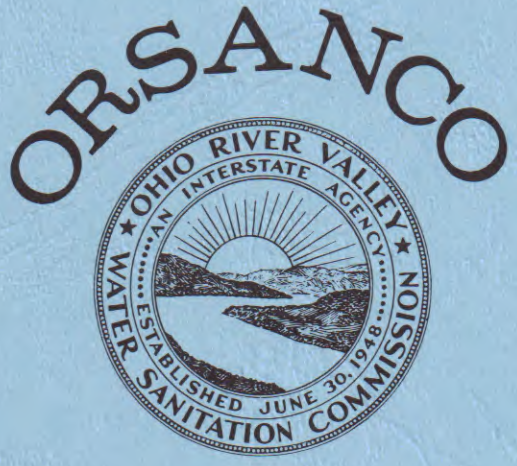
Water Quality Trends Ohio River and its Tributaries: Organic Compounds



Ohio River Valley Water Sanitation Commission
June 1992

Water Quality Trends
Ohio River and its Tributaries: Organic Compounds

STATISTICAL ANALYSES OF DATA RESULTING FROM MONITORING LEVELS OF ORGANIC COMPOUNDS IN THE OHIO RIVER

Water Quality Assessment Program

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June 1992

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PREFACE

The Seasonal Kendall Test is widely used for evaluating trends in water quality data by several government agencies including the United States Geographical Survey (U.S.G.S.), Pennsylvania Department of Environmental Resources (PADER), Maryland Department of the Environment, and the Ohio River Valley Water Sanitation Commission (ORSANCO). The evaluation of trends of Ohio River water quality is based on the U.S.G.S. 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 PADER. Modifications to the macro used in the ORSANCO publication, "Long- Term Trends Assessment of Fifteen Water Quality Parameters in the Ohio River" were required to accommodate the varying number of years in the data set.

OBJECTIVE

The objective of the long term trends program is to identify quantifiable trends in the Ohio River Basin water quality over time, allowing the identification of successes in water quality improvement and of problems yet to be addressed. The specific objective of this report is to determine, statistically, the presence of trends in the detection rate of organic compounds monitored by the Ohio River Valley Water Sanitation Commission.

INTRODUCTION

Trend studies are undertaken to determine the effectiveness of water pollution control efforts in recent years. The Ohio River Valley Water Sanitation Commission (ORSANCO) has worked toward control of water pollution of Ohio Valley waters since 1948. ORSANCO instituted regular monitoring of the Ohio River and its major tributaries in the 1970's to determine the success of pollution control programs.

Over $400 million has been spent to control the discharge of pollutants to the Ohio River from publicly owned treatment works (POTWs) along the Ohio River from 1977 through 1989. In 1978, 47% of the waste water treatment plants in the Ohio River Basin provided secondary treatment. As of December 1990, there were only five communities not providing secondary treatment (four in West Virginia, one in Illinois) discharging a total of 1 MGD to the Ohio River. Begin able to statistically quantify these improvements in water quality is a way of measuring the benefit of the money spent on water pollution control.

Analysis of the ORSANCO manual monitoring data showed improving water quality conditions at most locations (ORSANCO 1990). This report analyzes if a trend exists in data collected from the ORSANCO Organics Detection System (ODS) through application of the Seasonal Kendall Test. A trend is defined as a steady increase or decrease in data observations over time.

Requirements for Tests of Trends

Long-term trend analyses of river waters require a consistent data set over time and a testing method which accounts for water quality parameters that vary seasonally and with stream flow. A substantial amount of data has been produced from the operation of the Commission's ODS. Analyses have been performed at most ODS sites daily for the last several years, providing a database suitable for trend testing. The Seasonal Kendall Test provides methods which screen out any variations of a parameter due to season, serial correlation or skewness, making the test superior to other trend assessment methods.

DATA AVAILABILITY

Organics Detection System

In 1977, several spills and unreported discharges of certain organic compounds to the Ohio River and its tributaries caused problems for water supplies and concern for the general public. It was found that, while many waste water discharges to the river contained organic chemicals of concern, no routine monitoring of the river for those chemicals was being conducted.

Individual water utilities, working together through the ORSANCO Water Users Advisory Committee, developed the concept of the ODS. While most participants are drinking water utilities, three industries with intakes at key locations are also a part of the system. Participants in the system have been selected based on their proximity to upstream discharges or potential sources of the chemicals monitored, proximity to downstream water supply intakes, and willingness to participate in the system. The operation of the first phase of the ODS began in the spring of 1978, with a sample being taken every weekday at seven sites. By the summer of 1979, 11 stations were on-line and sampling frequency was increased to daily. In 1985, two locations were added to the ODS, totaling 13 stations. Presently, the ODS has grown to 15 stations with the incorporation of the 14th station in March 1990 at mile point 34.9 (Duquesne Light Company), and a 15th station in September 1990 at mile point 65.1 (Weirton Water Works). The locations of the ODS stations are shown in Figure 1 on the Ohio River Basin map. The ODS stations analyze each sample for 22 purgeable halogenated and aromatic organics by gas chromatography with detectors sensitive to part per billion (ppb) levels. Of the 22 organic compounds analyzed for, 13 currently appear on the U.S. Environmental Protection Agency's list of priority pollutants. The organics analyzed for are listed in Table 1 according to the respective detectors. Only seven compounds are used in the trend analyses based on data selection criteria outlined below. The Quality Assurance Plan for the ODS is attached as Appendix A.

The ODS data has been entered into the EPA's STORET database on a quarterly basis since the system's inception in 1978. For the purpose of this analysis, the number of detections and samples taken per month were retrieved from STORET for each parameter at each station from 1980 to 1989. From the data, the percent detection was calculated by dividing the number of detections by the number of samples and multiplying by 100%. If there were no detections for a parameter, a zero (0) is recorded in the matrix for that parameter. If no samples were taken, a "NA" is recorded in that position of the matrix. If samples were not taken for more than one-half of the month, that month was dropped from the data set and represented in the data matrix as "NB". If more than 50 percent of a matrix was occupied by missing values (NA or NB), the parameter was dropped from consideration for trend analysis at that station. Also, if a station did not contain more than five years of data in its matrix, it was dropped from the trend analysis. The data matrices used in the Seasonal Kendall Test and Kendall Slope Estimator are located in Appendix B separated by station from upstream to downstream.

FIGURE 1
ORGANICS DETECTION SYSTEM LOCATIONS

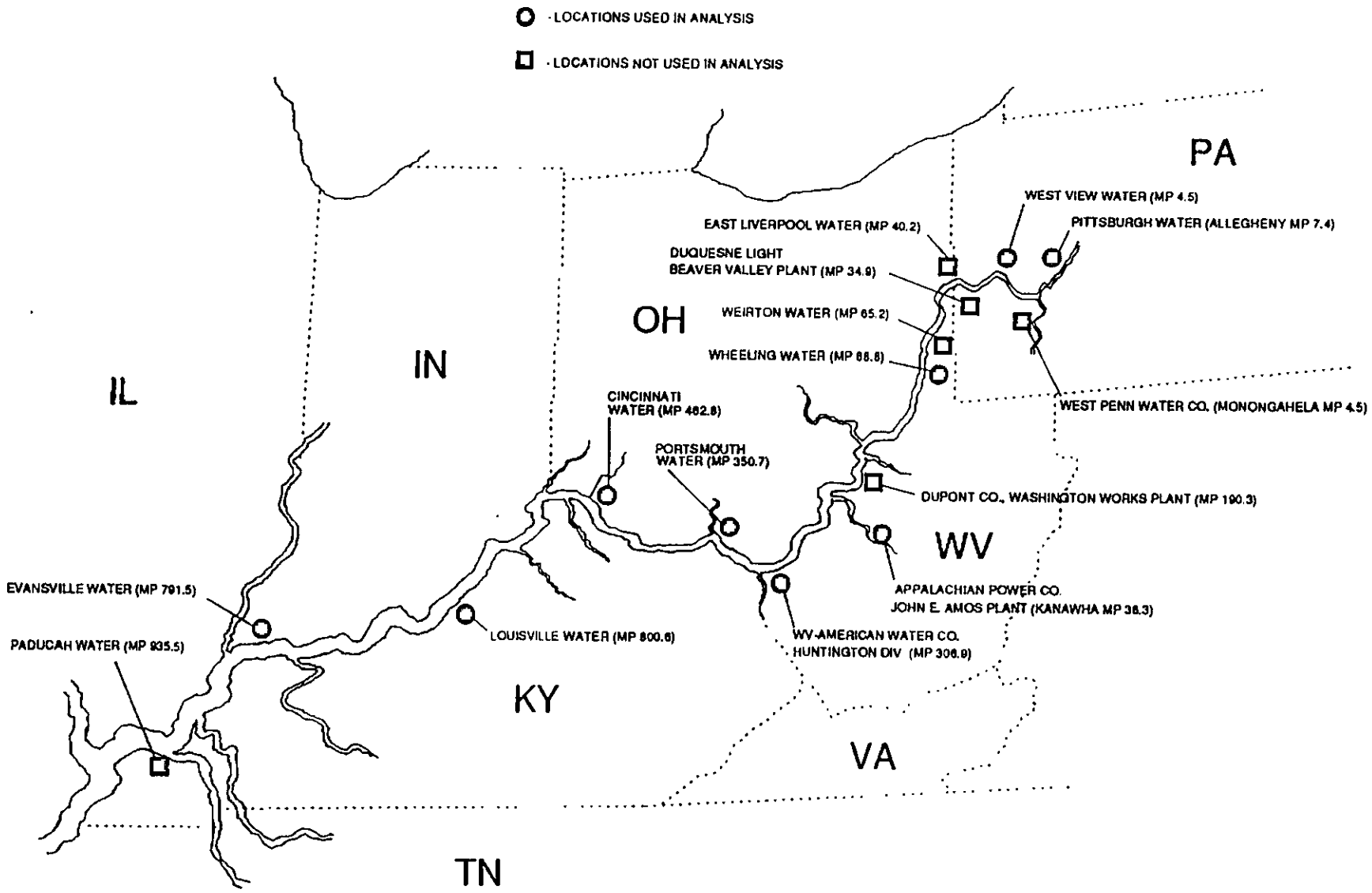

TABLE 1

PURGEABLE HALOGENATED AND AROMATIC ORGANICS DETECTED AT ODS STATIONS

Compounds detected with Electrolytic Conductivity Detector			
#	Methylene Chloride	*	Carbon Tetrachloride
	Trichlorofluoromethane	#	Bromodichloromethane
#*	1,1-Dichloroethylene		1,2-Dichloropropane
	Bromochloromethane	#*	Trichloroethylene
	1,1-Dichloroethane		Dibromochloromethane
#*	Chloroform		Bromoform
*	1,2-Dichloroethane	#*	Tetrachloroethylene
#*	1,1,1-Trichloroethane		Chlorobenzene
Compounds detected with Flame Ionization Detector (FID)			
All compounds above plus:			
*	Benzene	*	1,2-Dichlorobenzene
*	Toluene	*	1,3-Dichlorobenzene
*	Ethylbenzene	*	1,4-Dichlorobenzene
Compounds Detected with Photoionization Detector (PID)			
	Benzene		1,2-Dichlorobenzene
	Toluene		1,3-Dichlorobenzene
	Chlorobenzene		1,4-Dichlorobenzene
	Ethylbenzene		

 # - Compounds used in trends analysis
** - Compounds currently appearing on EPA Priority Pollutont List*

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 from a different month. Skewness refers to the lack of symmetry in underlying frequency distribution of the data, 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 types of comparisons are considered acceptable in the Seasonal Kendall Test, permitting comparison of data points 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. 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, only that there is a difference (Smith, et al., 1982). In this way, changes in water quality are recorded. 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. This method is described in more detail in Appendix B.

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 the 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 ODS data set begins in 1978 and extends to the present. However the usable data base available for trend assessment is the ten years from 1980 to 1989 in most cases. Only parameters with sufficient data can be used in the Seasonal Kendall Test. Missing values may constitute up to 50 percent of the observations without diminishing the power of the test (Garrison, 1981).

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 process involved in applying the Seasonal Kendall Slope Estimator is described in detail In Appendix B.

RESULTS

The results of the Seasonal Kendall Test of Trend and Kendall Slope Estimator are found in Table 2, which displays the z-statistic and slope estimates calculated from the tests. The Seasonal Kendall Test is a two-tailed test; using a 95 percent confidence interval, a significant trend exists if the z-statistic is greater than +1.96 or less than -1.96. The results of the tests are discussed for each station in the sections that follow.

TABLE 2

RESULTS OF SEASONAL KENDALL TEST AND KENDALL SLOPE ESTIMATOR (Z-STATISTIC AND % CHANGE)

STATION	CHLOROFORM		METHYLENE CHLORIDE		TETRACHLORO-ETHYLENE		1,1,1-TRICHLORO-ETHANE		TRICHLORO-ETHYLENE		BROMODICHLORO-METHANE		1,1-DICHLORO ETHYLENE	
	Z	S	Z	S	Z	S	Z	S	Z	S	Z	S	Z	S
PITTSBURGH	- 3.71	- 1.11	- 3.70	- 0.81	- 3.89	- 0.81								
WEST VIEW	- 5.09	- 3.76	- 7.39	- 3.89	- 8.41	- 9.17	- 6.78	- 3.33						
WHEELING	- 0.84	0	- 5.44	- 3.23	- 6.69	- 6.75	- 8.32	- 9.68	- 8.25	- 6.30				
ST ALBANS	- 4.40	-14.30	- 3.61	- 3.53									- 1.95	- 4.92
HUNTINGTON	- 5.44	- 7.35	- 3.44	- 0.71	- 6.13	- 5.55	- 3.66	- 0.65	- 5.76	- 3.75	- 6.10	- 2.29		
PORTSMOUTH	- 3.395	- 6.35	- 3.14	- 1.04	- 6.32	- 7.89								
CINCINNATI	- 4.80	- 4.76	- 4.63	- 2.77			- 1.38	0						
LOUISVILLE	- 6.40	- 6.67	- 0.17	0	- 6.47	- 1.72	- 9.47	- 9.52						
EVANSVILLE	- 1.88	- 0.54	- 1.34	0	- 6.86	- 1.94	- 5.75	- 2.22			- 2.54	0		

Z = Z-STATISTIC
S = SLOPE (% CHANGE PER YEAR)

In an attempt to quantify any trends determined by the analysis, an investigation of discharges within 20 miles upstream of the ODS stations was performed. Discharge monitoring reports (DMR's) were retrieved from the EPA Permit Compliance System (PCS) to determine if any discharges upstream of ODS stations monitor for organics. This information was compiled to determine any effects on levels of organics at ODS stations.

Also, ORSANCO has compiled a list of potential sites with ground water contamination along the Ohio River. This information has been confirmed by the states in which the contamination occurs. These two investigations will be referenced in the sections to follow that assess the trends at each station.

Historical records from the ODS were also reviewed to determine any effects that maintenance or equipment replacement might have on detection limits, or percent detection.

An overview of each station follows. Even through equipment changed over time, the reported lower level of detection (LLD) was 0.1 ug/L for the full period of record at all stations considered. Therefore the percent detection calculations should not be effected. Tables are included to show the maximum and average values for compounds used In the analyses. These values were not used in the trend assessment but are provided for information. The averages are the averages of detections only and therefore overestimate actual conditions. The reader is referred to Appendix C which include the data matrices.

Pittsburgh Water Company (Allegheny River MP 7.4

The Pittsburgh Water Company began participating in the ODS in 1978 as part of the original system. The percent up (run) time for this station for the period of record (1980-1989) is approximately 93 percent. The down time can be attributed mostly to microprocessor and sensitivity problems on various occasions. A chronological history of equipment replacement and installation is included as Table 3 below.

TABLE 3

EQUIPMENT REPLACEMENT - PITTSBURGH WATER COMPANY

Date	Comment
10/80	Varian 3700 GC installed
07/84	SP4100 microprocessor installed
N/A	DB-624 Megabore column installed; Tracor 703 PID installed
07/89	Varian 3400 GC installed; Tracor Hall 1000 detector installed; Tekmar LSC-2000 concentrator installed

N/A = No Date Available

Three parameters met the criteria for analysis using the trend tests: chloroform, methylene chloride and tetrachloroethylene. All parameters displayed significant decreasing trends ($z \leq -1.96$) (Table 2). Table 4 below displays the maximum and average values for the above mentioned parameters for the period of record.

TABLE 4

Parameter	Maximum (µg/L)	Average (µg/L)
Chloroform	16.00	0.20
Methylene Chloride	13.80	0.17
Tetrachloroethylene	20.10	0.15

There are no industrial or municipal discharges monitoring for organics within 20 miles upstream of this station. Also, there are no known ground water sites contaminated with organics upstream of this station.

West View Water (Mile Point 4.5)

The West View Water ODS station was established and operating in July 1981. The percent up (run) time for this station for the period of record (1981 - 1989) is 73 percent. The down time can be attributed mainly to leaks in the GC system and detector problems. A chronological history of equipment replacement and installation is included as Table 5 below.

TABLE 5

EQUIPMENT REPLACEMENT - WEST VIEW WATER

Date	Comment
07/81	Equipment installed, no specific information available
11/82	New SP-1000 column installed
01/83	LSC-3 concentrator installed; new column installed
03/83	New column installed
10/83	HNU 401 GC installed; CCD installed; Continued use of Sigma 1 microprocessor
11/83	New column installed
03/84	New column installed
07/84	New SP4270 microprocessor installed
12/84	PID installed, now have CCD and PID
06/85	New column installed
08/85	Two columns installed, 1 for CCD and 1 for PID
07/87	Varian 3400 GC installed; Tracor Hall 1000 Detector installed, FID installed; Tekmar LSC-2000 concentrator installed; DB-624 Megabore Column installed

Four parameters met the criteria for trend analysis: chloroform, methylene chloride, tetrachloroethylene, and 1,1,1-trichloroethane. All parameters displayed significantly decreasing trends ($z \leq -1.96$) (Table 2). Table 6 below displays the maximum and average concentration values for the above mentioned parameters for the period of record.

TABLE 6

Parameter	Maximum (μg/L)	Average (μg/L)
Chloroform	16.60	0.10
Methylene Chloride	26.30	0.16
Tetrachloroethylene	18.70	0.19
1,1,1-Trichloroethane	3.30	0.13

Discharge monitoring data did not reveal any discharges monitoring for organics upstream of this station. There are two ground water sites known to have been contaminated with organics within two miles upstream of this station. The facilities are a power plant and steel manufacturer and are weighted a 3 (moderate contamination) on a scale of 1 to 6. This scale is based on discussions with state regulatory agencies. Refer to Table 7 for a description of the ground water sites contaminated with organics within 20 miles upstream of this facility as well as other ODS stations. These sites could very well be contributing organics in significant amounts to be detected at the West View station.

TABLE 7

CONTAMINATED GROUND WATER SITES

Site Name	River Mile	Facility Name	Problem	Weight (1 - 5)	State
Duquesne Light	2.3	Power Plant	Organics, Inorganics	3	PA
US Steel and Axle	4.0	Steel Mfg.	Organics, Metals	3	PA
West View Water	4.5	ODS Station			PA
Wheeling-Pitt. Steel	68.6	Steel Mfg.	Organics, Metals	3	OH
Wheeling-Pitt. Steel	68.7	Steel Mfg.	Organics, Metals	5	WV
Koppers Co.	69.5	Chemical Mfg.	Organics, RCRA	5	WV
Wheeling-Pitt. Steel	70.0	Steel Mfg.	Organics, Metals	4	WV
Wheeling-Pitt. Steel	71.0	Steel Mfg.	Organics, Metals	3	OH
Deandale Rail Yard	72.0	Rail Yard	Fuel Contamination	4	OH
Wheeling-Pitt. Steel	79.4	Steel Mfg.	Organics, Metals	4	WV
Tri State Asphalt	81.1	Bulk Terminal	Organics	2	OH
Wheeling-Pitt. Steel	83.7	Steel Mfg.	Organics, Metals	2	OH
Wheeling Water	86.8	ODS Station			WV
Gulf Refining Company	303.5	Bulk Terminal	Gasoline, Oil	1	WV
Huntington Water	306.9	ODS Station			WV
DuPont	333.2	Chemical Mfg.	Organics, Metals	2	KY
Aristech Chemicals	336.5	Chemical Mfg.	Organics	3	OH
Bel Docking Corp.	345.0	Coal Terminal	Inorganics. Heavy Metals	2	OH
Standard Slag Company	347.2	Coal Terminal	Inorganics	1	OH
Standard Oil Company	349.2	Bulk Terminal	Organics	1	OH
Portsmouth Water Company	350.7	ODS Station			OH

Wheeling Water (Mile Point 86.8)

The Wheeling ODS station was installed in 1978 as part of the original system. The percent up (run) time for this station for the period of record (1980-1989) is 88 percent. The down time is attributed mainly to microprocessor and detector problems in the early stages of operation, and start-up time due to the installation of new equipment. A chronological history of equipment replacement is characterized in Table 8.

TABLE 8

EQUIPMENT REPLACEMENT - WHEELING WATER

Date	Comment
1978	Sigma 1 GC installed CCD and FID installed Sparging Trapping concentrator installed
08/80	HNU PID installed
11/83	HNU 401 GC installed Tekmar LSC-3 concentrator installed CCD installed SP4270 microprocessor installed
N/A	Varian 3700 GC installed Tracor Hall 1000 detector installed DB-624 Megabore column installed
1986	Varian 3400 GC installed PID installed Tracor Hall 1000 detector installed Tekmar LSC-2000 concentrator installed

N/A = No date available

Five parameters met the criteria to be analyzed by the Seasonal Kendall analysis for percent detection: chloroform, methylene chloride, tetrachloroethylene, 1,1,1 trichloroethane, and trichloroethylene. Of the parameters analyzed, four displayed a significant decreasing trend ($z \leq -1.96$) while one, chloroform, displayed no trend ($-1.96 \leq z \leq +1.96$) (Table 2). Table 9 below displays the maximum and average values for the parameters analyzed to give an idea of the organic concentrations that are routinely detected at the Wheeling ODS station.

TABLE 9		
Parameter	**Maximum (µg/L)**	**Average (µg/L)**
Chloroform	79.90	0.80
Methylene Chloride	11.30	0.15
Tetrachloroethylene	6.40	0.18
1,1,1-Trichloroethane	8.90	0.22
Trichloroethylene	4.60	0.14

Nine sites were identified as having the potential for ground water contamination within 20 miles upstream of the Wheeling ODS station. Table 7 lists the location of the sites, the type of facility, and the contamination occurring at that site. The majority of the sites are steel manufacturing facilities that are contaminated with metals and organics. The sites are weighted (1-5) based on the severity of the contamination with 5 being the most severe. Several of the sites are weighted a 4 or 5 with the potential to contribute significant amounts of organics to the river.

Appalachian Power Company (Mile Point 38.3, Kanawha River

This ODS station was started in 1978 as part of the original system. The percent up (run) time for this station for the period of record (1980-1984, 1987-1989) is approximately 50 percent. The down time can be mainly attributed to electrical malfunctions and detector problems. A chronological history of equipment replacement and installation is included as Table 10.

TABLE 10

EQUIPMENT REPLACEMENT - APPALACHIAN POWER

Date	Comment
1978	Sigma 1 GC installed CCD and FID installed Sparging Trapping concentrator installed
11/83	New column installed
N/A	Varian 3700 GC installed Tekmar LSC-3 concentrator installed DB-624 Megabore column installed
1986	Varian 3400 GC installed FID installed Tekmar LSC-2 concentrator installed

N/A = No date available

Three parameters met the criteria to be analyzed using the trend tests: chloroform, methylene chloride, and 1,1-dichloroethylene. All parameters used in the analysis display significant decreasing trends ($z \leq -1.96$) (Table 2). Table 11 below lists the maximum and average concentrations detected at this station.

TABLE 11

Parameter	Maximum (µg/L)	Average (µg/L)
Chloroform	218.80	0.90
Methylene Chloride	73.50	0.25
1,1-Dichloroethylene	23.20	0.32

There are two discharges within ten miles upstream of this station that monitor effluent for organics, particularly chloroform and methylene chloride. The maximum and average concentrations for these parameters at the ODS station is much higher than those on the main stem Ohio River. This most likely is a result of known discharge of organics directly upstream of this station. The potential for ground water contamination upstream of this station has not yet been investigated.

WV-American Water Co., Huntington Div. (Mile Point 306.9)

The Huntington ODS station was installed in 1978 as part of the original system. The percent up (run) time for this station during the period of record (1980-1989) is 78 percent. The down time can be attributed mainly to leaks in the GC system, detector problems, and electric malfunctions. A chronological history of equipment replacement is characterized as Table 12.

TABLE 12

EQUIPMENT REPLACEMENT - HUNTINGTON WATER WORKS

Date	Comment
1978	Sigma 1 GC installed CCD and FID installed Sparging Trapping concentrator installed
09/80	HNU PID installed
11/82	New Sparging Trapping concentrator installed
05/83	New SP-1000 installed
09/83	HNU 401 GC installed Tekmar LSC-3 concentrator installed CCD installed SP4270 microprocessor installed
11/84	New columns installed
06/85	New SP1000 installed
07/87	Varian 3400 GC installed FID installed Tracor Hall 1000 detector installed Tekmar LSC-2000 concentrator installed DB-624 Megabore column installed

Six parameters met the criteria to be analyzed using the trend tests: chloroform, methylene chloride, tetrachloroethylene, 1,1,1 trichloroethane, trichloroethylene, and bromodichloromethane. All parameters used in the analysis display significant decreasing trends ($z \leq -1.96$) (Table 2). Table 13 below displays the maximum and average concentrations for the above mentioned parameters for the period of record.

TABLE 13		
Parameter	**Maximum (µg/L)**	**Average (µg/L)**
Chloroform	59.80	0.60
Methylene Chloride	27.80	0.17
Tetrachloroethylene	7.90	0.23
1,1,1-Trichloroethane	19.20	0.20
Trichloroethylene	9.00	0.18
Bromodichloromethane	7.90	0.10

One site 4 miles upstream of this station has been identified as having contaminated ground water. The site is a bulk terminal that may be contaminated with gasoline and oil. The contamination is the least severe, weighted a 1 on a scale of 1 to 5. Refer to Table 7 for a list of facilities with ground water contamination and the problems associated with them.

Portsmouth Water (Mile Point 350.7)

The Portsmouth ODS station was installed as part of the original ODS system in 1978. This station has gone through several equipment upgrades over the period of record and its history is characterized in Table 14. The percent up (run) time for this station for the period of record (1980-1989) is 72 percent. The down time can be attributed mostly to minor problems on several occasions.

TABLE 14

EQUIPMENT REPLACEMENT - PORTSMOUTH WATER

Date	Comment
08/78	Sigma 1 GC installed Sparging Trapping concentrator installed
02/83	New Tekmar LSC-3 installed
09/83	HNU 401 GC installed CCD installed SP4270 microprocessor installed
12/85	Reconditioned CCD installed
	Varian 3700 GC installed DB-624 Megabore column installed
08/90	Varian 3400 GC installed FID Installed Tekmar LSC-2000 concentrator installed

Three parameters met the criteria to be analyzed using the trend tests: chloroform, methylene chloride, and tetrachloroethylene of which all displayed significant decreasing trends ($z \leq -1.96$) (Table 2). Table 15 below displays the maximum and average values for the parameters at the Portsmouth station for the period of record.

TABLE 15

Parameter	Maximum (µg/L)	Average (µg/L)
Chloroform	12.50	0.30
Methylene Chloride	17.00	0.16
Tetrachloroethylene	10.60	0.25

Five contaminated ground water sites have been identified with 20 miles upstream. These sites are known to have been contaminated with organics and metals, and are comprised of chemical manufacturers, coal terminals and a bulk terminal. Based on the weighted scale (1 - 5), these sites are not severely contaminated (Table 7).

Cincinnati Water Works (Mile Point 462.8)

The Cincinnati ODS station was installed in 1978 as part of the original system. The percent up (run) time for this station for the period of record (1980-1989) is 99 percent. This level of performance results in a highly reliable, consistent data base for the period of record with very few missing data points. With fewer missing data points, more comparisons are made during the Seasonal Kendall Test and Slope Estimator, which result in more accurate predictions of trends. A chronological history of equipment replacement and installation is included in Table 16.

TABLE 16

EQUIPMENT REPLACEMENT - CINCINNATI WATER

Date	Comment
1978	Sigma 1 GC installed CCD and FID installed Sparging Trapping concentrator installed
09/78	Varian 3700 GC installed Tracor Hall 700/700A detectors installed
N/A	Tekmar LSC-3 concentrator installed SP4270 microprocessor installed DB-624 Megabore column installed
08/90	Varian 3400 GC installed PID installed Tracor Hall 1000 detector installed Varian 4400 integrator installed Restec 105 Megabore column installed

N/A = No date available

Three compounds met the criteria to be analyzed using the trend tests: chloroform, methylene chloride, and 1,1,1-trichloroethane. Chloroform and methylene chloride displayed significant decreasing trends ($z \leq -1.96$) and 1,1,1-trichloroethane displayed no trend ($z \leq -1.96$) (Table 2).

Table 17 below displays the maximum and average concentrations of the organic compounds used in the analyses. The average chloroform and 1,1,1-Trichloroethane concentrations at the Cincinnati ODS station are considerably lower than the averages at the upper river ODS stations. This can probably be attributed to the fact that there are no major industrial discharges or known contaminated ground water sources upstream of the station.

TABLE 17		
Parameter	**Maximum (μg/L)**	**Average (μg/L)**
Chloroform	6.80	0.20
Methylene Chloride	9.70	0.16
1,1,1-Trichloroethane	4.50	0.12

Louisville Water Company (Mile Point 600.6)

The Louisville ODS station was also installed as part of the original system in 1978. The percent up (run) time for this station during the period of record (1980-1989) is 96 percent. This high level of dedicated service results in a reliable data base with very few missing points. Since missing data points are infrequent, more comparisons are made during the analyses of the Seasonal Kendall Test and Seasonal Kendall Slope Estimator resulting in a higher confidence in the trends analysis. A chronological history of the ODS station at Louisville is displayed in Table 18.

TABLE 18

EQUIPMENT REPLACEMENT - LOUISVILLE WATER COMPANY

Date	Comment
1978	HP5840 GC installed CCD and FID installed Sparging Trapping concentrator installed
N/A	HNU PID installed Tekmar LSC-3 concentrator installed SP4270 microprocessor installed DB-624 Megabore column installed
08/90	HP5890 GC installed OI conductivity detector installed OI PID installed Tekmar LSC-200 concentrator installed HP2296A integrator installed VOLCOL Megabore column installed

N/A = No date available

Four compounds met the criteria to be analyzed for trends analysis: chloroform, methylene chloride, tetrachloroethylene, and 1,1,1 trichloroethane. All parameters analyzed displayed a significant decreasing trend ($z \leq -1.96$) except methylene chloride, which displayed no trend ($-1.96 \leq z \leq +1.96$) (Table 2). Table 19 below displays the maximum and average values for the organic compounds analyzed.

TABLE 19

Parameter	Maximum (µg/L)	Average (µg/L)
Chloroform	7.50	0.10
Methylene Chloride	10.30	0.14
1,1,1-Trichloroethane	79.50	0.21
Tetrachloroethylene	6.30	0.12

There are no significant industrial discharges or known contaminated ground water sites identified directly upstream of the Louisville ODS station. The average concentration of parameters at this station are somewhat lower than those of the upper and mid river stations. This can be attributed mainly to the fact that this section of the river is not highly industrialized and most land-use is agricultural.

Evansville Water Works (Mile Point 791.5)

The Evansville ODS station was installed and operating in December 1980. The percent up (run) time for this station for the period of record (1980-1989) is nearly 100 percent. This nearly perfect operation and dedication of the Evansville ODS station results in a highly reliable, extensive data set. With fewer missing data points, more comparisons are made during the analysis, resulting in more accurate trend predictions. A chronological history of equipment replacement and installation is included in Table 20.

TABLE 20

EQUIPMENT REPLACEMENT - EVANSVILLE WATER WORKS

Date	Comment
12/80	Varian 3700 GC installed
08/84	LSC-3 concentrator installed
07/87	Varian 3400 GC Installed Tracor Hall 1000 detector installed FID installed DB-624 Megabore column installed

Five compounds met the criteria for trend analysis: chloroform, methylene chloride, tetrachloroethylene, 1,1,1 trichloroethane, and bromodichloromethane. Three compounds, tetrachloroethylene, 1,1,1-trichloroethane and bromodichloromethane displayed significant decreasing trends ($z \leq -1.96$), while two, chloroform and methylene chloride, displayed no trend ($-1.96 \leq z \leq +1.96$) (Table 2). The maximum and average concentrations for the above mentioned are listed in Table 21 below.

TABLE 21

Parameter	Maximum (µg/L)	Average (µg/L)
Chloroform	13.40	0.20
Methylene Chloride	3.80	0.12
1,1,1-Trichloroethane	1.80	0.11
Tetrachloroethylene	2.60	0.11
Bromodichlorometha ne	1.20	0.10

There are no identified contaminated ground water sites upstream of the Evansville ODS station. However, there are several industrial discharges within 20 miles upstream of the station including an oil terminal and a power plant that could possibly be a source of organics in the Ohio River at this station. Another potential source of organics if the Green River which enters the Ohio River approximately seven miles upstream of the Evansville ODS station.

EXPLANATION OF TRENDS

In an attempt to quantify the decreasing trends seen in percent detections throughout the ODS, several avenues were investigated, these include: industrial and municipal discharges, ground water contamination and non-point source pollution, as a source of organic pollution.

There are municipal and industrial discharges upstream of several ODS stations. Most are not required to monitor for organics in the outfall. Therefore, no historic data exists to compare the levels of organics being detected at the ODS stations with the outfall loadings from the facilities.

Ground water contamination upstream of ODS stations is another potential source of organics in the Ohio River. Several sites have been identified (Table 8) as being contaminated with organics. The interaction (flow rate, temperature, volatility of organics, etc.) between ground water and the river needs to be defined in order to determine the impact of ground water on organic levels in the river.

Another potential source of organics in the river is non-point source pollution. According to Results of the Nationwide Urban Runoff Program, Volume I - Final Report by the U.S. EPA, several organics were detected in 10 to 19 percent of the samples taken. Methylene Chloride was the only compound detected at ODS stations that was found in the NURP samples. The occurrence of methylene chloride in the NURP samples was 11 percent.

CONCLUSIONS AND RECOMMENDATIONS

Most compounds that met the criteria for analysis using the Seasonal Kendall Test displayed significant decreasing trends in percent detection, signifying improving water quality. However, concrete evidence of the origin of organics in the river does not exist. It is suspected that organic levels in the river can be attributed to point source discharges that are not monitored for organics, ground water contamination, and possibly nonpoint sources such as urban runoff.

Since most discharges are not monitored for organics, no historic record exists to correlate discharge loadings to organic levels being detected at ODS stations. It is unlikely that these discharges will ever monitor for organics, therefore a different approach needs to be pursued to quantify organic levels in the river.

One recommendation would be to define the interaction between contaminated ground water sites and the river. A significant data base exists that contains the organic concentrations and flows at ODS stations. This information, along with ground water contamination data (if available) could be analyzed to determine the effects of ground water on organic levels detected. An investigation of this sort would be very time consuming, involving mathematical modeling of the ground water and stream. A recommendation would involve only the most severely contaminated sites in the closest proximity to ODS stations.

While investigating ORSANCO's historic records of the ODS stations, several problems became obvious. Records kept in the early stages of development included detailed quarterly progress reports. These reports contained information such as number of detections for each parameters, percent run time, maintenance performed, equipment replaced, and any notes that were pertinent to the operation for each station. These progress reports continued and eventually were written on a monthly basis until 1985. Very few maintenance records exist from 1985 to present. It is recommended that a detailed recordkeeping process such as was kept before, be initiated, documenting any maintenance performed, equipment replacement, or any unusual conditions that may be helpful in assessing ODS data.

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APPENDIX A

QUALITY ASSURANCE PLAN FOR ORGANICS DETECTION SYSTEM

QUALITY ASSURANCE WORK PLAN

FOR

ORGANICS DETECTION SYSTEM

December 1988

Ohio River Valley Water Sanitation Commission
49 E. 4th Street, Suite 815
Cincinnati, Ohio 45202

PROGRAM NAME: Organics Detection System

PROGRAM INITIATION: 1978

PROGRAM OBJECTIVE: To provide data on selected organic chemicals for water quality assessment, spills detection and toxic substances control.

PROGRAM DESCRIPTION:

The Organics Detection System (ODS) consists of 13 stations operated in cooperation with eleven water utilities and two industries along the Ohio, Allegheny, Monongahela, and Kanawha Rivers. Volatile organic compounds are analyzed daily in grab samples of river water using purge and trap gas chromatography with detection capability at the parts-per-billion level.

The ODS provides ambient data on trace organics in the river and serves as a spill detection system. When a significant detection occurs, state/federal regulatory agencies as well as downstream water supplies are notified and monitoring is increased to track the contaminant. ODS data are entered into STORET and published quarterly.

MONITORING SYSTEM DESIGN AND RATIONALE

The ODS network was established in 1978 in response to a major carbon tetrachloride spill which inadvertently contaminated several Ohio River public water supplies. The incident focused attention on the lack of monitoring for organic substances in the Ohio River and the inadequacies in notifying downstream water utilities. The ODS was designed to provide daily analysis of river water for selected organic compounds at locations that would adequately protect water supplies. Three criteria were used for selection of the ODS sites:

1) Location of the site relative to major sources of pollution and other public water supply intakes.

2) Adequate laboratory facilities and 24 operations at the plant.

3) Willingness of the utility to participate and dedicate time and resources to the program.

The ODS network was implemented over a two year period with eleven stations operational by 1980. In 1983 and 1985 the network was expanded with the addition of a station at East Liverpool, Ohio and Paducah, Kentucky respectively. The current ODS stations are described in Attachment A, Table 1.

MONITORING PARAMETERS AND FREQUENCY

Twenty-two volatile organics are analyzed daily in grab samples of river water using purge and trap gas chromatography with detectors sensitive to halogenated and aromatic compounds. The analytical methods employed are based on approved US EPA methods for analysis of treated drinking water and raw source water (Methods 502.1 and 502.2). The compounds include halogenated methanes, ethanes, ethylenes, propanes, benzene and its derivatives.

Compound	Number of Samples	Analytical Method	Sample Preservation	Holding Time
Bromochloromethane	4500/yr.	EPA 502.1	Cool 4°C	14 days
Bromodichloromethane	"	"	"	"
Bromoform	"	"	"	"
Carbon Tetrachloride	"	"	"	"
Chloroform	"	"	"	"
Dibromochloromethane	"	"	"	"
1,1 Dichloroethane	"	"	"	"
1,2 Dichloroethane	"	"	"	"
1,1 Dichloroethylene	"	"	"	"
1,2 Dichloroethylene	"	"	"	"
Methylene Chloride	"	"	"	"
Tetrachloroethylene	"	"	"	"
1,1,1 Trichloroethane	"	"	"	"
Trichloroethylene	"	"	"	"
Trichlorofluoromethane	"	"	"	"
Benzene	"	EPA 502.2	Fix pH <2	7 days
Chlorobenzene	"	"	HCl	"
Ethylbenzene	"	"	Cool 4°C	"
1,2 Dichlorobenzene	"	"	"	"
1,3 Dichlorobenzene	"	"	"	"
1,4 Dichlorobenzene	"	"	"	"
Toluene	"	"	"	"

EPA Method 502.1 - Volatile Halogenated Organic Compounds in water by Purge and Trap Gas Chromatography (1985, Ed. Rev. 1986.

EPA Method 502.2 - Volatile Organic Compounds in water by Purge and Trap Capillary Column Gas Chromatography with Photoionization and Electrolytic Conductivity Detector in Series

PROJECT ORGANIZATION AND RESPONSIBILITY

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

Water User/Industry Personnel	-sampling operations/QC -laboratory analysis/QC
Environmental Chemist	-data quality review -performance audits -system audits
Computer Operator	-data processing/QC
Monitoring Programs Manager	-overall program coordination -overall QA

DATA QUALITY OBJECTIVES AND ASSESSMENTS

Data quality requirements for accuracy and precision are compound specific and vary with purging efficiency and concentration. Spike recovery criteria is ±40% for low level concentrations <10 ug/L.

Method detection limits for each volatile compound are provided in Method 502.1 and 502.2. These detection limits will vary among laboratories since results are dependent upon instrument sensitivity and matrix effects.

COMPOUND	METHOD DETECTION LIMIT, lg/L		
	HECD	PID	PID[1]
Bromochloromethane	.01	-	-
Bromodichloromethane	.02	-	.37
Bromoform	1.6	-	2.2
Carbon Tetrachloride	.01	-	.80
Chloroform	.02	-	.29
Oibromochloromethane	.03	-	.71
1,1 Dichloroethane	.07	-	.13
1,2 Dichloroethane	.03	-	.14
1,1 Oichloroethylene	.07	-	.68
1,2 Dichloropropane	.01	-	
Methylene Chloride	.02	-	.14

[1] Performance Aspects of Volatile Organics Analysis by Purge and Trap Capillary Column Gas Chromatography with Flame Ioni-zation Detectors. R.G. Westendorf, Tekmar Company, November 1986.

COMPOUND	METHOD DETECTION LIMIT, lg/L (continued)		
	HECD	PID	PID
Tetrachloroethylene	.04	.05	.17
1,1,1 Trichloroethane	.03	-	.22
Trichloroethylene	.01	.02	.14
Trichlorofluoromethane	.03	-	-
Benzene	-	.009	.03
Chlorobenzene	.01	.003	.03
Ethylbenzene	-	.005	.03
1,2 Dichlorobenzene	.02	.05	.05
1,3 Dichlorobenzene	.02	.02	.04
1,4 Dichlorobenzene	.01	.007	.05
Toluene	-	.01	.03
Styrene	-	.01	-

HECD = Hall Electrolytic Conductivity Detector
PID = Photoionization Detector
FID = Flame Ionization Detector

Due to variations in instrument performance among the ODS stations the practical quantitation level for most volatile compounds ranges from 0.1 - 0.5 ug/L. Carbon Tetrachloride and the trihalomethanes show poor FID responses and their quantitation limits are typically 1-5 ug/L.

[1]Performance Aspects of Volatile Organics Analysis by Purge and Trap Capillary Column Gas Chromatography with Flame Ionization Detectors. R.G. Westendorf, Tekmar Company, November 1986.

Routine quality control activities consist of the following:

Daily:	-Collection of duplicate raw water samples. -Analysis of reagent water to check for interferences and contamination. -Analysis of raw water sample. -Analysis of duplicate sample if significant detection occurs, i.e. $\geq$ 5 ug/L.
Weekly:	-Analysis of multi-component calibration standard to insure proper peak identification, detector performance and reproducibility.
Semi-annual:	-Analysis of EPA Performance Evaluation samples to check laboratory precision and accuracy. Test results are compared to the true value and the 95% confidence limits established for each compound.

DATA REPRESENTATIVENESS, COMPARABILITY, AND COMPLETENESS

During the last ten years of operation, the ODS network has undergone improvements in instrumentation and detection capability. Electrolytic conductivity detectors have been used since 1979 to measure the halogenated organics at the 0.1 ug/L level. Thus an extensive database for 16 of the twenty-two volatile organics has been established. In 1987 a significant upgrade in the system was completed that provided uniformity ininstrument design and more reliable performance across the system. Six additional aromatic compounds were added to the daily monitoring schedule at that time.

The period of record for the ODS network is listed by station in Attachment A, Table 2. For the water years 1986-87 the ODS data collection efficiency was 83%.

SAMPLING PROCEDURES

Daily raw water samples are collected from the plant's water intake system prior to any chemical treatment. The sample tap is flushed for 2 - 3 minutes and the flow adjusted to minimize entrained air in the sample. Duplicate samples are collected in pre-cleaned 40 ml amber bottles and sealed with a teflon-lined cap so that no air bubbles are entrapped in the sample. The bottles are labeled with date, time and location and stored at4#C until analysis.

SAMPLE CUSTODY

Special chain of custody procedures are not required.

CALIBRATION PROCEDURES AND PREVENTIVE MAINTENANCE

A multi-component mixture of volatile organics is analyzed at minimum once per week to calibrate the ODS gas chromatograph. Detailed instructions for calibration are contained in Standard Operating Procedures for the Organics Detection System, Part III of the Quality Assurance Manual.

Laboratory personnel carry out routine checks on instrument operation and prepare weekly data reports. The Commission provides consumable supplies such as compressed gas, calibration standards, and peripheral equipment as needed. All gas chromatographs and associated detectors are covered under a service contract with the manufacturer which includes a yearly preventive maintenance visit. A description of the current ODS analytical instrumentation is listed in Attachment A, Table 3.

DATA REDUCTION, VALIDATION AND REPORTING

ODS data is received weekly in the form of daily chromatograms and a summary sheet of test results. The chromatograms are reviewed for peak identification and integration errors. There agent water analysis is checked for the presence of interferences and contamination problems. Calibrations runs are checked for proper compound identification, retention times and response factors. Any errors found are corrected manually using the internal standard calculation method. The data is then entered in the Commission's computer database, retrieved and edited before transmittal to the EPA STORET system. The data is also published in the Quality Monitor with an assessment of detection frequencies, trends, and comparisons to US EPA water quality criteria. Original data sheets and chromatograms are retained for one year in the Commission's files.

ANALYTICAL PROCEDURES

See Standard Operating Procedures for the Organics Detection System, Part III of the Quality Assurance Manual.

DATA USAGE

The ODS provides quantitative data on ambient levels of volatile organic compounds in the Ohio River. The data is used in the Toxics Control Program to help determine the occurrence and persistence of toxics in the river, identify potential sources and develop control programs. Cancer risk level criteria are e established for 11 of the volatile organics measured by the ODS. Concentrations found in the river above the detection level are compared to these criteria in water quality assessment studies.

As a spill detection system, the ODS serves an essential role in protecting public drinking water supplies which use the Ohio and three major tributaries as source water. When significant concentrations are measured, the appropriate state/federal agencies and water utilities are notified so that adjustments intreatment can be made to protect drinking water quality.

PERFORMANCE AND SYSTEM AUDITS

The operational status of each ODS station is reviewed weekly (or more frequently if necessary) with lab personnel to identify and correct any performance problems. EPA Performance Evaluation samples are analyzed semi-annually to check the precision and accuracy of each laboratory in the performing of the volatile organic analysis. In addition, confirmational analyses by a contract laboratory are performed to verify significant detections of organic compounds.

CORRECTIVE ACTION

Commission staff provide on-site operator training, technical support in solving chromatographic problems and arrange for instrument repair and servicing. Evaluation of equipment needs is done each year to better plan and implement system upgrades.

REPORTS

Quarterly summaries of organic detections, maximum and average concentrations, and number of samples exceeding US EPA water quality criteria are provided in the Quality Monitor. Status reports are prepared for the ODS participants which review overall system performance and quality control activities.

ATTACHMENT A

ORGANICS DETECTION SYSTEM

TABLE 1. ORGANICS DETECTION SYSTEM MONITORING STATIONS			
STORET PRIMARY NO.	STATION NAME	MILE POINT	STATION DESCRIPTION
AR7.40	City of Pittsburgh Water Treatment Plant	7.4	Allegheny River at Pittsburgh, PA
MR24.5	PA-American Water Company Hays Mine Lab	4.5	Monongahela River at Becks Run, PA
OR976.50	West View Water Authority	4.5	Ohio River at Neville Island, PA
OR940B	City of East Liverpool Water Works	40.2	Ohio River at East Liverpool, OH
OR894.2	Wheeling Water Treatment Plant	86.8	Ohio River at Wheeling, WV
OR790.7	E.I. duPont deNemours & Co.	190.3	Ohio River at Parkersburg, WV
KR38.3	Appalachian Power Company	38.3	Kanawha River at St. Albans, WV
OR674.1	Huntington, WV-American Water Co.	306.9	Ohio River at Huntington, WV
OR630.9	City of Portsmouth Water Treatment Plant	350.1	Ohio River at Portsmouth, OH
OR518.2	City of Cincinnati Water Works	462.8	Ohio River at Cincinnati, OH
OR380.4	Louisville Water Company	600.6	Ohio River at Louisville, KY
OR189.5	Evansville Water Works	791.5	Ohio River at Evansville, IN
OR45.5	Paducah Water Works	935.5	Ohio River at Paducah, KY

TABLE 2: STATION DATA BASE: ODS MONITORING SYSTEM

OHIO RIVER MILE POINT	STATION NAME	RIVER	STORET#	WATERBODY ID	WATERBODY NAME	BEGIN DATE	END DATE
0.0	PITTSBURGH WATER WORKS	ALLEGHENY	AR7.4		ALLEGHENY	02/12/79	CURRENT
0.0	SOUTH PITTSBURGH	MONONGAHELA	MR4.5		MONONGAHELA	07/01/86	CURRENT
0.0	ELRAMA	MONONGAHELA	MR24.5		MONONGAHELA	02/26/80	06/30/86
4.5	WEST VIEW WATER AUTHORITY	OHIO	OR975.5	ORW801	POINT - EMSWORTH	07/15/81	CURRENT
40.2	EAST LIVERPOOL WATER WORKS	OHIO	OR940.8	ORW8054.4	PA STATE LINE - NEW CUMBERLAND	12/15/82	CURRENT
86.8	WHEELING WATER TREATMENT PLANT	OHIO	OR894.2	ORW808	PIKE ISLAND - HANNIBAL	07/16/86	CURRENT
190.3	PARKERSBURG	OHIO	OR790.7	ORW811	MUSKINGUM - BELLEVILLE	05/27/80	CURRENT
265.7	ST. ALBANS	KANAWHA	KR38.3		KANAWHA	01/09/79	CURRENT
306.9	HUNTINGTON WATER CORPORATION	OHIO	OR674.1	ORW815	GALLIPOLIS - BIG SANDY	10/01/79	CURRENT
350.7	PORTSMOUTH WATER TREATMENT PLANT	OHIO	OR630.9	ORW817	GREENUP - SCIOTO	07/09/86	CURRENT
462.8	CINCINNATI WATER WORKS	OHIO	OR518.2	ORW820	LITTLE MIAMI - LICKING	01/02/79	CURRENT
600.6	LOUISVILLE WATER COMPANY	OHIO	OR380.4	ORW824	KENTUCKY - McALPINE	10/28/80	CURRENT
791.5	EVANSVILLE WATER COMPANY	OHIO	OR189.5	ORW827	GREEN - UNIONTOWN	09/14/79	CURRENT
935.5	PADUCAH WATER WORKS	OHIO	OR45.5	ORW834	TENNESSEE - CAIRO	06/06/85	CURRENT

TABLE 3: ANALYTICAL INSTRUMENTATION - ORGANICS DETECTION SYSTEM

STATION	INSTRUMENTATION
Pittsburgh Water	Varian 3400 Gas Chromatograph Tracor Hall 1000 Detector Tracor 703 Photoionization Detector Tekmar LSC2000 Concentrator DB 624 Megabore Column
PA-American Water Co. Hays Mine Lab	Varian 3400 Gas Chromatograph Tracor Hall 1000 Detector Flame Ionization Detector Tekmar LSC3 Concentrator DB-624 Megabore Column
West View Water	Varian 3400 Gas Chromatograph Tracor Hall 1000 Detector Flame Ionization Detector Tekmar LSC3 Concentrator DB-624 Megabore Column
East Liverpool Water	Varian 3700 Gas Chromatograph Flame Ionization Detector Tekmar LSC--3 Concentrator SP 4270 Integrator DB-624 Megabore Column
Wheeling Water Treatment Plant	Varian 3400 Gas Chromatograph Tracor Hall 1000 Detector Tracor 703 Photoionization Detector Tekmar LSC-3 Concentrator SP 4270 Integrator DB624 Megabore Column
DuPont Company Washington Works Plant	Varian 3700 Gas Chromatograph Flame Ionization Detector Tekmar LSC-3 Concentrator SP 4270 Integrator DB624 Megabore Column
Appalachian Power Co. John E. Amos Plant	Varian 3400 Gas Chromatograph Flame Ionization Detector Tekmar LSC-2 Concentrator DB624 Megabore Column

TABLE 3: ANALYTICAL INSTRUMENTATION - ORGANICS DETECTION SYSTEM

STATION	INSTRUMENTATION
WV-American Water Co. Huntington Division	Varian 3400 Gas Chromatograph Tracor Hall 1000 Detector Flame Ionization Detector Tekmar LSC-3 Concentrator DB624 Megabore Column
Portsmouth Water Treatment Plant	Varian 3700 Gas Chromatograph Flame Ionization Detector Tekmar LSC-3 Concentrator SP 4270 Integrator DB624 Megabore Column
Cincinnati Water Works	Varian 3700 Gas Chromatograph Tracor 700/700A Detectors Flame Ionization Detector Tekmar LSC-2 Concentrator SP 4100 Integrator DB624 Megabore Column VOCOL Column, SP1000 Packed Column
Louisville Water Company	HP 5840 Gas Chromatograph Coulson Conductivity Detector HNU Photoionization Detector Tekmar LSC3 Concentrator SP 4270 Integrator DB624 Megabore Column
Evansville Waterworks	Varian 3400 Gas Chromatograph Tracor Hall 1000 Detector Flame Ionization Detector Tekmar LSC-3 Concentrator DB624 Megabore Capillary Column
Paducah Water Works	Varian 3400 Gas Chromatograph Tracor Hall 1000 Detector Flame Ionization Detector Tekmar LSC-3 Concentrator DB624 Megabore Capillary Column

APPENDIX B

SEASONAL KENDALL TEST METHODOLOGY AND FORMULAS

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. Retrieval and preparation of the data sets.
3. Statistical analysis of the data sets using the Seasonal Kendall Test and Kendall Slope Estimator.

SELECTION OF STATIONS AND PARAMETERS FOR ANALYSIS

Many missing values in a data set decrease the reliability of the results. The Seasonal Kendall Test requires at least five data points in each month over the 10 year interval. If there were no detections for a parameter, a zero (0) is recorded in the matrix for that parameter. If no samples were taken, a "NA" is recorded in that position of the matrix. If samples were not taken for more than one-half of the month, that month was dropped from the data set and represented in the matrix as "NB". If more than 50 percent of the matrix was occupied by missing values (NA or NB), the parameter was dropped from consideration for trend analysis at that station.

RETRIEVING AND PREPARING DATA SETS

The entire data set used in the analyses is in STORET as number of samples and detections. The number of detections and samples taken were retrieved for each station from 1980-1989. From the data, the percent detection was calculated by dividing the number of detections by the number of samples and multiplying by 100 percent. The tables of percent detections were imported into the LOTUS 123® spreadsheets containing the trend tests and analyzed. The data matrices used in the analyses are included as Appendix B.

SEASONAL KENDALL TEST OF TREND

The Seasonal Kendall Test is applied using a macro written in LOTUS 123®. 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 statistics and monthly variance, and (5) calculate a z-statistic. The z-statistic is used to test the null hypothesis. The null hypothesis is rejected if z indicates z indicates a $p<.05$. The resulting z-statistic determines the probability of a trend, and whether that trend is increasing or decreasing. An increasing trend indicates that parameter percent detections are increasing in the Ohio River water column over time, suggesting deteriorating water quality. A decreasing trend indicates that parameter percent detections are decreasing over time, suggesting an improvement in water quality.

is increasing or decreasing. An increasing trend indicates that parameter percent detections are increasing in the Ohio River water column over time, suggesting deteriorating water quality. A decreasing trend indicates that parameter percent detections are decreasing over time, suggesting an improvement in water quality.

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:

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

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, or the slope.

The slope can then be compared with the trend direction at that station. The slope calculated is not intended to imply that a linear trend is assumed. 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

DATA MATRICES USED IN SEASONAL KENDALL TESTS

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WHEELING WATER (MP 86.8)
Parameter: TRICHLOROETHYLENE
Z–Statistic: –8.25
Slope: –6.30%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	100.00	92.86	100.00	56.67	83.87	46.67	NB	58.06	80.00	NB	NB	36.00
1981	100.00	100.00	100.00	94.44	88.89	44.00	NA	NA	NB	NA	NB	88.89
1982	78.57	78.57	93.55	86.67	93.55	76.67	40.00	96.77	100.00	96.77	96.67	45.16
1983	32.26	100.00	3.23	0.00	6.45	10.34	12.90	3.23	6.67	0.00	0.00	NB
1984	81.48	54.17	36.67	20.00	26.67	16.00	17.86	33.33	10.00	3.23	7.69	6.45
1985	19.35	31.82	3.23	0.00	0.00	0.00	3.85	12.90	6.67	0.00	0.00	0.00
1986	NB	0.00	3.33	0.00	0.00	3.33	3.33	0.00	3.45	5.00	0.00	5.88
1987	0.00	10.00	0.00	0.00	3.23	0.00	0.00	3.23	0.00	0.00	0.00	0.00
1988	33.33	3.85	0.00	0.00	0.00	3.33	3.45	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	3.23	6.67	0.00	0.00	0.00	0.00	0.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WHEELING WATER (MP 86.8)
Parameter: TETRACHLOROETHYLENE
Z-Statistic: -6.69
Slope: -6.75%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	100.00	100.00	96.77	100.00	100.00	100.00	NB	80.65	53.33	NB	NB	64.00
1981	100.00	100.00	100.00	83.33	3.70	0.00	NA	NA	NB	NA	NB	55.56
1982	53.57	78.57	83.87	33.33	64.52	36.67	30.00	74.19	70.00	87.10	93.33	48.39
1983	32.26	60.00	12.90	3.33	22.58	34.48	3.23	0.00	0.00	0.00	6.90	NB
1984	92.59	91.67	70.00	66.67	46.67	8.00	21.43	22.22	16.67	16.13	11.54	22.58
1985	16.13	27.27	0.00	0.00	0.00	3.33	7.69	6.45	6.67	0.00	3.33	0.00
1986	NB	7.41	3.33	0.00	0.00	10.00	3.33	14.81	0.00	0.00	36.36	5.88
1987	0.00	0.00	4.55	0.00	3.23	0.00	0.00	0.00	0.00	0.00	0.00	3.45
1988	23.33	34.62	13.33	0.00	12.90	0.00	3.45	0.00	3.33	0.00	20.00	6.45
1989	9.68	3.57	3.23	13.33	3.23	0.00	0.00	0.00	23.33	29.03	10.00	3.23

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WHEELING WATER (MP 86.8)
Parameter: CHLOROFORM
Z–Statistic: –0.84
Slope: 0%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	100.00	100.00	100.00	90.00	100.00	100.00	100.00	90.32	100.00	96.55	100.00	92.86
1981	73.33	52.00	6.45	50.00	67.74	36.67	80.00	51.61	40.00	77.42	100.00	100.00
1982	80.00	64.29	90.32	63.33	100.00	96.67	100.00	93.55	50.00	32.26	80.00	61.29
1983	93.55	67.86	90.32	86.67	87.10	100.00	93.55	96.77	83.33	38.71	100.00	100.00
1984	100.00	100.00	100.00	100.00	83.87	100.00	96.77	80.65	70.00	100.00	96.67	100.00
1985	93.55	96.43	61.29	30.00	96.77	93.33	74.19	54.84	16.67	9.68	36.67	6.45
1986	32.26	35.71	19.35	60.00	50.00	43.33	26.09	61.29	20.00	83.87	93.33	22.58
1987	0.00	3.57	3.23	20.00	58.06	100.00	90.32	9.68	73.33	96.77	93.33	100.00
1988	96.55	89.66	35.48	54.55	90.32	3.33	0.00	3.23	23.33	25.81	33.33	41.94
1989	19.35	10.71	19.35	43.33	38.71	23.33	9.68	70.97	76.67	48.39	36.67	77.42

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WHEELING WATER (MP 86.8)
Parameter: METHYLENE CHLORIDE
Z–Statistic: –5.44
Slope: –3.23%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	77.42	92.86	100.00	30.00	45.16	13.33	NB	9.68	6.67	NB	NB	0.00
1981	77.42	100.00	92.59	88.89	85.19	60.00	NA	NA	NB	NA	NB	3.70
1982	0.00	14.29	9.68	20.00	3.23	20.00	15.00	74.19	33.33	35.48	56.67	32.26
1983	19.35	40.00	6.45	10.00	6.45	6.90	3.23	0.00	0.00	0.00	13.79	NB
1984	55.56	79.17	40.00	63.33	60.00	44.00	39.29	55.56	3.33	19.35	69.23	93.55
1985	48.39	95.45	61.29	56.67	35.48	33.33	46.15	22.58	16.67	6.45	10.00	13.64
1986	NB	7.41	6.67	0.00	3.33	0.00	0.00	0.00	0.00	20.00	9.09	0.00
1987	6.67	40.00	4.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.41	37.93
1988	40.00	65.38	56.67	16.67	9.68	3.33	0.00	0.00	3.33	3.23	26.67	3.23
1989	12.90	3.57	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WHEELING WATER (MP 86.8)
Parameter: 1,1,1 TRICHLOROETHANE
Z–Statistic: –8.32
Slope: –9.68%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	93.55	96.43	100.00	83.33	87.10	66.67	NB	67.74	70.00	NB	NB	92.00
1981	100.00	100.00	100.00	100.00	96.30	100.00	NA	NA	NB	NA	NB	96.30
1982	96.43	96.43	96.77	100.00	96.77	86.67	75.00	100.00	96.67	96.77	96.67	90.32
1983	83.87	93.33	45.16	13.33	16.13	3.45	3.23	0.00	6.67	16.67	6.90	NB
1984	85.19	95.83	73.33	83.33	90.00	84.00	78.57	81.48	60.00	45.16	88.46	87.10
1985	100.00	95.45	80.65	63.33	58.06	56.67	61.54	54.84	46.67	35.48	53.33	31.82
1986	NB	66.67	63.33	62.96	50.00	20.00	10.00	18.52	17.24	40.00	45.45	41.18
1987	26.67	40.00	31.82	4.00	6.45	0.00	0.00	0.00	0.00	0.00	0.00	17.24
1988	40.00	46.15	33.33	13.33	12.90	3.33	6.90	19.35	23.33	25.81	13.33	6.45
1989	12.90	0.00	19.35	6.67	3.23	0.00	0.00	0.00	0.00	6.45	6.67	19.35

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WEST VIEW WATER (MP 4.5)
Parameter: TETRACHLOROETHYLENE
Z–Statistic: –8.41
Slope: –9.17%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1981	NA	NA	NA	NA	NA	NA	NB	NB	NB	55.56	80.95	93.10
1982	64.52	42.86	70.97	43.33	93.55	100.00	74.19	96.77	96.67	93.55	NB	NA
1983	NB	92.86	87.10	50.00	83.87	100.00	90.32	96.77	96.67	80.65	40.91	NB
1984	NA	NB	54.84	27.59	25.81	30.00	16.13	25.81	23.33	74.19	26.67	9.68
1985	6.45	0.00	0.00	0.00	0.00	NB	65.00	54.17	30.43	25.81	36.67	8.70
1986	14.29	17.86	16.13	6.90	17.86	20.00	3.70	NB	13.33	3.23	7.14	0.00
1987	0.00	0.00	3.23	0.00	3.33	0.00	0.00	0.00	0.00	10.34	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	16.13	0.00	0.00	3.23	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WEST VIEW WATER (MP 4.5)
Parameter: METHYLENE CHLORIDE
Z–Statistic: –7.39
Slope: –3.89%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1981	NA	NA	NA	NA	NA	NA	NB	NB	NB	50.00	23.81	93.10
1982	87.10	85.71	87.10	90.00	96.77	91.30	83.87	45.16	23.33	19.35	NB	NA
1983	NB	50.00	12.90	10.00	9.68	6.67	12.90	48.39	23.33	9.68	27.27	NB
1984	NA	NB	0.00	10.34	3.23	6.67	9.68	25.81	53.33	41.94	20.00	6.45
1985	3.23	0.00	0.00	3.33	0.00	NB	25.00	58.33	26.09	12.90	20.00	0.00
1986	35.71	21.43	45.16	6.90	32.14	10.00	7.41	NB	3.33	0.00	3.57	30.77
1987	9.68	7.14	9.68	0.00	0.00	0.00	0.00	0.00	0.00	3.45	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WEST VIEW WATER (MP 4.5)
Parameter: CHLOROFORM
Z-Statistic: -5.09
Slope: -3.76%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1981	NA	NA	NA	NA	NA	NA	NB	NB	NB	44.44	38.10	31.03
1982	32.26	14.29	19.35	30.00	74.19	95.65	70.97	58.06	90.00	77.42	NB	NA
1983	NB	50.00	22.58	0.00	19.35	46.67	61.29	80.65	96.67	74.19	40.91	NB
1984	NA	NB	41.94	10.34	6.45	6.67	3.23	3.23	56.67	70.97	0.00	0.00
1985	9.68	10.71	0.00	0.00	0.00	NB	35.00	58.33	26.09	9.68	20.00	0.00
1986	0.00	0.00	0.00	0.00	0.00	0.00	11.11	NB	0.00	3.23	7.14	0.00
1987	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.00	0.00	41.38	81.48	3.85
1988	0.00	0.00	6.45	0.00	3.23	0.00	3.23	6.45	0.00	3.23	10.00	8.33
1989	0.00	0.00	0.00	30.43	0.00	10.00	6.45	3.23	0.00	0.00	0.00	3.23

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WEST VIEW WATER (MP 4.5)
Parameter: 1,1,1 TRICHLOROETHANE
Z-Statistic: -6.78
Slope: -3.33%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1981	NA	NA	NA	NA	NA	NA	NB	NB	NB	44.44	76.19	82.76
1982	83.87	35.71	61.29	63.33	77.42	47.83	45.16	67.74	73.33	67.74	NB	NA
1983	NB	42.86	19.35	33.33	25.81	30.00	48.39	80.65	60.00	54.84	18.18	NB
1984	NA	NB	9.68	0.00	6.45	10.00	3.23	0.00	0.00	9.68	0.00	0.00
1985	0.00	0.00	0.00	0.00	0.00	NB	10.00	4.17	8.70	3.23	0.00	0.00
1986	3.57	7.14	0.00	0.00	3.57	0.00	7.41	NB	3.33	6.45	0.00	0.00
1987	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: PORTSMOUTH WATER (MP 350.7)
Parameter: TETRACHLOROETHYLENE
Z-Statistic: -6.32
Slope: -7.89%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NA	NA	NB	NB	NB	63.16	37.04	68.75	34.48	40.00	93.10	NB
1981	NA	86.36	100.00	100.00	100.00	96.67	100.00	100.00	100.00	96.15	100.00	100.00
1982	100.00	100.00	61.90	NA	NA	70.00	29.03	48.39	36.67	81.48	83.33	20.00
1983	60.00	NB	8.70	25.00	NB	0.00	27.78	NB	17.65	16.67	60.00	65.38
1984	5.00	25.00	0.00	0.00	0.00	14.81	24.14	0.00	0.00	10.00	33.33	55.17
1985	15.38	100.00	100.00	100.00	100.00	96.67	100.00	100.00	56.67	53.33	24.00	NB
1986	48.39	NB	NA	NA	NA	NA	20.00	4.55	0.00	16.67	NB	NB
1987	NB	NB	87.10	96.67	64.52	25.93	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	NB	NB	NA	0.00	0.00	0.00	NB	0.00	3.33	0.00
1989	0.00	0.00	3.23	13.33	5.00	6.67	0.00	3.23	6.67	12.90	0.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: PORTSMOUTH WATER (MP 350.7)
Parameter: METHYLENE CHLORIDE
Z-Statistic: -3.14
Slope: -1.04%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NA	NA	NB	NB	NB	0.00	0.00	0.00	0.00	6.67	13.79	NB
1981	NA	54.55	64.52	63.33	64.29	20.00	23.53	72.41	13.33	23.08	100.00	10.00
1982	9.68	0.00	0.00	NA	NA	5.00	9.68	0.00	20.00	0.00	0.00	24.00
1983	56.00	NB	8.70	6.25	NB	0.00	0.00	NB	NB	23.33	33.33	73.08
1984	100.00	60.71	44.44	11.54	16.67	22.22	20.69	0.00	3.33	20.00	23.33	6.90
1985	30.77	96.43	31.58	50.00	25.81	13.33	0.00	3.85	3.33	10.00	0.00	NB
1986	16.13	NB	NA	NA	NA	NA	0.00	0.00	0.00	8.33	NB	NB
1987	NB	NB	25.81	66.67	3.23	0.00	0.00	0.00	13.33	3.33	0.00	18.52
1988	61.29	0.00	NB	NB	NA	13.33	0.00	0.00	NB	0.00	0.00	6.67
1989	0.00	0.00	0.00	0.00	5.00	0.00	3.23	0.00	0.00	0.00	0.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: PORTSMOUTH WATER (MP 350.7)
Parameter: CHLOROFORM
Z-Statistic: -3.95
Slope: -6.35%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NA	NA	NB	NB	NB	26.32	33.33	50.00	79.31	53.33	89.66	NB
1981	NA	77.27	83.87	86.67	85.71	16.67	52.94	93.10	100.00	100.00	100.00	100.00
1982	96.77	100.00	100.00	NA	NA	95.00	96.77	93.55	96.67	88.89	91.67	80.00
1983	100.00	NB	21.74	43.75	NB	25.93	94.44	NB	58.82	63.33	100.00	100.00
1984	100.00	100.00	48.15	88.46	62.50	92.59	100.00	90.32	6.67	83.33	86.67	96.55
1985	65.38	100.00	100.00	100.00	100.00	100.00	100.00	100.00	90.00	86.67	72.00	NB
1986	0.00	NB	NA	NA	NA	NA	16.67	54.55	20.83	75.00	NB	NB
1987	NB	NB	90.32	100.00	100.00	100.00	25.81	9.68	70.00	96.67	84.00	44.44
1988	41.94	13.79	NB	NB	NA	53.33	37.50	16.67	NB	31.58	3.33	0.00
1989	3.23	0.00	6.45	10.00	10.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: LOUISVILLE WATER (MP 600.6)
Parameter: TETRACHLOROETHYLENE
Z–Statistic: –6.47
Slope: –1.72%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	6.45	75.00	75.00	50.00	40.00	36.67	12.90	9.68	6.67	9.68	27.59	10.00
1981	27.59	35.71	32.26	60.00	45.16	53.33	9.68	25.81	13.33	16.13	66.67	64.52
1982	NB	NA	NA	NB	9.68	3.57	0.00	25.81	3.33	22.58	20.00	12.90
1983	51.61	22.22	16.13	40.00	25.81	20.00	12.90	0.00	0.00	3.23	6.90	0.00
1984	0.00	6.90	3.23	3.33	16.13	23.33	16.13	9.68	6.67	19.35	23.33	3.23
1985	0.00	0.00	3.33	0.00	6.45	0.00	0.00	3.45	3.33	27.59	3.33	32.26
1986	35.48	39.29	3.23	3.45	6.45	3.33	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	6.45	0.00	0.00	0.00	0.00	6.45	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	3.33	0.00	6.45	0.00	0.00	0.00	0.00
1989	3.23	28.57	12.90	60.00	9.68	0.00	0.00	3.23	0.00	12.90	3.33	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: LOUISVILLE WATER (MP 600.6)
Parameter: METHYLENE CHLORIDE
Z–Statistic: –0.17
Slope: 0%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.45	3.33	0.00	0.00	0.00
1981	6.90	0.00	3.23	0.00	0.00	0.00	9.68	16.13	3.33	0.00	0.00	0.00
1982	NB	NA	NA	NB	3.23	0.00	0.00	0.00	0.00	6.45	36.67	12.90
1983	48.39	88.89	93.55	93.33	90.32	83.33	83.87	83.87	93.33	16.13	0.00	3.45
1984	45.16	44.83	58.06	0.00	9.68	6.67	12.90	6.45	16.67	9.68	30.00	12.90
1985	9.68	0.00	16.67	58.62	35.48	3.33	3.85	13.79	40.00	48.28	46.67	25.81
1986	45.16	75.00	58.06	51.72	45.16	13.33	6.45	6.45	10.00	6.45	20.00	0.00
1987	0.00	28.57	3.23	13.33	16.13	19.23	53.33	3.23	0.00	16.13	6.67	12.90
1988	6.45	0.00	16.13	0.00	10.71	10.00	3.23	3.23	3.45	6.45	10.00	0.00
1989	12.90	3.57	0.00	0.00	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: LOUISVILLE WATER (MP 600.6)
Parameter: CHLOROFORM
Z-Statistic: -6.40
Slope: -6.67%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	45.16	60.71	96.43	100.00	73.33	20.00	6.45	29.03	76.67	35.48	48.28	76.67
1981	44.83	82.14	38.71	90.00	54.84	96.67	83.87	51.61	70.00	38.71	95.83	100.00
1982	NB	NA	NA	NB	35.48	25.00	61.29	38.71	6.67	35.48	83.33	90.32
1983	100.00	100.00	100.00	100.00	100.00	93.33	100.00	61.29	53.33	61.29	100.00	100.00
1984	96.77	100.00	83.87	70.00	74.19	93.33	100.00	93.55	50.00	51.61	96.67	96.77
1985	29.03	48.15	6.67	13.79	6.45	6.67	0.00	0.00	20.00	24.14	30.00	6.45
1986	32.26	46.43	32.26	51.72	45.16	6.67	3.23	6.45	6.67	19.35	6.67	0.00
1987	0.00	14.29	3.23	3.33	9.68	57.69	40.00	16.13	23.33	51.61	43.33	100.00
1988	29.03	17.86	3.23	0.00	25.00	96.67	45.16	58.06	6.90	0.00	0.00	3.33
1989	16.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	22.58	0.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: LOUISVILLE WATER (MP 600.6)
Parameter: 1,1,1 TRICHLOROETHANE
Z–Statistic: –9.47
Slope: –9.52%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	38.71	78.57	57.14	85.71	66.67	96.67	90.32	77.42	60.00	64.52	68.97	73.33
1981	72.41	100.00	67.74	66.67	80.65	76.67	87.10	61.29	83.33	87.10	50.00	87.10
1982	NB	NA	NA	NB	51.61	57.14	45.16	35.48	6.67	3.23	30.00	16.13
1983	51.61	74.07	83.87	73.33	74.19	76.67	61.29	25.81	30.00	64.52	100.00	96.55
1984	93.55	82.76	58.06	53.33	58.08	53.33	48.39	16.13	16.67	58.06	100.00	41.94
1985	12.90	0.00	3.33	6.90	6.45	0.00	0.00	0.00	6.67	17.24	20.00	3.23
1986	35.48	35.71	9.68	24.14	25.81	6.67	16.13	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	3.23	0.00	3.23	0.00	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WV--AMERICAN WATER CO.
HUNTINGTON DIV. (MP 306.9)
Parameter: TRICHLOROETHYLENE
Z--Statistic: -5.76
Slope: -3.75%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NB	41.18	NB	95.83	NB	NA	NB	14.29	10.71	48.15	25.00	3.57
1981	100.00	100.00	93.10	100.00	100.00	100.00	67.86	93.55	100.00	100.00	100.00	96.67
1982	92.86	88.46	83.87	26.92	59.09	8.70	38.10	16.00	23.53	4.76	NB	90.48
1983	100.00	92.86	38.10	0.00	0.00	NB	NB	58.62	NB	NB	35.00	8.33
1984	0.00	0.00	31.03	80.77	0.00	0.00	4.17	0.00	0.00	NA	NB	18.75
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NB	0.00	0.00	0,00	0.00
1986	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	0.00	7.14	4.35	0.00	0.00	0.00	0.00	0.00
1988	3.33	0.00	3.23	3.70	6.45	3.33	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	9.68	12.90	0.00	9.68	16.67	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WV–AMERICAN WATER CO.
HUNTINGTON DIV. (MP 306.9)
Parameter: 1,1,1 TRICHLOROETHANE
Z–Statistic: –3.66
Slope: –0.65%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NB	76.47	NB	95.83	NB	NA	NB	33.33	25.00	85.19	41.67	3.57
1981	28.00	0.00	0.00	0.00	0.00	0.00	32.14	3.23	3.45	0.00	7.69	86.67
1982	42.86	23.08	12.90	30.77	36.36	8.70	23.81	12.00	5.88	9.52	NB	90.48
1983	80.00	42.86	4.76	4.76	6.67	NB	NB	27.59	NB	NB	25.00	0.00
1984	0.00	0.00	6.90	15.38	0.00	0.00	4.17	0.00	0.00	NA	NB	12.50
1985	0.00	0.00	3.23	0.00	0.00	0.00	0.00	NB	0.00	0.00	3.33	0.00
1986	NA	NA	NA	NA	NA	NA	0.00	0.00	3.33	0.00	3.70	0.00
1987	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.67	0.00	0.00	0.00
1988	6.67	0.00	0.00	0.00	0.00	6.67	3.45	3.23	0.00	0.00	3.70	0.00
1989	0.00	0.00	0.00	6.67	3.23	0.00	9.68	12.90	0.00	12.90	10.00	3.23

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: EVANSVILLE WATER (MP 791.5)
Parameter: TETRACHLOROETHYLENE
Z–Statistic: –6.86
Slope: –1.94%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.00	14.29	6.90	3.33	3.23	0.00	16.00	25.81	0.00	6.45	21.43	32.26
1981	87.10	100.00	80.65	76.67	70.97	60.00	77.42	74.19	80.00	22.58	13.33	29.03
1982	9.68	75.00	35.48	33.33	35.48	16.67	12.90	6.45	0.00	0.00	6.67	16.13
1983	16.13	32.14	3.23	13.33	6.45	20.00	9.68	3.23	6.67	12.90	3.33	6.45
1984	0.00	0.00	16.13	3.33	9.68	23.33	32.26	64.52	83.33	83.87	33.33	3.23
1985	3.23	10.71	12.90	20.00	9.68	10.00	9.68	3.23	0.00	0.00	3.33	0.00
1986	3.23	0.00	0.00	3.33	9.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	3.70	0.00	0.00	3.33	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.23
1989	0.00	3.57	0.00	0.00	3.23	0.00	6.45	12.90	0.00	0.00	0.00	12.90

NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: EVANSVILLE WATER (MP 791.5)
Parameter: METHYLENE CHLORIDE
Z–Statistic: –1.34
Slope: 0%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	3.23	0.00	3.45	3.33	0.00	6.67	12.00	12.90	3.33	0.00	3.57	20.00
1981	77.42	85.71	64.52	63.33	67.74	10.00	58.06	41.94	36.67	29.03	6.67	16.13
1982	16.13	14.29	22.58	10.00	0.00	0.00	3.23	0.00	0.00	0.00	3.33	0.00
1983	0.00	7.14	0.00	0.00	3.23	0.00	3.23	0.00	16.67	0.00	6.67	3.23
1984	22.58	0.00	3.23	6.67	3.23	3.33	9.68	58.06	83.33	87.10	90.00	83.87
1985	67.74	100.00	70.97	66.67	64.52	33.33	48.39	29.03	13.33	6.45	10.00	3.23
1986	32.26	78.57	54.84	53.33	9.68	6.67	0.00	0.00	0.00	0.00	3.33	3.23
1987	0.00	7.14	0.00	0.00	6.45	0.00	0.00	0.00	0.00	3.23	0.00	0.00
1988	12.90	0.00	0.00	3.33	6.45	3.33	0.00	6.45	0.00	0.00	13.33	3.23
1989	16.13	57.14	9.68	10.00	6.45	10.00	0.00	0.00	3.33	6.45	6.67	9.68

NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: EVANSVILLE WATER (MP 791.5)
Parameter: CHLOROFORM
Z–Statistic: –1.88
Slope: –0.54%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	12.90	53.57	41.38	76.67	54.84	36.67	72.00	96.77	70.00	70.97	46.43	80.65
1981	96.77	96.43	87.10	100.00	100.00	96.67	100.00	96.77	86.67	38.71	60.00	51.61
1982	64.52	100.00	100.00	100.00	100.00	100.00	100.00	93.55	100.00	100.00	100.00	100.00
1983	100.00	100.00	100.00	100.00	96.77	100.00	100.00	100.00	96.67	100.00	100.00	100.00
1984	100.00	86.21	70.97	93.33	80.65	100.00	100.00	100.00	100.00	100.00	96.67	100.00
1985	48.39	96.43	90.32	76.67	90.32	90.00	100.00	100.00	93.33	80.65	80.00	77.42
1986	100.00	100.00	96.77	100.00	96.77	46.67	35.48	64.52	26.67	41.94	46.67	6.45
1987	32.26	21.43	51.85	6.67	41.94	93.33	77.42	93.55	93.33	80.65	26.67	9.68
1988	9.68	58.62	96.77	66.67	93.55	86.67	90.32	67.74	93.33	74.19	66.67	77.42
1989	35.48	71.43	25.81	46.67	93.55	100.00	96.77	96.77	93.33	83.87	83.33	93.55

NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: CINCINNATI WATER (MP 462.8)
Parameter: METHYLENE CHLORIDE
Z–Statistic: –4.63
Slope: –2.77%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.00	0.00	0.00	0.00	86.67	43.33	36.67	0.00	0.00	3.45	0.00	14.29
1981	40.00	52.00	3.23	10.00	64.52	6.67	50.00	19.35	6.67	16.13	56.67	25.81
1982	46.67	42.86	64.52	36.67	51.61	40.00	16.13	25.81	6.67	29.03	3.33	0.00
1983	3.23	35.71	90.32	60.00	61.29	43.33	51.61	58.06	30.00	51.61	70.00	70.97
1984	96.77	100.00	100.00	86.67	58.06	56.67	38.71	38.71	70.00	70.97	60.00	80.65
1985	29.03	28.57	6.45	3.33	32.26	30.00	19.35	12.90	0.00	9.68	3.33	6.45
1986	6.45	7.14	9.68	10.00	0.00	13.33	4.35	6.45	3.33	12.90	6.67	0.00
1987	0.00	0.00	0.00	0.00	3.23	0.00	0.00	3.23	3.33	3.23	3.33	0.00
1988	20.69	6.90	3.23	9.09	22.58	23.33	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	3.23	0.00	3.23	29.03	6.67	3.23	0.00	0.00

NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: CINCINNATI WATER (MP 462.8)
Parameter: CHLOROFORM
Z–Statistic: –4.80
Slope: –4.76%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	100.00	100.00	100.00	90.00	100.00	100.00	100.00	90.32	100.00	96.55	100.00	92.86
1981	73.33	52.00	6.45	50.00	67.74	36.67	80.00	51.61	40.00	77.42	100.00	100.00
1982	80.00	64.29	90.32	63.33	100.00	96.67	100.00	93.55	50.00	32.26	80.00	61.29
1983	93.55	67.86	90.32	86.67	87.10	100.00	93.55	96.77	83.33	38.71	100.00	100.00
1984	100.00	100.00	100.00	100.00	83.87	100.00	96.77	80.65	70.00	100.00	96.67	100.00
1985	93.55	96.43	61.29	30.00	96.77	93.33	74.19	54.84	16.67	9.68	36.67	6.45
1986	32.26	35.71	19.35	60.00	50.00	43.33	26.09	61.29	20.00	83.87	93.33	22.58
1987	0.00	3.57	3.23	20.00	58.06	100.00	90.32	9.68	73.33	96.77	93.33	100.00
1988	96.55	89.66	35.48	54.55	90.32	3.33	0.00	3.23	23.33	25.81	33.33	41.94
1989	19.35	10.71	19.35	43.33	38.71	23.33	9.68	70.97	76.67	48.39	36.67	77.42

NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: EVANSVILLE WATER (MP 791.5)
Parameter: BROMODICHLOROMETHANE
Z–Statistic: –2.54
Slope: 0%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.00	7.14	0.00	0.00	0.00	0.00	12.00	0.00	0.00	0.00	0.00	16.13
1981	9.68	0.00	0.00	13.33	9.68	0.00	51.61	41.94	26.67	6.45	3.33	3.23
1982	0.00	0.00	3.23	3.33	3.23	6.67	9.68	19.35	6.67	38.71	40.00	19.35
1983	3.23	14.29	12.90	10.00	12.90	63.33	54.84	45.16	50.00	19.35	20.00	0.00
1984	12.90	0.00	0.00	3.33	0.00	33.33	83.87	77.42	26.67	70.97	66.67	70.97
1985	58.06	89.29	48.39	43.33	32.26	10.00	6.45	9.68	13.33	32.26	23.33	3.23
1986	70.97	35.71	16.13	16.67	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	9.68	10.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.23
1988	0.00	0.00	0.00	0.00	0.00	3.33	0.00	3.23	3.33	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.23	0.00	0.00	3.33	3.23

NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: EVANSVILLE WATER (MP 791.5)
Parameter: 1,1,1 TRICHLOROETHANE
Z–Statistic: –5.75
Slope: –2.22%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	0.00	0.00	6.90	3.33	3.23	0.00	20.00	0.00	0.00	3.23	0.00	45.16
1981	19.35	89.29	38.71	23.33	32.26	30.00	19.35	12.90	3.33	0.00	0.00	0.00
1982	19.35	82.14	32.26	76.67	90.32	46.67	35.48	9.68	13.33	9.68	30.00	48.39
1983	35.48	85.71	70.97	53.33	32.26	53.33	32.26	9.68	6.67	29.03	60.00	38.71
1984	70.97	55.17	25.81	10.00	9.68	26.67	9.68	38.71	16.67	25.81	70.00	93.55
1985	77.42	71.43	64.52	46.67	19.35	16.67	3.23	3.23	10.00	6.45	6.67	6.45
1986	9.68	25.00	16.13	3.33	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	3.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	3.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: CINCINNATI WATER (MP 462.8)
Parameter: 1,1,1 TRICHLOROETHANE
Z–Statistic: –1.38
Slope: 0%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	12.90	60.71	38.71	26.67	16.67	10.00	26.67	3.23	3.33	3.45	6.67	3.57
1981	3.33	16.00	0.00	0.00	3.23	0.00	0.00	0.00	0.00	0.00	3.33	19.35
1982	16.67	21.43	6.45	30.00	12.90	6.67	6.45	3.23	3.33	3.23	0.00	0.00
1983	0.00	3.57	9.68	3.33	9.68	6.67	3.23	0.00	10.00	3.23	0.00	6.45
1984	22.58	58.62	16.13	16.67	0.00	3.33	0.00	0.00	0.00	6.45	3.33	9.68
1985	6.45	0.00	9.68	13.33	9.68	23.33	0.00	0.00	10.00	0.00	3.33	0.00
1986	22.58	10.71	6.45	0.00	0.00	0.00	0.00	6.45	0.00	6.45	16.67	3.23
1987	3.23	0.00	0.00	6.67	32.26	0.00	9.68	0.00	20.00	25.81	30.00	29.03
1988	6.90	37.93	19.35	4.55	6.45	3.33	6.67	0.00	20.00	3.23	0.00	0.00
1989	0.00	0.00	0.00	0.00	9.68	0.00	0.00	3.23	0.00	3.23	3.33	48.39

NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: APPALACHIAN POWER CO.
JOHN E. AMOS PLANT (KANAWHA MP 38.3)
Parameter: METHYLENE CHLORIDE
Z–Statistic: –3.61
Slope: –3.53

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NB	NB	NA	NB	NB	5.56	17.65	NB	NB	6.25	5.88	NB
1981	NB	NB	NB	38.10	63.16	50.00	NA	NA	100.00	100.00	100.00	94.12
1982	73.68	84.21	NB	NB	30.00	21.05	10.00	NB	0.00	15.79	52.63	5.26
1983	14.29	NB	NB	NB	22.22	35.00	55.00	68.18	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1987	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00	0.00	NB	NB
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.35	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	6.67	16.13	3.23	0.00	0.00	3.33	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: APPALACHIAN POWER CO.
JOHN E. AMOS PLANT (KANAWHA MP 38.3)
Parameter: CHLOROFORM
Z-Statistic: -4.40
Slope: -14.3%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NB	NB	NA	NB	NB	94.44	100.00	NB	NB	100.00	70.59	NB
1981	NB	NB	NB	100.00	100.00	75.00	NA	NA	100.00	100.00	100.00	100.00
1982	94.74	100.00	NB	NB	100.00	100.00	100.00	NB	100.00	78.95	94.74	84.21
1983	95.24	NB	NB	NB	88.89	100.00	100.00	100.00	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1987	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00	0.00	NB	NB
1988	0.00	0.00	0.00	5.00	9.52	26.09	15.00	39.13	38.10	52.38	3.70	3.70
1989	3.23	3.57	0.00	3.33	3.23	13.33	16.13	0.00	26.67	0.00	0.00	9.68

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: APPALACHIAN POWER CO.
JOHN E. AMOS PLANT (KANAWHA MP 38.3)
Parameter: 1,1 DICHLOROETHYLENE
Z–Statistic: –1.95
Slope: –4.92

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NB	NB	NA	NB	NB	0.00	11.76	NB	NB	6.25	5.88	NB
1981	NB	NB	NB	76.19	100.00	75.00	NA	NA	93.75	59.09	93.75	70.59
1982	47.37	68.42	NB	NB	50.00	68.42	55.00	NB	40.00	36.84	47.37	52.63
1983	71.43	NB	NB	NB	66.67	75.00	75.00	4.55	NA	NA	NA	NA
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1987	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00	22.22	NB	NB
1988	0.00	5.56	0.00	5.00	4.76	0.00	0.00	4.35	0.00	9.52	0.00	3.70
1989	3.23	28.57	19.35	46.67	38.71	36.67	19.35	9.68	6.67	16.13	3.33	22.58

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: PITTSBURGH WATER (ALLEGHENY MP 7.4)
Parameter: TETRACHLOROETHYLENE
Z–Statistic: –3.89
Slope: –0.81

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	6.45	38.10	NA	NB	33.33	21.43	16.67	0.00	30.77	NB	NB	22.22
1981	55.00	10.00	0.00	6.67	3.23	6.90	13.79	45.16	35.71	93.33	NB	NB
1982	6.67	71.43	68.97	36.67	46.67	23.33	61.29	12.90	23.33	25.81	0.00	6.45
1983	3.23	0.00	NB	18.18	32.26	6.67	9.68	19.35	26.67	35.48	33.33	NB
1984	19.35	0.00	9.68	16.67	3.23	10.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.45	0.00	0.00
1987	0.00	3.85	3.57	0.00	3.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	6.45	37.93	19.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	32.26	0.00	6.45	3.33	32.26	6.67	12.90	6.45	10.00	45.16	0.00	3.23

NB = FEWER THAN 50% SAMPLES TAKEN FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: PITTSBURGH WATER (ALLEGHENY MP 7.4)
Parameter: METHYLENE CHLORIDE
Z–Statistic: –3.70
Slope: –0.81

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	22.58	38.10	NA	NB	36.67	14.29	13.33	9.52	11.54	NB	NB	83.33
1981	90.00	45.00	14.81	23.33	12.90	37.93	3.45	16.13	3.57	6.67	NB	NB
1982	16.67	7.14	6.90	26.67	0.00	6.67	22.58	6.45	3.33	3.23	0.00	0.00
1983	12.90	0.00	NB	54.55	19.35	10.00	9.68	6.45	10.00	0.00	36.67	NB
1984	9.68	3.45	19.35	10.00	6.45	0.00	3.23	6.45	0.00	0.00	0.00	0.00
1985	3.23	3.57	0.00	0.00	0.00	0.00	3.23	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.23
1987	12.90	19.23	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	12.90	20.00	0.00	19.35	13.33	3.23	6.67	20.00
1989	0.00	17.86	6.45	0.00	9.68	13.33	19.35	16.13	3.33	6.45	13.33	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WV–AMERICAN WATER CO.
HUNTINGTON DIV. (MP 306.9)
Parameter: TETRACHLOROETHYLENE
Z–Statistic: –6.13
Slope: –5.55%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NB	70.59	NB	95.83	NB	NA	NB	23.81	32.14	62.96	83.33	53.57
1981	100.00	100.00	100.00	100.00	100.00	96.43	100.00	96.77	96.55	100.00	96.15	100.00
1982	89.29	84.62	83.87	61.54	0.00	0.00	14.29	0.00	11.76	0.00	NB	90.48
1983	95.00	92.86	57.14	0.00	0.00	NB	NB	89.66	NB	NB	40.00	33.33
1984	0.00	4.17	44.83	73.08	4.00	0.00	12.50	3.70	0.00	NA	NB	31.25
1985	0.00	0.00	0.00	0.00	0.00	0.00	3.33	NB	3.33	0.00	0.00	3.23
1986	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00	3.23	0.00	0.00
1987	6.45	0.00	0.00	0.00	0.00	3.57	4.35	0.00	0.00	0.00	0.00	0.00
1988	20.00	34.78	22.58	7.41	0.00	0.00	0.00	3.23	0.00	0.00	3.70	6.45
1989	3.23	0.00	0.00	6.67	0.00	3.33	3.23	0.00	0.00	0.00	3.33	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WV–AMERICAN WATER CO.
HUNTINGTON DIV. (MP 306.9)
Parameter: METHYLENE CHLORIDE
Z–Statistic: –3.44
Slope: –0.71%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NB	0.00	NB	4.17	NB	NA	NB	0.00	14.29	29.63	20.83	3.57
1981	92.00	81.48	10.34	0.00	43.75	25.00	39.29	22.58	82.76	90.00	92.31	73.33
1982	14.29	23.08	25.81	19.23	45.45	8.70	0.00	0.00	11.76	19.05	NB	90.48
1983	90.00	57.14	9.52	4.76	0.00	NB	NB	3.45	NB	NB	10.00	12.50
1984	24.14	66.67	37.93	23.08	4.00	0.00	0.00	0.00	10.71	NA	NB	0.00
1985	11.11	0.00	0.00	0.00	0.00	0.00	0.00	NB	0.00	0.00	0.00	0.00
1986	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	3.23	10.00	10.34	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	3.23	6.67	16.13	20.00	19.35	9.68	13.33	3.23	0.00	6.45

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WV--AMERICAN WATER CO.
HUNTINGTON DIV. (MP 306.9)
Parameter: CHLOROFORM
Z-Statistic: -5.44
Slope: -7.35%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NB	58.82	NB	62.50	NB	NA	NB	100.00	71.43	81.48	83.33	89.29
1981	92.00	100.00	89.66	96.55	87.50	78.57	96.43	100.00	100.00	100.00	100.00	100.00
1982	100.00	92.31	96.77	96.15	95.45	86.96	71.43	100.00	88.24	95.24	NB	100.00
1983	100.00	100.00	100.00	76.19	6.67	NB	NB	79.31	NB	NB	75.00	83.33
1984	96.55	87.50	65.52	80.77	84.00	96.15	95.83	81.48	100.00	NA	NB	56.25
1985	44.44	47.37	19.35	10.71	12.90	8.33	70.00	NB	16.67	3.23	0.00	0.00
1986	NA	NA	NA	NA	NA	NA	40.00	38.71	30.00	100.00	100.00	62.07
1987	3.23	0.00	0.00	0.00	92.59	100.00	8.70	0.00	0.00	0.00	0.00	0.00
1988	16.67	0.00	19.35	48.15	87.10	63.33	82.76	77.42	3.33	3.23	14.81	0.00
1989	3.23	0.00	0.00	33.33	74.19	70.00	93.55	77.42	63.33	58.06	70.00	87.10

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: WV–AMERICAN WATER CO.
HUNTINGTON DIV. (MP 306.9)
Parameter: BROMODICHLOROMETHANE
Z–Statistic: –6.10
Slope: –2.29%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	NB	58.82	NB	54.17	NB	NA	NB	23.81	57.14	81.48	62.50	50.00
1981	56.00	25.93	48.28	55.17	6.25	7.14	57.14	70.97	100.00	100.00	100.00	80.00
1982	28.57	34.62	16.13	3.85	9.09	4.35	0.00	16.00	0.00	4.76	NB	47.62
1983	85.00	14.29	4.76	0.00	0.00	NB	NB	13.79	NB	NB	40.00	0.00
1984	3.45	0.00	13.79	19.23	0.00	0.00	0.00	3.70	3.57		NB	6.25
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NB	0.00	3.23	0.00	0.00
1986	NA	NA	NA	NA	NA	NA	10.00	0.00	13.33	16.13	3.70	0.00
1987	0.00	0.00	0.00	0.00	3.70	7.14	0.00	0.00	3.33	0.00	0.00	0.00
1988	20.00	0.00	3.23	3.70	0.00	3.33	0.00	0.00	0.00	3.23	0.00	0.00
1989	0.00	0.00	0.00	3.33	0.00	3.33	0.00	3.23	0.00	0.00	0.00	0.00

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

Seasonal Kendall Test of Trend
Kendall Slope Estimator
Location: PITTSBURGH WATER (ALLEGHENY MP 7.4)
Parameter: CHLOROFORM
Z–Statistic: –3.71
Slope: –1.11%

TABLE OF PERCENT DETECTIONS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1980	80.65	23.81	NA	NB	90.00	39.29	53.33	85.71	73.08	NA	NB	83.33
1981	85.00	10.00	18.52	13.33	19.35	10.34	13.79	19.35	28.57	46.67	50.00	NB
1982	3.33	0.00	13.79	13.33	16.67	16.67	32.26	6.45	3.33	6.45	3.33	9.68
1983	3.23	NB	0.00	4.55	9.68	13.33	9.68	22.58	10.00	9.68	26.67	NB
1984	12.90	0.00	16.13	10.00	6.45	10.00	0.00	3.23	6.67	0.00	0.00	3.23
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	11.54	21.43	3.33	13.79	3.33	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	3.45	9.68	16.67	16.13	32.26	23.33	6.45	26.67	6.67
1989	19.35	14.29	12.90	0.00	9.68	16.67	25.81	29.03	10.00	12.90	13.33	16.13

NB = FEWER THAN 50% SAMPLES FOR THAT MONTH
NA = NO SAMPLES TAKEN

APPENDIX D

BASINWIDE TRENDS

FIGURE 2

BASINWIDE CHLOROFORM TRENDS

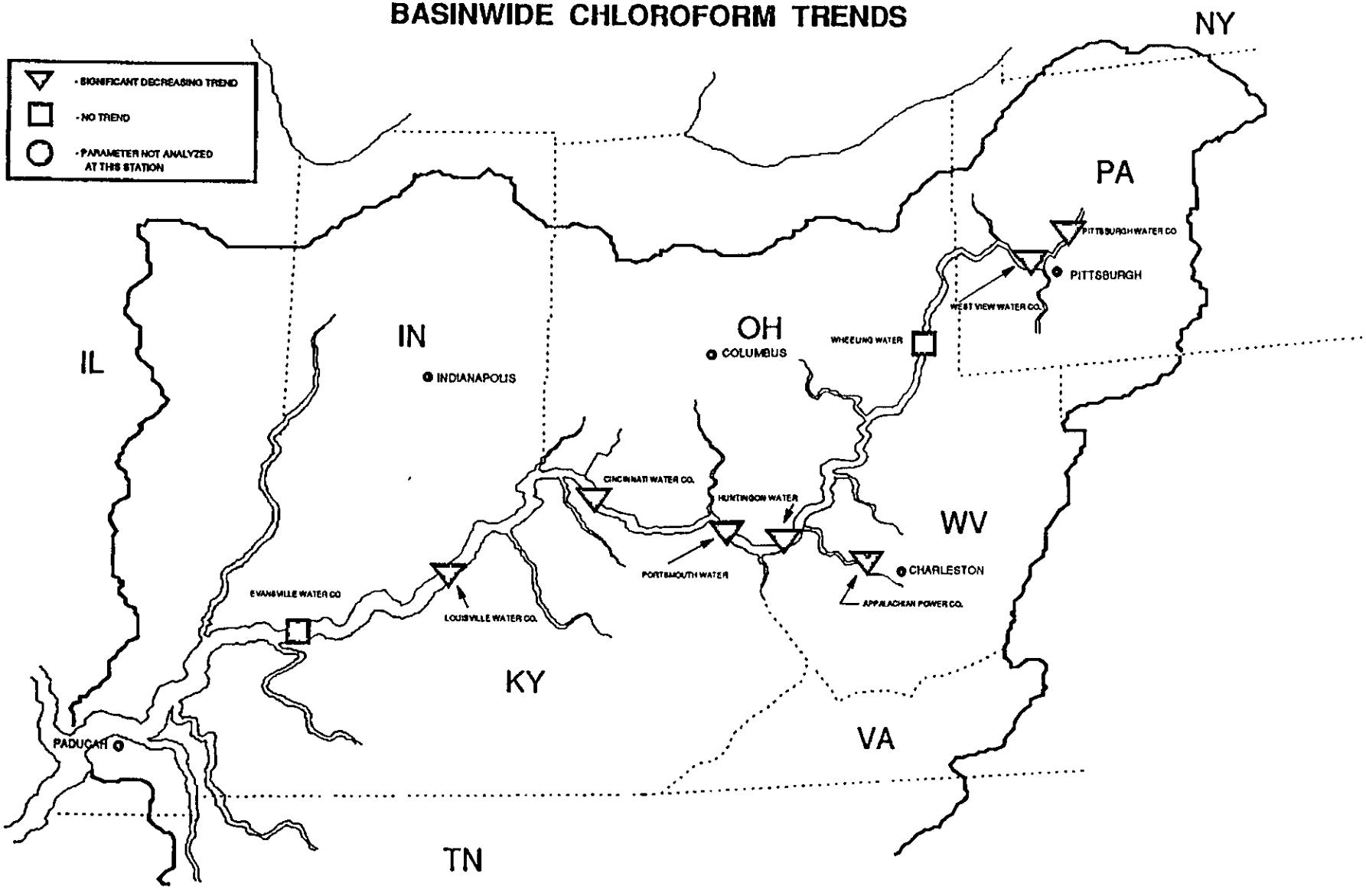

FIGURE 3

BASINWIDE METHYLENE CHLORIDE TRENDS

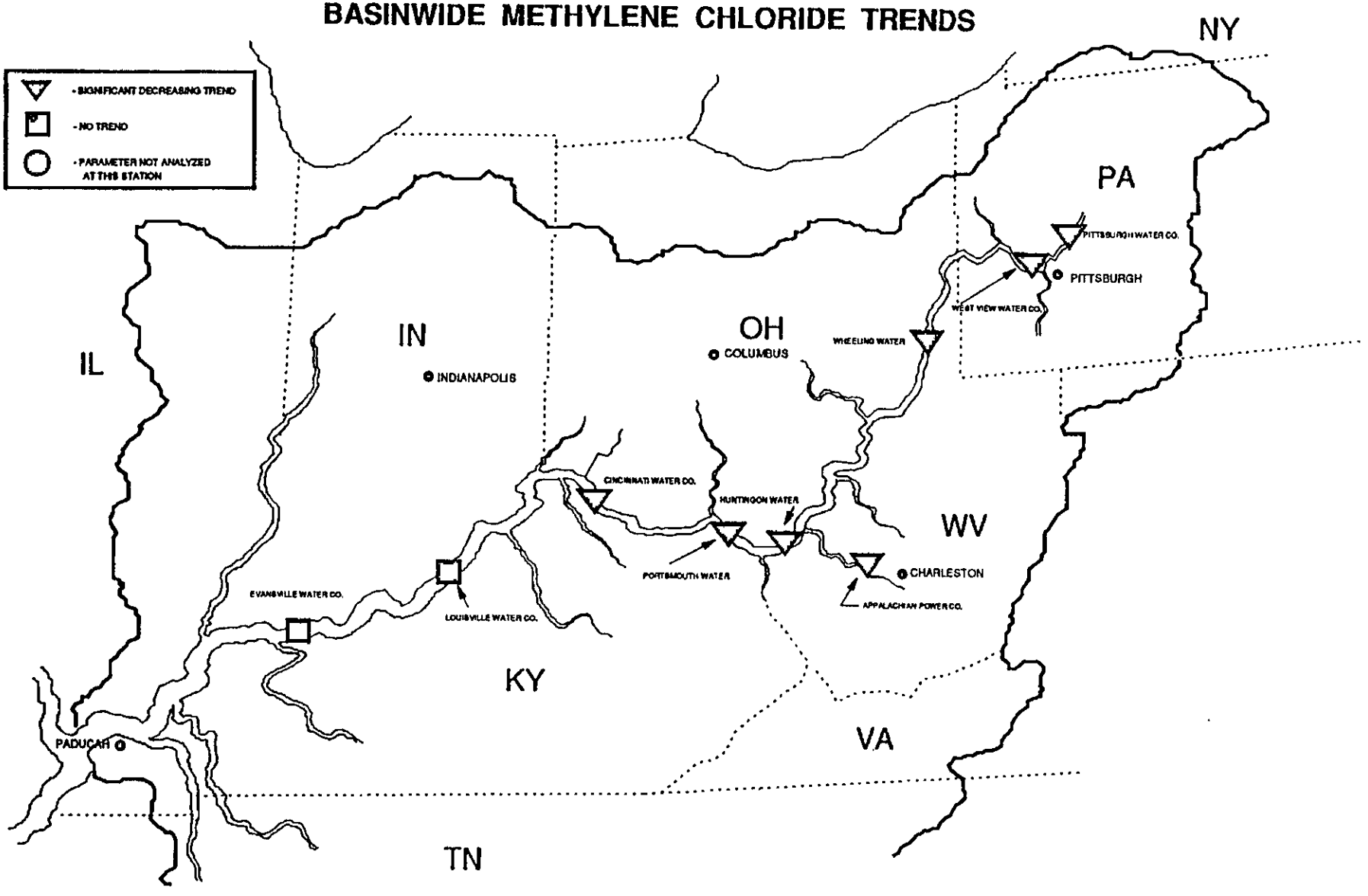

FIGURE 4

BASINWIDE TETRACHLOROETHYLENE TRENDS

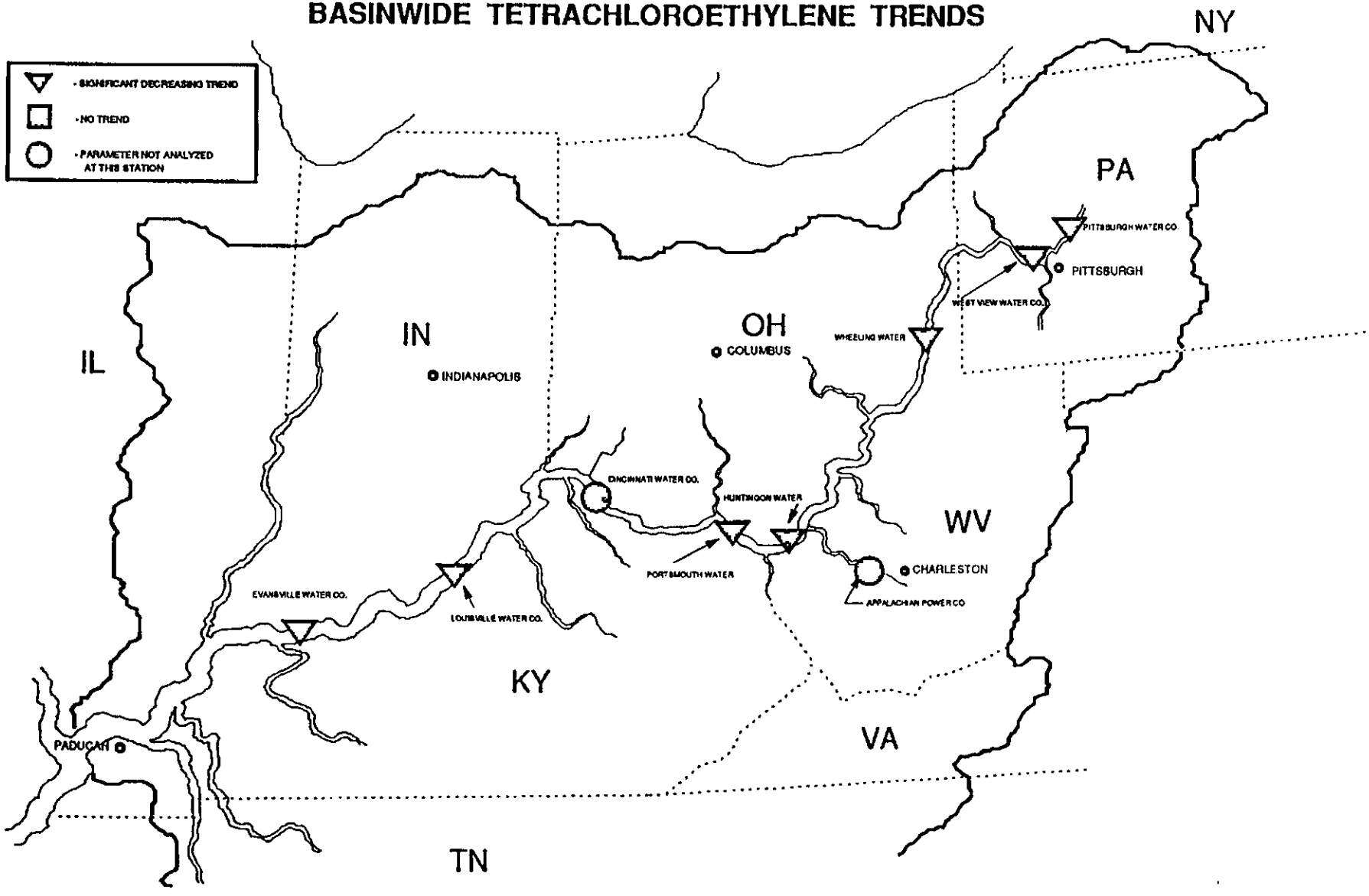

FIGURE 5

BASINWIDE 1,1,1-TRICHLOROETHANE TRENDS

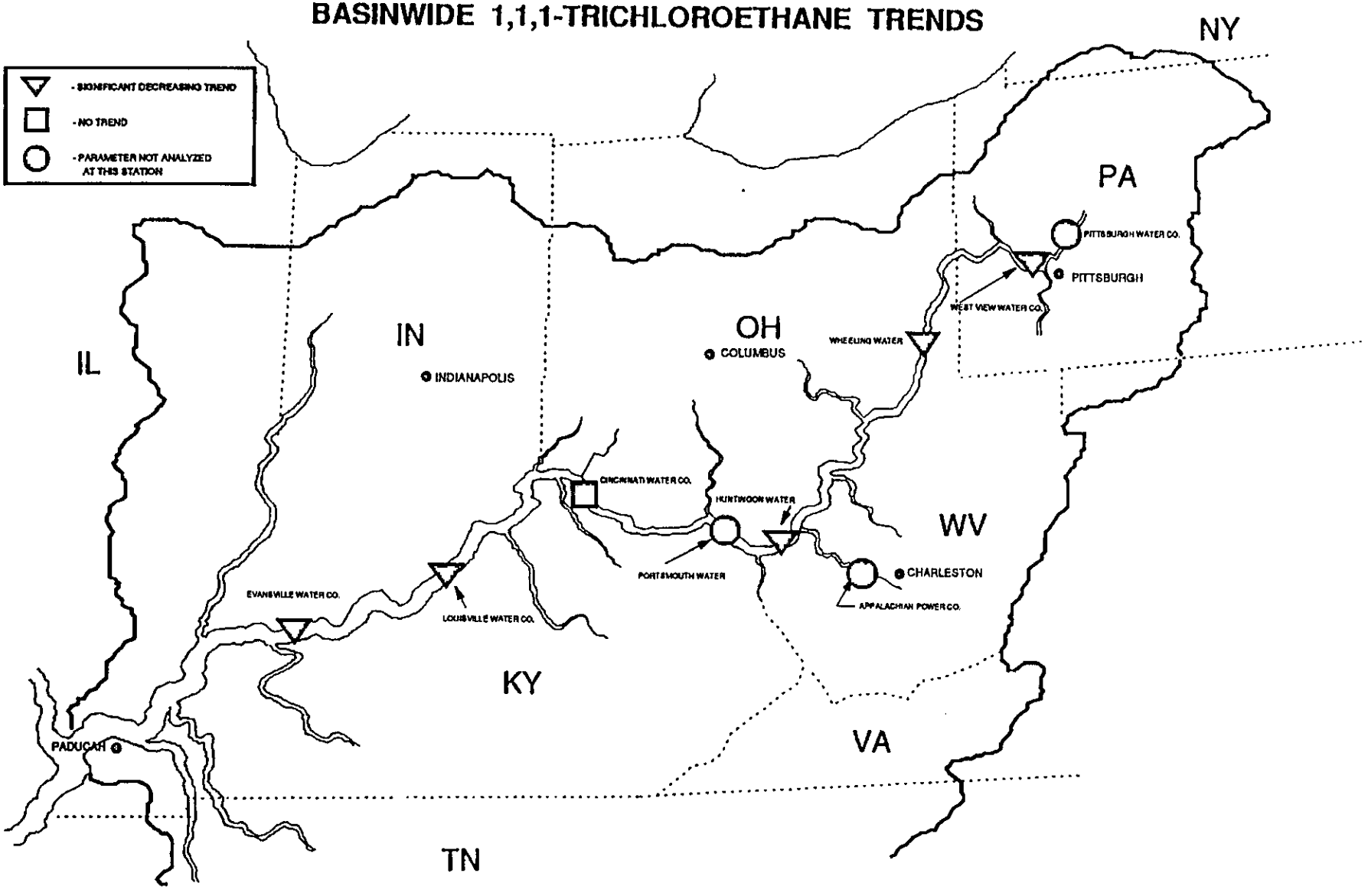

FIGURE 6

BASINWIDE TRICHLOROETHYLENE TRENDS

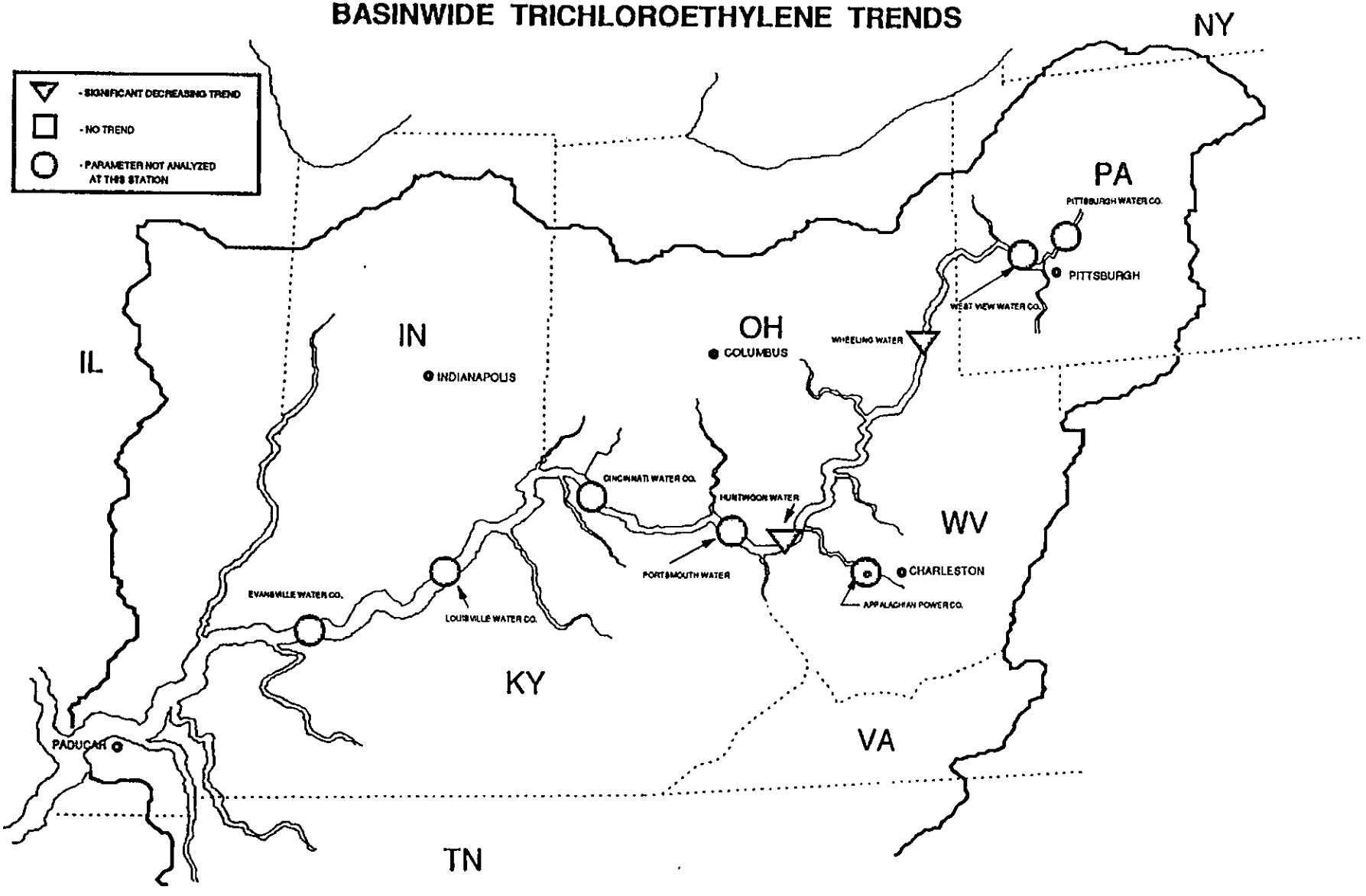

FIGURE 7

BASINWIDE BROMODICHLOROMETHANE TRENDS

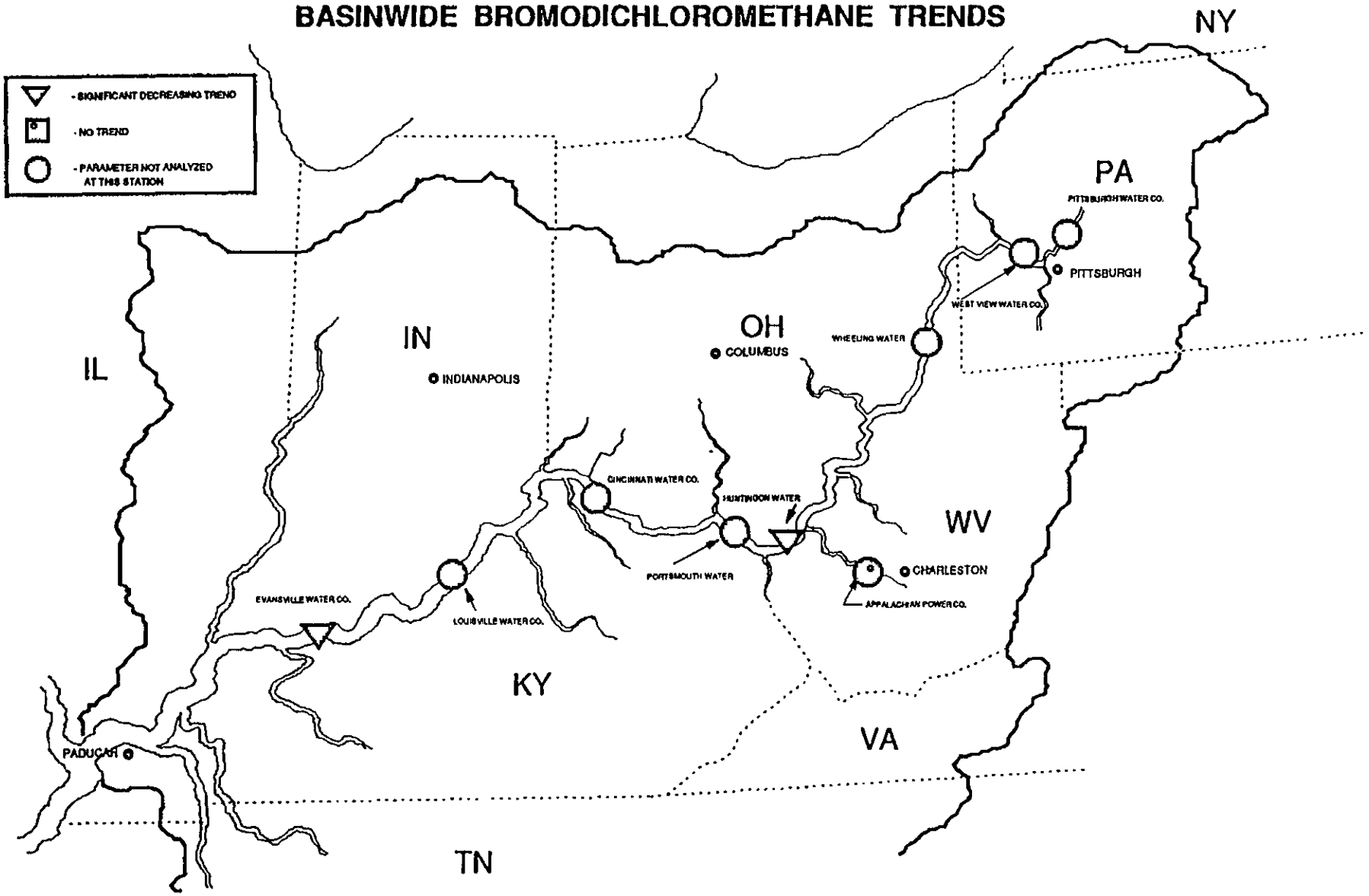

FIGURE 8

BASINWIDE 1,1-DICHLOROETHYLENE TRENDS