SURFACE-WATER QUALITY IN THE WEST BRANCH

SUSQUEHANNA RIVER BASIN, PENNSYLVANIA:

An Appraisal of Areal and Temporal Variability from 1962 to 1982 in Hydrologic Accounting Unit 020502

By Robert A. Hainly, John F. Truhlar, and Kim L. Wetzel

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who prefer metric (International System) units rather than the inch-pound units in this report, the following conversion factors may be used:

Multiply inch-pound units	By	To obtain metric units
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
degree Fahrenheit (°F)	°C=5/9 (°F-32)	degree Celsius (°C)

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ABSTRACT

The West Branch Susquehanna River basin has a drainage area of 6,955 square miles in north-central Pennsylvania and comprises Hydrologic Accounting Unit 020502. A National Stream Quality Accounting Network (NASQAN) water-quality data collection site, maintained by the U.S. Geological Survey, is located on the river near its mouth at Lewisburg, Pennsylvania. Water-quality data are collected at numerous other sites throughout the basin by the Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management.

Data collected from the NASQAN site and the sites operated by the Pennsylvania Department of Environmental Resources from 1962 to 1982 were used to evaluate water-quality variability in the basin. The following objectives were addressed: (1) describe the surface-water quality upstream of the NASQAN site on an areal and temporal basis; (2) relate the water-quality variability, on both an areal and temporal basis, to general basin characteristics; and (3) assess the ability of the water-quality data collected at the NASQAN site to represent, on both an areal and temporal basis the water quality for Hydrologic Accounting Unit 020502 upstream from the site.

Areally, the water quality varies considerably throughout the basin. Generally, the river was found to have moderately good water quality in the upper reaches, poor water quality in its middle reach, and good water quality near the mouth. Two tributaries, Moshannon Creek (median pH 3.9) and Bald Eagle Creek (median pH 7.8), had the most pronounced effect on the water quality of the river.

Temporal trends were found in the concentrations of several of the constituents at most of the stations. Of the constituents analyzed, those which exhibited increasing or decreasing trends most frequently were pH, alkalinity, dissolved sulfate, total ammonia, and total nitrite plus nitrate. The largest trends were in the concentrations of total-recoverable aluminum, manganese, and zinc.

Causes of areal variation were attributed to land use and geologic variations throughout the basin. Trends which indicated an improvement in water quality are believed to be caused by improvements in the treatment of acid mine drainage and wastewater. Trends which indicated degradation of water quality were generally found in areas where these types of treatment are not yet effective.

The NASQAN site at Lewisburg was shown not to represent the water quality of the entire basin, either areally or temporally. It does, however, represent the water quality of the West Branch Susquehanna River at its mouth.

INTRODUCTION

Efficient water management, planning and pollution control require a knowledge of streamflow and water quality, which in turn require organized systems of data collection. Optimum data-collection systems differ, depending on the purpose of the study. Studies may range from intensive examinations of individual streams with specific problems to nationwide assessments of overall water quality. The need for the different systems and advantages of each are described by van Belle and Hughes (1983). One network operated by the U.S. Geological Survey is NASQAN.

NASQAN is a national network of surface-water stations at which many water-quality characteristics are measured on a systematic and continuing basis in order to assess the quality of the nation's larger rivers. The primary purpose of NASQAN is to provide information for national water management and planning. Ficke and Hawkinson (1975) list other objectives of NASQAN and describe design criteria and many other details of the program.

The West Branch Susquehanna River drains Hydrologic Accounting Unit 020502 in north-central Pennsylvania. Hydrologic units identify a hydrologic system; accounting units delineate river basins having drainage areas usually greater than 700 mi^2 (square miles) (U.S. Geological Survey, 1982). This report is an appraisal of the surface-water quality in Hydrologic Accounting Unit 020502. Water-quality data for NASQAN for the Hydrologic Accounting Unit are collected from the West Branch Susquehanna River at Lewisburg (station number 01553500). Figure 1 shows the West Branch Susquehanna River basin, the subdivisions (Cataloging Units) of the Hydrologic Accounting Unit, and the major tributaries to the West Branch Susquehanna River.

The purpose of this report is to describe the characteristics of the basin that affect surface-water quality and to evaluate the water-quality variability and trends in the basin. The following objectives were addressed:

1. Describe, on both an areal and temporal basis, the surface-water quality throughout Hydrologic Accounting Unit 020502 upstream of the NASQAN site on the West Branch Susquehanna River at Lewisburg, Pennsylvania.

2. Relate the water-quality variability, on both an areal and temporal basis, to general causes such as selected basin characteristics including land use and water use.

3. Assess the ability of water-quality data collected at the NASQAN station to represent, on both an areal and temporal basis, the water quality for Hydrologic Accounting Unit 020502 upstream from the station.

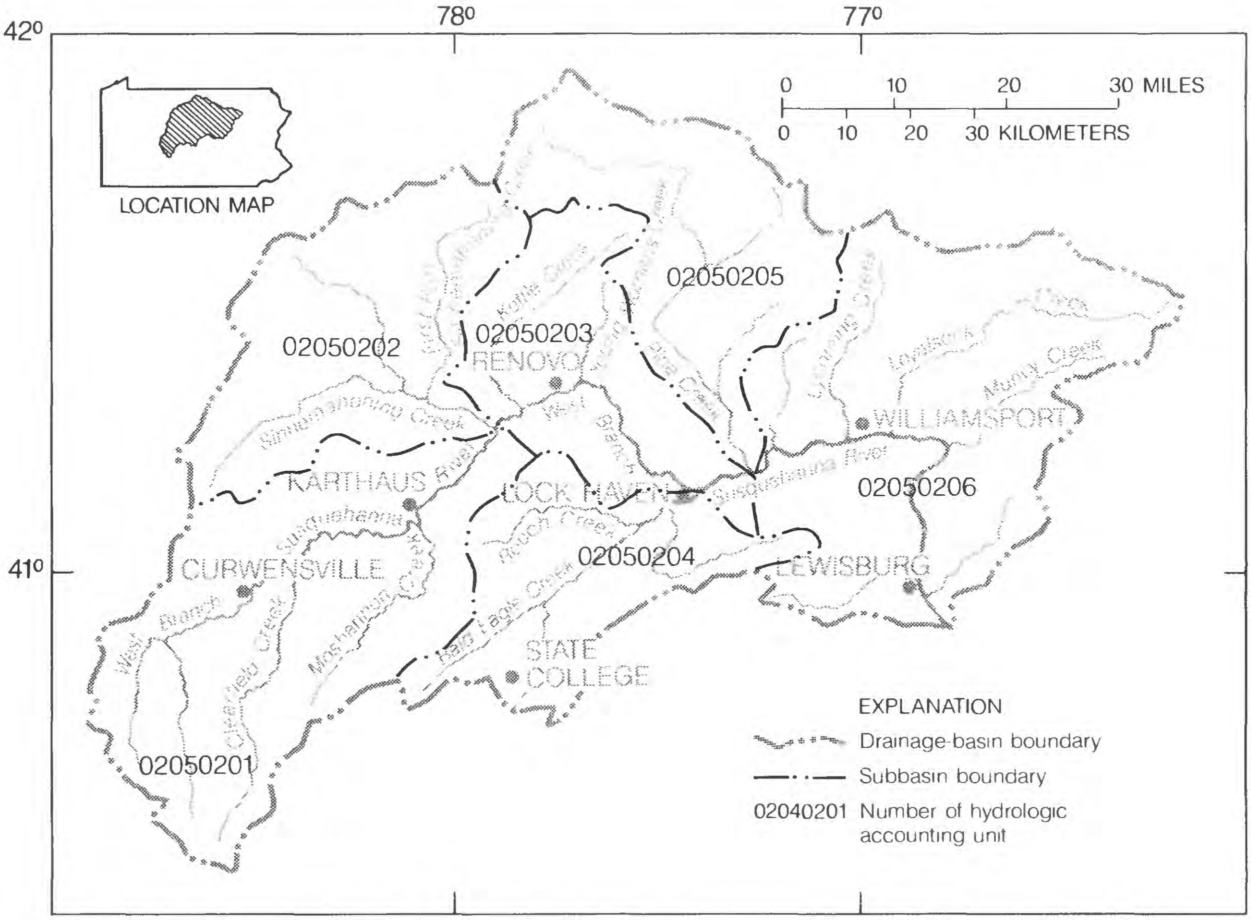


Figure 1.--Hydrologic accounting unit and major tributaries.

BASIN CHARACTERISTICS

The West Branch Susquehanna River drains 6,955 mi² in north-central Pennsylvania. It flows generally eastward and joins the Susquehanna River at the southeast corner of the basin, 7.4 mi (miles) downstream from Lewisburg. The drainage area at the NASQAN gage site at Lewisburg is 6,847 mi², slightly more than 98 percent of the basin. Average flow at the gage is 10,820 ft³/s (cubic feet per second), which is equal to 21.46 in. (inches) per year runoff.

Physiography

The West Branch Susquehanna River basin comprises parts of two physiographic provinces, the Appalachian Plateaus Province and the Valley and Ridge Province (fig. 2). An erosional scarp, the Allegheny Front, marks the boundary between the two provinces. Northwest of the Front, flat-topped mountains and deeply incised streams with steep-walled valleys characterize the topography of the Allegheny High Plateaus Section. The mountains are more rounded and the valleys are more open in the remainder of the Appalachian Plateaus Province. Folded mountains forming long, narrow ridges and broad valleys characterize the Valley and Ridge Province (Pennsylvania Department of Environmental Resources, 1979, 1980).

Altitudes of the mountain tops in both provinces are generally from 2,000 to 2,200 ft (feet), but some mountains in the Appalachian Plateaus Province are as high as 2,500 ft. Valley altitudes adjacent to the river range from about 1,220 ft at Bower to about 440 ft at Lewisburg.

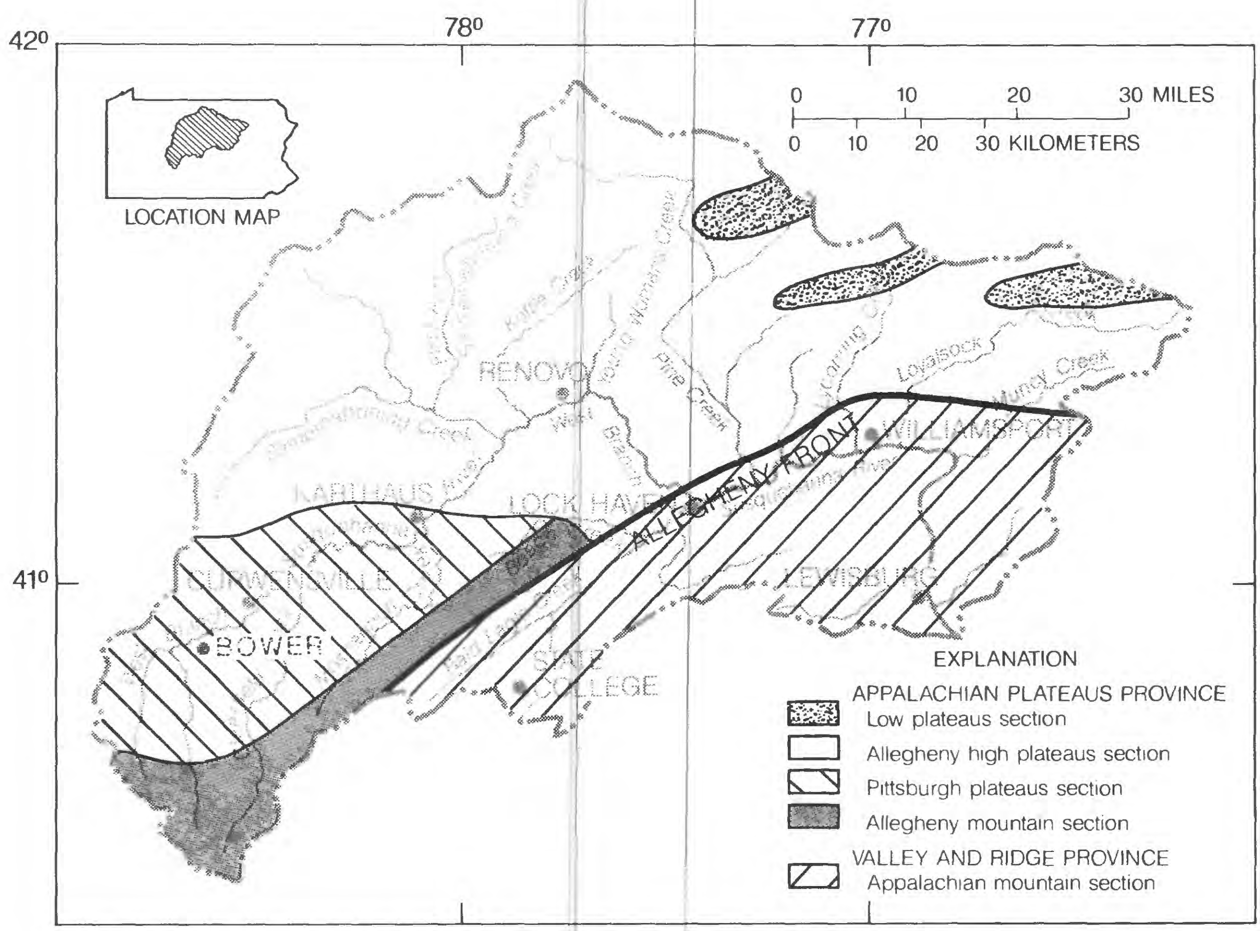


Figure 2.--Physiographic provinces. (Adaped from Pennsylvania Department of Environmental Resources, Topographic and Geologic Survey, 1962 Map 13.)

Geology

Paleozoic sedimentary rocks underlie the entire West Branch Susquehanna River basin (fig. 3). Sandstone and shale are the predominant rock types but extensive formations of limestone and dolomite occur in the Valley and Ridge Province (fig. 4). Minor amounts of limestone also occur in the Plateau Province but have little effect on surface-water quality. Streams draining the Plateau generally have low concentrations of dissolved solids and alkalinity in areas where they have been relatively unaffected by man's activities. Streams draining limestone areas in the Valley and Ridge Province have comparatively high concentrations of dissolved solids and alkalinity.

Much of the West Branch Susquehanna River basin is underlain by coal of Pennsylvanian age (fig. 4). Although the distribution of coal is extensive, less than 4 percent of the surface area of the basin has been disturbed by mining. Nevertheless, mine drainage from surface mines and abandoned deep mines is the major water-quality problem in the basin (Pennsylvania Department of Environmental Resources, 1982).

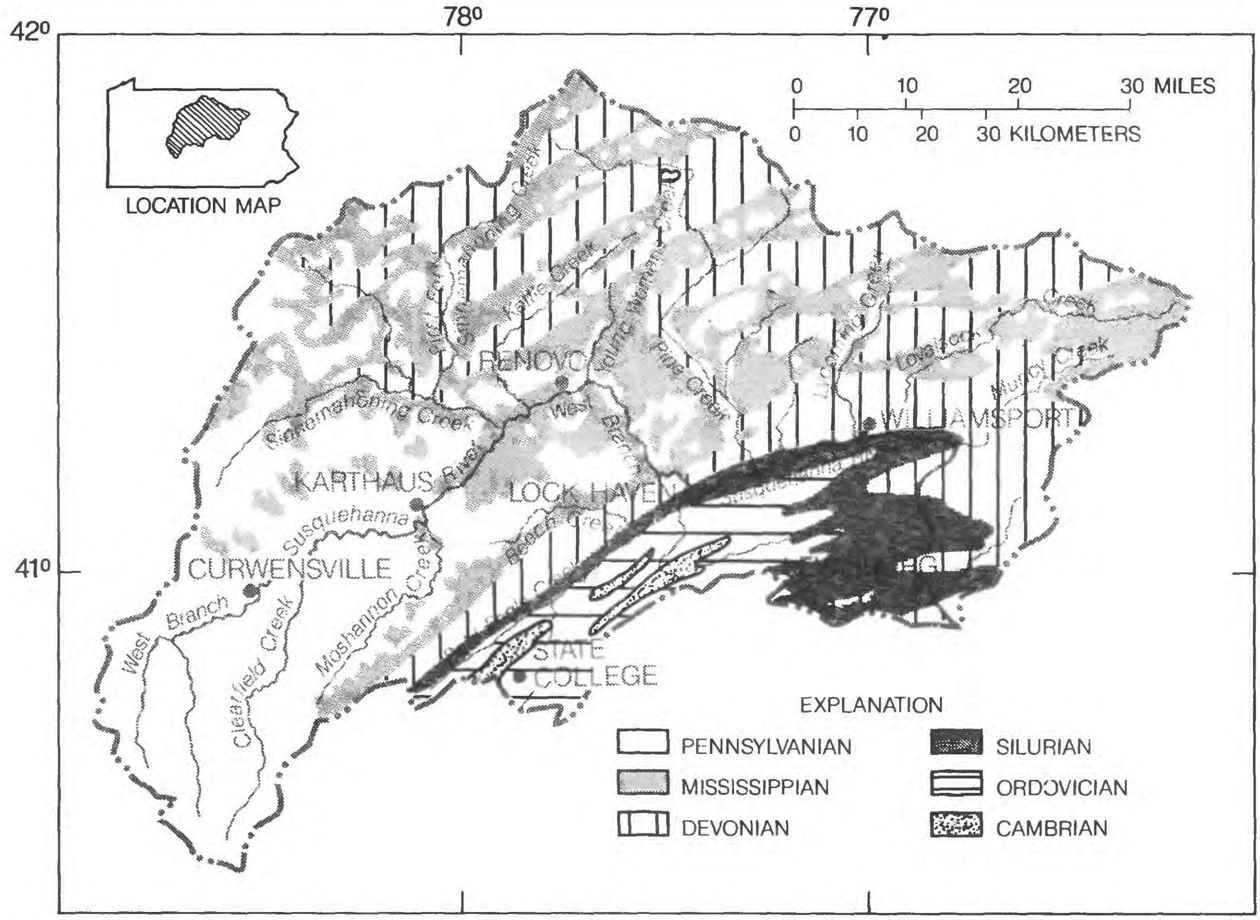


Figure 3.--Geology. (Adapted from Pennsylvania Department of Environmental Resources, Topographic and Geologic Survey, 1962 Map 7.)

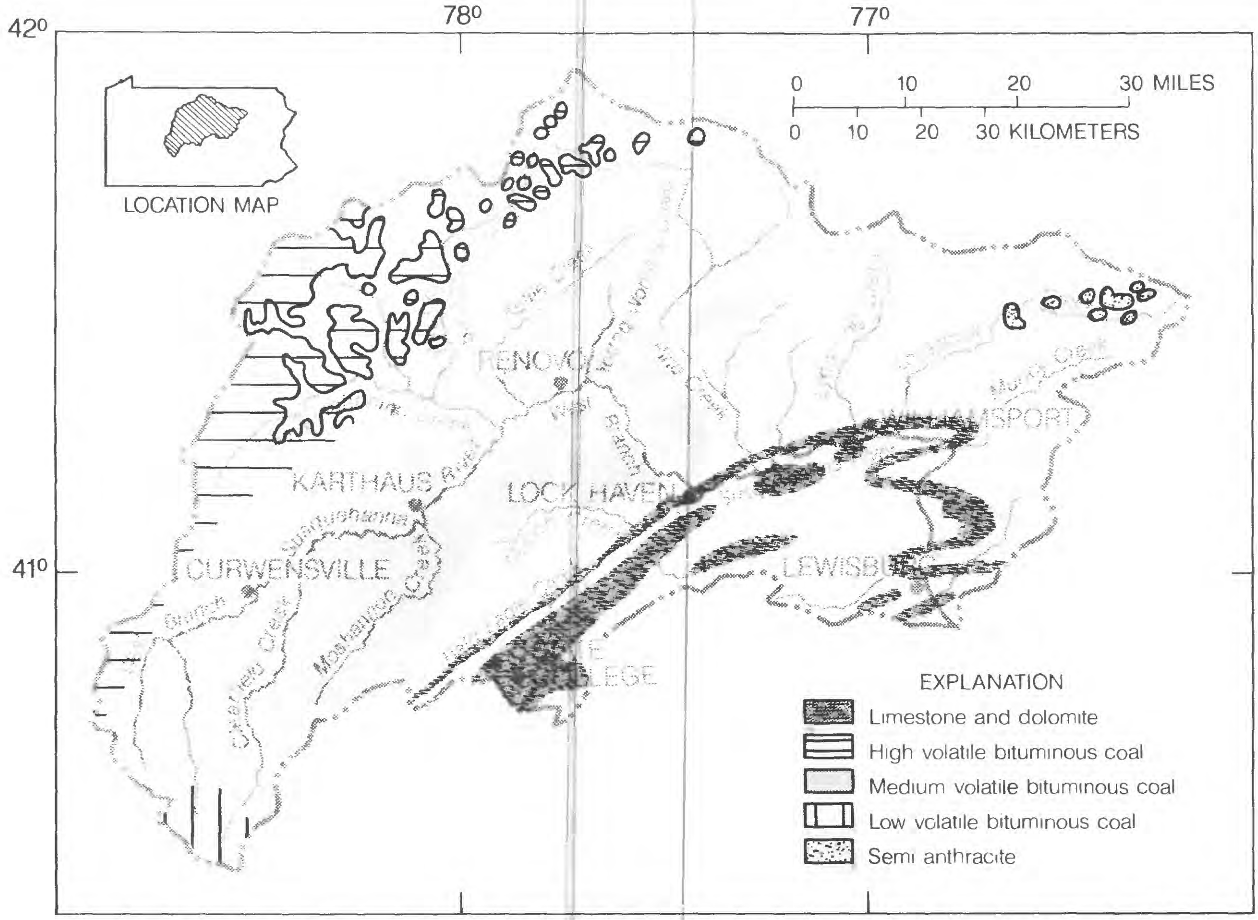


Figure 4.--Surface distribution of limestone and dolomite and of coals. (Adapted from Pennsylvania Department of Environmental Resources, Topographic and Geologic Survey, 1964, Map 11, and 1974, Map 15.)

Climate

The West Branch Susquehanna River basin has a continental inland climate with warm humid summers and moderately cold winters. Prevailing winds are from the west and northwest but easterly winds accompany major storms that move northeast from the Gulf of Mexico. Monthly mean temperatures range from about 25 °F in January to 69 °F in July. Precipitation averages about 40 in. per year and ranges from about 2.3 in. in February to 4.2 in. in May (U.S. Department of Commerce, 1982).

Land Use

The West Branch Susquehanna River basin was divided into three subbasins for the State Water Plan (Pennsylvania Department of Environmental Resources, 1979, 1980). Forests occupy an average of 79 percent of the West Branch Susquehanna River basin (fig. 5). Agricultural and open land account for 13 percent of the land use, and 4 percent of the land is urban or suburban. The remaining 4 percent includes land that has been disturbed by surface mining and other miscellaneous uses. The northern and western parts of the basin are the most heavily forested. Agriculture occurs mostly in the limestone valleys in the southeastern part of the basin. Urbanized areas are concentrated in the southern half of the basin.

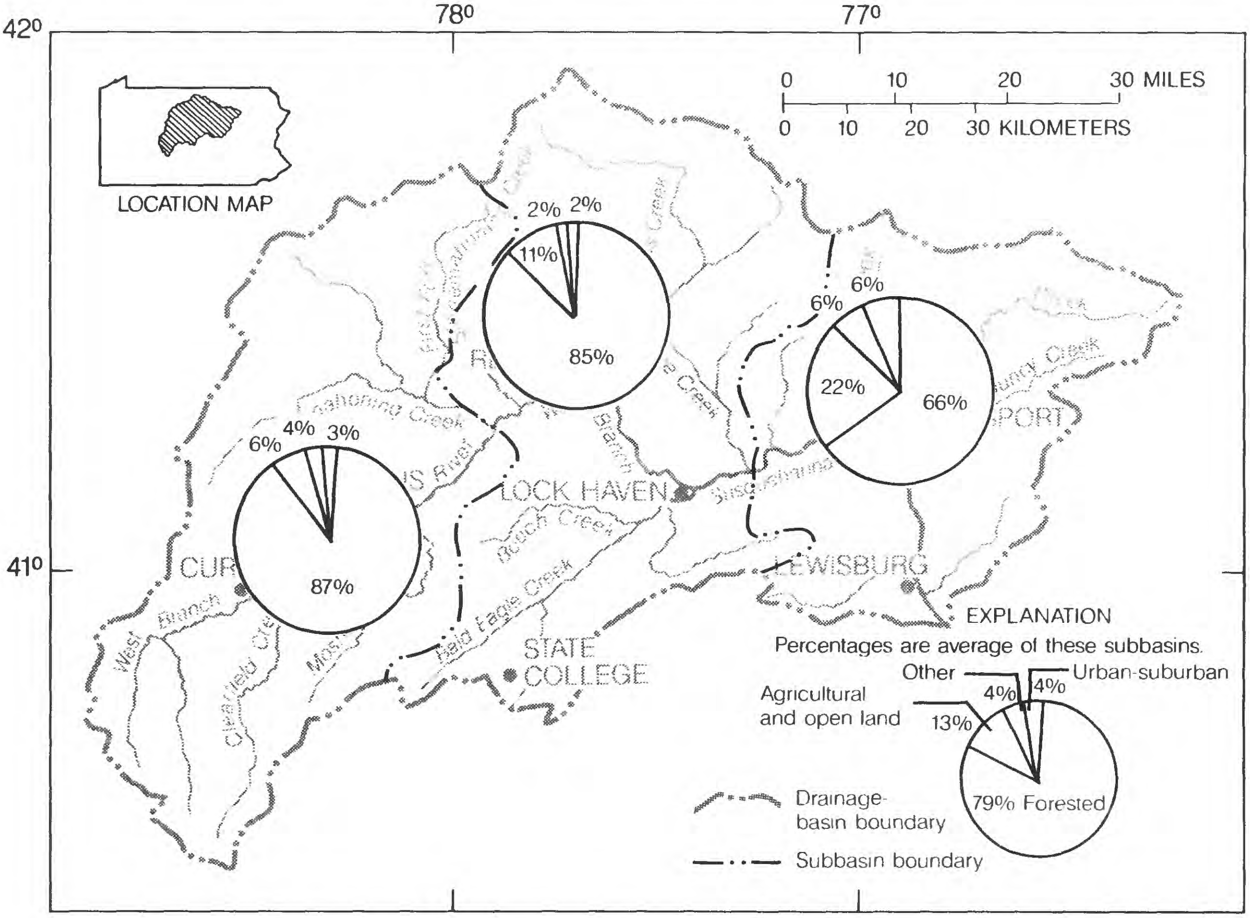


Figure 5.--Land use by State Water Plan subbasin.

Population

The West Branch Susquehanna River basin is in a lightly populated area of the state. The 1980 population for the basin was projected to be 441,445 in the State Water Plan (Pennsylvania Department of Environmental Resources, 1979, 1980). Most of the population is concentrated in the southern half of the basin, especially along the West Branch Susquehanna River Valley downstream from Bald Eagle Creek and in the upper reaches of the Bald Eagle Creek basin. The combined metropolitan areas of Williamsport and State College account for about one-fourth of the total population.

Surface-Water-Quality Problems

Acid mine drainage is the major cause of water-quality degradation in the West Branch Susquehanna River basin and often masks other water-quality problems (Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management, 1982). Mine-drainage problems are concentrated in the southwestern part of the basin but also occur in isolated locations throughout the Appalachian Plateaus Province. The problem is so severe that the river is virtually devoid of fish between the mouths of Moshannon Creek and Bald Eagle

Creek (Pennsylvania Department of Environmental Resources, Office of Resources Management, 1980). High alkalinity water--mean 96.9 mg/L (milligrams per liter)--from Bald Eagle Creek and relatively good-quality water from Pine and Lycoming Creeks combine to improve the quality of the West Branch Susquehanna River so that it supports a variety of fish at Williamsport.

Effluents from municipal wastewater treatment facilities are concentrated in the southern half of the basin as indicated in figure 6. The amount of population served and the size of each facility is shown by the sizes of the areas indicated as planning areas by the Comprehensive Water Quality Management Plan (COWAMP). These are areas identified in the COWAMP studies (Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management, 1981, 1982, 1983) which may need additional sewage treatment facilities, including on-lot disposal systems.

Water-quality degradation from municipal wastewater effluents has generally not been a serious problem in the West Branch Susquehanna River basin, although enrichment and eutrophication in Bald Eagle Creek have resulted from discharges in the State College area.

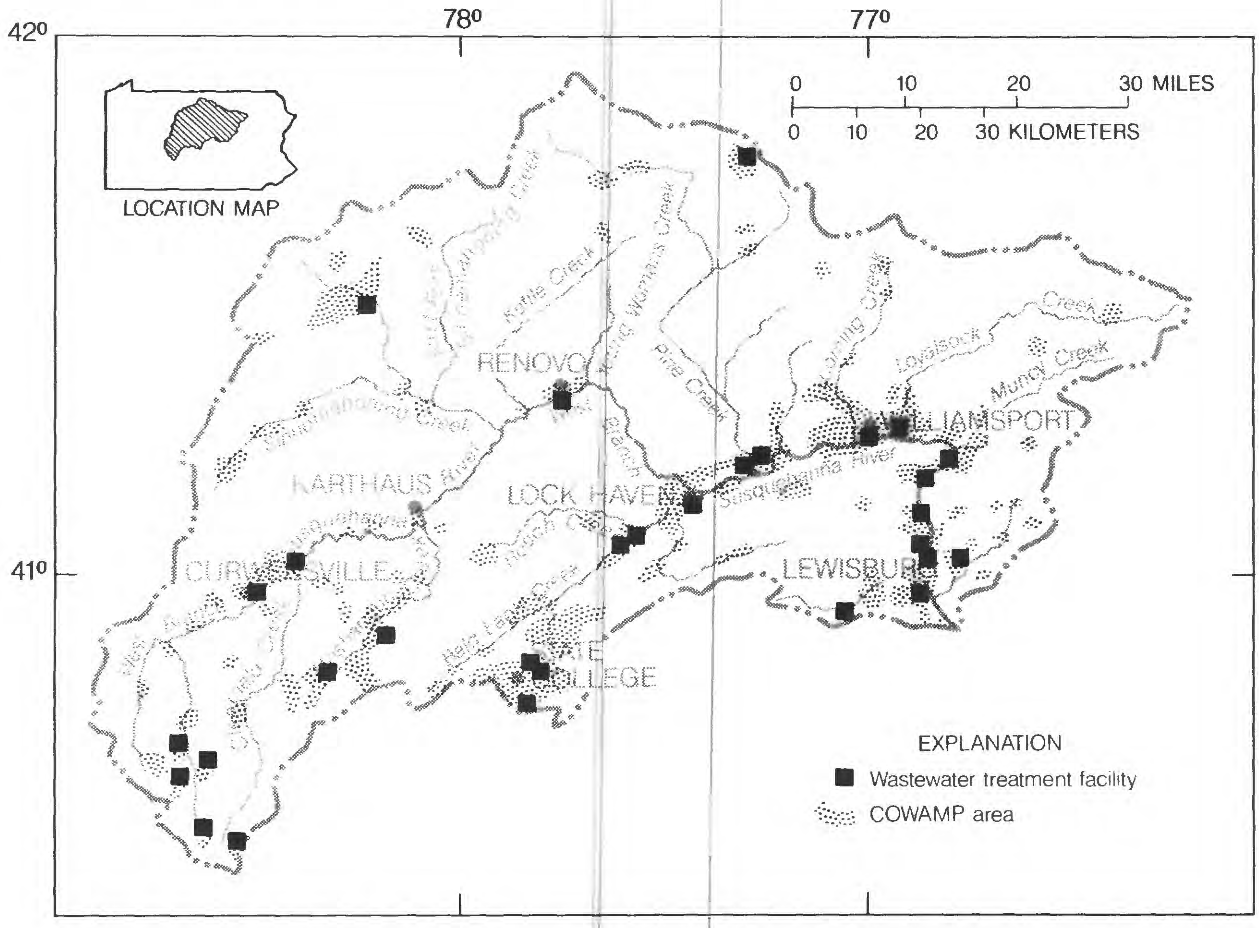


Figure 6.--Municipal waste water treatment facilities and Comprehensive Water Quality Management Plan areas.

DATA COLLECTION AND ANALYSIS

Sources

The data used for this study were collected by two agencies: the U.S. Geological Survey and the Pennsylvania Department of Environmental Resources (PaDER). The stations maintained by the U.S. Geological Survey are part of the NASQAN and the Hydrologic Bench-Mark Program. The stations operated by the PaDER are part of the State-wide Water Quality Network.

The stations that were selected for this investigation are listed in table 1 and are shown in figure 7. Generally, stations were selected if they were located on the main stem of the river or on a large tributary near its mouth. Two of the stations listed in the table are operated by the U.S. Geological Survey--Young Womans Creek near Renovo and West Branch Susquehanna River at Lewisburg. Water-quality data from the remaining 16 stations were collected by PaDER. The U.S. Geological Survey collects streamflow data at 14 of these 16 stations. No streamflow data are available for Clearfield Creek at Mount Hope and Muncy Creek at Hughesville.

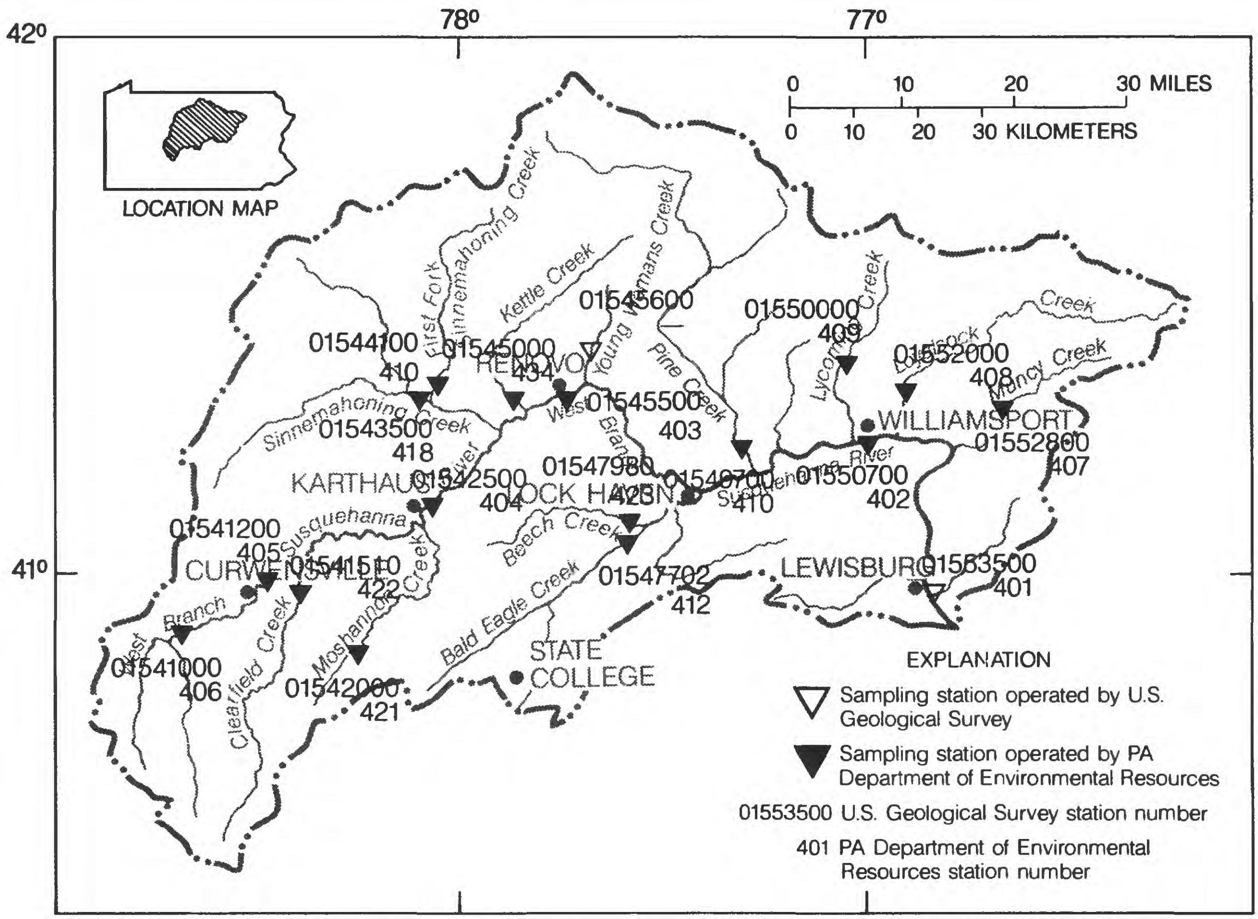


Figure 7.--Locations of surface-water-quality stations.

Many chemical, physical, and biological characteristics were available for analysis from the combined data collected by the two agencies. Several of the characteristics were analyzed by both agencies, although the PaDER generally analyzed whole water samples; whereas, the U.S. Geological Survey analyzed filtered water samples. After examination of all available data, 25 characteristics were selected for analysis based on length of record, continuity of record, and sample frequency. The characteristics, the statistical analyses, and the period of record used are shown in table 2. All the characteristics except metals were analyzed for each sample collected (sample frequency is shown in table 1). Samples for metals concentrations were taken usually during low base flow in August and occasionally during high spring base flow.

Table 1.--Surface-water-quality stations
[USGS, U.S. Geological Survey; PaDER, Pennsylvania Department of Environmental Resources; deg, degrees; min, minutes; sec, seconds; mi^2, square miles; ND, not determined]

USGS no. PaDER no.	Station name	Latitude Longitude (deg, min, sec)	Drainage area (mi^2)	Sample frequency
01541000 406	West Branch Susquehanna River at Bower	40 53 49 78 40 38	315	monthly
01541200 405	West Branch Susquehanna River at Curwensville	40 57 41 78 31 10	367	monthly
01541510 422	Clearfield Creek at Mount Hope	40 59 09 78 24 22	ND	quarterly
01542000 421	Moshannon Creek at Osceola Mills	40 50 58 78 16 05	68.8	quarterly
01542500 404	West Branch Susquehanna River at Karthaus	41 07 03 78 06 33	1,462	quarterly
01543500 418	Sinnemahoning Creek at Sinnemahoning	41 19 02 78 06 12	685	monthly
01544100 419	First Fork Sinnemahoning Creek at Sinnemahoning	41 19 12 78 04 51	267	monthly
01545000 434	Kettle Creek near Westport	41 19 12 77 52 27	233	quarterly
01545500 403	West Branch Susquehanna River at Renovo	41 19 24 77 45 02	2,975	quarterly
01545600 ---	Young Womans Creek near Renovo	41 23 22 77 41 28	46.2	monthly
01547702 412	Bald Eagle Creek at Eagleville	41 03 31 77 35 44	ND	monthly
01547980 423	Beech Creek at Beech Creek	41 04 29 77 35 32	ND	quarterly
01549700 410	Pine Creek below Little Pine Creek near Waterville	41 16 25 77 19 28	944	monthly
01550000 409	Lycoming Creek near Trout Run	41 25 06 77 01 59	173	monthly
01550700 402	West Branch Susquehanna River at Williamsport	41 13 44 77 01 09	5,682	monthly
01552000 408	Loyalsock Creek at Loyalsockville	41 19 26 76 54 42	443	monthly
01552800 407	Muncy Creek at Hughesville	41 14 55 76 43 03	ND	monthly
01553500 401	West Branch Susquehanna River at Lewisburg	40 58 05 76 52 25	6,847	monthly

Table 2.--Statistical analyses and periods of record used for characteristics examined at each water-quality station

Characteristics, by group	Trend analysis 1972-82	Trend analysis 1962-82	Areal analysis 1972-82
Physical properties, pH and alkalinity			
pH	x	x	x
Specific conductance	x	x	x
Alkalinity as $CaCO_3$	x	x	x
Dissolved solids at 105 °C	x	x	x
Dissolved solids at 180 °C	x		
Suspended sediment	x		
Suspended solids	x	x	
Major ions			
Calcium, total as Ca	x		x
Calcium, dissolved as Ca	x	x	
Magnesium, total as Mg	x		x
Magnesium, dissolved as Mg	x	x	
Chloride, dissolved as Cl	x	x	x
Sulfate, dissolved as SO_4	x	x	x
Nutrients			
Nitrogen, ammonia, total as N	x		x
Nitrite plus nitrate, total as N	x		x
Phosphorus, total as P	x	x	
Trace metals			
Iron, total recoverable as Fe	x	x	x
Iron, dissolved as Fe	x		
Manganese, total recoverable as Mn	x	x	x
Manganese, dissolved as Mn	x		
Aluminum, total recoverable as Al	x	x	x
Zinc, total recoverable as Zn	x		x
Zinc, dissolved as Zn	x		
Lead, total recoverable as Pb	x		x

Quality Assurance

The samples collected and analyzed by the U.S. Geological Survey were done according to methods suggested by Brown and others (1970) and Skougstad and others (1979). PaDER follows guidelines recommended in "Standard Methods" (American Public Health Association, 1980) for data collection and laboratory analyses. PaDER laboratory also participates in the Survey's Standard Reference Water Sample program. The U.S. Geological Survey then provides the PaDER laboratory with a statistical report on the results of the quality-assurance samples (Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management, 1982).

Data have been collected since 1972 at the station located on the West Branch Susquehanna River at Lewisburg by both PaDER and the U.S. Geological Survey. The simultaneous collection of these data allows a direct comparison of the sample collection techniques and analysis methods of the two agencies. It also allows the determination of their comparability for areal and temporal analyses and the ability of the NASQAN station to represent the water quality of the entire basin. The data were compared for the 1972-82 water years using the Wilcoxon rank sum nonparametric test. This procedure is used to ascertain whether two exclusive sets of data exhibit equivalent population distributions for a common constituent (Lewis and Ford, 1983). This test does not require any assumptions regarding the normalcy of the data. Therefore, if the two data sets are from the common population of data collected, then no distinction between the two will be detected.

Equivalent population distributions were found for the characteristics collected at Lewisburg by the Survey and the PaDER at the 99 percent confidence level except for total phosphorus, total nitrite plus nitrate, and dissolved chloride. The differences observed for the three constituents are probably due to a combination of differences in data collection and laboratory analysis techniques. Although the data differ slightly, they are still acceptable as indicators of variation because the methods of collection and analysis were constant throughout the period covered by this study.

DESCRIPTION OF SURFACE-WATER-QUALITY VARIABILITY

Areal Variability

Variability was examined using the data collected during the 1972-82 water years in four groups (table 2): (1) physical properties, pH, and alkalinity; (2) major ions; (3) nutrients; and (4) trace metals.

The computed constituent values presented in this report may vary from the actual values due to the type of sampling program. Values given for range, mean, or median are computed from intermittent samples collected monthly or quarterly (table 1). The majority of water-quality samples collected cover about 85 percent of the range of streamflows at a sampling site. Sparse coverage usually is within the lower 5 percent and upper 10 percent of the measured streamflows. There are some samples collected in these extreme ranges but not enough to be representative of these periods. Inadequate coverage of high flows can affect the ranges and means reported for the data and has the least effect on the reported medians. For the trace metals, which were only sampled once or twice a year, even the medians may be affected. Therefore, the data presented in the following sections do not represent conditions actually present in the streams during high flows.

Physical Properties, pH and Alkalinity

The water-quality characteristic, pH, commonly is used as an indicator of water quality. Generally, good quality water has a pH range of 6.0 to 8.0. The lowest pH values measured were generally at the station on Moshannon Creek (median 3.9); the highest at the station on Bald Eagle Creek (median 7.8) (fig. 8). The effect of acid mine drainage on the water quality of Clearfield and Moshannon Creeks and the West Branch Susquehanna River is pronounced, as shown by the decrease in median pH between Curwensville (6.9) and Karthaus (4.3). The value of pH is slightly higher at Renovo (median 4.8) because of inflow from Sinnemahoning (median 6.1) and Kettle Creeks (median 6.8). The value of pH significantly increases between Renovo and Williamsport (median 6.7) because of the relatively good water quality of three large tributaries--Bald Eagle Creek (median 7.8), Pine Creek (median 7.1), and Lycoming Creek (median 7.2). There is little difference in median pH value between the stations at Williamsport and Lewisburg (7.1).

Variations in mean alkalinity at selected stations in the West Branch Susquehanna River basin are shown in figure 8. As indicated by the figure, most of the stations have a very low mean alkalinity, 2.0 to 23 mg/L, compared to Bald Eagle Creek (103 mg/L). Alkalinity decreases between Curwensville and Karthaus because of the inflow of the acidic waters of Clearfield (mean alkalinity 3.8 mg/L) and Moshannon Creeks (mean alkalinity 8.6 mg/L). Generally, the lowest values of pH were measured in water samples from these two stations and from the station on Beech Creek. Acidity in these streams normally is higher than the alkalinity in the river. Between the Karthaus and Renovo stations on the main stem, mean alkalinity increases slightly from 2.8 to 5.6 mg/L. It continues to increase, at a higher rate, downstream to Lewisburg. The major contributor of alkalinity to the main stem is Bald Eagle Creek, where the mean concentration for the 1972 to 1982 water years was five to ten times higher than the mean concentration at any of the other stations.

As shown by figure 8, the variability of specific conductance and the concentrations of dissolved solids throughout the basin is very similar. This is understandable because of the close relationship of these two characteristics. The highest values were found at the stations on streams with poor water quality, Moshannon and Clearfield Creeks, and at the station on the West Branch Susquehanna River at Karthaus. The lowest values, indicators of good water quality, were found at all the tributary stations below Sinnemahoning Creek, except Bald Eagle Creek. The dissolution of limestone within the Bald Eagle Creek basin produces rather hard water with moderately high specific conductance--mean 291 μS/cm (microsiemens per centimeter at 25 degrees Celsius)--and concentrations of dissolved solids (mean 196 mg/L).

Figure 9 shows the range, mean, and median for the 1972-82 water years for specific conductance at the indicated stations. Upstream stations on the main stem have moderately high mean values of specific conductance. The values increase at Karthaus after the contributions of Clearfield (mean 357 μS/cm) and Moshannon Creeks (mean 597 μS/cm) and then, generally, decrease from Karthaus (mean 391 μS/cm) to Lewisburg (mean 197 μS/cm). The figure also shows the variability of specific conductance at each site. In most cases, those with the largest range are the stations on the main stem or the tributaries significantly affected by acid mine drainage.

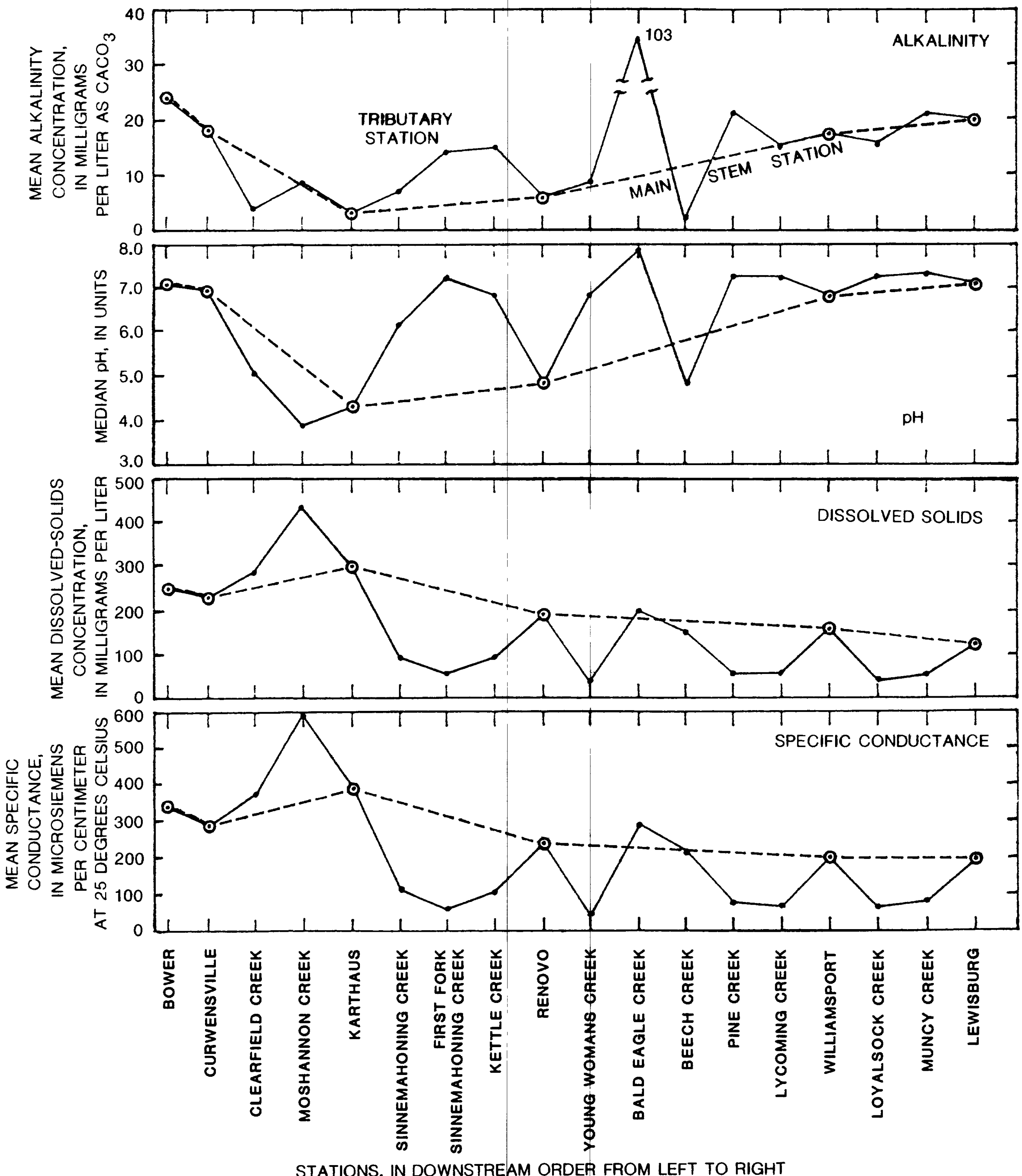


Figure 8.--Variations in mean alkalinity, specific conductance, dissolved-solids concentration, and median pH at water-quality stations, 1972-82 water years.

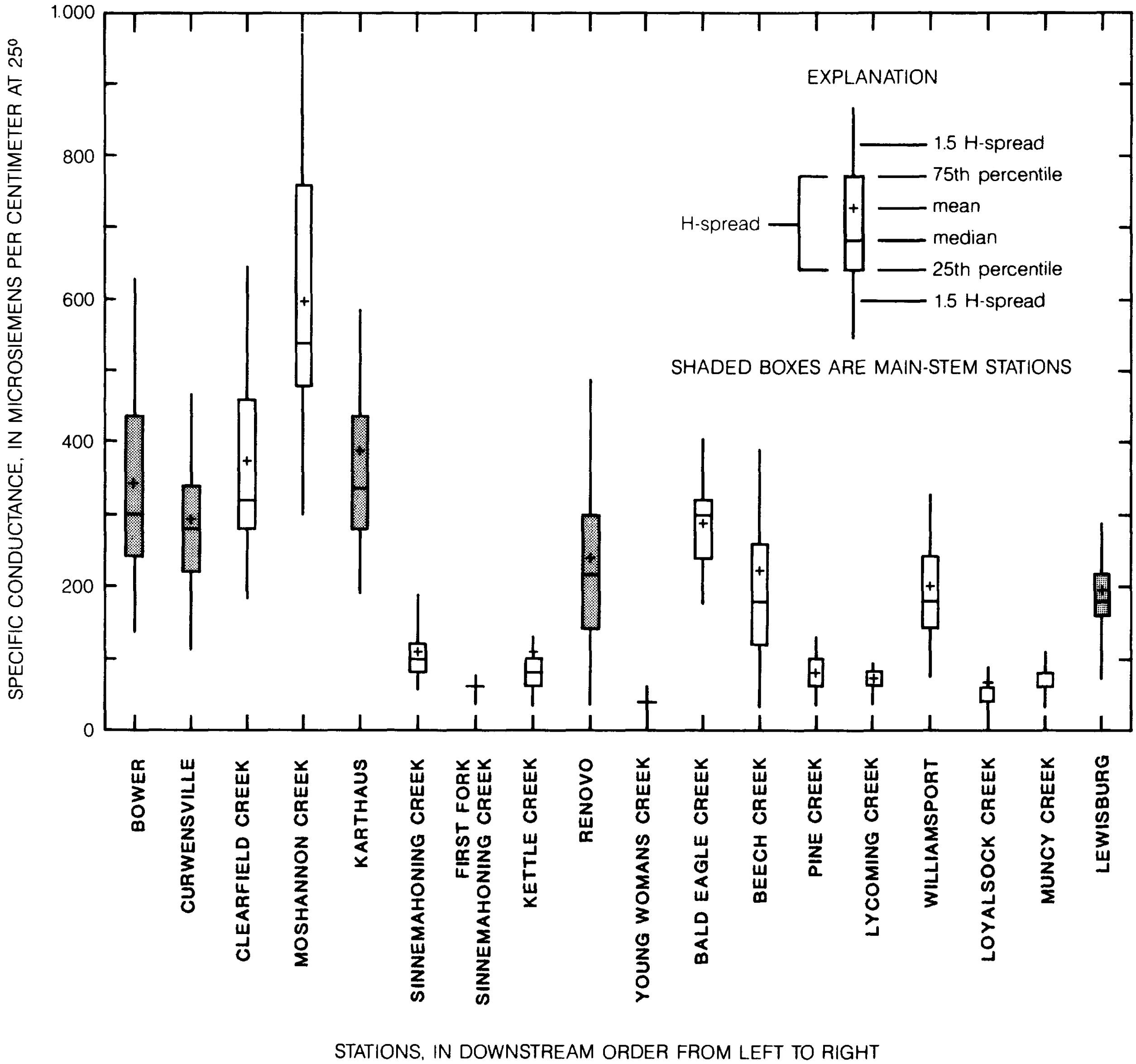


Figure 9.--Specific conductance at water-quality stations, 1972-82 water years.

Major Ions

The group of chemical constituents labeled "major ions" includes total calcium, total magnesium, dissolved sulfate, and dissolved chloride. Variations in the mean concentrations of these four constituents are shown in figure 10. Much of the total calcium and magnesium appears to be contributed from the area drained by the main stem above Bower, Bald Eagle Creek, and the three more acidic streams, Clearfield, Moshannon, and Beech Creeks. The highest mean concentrations of total calcium were found in the West Branch Susquehanna River at Bower (37 mg/L) and in Moshannon Creek (42 mg/L); the lowest in Young Womans Creek (4.0 mg/L). The highest total magnesium concentrations were found in Clearfield (18 mg/L) and Moshannon Creeks (25 mg/L) and in the main stem at Karthaus (19 mg/L); the lowest, again, in Young Womans Creek (1.0 mg/L). In the main stem, mean concentrations for both constituents are relatively high at Bower, increase slightly at Karthaus, and then decrease to Williamsport. There is little change in calcium and magnesium concentrations in the river between Williamsport and Lewisburg. The relatively large calcium and magnesium contribution of Bald Eagle Creek tends to maintain constant concentrations between the main stem stations at Renovo and Williamsport.

Dissolved-chloride concentrations throughout the basin vary only slightly. Figure 10 shows the range of all the mean values at the surface-water-quality stations in the basin. With the exception of Young Womans Creek (1.3 mg/L) and Bald Eagle Creek (13.5 mg/L), the means range from about 3 to 11 mg/L. The mean concentrations at the stations on the main stem decrease in a downstream direction except for a slight increase between Renovo and Williamsport, primarily because of the influence of Bald Eagle Creek.

High dissolved-sulfate concentrations, like low pH values, are generally indicators of poor water quality. Once again, the highest mean concentrations were found on the streams most affected by acid mine drainage--Clearfield (165 mg/L) and Moshannon Creeks (245 mg/L) and the West Branch Susquehanna River at Karthaus (175 mg/L) (fig. 10). The lowest mean concentrations were found at Young Womans (7.6 mg/L), Bald Eagle (24 mg/L), and Lycoming Creeks (13 mg/L). Figure 11 indicates the range of concentrations at each site. Moshannon Creek had the largest range of all the stations with values of 150 mg/L and 290 mg/L for the 25th and 75th percentiles, respectively. The station at Bower on the main stem has a moderately-high mean concentration of 120 mg/L. The mean concentration at Curwensville decreases slightly (102 mg/L), but the mean concentration at Karthaus increases sharply to 175 mg/L because of the sulfate discharged from Clearfield (mean 165 mg/L) and Moshannon Creeks (mean 245 mg/L) and other small tributaries. Following the increase at the main stem station at Karthaus, the sulfate concentrations decrease along the main stem to Lewisburg, where a mean concentration of 52 mg/L was found.

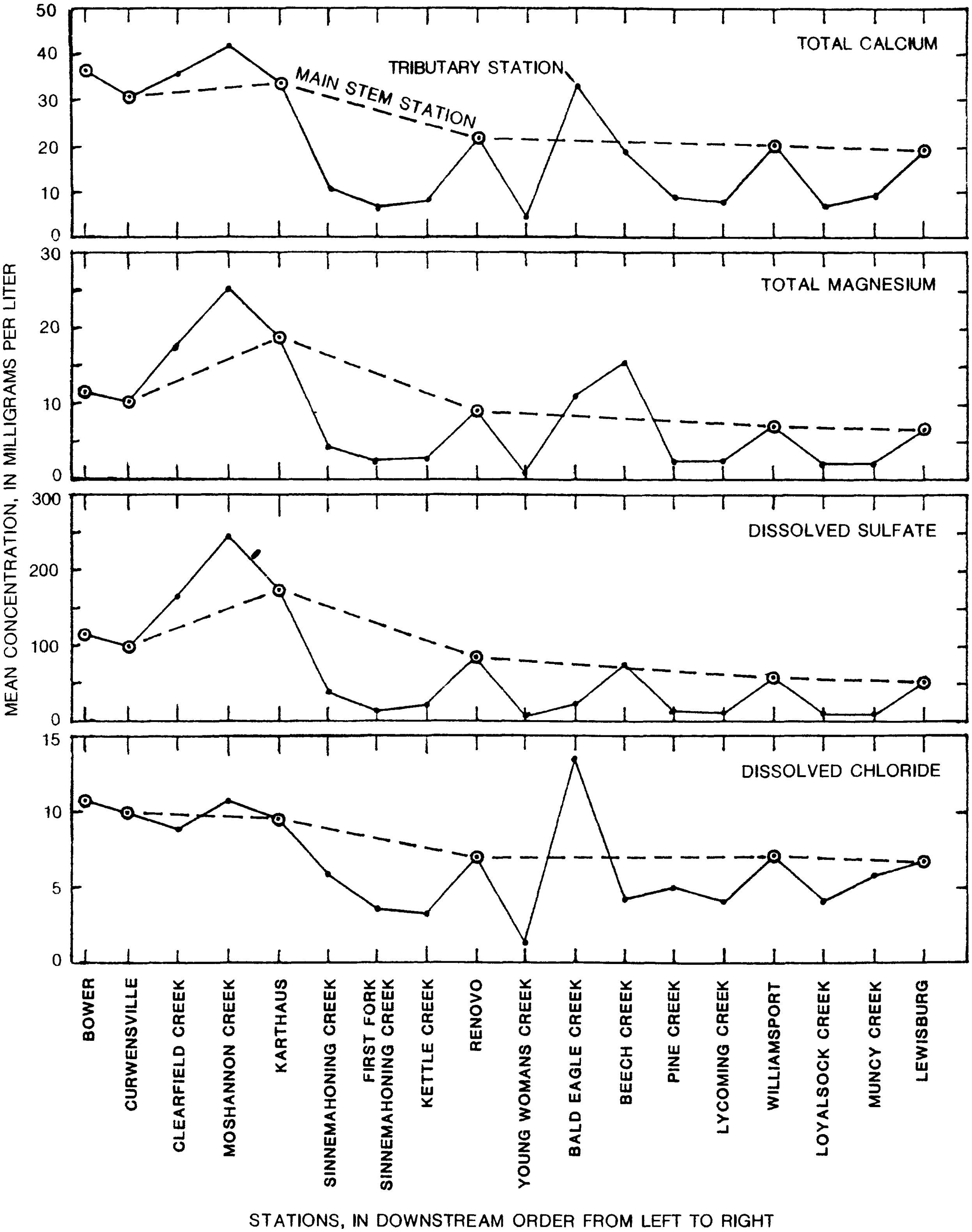


Figure 10.--Variations in mean concentrations of total calcium and magnesium and dissolved sulfate and chloride at water-quality stations, 1972-82 water years.

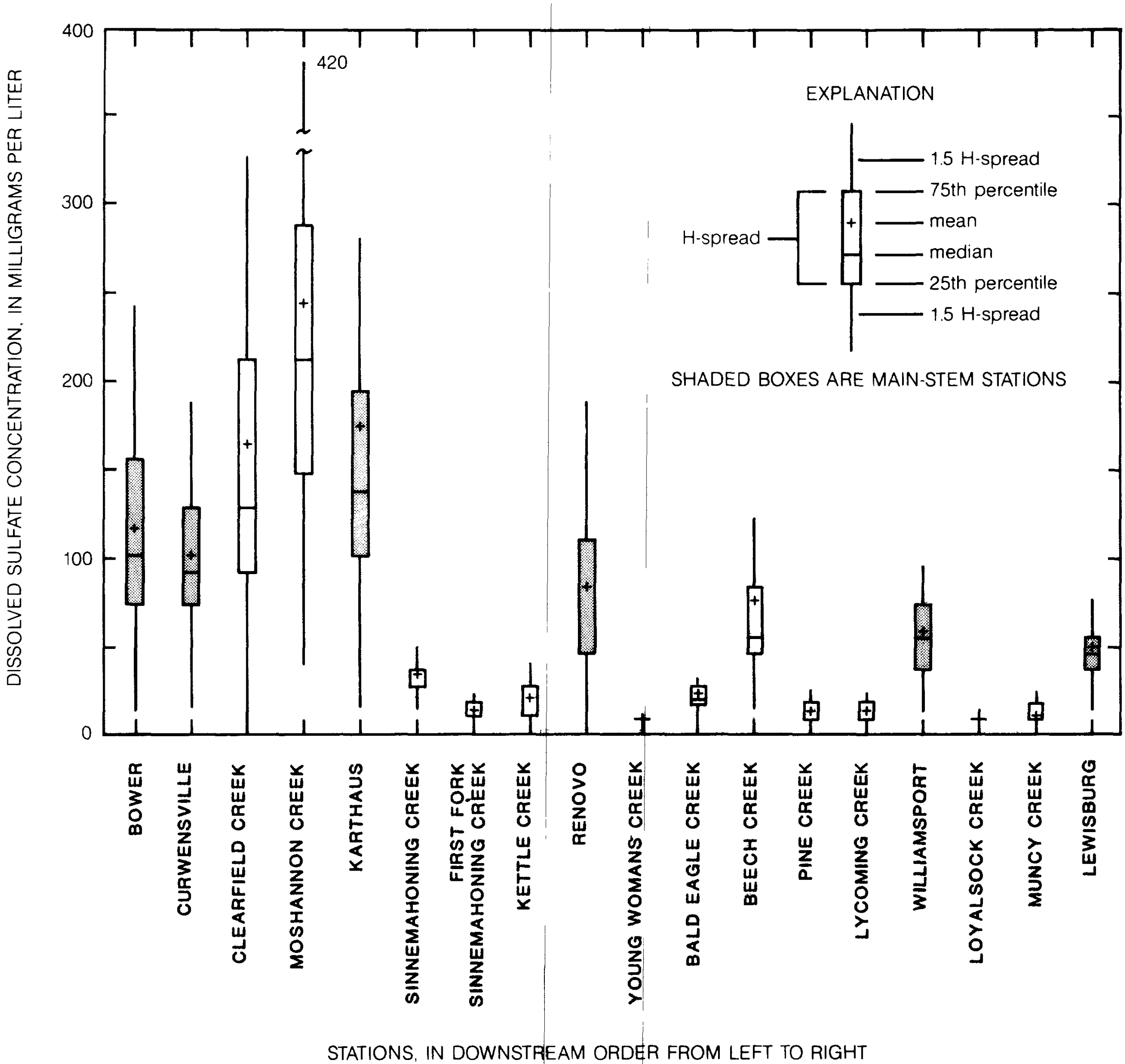


Figure 11.--Dissolved sulfate concentrations at water-quality stations, 1972-82 water years.

Nutrients

The three chemical constituents included in this group are total ammonia as nitrogen, total nitrite plus nitrate as nitrogen, and total phosphorus. Mean concentrations of total nitrite plus nitrate and total phosphorus were fairly uniform throughout the basin (fig. 12). The mean nitrite plus nitrate concentrations were about 0.6 mg/L except for the main stem stations at Bower (0.9 mg/L) and Curwensville (0.8 mg/L) and at Bald Eagle Creek (1.4 mg/L). The mean phosphorus concentrations were about 0.05 mg/L at all the stations except for 0.11 mg/L at Bald Eagle Creek and 0.01 mg/L at Young Womans Creek. Total ammonia concentrations exhibited the most variation. The mean concentration decreased abruptly from 0.20 mg/L at Moshannon Creek to 0.07 mg/L at Kettle

Creek and then increased to 0.17 mg/L at Bald Eagle Creek. No ammonia data were available for the station on Young Womans Creek.

The ranges for each constituent were fairly consistent throughout the basin. The largest range for ammonia concentrations, 0.05 to 0.66 mg/L, was found on Moshannon Creek. Minimum phosphorus concentrations ranged from 0.00 to 0.03 mg/L throughout the basin; maximum concentrations ranged from 0.08 to 1.62 mg/L. The largest range, 0.01 to 1.62 mg/L was found on Lycoming Creek. The largest range for total nitrite plus nitrate concentrations, 0.33 to 4.56 mg/L, was found at the site on Bald Eagle Creek (fig. 13).

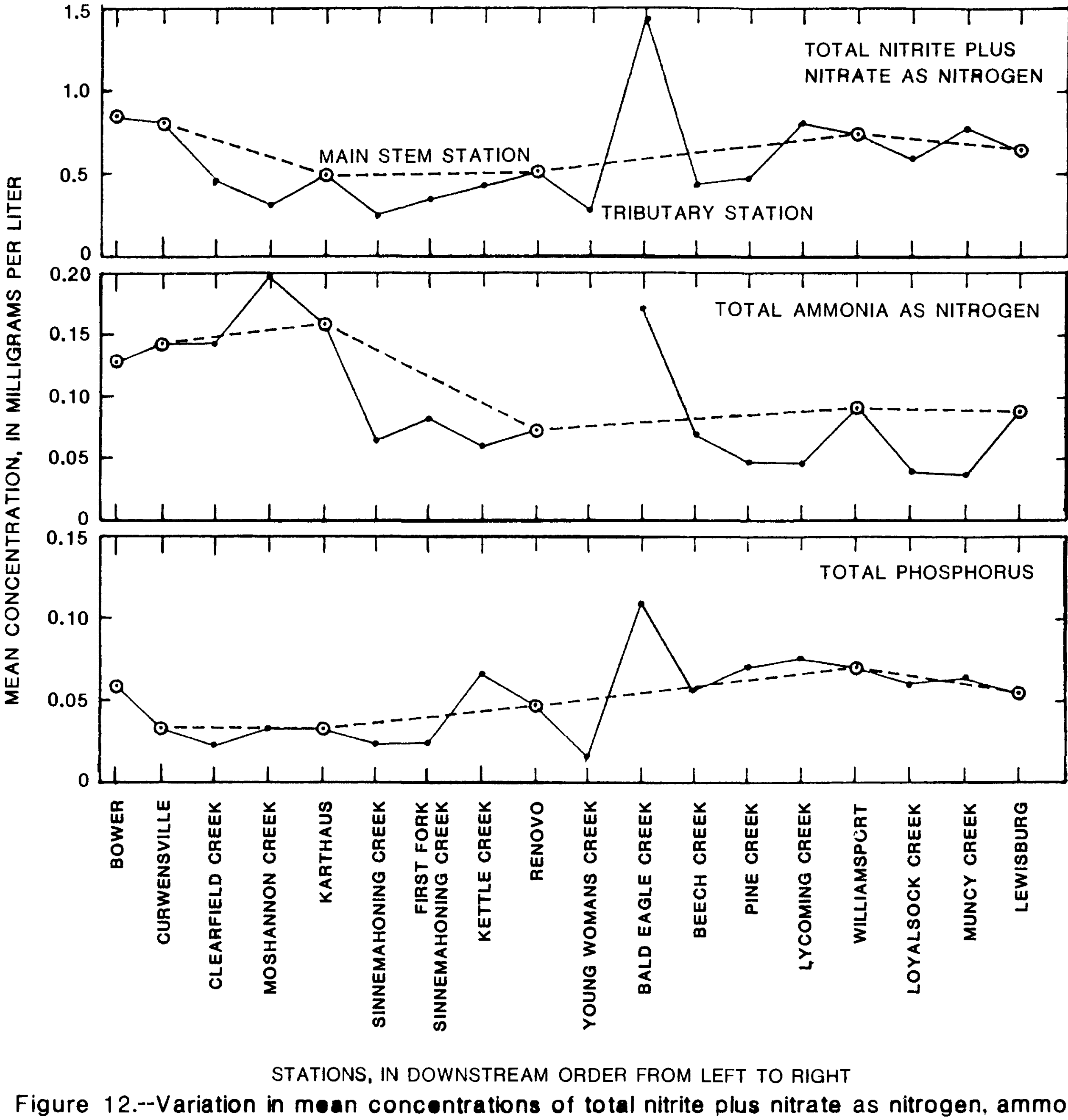


Figure 12.--Variation in mean concentrations of total nitrite plus nitrate as nitrogen, ammonia as nitrogen, and phosphorus at water-quality stations, 1972-82 water years.

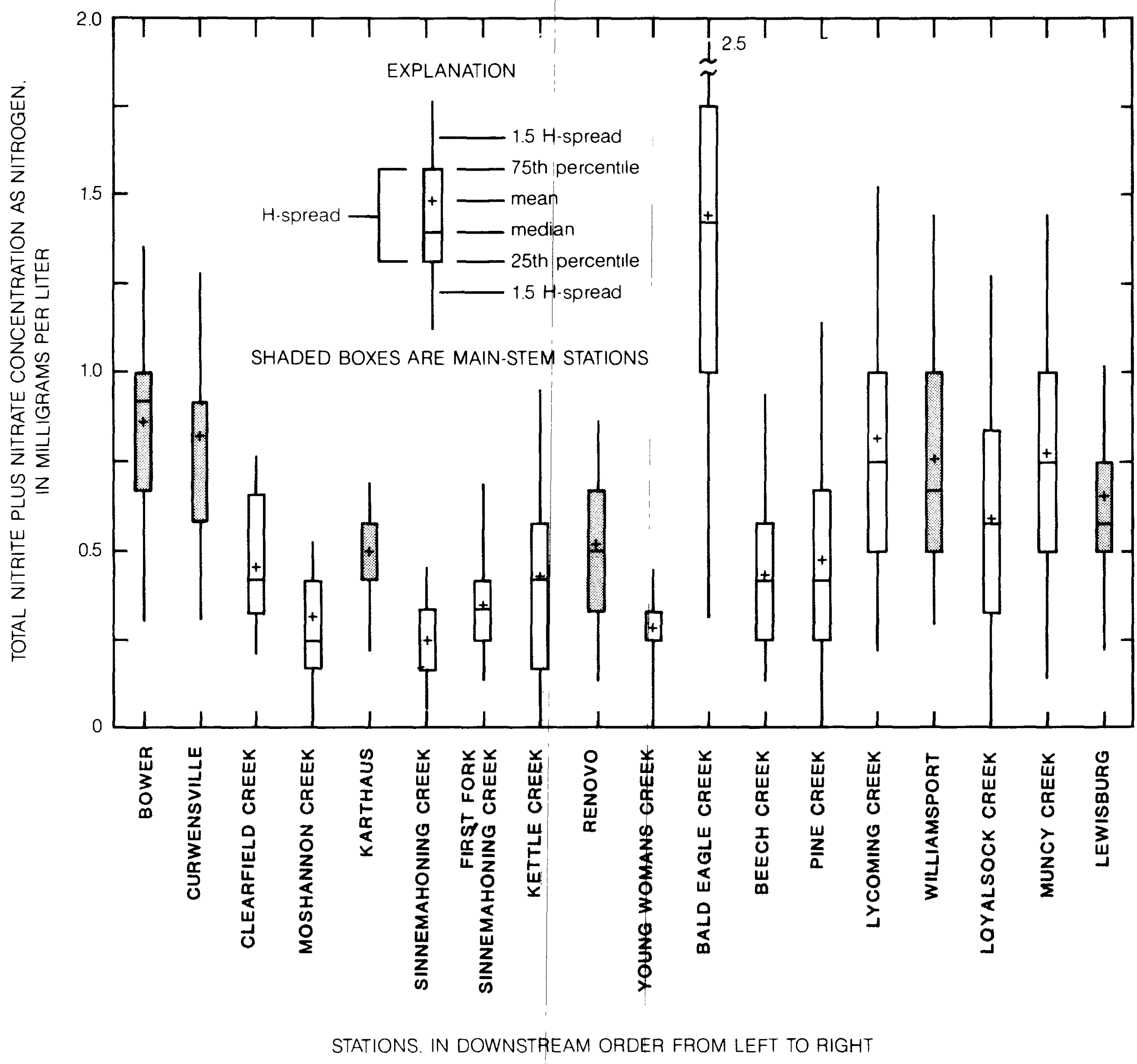


Figure 13.--Total nitrite plus nitrate concentrations as nitrogen at water-quality stations, 1972-82 water years.

Trace Metals

The trace metals group of water-quality characteristics includes five metals: total-recoverable iron, manganese, aluminum, zinc, and lead. The mean concentration for each constituent at each water-quality site is shown in figures 14 and 15. No aluminum data were available for Young Womans Creek. The highest mean concentrations for iron--9,300 μg/L (micrograms per liter)--manganese (4,420 μg/L), and aluminum (5,420 μg/L) were found at the sampling site on Moshannon Creek. The highest mean concentration for zinc, 584 μg/L, was found at the station on Clearfield Creek; and the highest mean concentration for lead, 50 μg/L, was found at the station on Beech Creek. Karthaus had the highest mean iron (2,430 μg/L), manganese (3,010 μg/L),

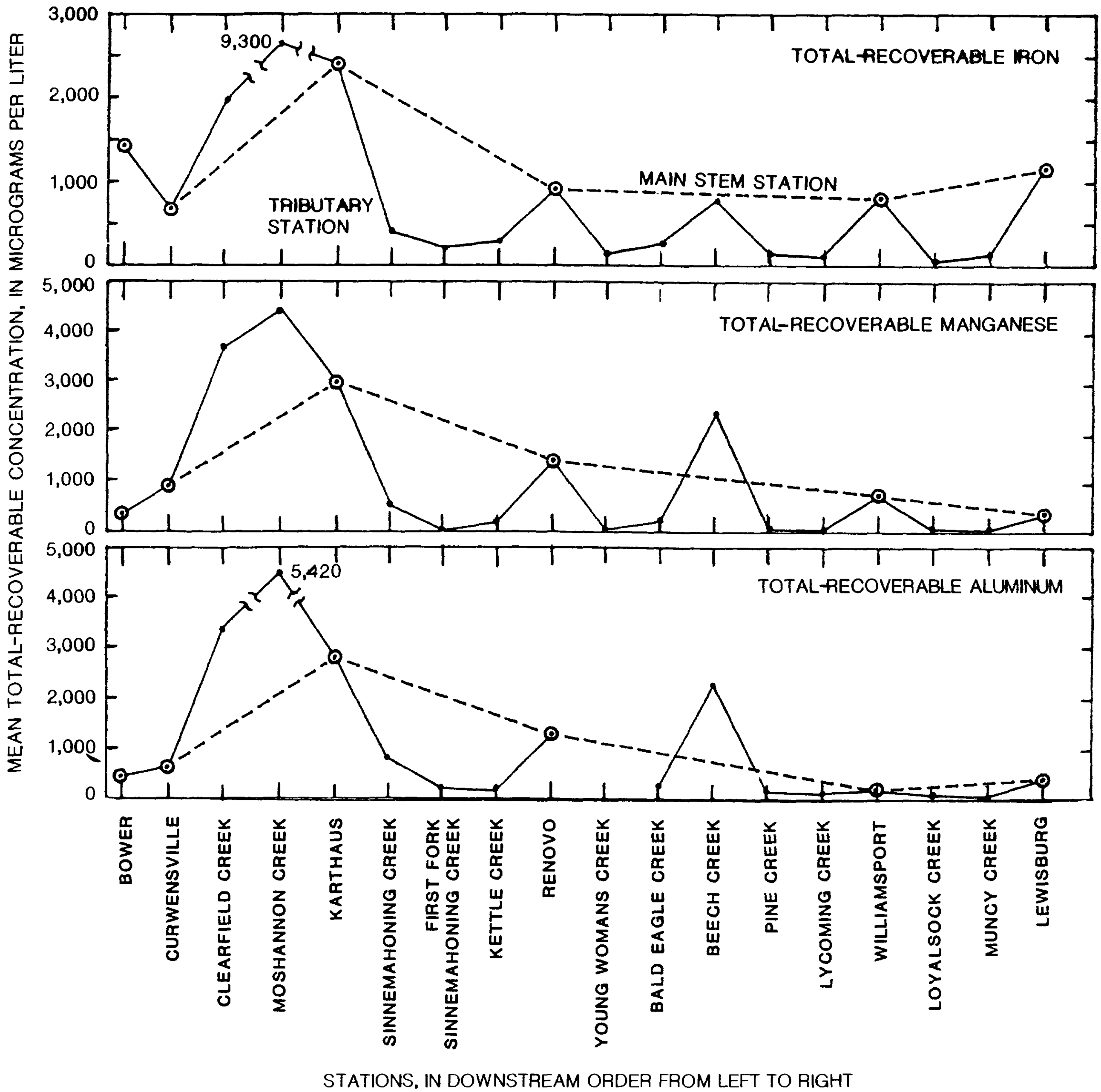


Figure 14.--Variations in mean concentrations of total-recoverable iron, manganese, and aluminum at water-quality stations, 1972-82 water years.

aluminum (2,810 μg/L), and zinc (156 μg/L) concentrations of the main stem stations. The highest mean lead concentration, 43 μg/L, was found at the main stem station at Williamsport.

The large ranges of concentrations of metals found at these sites make the schematic plots shown for previously-discussed constituents impractical. For instance, iron concentrations found in the basin ranged from 10 μg/L at several of the sites to nearly 30,000 μg/L at the site on Moshannon Creek. Generally, those stations with the highest concentrations also had the largest ranges. Water samples taken from Moshannon Creek indicated the largest range

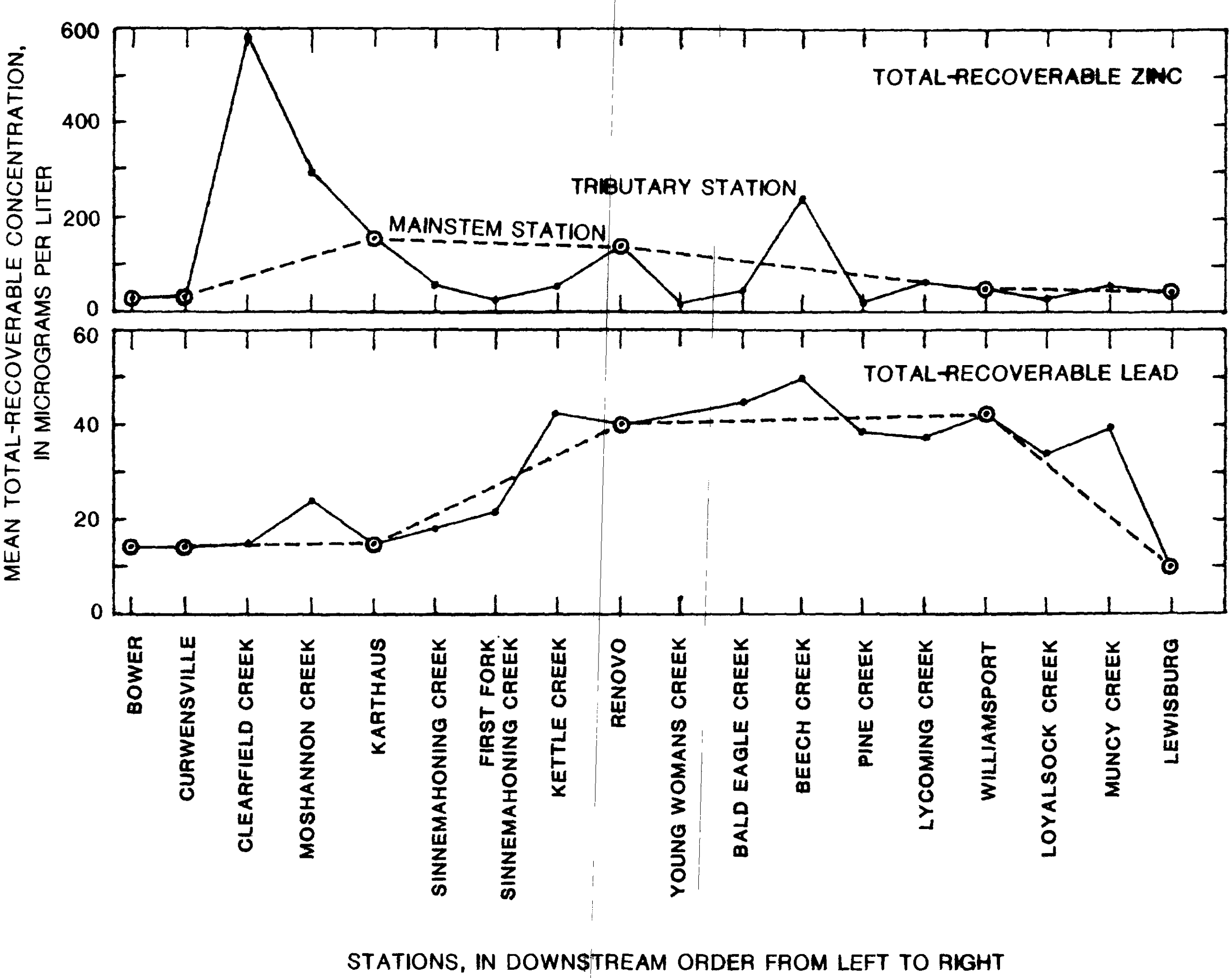


Figure 15.--Variations in mean concentrations of total-recoverable zinc and lead at water-quality stations, 1972-82 water years.

of concentrations of iron (1,600-29,500 μg/L), manganese (1,900-7,480 μg/L), and aluminum (3,300-9,915 μg/L). The largest range of concentrations of zinc, 130 μg/L to 2,900 μg/L, was found at the sampling site on Clearfield Creek. The ranges of lead concentrations are distorted by its detection limits and the number of significant figures used to report the concentrations. However, of the stations with sufficient data available, the largest ranges are found at the tributary stations on Moshannon (2.0-60 μg/L), First Fork Sinnemahoning (1.0-50 μg/L), and Loyalsock Creeks (3.0-50 μg/L) and the station on the main stem at Williamsport (5.0-50 μg/L).

The smallest ranges, lowest means, and lowest concentrations for the trace metals were found at the stations on Young Womans, Pine, Lycoming, Loyalsock, and Muncy Creeks.

Temporal Variability

Seven different regression analyses that related constituent concentration to instantaneous or daily mean streamflow were used to adjust the sample concentrations for flow in order to eliminate apparent trends that were caused by changing flow conditions. Daily mean streamflow was used in cases where an instantaneous streamflow was not available. In these cases streamflow did not vary considerably during the day and the mean streamflow was considered representative of the instantaneous value. Trend analyses on flow-adjusted concentrations were performed only if the regression analyses had a coefficient of determination (R^2) greater than or equal to 0.25. The equations used for the regression analyses were:

(1) linear $C = a + bQ$

(2) logarithmic-linear $C = a + b(\ln Q)$

(3) hyperbolic $C = a + \frac{b}{1+BQ}$, generally $10^{-3} \leq B \leq 10^{-1}$

(4) inverse $C = a + \frac{b}{Q}$

(5) quadratic $C = a + b_1Q + b_2Q^2$

(6) logarithmic $\ln C = a + b(\ln Q)$

(7) logarithmic quadratic $\ln C = a + b_1(\ln Q) + b_2(\ln Q)^2$

where C = predicted concentration, in milligrams per liter;
Q = streamflow, in cubic feet per second.

Trend analyses were done to determine if there were any water-quality changes over time. A common test for trend is the linear regression of the dependent variable against time. This method requires that the variable and time are unrelated and that the data are normally distributed, independent, and identically distributed in time. Even though this test is widely used, the assumptions are usually violated. In general, water-quality data are related to the season of the year, due to both temperature and type and amount of runoff, have skewed distributions rather than normal distributions (the sample extremes distort the distribution), and are serially correlated or are not independent; generally, later values are dependent on preceding values (Crawford and others, 1983).

The procedure used for trend analysis in this study, the Seasonal Kendall test developed by Smith and others (1982), attempts to correct the invalid assumptions used in the linear regression test. This particular test uses a distribution-free test developed by Kendall (1975) which ignores the magnitudes of the data and evaluates the relative ranks (Smith, 1980). However, because the values of the data are not used, Kendall's Tau statistic provides only an indication and not a magnitude of the trend. The Seasonal Kendall test adjusts for seasonality by comparing only those values which are collected in like months (January values are compared only to other January values and July values are compared only to other July values). These two adjustments, a distribution-free test, and the correction for seasonality, eliminate two of the invalid assumptions normally made for trend tests. The Seasonal Kendall test was tested to determine the effects of serial correlation by Hirsch and others (1982). It was found that serial correlation had no more an effect on the Seasonal Kendall test than on the linear regression test. For these reasons, the Seasonal Kendall test was selected as the best available test for the determination of trends.

The Seasonal Kendall test also produces a slope estimator term which is defined as the median of the differences of the ordered pairs of values which are compared for Kendall's Tau. This value then, through certain transformations, may be used to indicate a trend magnitude for a selected period of time. One other statistic produced by the Seasonal Kendall test is the probability value. This value, denoted by the Greek letter alpha (α), indicates the frequency of cases where a trend may be detected when there is none. For instance, an α=0.05 indicates a trend that is statistically significant at the 5 percent level and implies that 5 out of 100 trend tests with this significance level may indicate a trend when none exists.

Trend analyses were done on data collected during the 1972-82 water years at all 18 stations. Analyses also were done on data collected during the 1962-82 water years at the six stations located on the main stem of the river. Trend analyses were performed on unadjusted and flow-adjusted concentrations or values if the data indicated that a streamflow-concentration relation existed. Only trends in the unadjusted or flow-adjusted concentrations at the 10 percent significance level (α=0.10) or less were accepted.

1972 to 1982 Water Years

A summary of the statistics generated by the flow-adjustment regressions and the Seasonal Kendall test for the 1972-82 water years are presented in table 3. The mean values are arithmetic averages of the observations during the selected time period. Because no adjustment was made for months without a value, the mean for a station with missing values is not a time-weighted mean, but simply a sample mean. The effect of the averaging method is most pronounced for constituents that were sampled only at low flows or once per year. For example, most of the trace metals were sampled once per year in August. For this reason, the sample mean for trace metals is probably much higher than the mean for the entire year.

The sample discharges were computed by multiplying the sample value, the available streamflow (either instantaneous or daily mean), and the factor for converting discharge into tons per day. The mean discharge shown in the table is the mean of the computed instantaneous discharges. Some streamflows used for this computation were measured at a site some distance from the surface water-quality sampling site. For this reason, the mean sample discharges presented in the table may not be accurate, but the trends listed are still valid because they are given as a proportion of the mean. No discharges were computed for pH and specific conductance.

If the trend test on either the unadjusted or the flow-adjusted sample values indicated statistical evidence of a trend, then trend values for both are shown. Trend values for unadjusted sample discharges are shown if a trend was indicated in either the unadjusted or the flow-adjusted values. If the alpha value of one of the trends was greater than 0.10, the value is shown on the table. All trend values without an accompanying alpha value have alpha values less than or equal to 0.10. Any constituents analyzed but not shown on the tables did not indicate a trend in either the unadjusted or the flow adjusted values at the 10 percent significance level.

The largest negative trends were found in the concentrations of various trace metals and total ammonia nitrogen. These trends, indicating an improvement in water quality, are believed to be caused by improvements in the treatment of acid mine drainage and wastewater. The largest negative trend in the basin was -23.5 percent per year in the total-recoverable aluminum concentration in Bald Eagle Creek. The largest positive trend was 14.0 percent per year in the total-recoverable aluminum concentration in the West Branch Susquehanna River at Williamsport. This increase in trace metal concentration probably is related to the industrial wastes around the metropolitan areas.

Table 4 summarizes the unadjusted concentration or value trends in the West Branch Susquehanna River basin for the 1972-82 water years. The constituents which had trends at the largest number of stations were pH, alkalinity, total ammonia as nitrogen, and total nitrite plus nitrate as nitrogen. At all the sites where a pH trend was indicated, it was positive. Trends in total ammonia as nitrogen were all negative. The trends of alkalinity and total nitrite plus nitrate as nitrogen were positive at Lewisburg and the uppermost stations. However, the trends for these two constituents were generally negative between Karthaus and Lewisburg.

Table 3.--Constituents that had trends for the 1972-82 water years at the indicated station

[mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25° Celsius; ft^3/s, cubic feet per second; α, probability value; ----, no information]

Constituent and reporting units	Concentration or value			Discharge			Flow-adjusted concentration or value		
	Mean	Standard deviation	Trend(α) (percent/ year)	Mean (ton/ day)	Standard deviation	Trend(α) (percent/ year)	Trend(α) (percent/ year)	Model[1]	Slope[2]
West Branch Susquehanna River at Bower									
pH (units)	7.09[3]	0.60	1.0[3]	----	----	----	----	NM	----
Alkalinity (mg/L as $CaCO_3$)	23.9	12.6	4.2	25.2	19.8	4.5	----	NM	----
Dissolved chloride (mg/L)	10.8	3.84	3.6	14.4	16.8	3.1 (0.21)	----	NM	----
Total ammonia (mg/L as N)	.13	.12	-7.5	.20	.32	-3.0	----	NM	----
Total nitrite + nitrate (mg/L as N)	.88	.35	2.6	1.62	2.92	1.8	----	NM	----
West Branch Susquehanna River at Curwensville									
Alkalinity (mg/L as $CaCO_3$)	18.4	8.69	7.5	32.5	27.6	2.7 (.17)	----	NM	----
Dissolved solids (mg/L)	229	86.4	-2.9	431	472	-2.6 (.32)	0.6 (0.43)	hyper	----
Total magnesium (mg/L)	10.5	4.48	-2.7	19.9	18.4	-2.1 (.57)	----	NM	----
Dissolved chloride (mg/L)	9.99	3.96	3.3	20.5	25.5	2.5 (.11)	----	NM	----
Total ammonia (mg/L as N)	.14	.18	-8.3	.41	1.20	-2.1	----	NM	----
Total nitrite + nitrate (mg/L as N)	.82	.32	4.5	2.01	2.58	1.1 (.30)	----	NM	----
Total-recoverable aluminum (µg/L)	642	988	-7.0	1.21	1.95	-6.2 (.13)	----	NM	----
Clearfield Creek at Mount Hope									
Alkalinity (mg/L as $CaCO_3$)	3.83	6.25	-4.4	----	----	----	----	NM	----
Total ammonia (mg/L as N)	.14	.10	-7.1	----	----	----	----	NM	----
Total nitrite + nitrate (mg/L as N)	.46	.18	3.5	----	----	----	----	NM	----
Moshannon Creek at Osceola Mills									
Alkalinity (mg/L as $CaCO_3$)	8.62	14.2	0	1.34	2.60	0	----	NM	----
Total phosphorus (mg/L)	.03	.03	8.3	.01	.01	5.8 (.15)	----	NM	----
Streamflow (ft^3/s)	89.5	73.6	-5.8	----	----	----	----	NM	----

Table 3.--Constituents that had trends for the 1972-82 water years at the indicated station--Continued

Constituent and reporting units	Concentration or value			Discharge			Flow-adjusted concentration or value		
	Mean	Standard deviation	Trend(α) (percent/ year)	Mean (ton/ day)	Standard deviation	Trend(α) (percent/ year)	Trend(α) (percent/ year)	Model[1]	Slope[2]
West Branch Susquehanna River at Karthaus									
Alkalinity (mg/L as $CaCO_3$)	2.80	4.38	-7.1	17.0	24.7	-13.8	0 (0.33)	invs	----
Total calcium (mg/L)	33.9	14.2	3.6	211	201	-.1 (1.00)	.9 (.33)	logquad	----
Total ammonia (mg/L as N)	.16	.10	-5.9	1.06	1.16	-4.0	----	NM	----
Total nitrite + nitrate (mg/L as N)	.51	.19	2.1	4.39	5.73	1.2 (.40)	----	NM	----
Sinnemahoning Creek at Sinnemahoning									
Specific conductance (µS/cm)	112	43.0	4.5	----	----	----	.6 (.68)	hyper	----
Total calcium (mg/L)	10.7	5.28	5.3	26.6	22.3	.4 (1.00)	.6 (.68)	invs	----
Total ammonia (mg/L as N)	.07	.06	-12.5	.17	.18	-8.0	----	NM	----
Total-recoverable zinc (µg/L)	55.6	45.0	-18.0	.03	.03	-9.9 (.25)	1.0 (.53)	logquad	----
First Fork Sinnemahoning Creek at Sinnemahoning									
Total nitrite + nitrate (mg/L as N)	.35	.17	4.6	.34	.40	1.3 (.68)	----	NM	----
Total-recoverable aluminum (µg/L)	210	192	-14.3	101	122	-5.7 (.18)	----	NM	----
Total-recoverable zinc (µg/L)	22.0	10.3	-9.1	16.1	27.2	-4.6 (.47)	-3.2 (.35)	quad	----
Kettle Creek near Westport									
Total phosphorus (mg/L)	.07	.10	-4.8	.07	.10	19 (1.00)	----	NM	----
Total-recoverable manganese (µg/L)	205	365	-7.3	.04	.04	-17.7	-32.9 (.17)	invs	----
Total-recoverable lead (µg/L)	42.5	17.5	0	.02	.02	2.6 (.36)	----	NM	----
West Branch Susquehanna River at Renovo									
pH (units)	4.865	.80	1.0[3]	----	----	----	-.2 (.11)	logquad	+
Total ammonia (mg/L as N)	.07	.06	-16.0	1.09	2.02	-8.0	----	NM	----

Table 3.--Constituents that had trends for the 1972-82 water years at the indicated station--Continued

Constituent and reporting units	Concentration or value			Discharge			Flow-adjusted concentration or value		
	Mean	Standard deviation	Trend(α) (percent/ year)	Mean (ton/ day)	Standard deviation	Trend(α) (percent/ year)	Trend(α) (percent/ year)	Model[1]	Slope[2]
				Young Womans Creek near Renovo					
pH (units)	6.82[3]	0.33	0.4[3]	----	----	----	----	NM	----
Specific conductance (μS/cm)	39.2	4.59	0 (0.75)	----	----	----	0.4	hyper	----
Alkalinity (mg/L as $CaCO_3$)	8.71	4.01	3.8	1.59	1.99	-0.8 (0.44)	----	NM	----
Dissolved magnesium (mg/L)	1.03	.19	0	.21	.22	-3.0	----	NM	----
Dissolved sulfate (mg/L)	7.60	1.28	1.3	1.64	1.85	-2.3	----	NM	----
Total-recoverable manganese (μg/L)	14.4	9.91	0	.01	.01	-12.3	----	NM	----
Suspended sediment (mg/L)	9.35	65.2	0 (.11)	19.8	192	-.1	1.8	quad	+
Streamflow (ft^3/s)	83.3	119	-3.6	----	----	----	----	NM	----
				Bald Eagle Creek at Eagleville					
Specific conductance (μS/cm)	291	63.3	2.9	----	----	----	.8	loglin	----
Dissolved chloride (mg/L)	13.5	3.80	4.4	28.1	27.6	.3 (.88)	----	NM	----
Dissolved sulfate (mg/L)	23.5	12.2	-2.8	52.1	56.3	-4.0	----	NM	----
Total nitrite + nitrate (mg/L as N)	1.44	.61	-2.5	3.24	3.33	-2.1	----	NM	----
Total-recoverable aluminum (μg/L)	262	334	-23.5	.74	2.13	-3.0	----	NM	----
Total-recoverable zinc (μg/L)	43.6	59.2	-11.5	.05	.06	-7.4	----	NM	----
Total-recoverable lead (μg/L)	44.7	16.3	0	.08	.14	-5.8 (.18)	----	NM	----
				Beech Creek at Beech Creek					
Alkalinity (mg/L as $CaCO_3$)	2	1.91	-8.4	2.31	4.56	-3.6	----	NM	----
Dissolved chloride (mg/L)	4.32	1.72	2.9	2.98	2.92	.9 (.73)	.8(0.41)	invs	----

Table 3.--Constituents that had trends for the 1972-82 water years at the indicated station--Continued

Constituent and reporting units	Concentration or value			Discharge			Flow-adjusted concentration or value		
	Mean	Standard deviation	Trend(α) (percent/ year)	Mean (ton/ day)	Standard deviation	Trend(α) (percent/ year)	Trend(α) (percent/ year)	Model[1]	Slope[2]
Pine Creek below Little Pine Creek near Waterville									
pH (units)	7.23[3]	0.43	0.3[3]	----	----	----	----	NM	----
Alkalinity (mg/L as $CaCO_3$)	21.3	13.0	-1.6	51.2	47.8	-2.6	.5(0.55)	logquad	----
Total ammonia (mg/L as N)	.05	.05	-10.0	.13	.17	-6.8	----	NM	----
Total nitrite + nitrate (mg/L as N)	.48	.32	-9.2	1.86	3.13	-2.6	----	NM	----
Total phosphorus (mg/L)	.07	.12	-4.7	.20	.39	-3.2	----	NM	----
Total-recoverable iron (μg/L)	159	262	-4.2	.69	1.84	-1.4	----	NM	----
Total-recoverable lead (μg/L)	38.7	20.2	0	.03	.02	-20.3	----	NM	----
Lycoming Creek near Trout Run									
pH (units)	7.23[3]	.42	.9[3]	----	----	----	----	NM	----
Specific conductance (μS/cm)	72.7	22.9	.9	----	----	----	----	NM	----
Alkalinity (mg/L as $CaCO_3$)	15.5	5.89	-2.8	8.70	9.13	-3.7	----	NM	----
Total ammonia (mg/L as N)	.05	.07	-5.0	.03	.05	-4.5	----	NM	----
Total nitrite + nitrate (mg/L as N)	.81	.34	-7.4	.59	.95	-3.4	----	NM	----
Total phosphorus (mg/L)	.08	.19	-2.5	.04	.09	-3.3	----	NM	----
Total-recoverable iron (μg/L)	122	326	-3.6	.13	.56	-3.3	----	NM	----
Total-recoverable manganese (μg/L)	29.0	23.2	-9.5	.01	.01	-.01	----	NM	----
Total-recoverable lead (μg/L)	37.4	20.9	0	.01	.01	-17.3	----	NM	----

Table 3.--Constituents that had trends for the 1972-82 water years at the indicated station--Continued

Constituent and reporting units	Concentration or value			Discharge			Flow-adjusted concentration or value		
	Mean	Standard deviation	Trend(α) (percent/ year)	Mean (ton/ day)	Standard deviation	Trend(α) (percent/ year)	Trend(α) (percent/ year)	Model[1]	Slope[2]
West Branch Susquehanna River at Williamsport									
pH (units)	6.84[3]	0.55	1.3[3]	----	----	----	----	NM	----
Specific conductance (μS/cm)	201	78.6	4.1	----	----	----	1.1(0.27)	loglog	----
Dissolved chloride (mg/L)	7.24	2.93	2.1	167	161	-0.4 (0.67)	.4 (.27)	invs	----
Dissolved sulfate (mg/L)	59.7	27.4	2.2	1,210	957	-1.1 (.42)	1.2 (.27)	loglog	----
Total nitrite + nitrate (mg/L as N)	.76	.29	-5.8	20.5	23.7	-5.0	----	NM	----
Total-recoverable aluminum (μg/L)	182	91.3	14.0	2.30	3.83	2.5 (.62)	----	NM	----
Loyalsock Creek at Loyalsockville									
pH (units)	7.23[3]	.45	0.8[3]	----	----	----	----	NM	----
Total ammonia (mg/L as N)	.04	.04	-5.0	.07	.12	-6.0	----	NM	----
Total nitrite + nitrate (mg/L as N)	.59	.30	-8.5	1.11	1.51	-5.4	----	NM	----
Total phosphorus (mg/L)	.06	.08	-3.3	.12	.31	-2.9	----	NM	----
Total-recoverable manganese (μg/L)	18.1	12.7	-11.0	.02	.03	-4.0 (.24)	----	NM	----
Total-recoverable lead (μg/L)	34.0	21.9	-7.4	.03	.04	-18.1	----	NM	----
Muncy Creek at Hughesville									
pH (units)	7.35[3]	.54	.8[3]	----	----	----	----	NM	----
Total ammonia (mg/L as N)	.04	.04	-4.2	----	----	----	----	NM	----
Total nitrite + nitrate (mg/L as N)	.78	.32	-7.7	----	----	----	----	NM	----
Total-recoverable lead (μg/L)	39.3	19.9	0	----	----	----	----	NM	----

Table 3.--Constituents that had trends for the 1972-82 water years at the indicated station--Continued

Constituent and reporting units	Concentration or value			Discharge			Flow-adjusted concentration or value		
	Mean	Standard deviation	Trend(α) (percent/ year)	Mean (ton/ day)	Standard deviation	Trend(α) (percent/ year)	Trend(α) (percent/ year)	Model[1]	Slope[2]
West Branch Susquehanna River at Lewisburg									
pH (units)	7.09[3]	0.51	1.1[3]	----	----	----	0.2	hyper	----
Specific conductance (μS/cm)	197	64	2.0	----	----	----	.8	hyper	----
Alkalinity (mg/L as $CaCO_3$)	20.1	12.4	5.0	504	494	-1.0 (0.51)	1.5	hyper	----
Dissolved solids (mg/L)	123	43.5	1.5	3,430	2,820	-1.7	1.1	hyper	----
Dissolved calcium (mg/L)	19.4	7.7	2.0	522	418	-1.3 (.27)	1.2	hyper	----
Dissolved magnesium (mg/L)	6.53	2.61	2.1	177	145	-1.0 (.17)	.9	hyper	----
Dissolved chloride (mg/L)	6.82	2.73	2.6	214	230	-.8 (.20)	1.1	loglog	----
Dissolved sulfate (mg/L)	52.5	19.8	1.1 (.21)	1,530	1,350	-3.1	1.1	loglog	----
Total nitrite + nitrate (mg/L as N)	.65	.24	4.8	22.9	27.0	2.5 (.89)	----	NM	----
Dissolved iron (μg/L)	44.9	66.7	-12.7	1.15	1.98	-5.6	----	NM	----
Dissolved manganese (μg/L)	358	207	-4.2	15.3	18.4	-1.0 (.62)	-.7 (.46)	logquad	+
Total-recoverable zinc (μg/L)	44.2	25.9	11.3	2.08	3.04	1.6 (.29)	----	NM	----
Suspended sediment (mg/L)	68.1	320	-1.2	5,440	18,360	-3.2 (.15)	-3.0	logquad	+
Streamflow (ft^3/s)	15,420	20,320	-1.8	----	----	----	----	NM	----

[1]NM, no model met the requirement that the coefficient of determination $R^2 \geq 0.25$; lin, linear; loglin, logarithmic-linear; hyper, hyperbolic; invs, inverse; quad, quadratic; loglog, logarithmic; logquad, logarithmic-quadratic. (See page 23 for general form of equation.)

[2]+, value increases with increasing water discharge;
-, value decreases with increasing water discharge.

[3]Median value; trend, percent per year of median.

Table 4.--Summary of constituent trends for the 1972-82 water years.
[↑, trend of increasing concentration; ↓, trend of decreasing concentration; -, no trend indicated at significance level of 0.10; blank indicates no analysis was performed]

Station	*pH*	*Specific conductance*	*Alkalinity as $CaCO_3$*	*Dissolved solids @ 180°C*	*Dissolved solids @ 105°C*	*Suspended sediment*	*Suspended solids @ 105°C*	*Total calcium*	*Dissolved calcium*	*Total magnesium*	*Dissolved magnesium*	*Dissolved chloride*	*Dissolved sulfate*	*Total ammonia as N*	*Total nitrite + nitrate as N*	*Total phosphorus*	*Dissolved iron*	*Total-recoverable iron*	*Dissolved manganese*	*Total-recoverable manganese*	*Total-recoverable aluminum*	*Dissolved zinc*	*Total-recoverable zinc*	*Dissolved lead*	*Total-recoverable lead*	*Streamflow*
West Branch Susquehanna River at Lewisburg	↑	↑	↑	↑		-			↑		↑	↑	-		↑	-	↓	-	↓	-		-	↑	-	-	↓
Muncy Creek at Hughsville	↑	-	-									-	-	↓	↓	-		-		-	-		-		↓	
Loyalsock Creek at Loyalsockville	↑	-	-									-	-	↓	↓	↓		-		↓	-		-		↓	-
West Branch Susquehanna River at Williamsport	↑	↑	-				-					↑	↑	-	↓	-		-		-	↑					-
Lycoming Creek near Trout Run	↑	↑	↓									-	-	↓	↓	↓		↓		↓	-		-		↓	-
Pine Creek near Waterville	↑	-	↓									-	-	↓	↓	↓		↓		-	-		-		↓	-
Beech Creek at Beech Creek	-	-	↓									↑	-	-	-	-		-								-
Bald Eagle Creek at Eagleville	-	↑	-									↑	↓	-	↓	-		-		-	↓		↓		↓	-
Young Womans Creek near Renovo	↑	-	↑	-		-			-		↑	-	↑		-	-		-		↓			-		-	↓

1962 to 1982 Water Years

Statistical analyses of data collected at the six stations located on the West Branch Susquehanna River were done for the 1962-82 water years. The results of these analyses are presented in table 5. For an explanation of the table, see the section discussing trends from 1972 to 1982. Table 6 summarizes the trends indicated by the analyses. Nutrients were not evaluated during this period because of inadequate data. Significant positive trends in pH, alkalinity, and streamflow and negative trends in dissolved sulfate and total-recoverable iron and manganese were found. Even though a positive trend in streamflow would produce an expected negative concentration trend for dissolved sulfate, total-recoverable iron, and total-recoverable manganese because of dilution, the negative concentration trends are supported by concurrent negative and relatively smaller trends in flow-adjusted concentrations. For example, a negative trend for dissolved sulfate concentration and a positive trend in the streamflows sampled were found at the water-quality station at Bower (table 5). The slope of the regression model found for sulfate and streamflow (-), indicates that decreasing sulfate concentrations are an expected result of an increase in streamflow. However, the negative trend shown for the flow-adjusted sulfate concentrations is determined following the elimination of the effects of a trend in streamflows sampled. For this reason, the decrease in dissolved sulfate concentrations found at this station is valid. The trends found in pH, alkalinity, dissolved sulfate and total-recoverable iron and manganese imply improvements in the quality or decreases in the quantity of acid mine drainage in the basin. The trends noted in these characteristics from 1972 to 1982 apparently are continuations of the trends shown to begin as early as 1962.

Table 5.--Constituents that had trends for the 1962-82 water years at the indicated station

[mg/L, milligrams per liter; µg/L, micrograms per liter; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25° Celsius; α, probability value]

	Concentration or value			Discharge			Flow-adjusted concentration or value		
Constituent and reporting units	Mean	Standard deviation	Trend(α) (percent/ year)	Mean (ton/ day)	Standard deviation	Trend(α) (percent/ year)	Trend(α) (percent/ year)	Model[1]	Slope[2]
West Branch Susquehanna River at Bower									
pH (units)	6.90[3]	0.94	1.4[3]	----	----	----	----	NM	----
Alkalinity (mg/L as $CaCO_3$)	21.1	13.3	4.7	22.2	20.0	4.5	----	NM	----
Dissolved solids (mg/L)	296	165	-2.2	290	267	.7(0.44)	-1.0	loglog	-
Suspended solids (mg/L)	24.1	30.3	-1.4	71.9	212	.03(.88)	1.7	loglog	+
Dissolved sulfate (mg/L)	146	93.1	-2.3	130	101	.1(.82)	-1.0	hyper	-
Total-recoverable iron (µg/L)	1,520	1,470	-2.1	3.90	12.6	.05(.85)	1.7	loglog	+
Total-recoverable manganese (µg/L)	765	556	-7.8	.72	.72	.4(.80)	-.6(0.24)	invs	-
Streamflow (ft^3/s)	565	789	.9	----	----	----	----	NM	----
West Branch Susquehanna River at Curwensville									
pH (units)	6.80[3]	.88	1.1[3]	----	----	----	----	NM	----
Alkalinity (mg/L as $CaCO_3$)	16.2	8.76	4.6	26.9	26.4	4.2	----	NM	----
Suspended solids (mg/L)	12.2	13.0	-.9(0.12)	46.2	11.6	.1(.70)	.6	quad	+
Dissolved solids (mg/L)	226	89.1	-2.2(.14)	426	472	-1.8(.57)	-.7	hyper	-
Dissolved chloride (mg/L)	9.64	4.25	1.0	17.6	23.2	2.8	----	NM	----
Dissolved sulfate (mg/L)	123	71.4	-3.0	174	175	-.05(1.00)	-.6	invs	-
Total phosphorus (mg/L)	.03	.03	3.0	.09	.17	1.1	----	NM	----
Total-recoverable iron (µg/L)	782	860	-2.6	2.35	5.35	-.2(.64)	----	NM	----
Total-recoverable manganese (µg/L)	952	1,210	-6.2	1.11	1.05	1.0(.54)	----	NM	----
Streamflow (ft^3/s)	794	975	1.3	----	----	----	----	NM	----

Table 5.--Constituents that had trends at the indicated station for the 1962-82 water years.--Continued

Constituent and reporting units	Concentration or value: Mean	Concentration or value: Standard deviation	Concentration or value: Trend(α) (percent/year)	Discharge: Mean (ton/day)	Discharge: Standard deviation	Discharge: Trend(α) (percent/year)	Flow-adjusted concentration or value: Trend(α) (percent/year)	Flow-adjusted concentration or value: Model[1]	Flow-adjusted concentration or value: Slope[2]
West Branch Susquehanna River at Karthaus									
pH (units)	4.00[3]	.76	1.0[3]	----	----	----	----	NM	----
Dissolved sulfate (mg/L)	198	146	-2.4	856	778	0.8(0.25)	-1.3	logquad	-
Total-recoverable iron (μg/L)	2,580	2,640	-1.6	24.9	65.1	.03(.89)	----	NM	----
Total-recoverable manganese (μg/L)	3,240	1,850	.6(0.77)	12.1	9.72	.6(.68)	-2.0	logquad	-
Total-recoverable aluminum (μg/L)	3,110	1,770	-2.8 (.63)	14.2	11.5	-1.7(.20)	-1.6	invs	-
Streamflow (ft^3/s)	2,400	2,840	1.1	----	----	----	----	NM	----
West Branch Susquehanna River at Renovo									
pH (units)	4.50[3]	.88	1.4[3]	----	----	----	.3	logquad	+
Alkalinity (mg/L as $CaCO_3$)	3.88	6.37	5.6	61.0	107	2.2	----	NM	----
Suspended solids (mg/L)	15.8	35.9	1.2	380	1,430	.9	----	NM	----
Dissolved chloride (mg/L)	7.33	5.33	0 (.51)	70.6	90.6	2.7	-.9	invs	-
Dissolved sulfate (mg/L)	116	83.1	-3.9	827	714	.5(.37)	-2.3	hyper	-
Total-recoverable iron (μg/L)	1,110	1,620	-2.4	26.9	104	.06(.74)	.2	quad	+
Total-recoverable manganese (μg/L)	2,540	2,670	-2.6	12.7	12.8	.9(.44)	-2.9	hyper	-
Total-recoverable aluminum (μg/L)	2,170	1,490	-2.8(.25)	17.3	17.5	-.7(.42)	-1.6	invs	-
Streamflow (ft^3/s)	4,380	5,160	2.0	----	----	----	----	NM	----

Table 5.--Constituents that had trends for the 1962-82 water years at the indicated station.--Continued

Constituent and reporting units	Concentration or value: Mean	Concentration or value: Standard deviation	Concentration or value: Trend(α) (percent/year)	Discharge: Mean (ton/day)	Discharge: Standard deviation	Discharge: Trend(α) (percent/year)	Flow-adjusted concentration or value: Trend(α) (percent/year)	Model[1]	Slope[2]
West Branch Susquehanna River at Williamsport									
pH (units)	6.60[3]	0.73	0.9[3]	----	----	----	----	NM	----
Alkalinity (mg/L as $CaCO_3$)	16.2	8.07	1.0	326	318	2.3	----	NM	----
Dissolved chloride (mg/L)	7.33	3.44	1.0	144	148	2.5	-0.4	invs	-
Dissolved sulfate (mg/L)	71.0	41.8	-1.4	1,180	918	.3(0.86)	-1.1	loglog	-
Total-recoverable manganese (μg/L)	1,050	546	-2.9	13.7	12.2	.9(.46)	----	NM	----
Streamflow (ft^3/s)	8,980	9,680	1.0	----	----	----	----	NM	----
West Branch Susquehanna River at Lewisburg									
pH (units)	6.90[3]	.60	.7[3]	----	----	----	-.1	hyper	-
Specific conductance (μS/cm)	207	78.4	0 (0.95)	----	----	----	-.7	hyper	-
Alkalinity (mg/L as $CaCO_3$)	18.1	13.7	3.1	365	399	4.1	-1.4	hyper	-
Dissolved solids (mg/L)	132	53.2	-.9	3,200	2,690	1.0(.15)	-.9	hyper	-
Dissolved calcium (mg/L)	20.2	8.50	0 (.56)	474	385	1.1	-1.0	hyper	-
Dissolved magnesium (mg/L)	6.75	2.79	.2(.36)	326	1,930	.3(.17)	-.8	hyper	-
Dissolved chloride (mg/L)	7.07	3.25	0 (.88)	169	188	1.8	-.9	loglog	-
Dissolved sulfate (mg/L)	62.1	29.6	-1.4	1,440	1,330	.6(.18)	-1.0	loglog	-
Streamflow (ft^3/s)	12,800	16,990	1.0	----	----	----	----	NM	----

[1]NM, no model met the requirement that the coefficient of determination $R^2 \geq 0.25$; lin, linear; loglin, logarithmic-linear; hyper, hyperbolic; invs, inverse; quad, quadratic; loglog, logarithmic; logquad, logarithmic-quadratic. (See page 23 for general form of equation.)

[2]+, value increases with increasing water discharge;
-, value decreases with increasing water discharge.

[3]Median value; trend, percent per year of median.

Table 6.--Summary of constituent trends for the 1962-82 water years

[↑, trend of increasing concentration; ↓, trend of decreasing concentration; -, no trend indicated at significance level of 0.10; blank indicates no analysis was performed]

Station	pH	Specific conductance	Alkalinity as $CaCO_3$	Dissolved solids @ 180 °C	Dissolved solids @ 105 °C	Suspended solids @ 105 °C	Total Calcium	Total Magnesium	Dissolved chloride	Dissolved sulfate	Total phosphorus	Total-recoverable iron	Total-recoverable manganese	Total-recoverable aluminum	Streamflow
West Branch Susquehanna River at Lewisburg	↑	-	↑	↓			-	-	-	↓					↑
West Branch Susquehanna River at Williamsport	↑		↑			-			↑	↓		-	↓	-	↑
West Branch Susquehanna River at Renovo	↑		↑			↑			-	↓		↓	↓	-	↑
West Branch Susquehanna at Karthaus	↑					-			-	↓		↓	-	-	↑
West Branch Susquehanna at Curwensville	↑		↑		-	-			↑	↓	↑	↓	↓	-	↑
West Branch Susquehanna at Bower	↑		↑		↓	↓			-	↓	-	↓	↓	-	↑

CAUSES OF SURFACE-WATER-QUALITY VARIABILITY

Areal Variation

The dominant influences on water quality in this basin are geology and land use. Sedimentary rocks underlie the entire basin. Relatively unreactive sandstone and shale are the predominant rock types as evidenced by the low concentrations of dissolved calcium, magnesium, and dissolved solids found throughout the basin. Extensive formations of reactive limestone and dolomite occur in the Bald Eagle Creek basin. Runoff from this watershed is relatively high in water hardness, dissolved solids, and alkalinity.

Agriculture is found mostly in the lower one-third of the basin because of the mountainous areas in the upper two-thirds of the basin. Agriculture has been identified by PaDER as a moderate problem in the Bald Eagle Creek basin and a potential problem in the Lycoming, Loyalsock, and Muncy Creek basins (Pennsylvania Department of Environmental Resources, Bureau of Water Quality Management, 1982). The fairly low concentrations of total nitrogen and phosphorus indicate that it was not a problem in these tributaries from 1972 to 1982.

Acid precipitation has been identified as a potential problem in headwaters streams of the basins with relatively good water quality, such as Kettle, Young Womans, and Pine Creeks. However, these effects are not seen in the data collected at the mouths of these tributaries.

Industrial and municipal waste discharge has been identified as a moderate problem in Muncy Creek and as a severe problem in Bald Eagle Creek. This is documented by the relatively high nutrient and lead concentrations found in these two streams, particularly Bald Eagle Creek.

Coal mining has the largest impact on water quality in the basin. Although surface mining occupies less than 4 percent of the land in the basin, it degrades about one-half of the main stem and most of the major tributaries west of Williamsport. Active mining and abandoned mine drainage are severe problems in the watersheds drained by Moshannon, Clearfield, and Sinnemahoning Creeks. Surface mining creates moderate problems in Pine, Kettle, Young Womans, Lycoming, and Loyalsock Creeks. The West Branch Susquehanna River is severely affected by mine drainage from the mouth of Moshannon Creek to the mouth of Bald Eagle Creek and moderately affected from the mouth of Bald Eagle Creek to Lewisburg.

Temporal Variation

The causes for the frequency and magnitude of the trends found are not clearly defined by available data. However, because metals are commonly associated with acid mine drainage and nutrients with wastewater treatment, the general negative trends of both metals and nutrients imply that the severity of acid mine drainage has decreased and that wastewater treatment has improved in the basin since 1972. The implication of the reduction of acid mine drainage also is supported by positive trends in pH and alkalinity.

Inconsistencies in the direction of concentration and discharge trends found at some of the stations generally are explained by trends in streamflows sampled. For instance, at the water-quality station on the West Branch Susquehanna River at Lewisburg, significant trends are found in the concentration and discharge of dissolved solids (table 3). The concentration trend is positive and the discharge trend is negative. This is explained by a negative trend in sample streamflow large enough to offset a positive concentration trend. The flow-adjusted concentration also is positive but, as expected, smaller than the unadjusted concentration trend.

ASSESSMENT OF NASQAN STATION INDICATOR ABILITY

The areal and temporal variations found in the West Branch Susquehanna River basin were compared to data for the West Branch Susquehanna River at Lewisburg to determine whether the fixed network NASQAN station represents the water quality of the entire basin.

Areal Variation

Areally, data from Lewisburg are not adequate to describe conditions in the other parts of the basin. For pH (fig. 16), about 60 percent of the stations have median values within one standard deviation of that at Lewisburg, while for specific conductance (fig. 16), only 3 of the 17 stations (18 percent) have mean values within that range. Likewise, for total calcium and dissolved sulfate (fig. 17), only four and two mean concentrations, (24 and 12 percent, respectively) fall within the range of one standard deviation of the mean concentration at Lewisburg. Mean total nitrite plus nitrate as nitrogen and phosphorus concentrations (fig. 18) at stations other than Lewisburg generally fall within the one standard deviation range at Lewisburg. About 70 percent of the mean concentrations of total nitrite plus nitrate and all of the mean total phosphorus concentrations are within the range. Although this agreement is good, it is partially explained by the small range of concentrations found throughout the basin relative to the large range found at Lewisburg. The large range of total-recoverable iron concentrations found at Lewisburg (fig. 19) includes all but one (Moshannon Creek) of the mean concentrations found at the other 17 stations. On the other hand, the relatively small range of total-recoverable manganese concentrations found at Lewisburg (fig. 19) includes only four of the mean concentrations of the other main stem and tributary stations. In summary, the data from Lewisburg indicate the concentrations or values found in other parts of the basin fairly for pH, total nitrite plus nitrate as nitrogen, total phosphorus, and total-recoverable iron and poorly for specific conductance, total calcium, dissolved sulfate, and total-recoverable manganese.

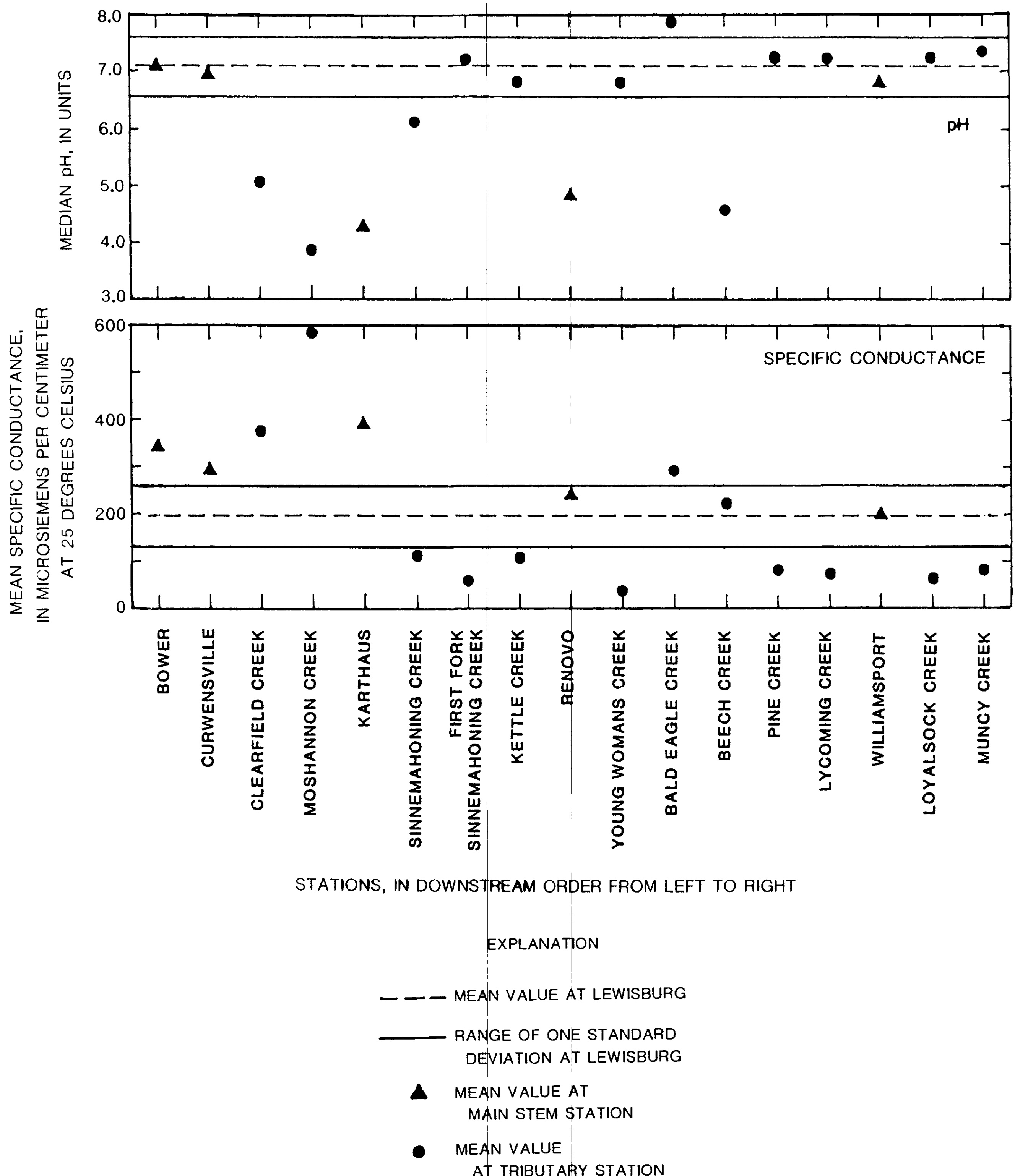


Figure 16.--Variation of median pH and mean specific conductance at water-quality stations, 1972-82 water years.

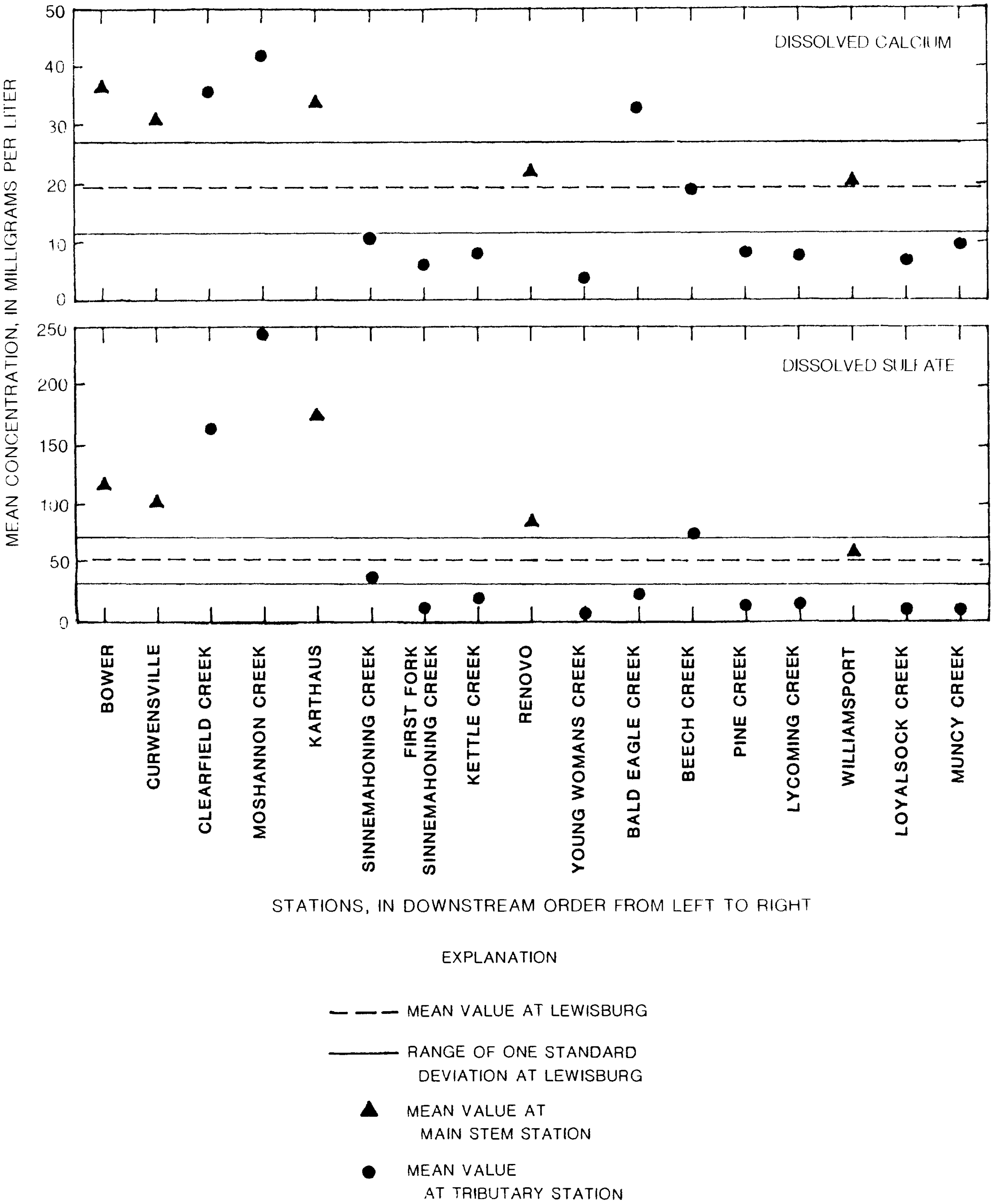
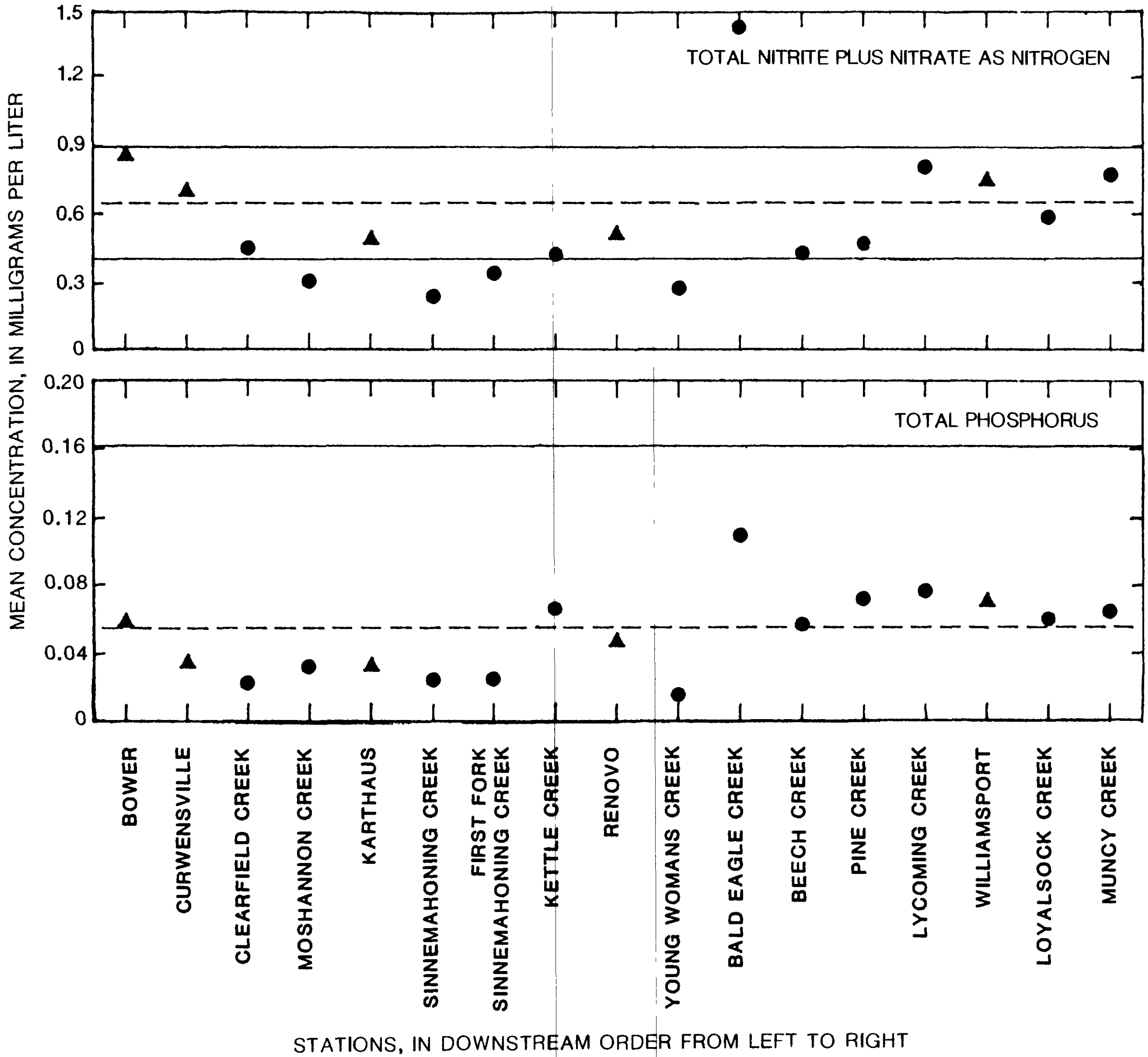


Figure 17.--Variation of dissolved calcium and sulfate at water-quality stations, 1972-82 water years.



EXPLANATION

— — — MEAN VALUE AT LEWISBURG

——— RANGE OF ONE STANDARD DEVIATION AT LEWISBURG

▲ MEAN VALUE AT MAIN STEM STATION

● MEAN VALUE AT TRIBUTARY STATION

Figure 18.--**Variation of total nitrite plus nitrate as nitrogen and phosphorus at water-quality stations, 1972-82 water years.**

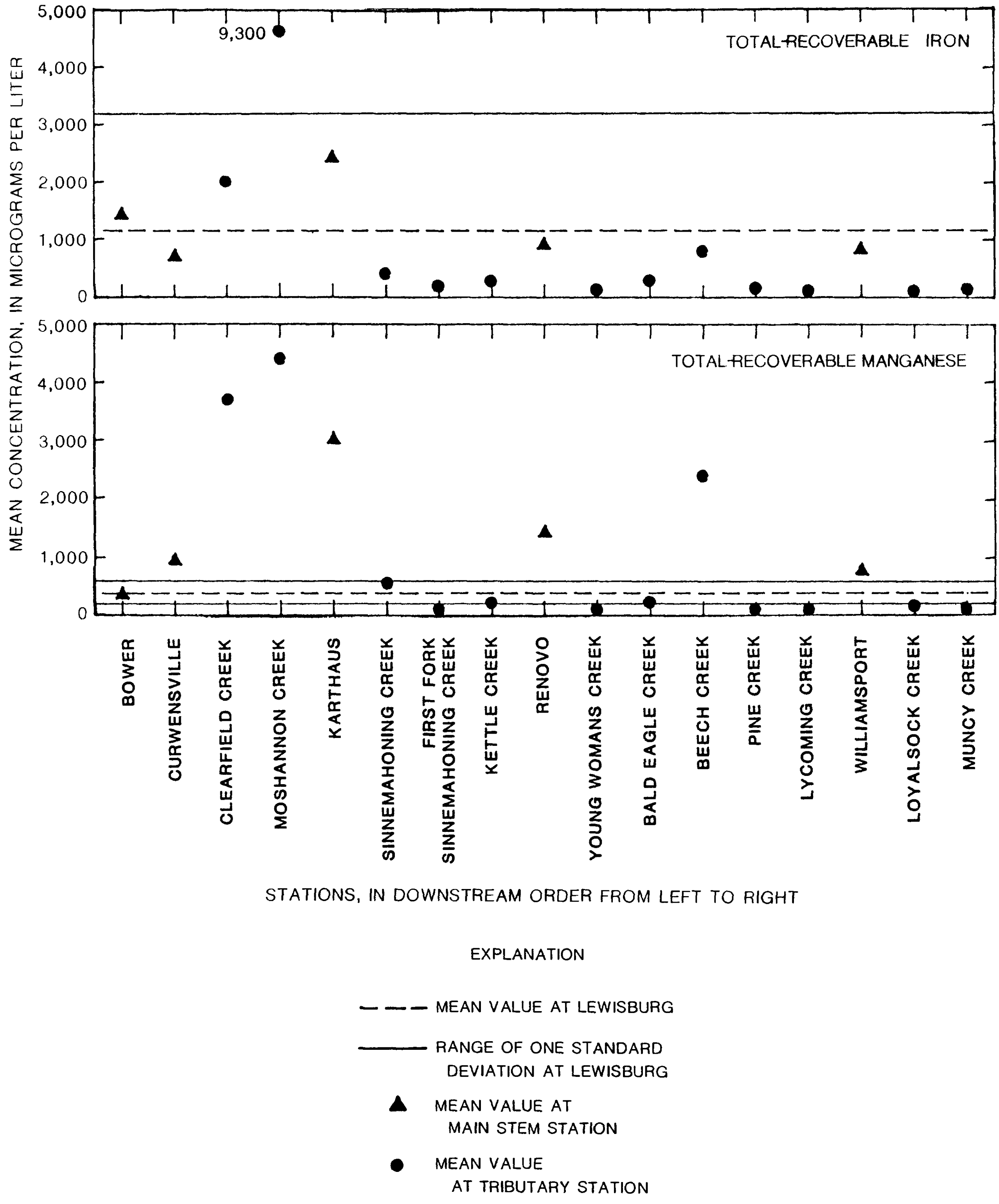


Figure 19.--Variation of total-recoverable iron and manganese at water-quality stations, 1972-82 water years.

Temporal Variation

Trend data were summarized in table 7 and used to evaluate whether the NASQAN station at Lewisburg is an indicator of water-quality trend direction and magnitude for the other stations in the basin. Numerical values were assigned to the observed trends at the West Branch Susquehanna River at Lewisburg and two station groupings: all stations on the main stem and all main stem and tributary stations upstream of Lewisburg. A value of (+1) was assigned to each increasing trend, a value of (-1) to each decreasing trend, and a value of (0) for no trend. Trends for each constituent were tabulated and divided by the number of stations with trends in that constituent for each group.

Trend direction can be evaluated by comparing the signs of the trends (+ or -) for Lewisburg to those for the other station groups. Slightly more than half of the trends for the 1972-82 water years agree with those of Lewisburg. The direction of all of the trends except dissolved chloride agree with those at Lewisburg for the 1962-82 water years. The close agreement of trend direction for 1962-82 indicates that these changes in water quality are probably occurring along the entire length of the West Branch Susquehanna River. These trends, however, may not be occurring on the tributary streams.

Trend magnitude can be evaluated by examining the relative size of the computed values shown in table 7. For the 1972-82 water years, few of the values for the two groups of stations are similar to those at Lewisburg. The computed values of stations located on the West Branch Susquehanna River are closer to those indicated for Lewisburg than the values for all the stations. Differences in trend magnitude between Lewisburg and the other stations on the West Branch Susquehanna River are less during the 1962-82 water years.

Generally, trends observed at Lewisburg are not indicative of trends which may be occurring in other parts of the basin. In fact, a large water-quality change over a large area would be necessary to affect a trend at Lewisburg. Therefore, the NASQAN station at Lewisburg is only a fair indicator of water-quality trend direction and a poor indicator of water-quality trend magnitude for other stations in the basin.

Table 7.--Summary of trend indicator strength values for the 1972-82 water years

[----, no data available; +, increasing trend; -, decreasing trend. See text for explanation of numeric strength value.]

Period of Record 1972-82 Water Years

Station	pH	Specific conductance	Alkalinity as $CaCO_3$	Dissolved solids	Calcium	Magnesium	Dissolved chloride	Dissolved sulfate	Total nitrite + nitrate	Total Phosphorus	Total-recoverable iron	Total-recoverable manganese	Total-recoverable zinc	Total-recoverable lead	Streamflow
West Branch Susquehanna River at Lewisburg	+1.0	+1.0	+1.0	+1.0	+1.0	+1.0	+1.0	0	+1.0	0	0	0	+1.0	0	-1.0
Stations located on West Branch Susquehanna River	+0.6	+0.2	+0.2	-0.3	+0.3	-0.3	+0.6	+0.2	+0.4	0	0	0	----	----	0
All stations upstream of Lewisburg	+0.5	+0.2	-0.2	-0.1	+0.3	0	+0.3	+0.1	-0.1	-0.2	-0.1	-0.3	-0.3	-0.7	-0.1

Period of Record 1962-82 Water Years

Station	pH	Specific conductance	Alkalinity as $CaCO_3$	Dissolved solids	Calcium	Magnesium	Dissolved chloride	Dissolved sulfate	Total nitrite + nitrate	Total Phosphorus	Total-recoverable iron	Total-recoverable manganese	Total-recoverable zinc	Total-recoverable lead	Streamflow
West Branch Susquehanna River at Lewisburg	+1.0		+1.0	-1.0			0	-1.0						+1.0	
Stations located on West Branch Susquehanna River	+1.0		+1.0	-0.5			+0.4	-1.0						+1.0	

SUMMARY

The water quality of the West Branch Susquehanna River basin, a largely forested watershed, varies considerably from its headwaters to the NASQAN station at Lewisburg, Pennsylvania. The dominant water-quality characteristic of the river at any point along the reach is generally determined by the geology and land use of the area drained by the next significant upstream tributary. Generally, the river was found to have moderately good water quality in the upper reaches, poor water quality in its middle reach, and good water quality near the mouth. Two tributaries, Moshannon Creek and Bald Eagle Creek, had the most pronounced effect on the water quality of the river.

The water-quality characteristic, pH, is commonly used as an indicator of water quality. The lowest pH values measured generally were at the station on Moshannon Creek (median 3.9); the highest at the station on Bald Eagle Creek (median 7.8). The effect of acid mine drainage on the water quality of the West Branch Susquehanna River is pronounced as shown by the decrease in median pH between Curwensville (6.9) and Karthaus (4.3). Below Renovo, the inflow of three tributaries with relatively good water quality increases the median pH substantially between Renovo (4.8) and Williamsport (6.7).

Most of the stations have a very low mean alkalinity, 2.0 to 23 mg/L, compared to Bald Eagle Creek (103 mg/L). Alkalinity decreases in the main stem because of the inflow of acidic waters from Clearfield (mean 3.8 mg/L) and Moshannon Creeks (mean 8.6 mg/L). Acidity in these streams is normally higher than the alkalinity in the river. The major contributor of alkalinity to the main stem is Bald Eagle Creek, where the mean concentration was five to ten times greater than the mean at any of the other stations.

The highest specific conductance and dissolved solids concentrations were found at the stations on streams with poor water quality, Moshannon and Clearfield Creeks, and at the station on the West Branch Susquehanna River at Karthaus. Lowest values, indicators of good water quality, were found at all the tributary stations below Sinnemahoning Creek, except Bald Eagle Creek. Bald Eagle Creek basin produces rather hard water with moderately high specific conductance (mean 291 μmhos) and concentrations of dissolved solids (mean 196 mg/L). The largest specific conductance ranges are on the tributaries significantly affected by acid mine drainage.

Concentrations of dissolved chloride vary only slightly throughout the basin. With the exception of Young Womans Creek (1.3 mg/L) and Bald Eagle Creek (13.5 mg/L), the means range from about 3 to 11 mg/L.

High dissolved sulfate concentrations, like low pH values, are generally indicators of poor water quality. The highest mean concentrations were found on the streams most affected by acid mine drainage--Clearfield (165 mg/L) and Moshannon Creeks (245 mg/L)--and the West Branch Susquehanna River at Karthaus (175 mg/L). The lowest mean concentrations were found at Young Womans (7.6 mg/L), Bald Eagle (24 mg/L), and Lycoming Creeks (13 mg/L).

Mean concentrations of total nitrite plus nitrate and total phosphorus were fairly uniform throughout the basin. The mean nitrite plus nitrate concentrations were about 0.6 mg/L except for the main stem stations at Bower (0.9 mg/L) and Curwensville (0.8 mg/L) and at Bald Eagle Creek (1.4 mg/L). The mean phosphorus concentrations were about 0.05 mg/L at all the stations except for 0.11 mg/L at Bald Eagle Creek and 0.01 mg/L at Young Womans Creek. Total ammonia concentrations exhibited the most variation.

Total-recoverable iron concentrations found in the basin ranged from 10 μg/L at several of the sites to nearly 30,000 μg/L at the site on Moshannon Creek. Generally, those stations with the highest concentrations also had the largest ranges. Water samples taken from Moshannon Creek indicated the largest range of concentrations for iron (1,600-29,500 μg/L), manganese (1,900-7,480 μg/L), and aluminum (3,300-9,915 μg/L). Of the stations with sufficient data available, the largest range for total-recoverable lead was also found on Moshannon Creek (2.0-60 μg/L).

The largest negative trends in the West Branch Susquehanna River basin from 1972-82 were observed for concentrations of various trace metals--total-recoverable manganese, aluminum, zinc, and lead--and total ammonia nitrogen. These negative trends, indicating an improvement in water quality, are believed to be caused by improvements in the treatment of acid mine drainage and wastewater. The largest negative trend in the basin was -23.5 percent per year in the total-recoverable aluminum concentration. The concentration of total-recoverable aluminum at the West Branch Susquehanna River at Williamsport had the largest positive trend--14.0 percent per year. This increase in trace-metal concentration probably was related to industrial wastes around the metropolitan areas.

Inconsistent variations were found in the concentrations of alkalinity, sulfate, and nitrite plus nitrate. Generally, the concentrations of metals associated with acid mine discharges and the concentrations of nutrients associated with wastewater treatment had negative trends. Most trends for pH and specific conductance were positive. The causes for these trends may be improvements in wastewater effluent quality and in the quality or quantity of acid mine discharges. Some of trends from 1972-82 are apparently the continuation of trends from 1962-72.

Because of the size of the basin and the impact of point and non-point sources on the water quality of the West Branch Susquehanna River, the water quality measured at the station on the West Branch Susquehanna River at Lewisburg does not represent the water quality throughout the basin. Water-quality trends observed at Lewisburg are fair indicators of trend direction and poor indicators of trend magnitude in other parts of the basin. The water quality at Lewisburg does, however, reflect the cumulative impact of geology and land use on the water quality of the West Branch Susquehanna River near its mouth.

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