Hydrology and the Effects of Selected Agricultural Best-Management Practices in the Bald Eagle Creek Watershed, York County, Pennsylvania, Prior To and During Nutrient Management

Water-Quality Study for the Chesapeake Bay Program

By Michael J. Langland and David K. Fishel

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
	Length	
inch (in.)	25.40	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
foot per mile (ft/mi)	0.1894	meter per kilometer
	Area	
acre	0.004047	square kilometer
square mile (mi^2)	2.590	square kilometer
	Flow	
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
gallon per minute per foot (gal/min)/ft	0.2070	liter per second per meter
	Volume	
gallon per minute (gal/min)	0.06309	liter per second
bushel (dry)	0.0284	liter
	Mass	
pound (lb)	0.4536	kilogram
pound per acre (lb/acre)	1.123	kilogram per hectare
pound per ton (lb/ton)	0.50	kilogram per megagram
	Temperature	
degree Fahrenheit (°F)	°C = 5/9 (°F - 32)	degree Celsius

Abbreviated water-quality units used in report:

micrograms per liter (µg/L)
micrometers (µm)
microsiemens per centimeter at 25 degrees Celsius (µS/cm)
milligrams per liter (mg/L)

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

HYDROLOGY AND THE EFFECTS OF SELECTED AGRICULTURAL BEST-MANAGEMENT PRACTICES IN THE BALD EAGLE CREEK WATERSHED, YORK COUNTY, PENNSYLVANIA, PRIOR TO AND DURING NUTRIENT MANAGEMENT

By Michael J. Langland and David K. Fishel

ABSTRACT

The U.S. Geological Survey, in cooperation with the Susquehanna River Basin Commission and the Pennsylvania Department of Environmental Resources, conducted a study as part of the U.S. Environmental Protection Agency's Chesapeake Bay Program to determine the effects of nutrient management on surface-water quality by reducing animal units in a 0.43 square-mile agricultural watershed in York County. The study was conducted primarily from October 1985 through September 1990 prior to and during the implementation of nutrient-management practices designed to reduce nutrient and sediment discharges. Intermittent sampling continued until August 1991.

The Bald Eagle Creek Basin is underlain by schist and quartzite. About 87 percent of the watershed is cropland and pasture. Nearly 33 percent of the cropland was planted in corn prior to nutrient management, whereas 22 percent of the cropland was planted in corn during the nutrient-management phase. The animal population was reduced by 49 percent during nutrient management. Average annual applications of nitrogen and phosphorus from manure to cropland were reduced by 3,940 pounds (39 percent) and 910 pounds (46 percent), respectively, during nutrient management. A total of 94,560 pounds of nitrogen (538 pounds per acre) and 26,400 pounds of phosphorus (150 pounds per acre) were applied to the cropland as commercial fertilizer and manure during the 5-year study.

Core samples from the top 4 feet of soil were collected prior to and during nutrient management and analyzed for concentrations of nitrogen and phosphorus. The average amount of nitrate nitrogen in the soil ranged from 36 to 135 pounds per acre, and soluble phosphorus ranged from 0.39 to 2.5 pounds per acre, prior to nutrient management. During nutrient management, nitrate nitrogen in the soil ranged from 21 to 291 pounds per acre and soluble phosphorus ranged from 0.73 to 1.7 pounds per acre. Precipitation was about 18 percent below normal and streamflow was about 35 percent below normal prior to nutrient management, whereas precipitation was 4 percent above normal and streamflow was 3 percent below normal during the first 2 years of nutrient management. Eighty-four percent of the 20.44 inches of streamflow was base flow prior to nutrient management and 54 percent of the 31.14 inches of streamflow was base flow during the first 2 years of the nutrient-management phase. About 31 percent of the measured precipitation during the first 4 years of the study was discharged as surface water; the remaining 69 percent was removed as evapotranspiration or remained in ground-water storage.

Median concentrations of total nitrogen and dissolved nitrate plus nitrite in base flow increased from 4.9 and 4.1 milligrams per liter as nitrogen, respectively, prior to nutrient management to 5.8 and 5.0 milligrams per liter, respectively, during nutrient management. Median concentrations of ammonia nitrogen and organic nitrogen did not change significantly in base flow. Median concentrations of total and dissolved phosphorus in base flow did not change significantly and were 0.05 and 0.03 milligrams per liter as phosphorus, respectively, prior to the management phase, and 0.05 and 0.04 milligrams per liter, respectively, during the management phase.

Concentrations and loads of dissolved nitrite plus nitrate in base flow increased following wet periods after crops were harvested and manure was applied. During the growing season, concentrations and loads decreased as nutrient utilization and evapotranspiration by corn increased. About 4,550 pounds of suspended sediment, 5,300 pounds of nitrogen, and 70.4 pounds of phosphorus discharged in base flow in the 2 years prior to nutrient management. During the first 2 years of nutrient management about 2,860 pounds of suspended sediment, 5,700 pounds of nitrogen, and 46.6 pounds of phosphorus discharged in base flow. Prior to nutrient management, about 260,000 pounds of suspended sediment, about 2,180 pounds of nitrogen, and about 235 pounds of phosphorus discharged in stormflow. During the first 2 years of nutrient management about 464,000 pounds of suspended sediment, 6,120 pounds of nitrogen, and 912 pounds of phosphorus discharged in stormflow.

The seasonal rank-sum test indicated that significant differences were detected in the medians of total nitrogen and dissolved nitrite plus nitrate in base flow prior to and during nutrient management. The seasonal Kendall test indicated significant upward trends in concentrations and loads of total nitrogen and dissolved-nitrite plus nitrate measured in base flow during the entire study. Neither significant differences nor trends were detected in the concentrations and loads for ammonia, ammonia plus organic nitrogen, phosphorus, or suspended sediment in base flow.

INTRODUCTION

The U.S. Geological Survey (USGS), in cooperation with the Susquehanna River Basin Commission (SRBC) and the Pennsylvania Department of Environmental Resources (PaDER) Bureau of Land and Water Conservation, conducted a study to determine the effects of agricultural best-management practices on surface-water quality in the Bald Eagle Creek watershed (site 1, fig. 1) from October 1, 1985, to September 30, 1990. The site is underlain by noncarbonate rock and is one of three small agricultural watersheds in the Lower Susquehanna River Basin that were studied prior to and during the implementation of nutrient management at the watersheds. This report includes a comparison of land-use and water-quality data from Bald Eagle Creek with data from Brush Run (site 2, fig. 1, also underlain by noncarbonate rock) and the Nutrient-Management Subbasin located in a carbonate-rock area (site 3, fig. 1) that is part of the Conestoga River headwaters being studied by Fishel and others (1992) as part of the Rural Clean Water Program (RCWP).

The full history of this study's conception is described in the characterization report (Fishel and others, 1991). In 1982, the RCWP initiated a 10-year study of the Conestoga River headwaters to determine the effects of agricultural-management practices on surface-water and ground-water quality. One of three components of the Conestoga River Headwaters Project was to evaluate the effects of nutrient management in a small intensively farmed watershed, the Little Conestoga Creek watershed, underlain by carbonate rock. Inasmuch as there was a need for a corresponding program in areas underlain by noncarbonate rocks in the Lower Susquehanna River basin, this study and a study of the Brush Run watershed were initiated by the USGS in 1985 (Fishel and others, 1992). The study was part of the U.S. Environmental Protection Agency (USEPA) Chesapeake Bay Program. The results from this study were planned to be compared to results from the carbonate-rock areas being studied for the RCWP, such as the Nutrient-Management Subbasin in the Little Conestoga Creek headwaters, and to results from Brush Run Creek, a second site in noncarbonate rock.

Initially, agricultural-management plans were to be designed and implemented at two of the farms in the 0.43-mi^2 Bald Eagle Creek study area and were to consist of a combination of management practices. Management plans included recommendations to install terraces, diversions, sediment-detention ponds, animal-waste storage facilities, barn gutters, and other innovative techniques to control nutrient and sediment loads in surface runoff. The installation of the management practices were to reduce the amount of nutrients available for leaching to the ground water and also discharged in base flow or storm runoff. Nutrient applications were to be balanced with crop requirements to obtain maximum crop yields. However, in September 1987, one of the cooperating farmers was permitted to withdraw from his Chesapeake Bay Program cost-sharing management plan after developing a medical difficulty. He later sold his dairy herd and changed his cropping patterns from predominantly corn to alfalfa. Subsequently, a second farmer within the study area sold his farm. The new owner reduced the number of animal units by reducing the dairy population at the farm. Monitoring continued at the site to determine the effects that these management changes--a reduction of animal units, manure applications, and corn production--would have on surface-water quality in the Bald Eagle Creek Basin.

Because a management practice was not implemented to control storm-water runoff, the monitoring effort was reduced and the project scope changed. The continuous streamflow gage and precipitation gage were discontinued in September 1989. After September 1989, the project scope concentrated on base-flow quality; however, in order to fully understand the hydrologic conditions at the site additional data from the ground-water system needed to be collected. Attempts were then made to collect limited ground-water information so that changes observed in water quality could be correlated with land-use activities that could potentially effect the base flow. Even though the ground-water basin was somewhat different than the surface-water basin, the assumption was made that any changes in the water quality of base flow were caused by land-use changes within the surface-water basin. Measurement of intermittent base-flow quantity and quality continued until August 1991 in an attempt to detect changes in water quality from the reduction in applications of animal waste.

Purpose and Scope

This report provides an evaluation of the effects of agricultural-management practices, with emphasis on the effects of reductions of (1) animal units, (2) nutrient applications, and (3) corn production on the surface-water quality of a 0.43-mi^2 watershed (fig. 2) in the Bald Eagle Creek headwaters near Fawn Grove, in York County, Pa. Data collected from the premanagement phase (October 1, 1985, through September 30, 1987) is compared with data collected during the management phase (October 1, 1987, through September 30, 1990)This report describes the study area, the data-collection methods used, and effects of nutrient-management practices on soil nutrients, and precipitation and surface-water quality. Target goals were established to determine the effects of nutrient-management practices on surface-water quality. This report will aid agricultural managers in the development of management plans for other farms. It will also help to determine whether voluntary implementation of management practices are successful in improving the water quality of the Lower Susquehanna River Basin.

Approach

Extensive land-use, hydrologic, and soil data were collected and used to evaluate the effects of nutrient-management practices on the water quality of stormflow and base flow at the Bald Eagle Creek site. Both historical and current data were used in the evaluation. Land-use data compiled from three farms at the site included crop acreage and yields, animal density, manure production, and nutrient applications. Soil-chemistry samples were used to identify areas where nutrient management may be most beneficial. Hydrologic data were collected and used to determine the quantity and quality of precipitation, base flow, and stormflow. Samples of base flow and stormflow were collected to document the water chemistry prior to and during the management phase. Nutrient and suspended-sediment loads were calculated to determine changes in yields of nutrients and suspended sediment as the result of the management practices.

Data were plotted and parametric and nonparametric statistics were calculated to identify seasonal variations and trends. Data were grouped into growing (April through September) and nongrowing (October through March) seasons. A modified form of the nonparametric-Wilcoxon-Mann-Whitney-rank-sum test for seasonal data (Crawford, Slack, and Hirsch, 1983) and Monte-Carlo simulations (R.M. Hirsch, U.S. Geological Survey, written commun., 1989) were used to estimate reductions necessary to observe statistical changes in concentrations and loads of nitrogen and phosphorus in base flow, on the basis of variances of the data collected prior to nutrient management. The Seasonal Kendall test was used to test for monotonic trend in water quality over the 5-year sampling period.

Related Studies

Studies related to this project include the comprehensive RCWP monitoring projects to determine the effects of agricultural best-management practices on water quality in Idaho, Illinois, South Dakota, Vermont, and Pennsylvania. The Pennsylvania and South Dakota projects are the only RCWP projects investigating nutrient transport in ground water.

Another related study is being conducted by the USGS in the Patuxent River Basin in Maryland (Steve Preston, U.S. Geological Survey, oral commun., 1987) in which nonpoint-source nutrient contamination and sediment loads in a 980 mi^2 watershed are being investigated. A study also is being conducted by the USGS and the SRBC to assess the sources of nutrient loads transported from selected watersheds of the Susquehanna River Basin to the Chesapeake Bay (Lloyd Reed, U.S. Geological Survey, oral commun., 1992). Studies by the PaDER, in cooperation with the Lancaster and Lebanon County Conservation Districts (D. Gregg, Pennsylvania Department of Environmental Resources, Bureau of Forestry, written commun., 1986) also are being conducted to determine the effects of manure disposal on ground water and undisturbed soils.

Acknowledgments

The authors thank the following individuals and respective agencies for their assistance and cooperation:

1. Landowner Kenneth Smith, who permitted the gage to be constructed on his property.
2. Four farmers, John Wilcox, Amos King, Kenneth Moore, and John Stolzfus, who volunteered to provide land-use data and access to their farms.
3. Riggs Harwell, District Conservationist for the U.S. Department of Agriculture, Soil Conservation Service, who assisted with project planning, gathering crop-yield data, and developing management plans.
4. Dr. Dale Baker and Leon Marshall from the Pennsylvania State University, Department of Agronomy, who collected and analyzed soil samples.

DESCRIPTION OF STUDY AREA

Bald Eagle Creek is located in south-central Pennsylvania and is part of the Lower Susquehanna River Basin (fig. 1). The stream flows northeastward and drains into Muddy Creek, then flows southeastward, draining into the Susquehanna River approximately 6 mi upstream from the Maryland-Pennsylvania state boundary.

The Bald Eagle Creek watershed is 0.43 mi^2 and is located in southern York County and is about 1.5 mi northwest of Fawn Grove. The streamflow-gaging station (fig. 2) was 0.6 mi downstream from the headwaters.

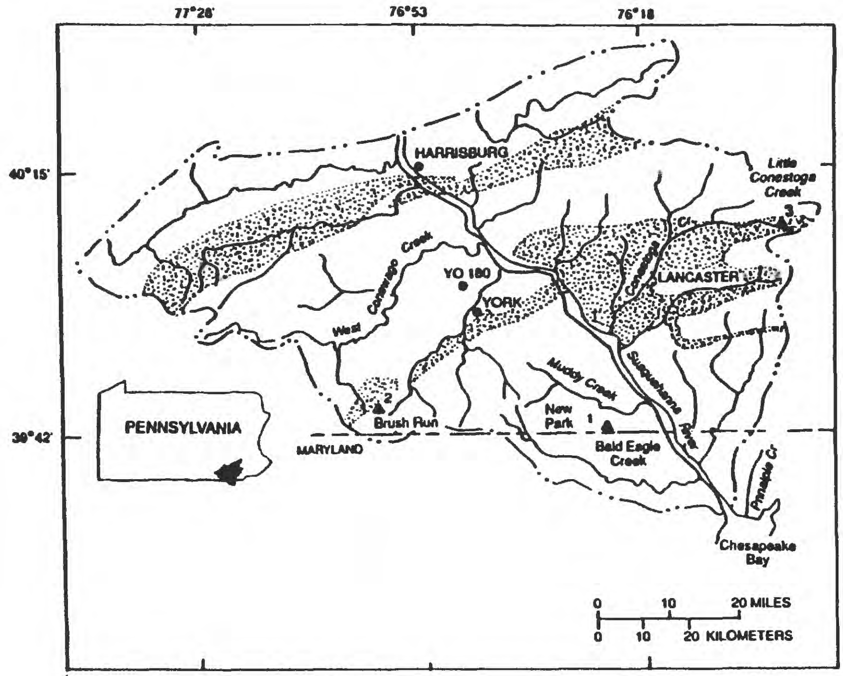

Figure 1. Locations of Bald Eagle Creek Site 1, Brush Run Site 2, and the Little Conestoga Creek (Nutrient-Management Subbasin) Site 3 in the Lower Susquehanna River Basin.

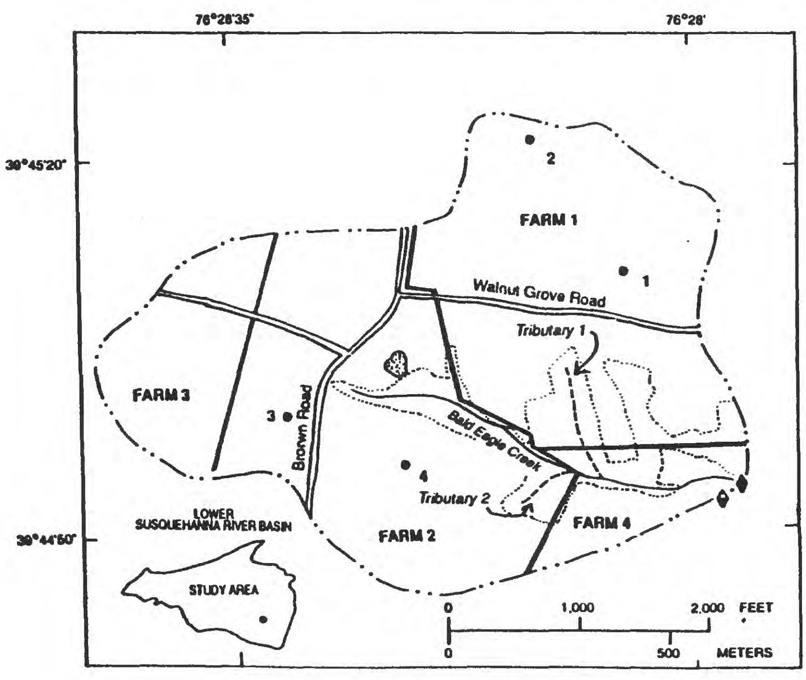

Figure 2. Locations of farms, streamflow and precipitation gages and sampling sites, and soil-sampling sites in Bald Eagle Creek Basin.

Climate

Climate at the Bald Eagle Creek site is relatively mild but humid and is classified as humid continental. Summers are relatively long and warm as evidenced by a growing season that begins in April and ends in September; winters are comparatively short. The average growing season ranges from 169 days near York to about 175 days at Hanover (U.S. Department of Agriculture, 1963). Normal precipitation is 44 in/yr at New Park and is evenly distributed and provides for sufficient rain during the growing season. However, occasional dry periods can cause major crop damage as evidenced during the study.

Geologic Setting

The geologic setting of the Piedmont Uplands in which the study area lies is described by Hall (1934), Lloyd and Growitz (1977), Taylor and Werkheiser (1984), and Gerhart and Lazorchick (1984). In summary, each described the geology of the Piedmont Uplands section as being extremely complex. The area is composed primarily of metamorphosed sedimentary rocks but also contains some igneous rocks and quartzite. The Bald Eagle Creek site is underlain by Wissahickon Formation of the Lower Paleozoic age. The Wissahickon Formation consists primarily of albite-chlorite schist and oligoclase-mica schist, also known as "Gneissic Rocks." This formation is not a natural source of nitrate or phosphorus to the ground water.

Geologic Structure

The major geologic structure in the area is the Martic overthrust--a block of rock that was believed to have been thrust into position from the southeast by mountain-building forces. Other minor structural features within the area are the Tuncquan anticline and the Peach Bottom, Wentz, and Yoe synclines. Within these features, the rocks are complexly folded and may be broken by minor faults. These Gneissic Rocks are regionally metamorphosed, indicating textural and compositional banding (Gary Barton, U.S. Geological Survey, written commun., 1992).

Geologic structure has an important influence on yields of wells, ground-water movement, and quantity of base flow. Faults may contain zones of fractured rock where large amounts of water may be stored. If faults become filled with clay, calcite, or quartz then little or no water can infiltrate and be stored causing base flow to decline rapidly. In areas where fold hinges are present, secondary permeability may develop because of numerous fractures, well-developed cleavage, and the presence of horizontal or nearly horizontal bedding that can increase well yields and may contribute to extended periods of high base flow.

Basin Morphology and Topography

The Bald Eagle Creek watershed lies in the Southeastern Upland subdivision of the Piedmont physiographic province of the Appalachian Highlands. The topography consists of broad ridgetops and steep hillsides. The underlying rocks are largely erosion-resistant schist and quartzite.

Differences between basin morphology and topography of the Bald Eagle Creek and the Brush Run site are illustrated in figure 3. Generally, the Bald Eagle Creek Basin is rotund in shape with little stream bifurcation, has steep hillslopes and traverses west to east. Land-surface elevations at Bald Eagle Creek range from 800 ft above sea level near the upper end of the basin to 591 ft above sea level at the streamflow-gaging site. Bald Eagle Creek descends rapidly from its headwaters to the gaging site, an average gradient of 152 ft/mi. Immediately downstream from the gage, elevations decrease and the gradient flattens to about 55 ft/mi from the gage to Muddy Creek. The steep channel slope causes the flood plain of Bald Eagle Creek to be prone to flash-flood conditions, especially during thunderstorms.

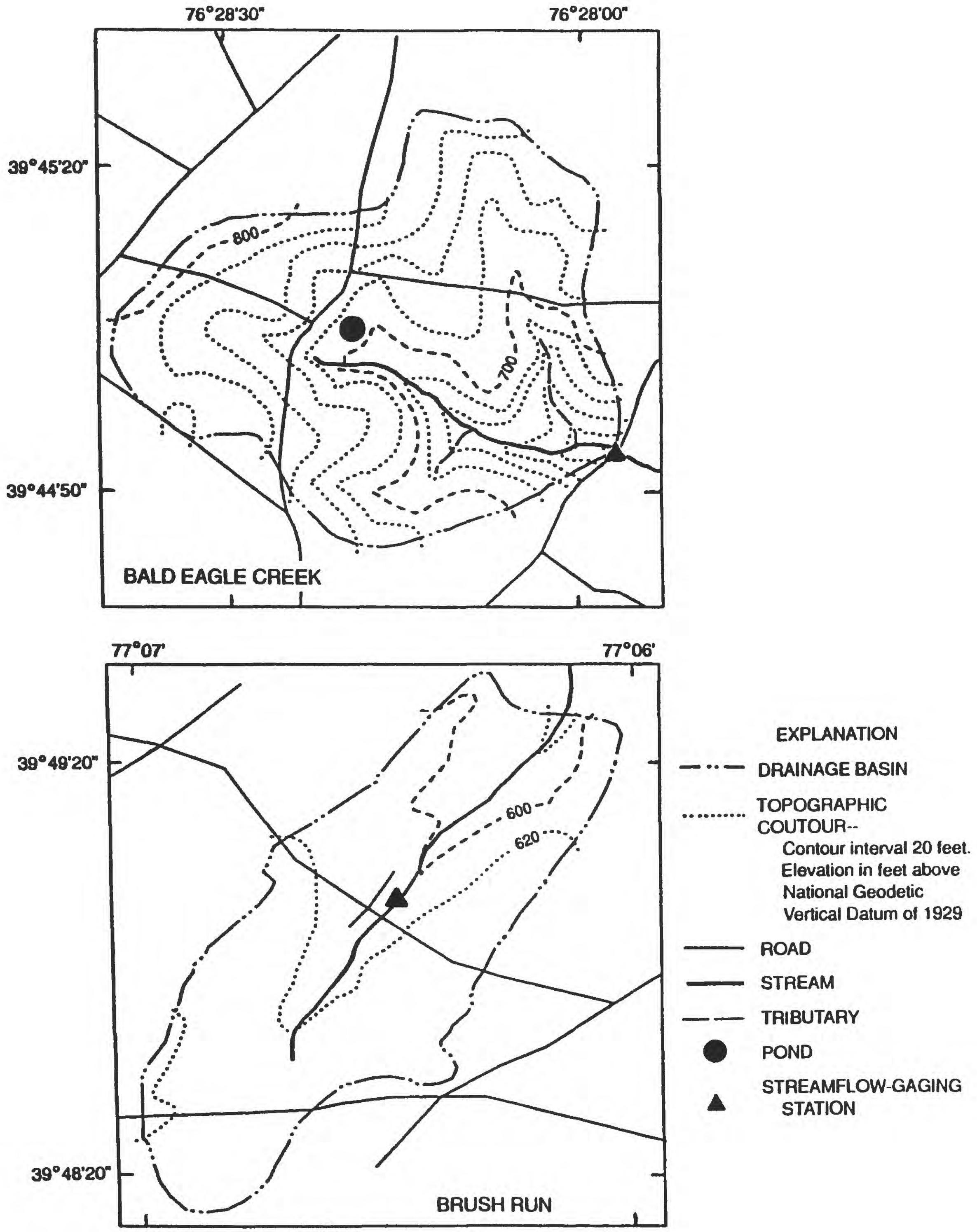

Figure 3. Basin topography and basin configuration at Bald Eagle Creek (top) and Brush Run (bottom) sites.

Bald Eagle Creek originates from a series of small springs. Several large springs discharge continuously forming two tributaries between the headwaters and the streamflow-gaging site. Another significant physical feature within the study area is the farm pond located at farm 2 (fig. 2). This pond is spring fed and, although it does not discharge from an outflow at the land surface, seepage from the pond has been observed to discharge directly to the Bald Eagle Creek.

At the Brush Run site, the basin is long, flat, and elongated, with no bifurcation. The Brush Run Creek traverses from southwest to northeast. Land-surface elevations range from 635 ft above sea level at the upper end of the watershed to 600 ft near the gaging site; a gradient of approximately 40 ft/mi. The farmer has installed a series of tile lines to help drain water from low lying fields into the stream.

Soils

The soils at the site are predominantly Glenelg channery and Elioak silt loam (fig. 4). Glenville and Chewacla silt loams and Manor channery loam also are present in smaller amounts, primarily in the valleys. These soils are described as being deep and well drained (U.S. Department of Agriculture, 1963, p. 99-101). However, when soil samples were collected at farm 2, bedrock was, in places, less than 3 ft below the surface. The parent material for the soils weathered from schist and phyllite. The Elioak silt loams have slopes ranging from 3 to 15 percent, the Glenville silt loams have slopes of 0 to 3 percent, and the Manor channery loams have slopes of 8 to 25 percent.

The predominant soils near the gage are from the Chewacla Series soils, which are acid and moderately fertile, but because they are located on narrow bottom lands they are not suitable for cultivation. The York County Soil Survey (U.S. Department of Agriculture, 1963, p. 92) suggests at sites where this soil extends to the stream bank, such as at the streamflow-gaging site, deepening of the stream channel is advisable, in addition to other drainage practices. It also recommends that because these soils remain moist, they provide pastures for grazing until midsummer, but to prevent erosion, the pastures should not be grazed until the ground is firm. Several steer pastured near the gage continuously.

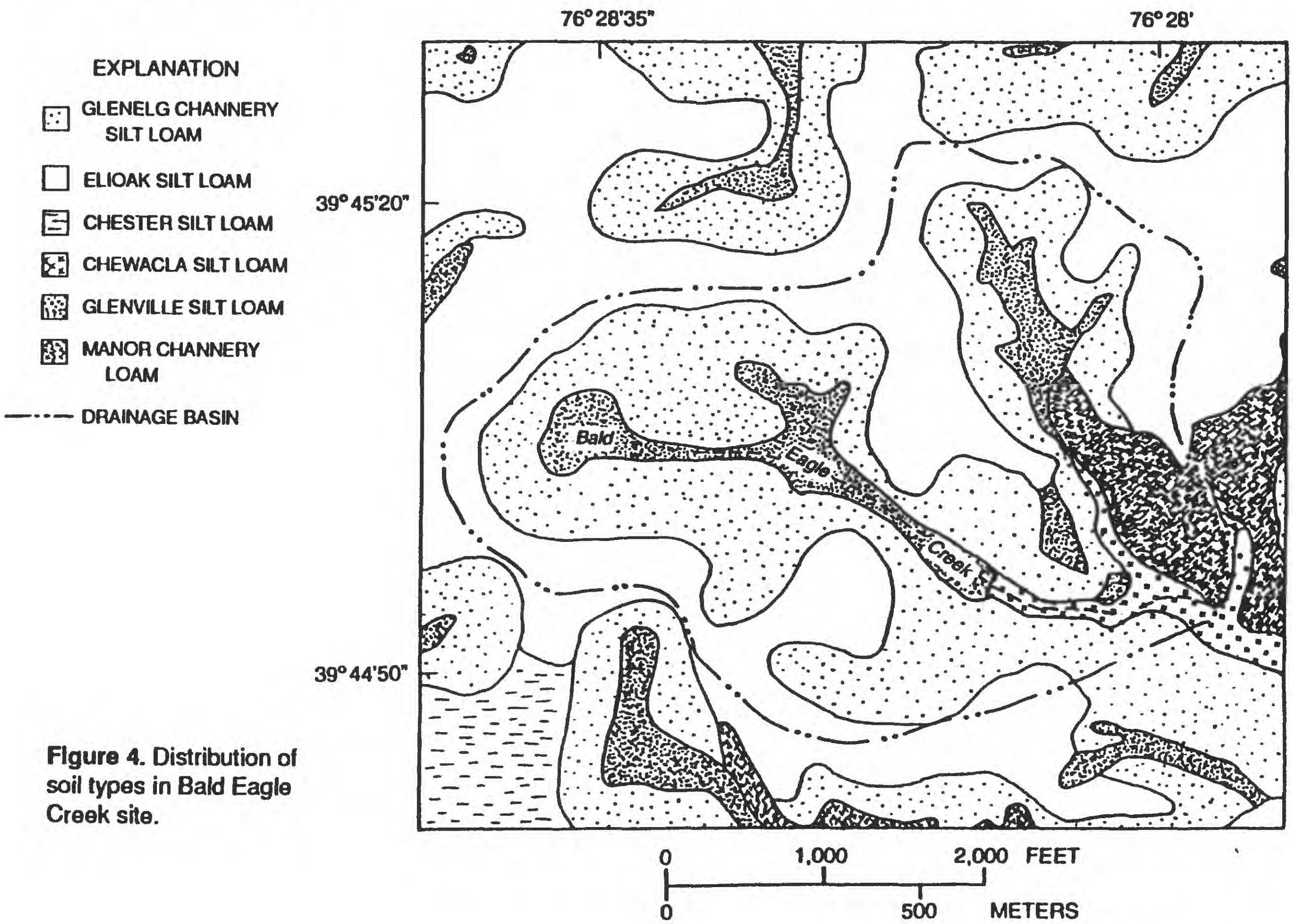

Figure 4. Distribution of soil types in Bald Eagle Creek site.

LAND USE, CROPS, AND NUTRIENT APPLICATIONS

During this study, the predominant land use within the Bald Eagle Creek Basin was agriculture. Between 63 to 66 percent of the basin was cropland, 21 to 24 percent was pasture, and 13 percent was forest (table 1).

Table 1. Land use and crop acreage in the Bald Eagle Creek Basin during the 1986-90 water years
[--, crop not planted; percent, percentage of total land-use area]

	Prior to nutrient management				During nutrient management					
	1986		1987		1988		1989		1990	
Land use	(Acres)	(Percent)	(Acres)	(Percent)	(Acres)	(Percent)	(Acres)	(Percent)	(Acres)	(Percent)
Cropland										
Alfalfa	45.5	16.6	30.0	10.9	38.3	13.9	53.4	19.4	55.6	20.2
Barley	12.8	4.7	--	--	--	--	--	--	--	--
Corn	94.2	34.2	92.6	33.6	67.3	24.5	41.9	15.2	74.8	27.2
Oats/Alfalfa	1.7	.6	11.7	4.3	--	--	--	--	--	--
Potatoes	--	--	12.8	4.7	4.0	1.5	--	--	--	--
Rye	--	--	--	--	--	--	2.8	1.0	--	--
Soybeans	18.3	6.6	34.2	12.4	54.4	19.8	62.3	22.7	42.4	15.4
Wheat	3.3	1.2	--	--	8.8	3.2	12.4	4.5	--	--
Subtotal	175.8	63.9	181.3	65.9	172.8	62.8	172.8	62.8	172.8	62.8
Pasture	64.1	23.3	58.6	21.3	67.1	24.4	67.1	24.4	67.1	24.4
Forest	35.3	12.8	35.3	12.8	35.3	12.8	35.3	12.8	35.3	12.8
Total	275.2	100.0	275.2	100.0	275.2	100.0	275.2	100.0	275.2	100.0

Parts of four farms are located within the watershed (fig. 2). Farm 4 consists of the pasture where the gaging site is located. This landowner generally raised three cattle and six hogs annually.

An average of about 34 percent (93 acres) of the cropland was planted in corn (fig. 5) prior to nutrient management, which decreased to an average of about 22 percent (60 acres) of the cropland during the management phase (fig. 5). During management years 1988, 1989, and 1990, the amount of cropland planted in corn was 67.3, 41.9, and 74.8 acres, respectively (table 1). Rye was commonly planted as a cover crop on corn fields to prevent fall and winter erosion. At the dairy farms (farms 1 and 2), crops were generally rotated on a 2-year corn and 3-year alfalfa sequence. Corn yields in the Bald Eagle Creek Basin prior to and during nutrient management are listed in table 2. They were slightly lower than the 146 bushels per acre average yields reported for 11 farms in the Nutrient-Management Subbasin in Lancaster and Berks Counties by Fishel and others (1992).

Farms 1 and 2 had dairy herds with 97 and 80 cows prior to the management phase. On December 8, 1987, the farmer at Farm 1 (fig. 2) sold 47 cows and began raising the remaining heifers for beef. On February 2, 1990, Farm 2 was sold and the new farm operator reduced the animal population from 99 dairy units to 67 dairy units and 10 horse units (table 3). One animal unit represents 1,000 lb of body weight regardless of animal type. Meanwhile, an increase in the number of steer grazing in the pasture (farm 4) at the water-quality gage increased from 3 to 12 beginning in November 1989. Farm 3 had no animals and relied entirely on commercial fertilizer for nutrient sources.

The animal density, which is based on crop acreage and pasture land available for disposal of manure within the basin, was about 0.85 AU/acre (animal units per acre) prior to the management phase, and 0.43 AU/acre at the end of the management phase. In both cases, the animal units were much less than the 2.50 AU/acre average for 10 farms in the RCWP's Nutrient-Management Subbasin of the Little Conestoga Creek Basin (site 3, fig. 1)(Fishel and others, 1992). They were also less than the 1.5 AU/acre recommended in the Conestoga Headwaters Plan of Work (U.S. Department of Agriculture, 1982) for nonpoint-source discharges. Although all the animals were housed in the basin, the farmers in the Bald Eagle Creek Basin owned additional land outside the subbasin on which they could spread manure. Therefore, if animal densities were calculated from total farm acreage or total farm cropland, rather than crop and pasture land located within the subbasin, the animal densities would be lower than those reported in this report.

The land used for pasture near the gage had a low slope and would often flood during high flows. In order to stabilize the stream channel and prevent further damage to the pasture, the landowner attempted to reroute the channel by use of a bulldozer. He also hauled in and deposited soil to confine the stream by increasing the height of the stream bank. The nutrient content of these exposed soils was unknown. Another attempt was made to reduce damage from flash-floods in the pasture late in July 1988 when a second culvert was added to the bridge located immediately downstream from the gage. Again, soils were exposed and susceptible to erosion during construction time.

According to the land-use data supplied by the farmers (table 4), less nitrogen and phosphorus from manure was applied to the crop and pasture land within the subbasin than was produced by the animal population housed within the subbasin. The land-use application data may contain some errors, because the amount of nitrogen and phosphorus applied within the subbasin plus the amount of nitrogen and phosphorus deposited by grazing animals was less than the amount produced. Perhaps some additional manure was spread outside the subbasin divide.

Most of the manure and commercial fertilizers were applied to the cropland between March and June (fig. 6). However, manure that was stored during the growing season was applied in September after the corn was harvested. Farmers reported that approximately 61,740 lb of nitrogen and 16,610 lb of phosphorus were applied as manure and commercial fertilizer to cropland during the 2 years prior to the management phase (table 5), and 32,820 lb of nitrogen and 9,790 lb of phosphorus were applied during the 3-year management phase. It was estimated that an additional 20,940 lb of nitrogen and 3,680 lb of phosphorus were deposited by cattle in pastures near the stream prior to the management phase (Owen Brubaker, United States Department of Agriculture, Agricultural Stabilization and Conservation Service, written commun., 1985). Likewise, an estimated 18,900 lb of nitrogen and 3,330 lb of phosphorus were contributed by the grazing animals during the 3-year management phase (table 4). Thus, prior to nutrient management, a total of 82,680 lb of nitrogen (172 lb/acre/yr) and 20,290 lb of phosphorus (42 lb/acre/yr) were applied to cropland and pastures; 50 percent of the nitrogen and 62 percent of the phosphorus were from commercial fertilizer. During the management phase, a total of 51,700 lb of nitrogen (72 lb/acre/yr) and 13,120 lb of phosphorus (18 lb/acre/yr) were applied to cropland and pastures; 28 percent of the nitrogen and 50 percent of the phosphorus were from commercial fertilizer. For the 5 years of land-use data collection, 94,560 lb of nitrogen and 26,400 lb of phosphorus were applied to the cropland and an additional 39,840 lb of nitrogen and 7,010 lb of phosphorus were deposited in pastures.

The farmers began reducing their nutrient applications voluntarily before recommendations were made by a nutrient-management specialist. About 31 percent less nitrogen and 3 percent more phosphorus from commercial fertilizer and manure were applied during the second year than during the first year of the study. Similar unsolicited reductions in applications of nutrients to cropland, especially commercial fertilizer, occurred prior to the implementation of nutrient management in the Nutrient-Management Subbasin for the RCWP (Fishel and others, 1991). The average amount of nitrogen and phosphorus applied annually as commercial fertilizer and manure decreased from 30,870 and 8,305 lb/yr, respectively, prior to nutrient management to 10,940 and 3,264 lb/yr, respectively, during the management phase.

Sixty-two percent less nitrogen and 61 percent less phosphorus were applied as commercial fertilizer and manure during the first 2 years of the management phase than during the 2 years prior to the management phase. The reductions in land applications of commercial and manure fertilizers resulted in a corresponding reduction in available nutrients, but changes in cropping patterns could have resulted in an increase of available nutrients for crops (discussed later in report). An average of 93.4 acres was planted in corn, a major consumer of nitrogen, prior to nutrient management. During the first 2 years of nutrient management, corn was planted on an average of 54.6 acres, a reduction of 42 percent. Also, because the farmers changed application rates from field to field as cropping patterns changed, it was difficult to evaluate the effects of the changes in nutrient applications to specific changes measured in surface-water quality.

The contribution of nutrients from human waste was not considered to be a major source because the population density was sparse at the site.

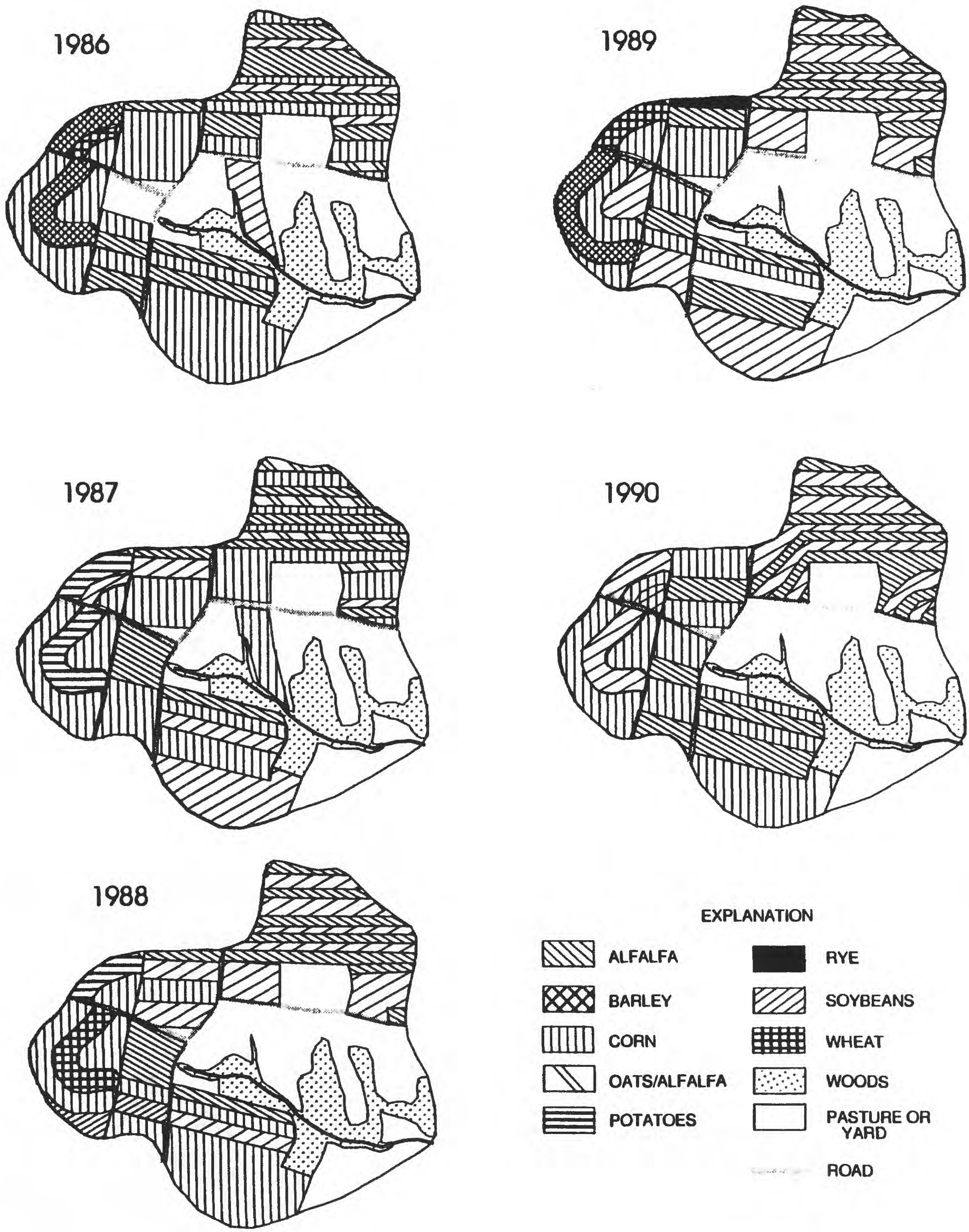

Figure 5. Land-use maps showing different cropping patterns at Bald Eagle Creek for (a) the premanagement period, 1986 and 1987 water years and (b) the nutrient-management period, 1988, 1989, and 1990 water years.

Table 2. Crop yields of farms at the Bald Eagle Creek site

[Yields are in units per acre; -, crop not planted; --, no data provided]

Farm	Crop	Yield prior to nutrient management	Yield during nutrient management
1	corn	100 bushels	--
	silage	20 tons	--
	soybeans	50 bushels	45 bushels
	alfalfa	3.5 tons	3 tons
	oats	1 ton	2 tons
2	corn	--	100 bushels
	silage	18 tons	14 tons
	rye	4 tons	3 tons
	alfalfa	--	3.5 tons
3	corn	140 bushels	130 bushels
	potatoes	2,000 pounds	--
	barley	70 bushels	100 bushels
	wheat	60 bushels	30 bushels

Table 3. Animal density at the Bald Eagle Creek site

[Animal units, in thousands of pounds of body weight; cropland, in acres; and animal density, in animal units per acre of crop and pasture land]

Farm	Animal type	Prior to nutrient management			End of nutrient management		
		Animal units	Crop and pasture land	Animal density	Animal units	Crop and pasture land	Animal density
1	Dairy						
	Cows	63.5			0.0		
	Heifers	36.0			20.0		
Subtotal		99.5	96.8	1.03	20.0	96.8	0.21
2	Dairy						
	Cows	87.5			50.0		
	Heifers	12.0			17.0		
	Horses	0.0			10.0		
Subtotal		99.5	93.8	1.06	77.0	93.8	.82
3		.0	34.5	.0	.0	34.5	.0
4		4.0	14.8	.27	6.0	14.8	.40
Total		203.0	239.9	.85	103.0	239.9	.43

Table 4. Total manure produced, its estimated nutrient content, and the nutrient content of manure applied to cropland and deposited by grazing animals at the Bald Eagle Creek site

[N, nitrogen; P, phosphorus; Manure produced, in tons; nitrogen and phosphorus, in pounds]

Year	Manure produced	Nutrient content of manure produced		Nutrient content of manure applied		Nutrient content of manure deposited by grazing animals		Total applied and deposited	
		N	P	N	P	N	P	N	P
1986	2,590	25,900	4,560	11,590	2,040	9,840	1,730	21,400	3,770
1987	2,910	29,100	5,130	8,440	1,920	11,100	1,950	19,540	3,870
1988	1,940	19,400	3,410	4,530	790	7,360	1,300	11,890	2,090
1989	1,630	16,300	2,870	6,440	1,130	6,200	1,090	12,640	2,220
1990	1,380	14,000	2,470	7,260	1,280	5,320	940	12,600	2,220

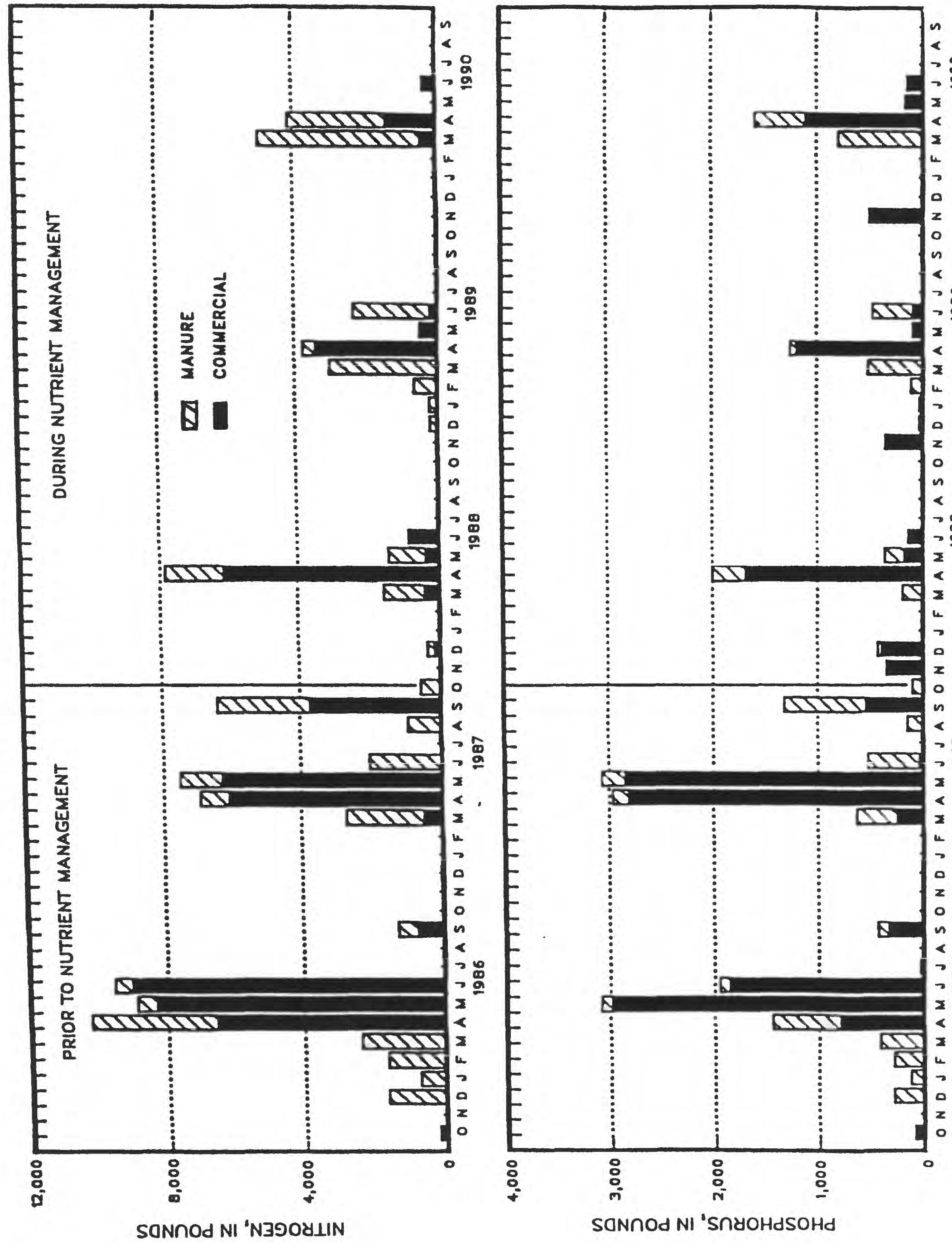

Figure 6. Nitrogen and phosphorus applications prior to and during nutrient management at Bald Eagle Creek.

Table 5. Manure and commercial fertilizer applications to cropland at the Bald Eagle Creek site

[Nitrogen and phosphorus in pounds; M, manure; F, commercial fertilizer]

Farm		Prior to nutrient management: 1986 Nitrogen	1986 Phosphorus	1987 Nitrogen	1987 Phosphorus	Total Nitrogen	Total Phosphorus	Average Nitrogen	Average Phosphorus
1	M	1,730	300	1,950	780	3,680	1,080	1,840	540
	F	2,710	860	2,630	1,970	5,340	2,830	2,670	1,415
	Total	4,440	1,160	4,580	2,750	9,020	3,910	4,510	1,955
2	M	9,860	1,740	6,490	1,140	16,350	2,880	8,175	1,440
	F	16,550	2,430	9,750	1,430	26,300	3,860	13,150	1,930
	Total	26,410	4,170	16,240	2,570	42,650	6,740	21,325	3,370
3	M	0	0	0	0	0	0	0	0
	F	5,690	2,830	4,380	3,130	10,070	5,960	5,035	2,980
	Total	5,690	2,830	4,380	3,130	10,070	5,960	5,035	2,980
Total	M	11,590	2,040	8,440	1,920	20,030	3,960	10,015	1,980
	F	24,950	6,120	16,760	6,530	41,710	12,650	20,855	6,325
Grand total		36,540	8,160	25,200	8,450	61,740	16,610	30,870	8,305

Farm		During nutrient management: 1988 Nitrogen	1988 Phosphorus	1989 Nitrogen	1989 Phosphorus	1990 Nitrogen	1990 Phosphorus	Total Nitrogen	Total Phosphorus	Average Nitrogen	Average Phosphorus
1	M	1,280	220	2,290	400	1,910	340	5,480	960	1,827	320
	F	0	780	0	840	0	1,090	0	2,710	0	903
	Total	1,280	1,000	2,290	1,240	1,910	1,430	5,480	3,670	1,827	1,223
2	M	3,250	570	4,150	730	5,350	940	12,750	2,240	4,250	746
	F	4,850	1,340	1,880	380	100	590	6,830	2,310	2,277	770
	Total	8,100	2,530	6,030	2,070	5,450	3,190	19,580	4,550	6,527	1,516
3	M	0	0	0	0	0	0	0	0	0	0
	F	3,250	670	2,340	540	2,170	360	7,760	1,570	2,587	523
	Total	3,250	670	2,340	540	2,170	360	7,760	1,570	2,587	523
Total	M	4,530	790	6,440	1,130	7,260	1,280	18,230	3,200	6,077	1,067
	F	8,100	2,790	4,220	1,760	2,270	2,040	14,590	6,590	4,863	2,197
Grand total		12,630	3,580	10,660	2,890	9,530	3,320	32,820	9,790	10,940	3,263

NETWORK DESIGN, INSTRUMENTATION, SAMPLING AND ANALYTICAL TECHNIQUES

The following section describes the network design, instrumentation and sampling techniques, and all analytical techniques used in this report.

Precipitation

Precipitation data were collected from October 1985 through September 1989 at one location (fig. 2) by use of a tipping-bucket rain gage in conjunction with punched tape level recorder. The precipitation gage was located approximately 25 ft from the streamflow-gaging station near the eastern boundary of the site. Precipitation was recorded at 15-minute intervals to determine the duration and intensity of storms, and the daily, monthly, and annual totals. Precipitation was estimated for periods of missing record by use of data from the National Oceanic and Atmospheric Administration (NOAA) station at New Park and from daily records kept by the landowner of farm 3 (fig. 2). Precipitation measured at the Bald Eagle Creek site was compared to normal precipitation measured at the NOAA station at New Park. The station at New Park is located approximately 2.5 mi southwest of the site.

Precipitation samples were collected by use of an 8 in. plastic funnel. The funnel collected rainfall continuously into a 1-liter precombusted glass bottle that was placed at ground level in a metal can packed with ice. Two precipitation samples were collected prior to the management phase. The first sample was collected in May 1987 near the beginning of the growing season, and the second was collected in September 1987, near the end of the growing season. Four precipitation samples were collected during the management phase: March 26, 1988; May 2, 1989; August 15, 1989; and May 6, 1990. The pH and specific conductance were determined for each sample in the field immediately after sample collection. Precipitation samples were chilled to 4°C, preserved with mercuric chloride, and sent to the USGS National Water-Quality Laboratory in Arvada, Colo., for analyses of total nitrate plus nitrite, ammonia, ammonia plus organic nitrogen, and total phosphorus. Nutrients were analyzed according to methods described by Skougstad and others (1979).

Streamflow

The methods and instrumentation used to collect continuous streamflow data are described in the characterization report (Fishel and others, 1991). The streamflow-gaging station (USGS 01577400) (fig. 2) became operational on October 24, 1985, and was located on the right bank (fig. 2) at latitude 39°44'54" and longitude 76°27'50", about 15 ft upstream from Kunkle Road. Continuous streamflow record was discontinued September 30, 1989, but base flow measurements were made monthly for an additional year.

The control during high flows was a 5.8 ft diameter nonstandard geometric culvert located at the bridge at Kunkle Road. Late in July 1988, a second culvert was installed by the state highway department to reduce flooding in the pasture. The installation of this new culvert made it necessary to develop a new rating curve for high flows above 25 ft^3/s.

Long-term streamflow record from the Principio Creek near Principio Furnace, Md., was used to compare the measured streamflow because long-term record was not available for the gage at Bald Eagle Creek. The gage at the Principio Creek was about 21 mi southeast of the study area and has been in operation since June 1967.

Water Quality

Water-quality data collection began in November 1985 and ended in September 1990. Water-quality samples were collected manually at the V-notch weir during base flows. A float/stage-triggered PS-69 automatic pumping sampler was used to collect streamflow samples during storms at 30-minute intervals. The perforated intake for the pumping sampler was located near the centroid of flow in the pool created by the weir so that representative samples could be collected. Streamflow samples were collected monthly during base flow and at selected stages during storms to characterize stormflow. Sampling frequency was such that seasonal relations between water quality and streamflow could be determined.

Water-quality samples were collected during base flow by use of methods described by Guy and Norman (1970). Manual samples were collected and compared with discrete automatically-collected samples to assure that the automatic samplers were operating properly. Samples to be analyzed for dissolved constituents were filtered with a

0.45-μm membrane filter mounted in a peristaltic filter assembly. Base-flow samples were filtered in the field and stormflow samples were filtered in the laboratory at Lemoyne, Pa., before being sent to the laboratory in Denver, Colo. Like the precipitation samples, all base-flow and stormflow samples were preserved with mercuric chloride and kept chilled at 4°C.

Water-quality samples were analyzed for concentrations of suspended sediment, total and dissolved nitrate plus nitrite, ammonia plus organic nitrogen, ammonia, phosphorus, and dissolved orthophosphorus. Suspended-sediment samples were analyzed for concentration as well as sand and silt fraction at the USGS Sediment Laboratory in Lemoyne, Pa., by use of methods described by Guy (1969). Water-quality samples for nutrient analysis were sent to the USGS laboratory in Colorado within 24 hours after collection and analyzed by use of the same methods as described for the precipitation samples.

Nutrient and suspended-sediment loads in stormflow were computed by use of discharge and concentration-integration methods described by Porterfield (1972) and estimated by use of regression techniques (SAS 1979). Missing storm concentration data were estimated by use of hydrograph comparisons of storms with similar magnitudes at similar times of the year.

Nutrient and suspended-sediment loads in base flow were computed by use of a 7-parameter log-linear model developed by Cohn and others (1989) to describe nutrient and sediment loads from the four river-input monitoring stations to the Chesapeake Bay. This model was validated by Cohn and others (U.S. Geological Survey, written commun., 1990) with repeated split-sample studies and is of the form

$$\ln[C] = \beta_0 + \beta_1 \ln[Q / \bar{Q}] + \beta_2 (\ln[Q / \bar{Q}])^2 + \beta_3 [T - \bar{T}] + \beta_4 [T - \bar{T}] + \beta_5 \cdot \sin[2 \pi T] + \beta_6 \cdot \cos[2 \pi T] + \varepsilon, \quad (1)$$

where

ln denotes natural logarithm function;

C is constituent concentration;

Q is discharge, in cubic feet per second;

$\bar{Q}$ is mean discharge, in cubic feet per second;

T is time, in years; and

$\bar{T}$ is mean time, in years;

β_0 through β_6 are the parameters of the model that were estimated from the data, and ε denotes the model errors, which are assumed to be independent and normally distributed with zero mean and variance σ_ε^2. Loads were calculated by substituting ln[C] from equation (1) into

$$L = \text{antilog} \ln[C] \cdot Q \cdot 5.4, \quad (2)$$

where L is load, in pounds per day;

ln denotes natural logarithm function;

Q is discharge, in cubic feet per second; and

5.4 is a constant.

Soil Nutrients

Soil samples were collected from two fields at two farms (fig. 2) to determine the nutrient content of the soil where manure and commercial fertilizer were applied. Soil nutrient results provided information for the nutrient-management specialist so that management plans could be developed for each farm.

Soil-nutrient samples from the upper 4 ft were collected in the fall of 1985, and the spring and fall of 1987, 1988, 1989, and 1990. The samples were collected with the aid of a tractor mounted deep-soil probe. Each 4-ft sample core was divided into segments that represented 0 to 8 in., 8 to 24 in., and 24 to 48 in. below the surface. Two sets of three cores were taken at each location (fig. 2) and the segments from each core were composited in the field. The segments were analyzed for average soluble nitrate-nitrogen and phosphorus at the Pennsylvania State University, Soils and Environmental Chemistry Laboratory by use of methods described by Corey (1977) and by the USEPA (1979). Depths at which soil nutrients were concentrated were determined.

METHODS OF DATA ANALYSIS

The following section gives detailed explanations of the statistical tests and data analysis techniques used in the report.

Descriptive Statistics

In order to describe the hydrology of the Bald Eagle Creek, numerous descriptive statistics including maximum, minimum, and median values for streamflow, chemical concentrations, loads, and yields were calculated by use of the Statistical Analysis System (SAS) Institute, Inc. (1979; 1982a; 1982b) and P-STAT, Inc. (1986) statistical packages. Descriptive statistics were calculated for the entire study period, the periods prior to and during nutrient management, and the growing and nongrowing seasons. Frequency distributions were plotted to determine if chemical-quality data were normally distributed and to decide if data should be analyzed by use of parametric or nonparametric statistical procedures.

Correlation Analyses

Correlation analyses were performed to examine relations among concentrations and discharges of suspended sediment and nutrients, and streamflow and time. Relations were considered good if the correlation coefficient (r) was equal to or greater than 0.80, a value commonly used for chemical and biological studies.

Seasonal Wilcoxon-Mann-Whitney-Rank-Sum Test

Prior to implementation of nutrient management, estimates were made of the necessary amount of reduction needed to detect significant changes in concentrations and discharges of total nitrogen, dissolved nitrite plus nitrate nitrogen, and total and dissolved phosphorus in base flow. These estimates were established as targets for the nutrient-management phase assuming that variances in the data during nutrient management would be similar to variances prior to nutrient management. Data collected during the nutrient-management phase were tested to determine if data were significantly different from the data collected prior to nutrient management. Data were grouped into growing and nongrowing seasons after visual examination of time-series plots indicated visual differences between these periods. A null hypothesis of no difference between data collected prior to and during nutrient management was tested by means of a modified Wilcoxon-Mann-Whitney rank-sum test for seasonal data at the 0.05 alpha level (R.M. Hirsch, U.S. Geological Survey, written commun., 1989; Crawford and others, 1983).

Because of the limited amount of measured data, Monte Carlo simulation was used to synthesize data collected prior to and during the nutrient-management phases in order to establish target goals and to perform the rank-sum test. The premanagement data were synthesized by randomly generating 1,000 data sets of each chemical constituent tested on the basis of the statistical characteristics of the measured data--the number of seasons, the total number of observations in each season, and the mean and standard deviations for each season during the period prior to nutrient management. Data for the period during the management phase were synthesized by reducing the mean and the standard deviation of the data collected prior to nutrient management by a selected percentage. A second approach for generating the data for the management phase from normally-distributed data collected prior to nutrient management was to reduce the mean by a selected percentage without changing the standard deviation. The percentage by which the means of the synthesized data for the management phase were reduced was increased until the power of the test reached 1.0, which represented the greatest probability of rejecting the null hypothesis. Because the mean of the synthesized data for the management phase could only be lower than the mean of the data prior to nutrient management, the null hypothesis could only be rejected from one direction; thus, a one-tailed test was performed.

After the management phase was completed, the seasonal rank-sum test was used to determine if there was a change between the data collected prior to and during nutrient management. Because the mean of the data collected during the management phase could have either increased or decreased from the mean of the data collected prior to nutrient management, a two-tailed test was performed to determine if the target goals were achieved.

Seasonal Kendall Test

The seasonal Kendall test for trend (Hirsch and others, 1982) was used to analyze the Bald Eagle Creek base flow water-quality data. This nonparametric test for detecting monotonic trend was used because it is robust against seasonal behavior and departures from seasonality. In this test, Kendall's tau, ranging from -1.0 to +1.0, is a measure of monotonic association with 0.0 representing no association. Each tau value has an associated probability value (p), which is a measure of the confidence interval associated with that tau. For this study, a statistically significant or detectable change was defined as being within the 95-percent confidence interval ($p<0.05$). The estimate of slope trend was defined as the median slope for the period of record on the basis of the median values for all seasons.

EFFECTS OF SELECTED AGRICULTURE BEST-MANAGEMENT PRACTICES ON HYDROLOGY AND SOILS

Hydrology

Changes in quantity and quality of precipitation, streamflow and soils are included in the following sections under hydrologic effects of nutrient management.

Precipitation

Quantity

During the 4 years that precipitation was measured at the study area (1986-89 water years[2]), about 164 in. of precipitation were measured at the site (table 6); an additional 50.62 in. were measured at the New Park NOAA station during the fifth year (1990 water year). Precipitation was 2 percent below normal during the 5-year study, on the basis of long-term record at the nearby New Park NOAA station. Annual precipitation ranged from 37 percent below normal during the 1986 water year to 19 percent above normal during the 1989 water year. Precipitation was about 18 percent below normal prior to nutrient management and was about 4 percent above normal during the first 2 years of nutrient management. Precipitation during the nongrowing season (October-March) ranged from 17 percent below normal in 1988 to 28 percent above normal in 1990. During the growing season (April-September), precipitation ranged from 57 percent below normal in 1986 to 37 percent above normal in 1989. The greater variations in precip-itation during the growing season probably resulted in greater variations in hydrologic processes such as runoff, recharge, evapotranspiration, and nutrient transport. Because precipitation was similar in the growing and nongrowing seasons during the 1987 and 1990 water years at New Park, data collected during these 2 years probably provide the best comparison of data collected prior to and during the management phase.

A large difference (11.74 in.) existed between the measured precipitation at Bald Eagle Creek and the NOAA station at New Park for the 1989 growing season. This difference was because of missing and bad records at Bald Eagle Creek during short-duration intense rain events measured on May 5, 6, 16, 23, July 4, and September 20, 1989. Therefore, the precipitation record from New Park was used for the 1989 growing season. The rainfall from these six events accounted for 42 percent of the total precipitation for the entire 6-month growing season.

Monthly precipitation at Bald Eagle Creek was variable and ranged from 0.27 in. in September 1986 to 12.84 in. in May 1989 (fig. 7). Precipitation was more than 2 in. less than normal each month except April during the 1986 growing season. Precipitation was greater than normal during the 1987 water year because of the precipitation in November and December 1986 and September 1987, which was 3.29, 5.09, and 2.69 in. greater than normal, respectively (fig. 7). Prior to the wet September in 1987, the growing season was 29 percent drier than normal. Monthly precipitation during the 1988 water year ranged from 0.47 in. in June to 8.71 in. in May. During the 1989 water year, monthly precipitation ranged from 0.98 in. in December to 12.84 in. in May. Data from the New Park NOAA station indicated that the 1990 water year was 15 percent wetter than normal, and monthly precipitation ranged between 1.44 in. in December 1989 to 6.61 in. in May 1990.

Antecedent soil moisture conditions could have had an effect on the quality of surface water at the beginning of the study. Historical data from the New Park station indicate that the study began following a year that was 4 percent drier than normal and the 4 years prior to the study were 8 percent wetter than normal.

The monthly comparison of the positive and negative deviations from the normal precipitation (fig. 8) suggests months during which corresponding fluxes in nutrients may begin in base flow. For example, figure 8 shows that above normal precipitation was measured in November during the first 4 years of the study. Assuming that the quantity of nitrate nitrogen available for transport from the soil to the stream remains constant, then precipitation would have a greater influence on the transport of the nitrate during November. Likewise, since precipitation was more than 4 in. above normal during December 1986 and May 1988 and 1989, similar fluxes in nitrate nitrogen concentrations and discharges could be expected during or shortly after these months. In contrast, precipitation was significantly below normal during the month of June in each water year. Thus, fluxes opposite of those for the month of November might be expected during or shortly after these months.

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[2] Water year is the period October 1 through September 30 and is designated by the calendar year in which it ends.

Table 6. Precipitation at Bald Eagle Creek and New Park gages and deviations from normal during the growing and nongrowing seasons in the 1986-90 water years

[BEC, Bald Eagle Creek; NP, New Park; precipitation, in inches; deviation from normal, in percent; --, no data available]

Water year	Measured at Bald Eagle Creek			Measured at New Park			Normal at New Park			Deviations at Bald Eagle Creek and New Park from normal at New Park					
	Nongrowing season	Growing season	Total	Nongrowing season	Growing season	Total	Nongrowing season	Growing season	Total	Nongrowing season		Growing season		Total	
										BEC	NP	BEC	NP	BEC	NP
1986	17.25	10.45	27.70	17.78	12.44	30.22	19.40	24.53	43.93	-11	-8	-57	-49	-37	-31
1987	23.26	21.31	44.57	24.60	25.63	50.23	19.40	24.53	43.93	20	27	-13	4	1	14
1988	16.09	23.20	39.29	20.00	22.98	42.98	19.40	24.53	43.93	-17	3	-5	-6	-11	-2
1989	18.76	[1] 33.56	52.32	18.41	33.56	51.97	19.40	24.53	43.93	-3	-5	37	37	19	18
Subtotal	75.36	88.52	163.88	80.79	94.61	175.40	77.60	98.12	175.72	-3	4	-10	-4	-7	0
1990	[1] 24.80	[1] 25.82	[1] 50.62	24.80	25.82	50.62	19.40	24.53	43.93	28	28	5	5	15	15
Total	100.16	114.34	214.50	105.59	120.43	226.02	97.00	122.65	219.65	3	9	-7	-2	-2	3

[1] Measured at New Park.

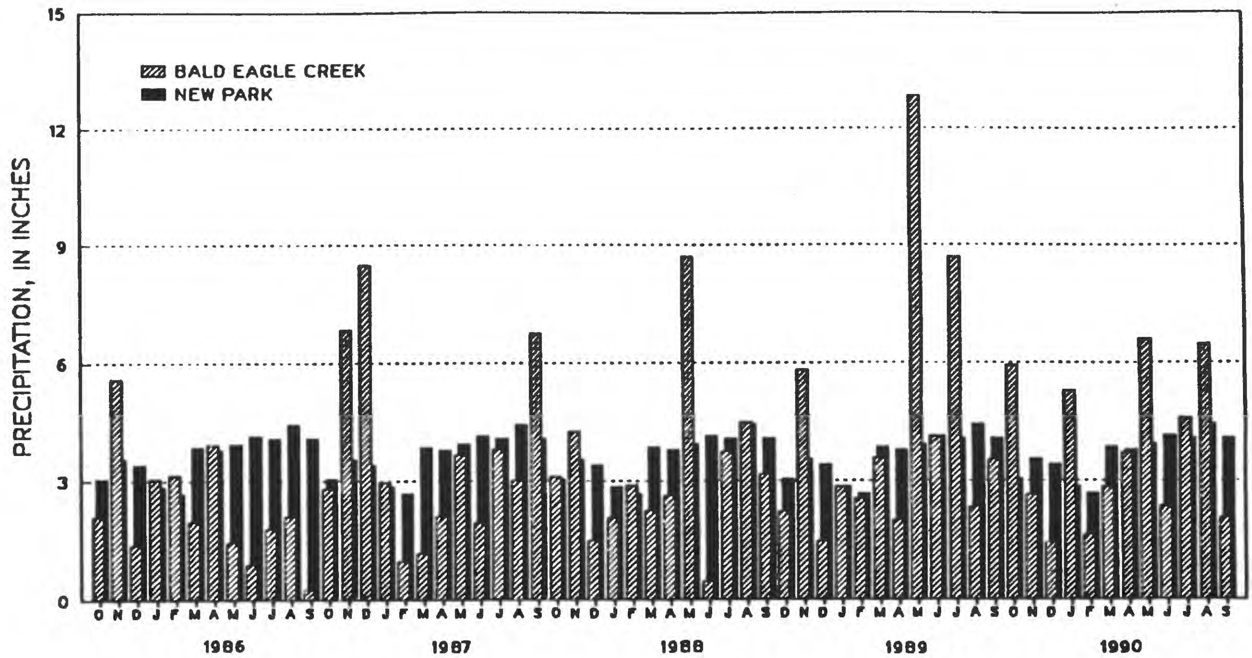

Figure 7. Measured monthly precipitation at Bald Eagle Creek and normal monthly precipitation at New Park for the 1986-89 water years.

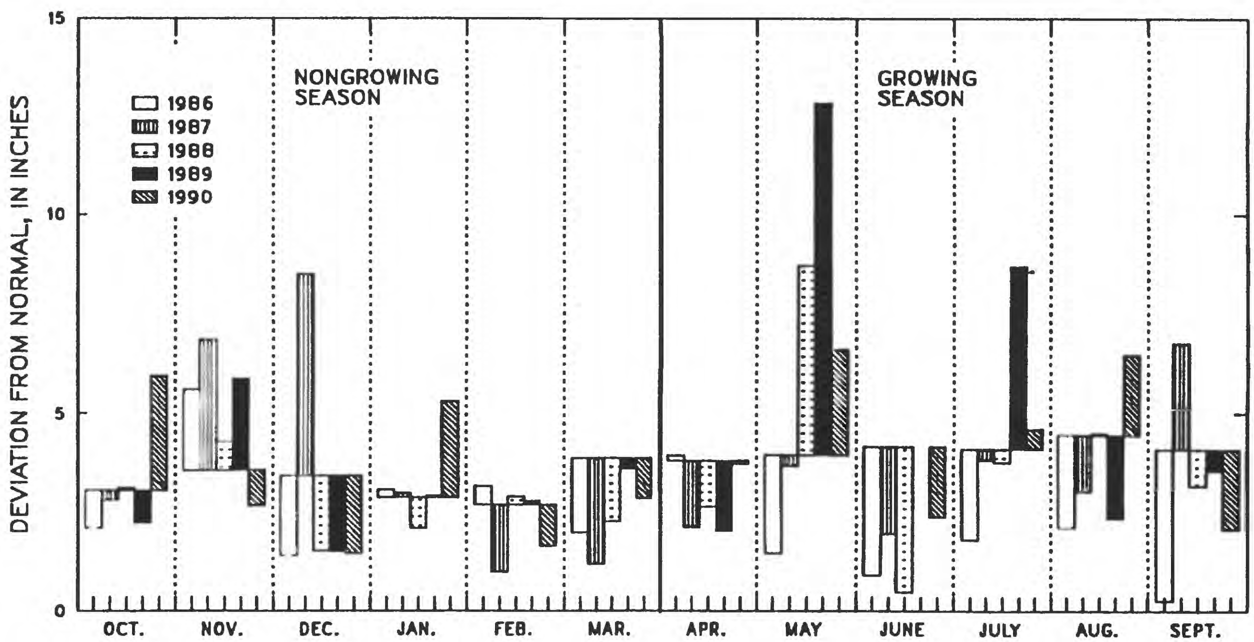

Figure 8. Monthly deviations of measured precipitation at Bald Eagle Creek from normal precipitation at New Park during the growing and nongrowing season for the 1986-90 water years.

Quality

Langland (1992) has shown that significant amounts of nitrogen contamination can be released to the atmosphere, carried great distances, and be deposited on the land surface by precipitation. For this reason, the quality of the precipitation deposited in the study area was determined prior to and during the management phase (table 7). Precipitation samples were collected prior to, during, and near the end of the growing season to investigate seasonal differences in precipitation quality. Most of the nitrogen in precipitation was in the form of ammonia and nitrate plus nitrite nitrogen. Concentrations of ammonia and nitrite plus nitrate in the precipitation were greater when less precipitation fell. These data suggest that the ammonia and nitrite plus nitrate may have been scavenged from the atmosphere during the early stages of precipitation events when volatilized ammonia and nitrite plus nitrate from manure was available and then diluted as the precipitation increased. Concentrations of ammonia in the precipitation were greatest near the end of the study when there was less precipitation and the number of cattle increased from 3 to 12 in the pasture near the precipitation gage. The nitrogen load contributed to the Bald Eagle Creek from precipitation may have averaged 8 lb/acre for the entire study, considering concentration data from table 7.

Generally, the data suggest that the contribution of nitrogen from precipitation at the Bald Eagle Creek site is seasonally variable, but it is not as significant as in other study areas within the Lower Susquehanna River Basin where animal densities are higher. For example, on May 20, 1987, 1.52 in. of precipitation were recorded at Bald Eagle Creek and concentrations of total nitrogen and total ammonia in precipitation were 0.80 and 0.25 mg/L, respectively. On the same day at Brush Run (site 1, fig. 1), where 57,000 chickens and 1,460 hogs are housed within 0.10 mi^2 of the sampling site, 0.74 in. of precipitation was recorded, and concentrations of total nitrogen and total ammonia in precipitation were 3.4 and 2.8 mg/L, respectively. On the basis of these limited concentration data, it was calculated that the total nitrogen deposited by precipitation on May 20, 1987, at Brush Run was 0.57 lb/acre, more than twice the amount that was deposited at Bald Eagle Creek (0.28 lb/acre) even though less than half the amount of precipitation fell at Brush Run. Because animal densities were lower at the Bald Eagle Creek site than at the Brush Run site, less nitrate and ammonia from animal waste was available for volatilization to the atmosphere and subsequent transport back to the land surface in precipitation.

Table 7. Water quality of precipitation in the Bald Eagle Creek Basin

[Precipitation, in inches; specific conductance in microsiemens per centimeter at 25 degrees Celsius; nitrogen and phosphorus in milligrams per liter; <, less than; --, no data]

Constituent	May 20, 1987	September 8, 1987	March 25-26, 1988	May 1-2, 1989	August 15, 1989	May 5-6, 1990
Precipitation	1.52	2.81	1.25	[1] 0.90	0.20	[1] 0.36
Specific conductance	30	8	14	--	45	--
pH	4.3	7.4	4.6	--	--	--
Nitrogen, total	.80	.30	.60	.70	2.3	2.2
Organic, total	.25	.18	.28	<.10	.60	.10
Ammonia, total	.25	.02	.12	.30	.70	1.1
Nitrate plus nitrite, total	.30	.10	.20	.40	1.0	1.0
Phosphorus, total	.01	.30	.02	.01	.02	.24

[1] Precipitation data was estimated from data collected at New Park.

Streamflow

The following section gives information concerning the quantity and quality of base flow and stormflow. This information includes hydrograph separations and descriptive statistics concerning nutrient and sediment concentrations and discharges in surface water at Bald Eagle Creek.

Quantity

Daily streamflows recorded at the Bald Eagle Creek site during the study ranged from a minimum of 0.00 ft^3/s (no flow) on several days in January and February 1986 to a maximum of 25 ft^3/s estimated for May 17, 1988 (fig. 9). The yearly mean streamflows were 0.33, 0.32, 0.58, and 0.42 ft^3/s for the 1986-89 water years, respectively. Total streamflow from the site was 20.44 in. prior to nutrient management; 10.47 and 9.97 in. were discharged during the 1986-87 water years, respectively. Total streamflow was 31.14 in. during the first 2 years of the management phase; 18.02 and 13.12 in. were discharged during the 1988-89 water years, respectively. About 31 percent of the 164 in. of measured precipitation was discharged as surface water during the first 4 years of the study; the remaining 69 percent was removed as evapotranspiration, flowed out of the site beneath the land surface, or remained in ground-water storage.

Daily streamflow data collected at the Bald Eagle Creek site were correlated with data collected at Principio Creek (fig. 1). The correlation coefficient (r) between log-transformed daily streamflows at the Bald Eagle Creek site and the Principio Creek station for the 2 years prior to nutrient management was 0.81 (considered good) with a standard error of 0.22, whereas, the correlation coefficient for streamflows during the nutrient-management phase was 0.62 (considered poor) with a standard error of 0.26. Streamflow, especially stormflow, was much more variable during the management phase of the study because of the increase in precipitation (fig. 9). This variability could account for the poor correlation between Principio Creek and Bald Eagle Creek data. At Principio Creek, streamflow was estimated to be about 35 percent below normal prior to nutrient management and 3 percent below normal during nutrient management. Thus, streamflow at Bald Eagle Creek was assumed to be about 35 percent below normal prior to nutrient management and 3 percent below normal during nutrient management.

Base flow.--Hydrograph separation techniques used to determine the contribution of base flow and stormflow to annual flow are described by Pettyjohn and Henning (1979). Sixty-six percent of the total streamflow during the study was base flow. Although nearly the same amount of base flow was discharged prior to and during the management phase, base flow comprised 84 percent (17.13 in.) of the total streamflow (20.44 in.) prior to nutrient management, but only 54 percent (16.70 in.) of the total streamflow (31.16 in.) during nutrient management (table 8). Base flow contributed 62 percent of the total streamflow during the nongrowing season and 68 percent of the total streamflow during the growing season. Eighty-one percent of the total streamflow during the nongrowing seasons prior to nutrient management was base flow, whereas only 45 percent of the total streamflow during the nongrowing seasons in the management phase was base flow. Base flow ranged between 58 and 98 percent of the monthly streamflow in September 1987 and June 1986, respectively, prior to nutrient management, and between 15 and 93 percent of the monthly streamflow in February 1988 and August 1989, respectively, during the management phase. The contribution of base flow to the total streamflow depended primarily on the duration, intensity, and amount of precipitation and antecedent soil moisture.

Stormflow.--Stormflow contributed 34 percent of the total streamflow during the study and comprised about 16 percent of total streamflow prior to the management phase and 46 percent of the total streamflow during the management phase. Nearly 11 in. more stormflow was discharged during nutrient management than prior to nutrient management (table 8). Thirty percent more of the total streamflow was stormflow during nutrient management than prior to nutrient management. Fifty-seven percent of the streamflow was stormflow in the 1988 water year but only 15 percent was stormflow in the 1986 water year.

The hydrograph separations (fig. 9) of the continuous streamflow data show that most of the overland runoff (stormflow) during nutrient management was discharged in the growing seasons during the month of May; 3.9 in. was discharged in 1988 and 1.3 in. was discharged in 1989 (table 8). About 29 percent of the stormflow for the entire 4 years was discharged during these 2 months of the nutrient-management phase. The sharp peaks of the stormflow indicate the rapid response shortly after precipitation began and the short stormflow durations, primarily caused by thin soils and steep slopes. The annual maximum instantaneous peak flows at Bald Eagle Creek for the 1986 through 1989 water years were 6.9 ft^3/s on November 5, 1985, 25 ft^3/s from a slope/area indirect measurement on September 18, 1987, 212 ft^3/s from a slope/area indirect measurement on May 17, 1988, and 107 ft^3/s on May 5, 1989.

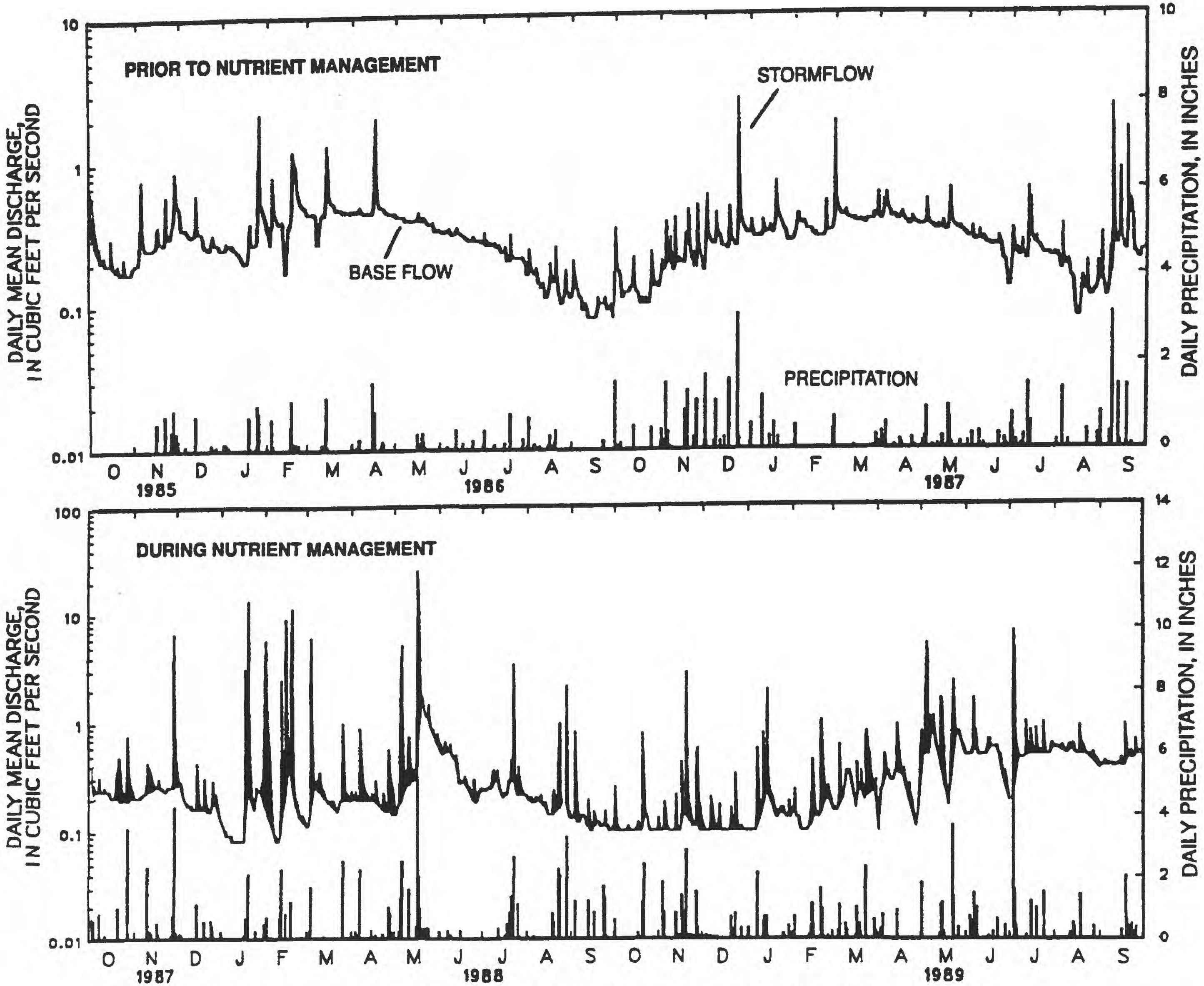

Figure 9. Relation between daily surface runoff and base-flow components obtained from hydrograph separation, and daily precipitation prior to and during nutrient management.

Table 8. Contribution of base flow to total streamflow at Bald Eagle Creek during the 1986-89 water years

Month	Year	Base flow (inches)	Stormflow (inches)	Total streamflow (inches)	Percentage of base flow in total streamflow
		NONGROWING SEASON			
October	1985	0.52	0.07	0.59	88
	1986	.33	.06	.39	85
	1987	.62	.13	.75	83
	1988	.28	.10	.38	74
November	1985	.72	.21	.93	77
	1986	.50	.16	.66	76
	1987	.63	.57	1.2	52
	1988	.30	.37	.67	45
December	1985	.82	.06	.88	93
	1986	.73	.37	1.1	66
	1987	.48	.08	.56	86
	1988	.27	.06	.33	82
January	1986	.55	.30	.85	65
	1987	.82	.10	.92	89
	1988	.39	.91	1.3	30
	1989	.38	.30	.68	56
February	1986	.90	.30	1.2	75
	1987	.77	.05	.82	94
	1988	.52	2.9	3.4	15
	1989	.34	.22	.56	61
March	1986	1.2	.20	1.4	86
	1987	1.0	.20	1.2	83
	1988	.52	.68	1.2	43
	1989	.61	.21	.82	74
		GROWING SEASON			
April	1986	1.2	.20	1.4	86
	1987	1.0	.10	1.1	91
	1988	.49	.18	.67	73
	1989	.60	.18	.78	77
May	1986	1.0	.10	1.1	91
	1987	.90	.07	.97	93
	1988	1.9	3.9	5.8	33
	1989	1.4	1.3	2.7	52
June	1986	.78	.02	.80	98
	1987	.63	.04	.67	94
	1988	.89	.11	1.0	89
	1989	1.2	.20	1.4	86
July	1986	.61	.03	.64	95
	1987	.62	.09	.71	87
	1988	.64	.35	.99	65
	1989	1.2	1.0	2.2	55
August	1986	.35	.06	.41	85
	1987	.36	.07	.43	84
	1988	.45	.30	.75	60
	1989	1.3	.10	1.4	93

Table 8. Contribution of base flow to total streamflow at Bald Eagle Creek during the 1986-89 water years--Continued

Month	Year	Base flow (inches)	Stormflow (inches)	Total streamflow (inches)	Percentage of base flow in total streamflow
		GROWING SEASON--Continued			
September	1986	0.24	0.03	0.27	89
	1987	.58	.42	1.0	58
	1988	.29	.11	.40	73
	1989	1.0	.20	1.2	83
Subtotals					
Water year					
	1986	8.89	1.58	10.47	85
	1987	8.24	1.73	9.97	83
	1988	7.82	10.20	18.02	43
	1989	8.88	4.24	13.12	68
Growing season					
Prior to management		8.27	1.23	9.50	87
During management		11.36	7.93	19.29	59
Subtotal		19.63	9.16	28.79	68
Nongrowing season					
Prior to management		8.86	2.08	10.94	81
During management		5.34	6.53	11.87	45
Subtotal		14.20	8.61	22.81	62
Totals					
Prior to management		17.13	3.31	20.44	84
During management		16.70	14.46	31.16	54
Entire study		33.83	17.77	51.60	66

Quality

Base flow.--Descriptive statistics (table 9) of streamflow and the concentrations and discharges of seven nitrogen and three phosphorus constituents and suspended sediment were calculated to provide a seasonal characterization of the base-flow quality of the Bald Eagle Creek. Statistics were calculated to investigate differences in data collected prior to and during nutrient management, during different seasons and water years. Concentrations and discharges listed in table 9 are from analyses of manually collected depth-integrated discrete samples. Median instantaneous streamflows measured during sample collection increased during nutient management as a result of the significant increase in precipitation. Concentrations and discharges of total nitrogen and total and dissolved nitrite plus nitrate increased during nutrient management in both the growing and nongrowing seasons. No significant changes were detected in concentrations or discharges through time or season for total and dissolved ammonia, ammonia plus organic nitrogen, phosphorus, and suspended sediment. Detailed discussion of each constituent is included later in the report.

Estimated monthly and annual nutrient and sediment loads in base flow prior to and during nutrient management, were calculated by use of the 7-parameter log-linear model (eqs. 1 and 2) (table 10). During nutrient management, estimated monthly and annual loads for total nitrogen, dissolved nitrite plus nitrate, dissolved phosphorus, and orthophosphorus increased; monthly and annual loads of total phosphorus and suspended sediment decreased. Loads for every constituent were greater in the growing season than the nongrowing season, especially during the 1989 growing season (table 10) when precipitation was 9.03 in. above normal. Generally, higher loads of nitrogen were measured during the months of March, April, May, and June when applications of manure and commercial fertilizers are greatest (fig. 10). Phosphorus loads were more variable than nitrogen loads, but were usually greater in March, April, and May than in other months (fig. 11). The percentage of dissolved nitrite plus nitrate to total nitrogen showed only slight variations during the study. For the growing and nongrowing seasons, the percentage was 85 and 82 percent, respectively, during the dry 1986 water year, and 86 percent during both seasons during the wet 1989 water year. This indicates that the dissolved nitrite plus nitrate available for transport was sufficient to maintain the levels observed despite seasonal and annual changes in application rates. The percentage of dissolved phosphorus to total phosphorus was highly variable, increasing from 55 percent prior to nutrient management to 87 percent during nutrient management, varied by water year (53 percent in 1987 and 92 percent in 1989), and varied by season (72 percent growing to 62 percent nongrowing). This suggests the phosphorus load is influenced more by variations in precipitation and application rates than is the nitrogen load.

Table 11 lists the parameter values used to calculate base-flow nitrogen and phosphorus concentrations and discharges by use of the 7-parameter log-linear model described earlier. The reported T values are a measure of the significance of the parameter in the model described earlier in equation 1. A T value with an absolute value greater than 2 was considered to be significant. During the nutrient-management period when precipitation increased, the coefficients that account for seasonality (β_5 and β_6) became insignificant. Because of a longer sampling period, the time parameter (β_3) became more significant for calculating the concentrations and loads for many of the constituents during nutrient management.

The load-estimator model explained 17 to 78 percent of the variability observed in the logarithms of the constituent concentrations in base flow prior to nutrient management and 10 to 52 percent during nutrient management. Likewise, the model explained 40 to 99 percent of the variability observed in the logarithms of the constituent loads in base flow prior to nutrient management and 30 to 99 percent during nutrient management. Lastly, the model added uniformity among other USGS projects for the Chesapeake Bay Program which also are using the model to calculate loads.

An increasing trend (positive tau and $p<.05$) was detected during the 5 years of base-flow data for concentrations and discharges of total and dissolved nitrite plus nitrate (table 12). By use of the Seasonal Kendall test, significant trends were not detected in either concentrations of ammonia, ammonia plus organic nitrogen, phosphorus, or suspended sediment in base flow or discharges of phosphorus and suspended sediment. Longer sampling times may be needed in order to see these trends become significant. The seasonal Kendall test was not used on ammonia and ammonia plus organic nitrogen discharges after inspection of the means showed no difference.

Concentrations and discharges of total nitrogen and dissolved nitrite plus nitrate in base flow (figs. 12 and 15) varied seasonally. As precipitation increased and cattle were permitted in the pasture near the gage during nutrient management, the annual ranges and maximum concentrations and discharges of total nitrogen and dissolved nitrite plus nitrate increased. This suggests that there was an increase in total nitrogen in base flow and part of it may have been contributed by grazing animals that deposited organic and ammonia nitrogen that mineralized to nitrite plus nitrate in and near the stream.

Median concentrations of total nitrogen and dissolved nitrite plus nitrate in base flow increased significantly from 4.7 and 4.0 mg/L, respectively, in the 1986 water year to 6.3 and 5.4 mg/L, respectively, in the 1990 water year. This significant increase is shown by the Seasonal Kendall trend lines in figure 12. Maximum concentrations of total nitrogen and dissolved nitrite plus nitrate in base flow were usually measured in February after applications of manure, and prolonged periods of precipitation. Minimum concentrations were measured in June and July when nitrogen uptake for crop growth, especially corn, was at a maximum, evapotranspiration rates were high, and precipitation was often below normal.

The median concentrations of total nitrogen and dissolved nitrite plus nitrate in base flow increased from 4.9 and 4.1 mg/L, respectively, prior to nutrient management, to 5.8 and 5.0 mg/L, respectively, during nutrient management (fig. 13). The maximum concentrations of total nitrogen and dissolved nitrite plus nitrate increased from 6.2 and 5.3 mg/L, respectively, prior to nutrient management, to 7.7 mg/L and 6.4 mg/L, respectively, during nutrient management. Concentrations of dissolved nitrite plus nitrate and total nitrogen also were measured in two tributaries (fig. 2, table 13) that drain into Bald Eagle Creek. Nitrogen concentrations were higher in tributary 1 than tributary 2 and the gage site, suggesting that base-flow discharges originating from different ground water sources in the basin mixed and were diluted before reaching the gage site, where concentrations of total nitrite plus nitrate and total nitrogen in base flow averaged 4.9 and 5.5 mg/L, respectively, during the 5-year study. These significant increases in concentrations of total nitrogen and dissolved nitrite plus nitrate during nutrient management were probably because of a combination of the following factors: (1) an increase in precipitation, (2) the associated increase in leaching of nitrate through the soils, (3) the reduction in nitrogen uptake by corn caused by the reduction in corn acreage, (4) an increase in nitrogen in the soil caused by an increase in nitrogen-fixing alfalfa, and (5) an increase in animal waste near the gage.

Discharges of total nitrogen and dissolved nitrite plus nitrate (fig. 14) in base flow varied seasonally as did the concentrations of total nitrogen and dissolved nitrite plus nitrate. The discharges of total nitrogen and dissolved nitrite plus nitrate were closely related to base flow. Total nitrogen and dissolved nitrite plus nitrate discharges decreased during the growing season as nitrogen requirements by corn increased, base flow and precipitation decreased, and evapotranspiration increased. About 4,420 lb (83 percent) of the 5,300 lb of total nitrogen in base flow was dissolved nitrite plus nitrate prior to nutrient management (table 10). Approximately 4,930 lb (86 percent) of the 5,700 lb of total nitrogen discharged was dissolved nitrate plus nitrite in base flow during nutrient management when 34 percent less cropland was devoted to corn. At the Nutrient-Management Subbasin in the Little Conestoga River watershed (site 3, fig. 1), 88 percent of the total nitrogen was dissolved nitrite plus nitrate prior to nutrient management and 91 percent of the total nitrogen was dissolved nitrite plus nitrate during nutrient management. Thus, the proportion of total nitrogen as dissolved nitrite plus nitrate increased during nutrient management in both basins.

Concentrations of total and dissolved organic nitrogen and total and dissolved ammonia nitrogen in base flow were considerably smaller and exhibited less seasonality than concentrations of nitrite plus nitrate (figs. 15 and 16). This suggests that transport and possibly the sources of organic nitrogen and ammonia nitrogen were probably different than the transport and sources of nitrite plus nitrate nitrogen. Although concentrations of ammonia and organic nitrogen were not significantly different (table 12) prior to and during nutrient management, median concentrations of total and dissolved organic nitrogen in base flow were lower during nutrient management than prior to nutrient management (fig. 17). The median concentration of total organic nitrogen decreased from 0.62 to 0.50 mg/L and the median concentration of dissolved organic nitrogen decreased from 0.58 to 0.41 mg/L (fig. 17). One possible explanation for the decrease in median concentrations in organic nitrogen is that manure applications, a major source of organic nitrogen, were reduced by 40 percent (tables 4 and 5). Maximum concentrations of total and dissolved ammonia prior to nutrient management (0.23 mg/L) and during nutrient management (0.54 and 0.50 mg/L) were measured on December 12, 1986, and February 12, 1990, respectively, during the nongrowing season.

Discharges of total and dissolved ammonia plus organic nitrogen and total and dissolved ammonia were not statistically significant. About 87 percent of the organic nitrogen and 84 percent of the ammonia in base flow was dissolved prior to nutrient management and 80 percent of the organic nitrogen and 92 percent of the ammonia was dissolved during nutrient management.

Concentrations of total and dissolved phosphorus in base flow did not exhibit seasonal trends (fig. 18) nor did the concentrations correlate with base flow (r = 0.16). Concentrations of total and dissolved phosphorus in base flow ranged from 0.02 to 0.18 mg/L and from 0.02 to 0.17 mg/L, respectively (table 9). Concentrations of dissolved orthophosphorus ranged from 0.01 to 0.16 mg/L and were greatest during the 1989 water year (table 9), the year with the most precipitation (52.32 in.) (table 6) measured during the study.

About 70.4 lb of total phosphorus and 38.5 lb of dissolved phosphorus were discharged in base flow during the 2 years prior to nutrient management; 46.6 lb of total phosphorus and 40.7 lb of dissolved phosphorus were discharged in the first 2 years of nutrient management (table 10). Discharge of dissolved orthophosphorus increased from 26.7 lb prior to nutrient management to 31.3 lb during the first 2 years of nutrient management. About 68 percent of the total phosphorus discharged in base flow during the 5-year study was dissolved phosphorus, and 50 percent was dissolved orthophosphorus. The maximum discharges of total phosphorus [0.466 lb/d (pounds per day)], dissolved phosphorus (0.441 lb/d), and orthophosphorus (0.415 lb/d) in base flow were measured during the growing season on July 24, 1989 (fig. 19, table 9).

Although the farmers reduced phosphorus applications 61 percent (table 5), no significant change was detected in concentrations or loads of phosphorus in base flow during the 3 years of nutrient management. The phosphorus yield from Bald Eagle Creek Basin in base flow for the 1986-89 water years was 0.42 lb/acre. The estimated loads for total phosphorus are from the log-linear regression model discussed earlier; data for the statistical test for trend (Seasonal Kendall test) is the base flow concentration data collected monthly.

Concentrations of suspended sediment in base flow were consistently greater after plowing and when cattle were turned out to pasture (April through June) in the growing season than in the nongrowing season. Median concentrations were 6.0 mg/L during the pre-nutrient management growing season and were 3.0 mg/L during the post-nutrient management nongrowing season (fig. 20, table 9). But concentrations of suspended sediment at Bald Eagle Creek were lower than concentrations measured in other intensively farmed basins in Pennsylvania. For example, Koerkle and others (U.S. Geological Survey, written commun., 1992) reported that, at the 1.42-mi^2 Nutrient-Management Subbasin in the Little Conestoga Creek headwaters (site 3, fig. 1), concentrations of suspended sediment in base flow ranged from 3 to 136 mg/L from April 1984 through September 1989; the median concentration was 17 mg/L. The low concentrations of suspended sediment in base flow at Bald Eagle Creek probably occur for several reasons: (1) fewer animals have direct access to the stream, (2) cover crops are used on steep slopes during the nongrowing season, (3) minimum or no-till plowing is utilized, and (4) there is a forested buffer strip along the stream in the downstream area of the basin.

Maximum concentrations of suspended sediment in base flow at Bald Eagle Creek were measured in May and July 1987, possibly in response to modifications made by the property owner to the stream channel immediately upstream from the gage, and in October 1989, May and June 1990 in response to animals pasturing upstream from the gage. However, no trend was detected in concentrations of suspended sediment during the 5-year study.

A total of about 4,550 lb of suspended sediment was discharged in base flow prior to nutrient management, and about 2,820 lb were discharged in base flow during the first 2 years of the management period (table 10). This decrease in sediment transport coincided with the rotation of 34 percent of the cropland from corn to alfalfa during nutrient management. Thus, less soil was exposed from plowing and planting and, therefore, available for erosion and transport to the stream.

Table 9. Water-quality characteristics of base flow at Bald Eagle Creek by growing and nongrowing season and by water year

[Max, maximum; Min, minimum; Med, median; n, number of samples; ft^3/s, cubic feet per second; N, nitrogen; P, phosphorus; concentrations, in milligrams per liter; and discharges, in pounds per day]

Constituent characteristic	Pre-nutrient management				Post-nutrient management				Pre-nutrient management growing season				Post-nutrient management growing season				Pre-nutrient management nongrowing season				Post-nutrient management nongrowing season			
	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n
Instantaneous streamflow (ft^3/s)	0.50	0.10	0.29	22	1.1	0.1	0.36	36	0.42	0.10	0.27	12	0.63	0.10	0.40	19	0.50	0.13	0.31	10	1.1	0.10	0.23	17
Nitrate + nitrite, dissolved as N																								
Concentration	5.3	3.4	4.1	22	6.4	4.1	5.0	36	4.6	3.4	3.9	12	5.7	4.1	5.0	19	5.3	4.1	4.6	10	6.4	4.2	5.0	17
Discharge	12.7	2.21	6.93	22	27.9	2.70	9.30	36	9.19	5.69	2.21	12	17.5	2.70	10.8	19	12.7	2.88	7.75	10	27.2	3.08	6.08	17
Nitrate + nitrite, total as N																								
Concentration	5.3	3.7	4.2	22	6.6	4.4	5.2	36	4.6	3.7	4.0	12	5.8	4.4	5.2	19	5.3	4.2	4.7	10	6.6	4.5	5.3	17
Discharge	12.7	2.21	7.18	22	27.9	2.70	10.4	36	9.19	2.21	5.98	12	17.5	2.70	11.9	19	12.7	2.95	8.17	10	27.9	3.08	6.08	17
Ammonia, dissolved as N																								
Concentration	.08	.01	.03	22	.05	.01	.04	36	.06	.01	.03	12	.20	.01	.04	19	.08	.01	.04	10	.50	.01	.03	17
Discharge	.189	.007	.052	22	1.48	.007	.041	36	.136	.009	.045	12	.616	.010	.078	19	.189	.007	.075	10	1.48	.007	.027	17
Ammonia, total as N																								
Concentration	.08	.01	.04	22	.05	.01	.04	36	.07	.01	.04	12	.20	.01	.04	19	.08	.01	.04	10	.54	.01	.04	17
Discharge	.189	.007	.067	22	1.60	.010	.068	36	.136	.009	.056	12	.616	.010	.089	19	.189	.007	.089	10	1.60	.012	.027	17
Ammonia + organic, dissolved as N																								
Concentration	.90	.20	.60	22	1.5	.20	.50	36	.80	.20	.60	12	1.5	.20	.50	19	.90	.20	.50	10	.90	.27	.40	17
Discharge	2.16	.275	.923	22	2.67	.211	.772	36	1.60	.275	.813	12	2.51	.308	1.08	19	2.16	.335	1.05	10	2.67	.211	.497	17
Ammonia + organic, total as N																								
Concentration	1.2	.30	.70	22	1.5	.30	.50	36	1.0	.30	.65	12	1.5	.30	.60	19	1.2	.50	.70	10	1.1	.40	.50	17
Discharge	3.24	.275	1.10	22	3.27	.308	1.08	36	1.60	.275	1.01	12	3.10	.308	1.23	19	3.24	.632	1.21	10	3.27	.324	.718	17

Table 9. Water-quality characteristics of base flow at Bald Eagle Creek by growing and nongrowing season and by water year--Continued

Constituent characteristic	Pre-nutrient management				Post-nutrient management				Pre-nutrient management growing season				Post-nutrient management growing season				Pre-nutrient management nongrowing season				Post-nutrient management nongrowing season			
	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n
Nitrogen, total N																								
Concentration	6.2	4.0	4.9	22	7.7	4.7	5.8	36	5.4	4.0	4.5	12	7.3	4.7	5.8	19	6.2	4.9	5.3	10	7.7	5.0	5.8	17
Discharge	15.9	2.59	8.48	22	30.8	3.02	12.4	36	10.8	2.59	6.56	12	19.4	3.02	13.5	19	15.9	3.44	9.29	10	30.8	3.40	6.95	17
Phosphorus, total as P																								
Concentration	.11	.03	.05	21	.18	.02	.05	36	.10	.04	.06	11	.18	.02	.05	19	.11	.03	.05	10	.10	.02	.05	17
Discharge	.181	.021	.084	21	.466	.021	.064	36	.181	.038	.080	11	.466	.034	.095	19	.172	.021	.105	10	.416	.021	.060	17
Phosphorus, dissolved as P																								
Concentration	.09	.02	.04	22	.17	.02	.04	36	.07	.02	.04	12	.17	.02	.04	19	.09	.02	.03	10	.08	.02	.04	17
Discharge	.141	.011	.053	22	.441	.017	.058	36	.102	.011	.053	12	.441	.017	.086	19	.141	.021	.062	10	.297	.021	.045	17
Ortho-phosphorus, dissolved as P																								
Concentration	.08	.01	.02	21	.16	.01	.03	36	.03	.01	.02	11	.16	.01	.03	19	.08	.01	.03	10	.08	.02	.03	17
Discharge	.125	.010	.032	21	.415	.009	.043	36	.068	.010	.029	11	.415	.008	.044	19	.125	.021	.058	10	.297	.016	.039	17
Sediment, suspended																								
Concentration	13	1.0	4.0	22	26	1	3	34	9.0	2.0	6.0	12	21	1	3.5	18	13	1.0	4.0	10	26	2	3	16
Discharge	16.0	1.08	7.96	22	75.8	.864	5.59	34	16.0	1.08	8.58	12	44.2	.864	8.91	18	15.2	1.46	7.96	10	75.8	1.40	3.73	16

Table 9. Water-quality characteristics of base flow at Bald Eagle Creek by growing and nongrowing season and by water year--Continued

Constituent characteristic	1986 Water Year				1987 Water Year				1988 Water Year				1989 Water Year				1990 Water Year			
	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n
Instantaneous streamflow (ft^3/s)	0.50	0.10	0.30	10	0.42	0.13	0.29	12	1.1	0.10	0.23	12	0.57	0.10	0.34	13	0.69	0.31	0.41	11
Nitrate + nitrite, dissolved as N																				
Concentration	4.9	3.6	4.0	10	5.3	3.4	4.2	12	5.0	4.4	4.7	12	5.7	4.1	5.1	13	6.4	4.2	5.4	11
Discharge	12.7	2.21	7.07	10	10.6	2.88	6.72	12	27.9	2.70	5.89	12	17.5	3.08	9.36	13	20.1	8.39	12.3	11
Nitrate + nitrite, total as N																				
Concentration	5.1	3.7	4.1	10	5.3	3.8	4.2	12	5.5	4.4	4.7	12	5.7	4.9	5.4	13	6.6	4.5	5.7	11
Discharge	12.7	2.21	7.18	10	10.6	2.95	7.03	12	27.9	2.70	5.89	12	17.5	3.08	9.36	13	22.4	9.71	12.4	11
Ammonia, dissolved as N																				
Concentration	.08	.01	.04	10	.04	.01	.03	12	.09	.01	.02	12	.20	.01	.05	13	.50	.01	.04	11
Discharge	.189	.009	.056	10	.086	.007	.049	12	.416	.010	.024	12	.616	.007	.077	13	1.48	.019	.117	11
Ammonia, total as N																				
Concentration	.08	.01	.05	10	.05	.01	.04	12	.09	.01	.03	12	.24	.02	.05	13	.54	.01	.04	11
Discharge	.189	.009	.081	10	.086	.007	.060	12	.534	.010	.026	12	.616	.013	.078	13	1.60	.019	.117	11
Ammonia + organic, dissolved as N																				
Concentration	.80	.30	.60	10	.90	.20	.65	12	.70	.27	.40	12	.70	.50	.30	13	1.50	.20	.40	11
Discharge	2.16	.275	.980	10	1.60	.292	.832	12	2.38	.308	.451	12	2.15	.211	.918	13	2.67	.454	.950	11
Ammonia + organic, total as N																				
Concentration	1.2	.30	.70	10	1.0	.40	.70	12	.80	.30	.55	12	.80	.40	.50	13	1.50	.04	.60	11
Discharge	3.24	.275	1.13	10	1.60	.583	1.08	12	2.97	.308	.562	12	2.46	.324	.918	13	3.27	.864	1.26	11

Table 9. Water-quality characteristics of base flow at Bald Eagle Creek by growing and nongrowing season and by water year--Continued

Constituent	1986 Water Year				1987 Water Year				1988 Water Year				1989 Water Year				1990 Water Year			
characteristic	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n	Max	Min	Med	n
Nitrogen, total N																				
Concentration	5.9	4.0	4.7	10	6.2	4.3	5.0	12	5.9	4.7	5.3	12	6.4	5.6	6.0	13	7.7	5.6	6.3	11
Discharge	15.9	2.59	8.48	10	12.0	3.44	8.28	12	30.9	3.02	6.58	12	19.1	3.40	10.6	13	24.2	12.2	13.8	11
Phosphorus, total as P																				
Concentration	.09	.03	.06	9	.11	.03	.05	12	.08	.02	.04	12	.18	.03	.05	13	.10	.02	.05	11
Discharge	.181	.038	.127	9	.172	.021	.081	12	.416	.034	.050	12	.466	.021	.078	13	.297	.039	.105	11
Phosphorus, dissolved as P																				
Concentration	.06	.02	.04	10	.09	.02	.04	12	.08	.02	.03	12	.17	.03	.04	13	.08	.02	.04	11
Discharge	.108	.011	.053	10	.141	.020	.060	12	.297	.017	.044	12	.441	.021	.060	13	.233	.039	.089	11
Orthophosphorus, dissolved as P																				
Concentration	.06	.02	.03	9	.08	.01	.02	12	.08	.01	.02	12	.16	.02	.04	13	.08	.02	.02	11
Discharge	.100	.025	.038	9	.125	.010	.031	12	.297	.009	.031	12	.415	.016	.060	13	.233	.039	.047	11
Sediment, suspended																				
Concentration	6.0	1.0	4.0	10	13	2.0	6.0	12	13.0	1.0	2.0	11	7.0	1.0	3.5	12	26.0	2.0	3.0	11
Discharge	15.2	1.08	6.86	10	16.0	2.05	9.10	12	17.8	.864	3.02	11	15.4	1.4	4.8	12	75.8	3.99	10.3	11

Table 10. Nitrogen, phosphorus, and suspended-sediment loads in base flow at Bald Eagle Creek prior to (October 1985 - September 1987) and during (October 1987-September 1989) nutrient management
[Base flow, in inches; loads, in pounds]

			Loads					
Month	Year	Base flow	Dissolved nitrate plus nitrite	Total nitrogen	Total phosphorus	Dissolved phosphorus	Dissolved orthophosphorus	Suspended sediment
			NONGROWING SEASON					
October	1985	0.52	120	160	1.6	1.3	0.9	110
	1986	.33	80	97	1.7	.6	.5	34
	1987	.62	92	110	.9	.7	.4	64
	1988	.28	88	98	.8	.8	.6	41
November	1985	.72	170	220	2.8	1.8	1.4	130
	1986	.50	130	150	2.8	1.1	.9	55
	1987	.63	140	160	1.3	1.0	.8	94
	1988	.30	91	100	.9	.8	.8	4
December	1985	.82	210	270	3.2	2.0	1.7	130
	1986	.73	180	220	3.6	1.5	1.3	74
	1987	.48	190	220	1.7	1.1	1.2	110
	1988	.27	92	100	1.0	1.4	.8	38
January	1986	.55	170	210	1.2	.9	.9	59
	1987	.82	230	270	3.7	1.6	1.4	92
	1988	.39	120	130	1.2	.9	.7	60
	1989	.38	130	140	1.3	1.2	1.2	60
February	1986	.90	220	270	2.5	1.4	1.4	130
	1987	.77	230	270	3.0	1.5	1.2	110
	1988	.52	120	140	1.3	.9	.7	67
	1989	.34	110	120	1.3	1.0	1.1	59
March	1986	1.2	330	380	4.5	2.4	2.2	280
	1987	1.0	300	350	4.3	2.2	1.5	220
	1988	.52	160	170	1.6	1.1	.9	98
	1989	.61	190	200	2.0	1.7	1.7	120
Subtotal			3,893	4,555	50.2	30.0	26.2	2,239

Table 10. Nitrogen, phosphorus, and suspended-sediment loads in base flow at Bald Eagle Creek prior to (October 1985 - September 1987) and during (October 1987-September 1989) nutrient management--Continued

			Loads					
Month	Year	Base flow	Dissolved nitrate plus nitrite	Total nitrogen	Total phosphorus	Dissolved phosphorus	Dissolved orthophosphorus	Suspended sediment
			GROWING SEASON					
April	1986	1.2	320	370	5.4	2.8	2.2	420
	1987	1.0	280	320	4.2	2.3	1.4	320
	1988	.49	140	150	1.4	1.0	.7	95
	1989	.60	200	220	2.2	1.7	1.6	130
May	1986	1.0	260	310	4.6	2.5	1.7	460
	1987	.90	230	270	3.5	2.2	1.1	370
	1988	1.9	540	650	3.7	3.1	1.1	130
	1989	1.4	430	500	4.3	3.7	2.5	220
June	1986	.78	180	220	3.4	1.9	1.2	360
	1987	.63	150	180	2.1	1.5	.6	270
	1988	.89	260	300	2.1	1.9	1.1	150
	1989	1.2	380	450	3.9	3.4	2.5	250
July	1986	.61	140	170	2.8	1.4	.9	240
	1987	.62	140	170	2.6	1.7	.6	290
	1988	.64	180	200	1.4	1.3	.9	120
	1989	1.2	350	420	3.4	3.3	2.5	260
August	1986	.35	79	95	1.5	.6	.5	72
	1987	.36	83	100	1.3	.8	.3	99
	1988	.45	120	140	1.0	1.0	.7	82
	1989	1.3	400	490	3.9	3.8	3.1	280
September	1986	.24	58	69	1.1	.4	.3	26
	1987	.58	130	160	3.0	2.1	.6	200
	1988	.29	89	100	.8	.8	.6	49
	1989	1.0	320	390	3.2	3.1	3.1	240
Subtotal			5,459	6,444	66.8	48.1	31.8	5,133
Prior to nutrient management								
	1986	8.89	2,257	2,744	34.6	19.4	15.3	2,417
	1987	8.24	2,163	2,557	35.8	19.1	11.4	2,134
Subtotal		17.13	4,420	5,301	70.4	38.5	26.7	4,551
During nutrient management								
	1988	7.82	2,151	2,470	18.4	14.8	9.8	1,119
	1989	8.88	2,781	3,228	28.2	25.9	21.5	1,702
Subtotal		16.70	4,932	5,698	46.6	40.7	31.3	2,821
Grand total		33.83	9,352	10,999	117.0	79.2	58.0	7,372

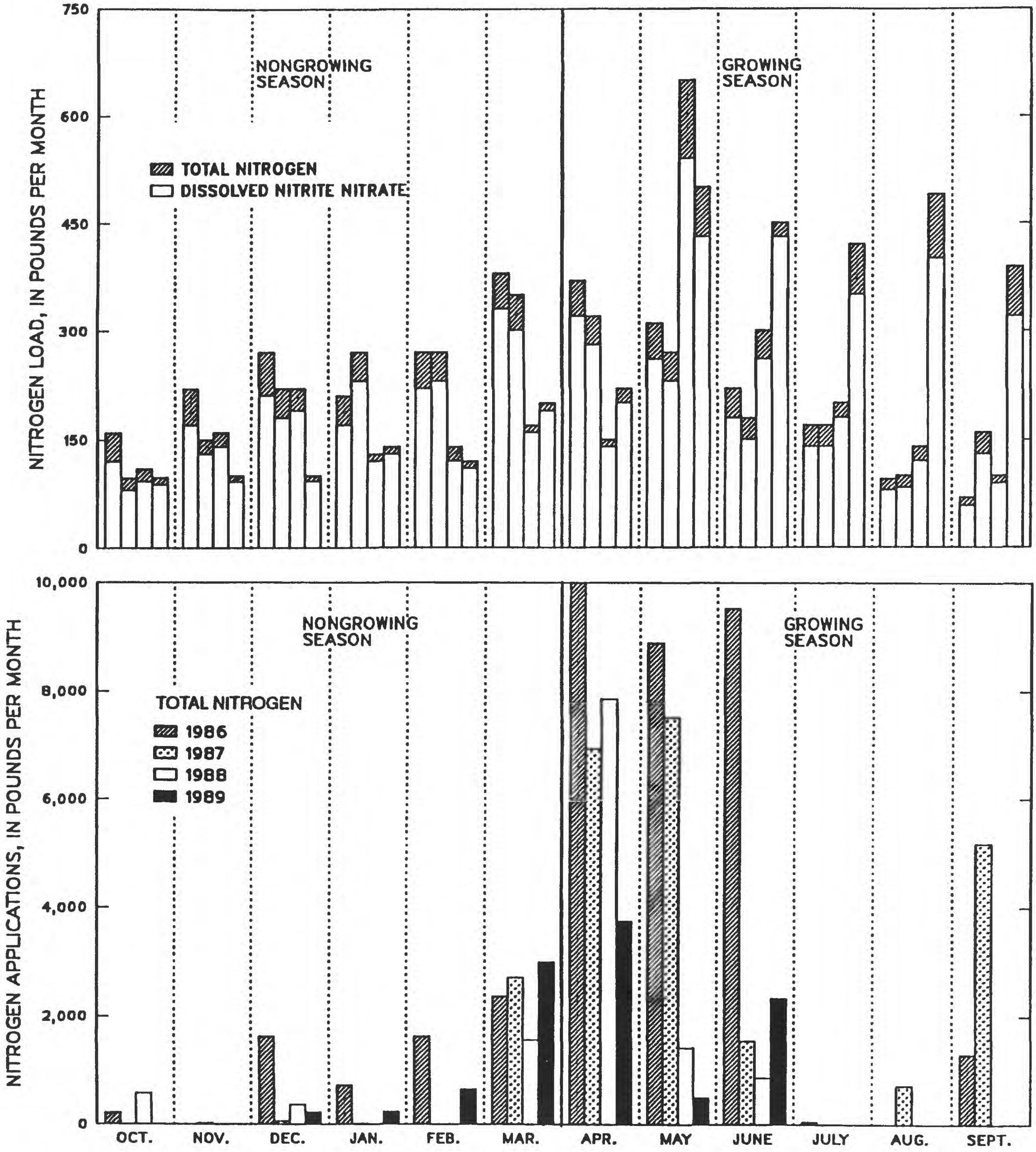

Figure 10. Relation between monthly nitrogen discharges in base flow (top) and monthly nitrogen applications (bottom).

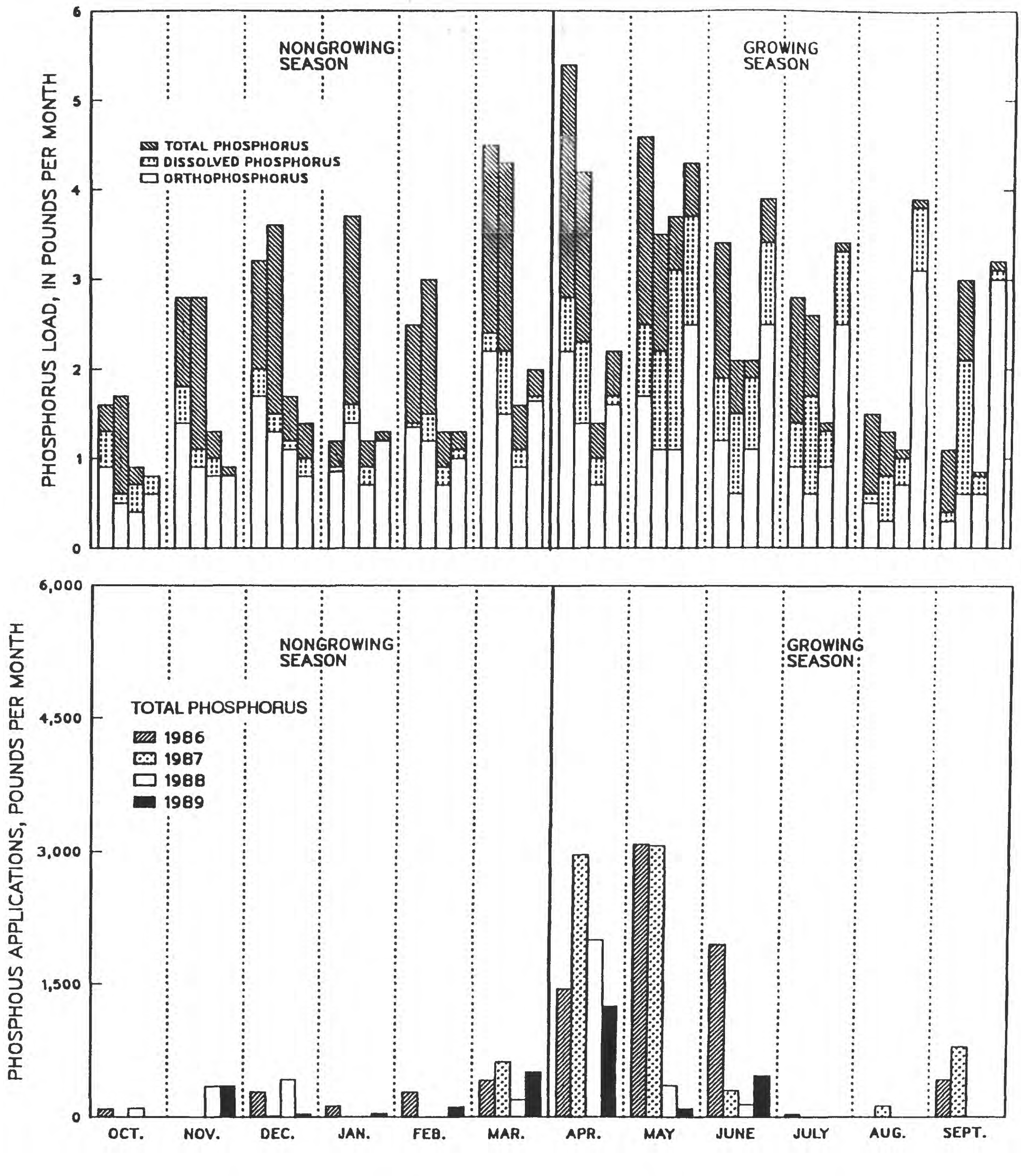

Figure 11. Relation between monthly phosphorus discharges in base flow (top) and monthly phosphorus applications (bottom).

Table 11. Coefficients, standard deviations, and T values for the 7-parameter log-linear model used to estimate concentrations and loads in base flow

[Pre, prior to nutrient management; Post, during nutrient management; β_0, constant; β_1, log of streamflow; β_2, log of streamflow squared; β_3, decimal time; β_4, decimal time squared; β_5, sin (time); β_6, cos (time)]

Constituent	Parameter	Coefficient		Standard deviation		T value	
		Pre	Post	Pre	Post	Pre	Post
Dissolved nitrite plus nitrate							
Concentration	β_0	1.4270	1.6038	0.0273	0.0551	52.26	29.12
	β_1	-.0990	-.0409	.0616	.0602	-1.62	-.68
	β_2	.0213	.0404	.5940	.0832	.36	.48
	β_3	.0178	.0569	.0252	.0316	.70	1.80
	β_4	.0085	-.0605	.0487	.0991	.17	-.61
	β_5	.1486	.0343	.0433	.0314	3.43	1.09
	β_6	.1152	.0311	.0196	.0351	5.87	.89
Load	β_0	.7434	1.0450	.0273	.0551	27.22	18.97
	β_1	.9003	.9591	.0616	.0602	14.62	15.94
	β_2	.0213	.0404	.0594	.0832	.36	.48
	β_3	.0178	.0569	.0252	.0316	.70	1.80
	β_4	.0085	-.0605	.0487	.0991	.17	-.61
	β_5	.1486	.0343	.0433	.0314	3.43	1.09
	β_6	.1152	.0311	.0196	.0351	5.87	.89
Total nitrogen							
Concentration	β_0	1.6078	1.6951	.0206	.0455	61.78	37.25
	β_1	-.0905	.0063	.0607	.0497	-1.49	.13
	β_2	-.0391	.1064	.0588	.0688	-.67	1.55
	β_3	-.0135	.0695	.0249	.0261	-.54	2.66
	β_4	.0805	.0021	.0456	.0891	1.76	.03
	β_5	.1172	.0150	.0415	.0259	2.82	.58
	β_6	.1127	.0308	.0193	.0290	5.83	1.06
Total nitrogen							
Load	β_0	.9308	1.1363	.0260	.0455	35.77	24.97
	β_1	.9095	1.0063	.0607	.0497	14.97	20.24
	β_2	-.0391	.1064	.0588	.0688	-.67	1.55
	β_3	-.0135	.0695	.0249	.0261	-.54	2.66
	β_4	.0805	.0021	.0456	.0819	1.76	.03
	β_5	.1172	.0150	.0415	.0259	2.82	.58
	β_6	.1127	.0308	.0193	.0290	5.83	1.06
Dissolved phosphorus							
Concentration	β_0	-3.6066	-3.5832	.1962	.4859	-18.38	-7.37
	β_1	.8233	-.2193	.4580	.5308	1.80	-.41
	β_2	-.0102	.0844	.4437	.7341	-.02	.11
	β_3	.0971	.5650	.1874	.2788	.52	2.03
	β_4	.1070	.3596	.3442	.8746	.31	.41
	β_5	-.4056	.0309	.3133	.2768	-1.29	.11
	β_6	-.1146	.1036	.1459	.3092	-.79	.34
Load	β_0	-4.2836	-4.1420	.1962	.4859	-21.83	-8.52
	β_1	1.8233	.7807	.4580	.5308	3.98	1.47
	β_2	-.0102	.0844	.4437	.7341	-.02	.11
	β_3	.0971	.5650	.1874	.2788	.52	2.03
	β_4	.1070	.3596	.3442	.8746	.31	.41
	β_5	-.4054	.0309	.3133	.2768	-1.29	.11
	β_6	-.1140	.1036	.1459	.3092	-.79	.34

Table 11. Coefficients, standard deviations, and T values for the 7-parameter log-linear model used to estimate concentrations and loads in base flow--Continued

Constituent	Parameter	Coefficient		Standard deviation		T value	
		Pre	Post	Pre	Post	Pre	Post
Dissolved orthophosphorus							
Concentration	β_0	-3.8487	-3.5832	0.2484	0.4859	-15.50	- 7.37
	β_1	.4268	- .2193	.6505	.5308	.66	- .41
	β_2	.1407	.0844	.6451	.7341	.22	.11
	β_3	- .2139	.5650	.2514	.2788	- .85	2.03
	β_4	- .2405	.3596	.4724	.8746	- .51	.41
	β_5	- .2139	.0309	.4198	.2768	- .51	.11
	β_6	.1352	.1036	.1951	.3092	.69	.34
Load	β_0	-4.4681	-4.1420	.2484	.4859	-17.99	-8.52
	β_1	1.4269	.7807	.6505	.5308	2.19	1.47
	β_2	.1407	.0844	.6451	.7341	.22	.11
	β_3	- .2139	.5650	.2514	.2788	- .85	2.03
	β_4	- .2405	.3596	.4724	.8746	- .51	.41
	β_5	- .2139	.0309	.4198	.2768	- .51	.11
	β_6	.1352	.1036	.1951	.3092	.69	.34
Total phosphorus							
Concentration	β_0	-3.0864	-3.3868	.3542	.3437	-8.71	-9.85
	β_1	.9275	- .3756	.8267	.3755	1.12	-1.00
	β_2	.5532	.3885	.8009	.5193	.69	.75
	β_3	.2051	.1960	.3383	.1972	.61	.99
	β_4	- .5562	.6828	.6213	.6187	- .90	1.10
	β_5	- .6739	.2227	.5655	.1958	- .19	1.14
	β_6	.0319	- .1350	.2633	.2188	- .12	- .62
Total phosphorus							
Load	β_0	-3.7634	-3.9457	.3542	.3437	-10.63	-11.48
	β_1	1.9275	.6244	.8267	.3755	2.33	1.66
	β_2	.5532	.3885	.8009	.5193	.69	.75
	β_3	.2051	.1960	.3383	.1972	.61	.99
	β_4	- .5562	.6828	.6213	.6187	- .90	1.10
	β_5	- .6739	.2227	.5655	.1958	- 1.19	1.14
	β_6	.0319	- .1350	.2633	.2188	- .12	- .62
Suspended sediment							
Concentration	β_0	.9318	.7738	.2192	.4534	4.25	1.71
	β_1	.9607	- .1813	.5034	.4825	1.91	- .38
	β_2	- .1535	- .0611	.4846	.6720	- .32	- .09
	β_3	- .0251	.1371	.1952	.2574	- .13	.53
	β_4	.3330	.6227	.3566	.7977	.93	.78
	β_5	- .1862	.1103	.3564	.2491	- .52	.44
	β_6	- .7128	- .1687	.1607	.2806	-4.44	- .60
Load	β_0	.2589	.2198	.2192	.4534	1.18	.48
	β_1	1.9607	.8187	.5034	.4825	3.89	1.70
	β_2	- .1535	- .0611	.4846	.6720	- .32	- .09
	β_3	- .0251	.1371	.1952	.2574	- .13	.53
	β_4	.3330	.6227	.3566	.7977	.93	.78
	β_5	- .1862	.1103	.3564	.2491	- .52	.44
	β_6	- .7128	- .1687	.1607	.2806	-4.44	-.60

Table 12. Seasonal Kendall test results for nitrogen (as N) and phosphorus (as P) constituents in base flow for the 1986-90 water years

[(p), probability value; (mg/L)/yr, milligrams per liter per year; (lb/yr), pounds per year; concentration, milligrams per liter; discharge, pounds per day ; cfs, cubic feet per second; +, significant increasing trend; 0, no trend]

Constituent	Kendall's tau		Significance	Estimate of slope	Median
	tau	(p)			
Discharge	0.1607	0.205	+	0.02 (mg/L)/yr	.31
Total nitrogen					
Concentration	.7757	.00	+	0.40 (mg/L)/yr	5.6
Discharge	.2678	.033	+	1.52 lb/yr	8.9
Nitrite plus nitrate					
Concentration					
Total	.8224	.00	+	.40 (mg/L)/yr	4.9
Dissolved	.6449	.001	+	.35 (mg/L)/yr	4.7
Discharge					
Total	.2857	.023	+	1.41 lb/yr	8.05
Dissolved	.2857	.022	+	1.17 lb/yr	7.52
Ammonia concentration					
Total	.0467	.758	0	.00 (mg/L)/yr	.04
Dissolved	.0841	.526	0	.00 (mg/L)/yr	.035
Ammonia plus organic concentration					
Total	-.1495	.233	0	-.02 (mg/L)/yr	.60
Dissolved	-.1963	.11	0	-.03 (mg/L)/yr	.50
Phosphorus					
Concentration					
Total	-.1402	.274	0	-.01 (mg/L)/yr	.05
Dissolved	.1215	.341	0	.00 (mg/L)/yr	.04
Ortho	.1308	.301	0	.00 (mg/L)/yr	.03
Discharge					
Total	-.0089	.100	0	-.01 lb/yr	.079
Dissolved	.1696	.183	0	.00 lb/yr	.056
Ortho	.2037	.111	0	.00 lb/yr	.04
Suspended sediment					
Concentration	-.0280	.866	0	.00 (mg/L)/yr	3.0
Discharge	.0857	.541	0	.25 lb/yr	6.8

Table 13. Results of synoptic sampling of base flow at the Bald Eagle Creek gaging station, tributary 1, and tributary 2

[Concentrations in milligrams per liter as N; --, data not available]

Date	Location	Concentration		Percentage total nitrite plus nitrate to total nitrogen
		Total nitrite plus nitrate	Total nitrogen	
September 27, 1990	Gaging station	5.8	7.3	79
	1	--	--	--
	2	5.4	6.3	86
October 31, 1990	Gaging station	5.8	6.3	92
	1	7.6	8.2	93
	2	--	--	--
December 12, 1990	Gaging station	6.5	7.0	93
	1	8.2	8.9	92
	2	6.2	6.7	93
December 26, 1990	Gaging station	5.9	6.3	94
	1	7.3	8.0	91
	2	5.6	6.2	90

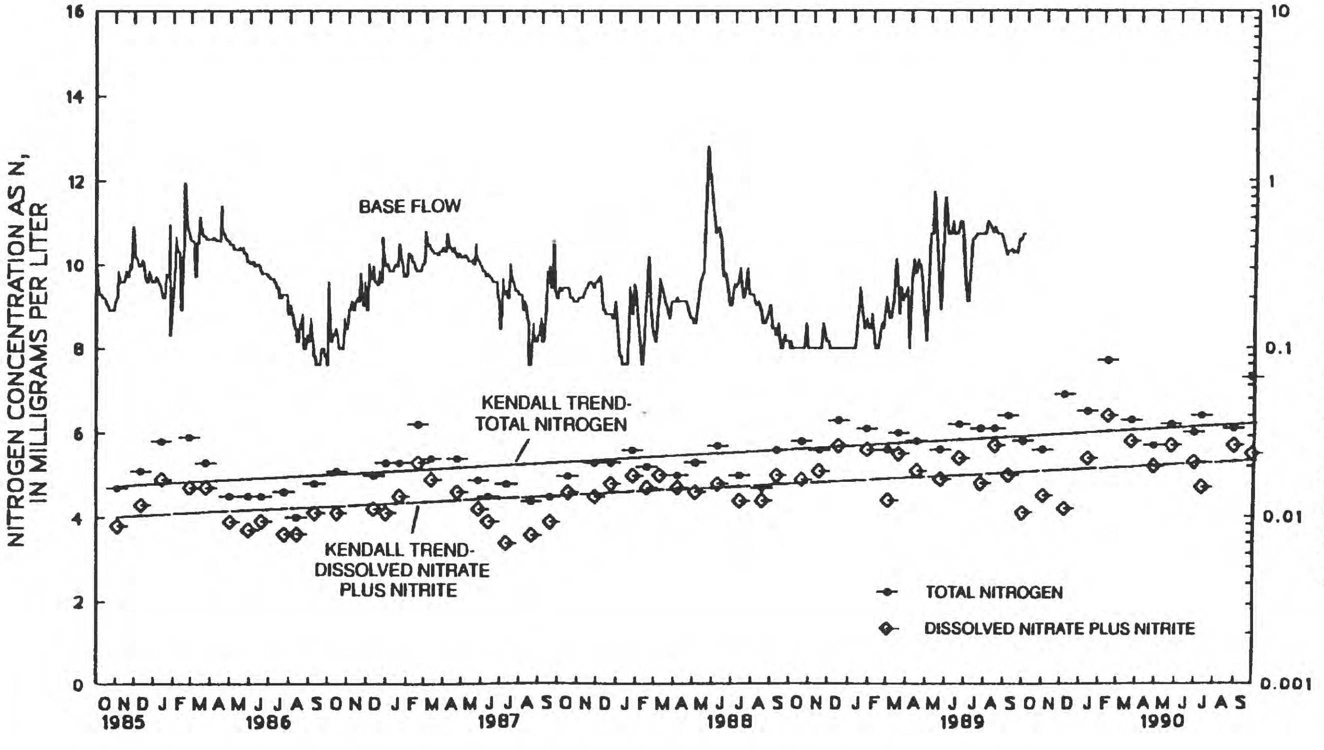

Figure 12. Total nitrogen and dissolved nitrate plus nitrate concentrations in base flow prior to and during nutrient management.

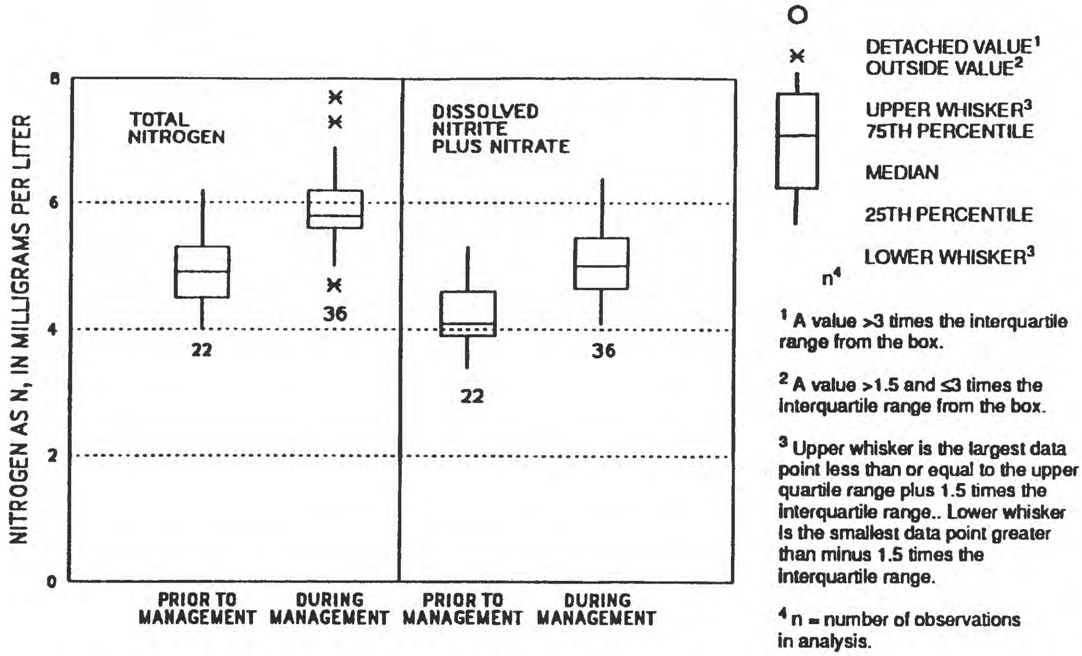

Figure 13. Distribution of concentrations of total nitrogen and dissolved nitrite plus nitrate in base flow prior to and during nutrient management in the Bald Eagle Creek subbasin.

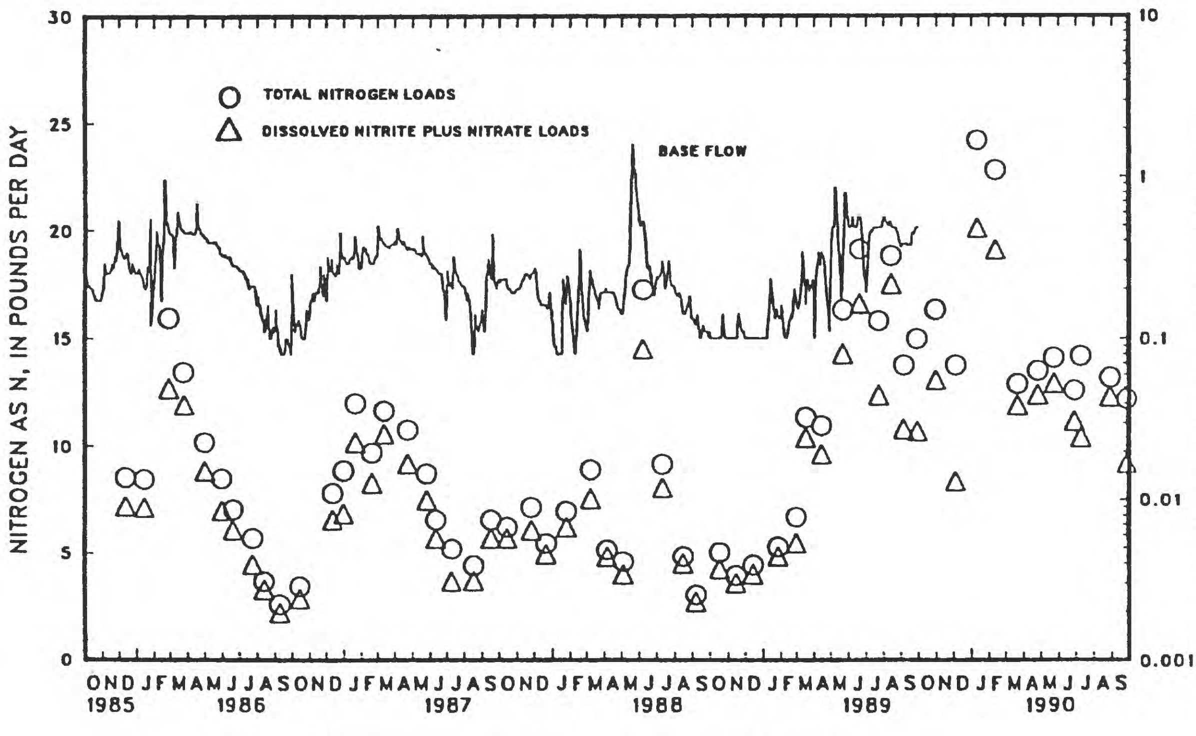

Figure 14. Relation between discharges of total nitrogen and dissolved nitrite plus nitrate and base flow in Bald Eagle Creek.

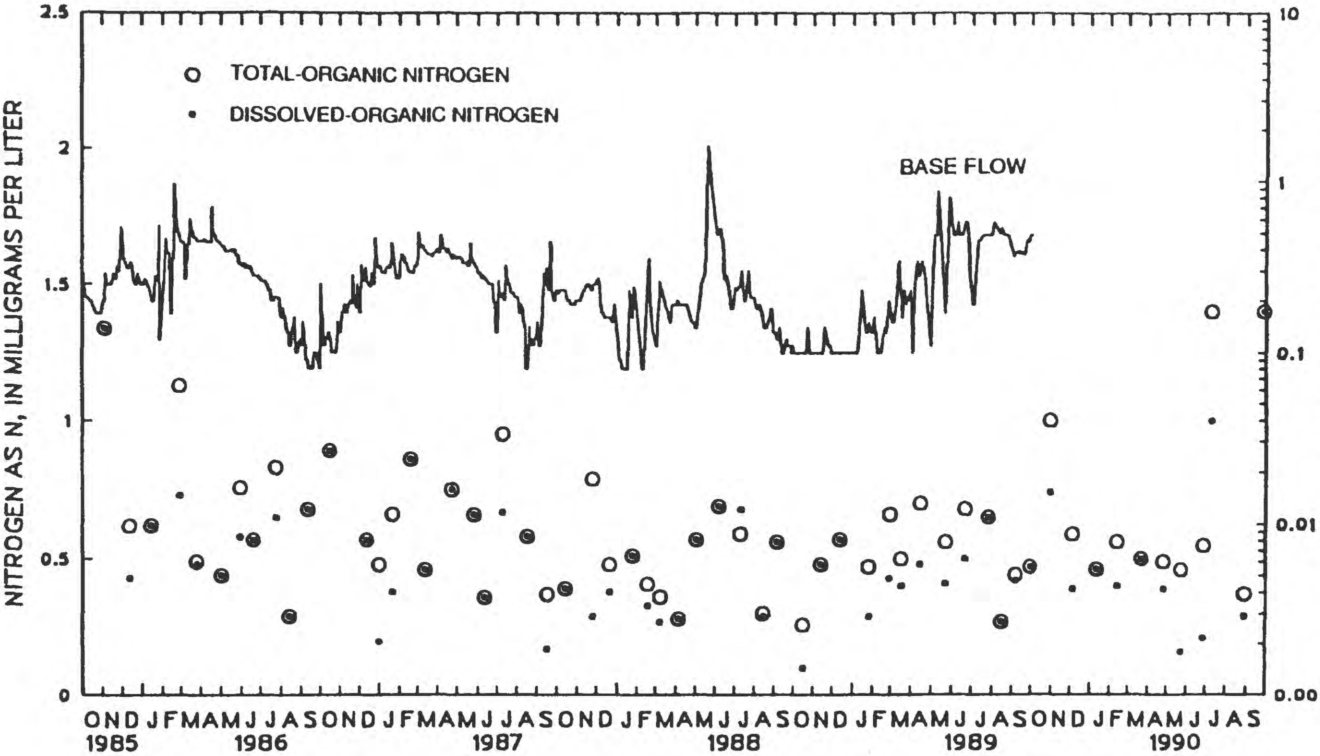

Figure 15. Relation between concentrations of organic nitrogen and base flow of Bald Eagle Creek.

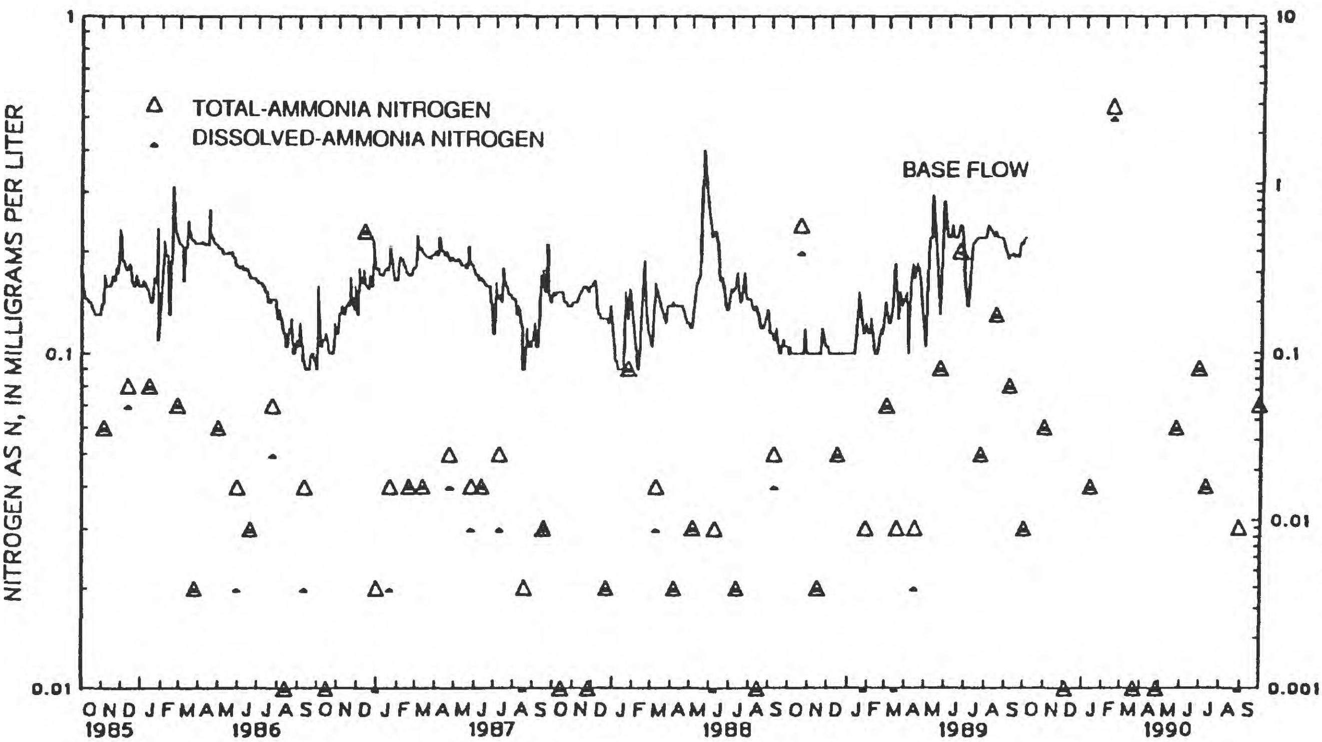

Figure 16. Relation between concentrations of total and dissolved ammonia nitrogen and base flow in Bald Eagle Creek.

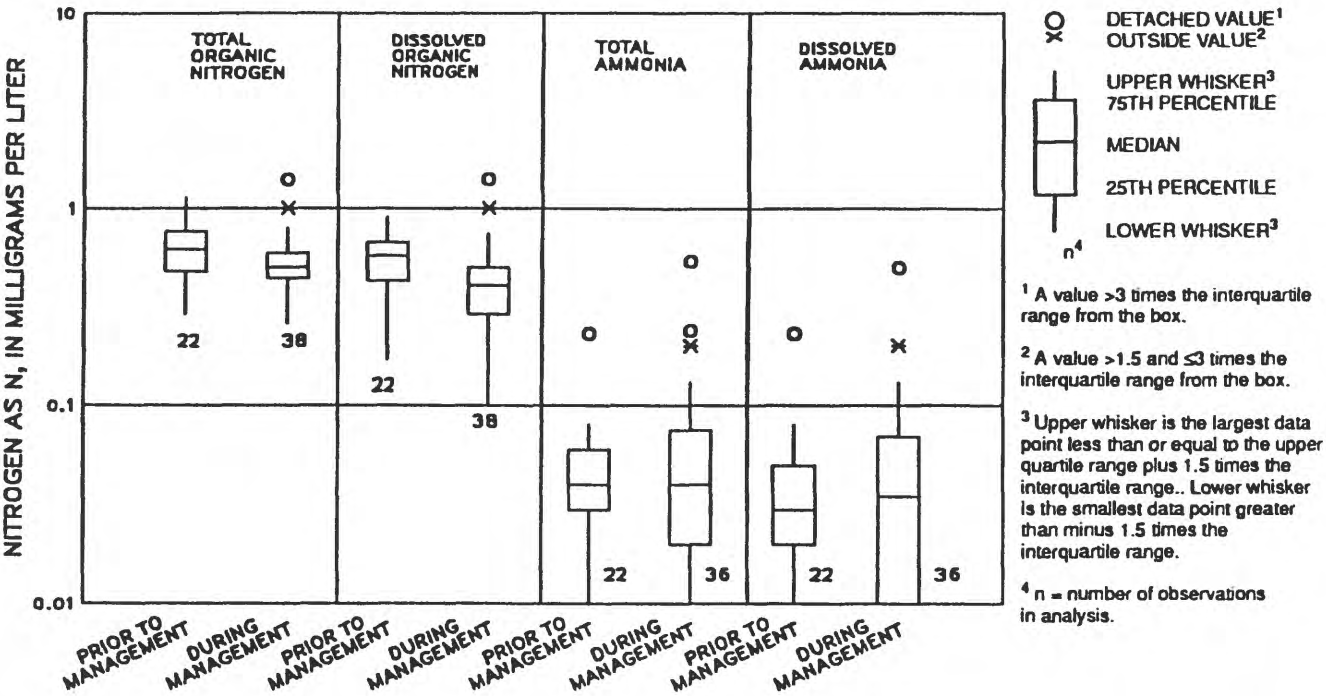

Figure 17. Distribution of total and dissolved organic nitrogen and ammonia concentrations in base flow prior to and during nutrient management in Bald Eagle Creek.

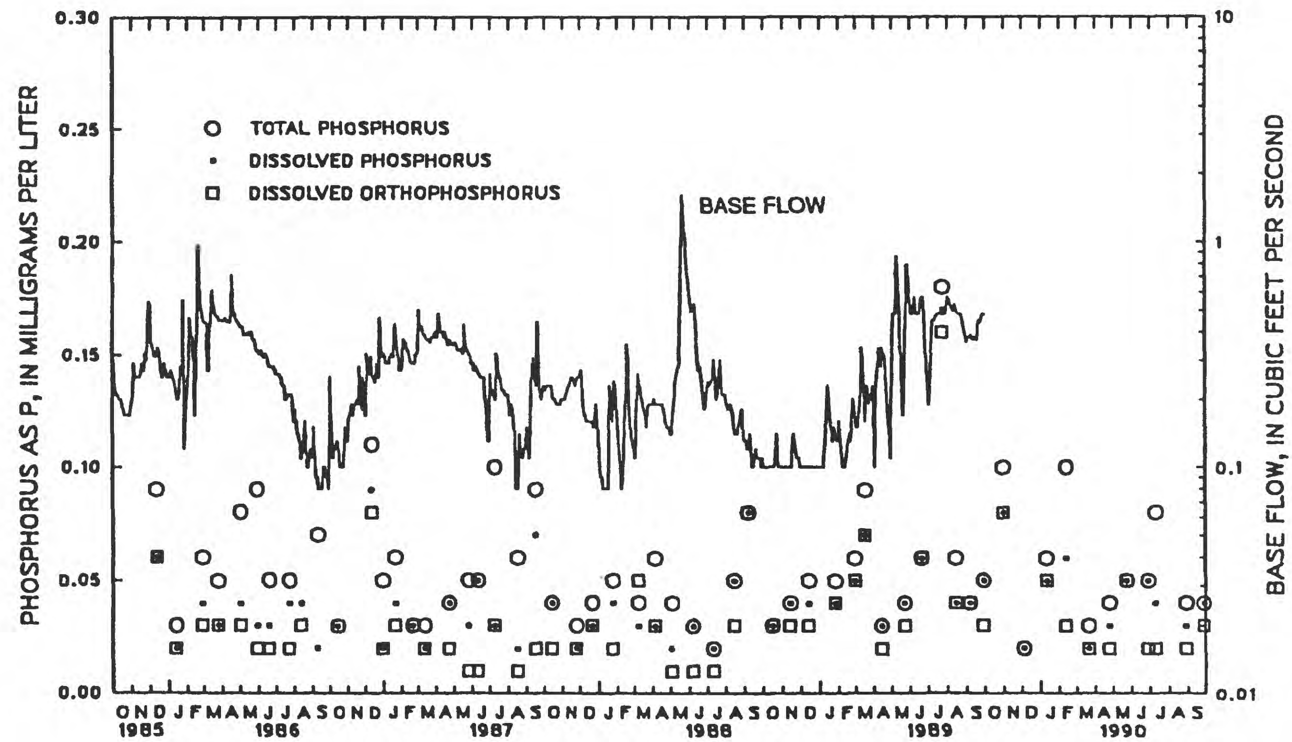

Figure 18. Relation between concentrations of total phosphorus, dissolved phosphorus, and orthophosphorus and base flow.

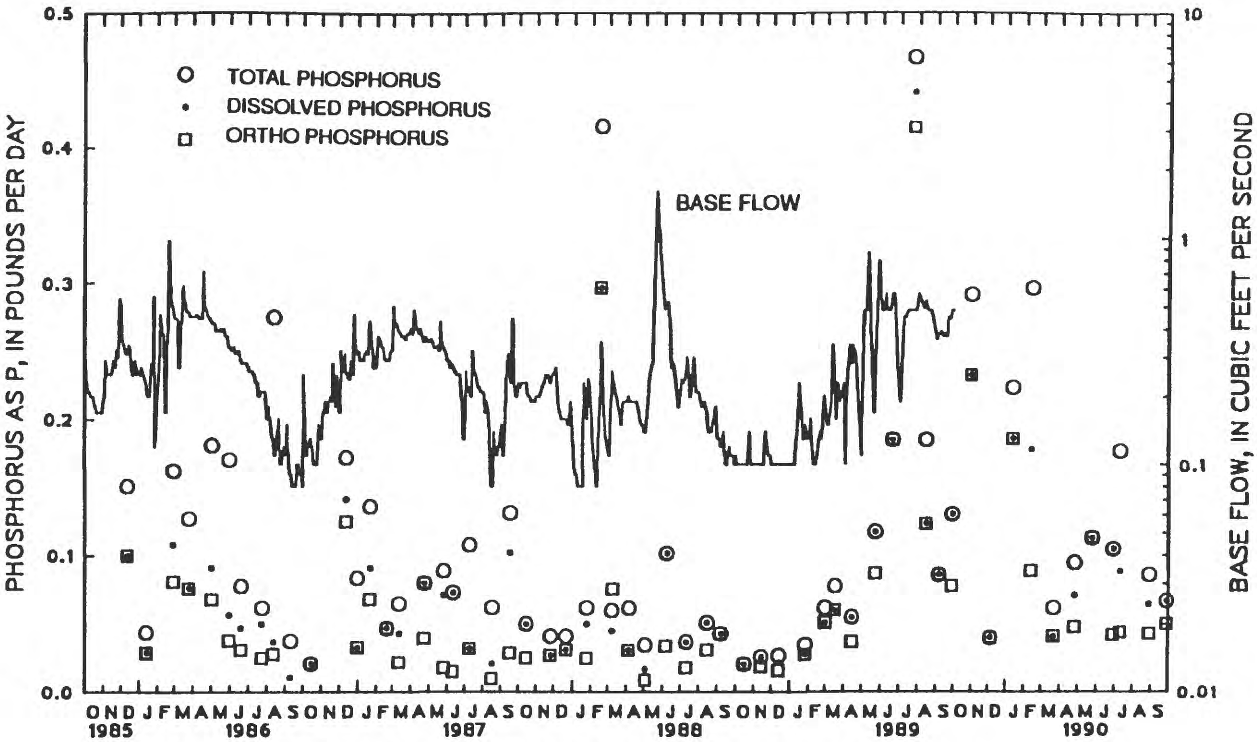

Figure 19. Relation between discharges of total phosphorus, dissolved phosphorus, and orthophosphorus and base flow.

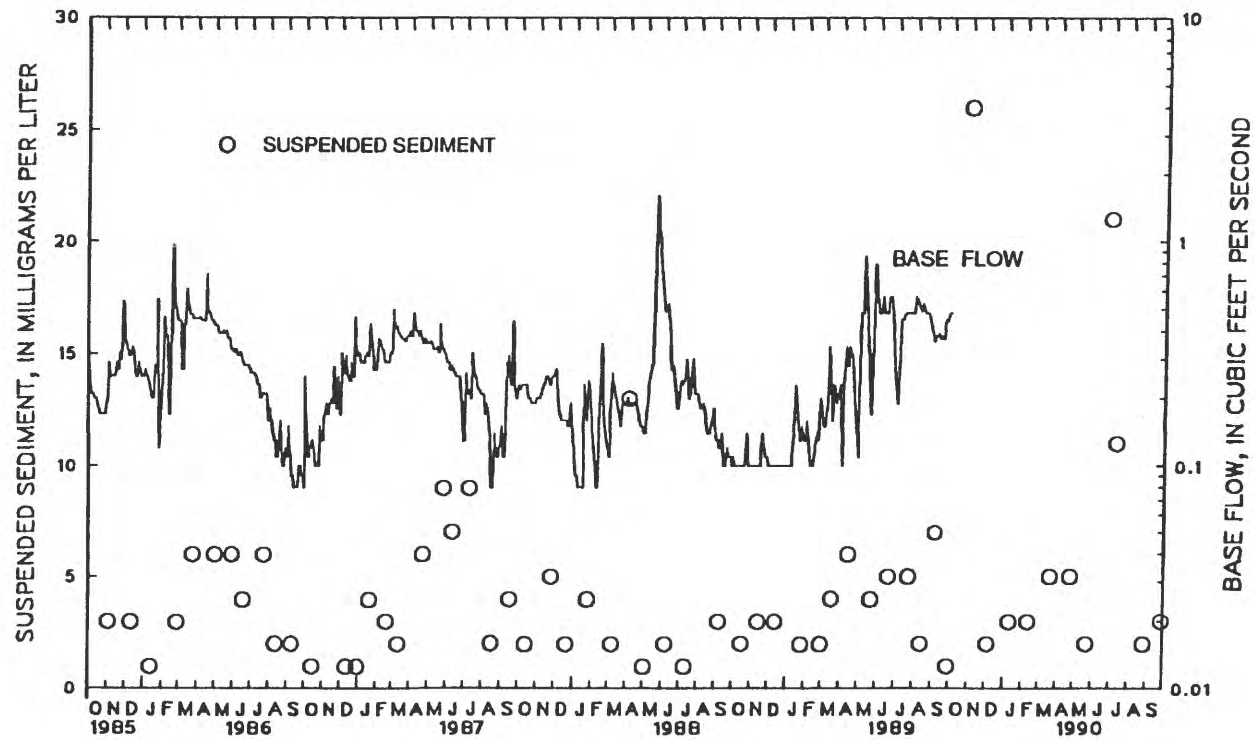

Figure 20. Relation between concentrations of suspended sediment and base flow.

Stormflow.--Trends in stormflow quality prior to and during nutrient management were difficult to determine because of the variability of runoff quantity and because only selected storms were sampled. Table 14 summarizes stormflow collected by water year. Twenty-eight of the 54 storms sampled were during the growing season. These 54 storms that were sampled during the study represent the quality and quantity of 84 percent of the total stormflow.

Table 15 lists the minimum and maximum concentrations of 11 constituents measured in stormflow. The maximum concentration of total nitrogen in stormflow was 61 mg/L on November 5, 1985. About 82 percent of the nitrogen in that sample was suspended-organic nitrogen. The maximum concentration of total nitrite plus nitrate was 5.5 mg/L measured in December 1989, and the maximum concentration of total ammonia was 10.0 mg/L measured in January 1988.

During stormflow, concentrations of total and dissolved phosphorus increased as water discharge and concentrations of suspended sediment increased. The maximum concentrations of total and dissolved phosphorus and orthophosphorus were measured prior to nutrient management and were 24, 6.0, and 3.7 mg/L, respectively. These concentrations were measured early in the study during the nongrowing season on November 5, 1985. During nutrient management, concentrations of total phosphorus, dissolved phosphorus, and orthophosphorus in stormflow were less than concentrations measured prior to nutrient management probably because the farmers reduced phosphorus applications to the cropland.

Sediment concentrations usually reached their peak just prior to or during the peak streamflow. The maximum concentration of suspended sediment prior to nutrient management was 8,730 mg/L on July 14, 1987, at a water discharge of 7.5 ft^3/s, and the maximum concentration during nutrient management was 15,100 mg/L on July 4, 1989, at a water discharge of 87 ft^3/s.

Table 16 lists daily storm loads of nitrogen, phosphorus, and suspended sediment that were measured from October 1, 1985, to September 30, 1989. In order to calculate total storm loads, regression equations (table 17) were developed to estimate loadings for the 112 storm days that were not sampled. Storm days were determined on the basis of precipitation and streamflow records. Because the majority of sampled stormflow produced medium to high flows, only 16 percent of the total stormflow was not sampled (table 14).

The statistics listed in table 17 were derived from regressions between the log of the daily stormflow and the log of the daily nutrient and suspended sediment loads measured in the 54 sampled storms described earlier.

Table 18 summarizes the measured streamflow loads (table 16) and the estimated loads for stormflow by month for the 1986-89 water years. Loads of total nitrogen, total phosphorus, and suspended sediment increased 64, 74, and 44 percent, to 6,119 lb, 913 lb, and 464,340 lb, respectively, during the first 2 years of nutrient management, primarily in response to a 21 percent increase in precipitation.

Loads of suspended sediment in stormflow were greater in the growing season when the soils were disturbed from farming activities that increased erosion. Loads of total nitrogen and phosphorus were greater in the nongrowing season when plants are dormant and nutrients are concentrated in the soil and available to be transported to the stream in runoff. During May 1988 and May 1989 when 8.71 and 12.84 in. of precipitation fell, respectively (fig. 7), 24 percent of the nitrogen, 19 percent of the phosphorus, and 36 percent of the suspended sediment for the entire study was discharged in stormflow.

In summary, the total loads in streamflow, prior to nutrient management, were 7,484 lb of total nitrogen, 305 lb of total phosphorus, and 264,785 lb of suspended sediment (table 19). During the first 2 years of nutrient management, loads were 11,817 lb of total nitrogen, 959 lb of total phosphorus, and 467,166 lb of suspended sediment, an increase of 37, 68, and 43 percent, respectively. The increase in nutrient and suspended-sediment loads during the first 2 years of nutrient management was because of the significant increase in precipitation. For the first 4 years of the study, 43 percent of total nitrogen, 91 percent of total phosphorus, and 99 percent of suspended sediment were transported in stormflow.

Table 14. Number of storms, number of sampled storms, number of samples collected, and the percentage of total stormflow sampled at the Bald Eagle Creek site for the 1986-89 water years

Water Year	Total storms	Storms sampled	Number of samples	Percentage of total stormflow sampled
1986	31	7	95	28
1987	32	19	180	75
1988	28	14	78	85
1989	23	14	103	94
Total	114	54	456	84

Table 15. Ranges of instantaneous streamflow and constituent concentrations in stormflow at Bald Eagle Creek for the 1986-89 water years

[Streamflow, in cubic feet per second; N, nitrogen; P, phosphorus; constituent concentration, in milligrams per liter; n, number of instantaneous samples and measurements; Min, minimum; Max, maximum; <, less than; --, not determined]

Constituent	1986 Water Year			1987 Water Year			1988 Water Year			1989 Water Year		
	Min	Max	n	Min	Max	n	Min	Max	n	Min	Max	n
Streamflow	0.21	6.9	95	0.08	12	180	0.34	105	78	0.19	147	103
Nitrite + nitrate, total as N	1.5	4.5	19	<.10	4.3	77	.10	5.2	63	.10	5.5	47
Nitrite + nitrate, dissolved as N	1.3	4.3	19	.60	3.8	13	--	--	0	2.4	4.1	10
Ammonia, total as N	.06	4.9	19	<.01	6.7	77	.04	10	63	.03	3.9	47
Ammonia, dissolved as N	.06	4.6	18	.06	1.3	13	--	--	0	.30	.97	10
Ammonia + organic nitrogen, total as N	.90	60	19	.40	28	75	.03	45	63	.90	26	47
Ammonia + organic nitrogen, dissolved as N	.70	10	18	<.20	7.9	13	--	--	0	1.9	4.4	10
Nitrogen, total as N	4.8	61	19	3.8	32	73	.60	23	61	2.3	27	46
Phosphorus, total as P	.03	24	19	.09	4.9	77	.02	13	63	.11	9.3	47
Phosphorus, dissolved as P	.03	6	18	.15	1.5	13	--	--	0	.43	1.5	10
Orthophosphorus, dissolved as P	.02	3.7	18	.12	1.1	13	--	--	0	.38	1.3	10
Sediment, suspended	3	4,350	81	<1	8,730	150	7	12,700	56	17	15,100	83

Table 16. Daily nitrogen, phosphorus, and suspended-sediment loads during sampled storms at the Bald Eagle Creek site for the 1986-89 water years

[Streamflow, in cubic feet per second; loads, in pounds; --, not determined; {, consecutive storm days]

Date	Daily streamflow	Total nitrite plus nitrate	Dissolved nitrite plus nitrate	Total ammonia	Dissolved ammonia	Total organic nitrogen	Dissolved organic nitrogen	Total nitrogen	Total phosphorus	Dissolved phosphorus	Dissolved ortho-phosphorus	Suspended sediment
PRIOR TO NUTRIENT MANAGEMENT												
{11/04/85	0.29	6	6	0.3	0.3	2	2	8.3	0.3	0.1	0.1	23
{11/05/85	.78	13	12	8	6	61	13	82	23	9	6	2,660
01/26/86	2.2	--	--	--	--	--	--	--	--	--	--	16,500
02/18/86	1.2	--	--	--	--	--	--	--	--	--	--	8,260
03/15/86	1.0	24	24	3	3	8	7	35	2	1	1	235
07/20/86	.31	5	5	1	1	7	3	13	.9	.3	.2	236
08/02/86	.24	--	--	--	--	--	--	--	--	--	--	386
{10/01/86	.34	8	6	2	2	28	10	38	4	1	1	5,290
{10/02/86	.25	4	4	1	1	5	5	10	.4	.3	.2	34
11/05/86	.37	7	--	2	--	1	--	24	2	--	--	134
11/18/86	.31	--	--	--	--	--	--	--	--	--	--	810
11/20/86	.45	--	--	--	--	--	--	--	--	--	--	4,090
11/26/86	.48	--	--	--	--	--	--	--	--	--	--	1,300
12/18/86	.47	8	--	4	--	13	--	25	1	--	--	524
12/24/86	2.6	--	--	--	--	--	--	--	--	--	--	39,100
02/23/87	.51	--	--	--	--	--	--	--	--	--	--	80
03/01/87	1.8	20	--	17	--	116	--	153	8	--	--	25,700
{05/19/87	.43	4	--	1	--	4	--	9	1	--	--	233
{05/20/87	.62	11	--	2	--	10	--	23	2	--	--	510
07/01/87	.33	--	--	--	--	--	--	--	--	--	--	730
07/12/87	1.9	--	--	--	--	--	--	--	--	--	--	27,100
07/14/87	.53	6	5	1	1	8	6	15	4	.6	.4	6,000
08/05/87	.35	6	--	3	--	23	--	32	3	--	--	3,230
09/01/87	.30	4	--	1	--	3	--	8	2	--	--	509
09/08/87	2.3	22	--	8	--	76	--	106	16	6	4	52,200
09/18/87	1.6	15	--	4	--	51	--	70	3	--	--	36,100

Table 16. Daily nitrogen, phosphorus, and suspended-sediment loads during sampled storms at the Bald Eagle Creek site for the 1986-89 water years--Continued

Date	Daily streamflow	Total nitrite plus nitrate	Dissolved nitrite plus nitrate	Total ammonia	Dissolved ammonia	Total organic nitrogen	Dissolved organic nitrogen	Total nitrogen	Total phosphorus	Dissolved phosphorus	Dissolved ortho-phosphorus	Suspended sediment
DURING NUTRIENT MANAGEMENT												
11/29/87	6.5	58	--	15	--	139	--	197	71	--	--	54,000
12/15/87	.41	9	--	.3	--	.6	--	10	.9	--	--	86
01/18/88	3.0	48	--	166	--	260	--	310	21	--	--	1,080
01/20/88	20.0	146	--	153	--	418	--	564	165	--	--	5,330
01/31/88	1.1	11	--	28	--	56	--	67	4	--	--	187
02/01/88	5.6	66	--	101	--	109	--	175	20	--	--	23,600
05/05/88	1.3	26	--	10	--	85	--	111	16	--	--	13,800
05/06/88	5.0	93	--	25	--	141	--	234	39	--	--	11,000
05/17/88	25.0	233	--	159	--	261	--	494	23	--	--	94,000
05/18/88	15.0	196	--	30	--	158	--	354	51	--	--	46,000
05/19/88	3.0	89	--	6	--	52	--	141	8	--	--	6,340
07/23/88	3.3	32	--	2	--	191	--	223	46	--	--	22,000
08/29/88	2.1	25	--	8	--	36	--	61	14	--	--	2,600
09/04/88	.91	17	--	6	--	15	--	32	3	--	--	426
10/21/88	.77	21	--	14	--	36	--	57	8	--	--	1,110
11/20/88	2.8	60	53	19	14	110	70	170	28	18	18	4,830
02/21/89	.94	4	--	3	--	13	--	17	17	--	--	209
03/18/89	.40	--	--	--	--	--	--	--	--	--	--	246
03/24/89	1.8	--	--	--	--	--	--	--	--	--	--	1,440
05/05/89	5.1	--	--	--	--	--	--	--	--	--	--	28,300
05/06/89	3.1	--	--	--	--	--	--	--	--	--	--	7,820
05/23/89	4.9	58	--	13	--	71	--	129	17	--	--	38,300
05/24/89	5.4	77	--	4	--	59	--	136	16	--	--	1,134
06/07/89	2.9	--	--	--	--	--	--	--	--	--	--	3,100
06/09/89	1.3	--	--	--	--	--	--	--	--	--	--	867
07/04/89	9.5	205	--	28	--	117	--	322	20	--	--	6,190
07/05/89	3.3	25	--	7	--	26	--	51	42	--	--	340
09/19/89	.93	--	--	--	--	--	--	--	--	--	--	780

Table 17. Regression statistics for estimating daily nitrogen, phosphorus, and suspended-sediment loads as a function of stormflow at the Bald Eagle Creek for the 1986-89 water years
[Constituent loads, pounds per day; stormflow, cubic feet per second]

y = ax+b

(x) Independent variable (log of stormflow)	(y) Dependent variable (log of load)	(a) Slope	(b) Intercept	Coefficient of determination (r^2)	Standard error of estimate: in log units	Standard error of estimate: plus (in percent)	Standard error of estimate: minus (in percent)
Stormflow	Total nitrogen	0.886714	1.63302	0.83	0.226	68	41
Stormflow	Total phosphorus	1.00475	.680612	.71	.361	129	56
Stormflow	Suspended sediment	1.38486	-.295788	.55	.654	351	78

Table 18. Measured and estimated nitrogen, phosphorus, and suspended-sediment loads in stormflow at Bald Eagle Creek for the 1986-89 water years
[Loads, in pounds; --, not determined]

Month	Year	Nitrogen Measured	Nitrogen Estimated	Nitrogen Total	Phosphorus Measured	Phosphorus Estimated	Phosphorus Total	Suspended sediment Measured	Suspended sediment Estimated	Suspended sediment Total
NONGROWING SEASON										
October	1985	--	--	--	--	--	--	--	--	--
	1986	48	22	70	4.4	2.1	6.5	5,324	240	5,564
	1987	0	87	87	0	8.9	8.9	0	1,420	1,420
	1988	57	13	70	8	1.2	9.2	1,100	140	1,240
November	1985	90	180	270	23	19	41	2,683	3,260	5,943
	1986	24	64	88	2	6.2	8.2	6,334	840	7,174
	1987	197	41	238	71	4.2	75.2	54,000	640	54,640
	1988	170	78	248	28	7.8	35.8	4,830	1,200	6,030
December	1985	0	28	28	0	2.9	2.9	0	510	510
	1986	25	122	147	1	15	16	39,624	2,420	42,044
	1987	10	15	25	.9	1.4	2.3	86	180	266
	1988	0	27	27	0	2.5	2.5	0	320	320
January	1986	0	94	94	0	9.6	9.6	16,500	1,620	18,120
	1987	0	74	74	0	7.7	7.7	0	1,260	1,260
	1988	941	25	966	190	2.6	192.6	6,597	440	7,037
	1989	0	135	135	0	15	15	0	3,560	3,560
February	1986	0	241	241	0	26	26	8,260	5,140	13,400
	1987	0	18	18	0	1.8	1.8	80	260	340
	1988	175	740	915	20	104	124	23,600	46,700	70,300
	1989	17	20	37	17	2.1	19.1	209	300	509
March	1986	35	132	167	2	14	16	235	2,820	3,055
	1987	153	75	228	8	7.9	15.9	25,700	1,300	27,000
	1988	0	249	249	0	33	33	0	12,800	12,800
	1989	0	62	62	0	6.6	6.6	1,686	1,200	2,886
Subtotal		1,942	2,542	4,484	375.3	301.5	676.8	196,848	88,570	285,418

Table 18. Measured and estimated nitrogen, phosphorus, and suspended-sediment loads in stormflow at Bald Eagle Creek for the 1986-89 water years--Continued
[Loads, in pounds; --, not determined]

		Nitrogen			Phosphorus			Suspended sediment		
Month	Year	Measured	Estimated	Total	Measured	Estimated	Total	Measured	Estimated	Total
GROWING SEASON										
April	1986	0	185	185	0	21	21	0	4,940	4,940
	1987	32	26	58	3	2.8	5.8	843	480	1,323
	1988	0	9	9	0	9.1	9.1	0	1,600	1,600
	1989	0	70	70	0	7.6	7.6	0	1,480	1,480
May	1986	0	20	20	0	2.1	2.1	0	300	300
	1987	0	24	24	0	2.5	2.5	0	400	400
	1988	1,334	265	1,599	137	30	167	171,140	7,580	178,720
	1989	265	123	388	33	14	47	75,554	3,600	79,150
June	1986	0	17	17	0	1.7	1.7	0	240	240
	1987	0	30	30	0	2.9	2.9	0	380	380
	1988	0	0	0	0	0	0	0	0	0
	1989	0	62	62	0	6.6	6.6	3,967	1,220	5,187
July	1986	13	16	29	.9	1.5	2.4	236	200	436
	1987	15	31	46	4	3.2	7.2	33,100	400	33,500
	1988	223	21	244	46	2.1	48.1	22,000	320	22,320
	1989	383	78	461	62	8.5	70.5	6,530	1,800	8,330
August	1986	0	24	24	0	2.3	2.3	386	260	646
	1987	32	20	52	3	1.8	4.8	3,230	200	3,430
	1988	61	65	126	14	7	21	2,600	1,320	3,920
	1989	0	39	39	0	4.3	4.3	0	860	860
September	1986	0	0	0	0	0	0	0	0	0
	1987	184	89	273	21	9.1	30.1	88,809	1,420	90,229
	1988	32	0	32	3	0	3	426	0	426
	1989	0	30	30	0	3.2	3.2	780	560	1,340
Subtotal		2,574	1,244	3,818	326.9	143.3	470.2	409,601	29,560	439,161
Prior to nutrient management										
	1986	138	937	1,075	25.9	100.1	126	28,300	19,290	47,590
	1987	513	595	1,108	46.4	63	109.4	203,044	9,600	212,644
Subtotal		651	1,532	2,183	72.3	163.1	235.4	231,344	28,890	260,234
During nutrient management										
	1988	2,973	1,517	4,490	481.9	202.3	684.2	280,449	73,000	353,499
	1989	892	737	1,629	148	79.4	227.4	94,656	16,240	110,896
Subtotal		3,865	2,254	6,119	629.9	281.7	911.6	375,105	89,240	464,345
Grand total		4,516	3,786	8,302	702.2	444.8	1,147	606,449	118,130	724,579

Table 19. Total base flow and stormflow loads for total nitrogen, total phosphorus, and suspended sediment in Bald Eagle Creek for the 1986-89 water years
[Load, in pounds]

Water year	Base flow			Stormflow		
	Nitrogen	Phosphorus	Suspended sediment	Nitrogen	Phosphorus	Suspended sediment
1986	2,744	34.6	2,417	1,075	126	47,590
1987	2,557	35.8	2,134	1,108	109	212,644
Subtotal	5,301	70.4	4,551	2,183	235	260,234
1988	2,470	18.4	1,119	4,480	684	353,499
1989	3,228	28.2	1,702	1,629	228	110,896
Subtotal	5,698	46.6	2,821	6,119	912	464,345
Total	10,999	117	7,372	8,302	1,147	724,579
GRAND TOTAL						
Nitrogen	19,301					
Phosphorus	1,264					
Suspended sediment	731,951					

Ground Water

Ground-water-level and ground-water-quality data for the study area were based primarily on historical data. However, current ground-water-level data and base-flow data support the historical findings.

Availability and occurrence

The availability of ground water is dependent on the capacity, storage characteristics, and transmissivity of the underlying rock structure. Much of the available ground water in the Wissahickon Formation is at shallow depths in the partially weathered bedrock and in a deeper network of joints and fractured cleavage planes (Gary Barton, U.S. Geological Survey, written commun., 1992). Wells drilled into the Wissahickon Formation usually provide sufficient water for domestic purposes. The greatest density of water-bearing zones are within 50-100 ft of the land surface; below 150 ft, the density of water-bearing zones decreases with increasing depth (Dennis Low, U.S. Geological Survey, written commun., 1991).

The topographic position of well sites significantly affect well yields. Yields from wells drilled in valleys are greater than yields from wells drilled on hillslopes or ridgetops. Lloyd and Growitz (1977) report that 1-hr specific capacities of 72 wells in the Wissahickon Formation ranged from 0.03 to 50 (gal/min)/ft; the median was 0.95 (gal/min)/ft. The average yield for a well drilled 400 ft deep is about 45 gal/min with 50 ft of drawdown after pumping 1 hr; after pumping for 24 hrs, the average yield is about 30 gal/min. The maximum yield measured for a well in this formation was 150 gal/min (Lloyd and Growitz, 1977). In a recent study by the USGS delineating wellhead-protection areas in Stewartstown, Pa., approximately 7 mi west of Bald Eagle Creek, specific capacities ranged from 0.001 to 1.4 (gal/min)/ft and yields ranged from 0.03 to 64 gal/min (Gary Barton, U.S. Geological Survey, written commun., 1992).

Recharge

In basins where surface water is largely comprised of base flow, factors influencing the presence of ground water are important to recharge. Ground-water recharge is dependent upon the size and shape of the ground water basin, the annual precipitation, surface runoff, soil infiltration, and evapotranspiration. The size and shape of the ground-water boundary at the site is assumed to be approximated by the surface-water subbasin boundary (fig. 2). Precipitation is the single input to recharge the ground-water system, whereas, ground-water seepage (base flow) to Bald Eagle Creek, seepage to the pond (fig. 2), and evapotranspiration are the three outputs discharged from the ground-water system.

The Wissahickon Formation also is in the East Branch Brandywine Creek Basin above Downington (USGS station number 01480700). This watershed has similar basin characteristics as Bald Eagle Creek. The average annual recharge to the ground water for the period 1974 through 1988 was estimated to be 15.4 in/yr or 32 percent of the annual precipitation (Ron Sloto, U. S. Geological Survey, written commun., 1992). Therefore, ground-water recharge at Bald Eagle Creek is estimated to be 15 in/yr.

Typically, ground water is recharged during March and April (after the spring thaw, but before the growing season) and between October and December (after crops are harvested but before the ground freezes). Ground-water levels usually decline during the growing season from April through September when evapotranspiration permits only small amounts of infiltrated water to recharge the saturated zone. Therefore, seasonal variations in precipitation can be more critical to the recharge of ground water than the annual total precipitation.

The relation between precipitation and base flow measured at Bald Eagle Creek and the ground-water level at observation well YO 180 (fig. 1), located about 20 mi north of the study area, is shown in figure 21. Well YO 180 is part of the USGS ground-water observation network and represents typical ground-water conditions in the region of the study site. The corresponding amplitudes suggests a positive relation between precipitation, base flow, and ground-water levels with a lag time in the order of 1 to 2 months. This relation was determined not to be significant. Ground-water levels and base flow increased rapidly in November 1985, November 1986, May 1988, and May 1989 in response to increased precipitation. Ground-water levels decreased steadily in May, June, and July 1986, May, June, July, and August 1987, and June through September 1988. During the growing season, especially summer months, evapotranspiration increases and precipitation generally decreases. The relation between ground-water levels and base flow suggests the seasonal influences on both are similar. The rise in ground-water levels at well YO 180 and the increase in precipitation over the 5-year study period is shown in figure 21.

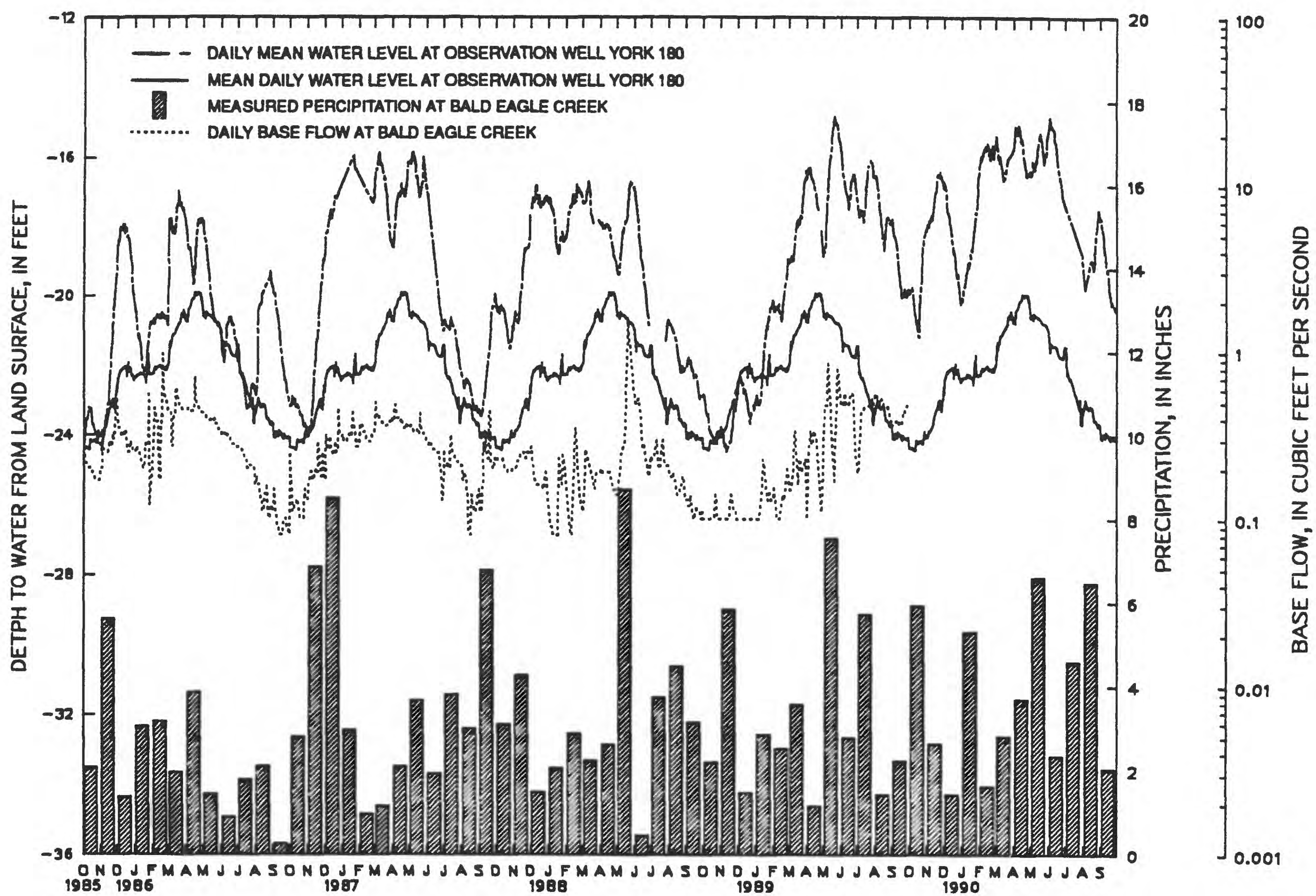

Figure 21. Relation between monthly precipitation, daily ground-water levels, mean daily ground-water levels, and daily base flow.

Quality

The quality of ground water is determined by the precipitation quality, composition of the soil and aquifer, nutrient applications to the soil through which infiltrated water flows, and residence time in the aquifer. Historical data indicate ground water from water-bearing zones in the Wissahickon Formation is generally soft with low concentrations of dissolved solids (Lloyd and Growitz, 1977). Hardness ranged from 17 to 170 mg/L on the basis of measurements from 92 wells sampled between November 1968 and December 1970; the median hardness was 34 mg/L. Field pH ranged from 5.0 to 7.0 on the basis of measurements in 48 wells in the Wissahickon Formation. Specific conductance ranged from 250 to 560 μS/cm in 115 wells; the median specific conductance was 125 μS/cm.

Concentrations of nitrate in the ground water commonly were elevated. Concentrations of nitrate nitrogen as N ranged from 0.5 to 21 mg/L in 34 samples; the median concentration was 6.3 mg/L. The maximum nitrate concentration measured in ground water of the noncarbonate rocks in southern York County was in the Wissahickon Formation (Lloyd and Growitz, 1977).

Water-quality samples collected from a production well in Stewartstown, Pa., had a specific conductance of 137 μS/cm, hardness of 36 mg/L, field pH of 5.9 units, concentration of dissolved nitrite plus nitrate of 5.4 mg/L as N, and iron and lead concentrations of 26 and 10 μg/L, respectively (Durlin and Schaffstall, 1991).

Soils and Soil Nutrients

Soil depths at the site were shallow, often less than 36 in. deep, especially the soil sampling locations at Farm 2 (fig. 2). The animal density also was lower at Bald Eagle Creek than at Brush Run and Little Conestoga Creek. Therefore, the total nutrient content of the soils at the Bald Eagle Creek site was probably lower than in fields at the shale site in Adams County (Brush Run) and the carbonate site of the RCWP Nutrient-Management Subbasin (Little Conestoga Creek) in Lancaster County (sites 2 and 3, fig. 1) simply because of the difference in soil depths and animal density.

Because soil nutrient concentrations were highly variable, no trends were apparent in concentrations of nitrate nitrogen in the soil with respect to season, or as a result of reductions in nutrient applications. Investigators have recognized the difficulty in collecting and interpreting representative soil samples because of varying soil and climatic conditions. Harmsen and Van Schreven (1955) stated reliable interpretations of soil data could be made when dealing with a single soil type, climatic zone, or farming system. However, variations occur from the same field for a number of reasons--different application rates for fertilizers, different subsurface water flow and nutrient transport paths, and different rates of nutrient uptake by plants.

Soils were sampled at Farm 1 on November 20, 1985, and at Farms 1 and 2 on May 20 and October 26, 1987, April 13 and October 15, 1988, April 15 and October 27, 1989, April 10 and November 15, 1990 (figs. 22 and 23), and analyzed for concentrations of nitrate nitrogen and phosphorus by the Pennsylvania State University, College of Agronomy, and reported to the USGS in pounds per acre. Methods of soil collection are described in the characterization report by Fishel and others (1991). The concentrations of nitrate nitrogen reflect the nitrogen immediately available to the plants, but may actually be a small percentage of the total nitrogen in the soil (fig. 22). Stevenson (1982) indicates that nitrogen from ammonia, or nitrogen that may become available from mineralization and nitrification of residual organic nitrogen in the soil, may comprise over 90 percent of the nitrogen in surface layers of most soils. Therefore, the concentrations of nitrate nitrogen measured may only represent one tenth of the nitrogen held in the soil at any particular time.

Concentrations of nitrate and soluble phosphorus were generally lower in the Bald Eagle Creek subbasin than in the Brush Run and Nutrient-Management Subbasins in the Little Conestoga Creek basin. The total amount of nitrate-nitrogen and soluble phosphorus in the Bald Eagle Creek Basin in the top 48 in. of soil ranged from 36 to 135 lb/acre and 0.39 to 2.5 lb/acre, respectively, prior to nutrient management (table 20). Concentrations of nitrate-nitrogen and soluble phosphorus in soil samples collected during the nutrient-management period ranged from 21 to 291 lb/acre and 0.73 to 1.7 lb/acre, respectively, in the top 48 in. of soil.

Table 20. Results of soil sampling at the Bald Eagle Creek Basin, Nutrient-Management Subbasin, and Brush Run study areas

[NM, nutrient management; lb/acre, pounds per acre; --, data not available]

		Location		
		Bald Eagle Creek	Nutrient-Management Subbasin	Brush Run Creek
Number of samples		34	40	73
Nitrate-nitrogen in soil range (lb/acre)	prior to NM	36. -135	46.-380	21 -452
	during NM	21. -291	--	17 -386
Percent greater than 50 lb/acre	entire study	74	95	77
Percent greater than 100 lb/acre	entire study	29	50	46
Soluble phosphorus in soil range in lb/acre	prior to NM	.39- 2.5	1.4- 37	.98- 93
	during NM	.73- 1.7	--	.29- 65

Results shown in table 20 can be explained because of the thin soils, the lower manure application rates, and the difference in the composition of the manure used at the Bald Eagle Creek site from the other sites. Only dairy manure that contains less nitrogen and phosphorus than poultry or swine manure (Pennsylvania State University, Agronomy Guide, 1987-88) was applied at the Bald Eagle Creek site. Also, the animal density at the Bald Eagle Creek site was less than the animal density at the Nutrient-Management Subbasin and Brush Run site and less nutrients were applied at the Bald Eagle Creek site than at the Nutrient-Management Subbasin where poultry, hog, and dairy manure were applied. For example, the phosphorus content (P_2O_5) of the dairy manure at Farm 1 was 4.9 lb/ton as compared to 54 lb/ton of phosphorus for turkey manure applied at Farm A in the Nutrient-Management Subbasin (Fishel and others, 1991).

Soil nutrients in the Bald Eagle Creek Basin were highly variable between fields and between seasons (figs. 22 and 23). However, nitrate concentrations were generally more uniform throughout the soil column in the Bald Eagle Creek subbasin than in the Brush Run and Nutrient-Management Subbasins. The data from the Bald Eagle Creek subbasin suggest that nitrate is highly mobile and infiltrated readily through the soil, because at times the highest concentrations were at depths between 24 to 48 in. below the surface (fig. 22). Similar observations were made in the noncarbonate shaley soils at Brush Run and the carbonate soils at the Nutrient-Management Subbasin (Fishel and others, 1992). In contrast to the nitrate concentrations, concentrations of phosphorus were greatest in the top 8 in. of the soil where fine soil particles absorb phosphorus (Finkl and Simonson, 1979, p. 374). Elevated concentrations of phosphorus are more likely to be present in the soil in spring before planting rather than the fall. Studies have shown that 69 to 80 percent of the total phosphorus in soil may be leached from dead or dormant vegetation (Ed Koerkle, U.S. Geo-logical Survey, written commun., 1992).

Soil monitoring studies in Nebraska, Iowa, and Wisconsin (Halberg and others, 1984; Rehm and others, 1983, p. 8-10) suggest that less than 100 lb/acre of nitrate nitrogen should remain in the top 48 in. of soil to insure that leachate to the ground water will not exceed 20 mg/L nitrate nitrogen. However, Baker (the Pennsylvania State University, College of Agriculture, Department of Agronomy, written commun., 1985) states that a more desirable environmental level for nitrate-nitrogen may be 50 lb/acre in the upper 48 in. of soil. Table 19 also indicates the percentage of soil samples exceeding 50 lb/acre and 100 lb/acre at Bald Eagle Creek is less than that at the Brush Run site and the Nutrient-Management Subbasin. Soil data in table 20 indicate that all three sites contain more than 50 lb/acre of soluble nitrate-nitrogen, but less than half of the soil samples contain more than 100 lb/acre.

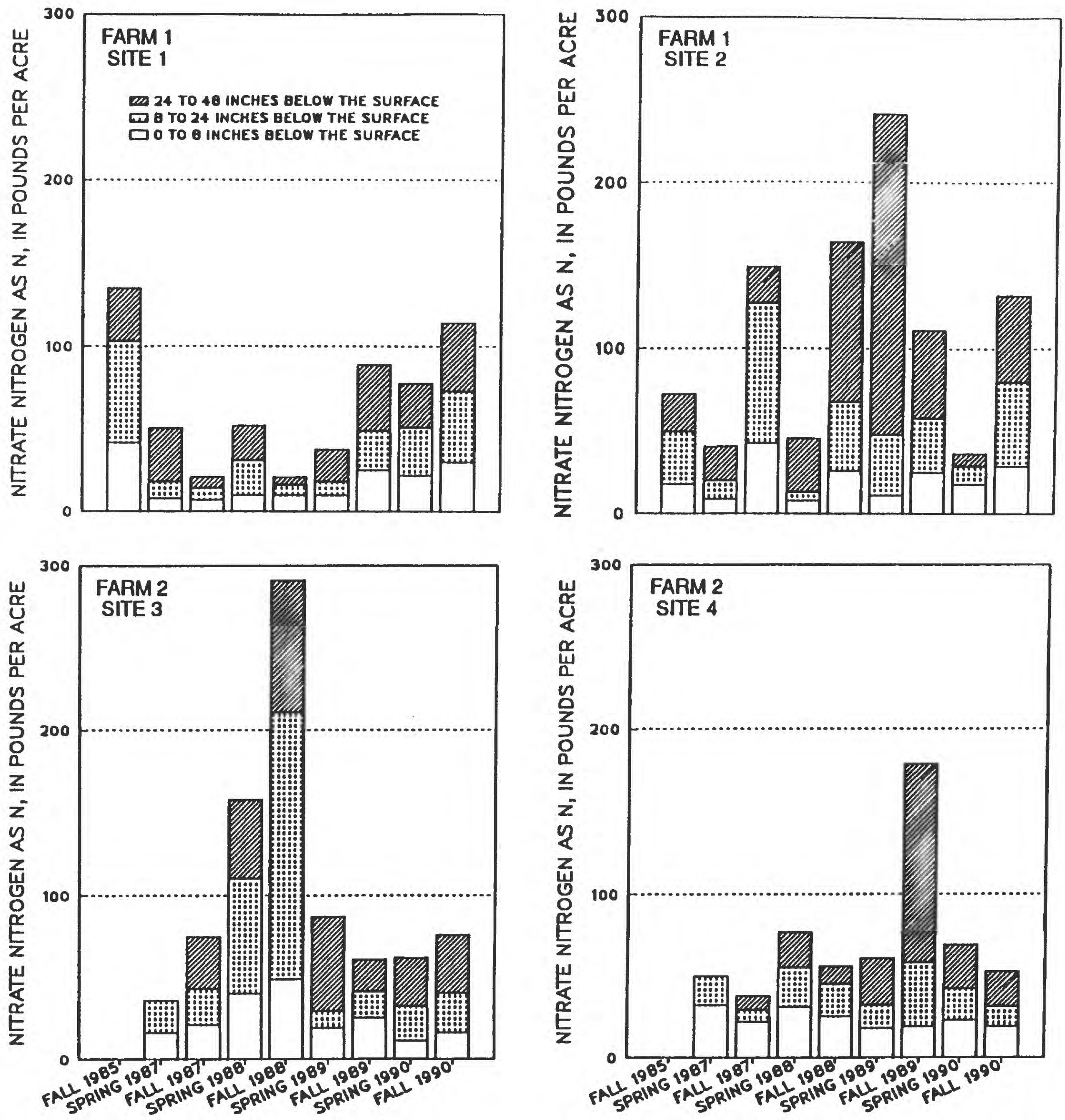

Figure 22. Soluble nitrate-nitrogen yields in selected soil increments on four fields in the Bald Eagle Creek Basin.

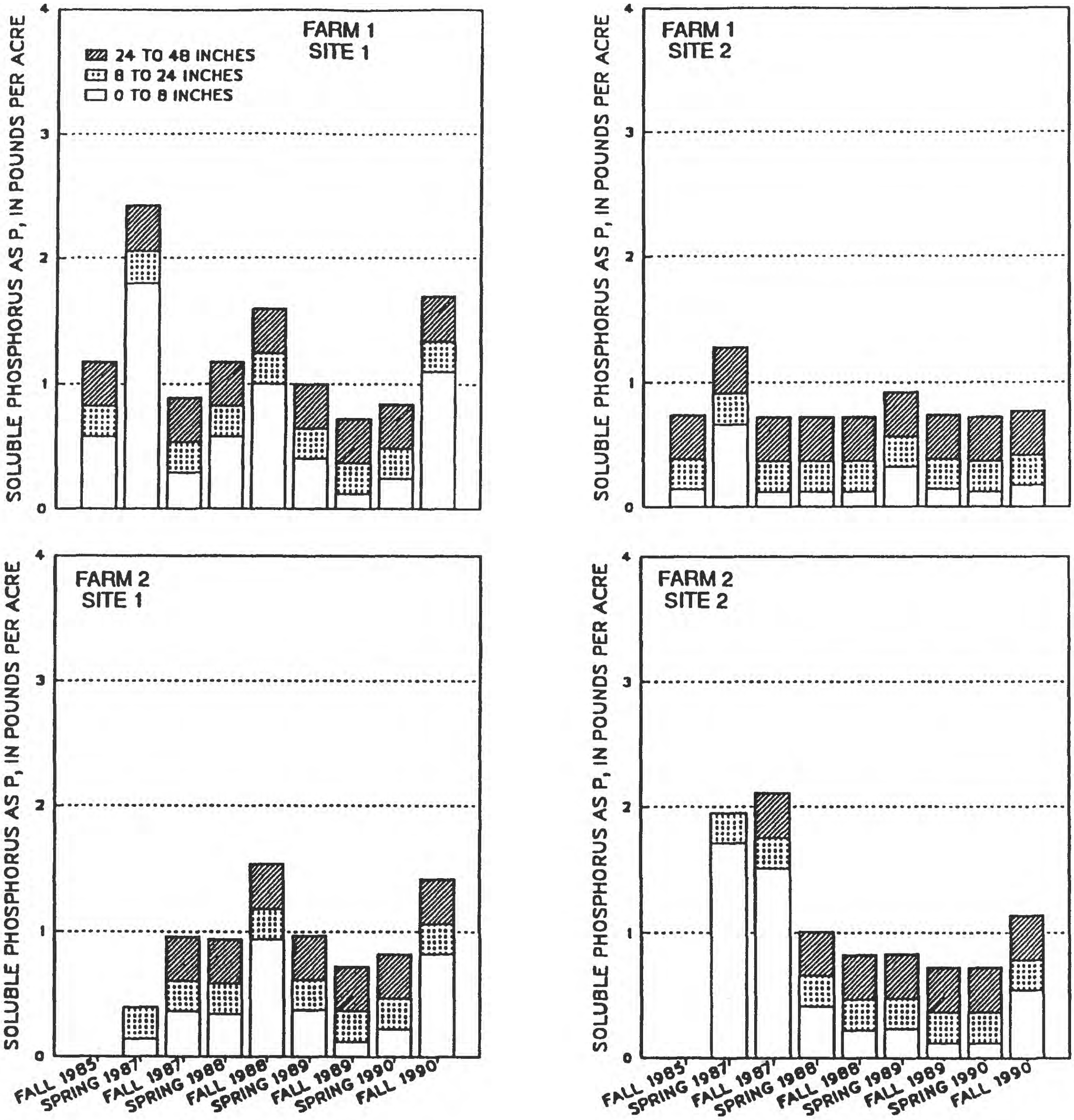

Figure 23. Soluble phosphorus yields in selected soil increments on four fields in the Bald Eagle Creek Basin.

EFFECTS OF CHANGES IN NUTRIENT APPLICATIONS, LAND USE, AND RANDOM EVENTS ON SURFACE-WATER QUALITY

Changes in Nutrient Applications

Farmers at the Bald Eagle Creek site, like those at the Small Watershed site in Lancaster County being studied as part of the RCWP, began reducing nutrient applications prior to the development of nutrient-management plans for their farms. This action taken voluntarily by the farmers prior to the implementation of nutrient management added an immeasurable variability in the premanagement data. It also created levels in both nutrient applications and concentrations and discharges of nutrients and suspended sediment in surface water that were probably different than previous levels.

Since nutrient-management plans were not implemented at the Bald Eagle Creek subbasin, the objectives of the study were modified when the animal population decreased just as the nutrient-management period was to begin. Data collection continued to monitor the effects of a reduction in animal units and a corresponding reduction in nutrient applications from animal waste. This was a rare opportunity to monitor these effects because few farmers are willing to voluntarily reduce their animal populations. Because of the reduction in animal units, corresponding feed requirements were reduced; thus, cropping patterns and nutrient applications changed. All of these changes were made without technical assistance from the nutrient-management specialist. Also, at the same time, one landowner permitted several head of cattle to graze near and immediately upstream from the sampling and gaging cross-section.

The reduction in animals units from 0.85 AU prior to nutrient management to 0.43 AU during nutrient management resulted in a 40 percent reduction in manure nitrogen and a 15 percent reduction in manure phosphorus applications to cropland and pasture. Additionally, commercial applications of nitrogen and phosphorus were reduced 70 percent and 64 percent, respectively, during the first 2 years of nutrient management when 41 percent less acreage was planted in corn. In summary, nitrogen and phosphorus applications were reduced by 19,900 lb (83 lb/acre) and 5,000 lb (21 lb/acre), respectively, during the nutrient-management period (table 5).

The increased use of manure-storage facilities also may effect the rate and timing of nutrient applications. If open storage facilities gain wider acceptance in the study area, nutrients can be conserved and applied when crops can readily utilize them. Recent studies by Langland (1992) and van Breeman and others (1982) indicate that nitrogen concentrations in precipitation, especially ammonia, may be significant near manure storage facilities.

Although applications of manure and commercial fertilizers were reduced, a significant increasing trend was detected in concentrations and loads of total nitrogen and dissolved nitrite plus nitrate in base flow. Concentrations and loads of total nitrogen and dissolved nitrite plus nitrate also increased in stormflow. However, significant trends were not detected in concentrations and discharges in total and dissolved ammonia, ammonia plus organic nitrogen, total and dissolved phosphorus, and orthophosphorus.

Without the determination of true long-term levels in nutrient applications, the evaluation of cause and effects between changes in nutrient applications and detected changes in water quality by use of statistical methods became difficult. Fishel and others (1991) used the seasonal rank-sum test to establish target goals to show what reductions in concentrations and discharges of nutrients and suspended sediment in base flow would result in statistically significant changes in water quality. These estimates were made by use of measured variation from the premanagement data. Comparisons were made of the estimated and actual measured changes (reductions or increases) in nutrient concentrations and discharges by use of water-quality data collected during the nutrient-management period. Because changes were constantly occurring in nutrient applications, cropping patterns, and precipitation, and knowing that the variation of the data during the management phase would probably be different than the variation of the data prior to the management phase, estimates were made for the entire study period of new reductions needed to detect significant changes in base-flow water quality (table 21).

The estimated and actual changes required to have the highest probability of detecting a significant change ($p<.05$) in base-flow water quality are listed in table 21. Because nutrient management was expected to cause reductions in nutrient concentrations and loads in base flow, a one-tailed test was used to estimate reductions. However, measured changes from table 21 show that all nutrient concentrations and loads increased except the concentration of total phosphorus. The measured changes in concentrations of total nitrogen and dissolved nitrite plus nitrate exceeded the estimated concentrations required to detect a significant change, and therefore, were considered to be significant.

Table 21. Estimates of reductions required in mean concentrations and mean loads to achieve statistically significant changes in base-flow water quality in the Bald Eagle Creek Basin

[N, nitrogen; P, phosphorus; concentration, in milligrams per liter; load, in pounds; estimated reduction, in percent]

Constituent	Prior to nutrient management Estimated reductions required			During nutrient management True measured changes			Entire study period New estimated reductions		
	Value	Percent	Change	Value	Percent	Change	Value	Percent	Change
Nitrite plus nitrate, dissolved as N									
Concentration	4.2	-14	-0.59	5.0	+16	+0.80	4.7	-11	-0.52
Load	6.9	-65	-4.5	9.8	+34	+2.9	8.7	-42	-3.6
Nitrogen, total as N									
Concentration	4.9	-12	- .59	5.9	+17	+1.0	5.5	-11	- .60
Load	8.2	-62	-4.3	11.6	+29	+3.4	10.2	-41	-4.2
Phosphorus, total as P									
Concentration	.06	-48	- .03	.05	-17	- .01	.06	-71	- .04
Load	.09	-57	- .05	.11	+18	+ .02	.11	-58	- .06
Phosphorus, dissolved as P									
Concentration	.03	-43	- .01	.04	+25	+ .01	.04	-36	- .01
Load	.06	-90	- .05	.09	+33	+ .03	.08	-62	- .05

Table 22 lists the means, standard deviations, and number of observations of the concentrations and loads of water quality characteristics analyzed during the study period and the growing and nongrowing seasons. Data from table 22 were used as inputs to the Monte-Carlo simulation to obtain the estimates for detecting a significant change in water quality. The nonparametric test Univariate (SAS) determined the data for the entire study period approached normality, therefore log transformations of the data were not required.

The probability of detecting a significant change in base-flow water quality when selected reductions in concentrations and loads are achieved was determined by use of a modified form of the nonparametric Wilcoxon-Mann-Whitney rank-sum test (figs. 24 and 25). The power of the seasonal rank-sum test ($1-\beta$) represents the probability of rejecting the null hypothesis when in fact it is false and the alternative hypothesis is true. The null hypotheses is that there is no difference in the means of the water-quality data collected prior to nutrient management and during nutrient management when the nutrient management data are reduced by the indicated percentages. Therefore, the power of the test gives the probability of detecting a change in base-flow water quality during the nutrient-management phase if the constituents were reduced by the indicated percentage. Greater reductions are required in nutrient loads than in concentrations because of increased variability of load data. In general, greater reductions are required for phosphorus concentrations and loads than nitrogen concentrations and loads for the Bald Eagle Creek site.

Power curves for Bald Eagle Creek are similar to these curves of other small forested and undisturbed watersheds in the Lower Susquehanna River Basin for two reasons. First, the effect of animal density is minimal, relative to the highly intensive farmed basins such as the agricultural Nutrient-Management and Brush Run subbasins where animal densities are greater. Second, at the Bald Eagle Creek site where the soils on steep slopes are underlain by schist, like at the RCWP Forested Subbasin in the Nutrient-Management Subbasin in the Conestoga Creek, where Triassic sandstone ridges are predominate, the geology and topography permit rapid transport of ground water through shallow subsurface soils with little leaching before it is released as base flow. In contrast, at the Nutrient-Management Subbasin, which lies within a carbonate valley, and the Brush Run Subbasin, which lies within non-carbonate terrain, the geology and topography permit longer subsurface transport of ground water through deeper soils, rich in nutrients before being released as base flow.

Several studies have associated specific concentrations of inorganic nitrogen and total phosphorus with particular environmental conditions. For example, 0.3 mg/L of inorganic nitrogen (nitrite, nitrate, and ammonia), and 0.01 mg/L of phosphorus are critical concentrations that, when exceeded, can stimulate excessive growth of algae in streams (McKee and Wolf, 1963; Harms and others, 1974). MacKenthum (1969) indicates that total phosphorus should not exceed 0.1 mg/L; the USEPA (1986) recommends total phosphorus should not exceed 0.05 mg/L if nuisance growths in free-flowing streams are to be prevented. All of the 266 samples collected at the Bald Eagle Creek site exceeded the critical concentration for inorganic nitrogen, 80 percent of the 266 samples exceeded the total phosphorus concentration suggested by MacKenthum (1969), and 86 percent of the 266 samples exceeded the 0.05 mg/L concentration recommended by the USEPA. Because water-quality criteria have not been established for nutrient loadings from nonpoint sources, the effects of reducing nitrogen and phosphorus loads on aquatic environments in stream reaches cannot be evaluated at this time.

Table 22. Water-quality characteristics of base flow at the Bald Eagle Creek site

[N, nitrogen; P, phosphorus; concentration, in milligrams per liter; load, in pounds; standard deviation, in percent except where noted; n, number of samples]

Water-quality characteristic	Management period				Nongrowing season				Growing season			
	Mean	Standard deviation		n	Mean	Standard deviation		n	Mean	Standard deviation		n
		Plus	Minus			Plus	Minus			Plus	Minus	
PRIOR TO NUTRIENT MANAGEMENT												
Nitrite plus nitrate, dissolved as N												
Concentration	4.2	[a]12	[a]12	22	4.6	[a]9	[a]8	10	3.9	[a]8	[a]8	12
Load	6.9	2.9	2.9	22	8.4	2.9	2.9	10	5.6	2.2	2.2	12
Nitrogen, total as N												
Concentration	4.9	[a]12	[a]10	22	5.4	[a]8	[a]7	10	4.6	[a]8	[a]7	12
Load	8.2	3.4	3.4	22	8.4	4.1	4.1	10	8.0	2.8	2.8	12
Phosphorus, total as P												
Concentration	.06	[a]33	[a]33	21	.05	[a]60	[a]40	10	.06	[a]36	[a]26	11
Load	.09	[a]67	[a]44	21	.08	[a]110	[a]50	10	.09	[a]56	[a]33	11
Phosphorus, dissolved as P												
Concentration	.03	[a]67	[a]33	22	.03	[a]64	[a]39	10	.03	[a]43	[a]30	12
Load	.06	.03	.03	22	.07	.04	.04	10	.06	.03	.03	12
ENTIRE STUDY PERIOD												
Nitrite plus nitrate, dissolved as N												
Concentration	4.7	.66	.66	58	4.9	.57	.57	27	4.6	.70	.70	31
Load	8.7	5.1	5.1	58	8.8	5.9	5.9	27	8.6	4.3	4.3	31
Nitrogen, total as N												
Concentration	5.5	.74	.74	58	5.7	.64	.64	27	5.4	.79	.79	31
Load	10.2	5.9	5.9	58	10.4	6.8	6.8	27	10.7	5.0	5.0	31
Phosphorus, total as P												
Concentration	.05	.03	.03	57	.05	.02	.02	27	.06	.03	.03	30
Load	.11	.09	.09	57	.10	.10	.10	27	.11	.08	.08	30
Phosphorus, dissolved as P												
Concentration	.04	.02	.02	58	.04	.02	.02	27	.04	.03	.03	31
Load	.08	.07	.07	58	.08	.07	.07	27	.08	.08	.08	31

[a] Results for these constituents come from log transformed data.

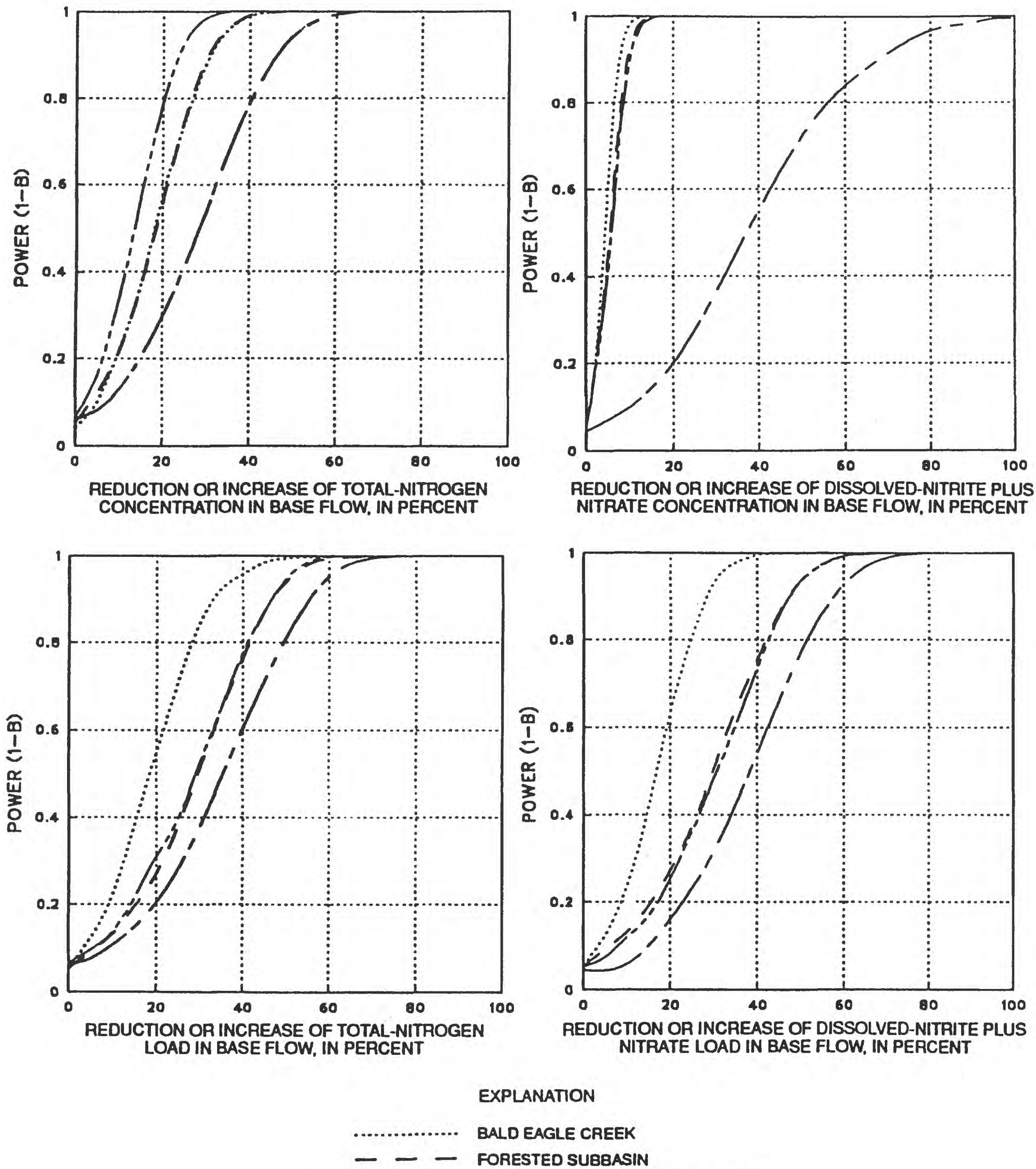

Figure 24. Probability of achieving statistically significant changes in base flow water quality at selected reductions or increases in total nitrogen and dissolved nitrite plus nitrate concentrations.

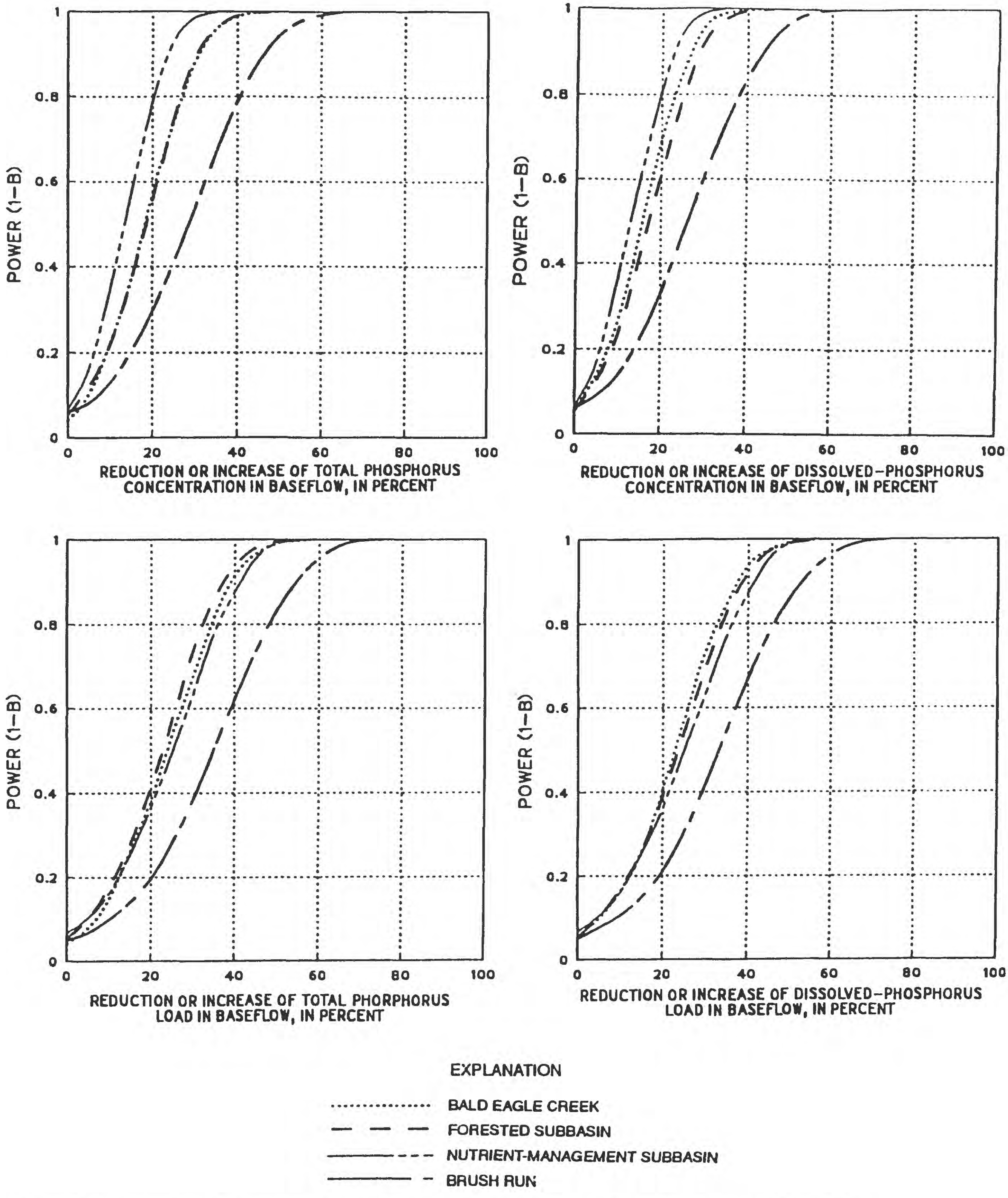

Figure 25. Probability of achieving statistically significant changes in base flow water quality at selected reductions or increases in total- and dissolved-phosphorus concentrations and loads in base flow.

Changes in Land Use

Although agriculture continued to be the dominant land use at the study area throughout the study period, the overall intensity of agriculture was reduced during the nutrient-management phase. In addition to the reduction of animal density from 0.85 to 0.43 AU/acre, the amount of cropland planted in corn changed annually and decreased from an average of 93 acres prior to nutrient management to 61 acres during the 3 years of nutrient management. The reductions in land applications of commercial and manure fertilizers and the changes in cropping patterns may have resulted in a reduction of excess nitrogen available to leach into the ground-water system. This reduction, however, was not enough to produce a statistically significant decrease in base-flow concentrations of total nitrogen or dissolved nitrite plus nitrate.

In each of the 5 years of the project, more nitrogen was applied to the land surface than was estimated to be removed by crops (table 23). Prior to nutrient management, approximately 23,150 lb/yr (205 lb/acre) more nitrogen was applied than was estimated to be removed by crops. During nutrient management, when applications of fertilizers decreased, about 9,030 lb/yr (157 lb/acre) more nitrogen was applied than was estimated to be removed by crops. The estimates of nitrogen removal and addition, which are based on crop type, crop yield, and crop acreage, were obtained from the Penn State Agronomy Guide (1987) and Bob Anderson (Penn State Agricultural Extension Service, written commun., 1991).

The annual differences in nitrogen removal by crops and nitrogen additions from fertilizer applications and legumes are represented by the shaded area (excess nitrogen) in figure 26. The excess nitrogen is the difference between nitrogen applications and nitrogen removal and may represent the annual amount of nitrogen available for transport to the surface-water and ground-water systems.

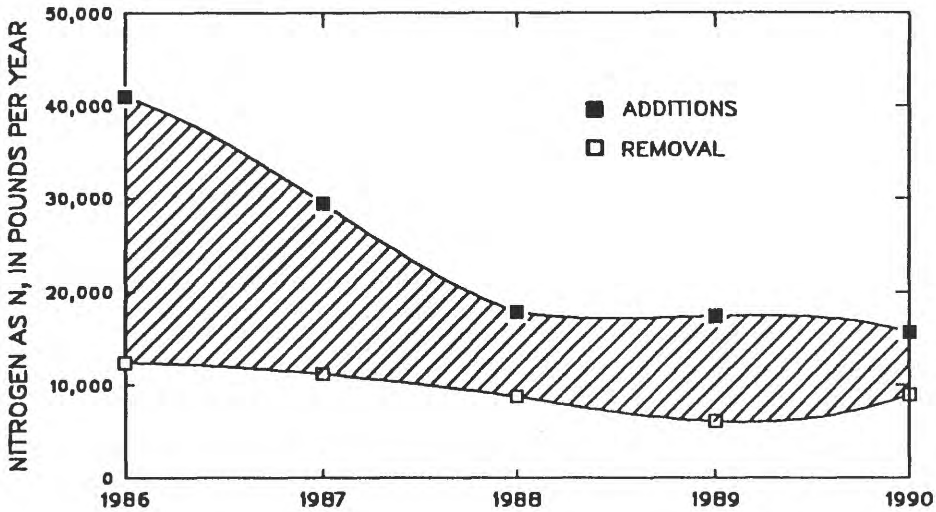

Figure 26. Estimated differences between nitrogen additions from fertilizer applications and legumes, and nitrogen removal by crops for 1986-90 water years at Bald Eagle Creek.

The changes in crop type discussed earlier and the resultant changes in nutrient utilization by the crops increased the transport availability of nitrogen and soluble phosphorus to the stream directly in surface runoff or indirectly to the ground water which later is released to the stream as base flow.

The landowner near the gaging cross-section and sampling site made several land-use changes that probably had an immediate effect on the surface-water quality. On two occasions, modifications were made to the stream channel by straightening and deepening the channel to prevent flooding of pasture land. The farmer also placed fill material soil along the streambank and in the pasture several hundred feet upstream from the gaging pool. The nutrient content of the fill material was unknown. However, because they were exposed soils, the potential for increases in nutrient transport in surface runoff during storms and the leaching of nutrients to ground water was increased.

The landowner at this site also permitted additional cattle to graze in the pasture upstream from the water-quality sampling site during the nutrient-management period. This may have increased the potential for nutrients to be deposited in the stream or transported to the stream in runoff. No management plan was developed for this landowner because his animal population consisted of a few steers and hogs raised for his own consumption and his cropland was located outside the basin.

Table 23. Estimated nitrogen addition from applications of manure and commercial fertilizer and legumes, and estimated nitrogen removal from crops, base flow, and stormflow for the 1986-90 water years at Bald Eagle Creek

[Total N, total nitrogen in pounds; lb/acre, pounds per acre; --, no data]

	1986			1987			1988			1989			1990		
	Acres	lb/acre	Total N	Acres	lb/acre	Total N	Acre	lb/acre	Total N	Acres	lb/acre	Total N	Acres	lb/acre	Total N
Nitrogen applications															
Manure nitrogen			11,590			8,440			4,530			6,440			7,260
Commercial nitrogen			24,950			16,670			8,100			4,220			2,270
Subtotal			36,540			25,110			12,630			10,660			9,530
Nitrogen additions by crop															
Alfalfa	45.5	80	3,640	30.0	80	2,400	38.3	80	3,064	53.4	80	4,272	55.6	80	4,448
Soybeans	18.3	40	732	34.2	40	1,368	54.4	40	2,176	62.3	40	2,492	42.4	40	1,696
Oats/Alfalfa	1.7	40	68	11.7	40	468	--	--	--	--	--	--	--	--	--
Subtotal	65.5		4,440	75.9		4,236	92.7		5,240	115.7		6,764	98.0		6,144
Nitrogen removal by crop															
Barley	12.8	70	896	--	--	--	--	--	--	--	--	--	--	--	--
Corn	94.2	120	11,300	92.6	120	11,110	67.3	120	8,076	41.9	120	5,028	74.8	120	8,976
Potatoes	--	--	--	12.8	67	86	4.0	67	27	--	--	--	--	--	--
Rye	11.7	40	468	--	--	--	--	--	--	2.8	40	112	--	--	--
Wheat	3.3	78	257	--	--	--	8.8	78	686	12.4	78	967	--	--	--
Subtotal	122.0		12,921	105.4		11,196	80.1		8,789	57.1		6,107	74.8		8,976
Excess nitrogen applications			28,062			18,240			9,081			11,317			6,698
Nitrogen removed in streamflow															
Base flow			2,744			2,557			2,470			3,228			--
Storm flow			1,075			1,108			4,490			1,629			--
Subtotal			3,819			3,665			6,960			4,857			--
Excess nitrogen			24,243			14,575			2,121			6,460			--

Other studies have shown that land use within a basin has a direct effect on the water quality within and potentially outside the basin. Agricultural activity, along with basin hydrogeology, is believed to have the greatest effect on nutrient discharges in surface and ground water in the Lower Susquehanna River Basin (Lietman and others, 1983; Lloyd Reed, U.S. Geological Survey, written commun., 1992). A comparison of data collected at five sites in Pennsylvania--the Bald Eagle Creek site, the Conestoga River, Little Conestoga Creek at Churchtown, Little Conestoga Creek at Morgantown, and Young Womans Creek at Renova--support this conclusion. Figure 27 and table 24 compare nitrogen, phosphorus, and suspended-sediment yields in pounds per acre per year as a function of discharge from different basins having different agricultural intensities and hydrogeologic characteristics in the Susquehanna River Basin.

Generally, as agricultural activities become more intensive (increase in acres in agriculture and increase in animal units) in each basin, nutrient yields increase. Three sites, Little Conestoga at Churchtown, Conestoga River at Conestoga, and Little Conestoga near Morgantown, located in the intensively farmed carbonate valleys of Lancaster County, have the highest yields for nitrogen, phosphorus, and sediment compared to the less intensively farmed Bald Eagle Creek site and the 100 percent forested site at Young Womans Creek near Renova. For example, at Young Womans Creek, where agricultural activities are not present, nitrogen yields averaged about 4 (lb/acre)/yr. At Bald Eagle Creek, where agricultural activities are moderate to low in intensity, the nitrogen yield averaged 20 (lb/acre)/yr, and at Little Conestoga at Churchtown, where agriculture activities are intensive, the nitrogen yield averaged about 38 (lb/acre)/yr, on the basis of data for the 1986-89 water years and a normal water discharge ratio of one. A water discharge ratio of one means normal flow, below normal flow is less than one, and above normal flow would be greater than one.

Table 24. Average annual yields for total nitrogen, total phosphorus, and suspended sediment in streamflow from five basins in the Susquehanna River Basin for the 1986-89 water years

[Drainage area, square miles; yields, pounds per acre per year; manure production, tons per acre of agricultural land]

Basin	Drainage area	Major underlying geology	Percent agriculture	Manure production[a]	Average yield		
					Nitrogen	Phosphorus	Sediment
Young Womans Creek near Renova	46.2	shale	0	0	4	0.2	250
Bald Eagle Creek near Fawn Grove	.43	schist	87	9.45	20	1.6	900
Conestoga River near Lancaster	324	carbonate	63	8.36	32	2.5	1,330
Little Conestoga Creek near Morgantown	1.42	carbonate	78	19.0	26	2.5	1,500
Little Conestoga Creek near Churchtown	5.82	carbonate	76	11.8	38	3.7	2,900

[a] Manure production data for Conestoga River at Lancaster and Young Womans Creek near Renova is from Hannawald (1989).

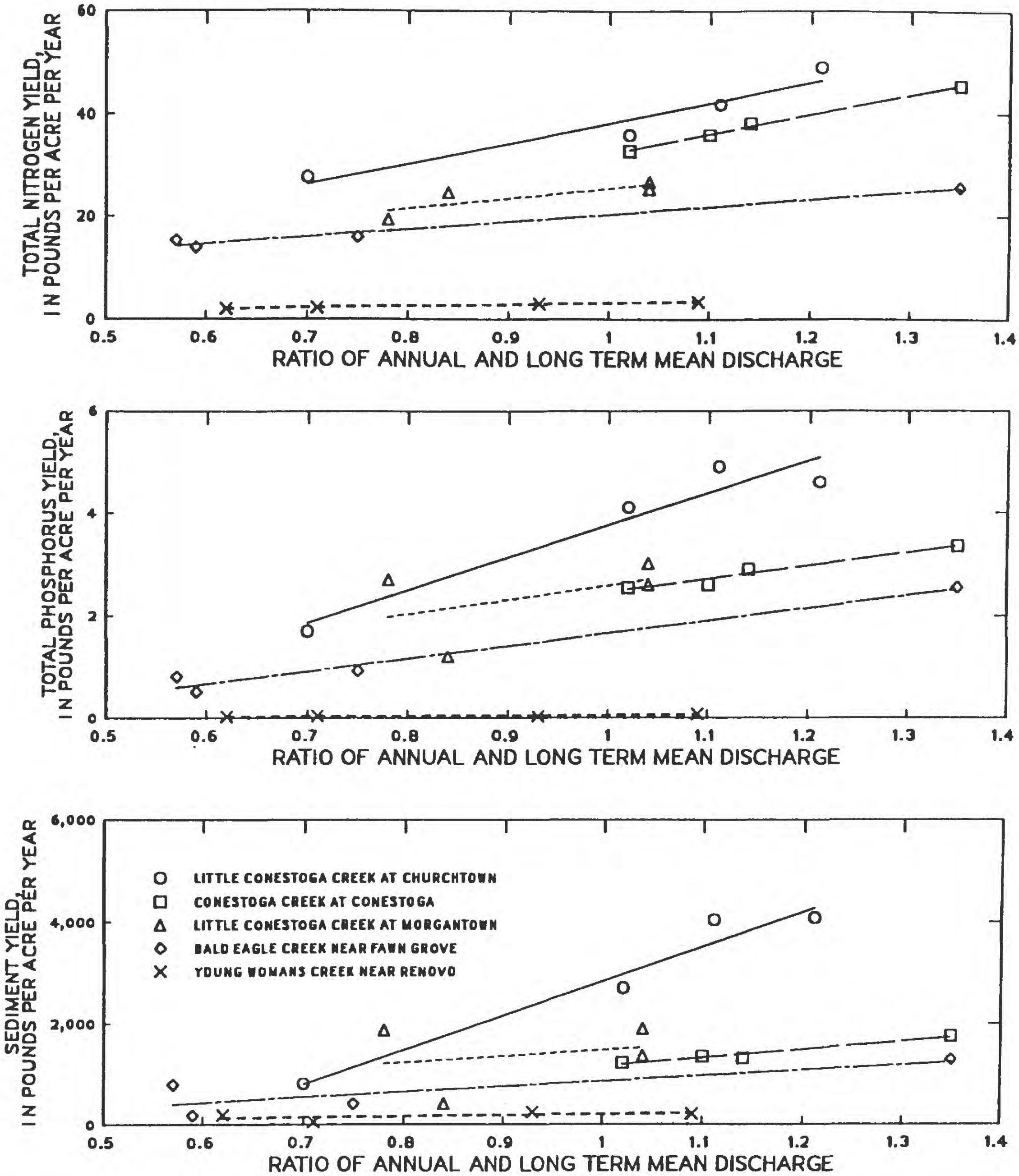

Figure 27. Nutrient yield as a function of annual and long-term discharge at four predominately agricultural basins and a forested basin (Young Womans Creek near Renovo) in the Susquehanna River Basin, 1986-89 water years.

Changes in Random Events

Numerous random events effected both nutrient management and the water quality at the Bald Eagle Creek site during the 5-year study. These random events included large precipitation events, drought conditions, severe wind damage to crops, changes in animal populations because of disease outbreaks and changes in market demands, and other social, economic, and cultural conditions. The effects of large storms or hurricanes on nutrient transport were pointed out by Fishel and others (1992). On May 19, 1988, and May 6, 1989, more than 3.5 in. of precipitation (fig. 7) fell within the Bald Eagle Creek subbasin producing the two largest monthly discharges of nutrients in stormflow (table 18). In contrast, precipitation was 51 percent below normal during the 1986 growing season months April through September when nutrient discharges in stormflow were virtually nonexistent. Events of this nature have substantial effects on water quality by effecting the processes of surface runoff, infiltration, recharge, crop uptake, evapotranspiration, and the timing of most farm operations.

Changes in animal populations or the type of animals raised cause associated changes in manure production and applications. Because the animal density at Bald Eagle Creek decreased from 0.85 to 0.43 AU/acre, applications of nitrogen and phosphorus from manure to the cropland and pasture were reduced 40 and 15 percent, respectively. Thus, animal density and nutrient applications to agricultural land are closely associated.

Other events that had undefinable and immeasurable effects on nutrient management and water quality included farmer cooperation after changes developed in (1) the economic condition of the agricultural community, (2) health of the land owners, and (3) the religious and cultural composition of the community. For example, one landowner within the subbasin sold his farm because of economic reasons. The new owner farmed the land by use of more traditional methods, which included the use of horse-drawn equipment in place of modern machinery and applied only manure fertilizers. A second farmer sold his dairy herd because of personal health conditions. All the farmers were hesitant to sign government contracts to implement conservation practices.

SUGGESTIONS FOR FURTHER STUDY

Although nitrogen, phosphorus, and suspended-sediment concentrations and loads did not decrease significantly during the 5-year study at Bald Eagle Creek, nutrient reductions totaling 30,920 lb of nitrogen and 7,170 lb of phosphorus were accomplished. Valuable information was gained about the water quality of surface-water hydrologic processes occurring within a small noncarbonate basin in southern York County, Pa.

In any future studies relating water quality to nutrient management, the study should be well designed and planned before sampling begins. A longer sampling period (>5 years) may be necessary to assure sampling over a full range of hydrologic conditions and allow water quality to reflect agricultural-activity changes. Extremely wet or dry periods make accurate interpretation of water-quality data difficult because nutrient-transport processes are controlled by precipitation. It is also important that water-quality studies fully incorporate all interactions of surface-water and ground-water. Only one specific nutrient-management practice should be tested within a watershed during the study. Problems arise with multiple practices occurring simultaneously, because relating the contribution of an individual practice to changes in water quality becomes difficult, if not impossible. Finally, future studies need to consider soil-nutrient interactions and transformations of nitrogen with changes in water quality.

Reliable land-use data are critical when trying to relate changes in nutrient management to changes in water quality. Therefore, a cooperative environment must exist between all federal, state, and local agencies, and the farmers. All concerns from project implications should be discussed with the farmers as the need arises. Farmers are more likely to participate in the project if they understand the goals, problems, and results of similar studies.

SUMMARY

Hydrologic and land-use data were collected at the Bald Eagle Creek watershed in York County, Pa., from October 1985 through September 1990 in cooperation with the SRBC and the PaDER Bureau of Land and Water Conservation, as part of the USEPA's Chesapeake Bay Program. This report documents and evaluates changes in water quality for a 5-year period from October 1985 through September 1990 during implementation of agricultural-management practices in the watershed.

Three small farms in the subbasin have a total acreage of about 275 acres. About 87 percent of the land is cropland and pasture. Prior to nutrient management, 33 percent of the cropland was used to produce corn, whereas during nutrient management, an average of 22 percent of the cropland was used to produce corn. Dairy farms at the site generally rotate crops on a 2-year corn and 3-year alfalfa sequence.

The animal population consists almost exclusively of dairy cattle. Several steer and hogs were raised near the water-quality monitoring gage during the final 2 years of the study. A sudden and unplanned decrease in the animal population occurred immediately after the onset of nutrient management in 1987, when one of the farmers sold his dairy herd. Later, a second farmer sold his farm and the new owner reduced his dairy herd. Thus, the animal density decreased from 0.85 AU/acre prior to nutrient management to 0.43 AU/acre during nutrient management.

The total amount of nitrogen and phosphorus applied to cropland and pasture decreased 62 and 61 percent, respectively, during the first 2 years of nutrient management. Applications of nitrogen and phosphorus applied were made primarily between March and June and were predominately commercial fertilizers. About 82,640 lb of nitrogen and 20,290 lb of phosphorus were applied to the cropland and pastures prior to nutrient management, and 51,720 lb of nitrogen and 13,120 lb of phosphorus were applied to cropland and pastures during the 3 years of nutrient management. Prior to nutrient management, 50 percent of the nitrogen and 62 percent of the phosphorus applied were from commercial fertilizer; during nutrient management, 28 percent of the nitrogen and 50 percent of the phosphorus applied were from commercial fertilizer. The reductions in the amounts of nitrogen and phosphorus applications resulted from the reductions in animal units and requirements for crops because of the rotation from corn to legumes.

Precipitation was 2 percent less than normal during the 5-year study. Prior to nutrient management (October 1985-September 1987), precipitation was 18 percent less than normal. During nutrient management (October 1987-September 1990), precipitation was 8 percent above normal. Annual precipitation ranged from 37 percent less than normal in the 1986 water year to 19 percent greater than normal during the 1989 water year. Extreme variations in seasonal precipitation were measured during the study. Precipitation during the growing seasons (April through September) ranged from 57 percent less than normal in 1986 to 37 percent greater than normal in 1989. Precipitation during the nongrowing seasons (October through March) ranged from 18 percent less than normal in 1988 to 25 percent greater than normal in 1990.

Streamflow was about 35 percent less than normal prior to nutrient management and 3 percent less than normal during the first 2 years of nutrient management. Annual mean streamflows were 0.33, 0.32, 0.58, and 0.42 ft^3/s for the 1986-89 water years, respectively. Prior to and during nutrient management, the base flow percentage of the total stream discharge was 84 and 54 percent, respectively. Fifty-seven percent of the total measured stormflow for the 4-year period (1986-89 water years) was discharged in the 1988 water year. About 24 percent of the total measured stormflow was discharged in May 1988 and May 1989. About 31 percent of the measured precipitation during the first 4 years of the study was discharged as surface water; the remaining 69 percent was removed as evapotranspiration or remained in ground-water storage.

Median concentrations of total nitrogen and dissolved nitrite plus nitrate in base flow increased significantly from 4.7 and 4.0 mg/L, respectively, in the 1986 water year, to 6.3 and 5.4 mg/L, respectively, in the 1990 water year. Concentrations and discharges of dissolved nitrite plus nitrate in base flow were greatest in February during the nongrowing season when base flow was high following prolonged periods of precipitation. Prior to nutrient management, about 83 percent of the approximate 5,300 lb of total nitrogen discharged in base flow was dissolved nitrite plus nitrate, whereas, 86 percent of the approximate 5,700 lb of total nitrogen discharged during nutrient management was dissolved nitrite plus nitrate. About 2,180 lb of total nitrogen were discharged in stormflow prior to nutrient management; about 6,120 lb of total nitrogen were discharged in stormflow during nutrient management. Eighty-four percent of the stormflow was sampled during the first 4 years of the study. No significant change was detected in concentrations or discharges of total and dissolved ammonia, ammonia plus organic nitrogen, phosphorus, or suspended sediment between the prior to and during nutrient-management periods, or between growing and nongrowing seasons.

Concentrations of total phosphorus in base flow, unlike concentrations of total nitrogen and dissolved nitrite plus nitrate, did not exhibit a seasonal trend. However, loads of phosphorus were more closely associated with base flow than were the concentrations of phosphorus. About 117 lb of total phosphorus were discharged in base flow during the first 4 years of the study; 68 percent of the measured phosphorus was dissolved and 50 percent was orthophosphorus. About 79 percent of the 1,150 lb of total phosphorus load discharged in stormflow was measured in the first 2 years of the nutrient-management period.

Monthly suspended-sediment concentrations and loads in streamflow were greatest in the growing season months of April and May, when the majority of the plowing was done. About 4,550 lb of sediment were discharged in base flow prior to nutrient management, and about 2,860 lb of sediment were discharged in base flow during nutrient management. About 64 percent of the 724,575 lb of suspended-sediment load was discharged in stormflow during the growing seasons.

Concentrations of nutrients in the soil were highly variable. No trends were detected in the concentrations of nitrate nitrogen in the soil with respect to season or as a result of reduced nutrient applications. Because some soils were less than 36 in. deep in the Bald Eagle Creek subbasin, the total nutrient content of soils at Bald Eagle Creek is inherently lower than the nutrient content of soils in other intensively farmed areas being studied at the Brush Run subbasin in Adams County and the Conestoga headwaters in Lancaster County. Concentrations of nitrate nitrogen in the Bald Eagle Creek Basin were generally uniform throughout the soil column, suggesting that nitrate is highly mobile, whereas, phosphorus concentrations consistently were greater in the top 8 in. of the soil. The amount of nitrate-nitrogen in the top 4 ft of soil at four field sites ranged from 36 to 135 lb/acre prior to nutrient management and from 21 to 291 lb/acre during nutrient management. The amount of available phosphorus in the top 4 ft of soil ranged from 0.39 to 2.5 lb/acre prior to nutrient management and 0.73 to 1.7 lb/acre during nutrient management.

In conclusion, a 7 percent increase in precipitation, a 34 percent reduction in cropland devoted to corn, and a 37 percent increase in cropland devoted to legumes coincided with a significant increase in base flow concentrations and discharges of total nitrogen and dissolved nitrite plus nitrate during nutrient management. Furthermore, a 49 percent reduction in animal units combined with a 77 and 65 percent reduction in commercial applications of nitrogen and phosphorus, respectively, did not result in a favorable detectable change in surface-water quality in the 3-year nutrient-management monitoring period.

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