZINC (UG/L)

(CONTINUED)

	YY										
	77	78	79	80	81	82	83	84	85	86	87
STATION											
462.8 CINCINN	70.8	55.0	40.8	130.0	67.0	56.8	56.1	49.5	83.4	41.3	18.5
464.1 LIL MIAMI	68.8	42.2	18.2	115.0	36.3	19.8	31.0	63.4	15.7	22.8	12.8
470.2 LICKING R	44.6	28.6	16.7	30.0	20.0	21.4	17.9	98.7	14.0	118.8	14.2
490.0 N BEND	55.4	66.8	34.2	17.5	34.5	39.5	35.5	29.7	19.6	25.3	44.7
491.1 GR MIAMI	130.0	60.9	41.7	40.8	37.1	55.4	29.0	35.9	19.1	29.8	34.8
531.5 MARKLAND	46.7	47.8	34.2	19.2	30.0	55.7	22.5	33.2	54.4	30.1	16.1
600.6 LOUISVL	116.0	65.0	27.5	19.1	29.0	30.8	33.4	32.0	34.5	19.4	14.3
625.9 W POINT	85.0	213.6	92.5	28.2	37.5	44.7	57.9	30.0	38.8	28.3	24.6
720.7 CANNELTN	50.0	55.5	59.2	28.3	30.8	73.3	55.5	58.8	42.4	27.7	35.4
784.2 GREEN R	40.0	52.5	50.0	16.4	28.2	29.6	23.8	25.0	22.3	17.8	16.3
791.5 EVANSVL	81.0	112.5	153.6	94.5	56.4	33.3	41.8	42.9	55.5	32.8	32.1
846.0 UNIONTOWN	52.9	54.3	53.6	22.5	29.0	32.2	32.5	33.6	41.2	31.1	32.8
848.0 WABASH R	48.3	37.5	46.7	22.8	35.5	47.7	27.5	37.5	36.8	38.3	39.3
918.5 SMITHLAND	.	.	.	.	.	37.0	35.6	39.5	29.2	22.2	31.2
920.4 CUMBRLD R	.	35.0	20.9	17.1	12.5	14.0	13.9	21.7	23.7	23.2	49.6
934.5 TENNESS R	36.0	20.0	18.2	11.7	12.0	18.0	14.2	21.9	15.4	14.3	27.9
952.3 JOPPA	50.0	157.1	32.7	23.5	28.7	25.8	29.5	25.5	30.7	30.2	54.8

ANNUAL MEAN OF FLOW (CFS)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
0.0 ALLEGY R	44450	19641	30375	22400	21833	21333	16609	19145	22573	20758	15433
0.0 MONOGA R	11678	16223	23425	15100	13575	9792	9427	11692	15191	12117	11425
15.2 S HEIGHTS	34986	36474	44350	30200	39492	32258	36473	33575	37625	34375	27717
25.4 BEAVER R	3878	4254	5908	3808	4560	3292	4330	4500	4642	3100	2892
40.2 E LIVERPL	40108	41336	51400	34792	45133	34725	37980	41658	42483	38558	31583
86.8 WHEELING	41770	41670	58550	47533	43267	43592	44908	36333	48092	43433	40427
126.4 HANNIBAL	53980	41238	50333	38417	47036	35375	44058	44567	46391	44683	35900
161.8 WILLOW IS	44531	43263	57925	40236	46583	36550	42075	49233	48091	43117	37745
172.2 MUSKGM R	7389	10082	12117	9458	10808	7692	17042	10025	9183	7583	6070
203.9 BELLEVL	46865	56939	76375	54508	65050	44692	62675	54725	70408	66583	43609
260.0 ADDISON	62828	68004	78625	44379	70050	52517	61533	58675	71117	66618	42683
265.7 KANAWA R	19987	19400	28155	19591	12464	17983	18292	20200	17450	14883	17158
279.2 GALLIPOL	83991	148933	99625	72283	84308	69617	79383	79650	86633	71417	62583
306.9 HUNTING	88381	72122	113809	66383	84667	72867	81942	84342	70950	92525	66208
317.1 BIG SANDY	6471	6800	9050	3425	6067	5100	2858	9033	4083	5400	6400
350.7 PORTSM	116709	95705	123542	72233	86067	87067	82190	103400	86100	80233	59982
356.5 SCIOTO R	5611	8235	9858	4608	5608	6650	5720	5427	4533	5633	3558
408.5 MAYSVILLE	100963	82910	129408	96608	83283	96650	75066	98158	92083	98018	61758

ANNUAL MEAN OF FLOW (CFS)

(CONTINUED)

						YY					
	77	78	79	80	81	82	83	84	85	86	87
STATION											
462.8 CINCINN	85018	122271	129267	100125	95900	83400	87366	98692	112283	91808	61917
464.1 LIL MIAMI	1082	1250	1992	2467	1573	910	2392	2200	1550	1842	1125
470.2 LICKING R	2463	6659	5950	2917	2225	2617	2355	4942	3308	2692	2582
490.0 N BEND	85467	100439	137575	83783	142707	114350	116383	92292	72573	98475	135217
491.1 GR MIAMI	2483	19635	7258	4258	3683	6208	6133	4092	6545	8167	4142
531.5 MARKLAND	95443	94617	162891	86642	118660	122125	125217	113583	105092	104533	95992
600.6 LOUISVL	118780	135104	193800	79875	115992	127592	105591	110400	130417	95142	85045
625.9 W POINT	156109	136330	198817	82308	89592	117675	105845	115000	130417	93755	85045
720.7 CANNELTN	100633	148130	181117	116742	107909	147575	109245	127175	153292	119117	101158
784.2 GREEN R	12359	11457	24558	9108	16669	14875	18209	17950	11108	10692	9408
791.5 EVANSVL	132989	159732	228208	135483	137533	142900	149033	131483	174950	107350	113858
846.0 UNIONTOWN	123428	143135	248425	138808	128117	111375	120591	159625	167842	128400	113292
848.0 WABASH R	26929	36468	53608	27167	24750	37500	43600	37125	51483	32558	16692
918.5 SMITHLAND	.	.	.	.	.	192367	173308	201150	238592	150317	113700
* 920.4 CUMBRLD R	.	.	.	.	56900	.	.	.	.	.	.
* 934.5 TENNESS R	.	.	.	.	55250	.	.	.	.	.	.
952.3 JOPPA	280853	275527	430500	265333	227958	308517	281525	303725	319550	198942	168192

* INCOMPLETE DATA SETS

APPENDIX E: Z-STATISTIC TABLE

TABLE OF Z-STATISTIC VALUES FOR FLOW-ADJUSTED CONCENTRATION RESULTS

OHIO MP	STATION	TRIB RM	TSS	TDS	HARDNES	SULFATE	TOTAL PHOS	AMMONIA	TKN	NITRATE/ NITRITE	TOT NITRO	PHENOL	COPPER	IRON	LEAD	MERCURY	ZINC
0.0	MONONGAHELA R	4.5	-1.75	-2.86	-2.06	-2.18	-3.63	-6.16	-6.57	-1.86	-6.97	-1.62	-4.41	-1.18	-3.43	0.00	-6.64
0.0	ALLEGHENY R	7.4	0.43	-2.19	-0.37	-2.91	-1.81	-4.56	-4.60	-0.10	-2.69	0.30	-3.07	0.42	0.27	0.00	-2.56
15.2	SOUTH HEIGHTS		0.00	-1.97	-1.66	-1.95	-4.55	-7.61	-6.54	-2.79	-6.88	-3.04	-4.62	-2.04	-2.97	0.69	-6.53
25.4	BEAVER R	5.3	3.05	-5.08	-1.82	-2.66	-0.86	-6.71	-6.21	0.00	-5.05	-2.27	-5.00	1.27	-3.33	-0.85	-2.90
40.2	EAST LIVERPOOL WW		-1.38	-2.06	0.55	-2.32	-3.28	-7.60	-5.17	-1.55	-6.04	-2.69	-4.35	-2.02	-3.82	0.00	-3.83
86.8	WHEELING WTP		-0.16	-1.35	0.16	-0.07	-2.37	-4.80	-4.43	-1.60	-4.45	-1.43	-0.48	-0.32	-3.17	-0.97	-2.97
126.4	HANNIBAL L&D		-0.82	-1.03	-1.62	1.28	-1.78	-6.13	-4.85	-4.40	-5.64	-2.35	-5.08	0.73	-3.65	-0.54	-3.75
161.8	WILLOW ISLAND L&D		-1.96	-1.06	-2.06	1.30	-1.55	-6.59	-6.07	-3.40	-6.97	-1.75	-5.01	-1.45	-4.95	-1.53	-4.83
172.2	MUSKINGUM R	5.8	-0.47	-4.07	-2.33	-1.30	:INS:	:INS:	:INS:	:INS:	:INS:	-0.72	-5.88	0.49	-4.09	-2.50	-0.83
203.9	BELLEVILLE L&D		-2.63	-1.63	-2.44	0.16	-3.87	-5.17	-5.15	-1.72	-5.45	-1.27	-5.78	0.28	-2.76	-0.82	-3.51
260.0	ADDISON-KYGER CR		-3.64	-1.93	-2.35	0.00	-4.76	-6.61	-5.36	-1.30	-5.72	-2.88	-3.32	-2.67	-4.67	0.00	-5.53
265.7	KANAWHA R	31.1	-3.33	-3.93	0.36	0.19	:INS:	:INS:	:INS:	:INS:	:INS:	-3.79	-6.82	-1.37	-1.57	-0.94	-6.11
279.2	GALLIPOLIS L&D		-3.29	-3.49	-2.48	-1.47	-4.39	-6.99	-5.07	-1.66	-5.25	-1.04	-6.34	0.02	-2.03	0.08	-4.97
306.9	HUNTINGTON WATER CO		-6.69	-0.64	-0.71	-0.74	1.22	-7.17	-7.22	0.75	-6.37	-2.69	-7.28	-7.44	-4.83	1.26	0.40
317.1	BIG SANDY R	20.3	-5.22	2.89	1.88	0.62	-6.73	-6.27	-6.39	-0.52	-5.73	-2.36	-0.55	-3.29	-3.73	0.00	-4.64
350.7	PORTSMOUTH		-1.40	-1.42	-1.98	1.30	-3.89	-2.37	-3.19	0.08	-2.26	-0.76	-2.53	0.00	-2.45	0.69	-0.14
356.5	SCIOTO R	15.0	-1.24	-0.20	-1.62	0.48	:INS:	:INS:	:INS:	:INS:	:INS:	0.43	-6.88	0.61	-3.31	-0.75	-3.45
408.5	MAYSVILLE WW		0.70	-0.24	0.42	0.12	:INS:	:INS:	:INS:	:INS:	:INS:	-1.36	0.47	1.30	-4.08	0.96	-1.29
462.8	CINCINNATI WW		-0.40	-1.49	-1.57	-0.76	:INS:	:INS:	:INS:	:INS:	:INS:	-1.53	-0.23	1.24	-2.63	0.57	-3.04
464.1	LITTLE MIAMI R	7.5	-1.10	2.34	-1.40	0.93	:INS:	:INS:	:INS:	:INS:	:INS:	-1.69	-4.53	0.46	-3.75	0.30	-4.20
470.2	LICKING R	4.5	-0.53	3.91	-0.48	1.90	-3.00	-4.17	-4.53	0.00	-2.66	-2.18	-4.02	0.86	-3.08	0.00	-2.60
490.0	NORTH BEND		-1.36	-0.45	-0.92	0.02	:INS:	:INS:	:INS:	:INS:	:INS:	-2.94	-3.07	-0.38	-4.43	1.45	-1.90
491.1	GREAT MIAMI R	5.5	-1.47	-0.85	-2.85	-0.66	:INS:	:INS:	:INS:	:INS:	:INS:	-2.65	-3.04	-0.99	-4.60	1.32	-5.48
531.5	MARKLAND L&D		-0.64	-0.34	-0.31	1.50	:INS:	:INS:	:INS:	:INS:	:INS:	-2.64	0.75	0.67	-4.18	-0.74	-3.04
600.6	LOUISVILLE WATER CO		-0.29	-0.66	-2.44	-1.29	-3.00	-4.78	-1.49	1.58	0.24	-0.30	-0.06	0.19	-3.20	-0.72	-2.54
625.9	WEST POINT		3.89	-0.42	-1.96	-1.12	-4.53	-0.73	-2.30	1.60	-1.16	-1.01	-4.34	-2.86	-4.57	0.41	-5.02
720.7	CANNELTON L&D		-1.20	-0.67	-0.19	-1.32	:INS:	:INS:	:INS:	:INS:	:INS:	-1.93	-2.65	0.02	-2.23	-2.29	-1.41
784.2	GREEN R	41.3	-0.90	2.74	1.89	2.60	-3.82	-0.72	0.95	1.81	1.88	-1.62	-2.42	-0.12	-3.68	-1.76	-2.84
791.5	EVANSVILLE WW		-3.21	-1.09	0.31	-2.18	-5.05	-3.35	-2.02	0.70	-0.68	-0.50	-5.14	-1.97	-1.14	-2.33	-3.62
846.0	UNIONTOWN L&D		0.81	-2.02	-0.87	-1.01	:INS:	:INS:	:INS:	:INS:	:INS:	-1.56	-1.17	1.12	-2.02	-1.53	-0.73
848.0	WABASH R	51.5	-0.88	-1.53	1.62	-1.23	:INS:	:INS:	:INS:	:INS:	:INS:	-0.88	-1.71	0.80	-0.69	-0.49	-0.45
918.5	SMITHLAND L&D		-1.38	-1.17	-2.32	0.72	:INS:	:INS:	:INS:	:INS:	:INS:	-2.77	-1.40	-0.49	-0.84	-1.70	-1.43
920.4	CUMBERLAND R	30.6	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:
934.5	TENNESSEE R	6.0	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:	:INS:
952.3	JOPPA		-3.91	0.32	-1.73	-1.20	-4.49	-3.84	-1.71	0.61	0.18	-0.63	-0.73	-1.37	-1.04	0.00	-0.31

:INS: Insufficient data available

STRONG SIGNIFICANT INCREASING TREND has a z-statistic of 1.96 OR ABOVE

SIGNIFICANT INCREASING TREND has a z-statistic BETWEEN 1.65 AND 1.96

NO TREND has a z-statistic BETWEEN 1.65 AND -1.65

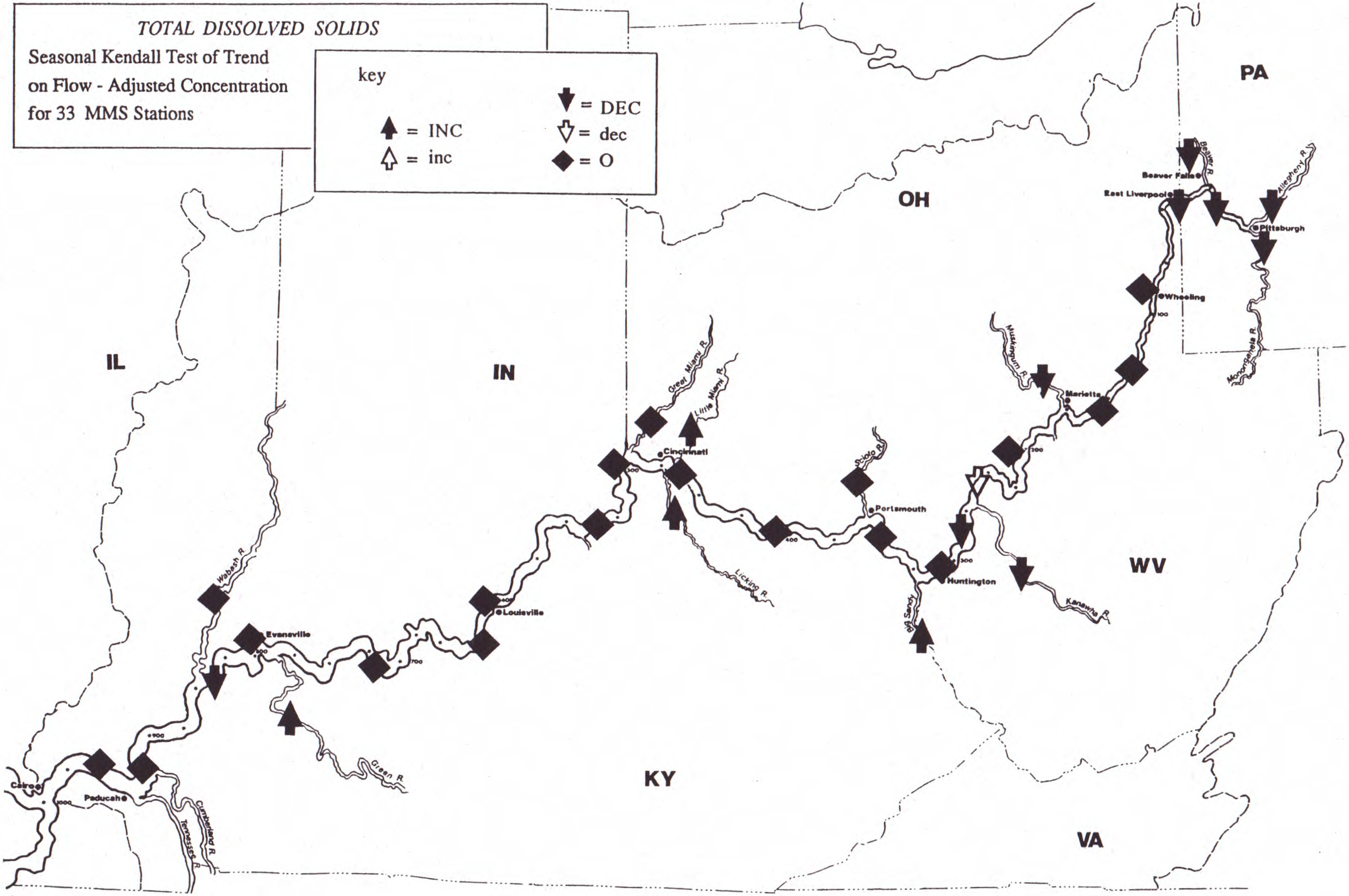
SIGNIFICANT DECREASING TREND has a z-statistic BETWEEN -1.65 AND -1.96

STRONG SIGNIFICANT DECREASING TREND has a z-statistic of -1.96 OR BELOW

APPENDIX F: TREND DIRECTION MAPS AND SLOPE MAGNITUDE BAR CHARTS

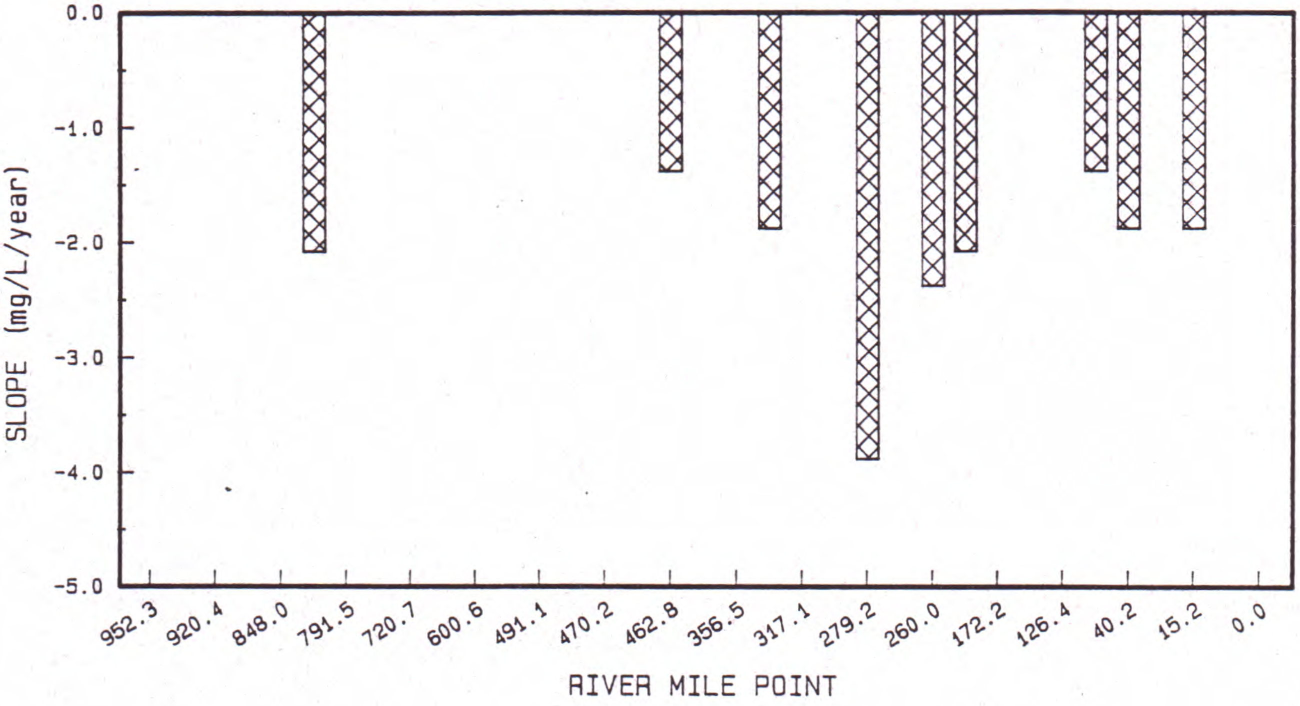
TOTAL DISSOLVED SOLIDS

Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 33 MMS Stations

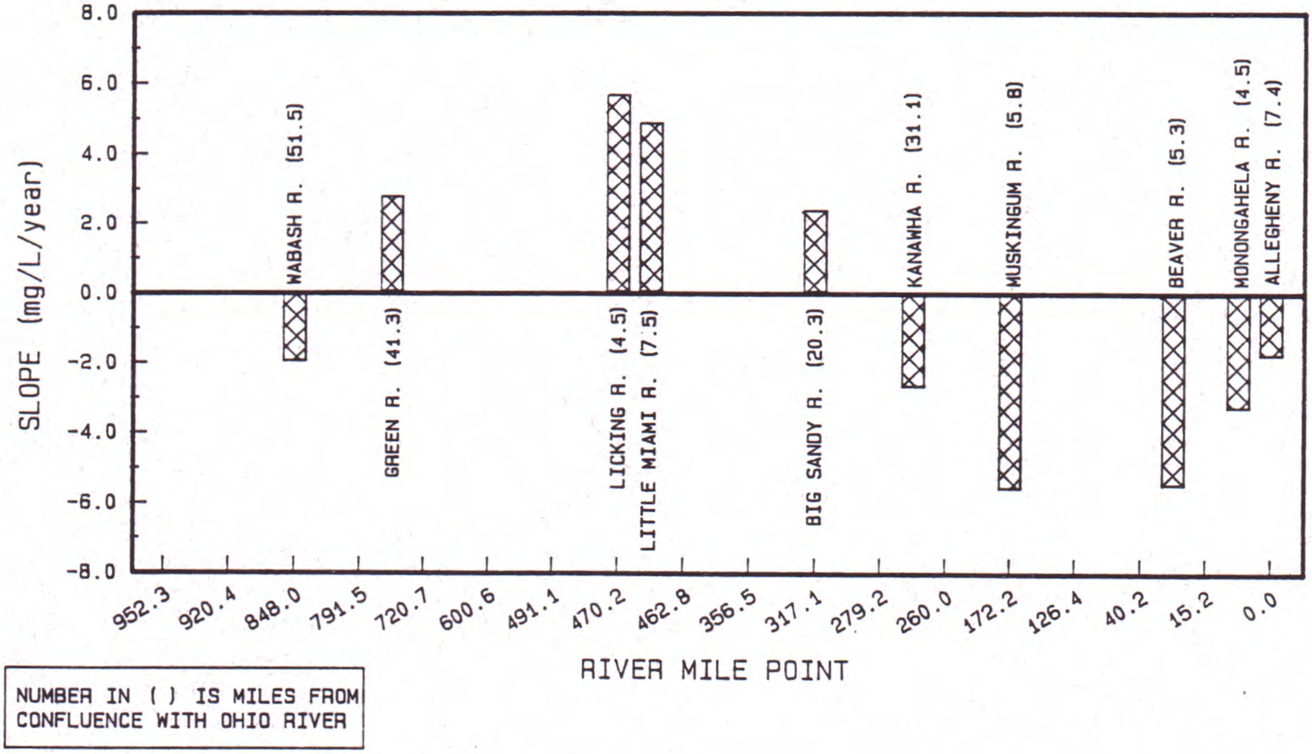


TREND ASSESSMENT SLOPE ESTIMATOR

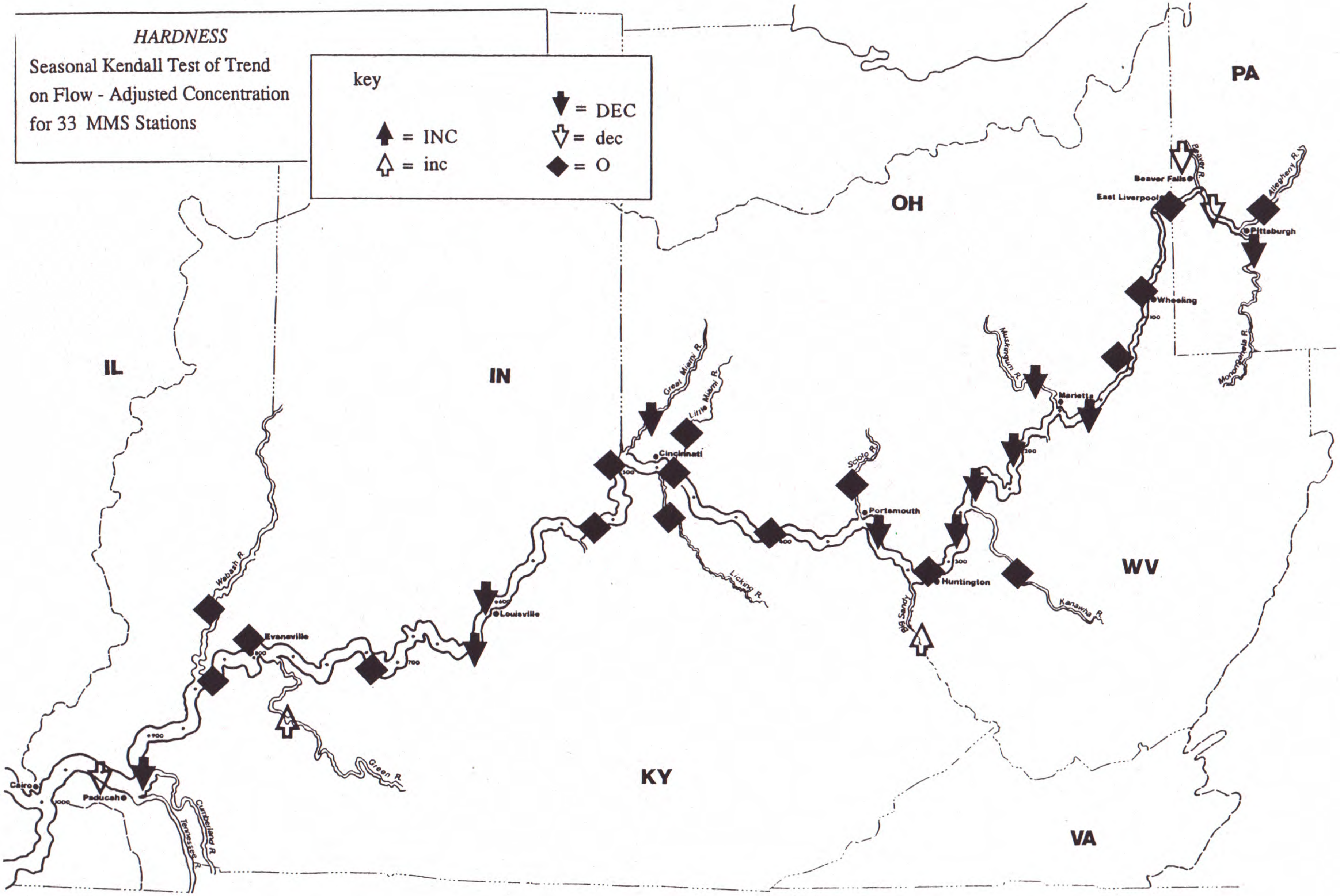
Total Dissolved Solids (Main Stem)



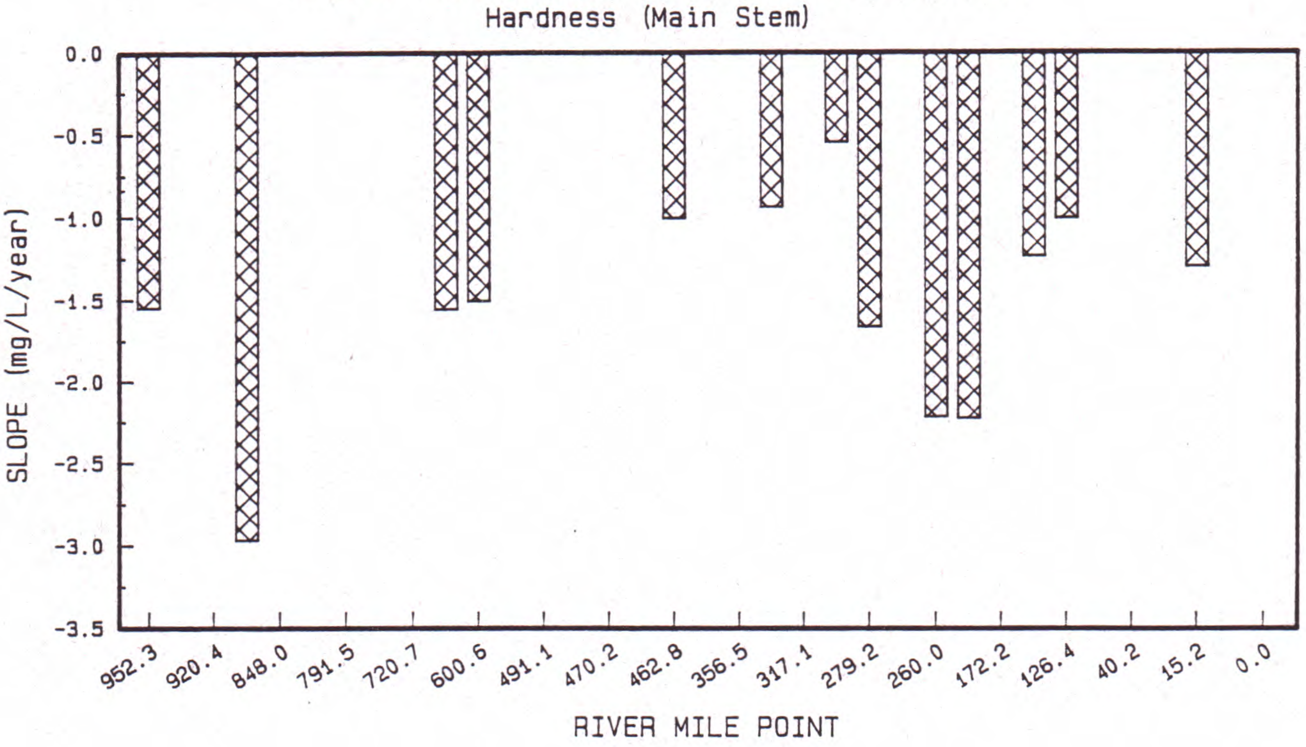
Total Dissolved Solids (Tributaries)

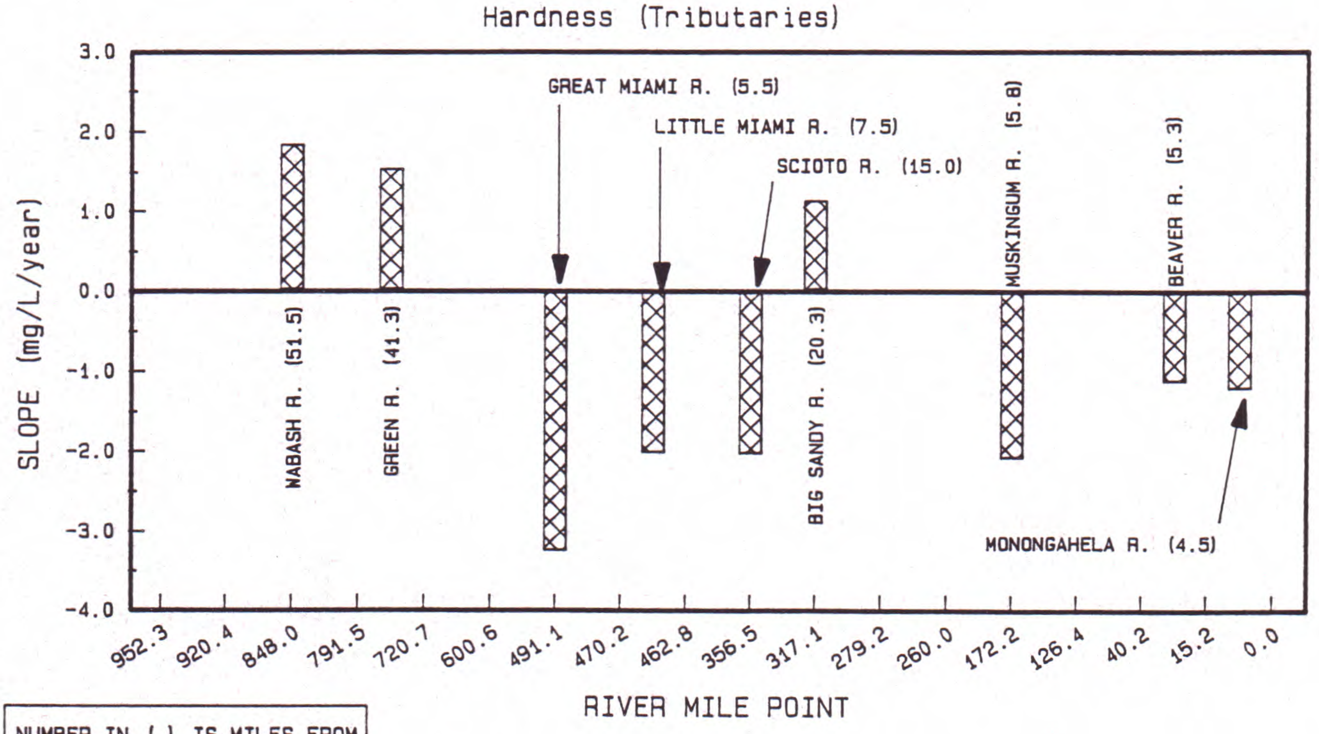


HARDNESS
Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 33 MMS Stations

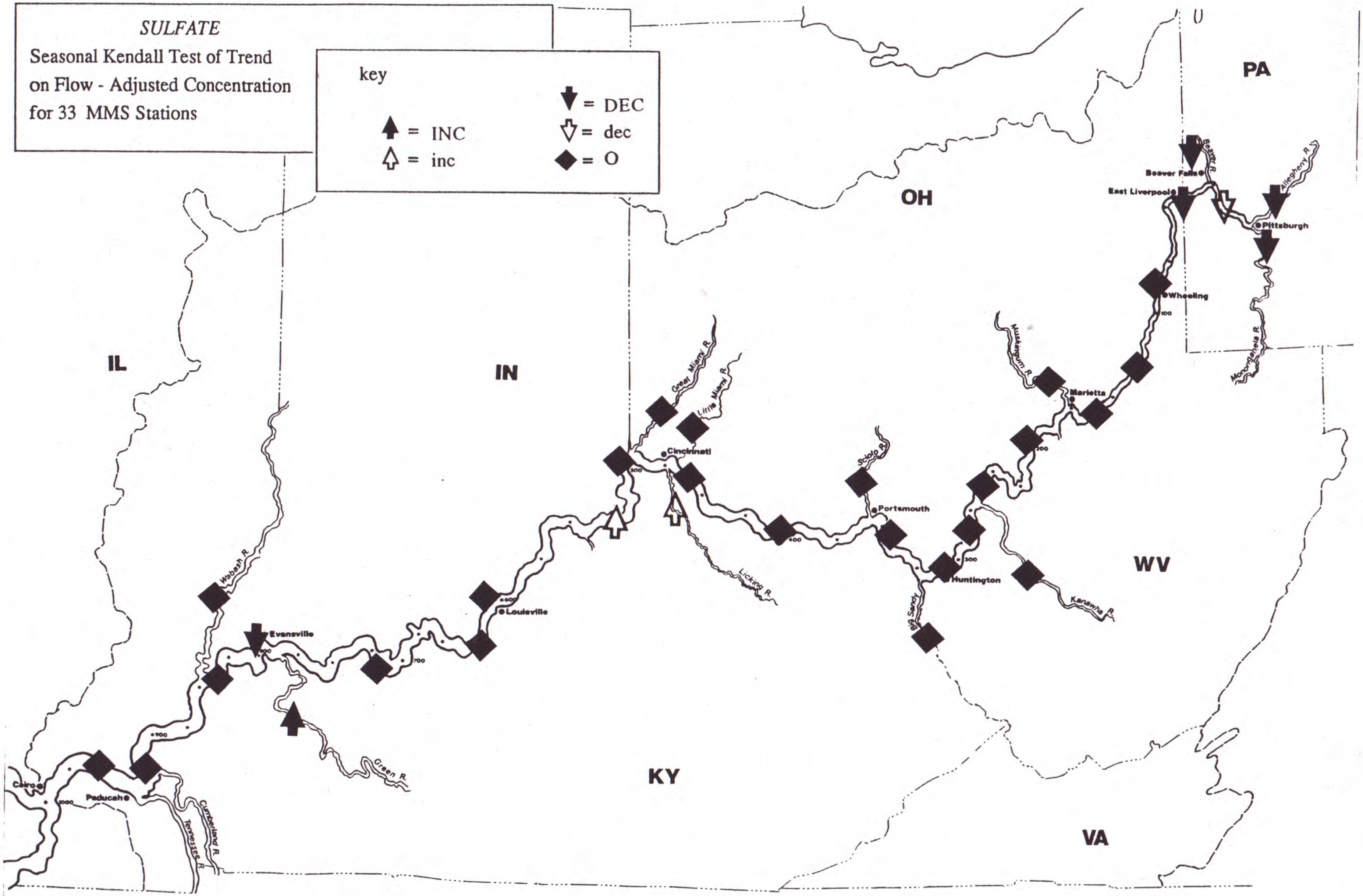


TREND ASSESSMENT SLOPE ESTIMATOR





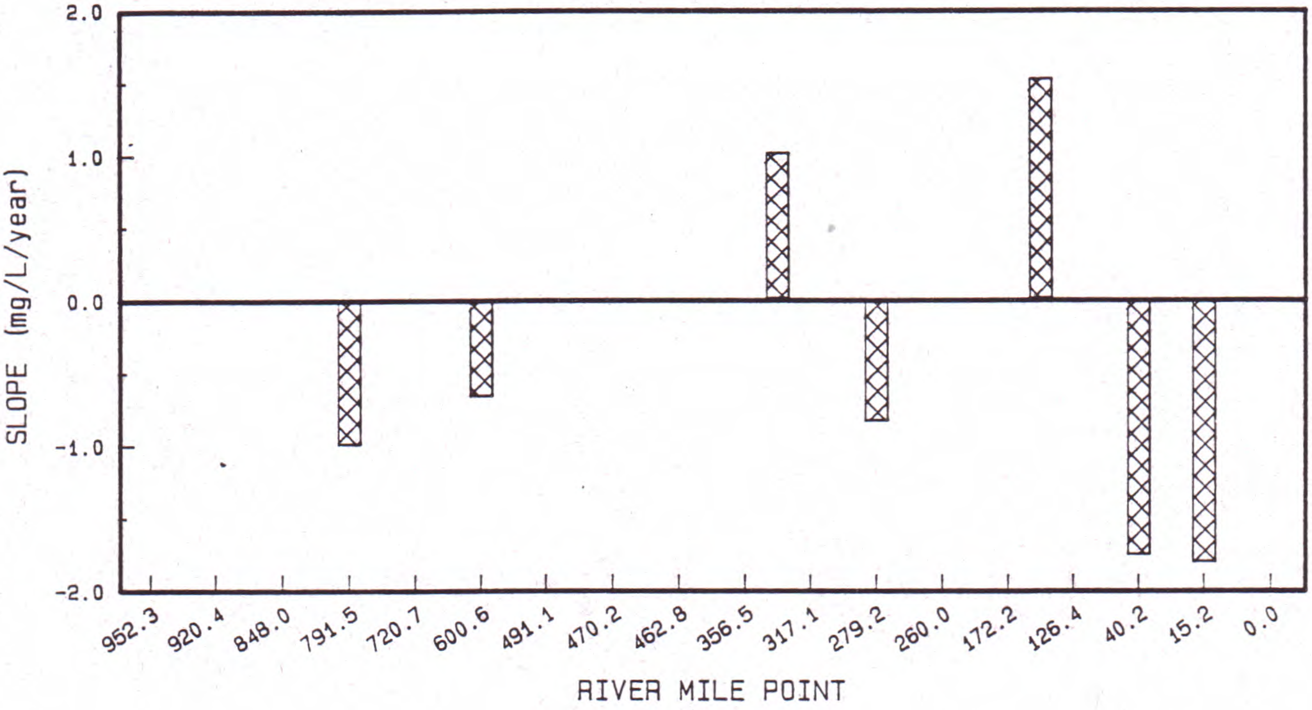
NUMBER IN ( ) IS MILES FROM
CONFLUENCE WITH OHIO RIVER



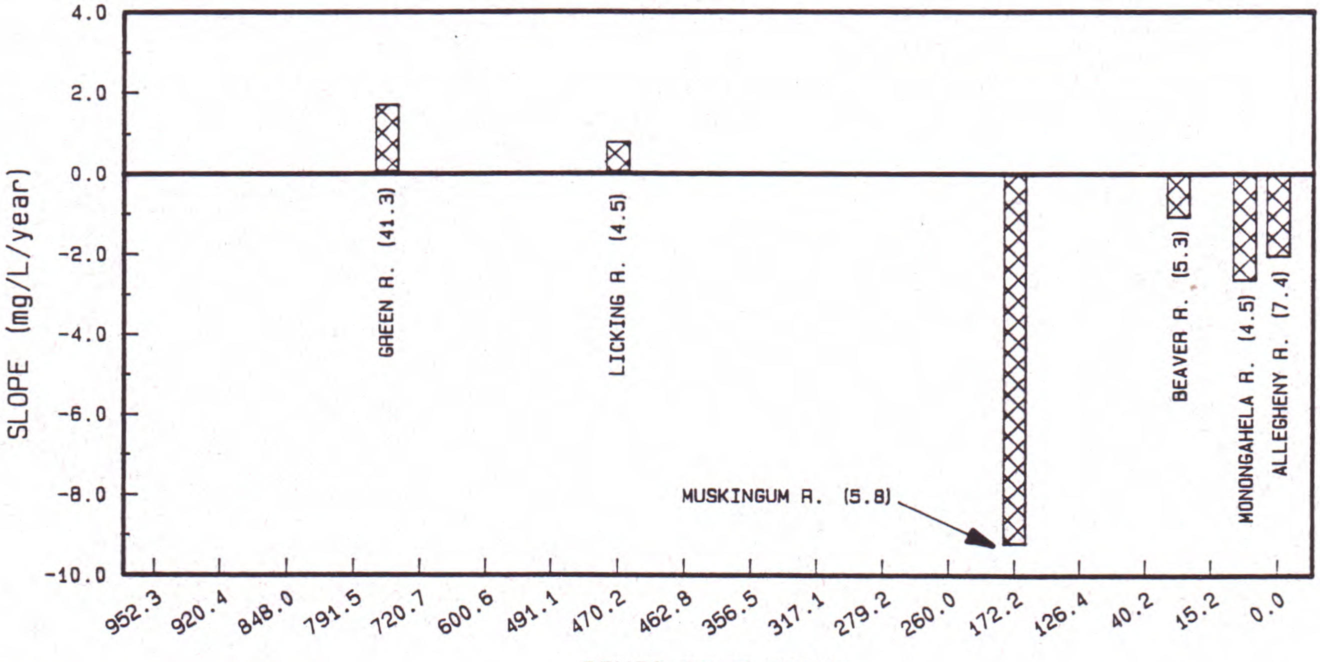
SULFATE
Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 33 MMS Stations

TREND ASSESSMENT SLOPE ESTIMATOR

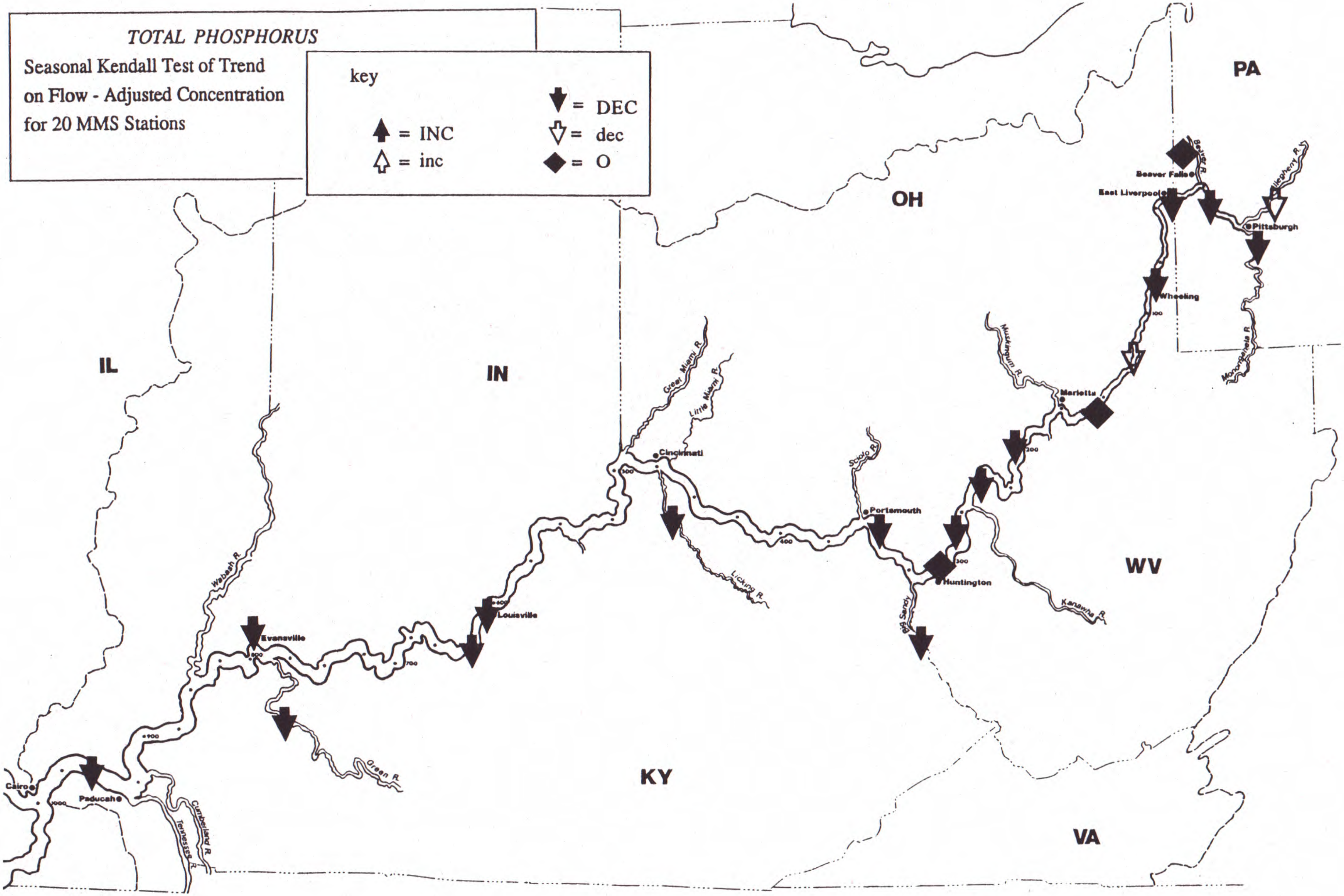
Sulfate (Main Stem)



Sulfate (Tributaries)



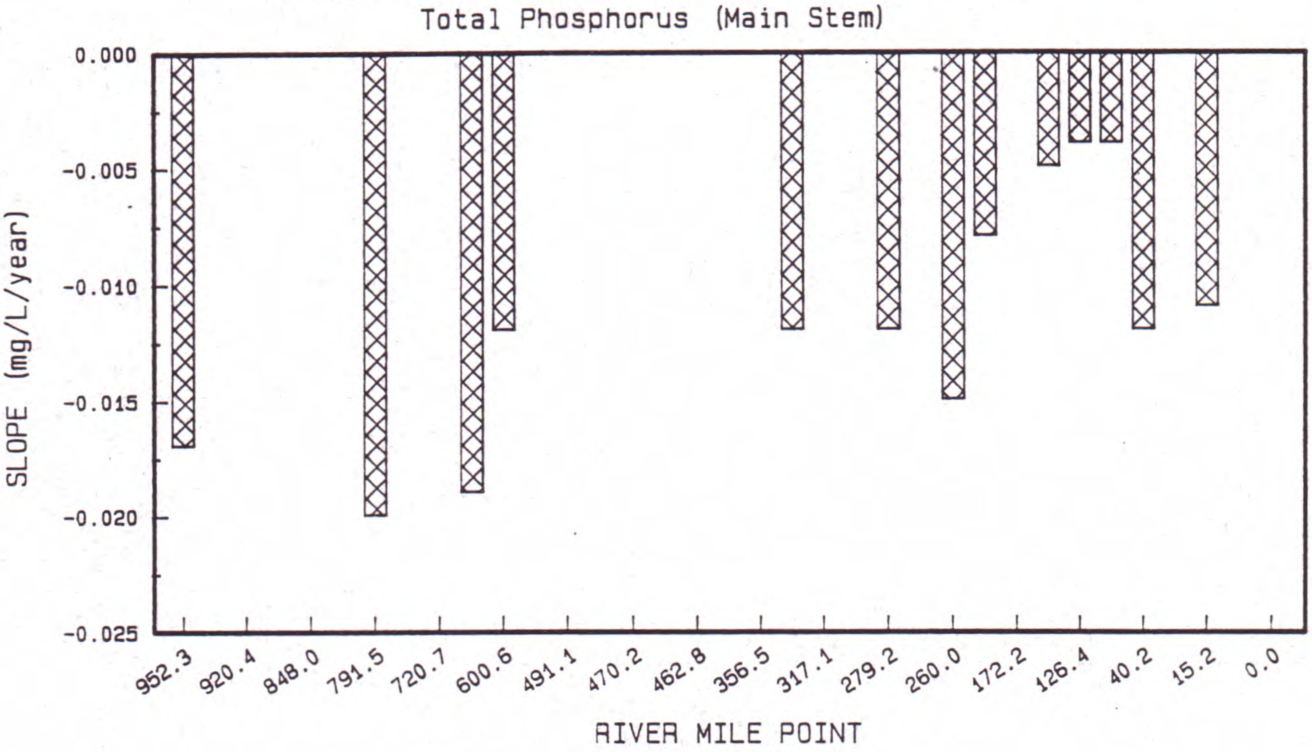
NUMBER IN ( ) IS MILES FROM
CONFLUENCE WITH OHIO RIVER

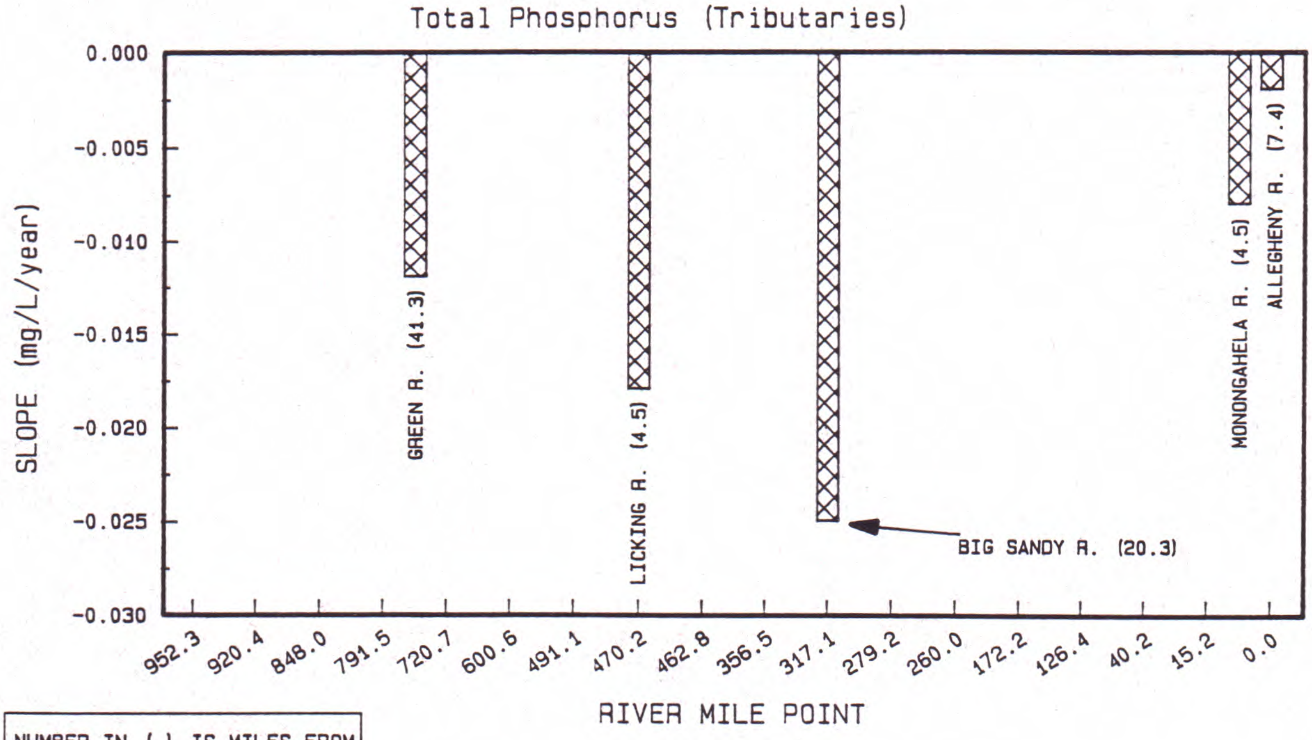


TOTAL PHOSPHORUS

Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 20 MMS Stations

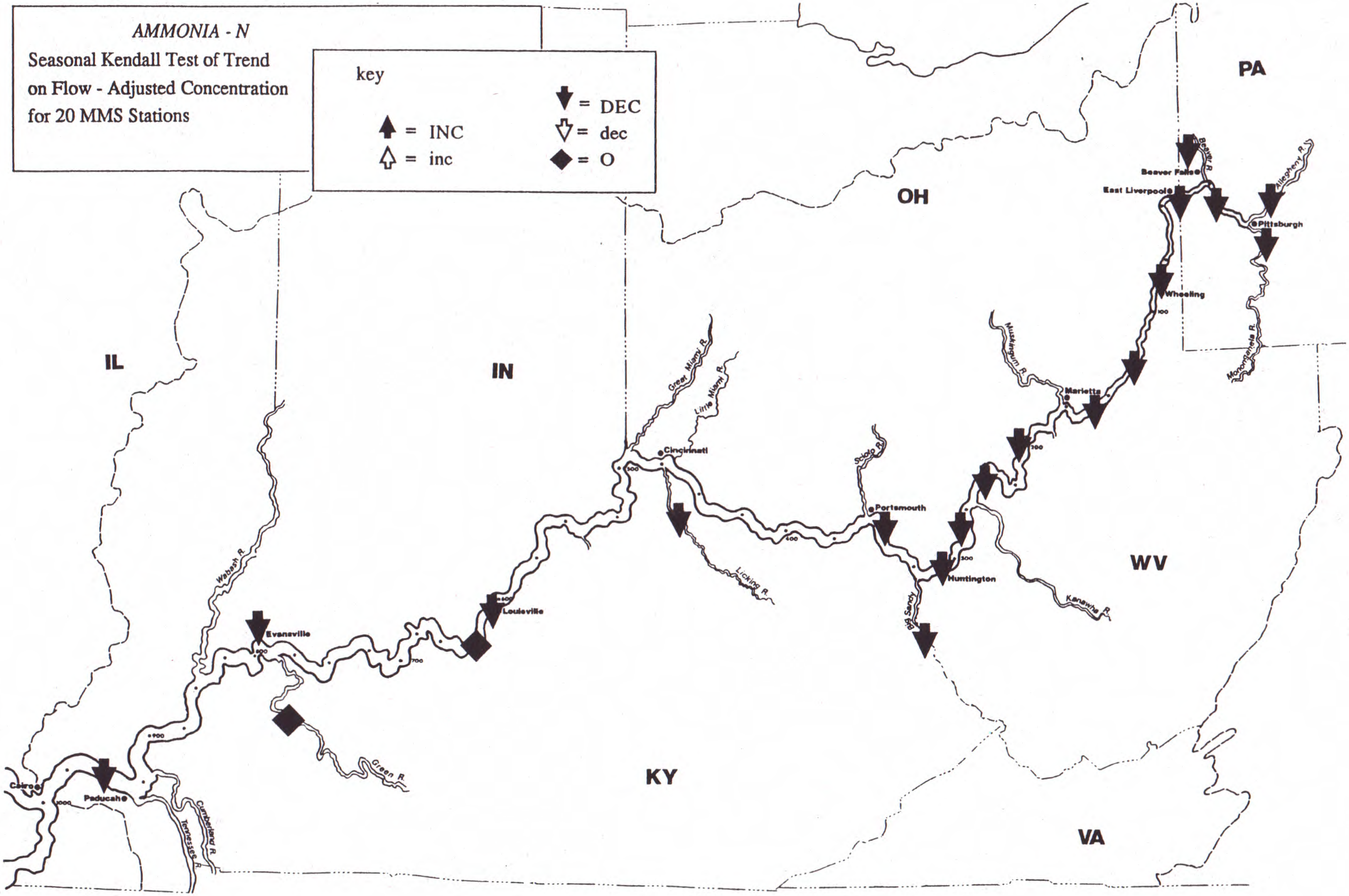
TREND ASSESSMENT SLOPE ESTIMATOR





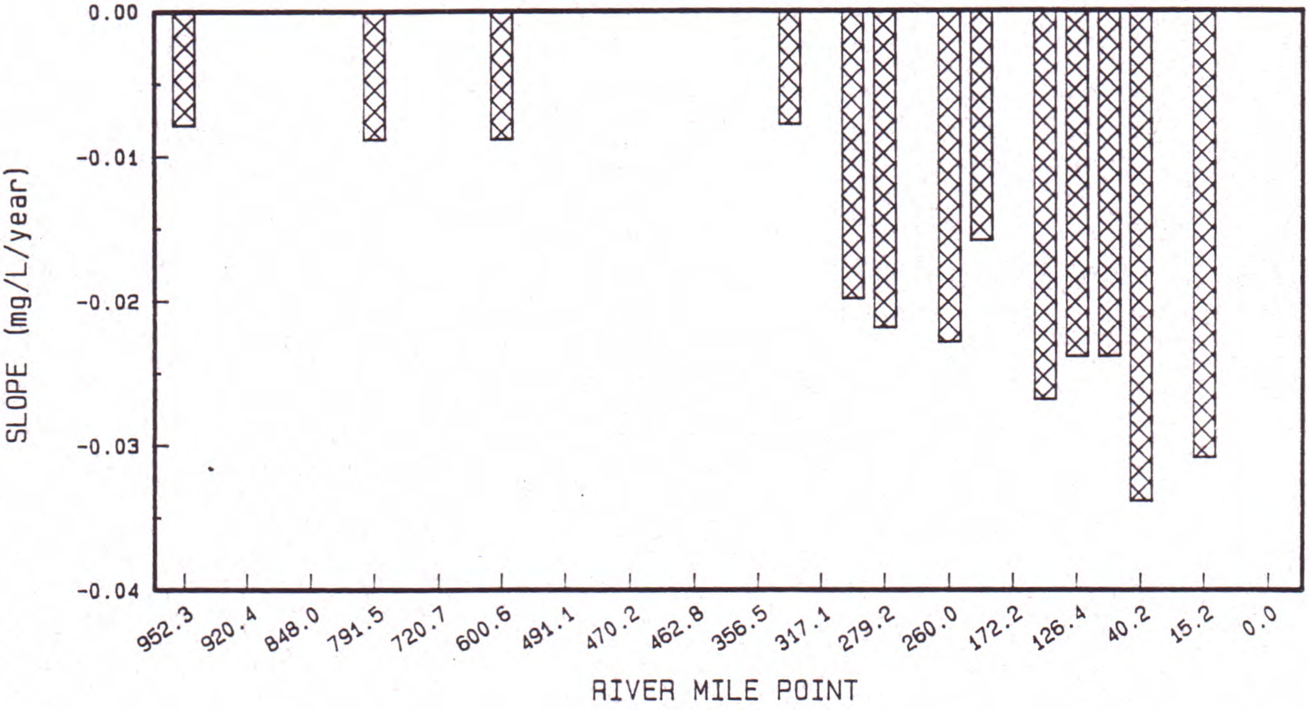
NUMBER IN ( ) IS MILES FROM
CONFLUENCE WITH OHIO RIVER

AMMONIA - N
Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 20 MMS Stations

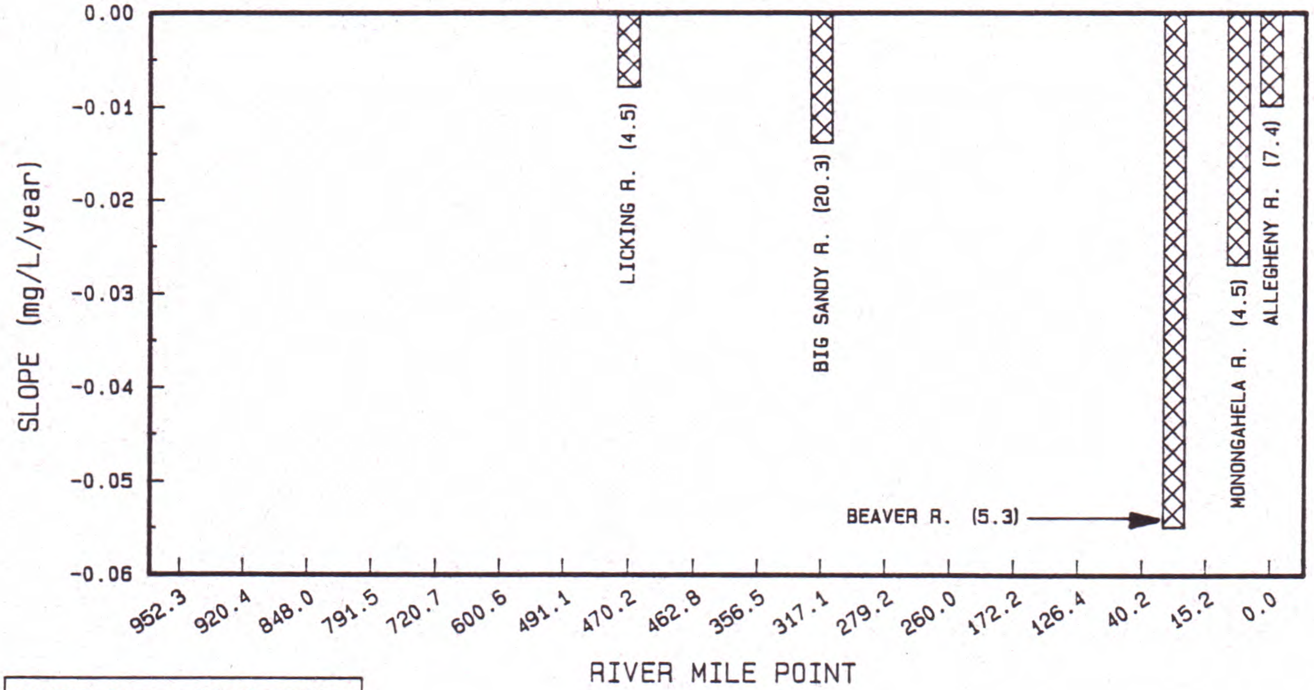


TREND ASSESSMENT SLOPE ESTIMATOR

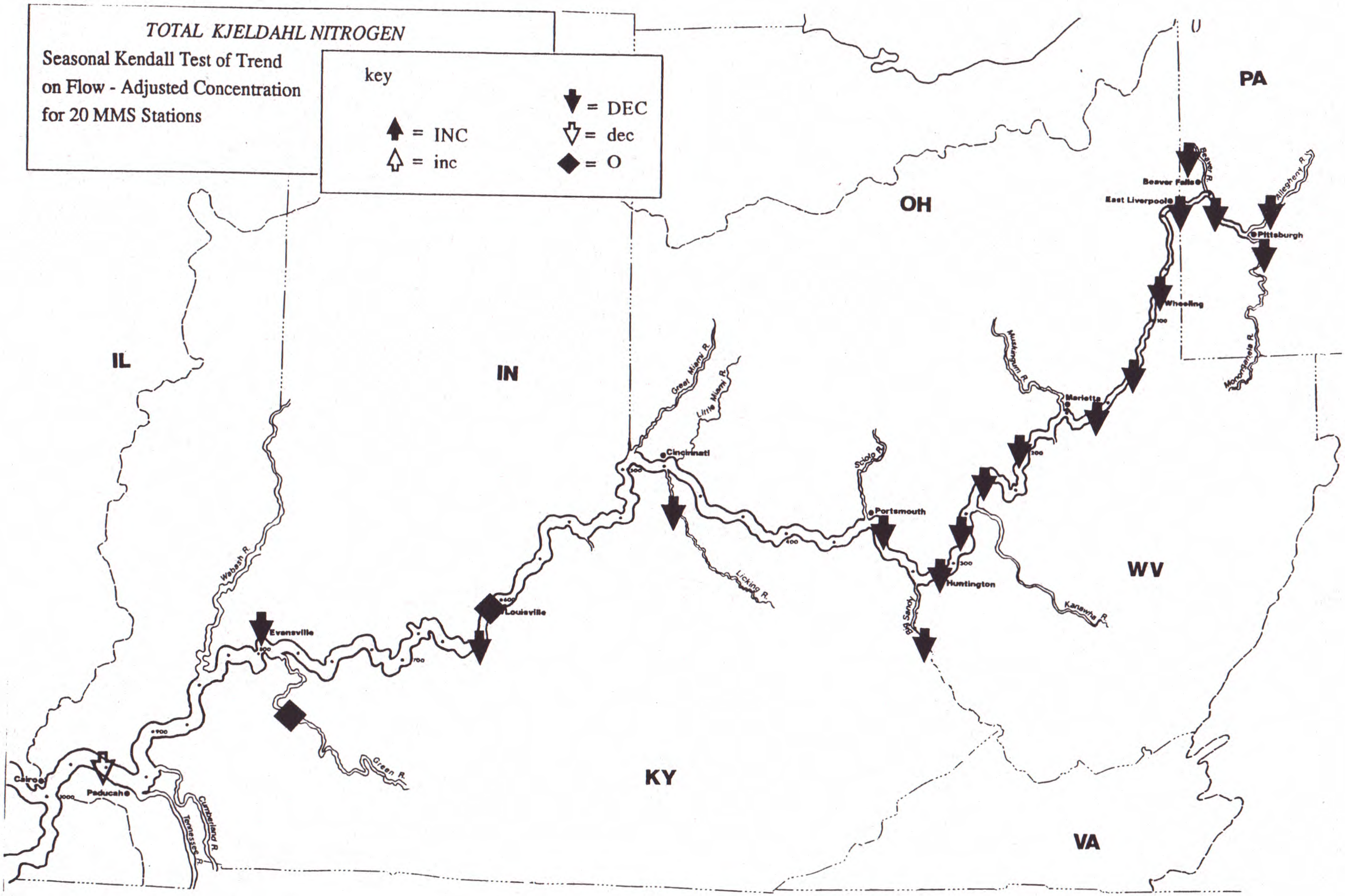
Ammonia (Main Stem)



Ammonia (Tributaries)



NUMBER IN ( ) IS MILES FROM
CONFLUENCE WITH OHIO RIVER

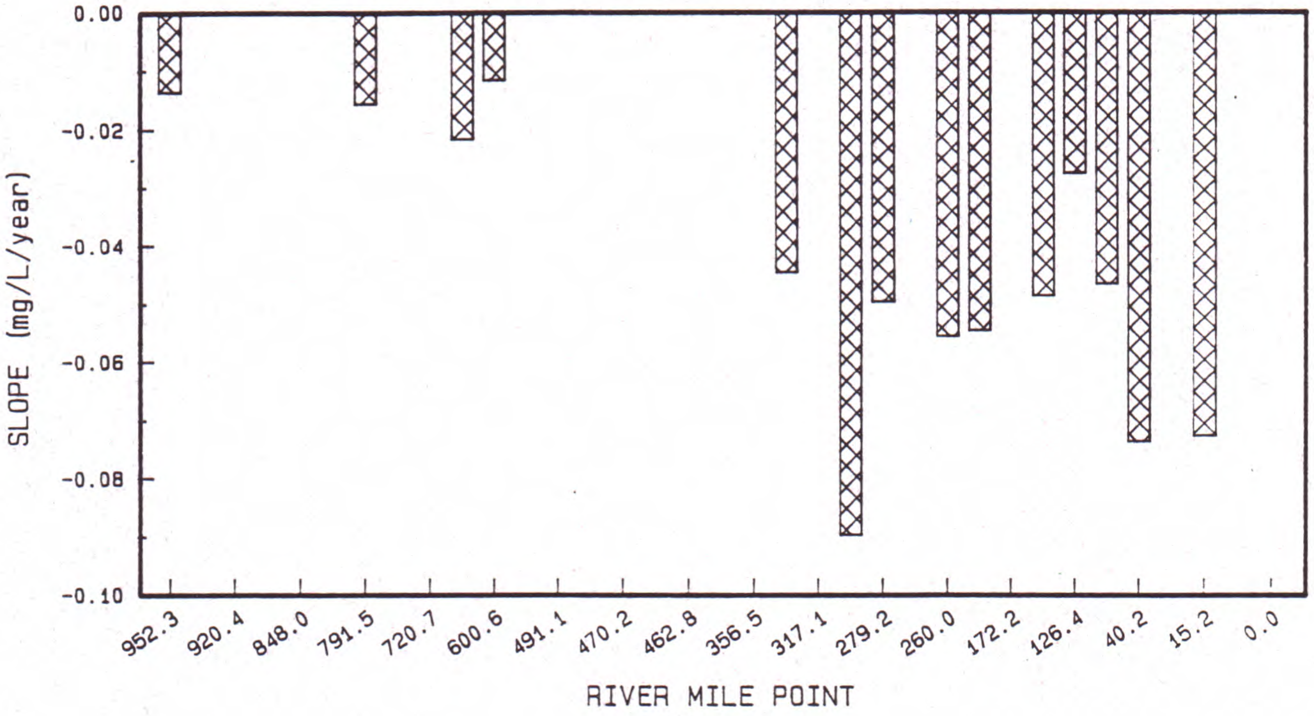


TOTAL KJELDAHL NITROGEN

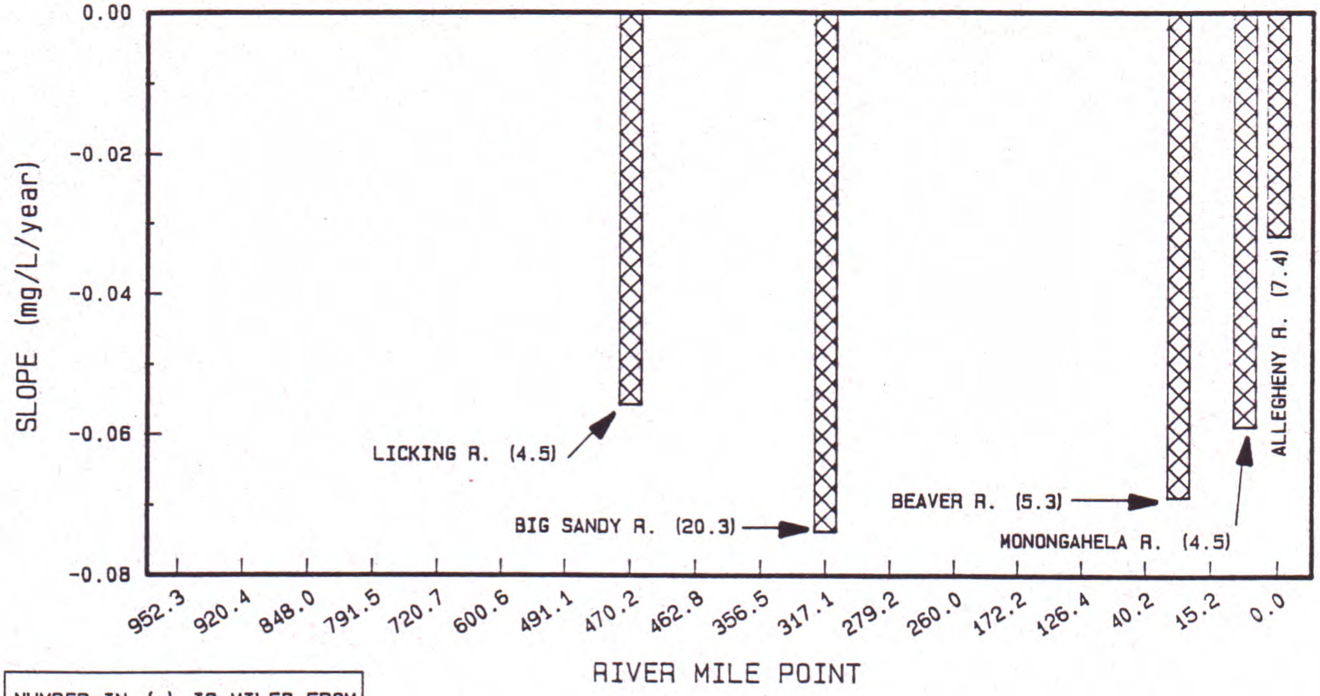
Seasonal Kendall Test of Trend on Flow - Adjusted Concentration for 20 MMS Stations

TREND ASSESSMENT SLOPE ESTIMATOR

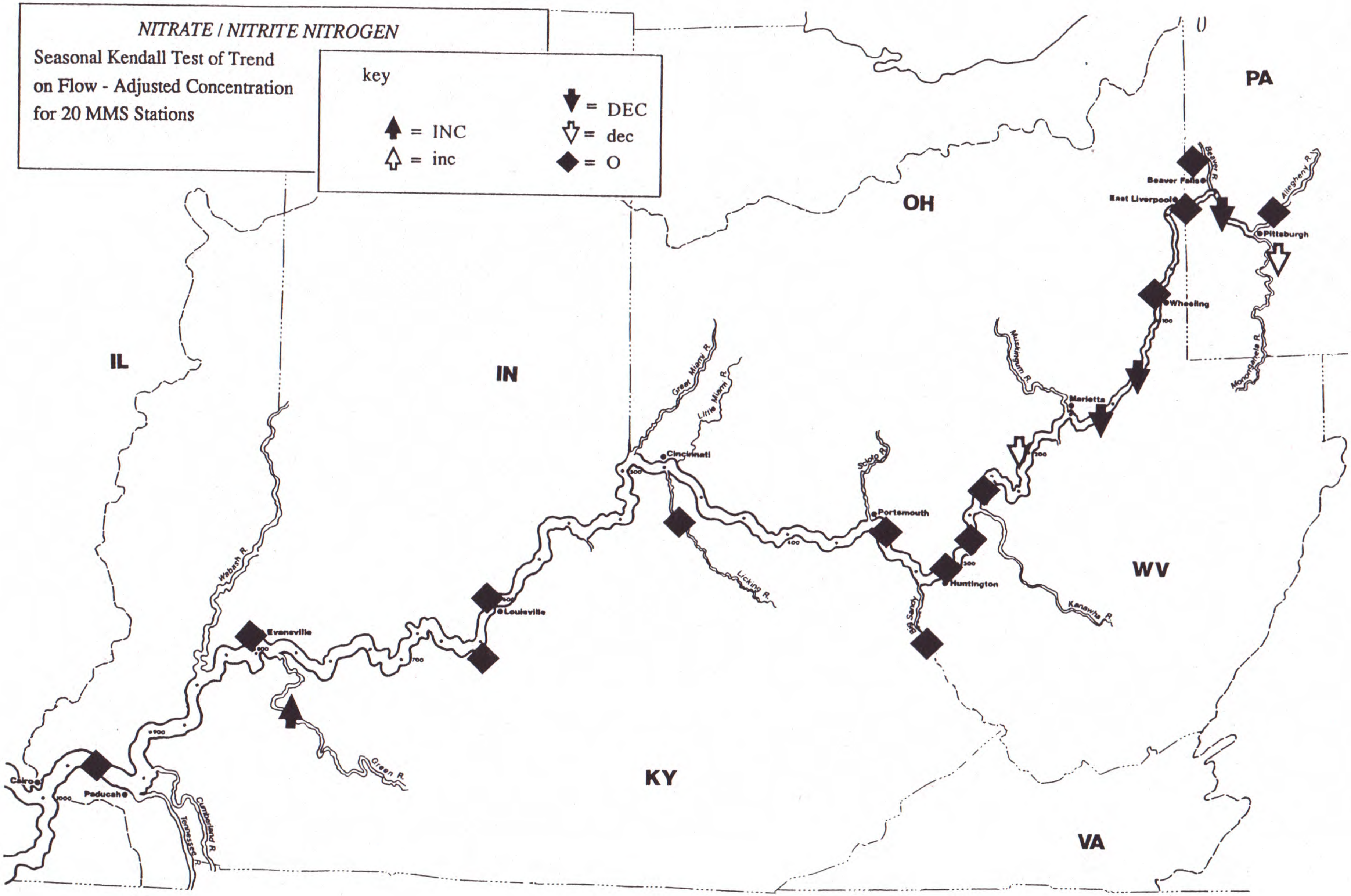
Total Kjeldahl Nitrogen (Main Stem)



Total Kjeldahl Nitrogen (Tributaries)



NUMBER IN ( ) IS MILES FROM
CONFLUENCE WITH OHIO RIVER

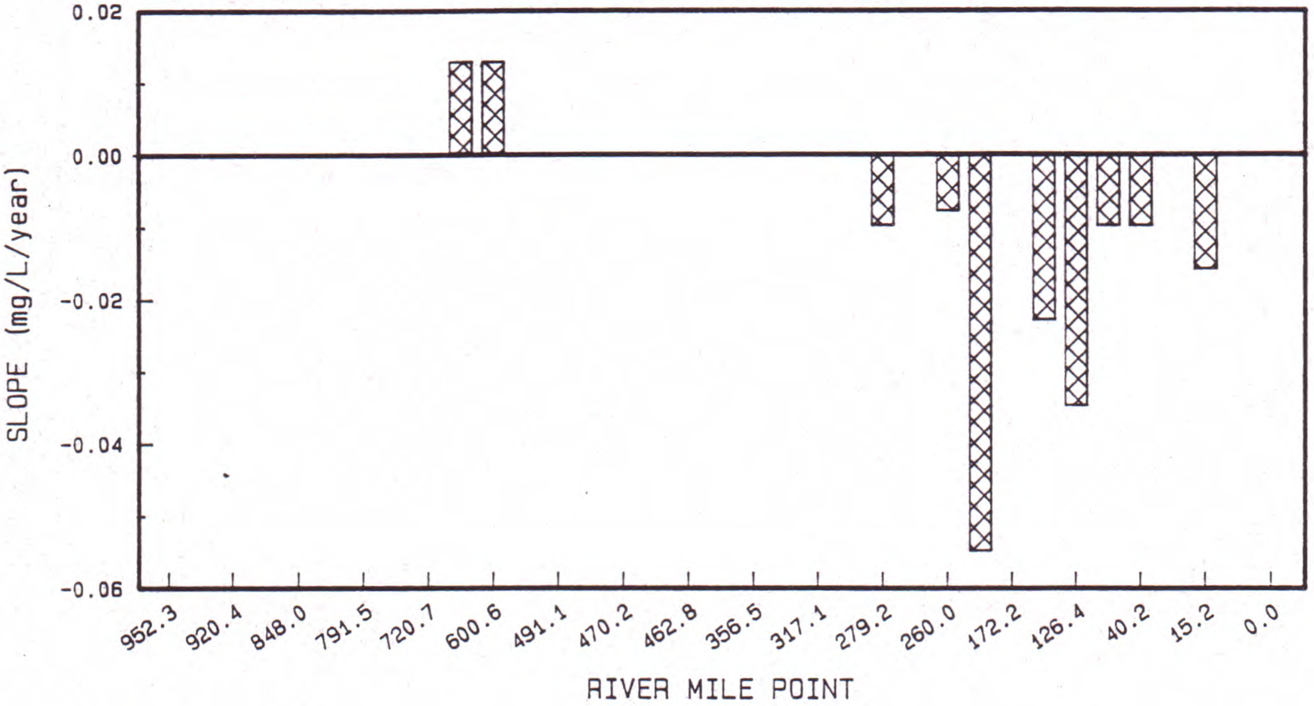


NITRATE / NITRITE NITROGEN

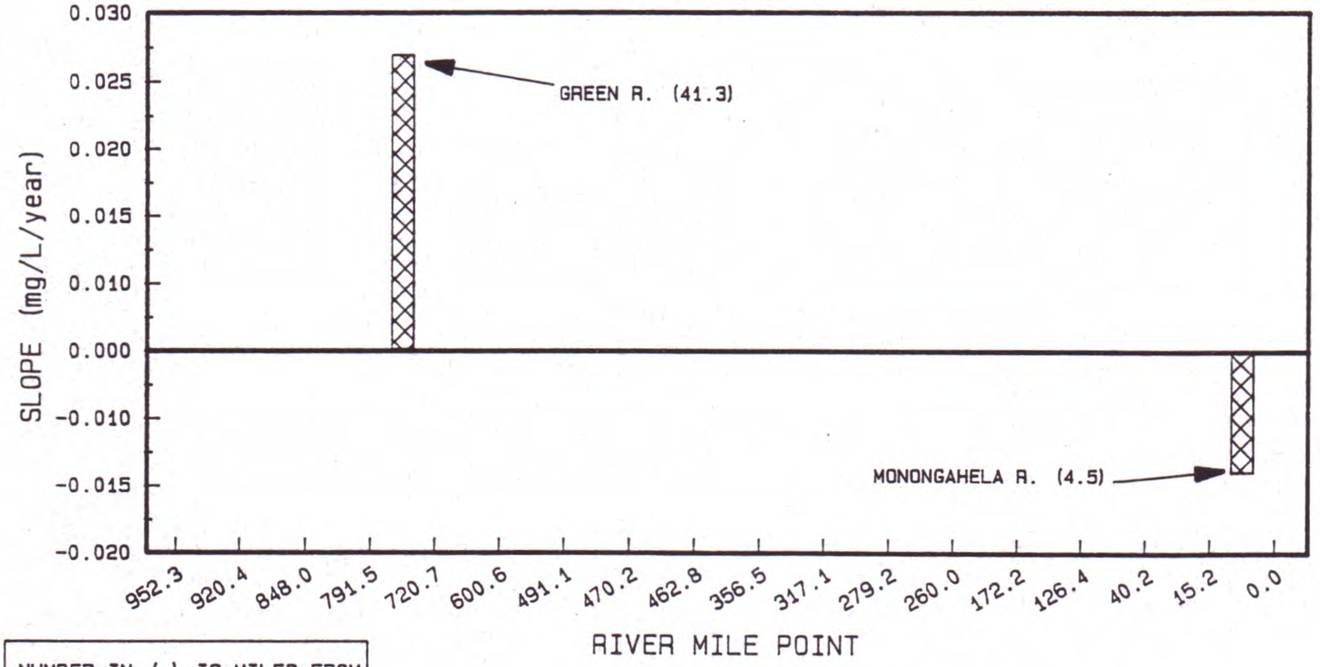
Seasonal Kendall Test of Trend on Flow - Adjusted Concentration for 20 MMS Stations

TREND ASSESSMENT SLOPE ESTIMATOR

Nitrate/Nitrite (Main Stem)

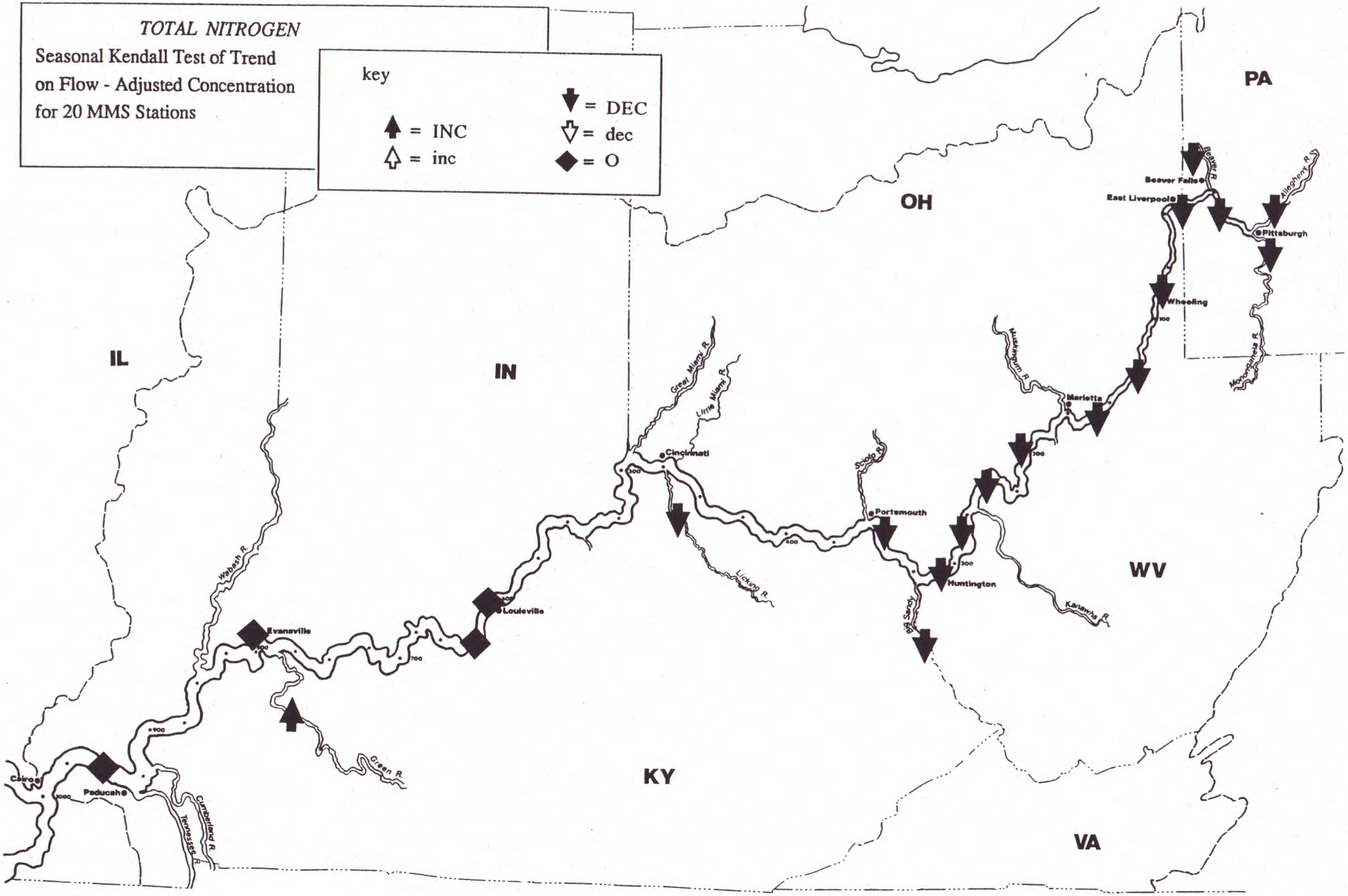


Nitrate/Nitrite (Tributaries)



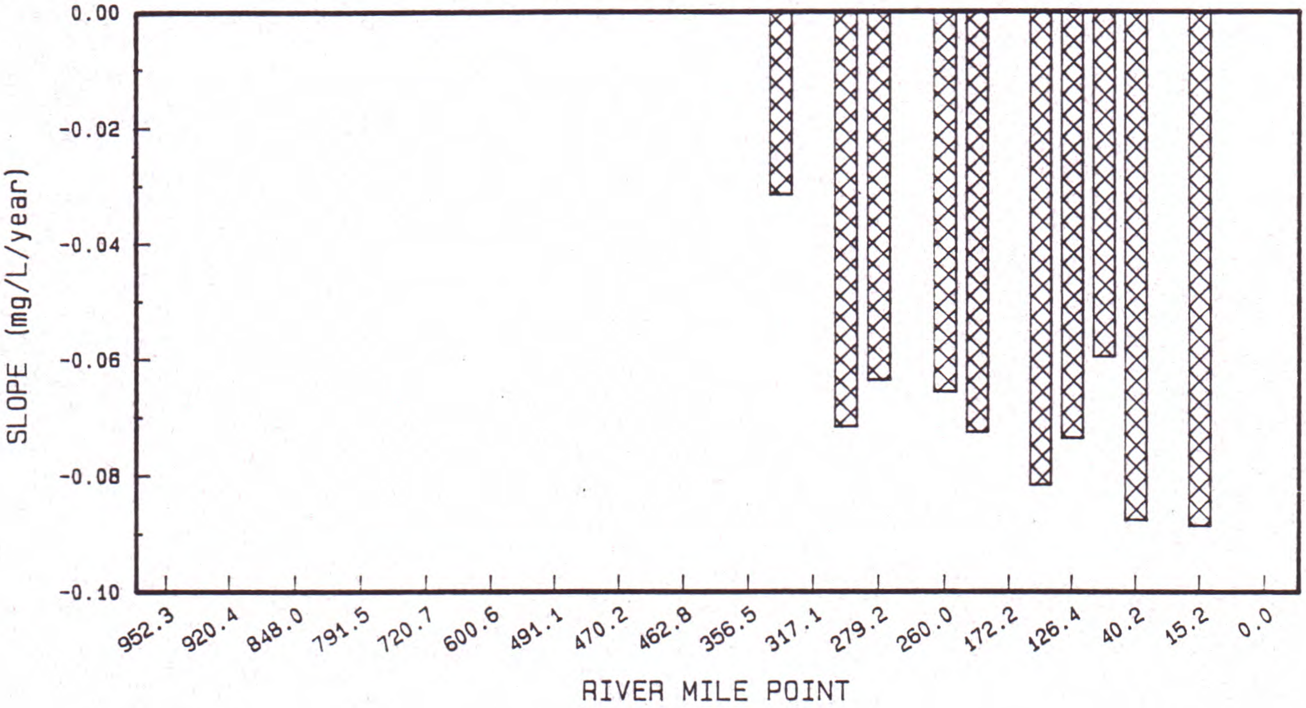
NUMBER IN ( ) IS MILES FROM
CONFLUENCE WITH OHIO RIVER

TOTAL NITROGEN
Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 20 MMS Stations



TREND ASSESSMENT SLOPE ESTIMATOR

Total Nitrogen (Main Stem)



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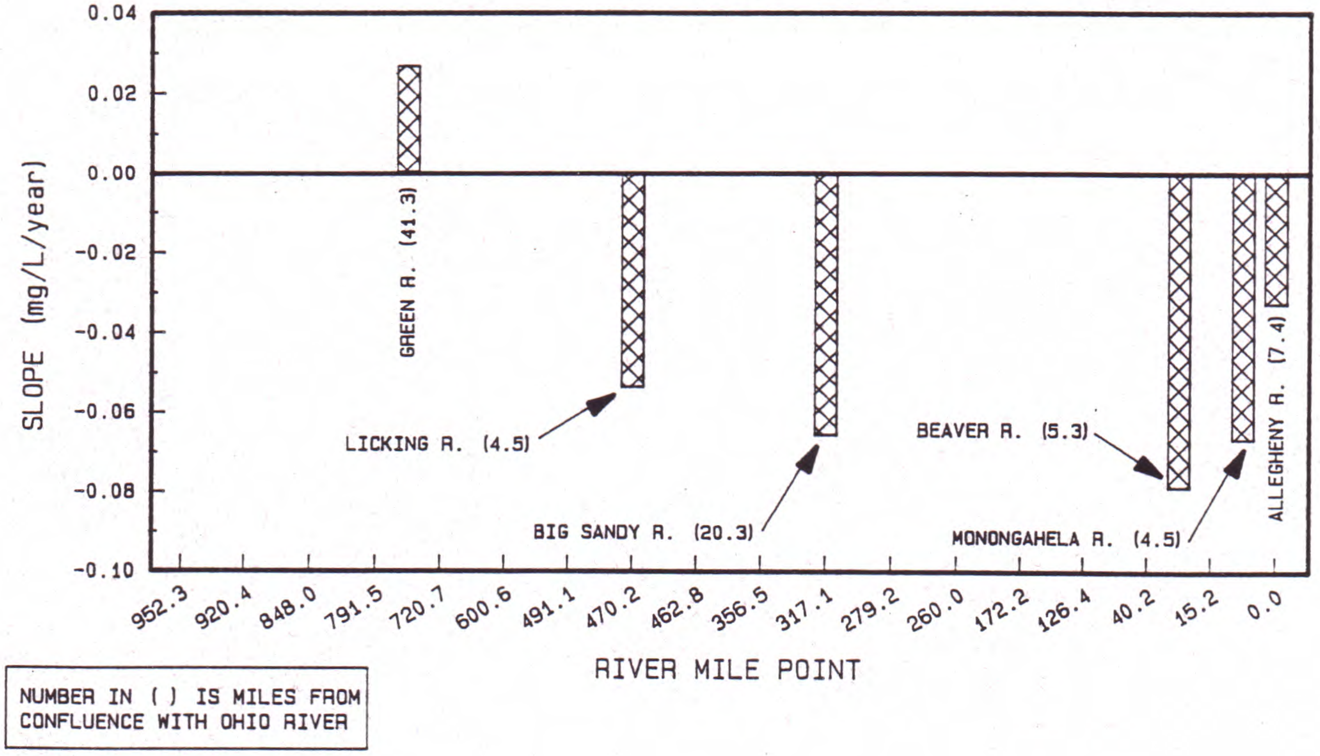
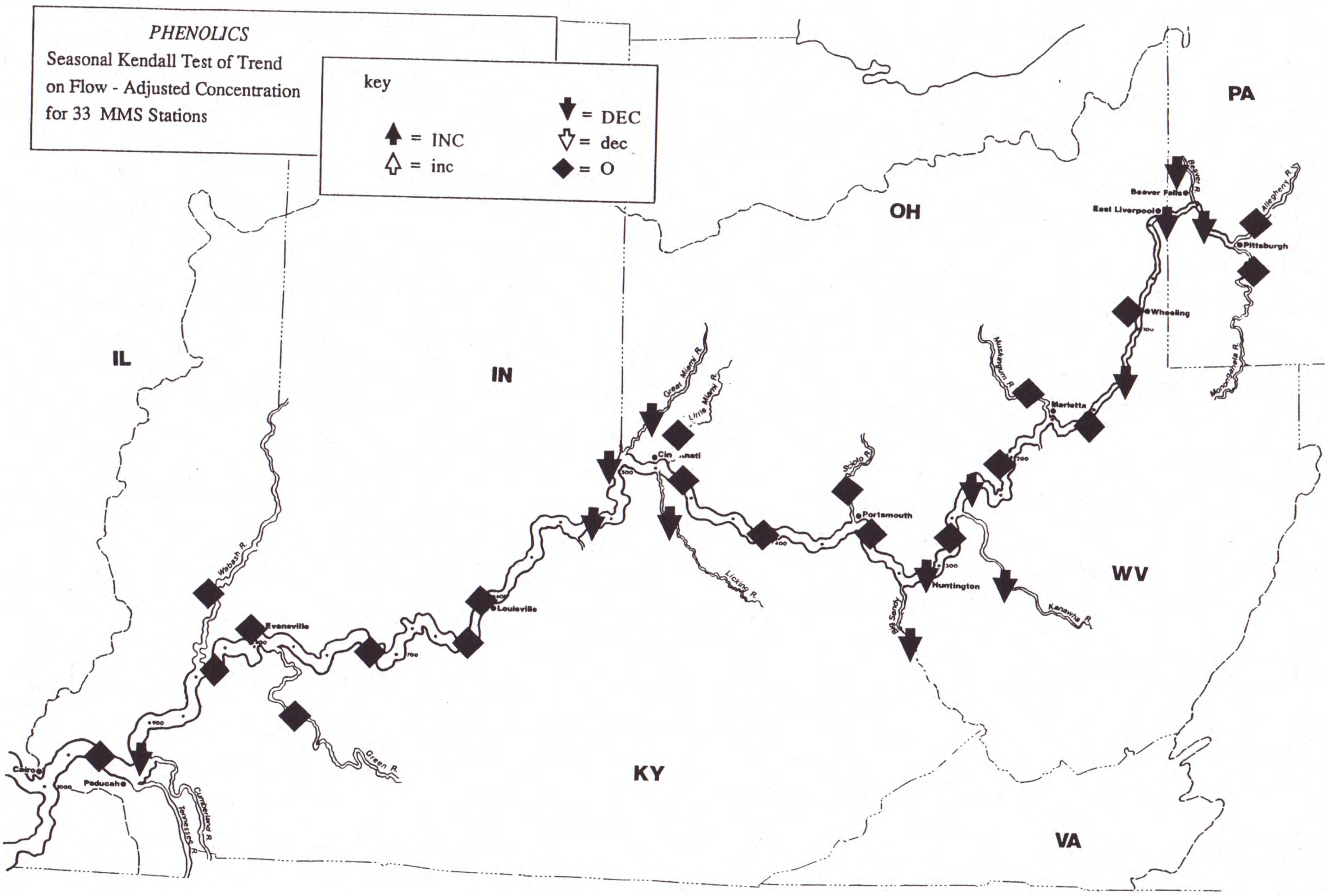
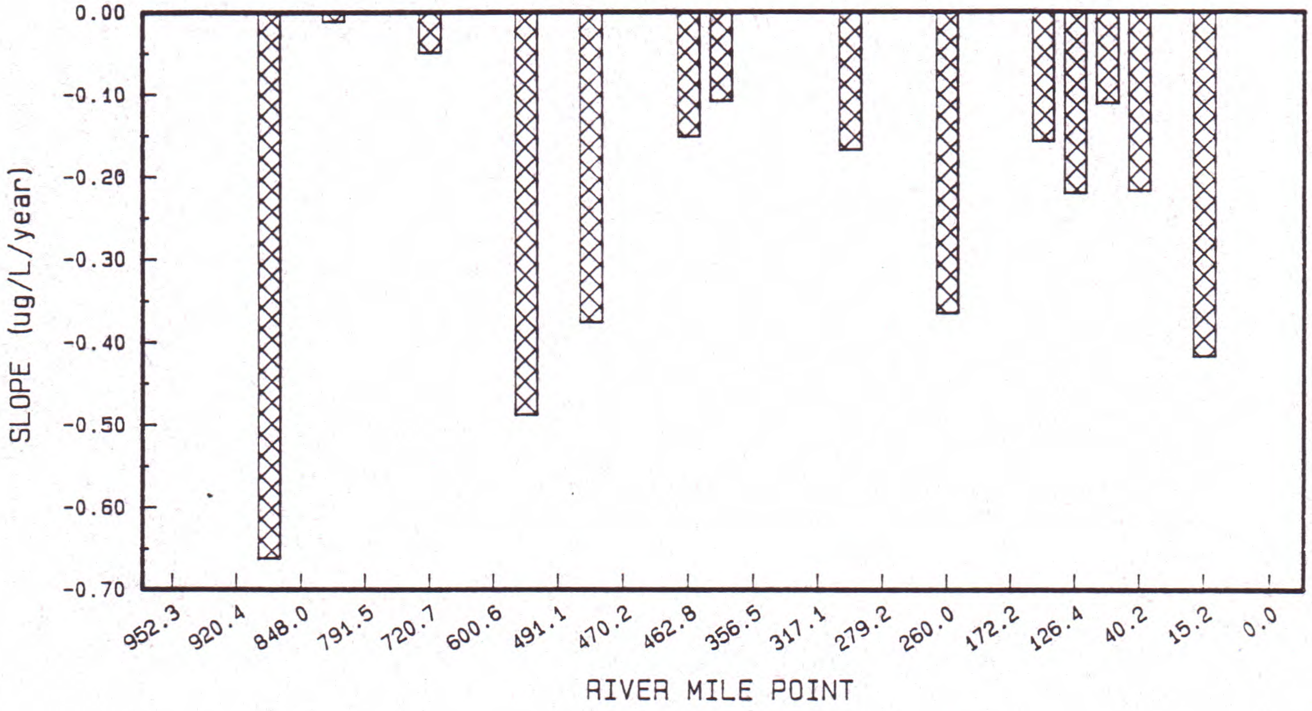




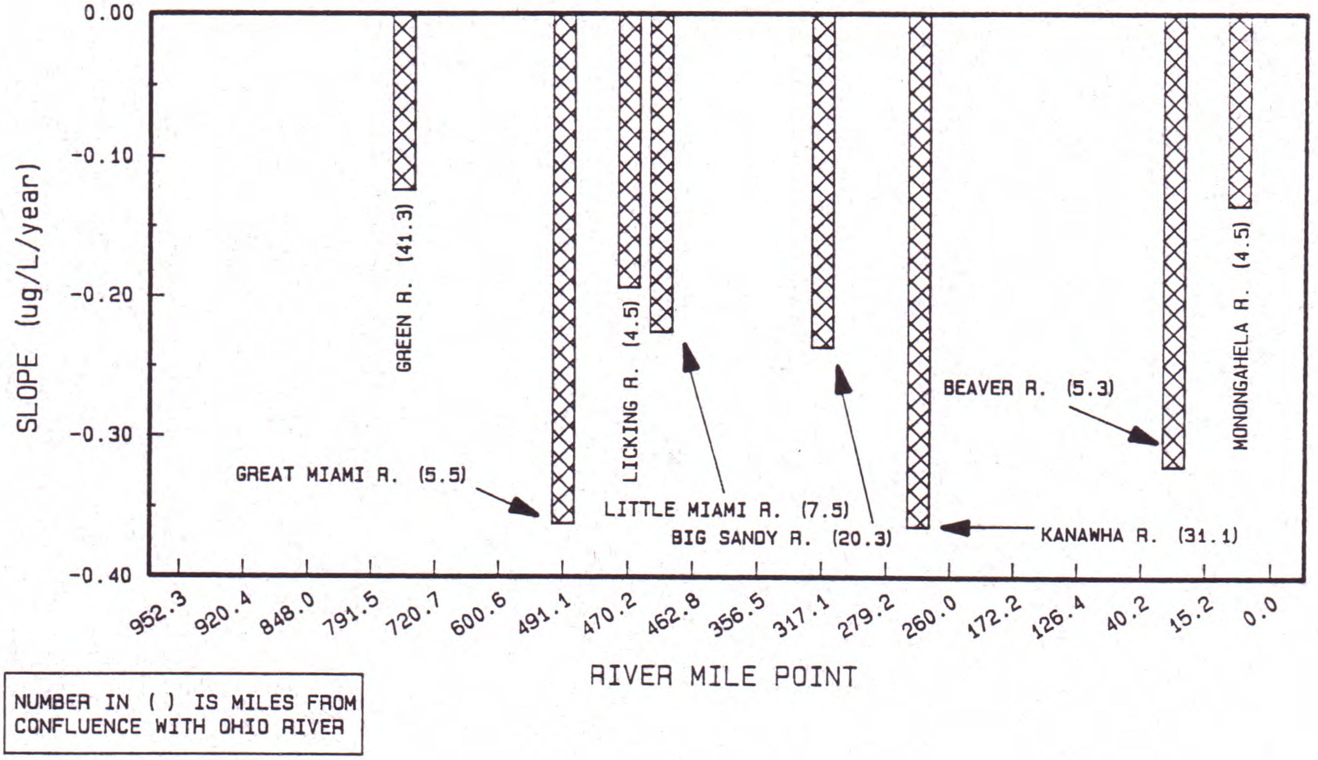
PHENOLICS
Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 33 MMS Stations

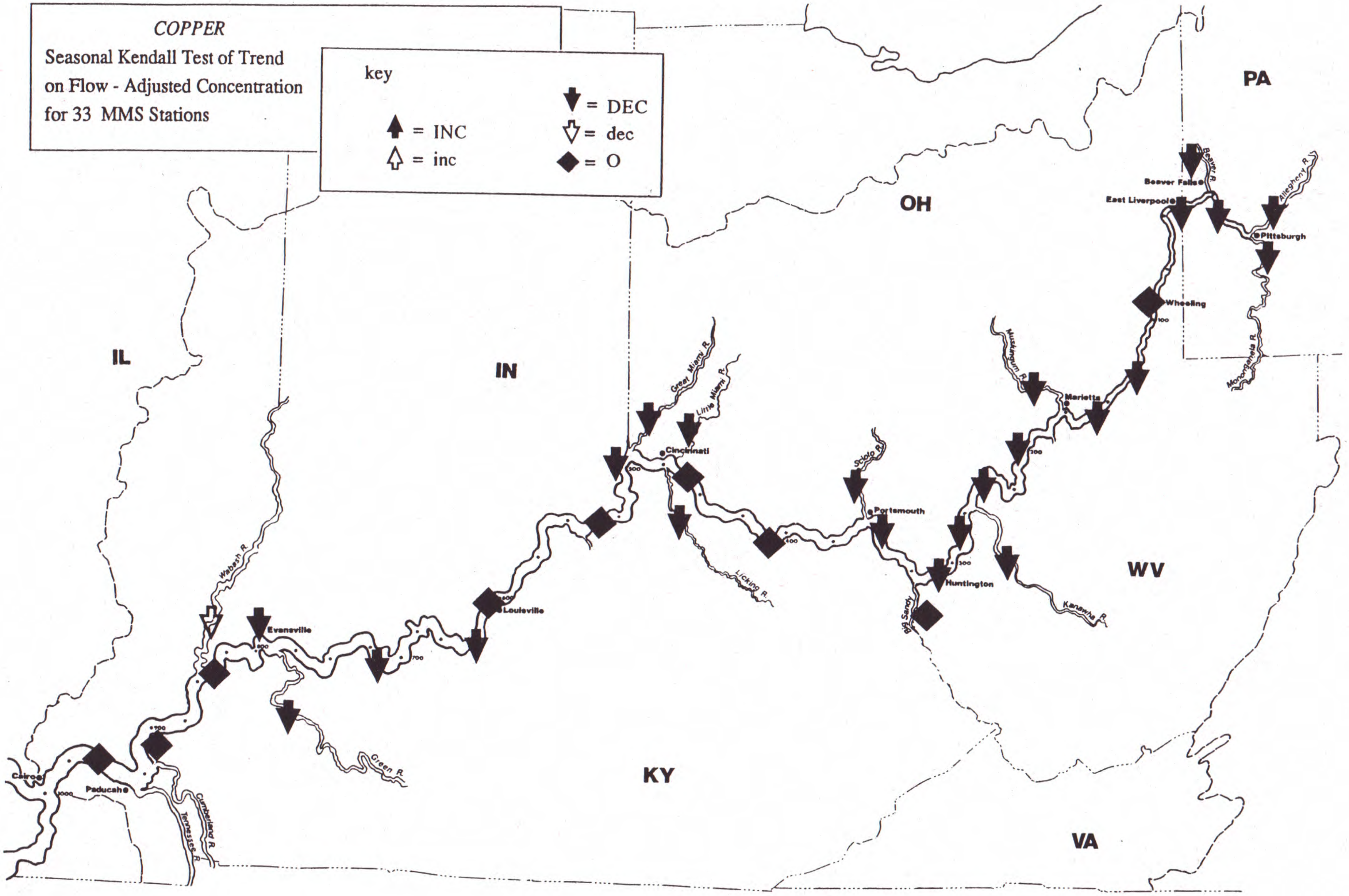
TREND ASSESSMENT SLOPE ESTIMATOR

Phenolics (Main Stem)



Phenolics (Tributaries)

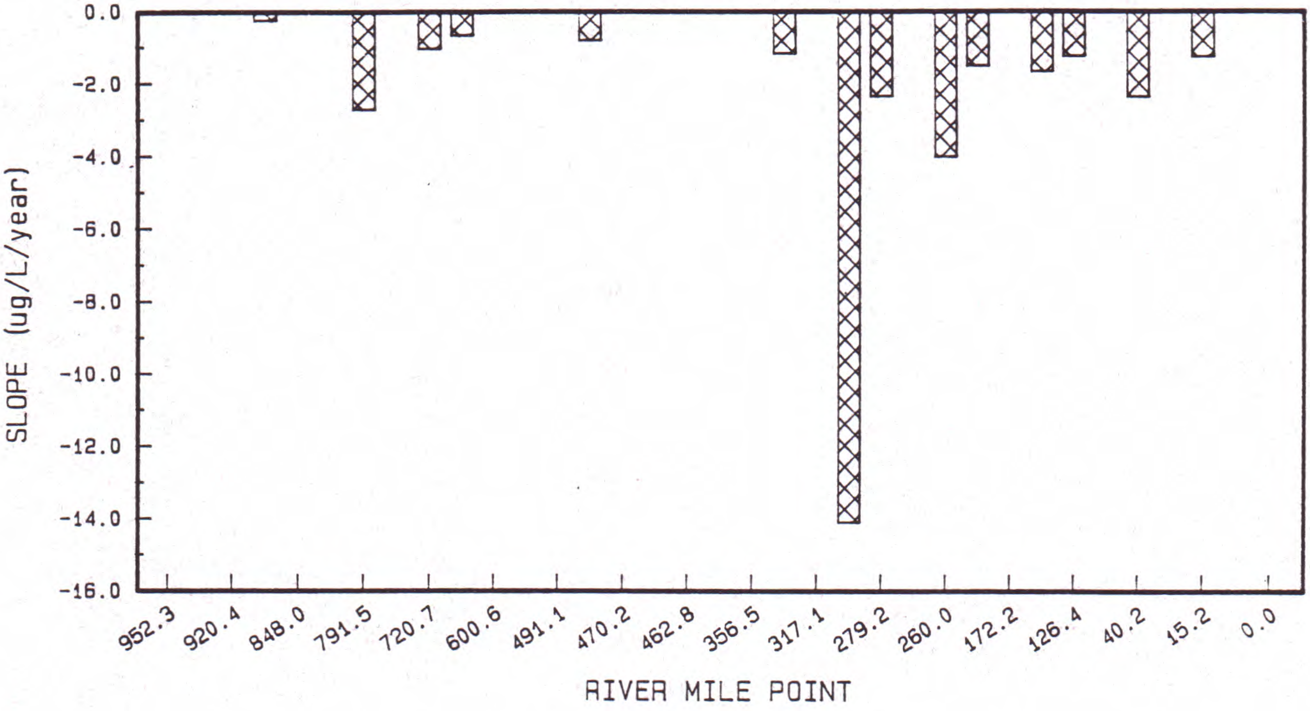




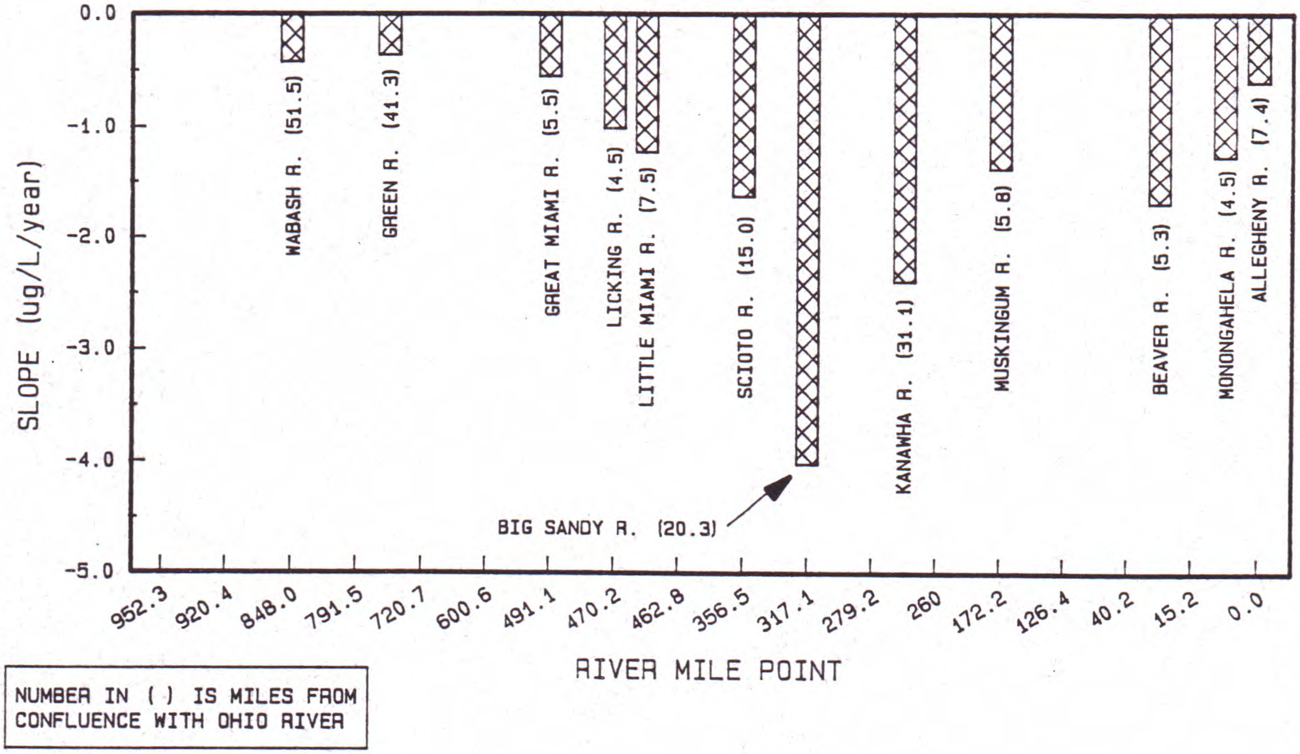
COPPER
Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 33 MMS Stations

TREND ASSESSMENT SLOPE ESTIMATOR

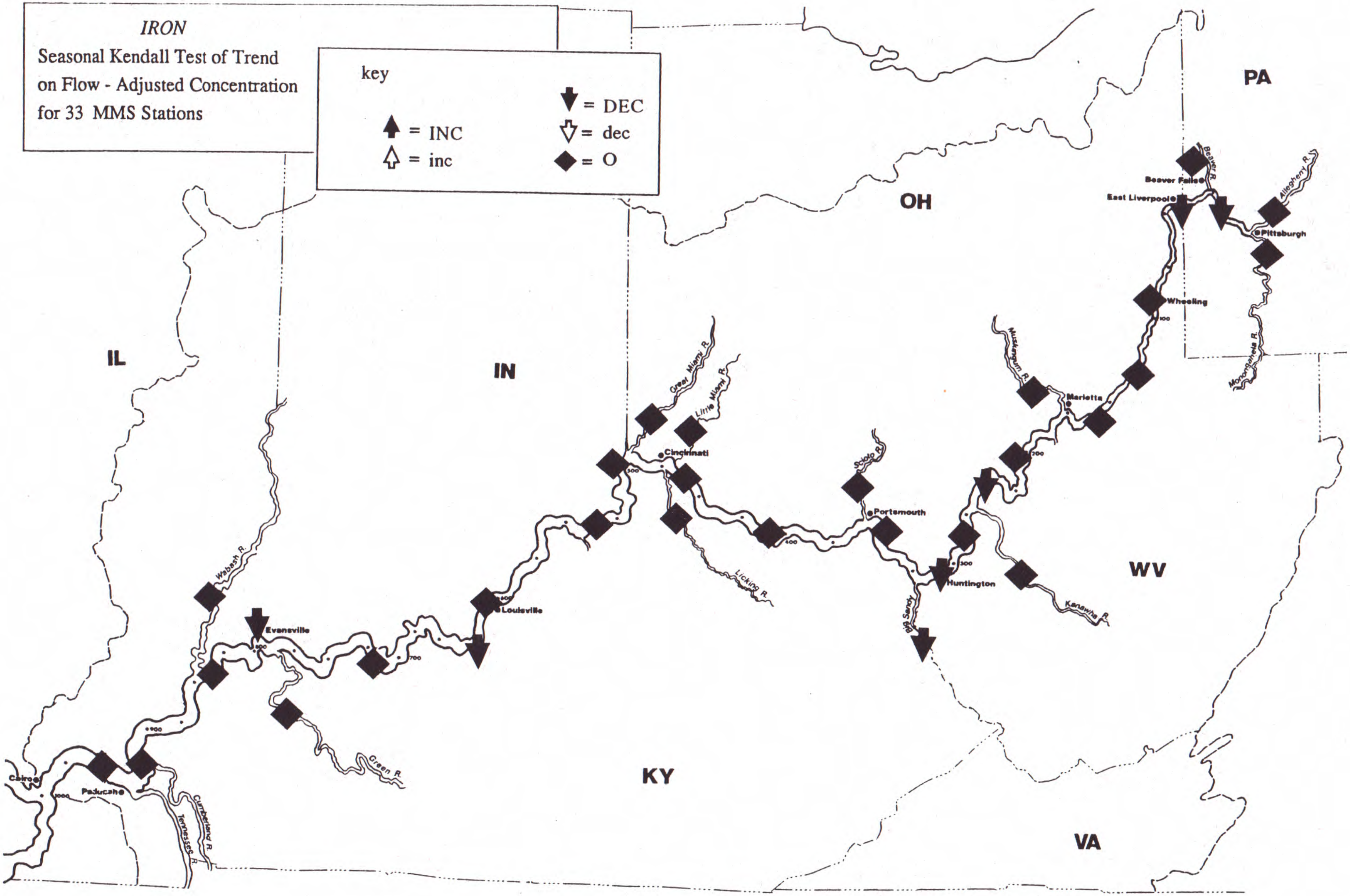
Copper (Main Stem)



Copper (Tributaries)

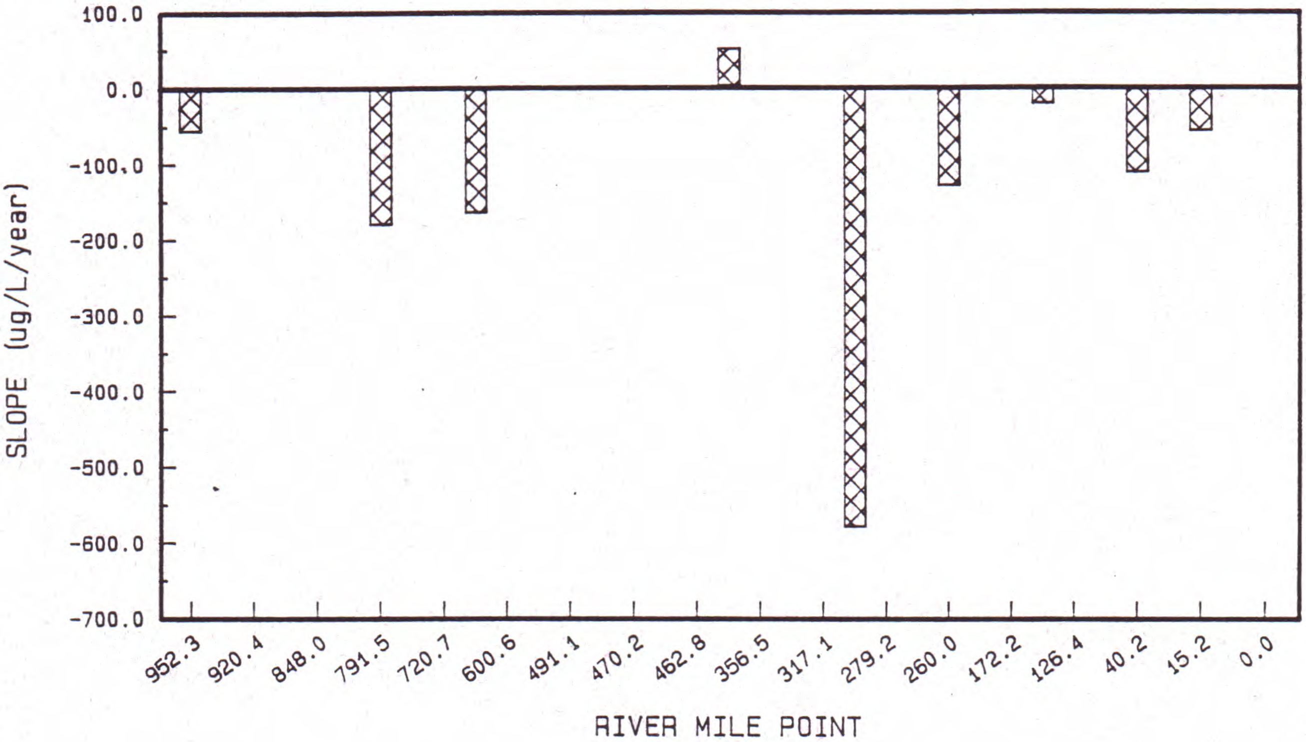


IRON
Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 33 MMS Stations

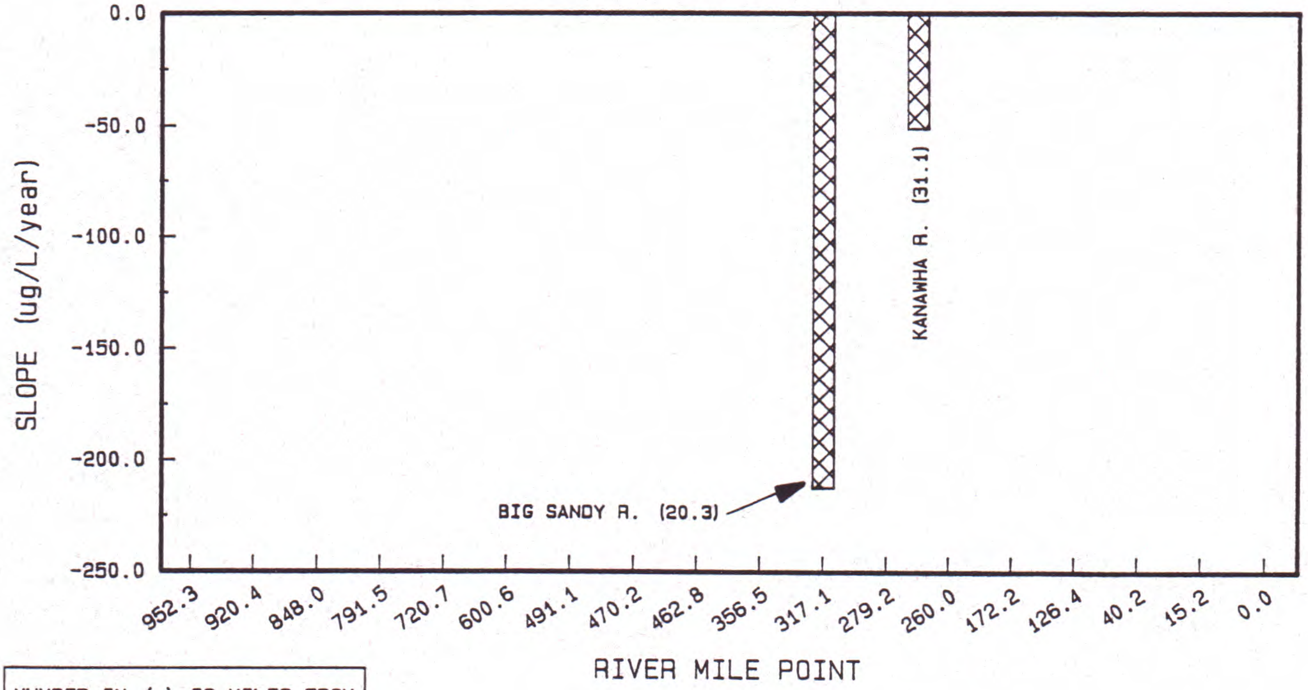


TREND ASSESSMENT SLOPE ESTIMATOR

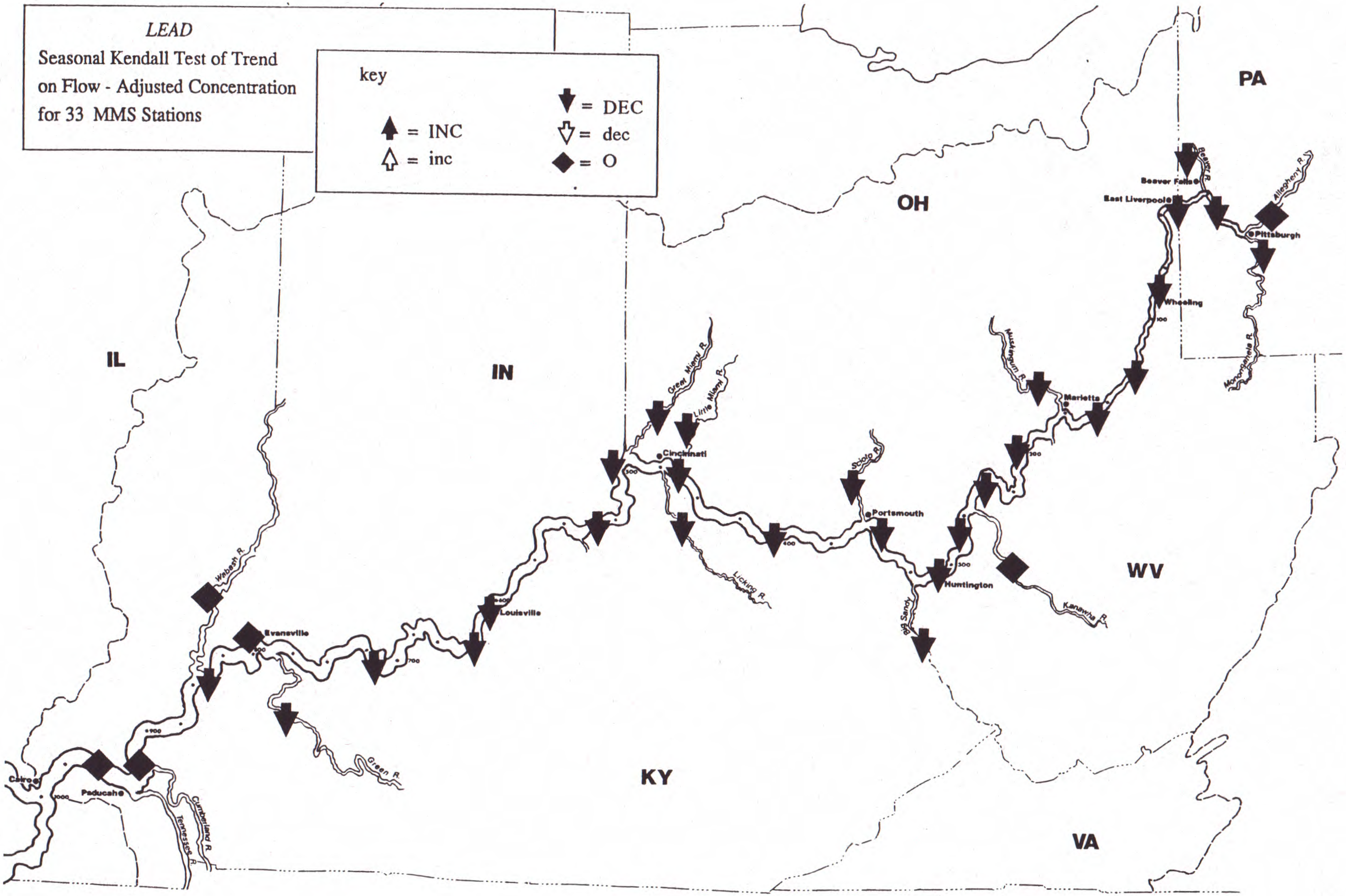
Iron (Main Stem)



Iron (Tributaries)



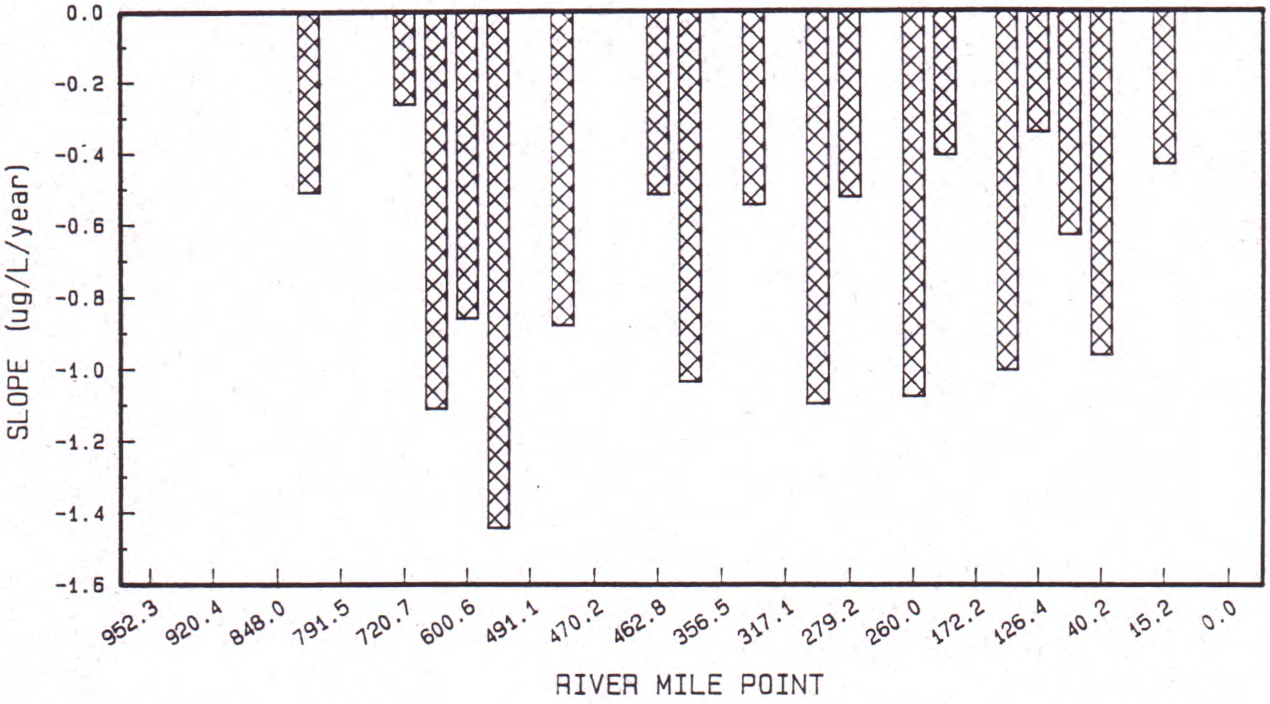
NUMBER IN ( ) IS MILES FROM
CONFLUENCE WITH OHIO RIVER



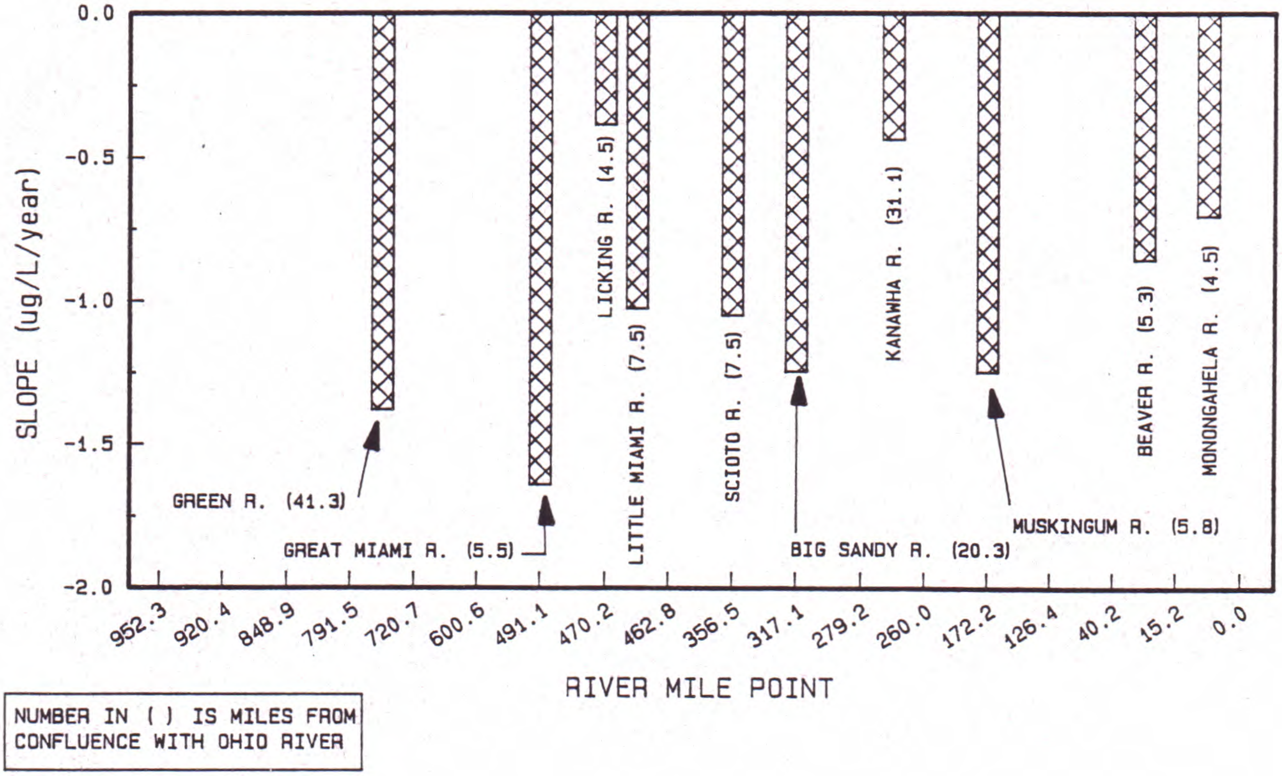
LEAD
Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 33 MMS Stations

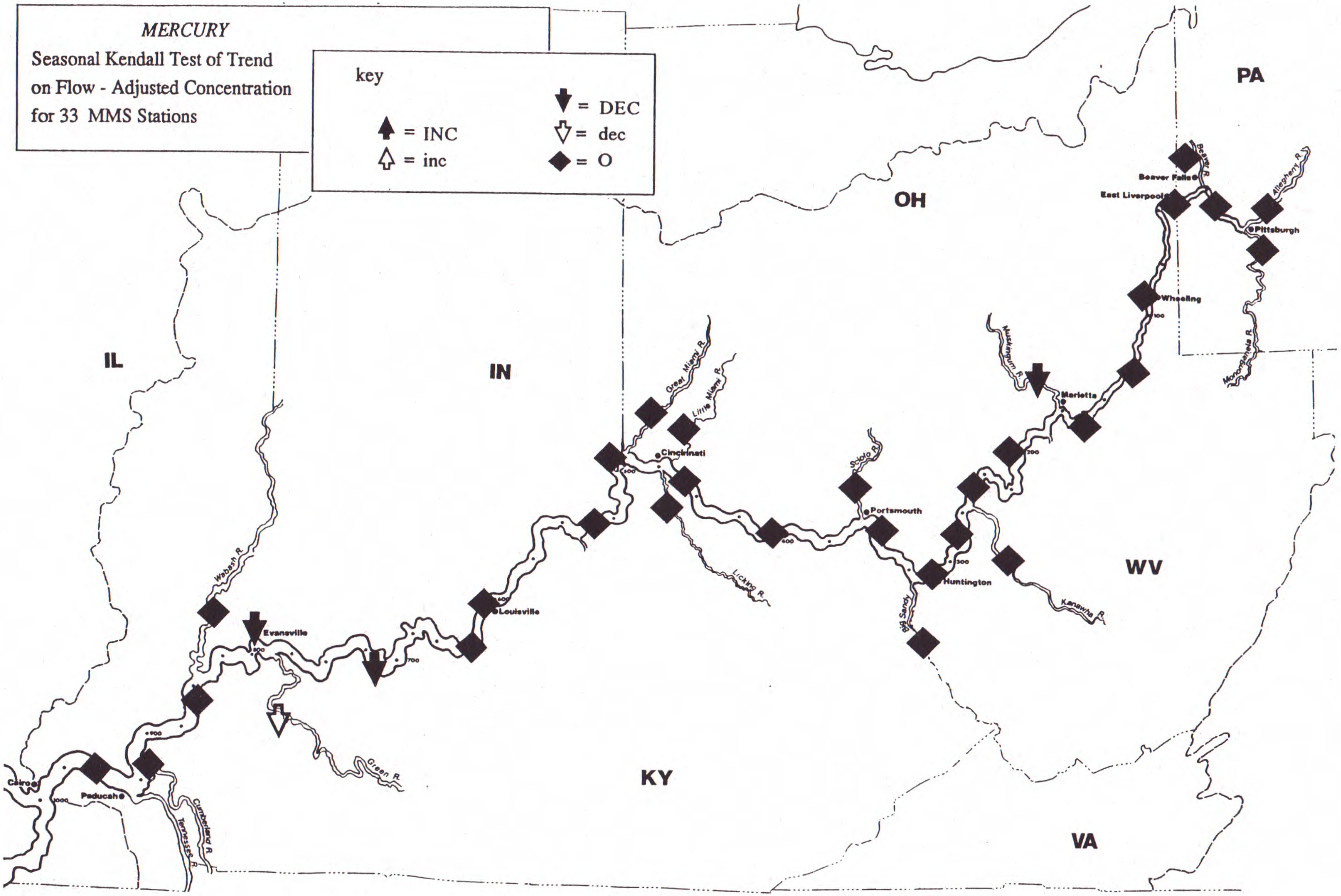
TREND ASSESSMENT SLOPE ESTIMATOR

Lead (Main Stem)



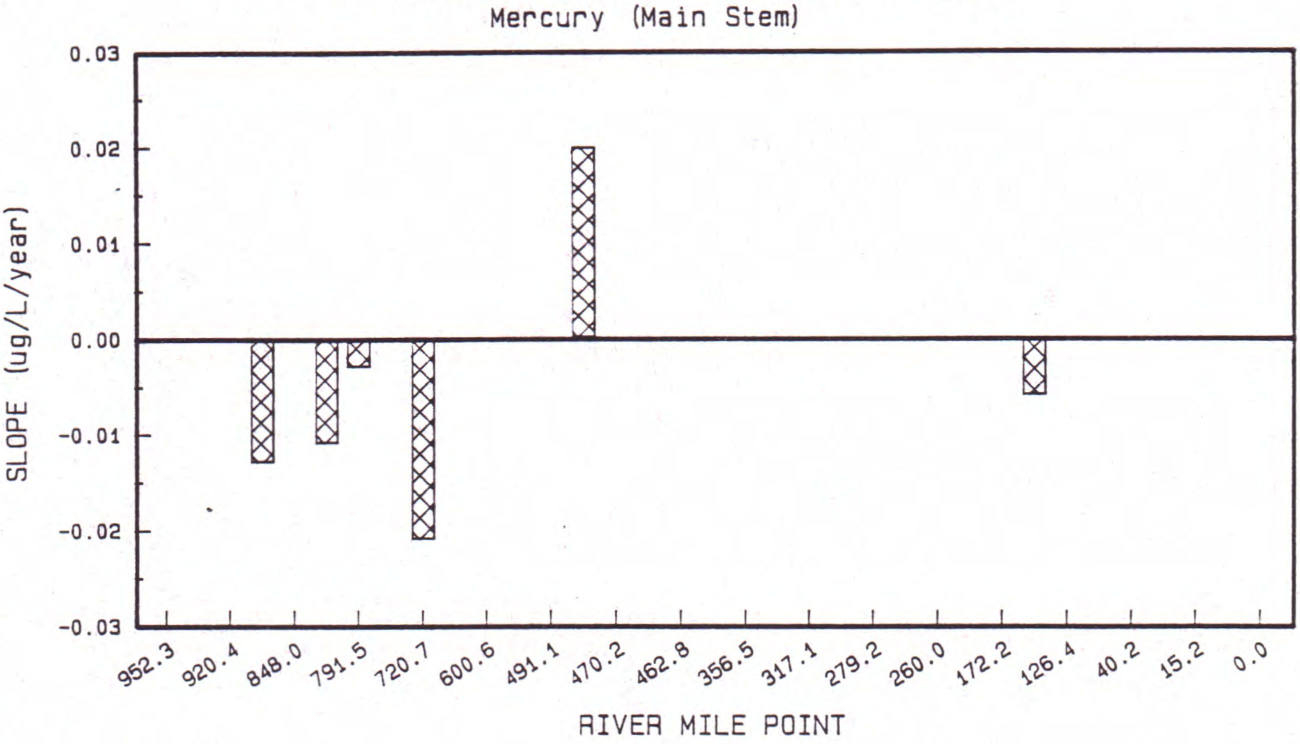
Lead (Tributaries)

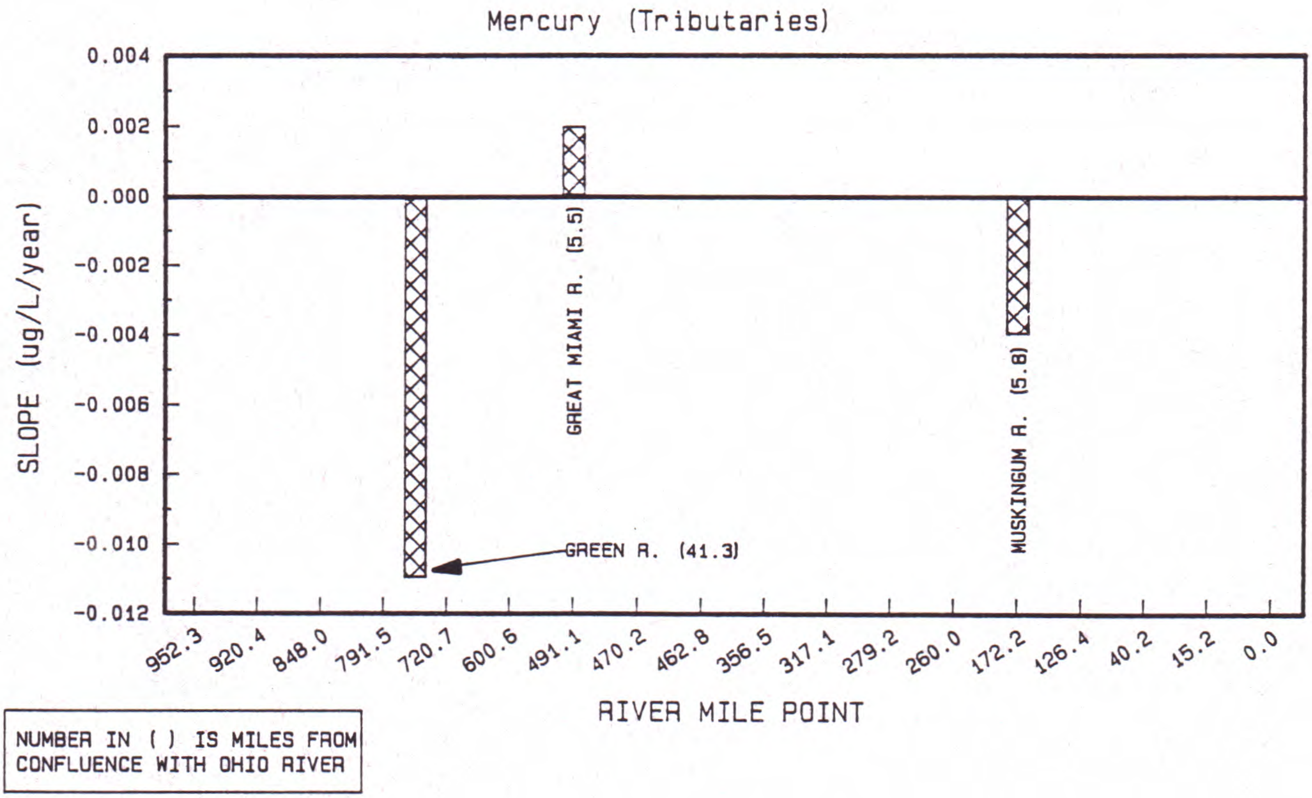




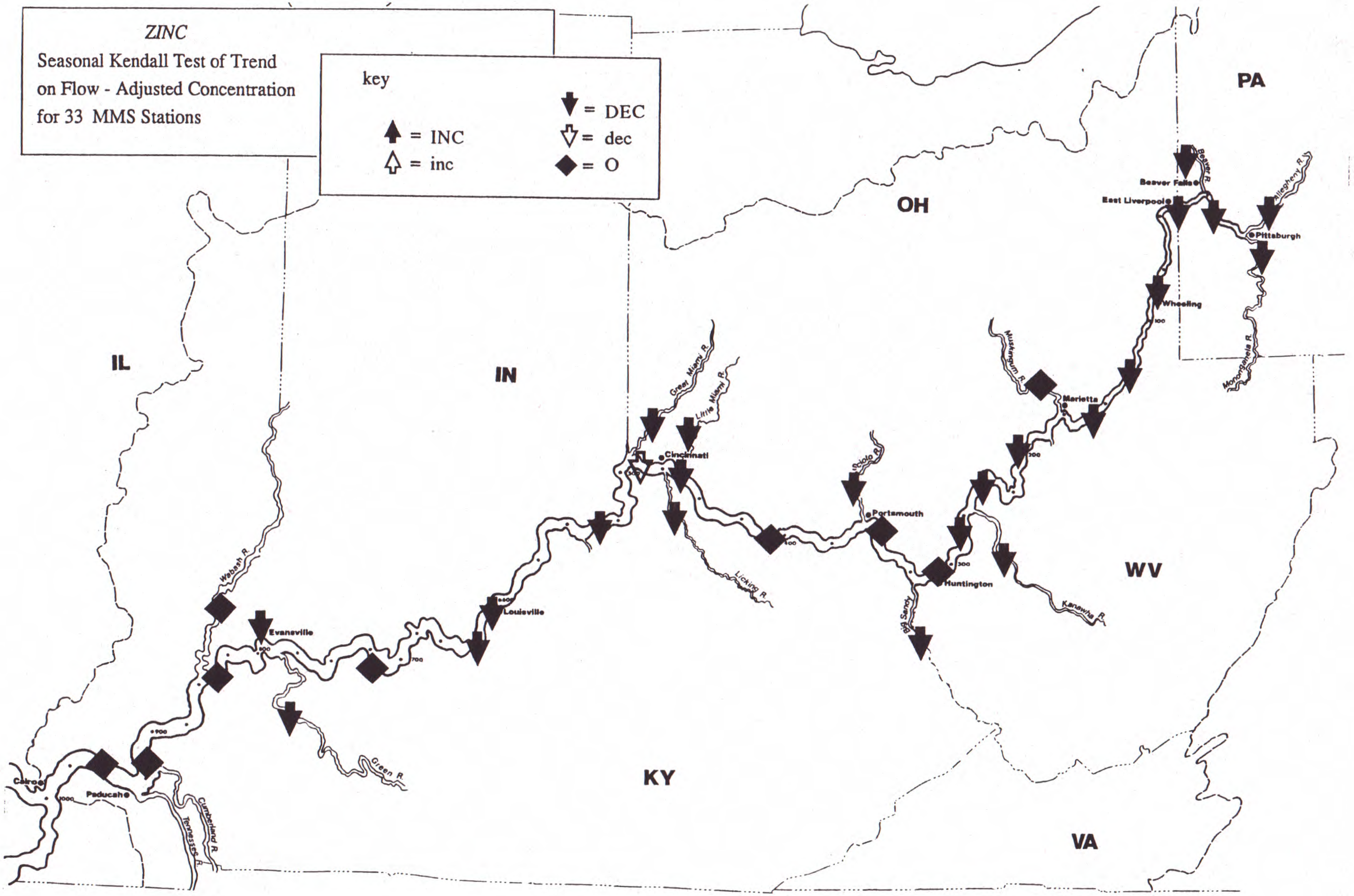
MERCURY
Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 33 MMS Stations

TREND ASSESSMENT SLOPE ESTIMATOR



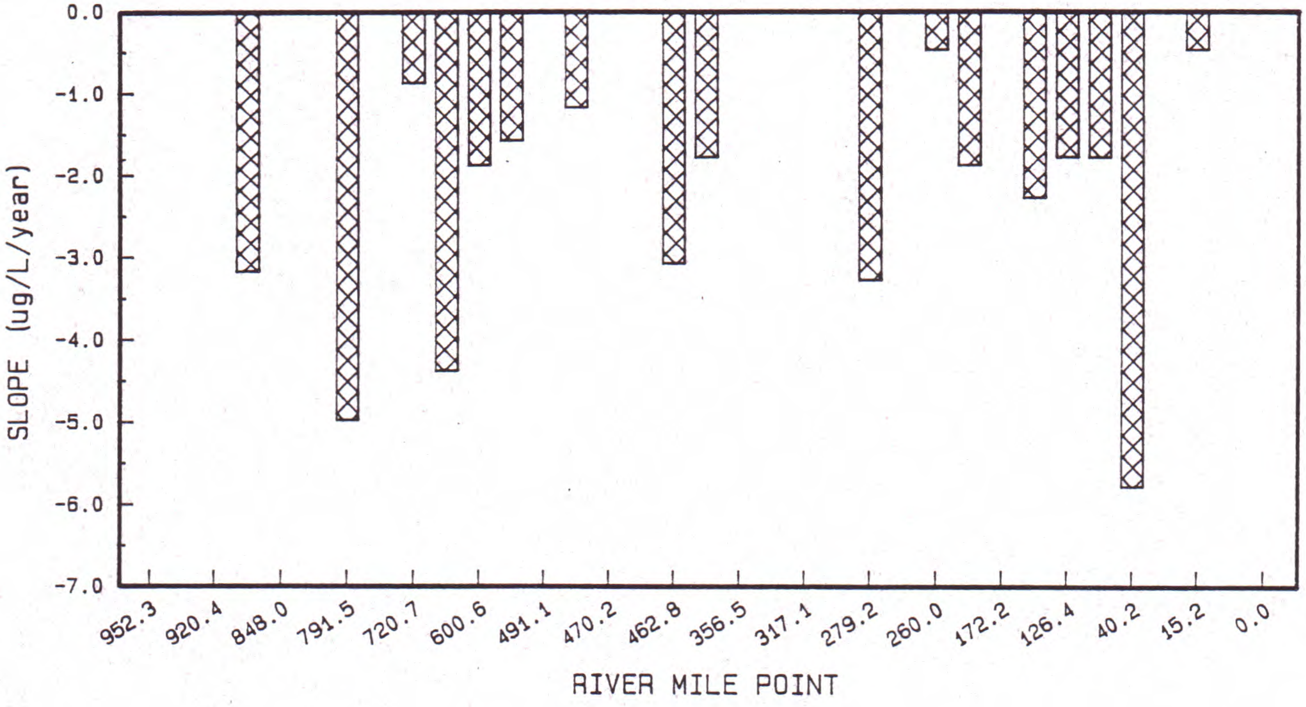


ZINC
Seasonal Kendall Test of Trend
on Flow - Adjusted Concentration
for 33 MMS Stations

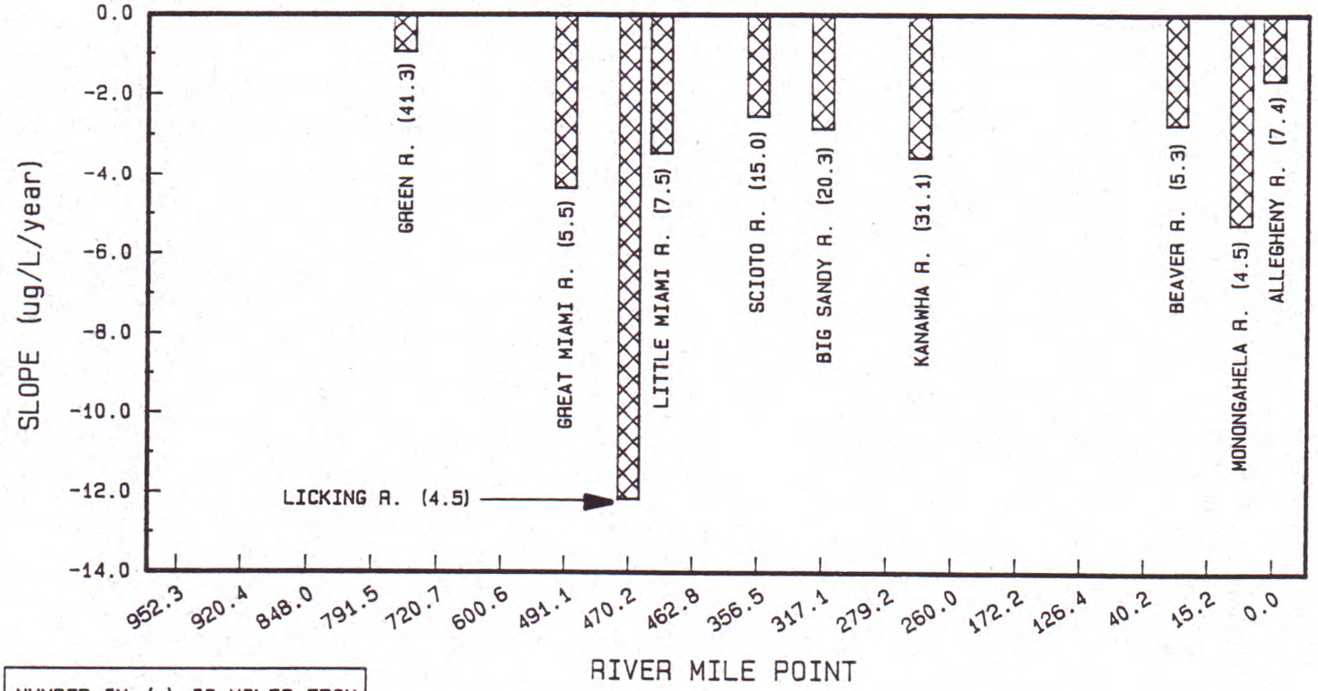


TREND ASSESSMENT SLOPE ESTIMATOR

Zinc (Main Stem)



Zinc (Tributaries)



NUMBER IN ( ) IS MILES FROM
CONFLUENCE WITH OHIO RIVER

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