LAND USE AND HYDROLOGIC IMPACTS ON WATER QUALITY OHIO RIVER BASIN

NONPOINT SOURCE ANALYSIS

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Ohio River Valley Water Sanitation Commission
414 Walnut Street Cincinnati, Ohio

SUMMARY

The following analysis provides an assessment of the relation of water quality in the lower reaches of the major Ohio River tributaries to dominant land uses and physiographic factors in the tributary drainage basins. The report appraises the relative importance of these factors in determining water quality in the Ohio River Basin.

The significance and reliability of various relationships between selected parameters of water quality and basin characteristics such as land use, hydrologic and physical factors have been appraised, using bivariate and stepwise regression analysis, within the constraints of the available data's quality. The water quality parameters selected are those generally associated with nonpoint sources--total nitrogen, nitrate nitrogen, ammonia nitrogen, organic nitrogen, total phosphorus, BOD, and suspended solids.

This analysis demonstrates both annual and seasonal relationships between water quality and major land uses, as well as the impact of runoff and other hydrologic factors in determining water quality in the lower reaches of the major Ohio River tributaries.

This assessment indicates that in the lower reaches of the tributaries to the Ohio River several water quality characteristics are influenced by nonpoint source pollutant levels directly related to the intensity of agricultural operations. Croplands are the major source of total nitrogen, expecially nitrate nitrogen. Urban and agricultural areas contribute significantly to the total phosphorus in the streams. Suspended solids concentration is not correlated significantly with any major land use, as it is influenced not only by urban and agricultural areas, but also by a number of other factors, including mining activities, construction, and stream bank erosion.

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INTRODUCTION

The use of land, especially in agricultural and urban areas, has long been recognized as a significant factor affecting the water quality of adjacent streams. There has been considerable effort to document the characteristics of runoff from urban and agricultural areas and its potential for polluting receiving streams (6-8, 12, 13). However, very little has been accomplished in assessing pollution as it relates to different land uses in a river basin. Such a study was facilitated by the availability of the water quality data gathered through ORSANCO's expanded monitoring program, which covers various physical and chemical parameters, including those generally associated with nonpoint sources.

Although the need for land use planning is not mentioned specifically in PL 92-500, other than as it relates to nonpoint source pollution, land use considerations are addressed in detail in U. S. Environment Protection Agency guidelines for 208 planning (15). In particular, the suggested procedures for 208 planning include the establishment of land use and water quality relationships. Chapters six and seven of the 208 planning guidelines emphasize the need for considering land use control and land management practices as means of abating nonpoint source pollution. Due to the direct relationship between water quality and land use practices, it is apparent that land use control will be necessary in certain sub-basins of the Ohio River Basin in order to achieve water quality goals.

This report is based on two years' water quality data covering water quality constituents generally considered to be associated with nonpoint sources. These constituents include suspended solids, BOD, total nitrogen, nitrate nitrogen, organic nitrogen, ammonia nitrogen, and total phosphorus. The analysis addresses the annual and seasonal impacts of major land uses and hydrological factors on water quality in the tributary basins. It also assesses the annual and seasonal runoff of the tributary basins and its relationship to water quality.

SPECIFIC OBJECTIVES

The temporal and spatial variations in a stream's water quality are the result of various complex processes within the drainage basin. To a great extent, these processes are controlled by the land use, physiography, and hydrology of the individual basin.

The specific objective of this study is to analyze the water quality characteristics of lower reaches of the major Ohio River tributaries in relation to the major land uses, hydrologic and physiographic characteristics of the drainage basins. The aim of the study is to determine the land use with the most significant impact on an individual stream's quality and to ascertain the extent to which variation in water quality may be explained by variation in land use and drainage basin characteristics. These determinations will aid in the development of land use and land management practices to minimize nonpoint source pollution. Emphasis in this analysis is placed only in those water quality constituents generally associated with nonpoint sources.

SCOPE OF THE STUDY

The scope of this study is limited to the development and verification of certain relationships between stream water quality and major land uses and hydrologic factors on a gross scale. These relationships may lead to the establishment of cause-and-effect relationships, which in turn may be translated to regional planning and management tools for the Ohio River Basin.

LITERATURE

Several studies have been reported relating land use practices with water pollution potential. For the most part, these investigations have been based on data collected on a small watershed, in the drainage area of a stream, within very specific geographic limits. Examples of these studies include forested (8) and rural (6) watersheds, as well as watersheds devoted to a variety of land uses (4).

J. M. Omernik's analysis of drainage area characteristics and stream nutrient runoff data compiled for 473 nonpoint source drainage areas in the Eastern United States indicates significant correlation between nutrient levels in the streams and agricultural and urban land use (12). In another study (2), urbanized watersheds were generally found to be associated with higher stream flow nutrient concentrations than forested areas.

Statistical analyses have been used for quantitative analysis of land use and water quality. Muir and his associates (10) computed correlation coefficients for both nutrients and sediment in relation to certain land use characteristics for a number of watersheds in Nebraska. Significant correlation was found between water quality and both cattle and human population.

The relationship between water quality and percentage of land planted in legumes was also determined to be significant. One of the most detailed studies of land use impact on water quality has been the investigation of eutrophication in Florida lakes (13). More than 80 percent of variation of a derived "tropic state index" was explained by a multiple regression on several land use characteristics. Heavily fertilized agricultural areas and forested land were found to be the land uses that explained the largest portion of variation in "tropic state index."

These studies have, in general, demonstrated the usefulness of correlation and regression procedures in the analysis of water quality and watershed characteristics. Many of these studies are limited, however, by the lack of complete land use and water quality data.

METHODOLOGY

One of the statistical procedures which offers considerable promise in the evaluation of land use and hydrologic impacts on water quality is stepwise regression analysis. In stepwise regression analysis a regression equation is constructed by adding or deleting variables one at a time. A variable is added if it results in a significant improvement in the explained variation of the dependent variable. After the addition of a variable, all variables in the regression equation are evaluated for possible removal on the basis of a variance criterion. A variable which may have been the best single variable to enter at an early stage, may at a latter stage be superfluous because of the relationships between it and other variables then in the equation. Any variable which provides a nonsignificant contribution is removed from the equation. This process is continued until no more variables are entered or removed from the equation. The final result is an equation with a minimum number of independent variables.

The equation is of the general form

$$Y_i = B_i + \sum_{j-1}^{n} A_{i,j} \cdot {}_{i,} X_j$$

where Y is the dependent variable, X is the independent variable, and A and B are coefficients.

Stepwise regression analysis is believed to be one of the best procedures in variable selection. Sensible judgment is required in the initial

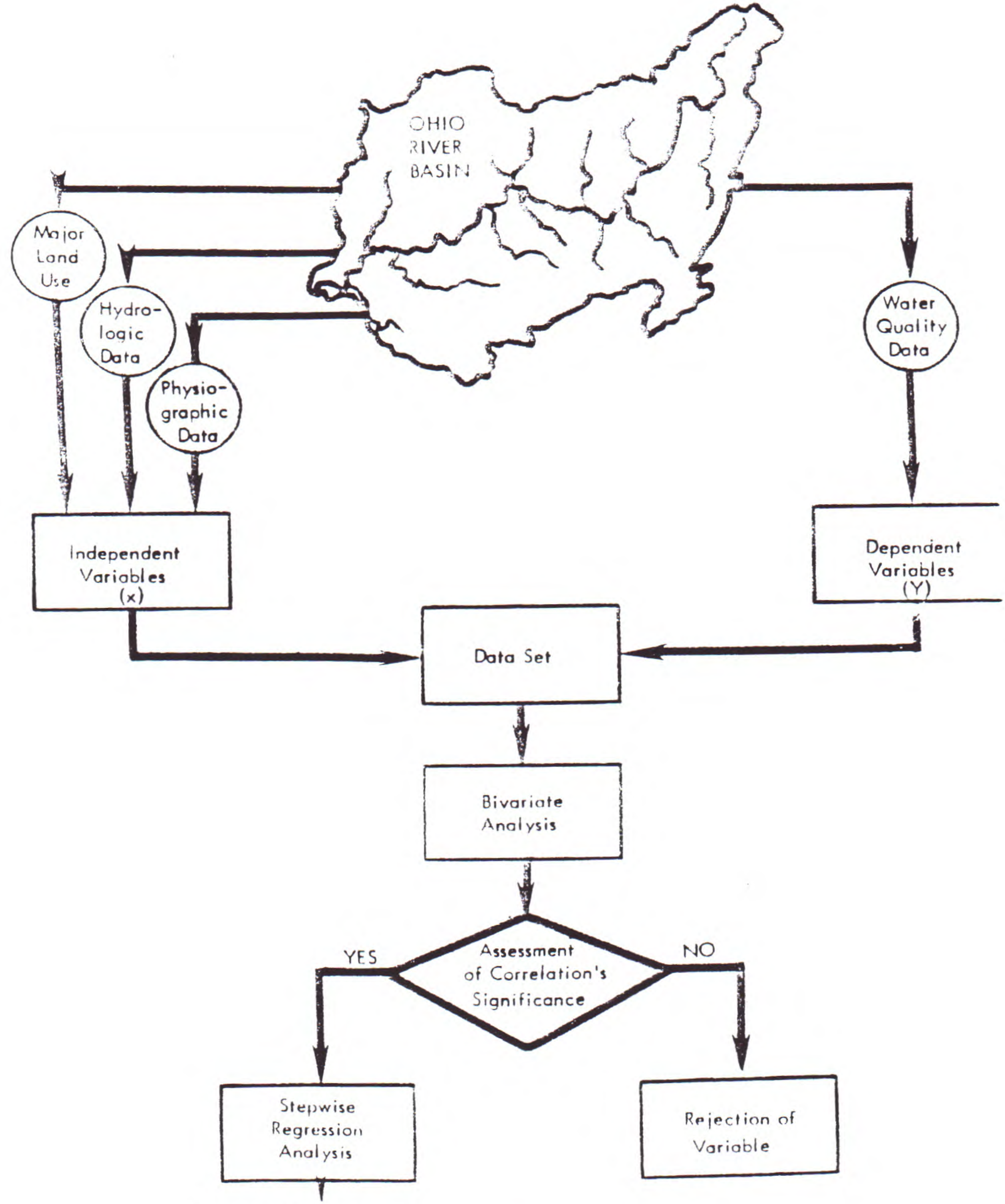

Figure 1: Schematic Diagram of Statistical Analysis

selection of variables and in the critical examination of the equation through the examination of residuals. The computational procedures for stepwise regression analysis have been outlined by Draper and Smith (4). A simplified schematic diagram of this approach is shown in Figure 1.

It should be noted that statistical analysis of water quality and land use should be approached with caution since it is unlikely that water quality is solely a function of land use. There are numerous other factors affecting water quality.

DATA NEEDED

Data required for this analysis included stream water quality at the lower reaches of major tributaries, major land uses, and hydrologic and physiographic features of the pertinent drainage basins. Figure 2 shows the Ohio River Basin with major drainage sub-basins.

The data was assembled for 12 major Ohio River tributaries, the watersheds of which range in size from 1,700 square miles to 33,000 square miles. These river basins are independent in the sense that none is downstream from the other, thus eliminating the possibility that water quality in any one drainage basin be influenced by another. The independence of the river basins rules out "collinearity," which could add an error in detecting significance of correlations.

Water Quality Data: ORSANCO water quality data from lower reaches of the major tributaries characterises the spatial variation in water quality. The location of sampling stations is shown in Figure 2. Two years' water data--from October, 1975, to September, 1977—were utilized in this analysis. The data included information regarding suspended solids, total nitrogen, nitrate nitrogen, organic nitrogen, ammonia nitrogen, total phosphorus and BOD. The ORSANCO data was collected throughout the year at a frequency of once every ten days. The one exception was BOD analyses which were performed on monthly samples. Annual and seasonal concentrations of these selected constituents appear in Tables 1 and 2.

Land Use Data: Land use information for each drainage basin was obtained from the U. S. Department of Agriculture and river basin reports. Data regarding major land uses are summarized in Table 4. Most of the

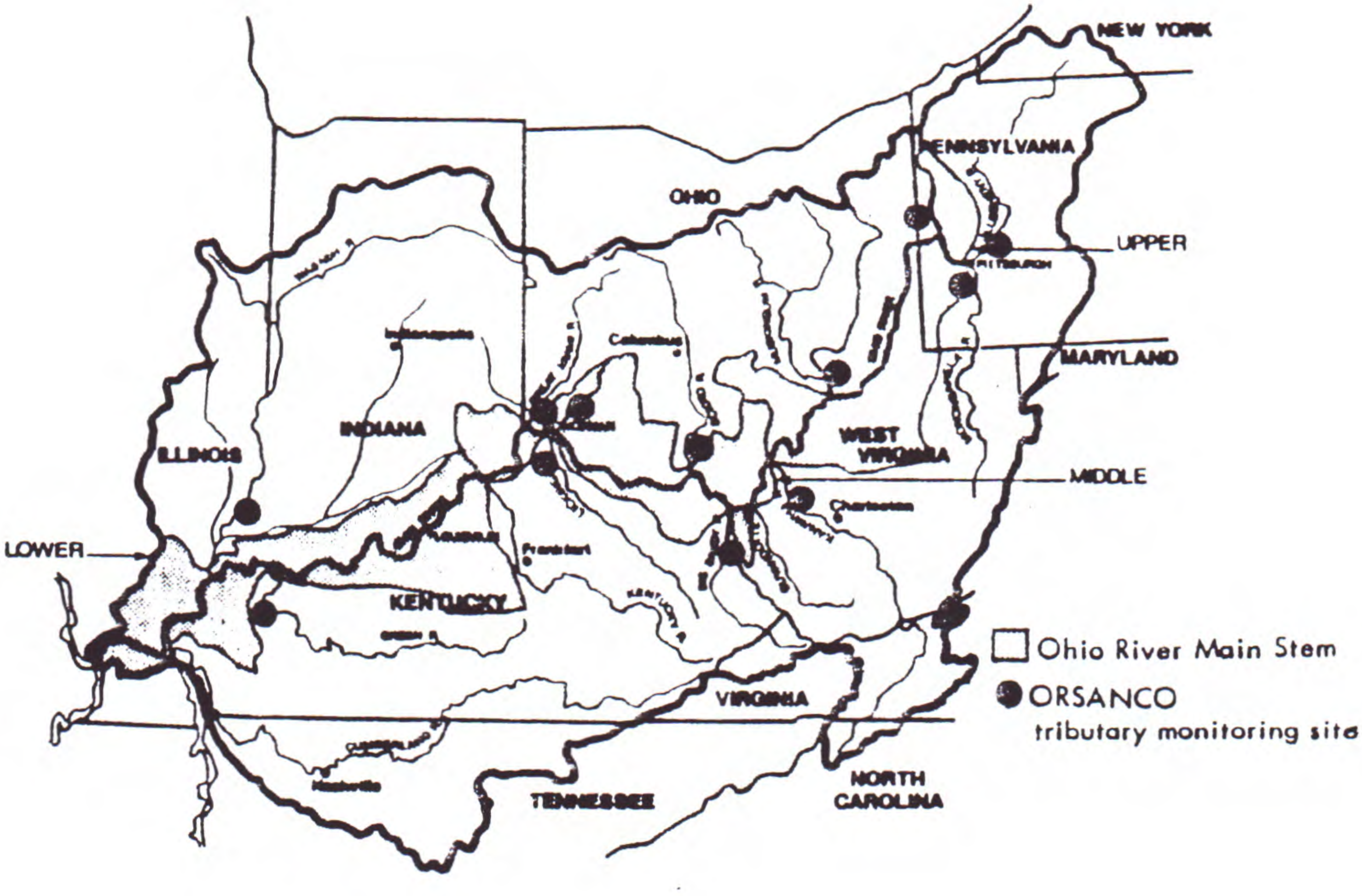

Figure 2: Ohio River Drainage Basin

Table 1: Water Quality Data Annual Mean Concentration (mg/l) Water Years 1975-1977

Parameter	Alle-ghany	Mon-gahela	Beaver	Muskin-gum	Kana-wha	Big Sandy	Scioto	Little Miami	Lick-ing	Great Miami	Green	Wabash
Total Nitrogen	1.86	2.12	3.10	2.30	1.92	1.45	4.30	2.99	1.56	4.23	1.19	2.70
Nitrate Nitrogen	0.65	0.75	1.22	0.94	0.57	0.41	2.02	1.40	0.52	2.38	0.77	1.56
Organic Nitrogen	0.94	1.05	1.23	1.10	0.93	0.95	1.95	1.27	1.00	1.54	0.34	0.95
Ammonia Nitrogen	0.27	0.44	0.81	0.24	0.38	0.12	0.35	0.23	0.15	0.43	0.11	0.13
Total Phosphorus	0.06	0.11	0.20	0.19	0.18	0.19	0.56	0.58	0.22	0.61	0.13	0.24
Suspended Solids	22.40	23.13	18.18	67.90	39.30	101.40	73.12	92.80	83.60	82.10	56.70	93.40
5-Day BOD	2.60	3.00	3.60	3.30	1.70	1.40	5.60	3.10	1.90	5.40	1.30	5.10

Table 2: Water Quality Data Seasonal Concentration (mg/l) Water Years 1975-1977

Season	Alle-ghany	Mon-gahela	Beaver	Muskin-gum	Kana-wha	Big Sandy	Scioto	Little Miami	Lick-ing	Great Miami	Green	Wabash
	Nitrate Nitrogen											
Fall	0.53	0.60	0.94	0.90	0.49	0.35	1.54	1.51	0.52	2.31	0.54	1.21
Winter	0.76	0.81	1.47	1.42	0.59	0.50	2.30	2.11	0.73	2.57	0.76	2.15
Spring	0.58	0.81	1.39	0.66	0.51	0.30	2.34	1.27	0.43	2.75	0.94	1.71
Summer	0.75	0.77	1.09	0.76	0.68	0.52	1.90	0.72	0.40	1.73	0.85	1.17
	Total nitrogen											
Fall	1.76	1.82	2.53	2.13	1.47	1.11	2.70	2.73	1.32	3.97	0.93	2.35
Winter	2.19	2.69	3.36	3.05	2.05	1.67	4.29	3.87	1.78	5.19	1.30	3.42
Spring	1.77	2.05	3.71	2.05	1.80	1.46	4.70	3.13	2.13	4.84	1.34	2.87
Summer	1.73	1.94	2.79	1.99	2.34	1.56	5.49	2.24	1.01	3.27	1.20	2.18
	Organic nitrogen											
Fall	1.02	0.88	1.17	1.01	0.74	0.63	0.87	1.01	0.75	1.38	0.33	0.84
Winter	1.11	1.48	1.14	1.27	1.26	1.08	1.51	1.38	0.94	1.51	0.40	1.04
Spring	0.91	0.99	1.51	1.17	0.75	1.06	2.12	1.57	1.49	1.93	0.34	1.02
Summer	0.73	0.85	1.09	0.98	0.98	1.05	3.30	1.13	0.83	1.33	0.29	0.92

Table 2: Water Quality Data Seasonal Concentration (mg/l) Water Years 1975-1977 (Continued)

Season	Alle-ghany	Mon-gahela	Beaver	Muskin-gum	Kana-wha	Big Sandy	Scioto	Little Miami	Lick-ing	Great Miami	Green	Wabash
	Ammonia Nitrogen											
Fall	0.22	0.35	0.60	0.20	0.29	0.14	0.40	0.21	0.09	0.37	0.16	0.09
Winter	0.31	0.54	1.18	0.32	0.20	0.09	0.48	0.40	0.12	0.98	0.12	0.30
Spring	0.33	0.48	0.82	0.21	0.50	0.13	0.25	0.22	0.24	0.20	0.09	0.06
Summer	0.24	0.37	0.63	0.25	0.53	0.13	0.27	0.12	0.16	0.16	0.07	0.06
	Total Phosphorus											
Fall	0.04	0.07	0.15	0.12	0.07	0.07	0.36	0.49	0.17	0.52	0.09	0.25
Winter	0.07	0.12	0.19	0.27	0.17	0.12	0.36	0.54	0.25	0.60	0.13	0.29
Spring	0.07	0.10	0.23	0.19	0.21	0.18	0.58	0.56	0.21	0.51	0.09	0.23
Summer	0.09	0.14	0.21	0.16	0.26	0.39	0.93	0.72	0.26	0.81	0.20	0.21
	Suspended Solids											
Fall	14.4	29.7	11.2	48.7	24.6	54.5	24.6	26.2	37.9	48.5	67.5	61.9
Winter	36.7	38.4	25.9	86.4	44.5	103.8	122.4	103.6	126.9	123.7	67.6	127.7
Spring	13.4	19.9	15.6	80.9	47.2	110.4	53.7	58.9	42.1	74.4	55.1	98.7
Summer	25.3	21.8	20.0	70.7	41.1	136.9	91.8	178.3	127.3	48.3	36.7	84.9

Table 2: Water Quality Data Seasonal Concentration (mg/l) Water Years 1975-1977

Season	Alle-ghany	Mon-gahela	Beaver	Muskin-gum	Kana-wha	Big Sandy	Scioto	Little Miami	Lick-ing	Great Miami	Green	Wabash
	5-Day BOD											
Fall	3.40	3.20	2.62	3.50	2.04	1.40	3.20	1.90	1.06	3.70	0.50	5.57
Winter	2.50	3.00	3.98	2.87	3.10	3.10	5.97	2.75	2.90	5.30	1.37	3.80
Spring	2.40	3.50	4.95	3.53	1.20	1.60	3.47	5.10	3.67	6.72	1.82	5.36
Summer	2.30	2.95	4.16	3.36	1.20	0.70	6.55	3.55	1.40	6.34	1.47	6.10

information regarding agricultural land use and cropping patterns was obtained from Conservation Needs Inventory Reports, U. S. Department of Agriculture (17). This inventory covers all acreage in each county, except urban acreage. These data include land capability classes and sub-classes, as well as information on row crops, close grown crops, summer fallow, total yield crops, rotation hay and pasture, and orchards.

Physiographic and Hydrologic Data: Physiographic and hydrologic data utilized in the study were information about runoff, precipitation, slope of drainage basins, cover factors, and land disturbed by mining activities.

The data on precipitation was obtained from the National Oceanic and Atmospheric Administration, U. S. Department of Commerce, and 303(e) basin plans; slope of drainage basins from drainage maps prepared by the U. S. Geological Survey and U. S. Corp of Engineers Reports (16); runoff from the U. S. Geological Survey (16) and the River Flow Forecast Center, Cincinnati, OH; and land disturbed by mining activities, from Appalachian Regional Commission Reports and U. S. Corp of Engineers Reports (1, 14).

The values of the cover factors for each drainage basin were determined from cropping patterns in the tributary basins (on a weighted basis). The cover factors were computed by dividing all the land in the basin into four groups--row crops, small grain crops, pasture and hay, and woodland--and assigning a weight to each group. The row crops were weighted 0.45, small grain 0.2, pasture 0.02, and woodland 0.005 (5). The sum of all weighted groups was divided by the area of the drainage basin, resulting in a weighted cover factor.

Seasonal and annual runoff values for each of the twelve major tributaries covering two water years from October, 1975, to September, 1977, are given in Table 3 and illustrated in Figure 3. For seasonal analysis, a year has been divided into four seasons: fall (October to December), winter (January to March), spring (April to June), and summer (July to September).

The annual and seasonal runoff values in inches were calculated by dividing the mean annual flow (F) in cubic feet per second by the drainage area (A) in square miles, as:

Table 3: Seasonal and Annual Runoff (Inches) of Major Sub-basins Water Year 1975-1977

Seasonal	Alle-ghany	Mon-gahela	Beaver	Muskin-gum	Kana-wha	Big Sandy	Scioto	Little Miami	Lick-ing	Great Miami	Green	Wabash
Fall	5.63	5.51	3.36	2.37	5.01	3.05	1.44	1.54	3.57	1.29	4.04	1.31
Winter	10.00	8.00	6.67	5.68	6.74	5.48	4.26	4.21	5.83	3.82	8.04	4.02
Spring	4.33	3.73	3.19	2.93	3.96	4.11	1.87	1.70	1.58	1.85	3.89	2.19
Summer	4.35	2.05	2.50	2.10	1.95	1.58	1.14	0.58	0.86	0.72	2.20	1.42
Average Annual.	24.31	19.29	15.69	12.97	17.67	14.23	8.37	8.02	11.85	7.67	18.17	8.95

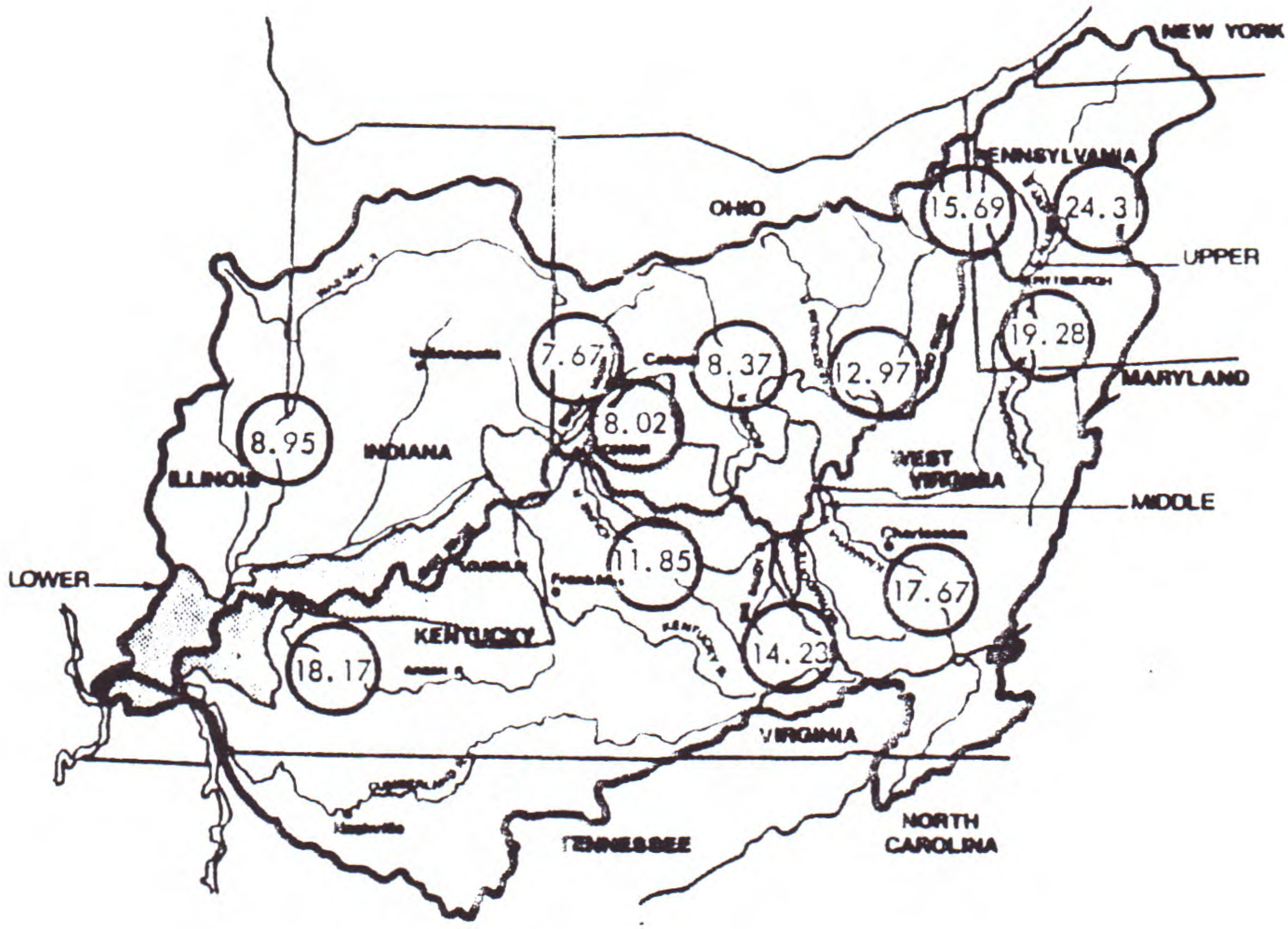

Figure 3: Annual Runoff in Inches
Selected Ohio River Sub-basins

$$\text{Annual runoff (inches)} = \frac{F \times C}{A}$$

where

F = Mean annual flow, cfs.

A = Area, square miles

C = Constant, 13.56

$$\text{Seasonal runoff} = \frac{F \times C}{A}$$

where

C = Constant, 3.39

It should be noted that runoff values calculated above also include the sub-surface flow and groundwater flow into the streams. The values of cover factors, percent land disturbed by mining activities, average annual precipitation, and average slope of the drainage basins are given in Table 4.

DESCRIPTION OF TRIBUTARY BASINS

An overview of the major tributary basins selected for this analysis covering land use activities, hydrologic characteristics and other pertinent information follows.

Allegheny: The Allegheny River drains an area of 11,700 square miles before its confluence with the Monongahela River. The average annual precipitation in the basin ranges from 36 to 50 inches. The average annual runoff is 24.3 inches, and slope 2.7 percent. The land use in the basin is 12.1 percent cropland, 3.3 percent pasture, 50.2 percent forest, and 34.4 percent urban/buildup, water surfaces, and mine-related areas. Approximately 2 percent of the total area is disturbed by mining activities.

Monongahela: The total drainage area of the Monongahela River Basin is 7,384 square miles, which includes 2,736 square miles in Pennsylvania, 4,228 square miles in West Virginia and 420 square miles in Maryland. The average annual precipitation in the basin ranges from 36 to 70 inches. The average annual runoff is 19.3 inches and average slope is 1.15 percent. Present land use in the basin is 8.7 percent cropland, 14.8 percent pasture, 50.7 percent forest. The remaining 27.8 percent is used in urban/buildup, water surfaces, and mine-related areas. Approximately 3 percent of the area is disturbed by mining operations.

Beaver: The Beaver River drains an area of 3,130 square miles in Pennsylvania and Ohio. Present land use in the basin is 33.6 percent cropland, 10.7 percent grassland, 30.7 percent forest, 11.9 percent urban buildup, and 13.1 percent other areas, including water surfaces. Average annual precipitation is about 35 inches, and runoff 15.7 inches. Average slope of the drainage basin is 4.1 percent.

Muskingum: The drainage area of the Muskingum River Basin is 8,051 square miles. Precipitation is evenly distributed across the basin and averages about 40 inches per year. Present land use in the basin is 34.0 percent cropland, 17.3 percent pasture, 34.3 percent forest, 8.6 percent urban, and 5.8 percent other areas, including water surface. The average annual runoff is 13 inches, and the basin slope is 1.5 percent.

Kanawha: The Kanawha River drains a total area of 12,300 square miles. Approximately 69 percent of the basin lies within West Virginia, 25 percent in Virginia and 6 percent in North Carolina. Within the Kanawha River Basin as a whole, approximately 7.6 percent of the area is devoted to cropland, 15.2 percent pasture land, 71 percent to forest, 3.1 percent urban/buildup and 3.1 percent to other lands, including water surfaces. The average annual runoff in the basin is 17.7 inches, and average slope is 1.4 percent.

Big Sandy: The total drainage area of the Big Sandy River, including its two tributaries, the Tug and Levish Fork, is 4,238 square miles, of which about 1,010 square miles are in West Virginia, 2,300 square miles in Kentucky, and the remaining in Virginia. The average annual runoff is approximately 14.2 inches, and the average slope is 1.2 percent.

Scioto: The Scioto River drains an area of 6,510 square miles. The average annual precipitation in the basin is about 44 inches and runoff 8.4 inches. Agricultural land use predominates, representing about 60 percent of the total basin area. The remaining area is 9 percent pasture, 21 percent forest, 7 percent urban/buildup, and 3 percent water surfaces and other idle lands.

Little Miami: The drainage area of Little Miami is about 1,755 square miles, and the average annual precipitation is 41.3 inches. The average annual runoff is about 8 inches. The land use in the basin is about 13.6 percent forest, 58.0 percent cropland, 12.3 percent pasture, 11.3 percent urban/buildup, and about 4.8 percent water surfaces and other idle areas.

Licking: The Licking drainage basin encompasses an area of about 3,700 square miles. The average slope of the basin is 1.7 percent. The average annual precipitation is 46 inches and runoff 11.8 inches. The land use includes 23.9 percent cropland, 33.8 percent pasture, 34.7 percent forest, and 3.9 percent urban.

Great Miami: The Great Miami has a total drainage area of about 5,385 square miles, of which 1,437 square miles are in Indiana, mainly in the Whitewater River Basin. The annual precipitation ranges from 42 inches in the lower basin to 35 inches in the upper basin, with an average of about 38 inches and runoff of 7.8 inches. The land use includes 62.8 percent cropland, 10.4 percent pasture, 10.5 percent forest, and 11.1 percent urban.

Green: The total drainage area of the Green River Basin is 9,230 square miles. Approximately 53 percent is agriculture, 42 percent forest, 2.7 percent urban and buildup, 1.3 percent mine-related areas, and 1.1 percent water surfaces and other idle land. The average annual precipitation is 46 inches and runoff 18 inches. The average slope of the basin is .2 percent.

Wabash: The Wabash River drains an area of about 33,100 square miles, which encompasses about two-thirds of Indiana, one-sixth of Illinois, and 319 square miles of Ohio. The average annual precipitation is 40 inches and runoff is 9 inches. The average slope of the basin is 1.5 percent. The land use is 64.0 percent cropland, 15.2 percent forest, 9.6 percent pasture, 5.5 percent urban, and 5.7 percent other areas, including water surfaces.

Table 4: Data on Land Use, Hydrologic and Physical Characteristics of the Major Sub-basins

Basin	Area in sq. miles	Percent cropland	Percent pasture	Percent forest	Percent Urban	Percent mine-disturbed	Cover factor	Percent Average slope	Rainfall (in/yr)	Runoff (in/yr
Allegheny	11,700	12.1	3.3	50.2	3.4	2.00	0.020	2.70	43.0	24.31
Mongahela	7,400	8.1	14.8	50.7	4.1	3.00	0.013	1.15	52.0	19.28
Beaver	3,130	33.6	10.7	30.7	11.9	1.99	0.048	4.10	35.0	15.69
Muskingum	8,040	34.0	17.3	34.3	8.6	3.49	0.059	1.50	40.0	12.97
Kanawha	12,200	7.6	15.2	71.0	3.1	1.56	0.019	1.40	46.5	17.67
Big Sandy	4,280	5.7	5.3	82.5	1.6	3.50	0.012	1.20	39.0	14.23
Scioto	6,510	60.0	9.0	21.0	7.0	0.02	0.159	2.40	44.0	8.37
Little Miami	1,670	58.0	12.3	13.6	11.3	0.00	0.160	7.30	41.3	8.02
Licking	3,670	23.9	33.8	34.7	3.9	0.08	0.095	1.70	46.0	11.85
Great Miami	5,400	62.8	10.4	10.5	11.1	0.00	0.180	3.60	39.0	7.67
Green	9,230	33.2	17.6	39.5	2.4	1.30	0.103	2.00	46.5	18.17
Wabash	33,100	43.3	9.9	15.0	4.8	0.44	0.239	1.50	40.0	8.95

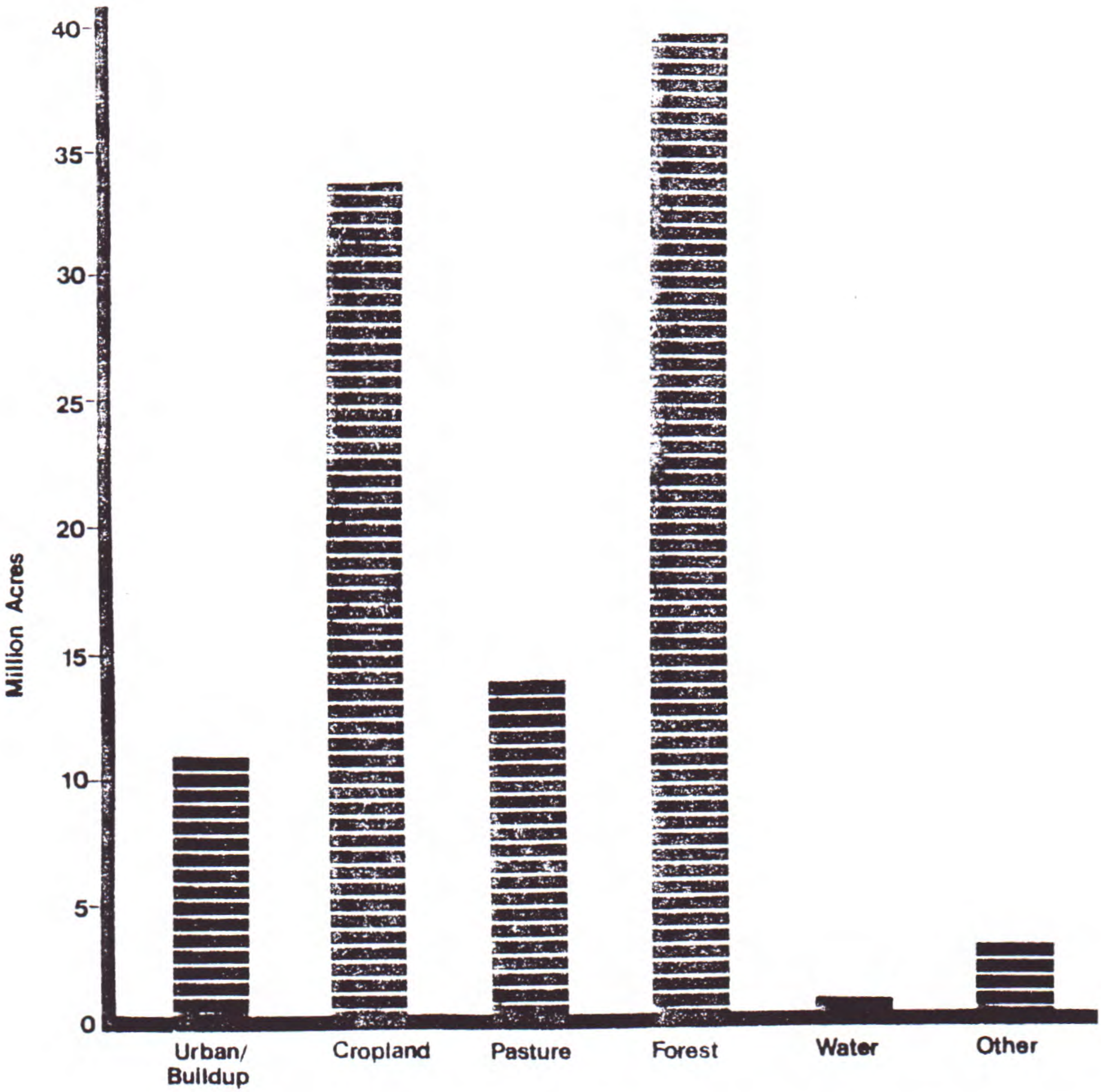

Figure 4: Existing Land Use in the Ohio River Basin

RESULTS AND DISCUSSIONS

The goal of this analysis of water quality data from the lower reaches of the major tributary basins was primarily to identify relationships between selected water quality variables and basin characteristics, including land use, hydrologic and physiographic features. The statistical techniques applied to determine the degree of correlation and functional relations between the variables were bivariate and stepwise regression analysis. As described in the schematic diagram, Figure 1, the parameters assumed to be independent were land use parameters, hydrologic and physical factors. The dependent variables were assumed to be the parameters of water quality, since land use activities and natural hydrological and physical factors cause changes in an adjacent stream's water quality. The water quality parameters selected for this study were only those generally associated with nonpoint sources.

The bivariate analysis was performed between water quality parameters, including total nitrogen, nitrate nitrogen, organic nitrogen, ammonia nitrogen, total phosphorus, suspended solids and BOD; and land use parameters, including percent cropland, percent pasture land, percent woodland, and percent urban. The same water quality parameters were also correlated with hydrologic and physiographic characteristics including runoff, cover factors, and percent slope. The summary of the bivariate analysis is given in Table 5.

Critical examination of the results of bivariate analysis was made to determine significant functional relationships between water quality characteristics and basin characteristics. These results were then used in the selection of variables to be subjected to stepwise regression analysis.

Total nitrogen, nitrate nitrogen, organic nitrogen, total phosphorus, and BOD were correlated with a number of land uses and hydrologic factors, especially cropland, urban areas, forest lands and runoff. There was no significant correlation between suspended solids and percent land uses; however, there was a strong correlation between suspended solids and runoff. This lack of correlation between suspended solids in the stream and land use adjacent to it is understandable, as the suspended solids concentration in a stream is influenced by many factors, including mining operations, construction, agricultural practices, and stream bank erosion. Some of these factors were not included in this analysis. The relative area disturbed by mining activities in each sub-basin was considered in this analysis, but it did not correlate significantly.

Other physical factors, such as average slope of the drainage basins and cover factors, were dropped out in the regression analysis. These were eliminated because they did not correlate significantly with the water quality parameters. The average slope of the drainage basins did have some influence in determining the total phosphorus concentration in the stream and, to a lesser degree, suspended solids concentration, but it was not very significant. The cover factors, which are primarily derived from the agricultural land uses, are not independent from the independent variables (agriculture land uses). The presence of non-independent variables in the stepwise regression can cause "collinearity" which may create severe limitations on the usefulness of the regressions. Collinearity may also add an error in detecting the significance of a correlation (4, 7, 9).

The independent variables initially selected for bivariate analysis were based on judgment and conceptual knowledge of the dominant characteristics on the drainage basins affecting water quality. Availability of data was a significant factor in the selection of these variables. For example, it is quite obvious that the nutrient concentrations in the streams would be greatly influenced by the intensity of nearby agricultural operations, the use of fertilizer, and the number of livestock and feed lot operations. However, the data regarding the amount of fertilizer used and the number of livestock in each basin considered, were not available and could not be used in this analysis. Therefore, it was assumed that the percentage of cropland and pasture land in each drainage basin would take care of such factors. These limitations must be recognized in the evaluation of cause-and-effect relationships identified between water quality and basin characteristics.

The results of bivariate analyses, Table 5, were utilized to select the final set of independent variables (basin characteristics), which were then subjected to stepwise regression analysis. The criteria for this selection were the degree of correlation and the standard error of estimates. The levels of significance used were 1 percent and 5 percent, and less significant variables were eliminated. In stepwise regression analyses, it is desirable to have a smaller number of variables; as the number of variables

Table 5: Correlation Between Water Quality Characteristics and Basin Characteristics

Basin Characterisics	Total Nitrogen	Nitrate Nitrogen	Organic Nitrogen	Ammonia Nitrogen	Total Phosphorus	Suspended Solids	5-Day BOD
Cropland	79.9 **	89.9 **	58.9 *	32.5	86.0 **	43.5	65.6 *
Pasture	31.9	28.3	23.4	8.9	11.4	11.4	31.3
Forest	69.1 *	80.3 **	45.5	8.3	65.3 *	25.9	66.8 *
Urban	78.8 **	68.0 *	59.9 *	58.3 *	64.6 *	6.5	14.8
Cover Factor	58.1 *	77.4 **	9.8	10.2	67.6 *	32.2	45.4
Annual Runoff	64.6 *	70.5 *	58.4 *	19.5	83.0 **	73.5 **	27.7
Slope	43.5	36.9	41.5	11.4	61.3 *	39.9	32.7
Mine Disturbed Area	—	—	—	—	—	41.3	—

* Significant at 5 percent level.

** Significant at 1 percent level.

approaches the number of samples, the explained variation (R^2) automatically approaches unity. Since, however, critical F-value for the test of significance also becomes greater with an increasing number of variables, it may become difficult to obtain significant correlation (7, 9).

The river basin characteristics or independent variables selected for stepwise regression analysis, were those which correlated significantly with the selected water quality parameters, had lowest standard error of estimates, and explained the greatest portion of variance in the dependent variables, the water quality parameters. These river basin characteristics include percent cropland, percent pasture, percent forest, percent urban, percent disturbed by surface mines and runoff. The percent of land disturbed by surface mines was used only in the analysis of suspended solids.

This analysis encompasses the development of annual as well as seasonal relationships between water quality characteristics and river basin characteristics. The results are illustrated in Tables 6 and 7 respectively. The explanation of the seasonal and annual relationships describing water quality parameters related to nonpoint sources, such as total nitrogen, nitrate nitrogen, organic nitrogen, ammonia nitrogen, total phosphorus, suspended solids, and BOD is as follows:

Annual Relationships

The regression equations for the selected water quality parameters obtained by each step of stepwise regression based on annual mean concentration are given in Table 6, along with F-values and the percentage of variations explained by the independent variables.

Total Nitrogen: Total nitrogen is a combination of organic nitrogen and inorganic nitrogen and is one of the best parameters to evaluate the nonpoint source impact. It nullifies the positive and negative effects occurring throughout the year because of changes from one form of nitrogen to the other in the total nitrogen system. These changes are the result of various climatological and hydrologic factors within the drainage basin. The organic nitrogen is converted to ammonia, to nitrite and nitrate, and vice versa.

The final step for total nitrogen (step 4) explained 78 percent of the observed total nitrogen variation, with cropland accounting for about 64 percent, and urban, pasture, and runoff, the remainder. In step 3, the cropland, pasture, and urban areas combined accounted for 76 percent of the variation.

Nitrate Nitrogen: Agricultural areas, especially cropland, are the major source of nitrate nitrogen. Approximately 81 percent variation in nitrate nitrogen concentration is explained by croplands. The remaining 13 percent is due to pasture, forest, urban, and runoff.

Ammonia Nitrogen: The autotrophic conversion of ammonia to nitrite or nitrate, depending upon the residence time, may provide misleading results in evaluating the impacts land use and hydrologic factors exert in determining ammonia concentrations in the streams. The drainage basins in this study are quite large and the sampling stations are located at the lower reaches of these basins. The autotrophic conversion of ammonia, depending upon the travel time to the sampling location or the proximity to major urban areas, may create an error in the analysis results. With these facts in mind, the analysis indicates that, on a gross scale, urban areas, croplands,and runoff factors account for 63 percent variation in ammonia nitrogen concentrations in the streams. The discharge from urban areas alone explained about 34 percent variation, while runoff and urban areas combined for about 59 percent.

Organic Nitrogen: The organic nitrogen in the streams primarily results from runoff from rural areas carrying humic material, debris and other waste material, as well as municipal discharges and runoff from urban areas. Algae growth can also add to the organic nitrogen in the stream. The analysis of ORSANCO data indicated that about 52 percent variation in the organic nitrogen concentration is due to urban buildup, pasture areas, and runoff. The urban areas alone explained about 36 percent variation, and both urban areas and runoff factors about 46 percent.

Total Phosphorus: Agricultural and urban areas are the major contributors of total phosphorus in the streams. In step 4 for the total phosphorus regression, 87 percent variation in total phosphorus is explained by cropland, forest, urban areas and runoff, with cropland and forest lands accounting for 82 percent of this variation. The remainder is due to runoff, which is a significant factor in determining the total phosphorus concentration. The phosphorus is usually associated with the sediments carried to the stream

Table 6: Stepwise Regression Analysis with Variables, Major Land Uses and Runoff, Versus Water Quality

ANNUAL

Step	Equation	% Explained Variation R^2	F-Value
	Ammonia Nitrogen (NH_3-N)		
1.	NH_3-N = 0.1156 + 0.0310 (UR)	34.02	5.16 *
2.	NH_3-N = -0.2950 + 0.0476 (UR) + 0.0221 (RO)	58.99	6.47 *
3.	NH_3-N = -0.1039 - 0.0038 (CR) + 0.0566 (UR) + 0.0133 (RO)	63.10	4.36 *
	Organic Nitrogen (org-N)		
1.	org-N = 0.7247 + 0.0621 (UR)	35.95	5.61 *
2.	org-N = 1.2265 + 0.0418 (UR) - 0.0271 (RO)	45.76	3.79
3.	org-N = 1.5021 - 0.0128 (PS) + 0.0356 (UR) - 0.0319 (RO)	52.10	2.90
	Nitrate Nitrogen (NO_3-N)		
1.	NO_3-N = 0.2377 + 0.0269 (CR)	80.94	42.48**
2.	NO_3-N = 0.4996 + 0.265 (CR) - 0.0187 (PS)	86.33	28.42**
3.	NO_3-N = 0.8268 + 0.0223 (CR) - 0.0206 (PS) - 0.0043 (FS)	76.65	8.76**
4.	NO_c-N = 1.4356 + 0.0159 (CR)- 0.0240 (PS) - 0.0068 (FS) - 0.0190 (RO)	78.00	6.20**

Note: For Legend, See Page 26.

Table 6: Stepwise Regression Analysis with Variables, Major Land Uses and Runoff, Versus Water Quality (Continued)

Step	Equation	% Explained Variation R^2	F-Value
	Total Nitrogen (T-N)		
1.	T-N = 1.230 + 0.0390 (CR)	63.97	17.76**
2.	T-N = 1.7347 + 0.0382 (CR) - 0.0359 (PS)	71.49	11.29**
3.	T-N = 1.5208 + 0.0268 (CR) - 0.0335 (PS) + 0.0897 (UR)	76.65	8.76**
4.	T-N = 2.3612 + 0.0185 (CR) - 0.0380 (PS) + 0.0930 (UR) -0.0386 (RO)	78.00	[illegible].20**
	Total Phosphorus (T-P)		
1.	T-P = 0.0185 + 0.0079 (CR)	73.95	26.39**
2.	T-P = 0.3933 + 0.0137 (CR) + 0.0059 (FS)	82.70	[illegible]
3.	T-P = 0.1037 + 0.0107 (CR) + 0.0050 (FS) - 0.0109 (RO)	85.82	16.1[illegible]**
4.	T-P = 0.1458 + 0.0099 (CR) - 0.0054 (FS) + 0.0081 (UR) -0.0133 (RO)	86.97	11.68**
	Suspended Solids (SS)		
1.	SS = 124.6930 - 4.4280 (RO)	60.75	15.4**
2.	SS = 173.6196 - 4.3172 (UR) - 6.0496 (RO)	81.52	19.85**
3.	SS = 176.2018 - 4.3331 (UR) + 3.5264 (MA) - 6.5946 (RO)	83.20	13.21**
4.	SS = 180.7151 - 0.2199 (PS) - 4.4378 (UR) + 3.2494 (MA) - 6.6339 (RO)	83.50	8.86**

Table 6: Stepwise Regression Analysis with Variables, Major Land Uses and Runoff, Versus Water Quality (continued)

Step	Equation	% Explained Variation R^2	F-Value
	5-Day Biochemical Oxygen Demand (BOD)		
1.	BOD = 4.9535 - 0.0454 (FX)	57.60	1[illegible].59**
2.	BOD = 5.8642 - 0.0622 (PS) - 0.0476 (FS)	70.32	10.6[illegible]**
3.	BOD = 6.4678 - 0.0652 (PS) - 0.0372 (FS) - 0.0687 (RO)	[illegible].38	[illegible]**
4.	BOD = 11.3544 - 0.0592 (CR) - 0.0930 (PS) - 0.0746 (FS) -0.1558 (RO)	81.13	75.[illegible]**

* Significant at 5% level

** Significant at 1% level

CR Cropland

PS Pasture

FS Forest

UR Urban

RO Runoff

MA Mine Disturbed Areas

with runoff.

The urban and agricultural areas could not be the cause of all phosphorus concentration in the streams. The phosphorus deposits in a stream's bottom may add to the phosphorus concentration during high runoff periods, due to a stream scour mechanism.

Suspended Solids: The suspended solids concentration in the stream is caused by such activities as construction and agricultural operations. Other contributors to this problem include mining activities, stream bank erosion, and runoff from rural and urban areas.

In step 4 of the suspended sediment regression, over 83 percent of sediment concentration is attributed to agricultural areas, urban areas, mining activities, and runoff. The runoff factor alone explained about 61 percent variation in the suspended solids (step 1).

5-Day BOD: In regard to 5-day BOD, cropland, pasture, forest and runoff accounted for about 81 percent variation. The urban areas have less impact in determining the BOD concentration.

Seasonal Relationships

Seasonal relationships between water quality parameters and river basin characteristics obtained by each step of stepwise regression analysis, along with F-values and the percentage of explained variation in the concentrations or selected water quality constituents are given in Table 6. The seasonal relationship analysis covers fall, winter, spring, and summer.

Total Nitrogen: During fall, the 82 percent variation in total nitrogen concentration is attributed to cropland, forest, pastures, and urban areas, with urban and cropland accounting for 76 percent. In winter, cropland, pasture, urban areas and runoff explained 77 percent variation, but forest land contribution was not significant. In spring, cropland, pasture, urban areas and runoff explained 79 percent variation, with cropland accounting for 72 percent. In summer, the cropland, pasture, and forest areas explained 53 percent variation, but contribution from urban areas was less significant.

Runoff had a major impact in determining total nitrogen concentrations in winter and spring, but did not have major impact in fall and summer. The reduction in nitrogen concentration during summer is due to growing crops accumulating a large part of the nitrate nitrogen in this period.

Nitrate Nitrogen: The major sources of nitrate nitrogen are urban and agricultural areas. The change in relative contribution of nitrate nitrogen by cropland during summer and winter is dramatic. The cropland explained about 87 percent variation in winter, and 53 percent in summer. The reduction of nitrate nitrogen in the July-August period is expected because growing crops, especially corn, accumulate a larger percentage of nitrogen during this period. The reduction appears to occur in late spring through August, a period of crop establishment and rapid plant growth which lead to nitrogen accumulation.

Ammonia Nitrogen: The major sources of ammonia nitrogen in the stream are urban areas and to some extent, croplands. The ammonia fertilizer applied to crops readily converts to nitrate nitrogen. However, depending upon the hydrologic factors and travel time to the sampling station, a part of the ammonia fertilizer may reach the stream.

In fall and winter, urban areas and runoff factors explained a larger part of variation in ammonia nitrogen concentration, and croplands were less significant. A higher percentage of nitrogen during winter runoff is in the ammonia form. During summer, croplands joined urban areas as significant contributors. A partial explanation of these variations apparently lies in the use of ammonia fertilizer in agricultural areas during establishment and growing seasons of crops, usually corn, during the spring and summer months.

Organic Nitrogen: The relationship of organic nitrogen concentration to major land uses and runoff was not as pronounced in winter and summer seasons as during fall and spring. In fall, urban areas explained 62 percent out of 75 percent variation in organic nitrogen, and the remainder was due to cropland, forest, and pasture. The runoff factor did not affect the organic nitrogen concentration to a significant extent.

In spring, however, runoff was a significant factor in determining the organic nitrogen concentration. Out of a total 82 percent variation, runoff was responsible for 57 percent, and the remainder was due to urban, pasture, and forest areas.

Total Phosphorus: Throughout the year, the agricultural areas, especially croplands and urban areas, contribute significantly to total phosphorus concentration in the streams; however, analyses of relationships during the summer season indicated they were not very significant. The variation in phosphorus concentration explained by cropland in fall, winter, and spring was 81 percent, 75 percent, and 69 percent respectively. The low contribution in late spring and summer is due to the utilization of a considerable part of the phosphorus (soluble) by growing plants. Clearly, the hazard posed by phosphorus (soluble) is not so great during the growing season as it is during fall, winter, and early spring. Additionally, during periods of high flow the increase in total phosphorus concentration is due to the suspension of particulate phosphorus from scour of bottom deposits, as well as contributions from surface runoff.

Suspended Solids: There are several factors which influence the degree of sediment concentration in the streams, including runoff, tillage, and other agricultural operations, land management, construction, stream bank erosion, and mining activities. Based on a selected set of basin characteristics, the analysis indicates that urban areas and runoff factors explain about 51 per cent of the variation in sediment concentrations in the fall. In the winter months, runoff, urban areas, and rural lands--including cropland, pasture, and forest areas--accounted for 87 percent variation, with runoff responsible for about 61 percent. No significant regression was found for spring. In summer, the runoff generated by high intensity-short duration rainfall explained about 45 percent variation.

5-Day BOD: For 5-day BOD, one significant regression is obtained in fall, one in winter, five in spring and four in summer. This indicates the seasonal signifance of various factors in determining BOD concentration.

In fall, 71 percent variation in BOD is explained by cropland, pasture, forest, and runoff. The significant regression for winter included only runoff factors, explaining about 38 percent variation. Out of spring's 88 percent explained variation, due to runoff, rural, and urban areas, 79 percent is attributable to urban and forest areas. In summer, 89 percent variation is due to cropland, forest, pasture and runoff. Of that total 64 percent is explained by croplands.

Table 7: Stepwise Regression Analysis with Variables, Major Land Uses and Runoff, Versus Water Quality

SEASONAL EVALUATION

Season	Step	Equation	% Explained Variation R^2	F-Value
		Ammonia Nitrogen (NH_3-N)		
Fall	1.	NH_3-N = 0.1176 + 0.0233 (UR)	33.93	5.13 *
	2.	NH_3-N = 0.1158 + 0.0348 (UR) + 0.0506 (RO)	56.70	5.88 *
	3.	NH_3-N = 0.0486 − 0.0049 (PS) + 0.0340 (UR) + 0.0515 (RO)	63.14	4.57 *
	4.	NH_3-N = 0.1295 + 0.0018 (CR) − 0.0050 (PS) + 0.0299 (UR) + 0.0665 (RO)	64.39	3.16
	5.	NH_3-N = 0.5348 + 0.0067 (CR) − 0.0031 (PS) + 0.0043 (FS) + 0.0323 (UR) = 0.0806 (RO)	70.08	2.81
Winter	1.	NH_3-N = 0.1909 + 0.0272 (UR)	68.09	21.34**
	2.	NH_3-N = 0.0969 + 0.0034 (CR) = 0.0252 (UR)	72.25	11.72**
	3.	NH_3-N = 0.2010 + 0.0033 (CR) − 0.0072 (PS) + 0.0246 (UR)	74.98	7.99**
	4.	NH_3-N = 0.3768 + 0.0016 (CR) − 0.0106 (PS) + 0.0238 (UR) − 0.0079 (RO)	77.26	5.94**
Spring	1.	NH_3-N = 0.1838 + 0.0180 (UR)	9.94	1.10
	2.	NH_3-N = 0.2612 − 0.0106 (CR) + 0.0608 (UR)	62.04	7.35 *
Summer	1.	NH_3-N = 0.1455 + 0.0579 (RO)	10.9	1.22
	2.	NH_3-N = −0.0001 + 0.0178 (UR) + 0.0785 (RO)	23.24	1.37
	3.	NH_3-N = 0.1941 − 0.0077 (CR) + 0.0441 (UR) + 0.0192 (RO)	53.15	3.02
	4.	NH_3-N = −0.0060 − 0.0052 (CR) + 0.0025 (FS) + 0.0456 (UR) +0.0261 (RO)	54.91	2.13

Note: For Legend, See Page 37.

Table 7: Stepwise Regression Analysis with Variables, Major Land Uses and Runoff, Versus Water Quality (continued)

Season	Step	Equation	% Explained Variation R^2	F-Value
		Organic Nitrogen (org-N)		
Fall	1.	org-N = 0.5395 + 0.0567 (UR)	62.59	16.73**
	2.	org-N = 0.5669 - 0.0037 (CR) + 0.0719 (UR)	66.76	9.04**
	3.	org-N = 0.6647 - 0.0036 (CR) - 0.0067 (FS) + 0.0703 (UR)	70.61	6.41 *
	4.	org-N = 1.1657 - 0.0094 (CR) - 0.0098 (PS) - 0.0064 (FS) + 0.0649 (UR)	75.06	5.27 *
	5.	org-N = 1.3462 - 0.0119 (CR) - 0.0099 (PS) - 0.0072 (FS) + 0.0662 (UR) - 0.0238 (RO)	75.60	3.72
Winter	1.	org-N = 0.9233 + 0.0415 (UR)	24.87	3.31
	2.	org-N = 1.0659 0.0098 (PS) + 0.0395 (UR)	30.69	2.01
	3.	org-N = 1.3515 - 0.0106 (PS) - 0.030 (UR) - 0.0362 (RO)	34,67	1.41
	4.	org-N = 1.7215 - 0.0078 (CR) - 0.0112 (PS) + 0.0519 (UR) - 0.0763 (RO)	43.49	1.34
Spring	1.	org-N = 2.3065 - 0.3628 (RO)	57.37	13.46**
	2.	org-N = 2.8063 - 0.0234 (PS) - 0.4264 (RO)	68.83	9.94**
	3.	org-N = 3.0291 - 0.0288 (PS) + 0.0081 (FS) - 0.5831 (RO)	72.85	7.16**
	4.	org-N = 2.2656 - 0.0226 (PS) + 0.0139 (FS) + 0.0589 (UR) - 0.5479 (RO)	81.69	7.81 *
Summer	1.	org-N = 0.5568 + 0.0177 (CR)	25.9	3.49
	2.	org-N = -1.4695 + 0.0464 (CR) + 0.0293 (FS)	40.8	3.11

Table 7: Stepwise Regression Analysis with Variables, Major Land Uses and Runoff, Versus Water Quality (continued)

Season	Step	Equation	% Explained Variation R^2	F-Value
		Nitrate Nitrogen (NO_3-N)		
Fall	1.	NO_3-N = 0.1463 + 0.0252 (CR)	81.29	43.46**
	2.	NO_3-N = 0.3234 + 0.0250 (CR) - 0.0126 (PS)	84.71	23.82**
	3.	NO_3-N = 0.2518 + 0.0211 (CR) - 0.0118 (PS) + 0.0300 (UR)	85.85	16.19**
Winter	1.	NO_3-N = 0.2370 + 0.0336 (CR)	87.04	67.16**
	2.	NO_3-N = 0.5336 + 0.0332 (CR) - 0.0186 (PS)	90.72	44.03**
	3.	NO_3-N = 1.0583 + 0.0261 (CR) - 0.0213 (PS) - 0.0072 (FS)	91.92	30.35**
	4.	NO_3-N = 1.3286 + 0.0236 (CR) - 0.0233 (PS) - 0.0104 (FS) - 0.0057 (UR)	92.24	20.82**
Spring	1.	NO_3-N = 0.1185 + 0.0306 (CR)	71.00	24.41**
	2.	NO_3-N = 0.4167 + 0.0301 (CR) - 0.0213 (PS)	75.76	14.07**
Summer	1.	NO_3-N = 0.4344 + 0.0160 (CR)	53.58	11.54**
	2.	NO_3-N = 0.7143 + 0.0155 (CR) - 0.0200 (PS)	65.18	8.43**
	3.	NO_3-N = 0.7605 + 0.0180 (CR) - 0.0205 (PS) - 0.0193 (UR)	66.38	5.27 *

Table 7: Stepwise Regression Analysis with Variables, Major Land Uses and Runoff, Versus Water Quality (continued)

	Step	Equation	% Explained Variation R^2	F-Value
		Total Nitrogen (T-N)		
Fall	1.	T-N = 0.9048 + 0.1907 (UR)	69.47	22.76**
	2.	T-N = 0.7930 + 0.0153 (CR) + 0.1289 (UR)	76.29	14.4[illegible]**
	3.	T-N = 1.1462 + 0.0155 (CR) - 0.0244 (PS) + 0.1230 (UR)	81.22	11.5[illegible]**
	4.	T-N = 1.9148 + 0.0067 (CR) - 0.0290 (PS) - 0.0099 (FS) - 0.1149 (UR)	82.25	8.11**
Winter	1.	T-N = 1.4477 + 0.0456 (CR)	66.27	19.13**
	2.	T-N = 1.9928 + 0.0445 (CR) - 0.0389 (PS)	72.95	12.13**
	3.	T-N = 2.6160 + 0.0379 (CR) - 0.0506 (PS) - 0.0290 (RO)	75.57	8.25**
	4.	T-N = 2.4663 + 0.0368 (CR) - 0.0476 (PS) + 0.0137 (UR) - 0.0258 (RO)	76.87	5.82 *
Spring	1.	T-N = 1.1597 + 0.0468 (CR)	66.21	19.59**
	2.	T-N = 0.9392 + 0.0328 (CR) + 0.1094 (UR)	71.76	11.44**
	3.	T-N = 1.2716 + 0.0330 (CR) + 0.1039 (UR) - 0.0229 (PS)	73.95	7.57 *
	4.	T-N = 4.1491 + 0.0103 (CR) - 0.0550 (PS) + 0.0973 (UR) - 0.5725 (RO)	78.85	6.53 *
Summer	1.	T-N = 1.2308 + 0.0338 (CR)	36.15	5.66 *
	2.	T-N = 1.9647 + 0.0327 (CR) - 0.0524 (PS)	48.16	4.18
	3.	T-N = -).1346 + 0.0602 (CR) - 0.0400 (PS) + 0.0279 (FS)	52.64	2.96

Table : Stepwise Regression Analysis with Variables, Major Land Uses and Runoff, Versus Water Quality (continued)

Season	Step	Equation	% Explained Variation R^2	F-Value
		Total Phosphorus (T-P)		
Fall	1.	T-P = -0.0317 + 0.0072 (CR)	81.52	44.12**
	2.	T-P = 0.0543 + 0.0061 (CR) - 0.0161 (RO)	82.26	20.87**
	3.	T-P = 0.0634 + 0.0051 (CR) + 0.0061 (UR) - 0.0202 (RO)	83.12	[illegible]
	4.	T-P = 0.0481 + 0.0065 (CR) _ 0.0012 (FS) + 0.0067 (UR) - 0.0157 (RO)	83.56	8.90**
Winter	1.	T-P = 0.0371 + 0.0069 (CR)	75.43	30.71**
	2.	T-P = -0.0860 + 0.0087 (CR) + 0.0018 (FS)	77.10	15.14**
	3.	T-P = 0.1445 + 0.0091 (CR) + 0.0023 (PS) + 0.0022 (FS)	78.20	9.57**
Spring	1.	T-P = 0.0325 + 0.0072 (CR)	69.57	22.87**
	2.	T-P = -0.3769 + 0.0130 (CR) + 0.0059 (FS)	79.44	17.39**
	3.	T-P = 0.1493 + 0.0115 (CR) + 0.0079 (FS) - 0.0869 (RO)	87.61	18.87**
	4.	T-P = 0.1892 + 0.0087 (CR) - 0.0062 (PS) + 0.0072 (FSP - 0.1349 (RO)	91.32	18.42**
Summer	1.	T-P = 0.5413 - 0.1280 (RO)	26.42	3.59
	2.	T-P = 0.7701 - 0.0124 (PS) - 0. 1634 (RO)	38.96	2.87
	3.	T-P = 0.6017 + 0.0024 (CR) - 0.0103 (PS) - 0.1289 (RO)	41.48	1.89

Table : Stepwise Regression Analysis with Variables, Major Land Uses and Runoff, Versus Water Quality (continued)

Season	Step	Equation	% Explained Variation R^2	F-Value
		5-Day Biochemical Oxygen Demand		
Fall	1.	BOD = 3.65 - 0.02 (FS)	18.30	2.23
	2.	BOD = 4.89 - 0.08 (PS) - 0.03 (FS)	40.60	3.10
	3.	BOD = 9.74 - 0.07 (CR) - 0.11 (PS) - 0.09 (FS)	53.10	3.69
	4.	BOD =14.52 - 0.13 (CR) - 0.12 (PS) - 0.11 (FS) - 0.60 (RO)	71.20	4.33 *
Winter	1.	BOD = 5.81 - 0.40 (RO)	38.30	6.21 *
	2.	BOD = 6.50 - 0.05 (PS) - 0.41 (RO)	47.60	4.10
	3.	BOD = 5.74 - 0.04 (PS) + 0.06 (UR) - 0.35 (RO)	50.10	2.70
Spring	1.	BOD = 6.01 - 0.06 (FS)	72.42	20.26**
	2.	BOD = 4.22 - 0.04 (FS) + 0.17 (UR)	79.46	17.41**
	3.	BOD = 5.77 - 0.03 (CR) - 0.06 (FS) + 0.19 (UR)	81.57	11.80**
	4.	BOD = 6.67 - 0.03 (CR) - 0.05 (FS) + 0.20 (UR) - 0.13 (RO)	83.17	8.65**
	5.	BOD =10.46 - 0.06 (CR) - 0.07 (PS) - 0.06 (FS) + 0.18 (UR) - 0.87 (RO)	88.15	8.93**
Summer	1.	BOD = 0.79 + 0.08 (CR)	64.34	18.04**
	2.	BOD = 1.77 + 0.08 (CR) - 0.07 (PS)	71.20	11.14**
	3.	BOD = 6.77 + 0.01 (CR) - 0.09 (PS) - 0.07 (FS)	79.4	10.30**
	4.	BOD = 8.12 - 0.03 (CR) - 0.09 (PS) - 0.10 (FS) + 1.15 (RO)	88.9	13.99**

Table 7: Stepwise Regression Analysis with Variables, Major Land Uses and Runoff, Versus Water Quality (continued)

Season	Step	Equation	% Explained Variation R^2	F-Value
		Suspended Solids (SS)		
Fall	1.	SS = 50.0273 - 3.9135 (RO)	11.82	1.47
	2.	SS = 88.2819 - 3.7465 (UR) - 8.9136 (RO)	50.92	5.19 *
	3.	SS = 88.235 - 3.7843 (UR) + 3.1844 (MA) - 10.2325 (RO)	55.63	3.76
	4.	SS =105.1270 - 0.4859 (FS) - 5.1064 (UR) + 6.8514 (MA) - 8.8280 (RO)	63.35	3.46
	5.	SS = 97.4026 + 0.3815 (PS) - 0.4493 (FS) - 4.8561 (MA) - 9.5044 (RO)	66.47	2.77
Winter	1.	SS =189.5165 - 16.9154 (RO)	61.57	17.62**
	2.	SS =241.8873 - 4.5415 (UR) - 21.1234 (RO)	75.08	15.07**
	3.	SS =274.6006 - 0.8542 (FS) - 7.4104 (UR) - 18.4054 (RO)	87.00	17.42**
	4.	SS =256.29 + 0.59 (PS) - 0.75 (FS) - 6.67 (UR) - 18.20 (RO)	87.00	13.39**
	5.	SS =218.21 + 0.47 (CR) + 0.78 (PS) - 0.43 (FS) - 6.80 (UR) - 16.67 (RO)	87.52	9.82**
Spring	1.	SS = 47,73 + 0.35 (CR)	5.59	0.65
	2.	SS = 51.19 + 1.70 (CR) + 1.40 (FS)	25.86	1.74
	3.	SS = 36.05 + 2.03 (CR) + 1.27 (FS) - 3.50 (UR)	34.16	1.55
	4.	SS = 31.49 + 2.35 (CR) + 0.83 (FS) - 5.64 (UR) + 0.93 (MA)	44.01	1.57
	5.	SS = 1.79 + 2.47 (CR) + 1.27 (FS) - 6.42 (UR) + 19.86 (MA) -21.32 (RO)	60.09	2.17

Table 7: **Stepwise Regression Analysis with Variables, Major** Land Uses and Runoff, Versus Water Quality (continued)

Season	**Step**	**Equation**	**% Explained Variation R^2**	F-Value
		Suspended Solids (SS) (continued)		
Summer	1.	SS = 136.56 - 34.28 (RO)	45.23	9.05 *
	2.	SS = 153.59 - 2.26 (UR) - 36.37 (RO)	47.59	[illegible] *

* Significant at 5% level

** Significant at 1% level

CR Cropland

PS Pasture

FS Forest

UR Urban

RO Runoff

MA Mine Disturbed Areas

It should be recognized that this analysis was based on very limited BOD data and results obtained may be misleading.

LIMITATIONS

Statistical analysis of water quality has some inherent limitations which must be recognized in evaluating the results of such an analysis. These limitations include:

1. Water quality in a stream is primarily determined by the major land use and other characteristics of the drainage basin. On some of these drainage basin characteristics information is lacking. For example, data on the use of fertilizer and the number of livestock in each sub-basin, which apparently influence the nutrient concentration in streams, are not available. It was assumed that percent of area under agricultural operations would take care of such factors.

2. The degree of treatment provided to municipal discharges is generally neglected in this analysis. It is assumed that the percent of urban areas in each sub-basin will serve as a factor for municipal sewage discharges and urban runoff, regardless of the degree of treatment being provided to these discharges.

3. This analysis did not take into account the influence exerted by the industrial discharges. However, the parameters selected for this study are less likely to be influenced by the industrial discharges.

4. Careful consideration is required in the selection of river basin characteristics, or independent variables. Some of the independent variables which indirectly explain the effect of another variable might cause collinearity, which creates problems in the detection of a correlation's significance.

5. The size of the watershed or sub-basin represented by a water quality station is critically important. The larger the drainage basin and the more diverse it becomes, the greater the uncertainty in pinpointing contribution from specific sources.

Regardless of these limitations, the results of this analysis indicate the nonpoint source pollutants nitrogen, phosphorus, and, to some degree, BOD correlate with the intensity of agricultural operations and runoff factors. The phosphorus emissions are not very strongly correlated with land use activities, indicating that phosphorus emissions are determined in part by geochemistry and phosphorus deposits in streams absorbed on sediment deposits. The BOD concentration level responds broadly to agricultural operations and urban areas.

CONCLUSIONS

Regulations under PL 92-500 require that water quality management plans should include land use considerations as they relate to nonpoint source pollution. One of the procedures which offers considerable promise in the evaluation of land use and hydrologic impacts on water quality is regression analysis.

Application of bivariate and stepwise regression analysis to sub-basins in the Ohio River Basin indicates that land use has a significant impact on river quality near the mouth of tributaries, especially the concentrations of total nitrogen, nitrate nitrogen, total phosphorus, and BOD, but not suspended solids. Suspended solids are influenced not only by agricultural and urban areas, but by a number of factors, including mining activities, construction, and stream bank erosion.

Agricultural and urban areas have a major impact upon the nutrient and BOD concentration in the streams. Cropland accounts for the large part of nitrogen concentration, especially nitrate nitrogen, but does not completely explain the suspended solids concentration.

The quality of surface runoff from agricultural areas is also affected by cultural and fertilization practices, and the number of cattle and feedlot operations. These factors could not be considered because of the lack of such data for all the sub-basins and because it is desirable to have a smaller number of variables to obtain significant regression.

This analysis provides annual and seasonal quantitative and qualitative relationships between water quality and major land uses, as well as the relative significance of each land use in determining water quality. This analysis also provides the impact of runoff and other hydrologic and physical factors in determining water quality. These relationships may be helpful in water quality management for the Ohio River Basin.

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