science for a changing world

QUALITY OF WATER IN TRIBUTARIES TO THE UPPER DELAWARE RIVER, NEW JERSEY, WATER YEARS 1985-2001

- *Measurements of nine chemical constituents and properties indicate that median concentrations of nitrate plus nitrite and total phosphorus and levels of fecal coliform bacteria were lower, and median concentrations of dissolved oxygen were higher, in samples from streams in the Upper Delaware River watershed than in samples from randomly selected streams across New Jersey.*

- *Concentrations of nutrients and dissolved and suspended solids, levels of fecal coliform bacteria, and water temperatures were lowest, and concentrations of dissolved oxygen were highest at sites on Dunnfield Creek, Flat Brook, and Vancampens Brook.*

- *Concentrations of nutrients and dissolved and suspended solids, fecal coliform bacteria levels, pH, and water temperatures generally were highest at sites on the Musconetcong River, Pohatcong Creek, the Pequest River, and the Paulins Kill.*

- *Fecal coliform bacteria, total phosphorus concentration, and water temperature are the water-quality measures that most frequently failed to meet water-quality reference levels.*

- *Concentrations of most chemical constituents studied and levels of fecal coliform bacteria were lowest, and concentrations of dissolved oxygen were highest, in streams whose watersheds contain the most forested or most undeveloped land.*

- *No significant trend over time was found for most of the constituents and properties at most of the 10 sites for which a trend test was conducted; however, concentrations of total phosphorus and un-ionized ammonia decreased at 5 or more of these sites. Water temperature and pH decreased, but concentrations of nitrate plus nitrite, dissolved oxygen, and dissolved-solids increased, at fewer than half of these sites.*

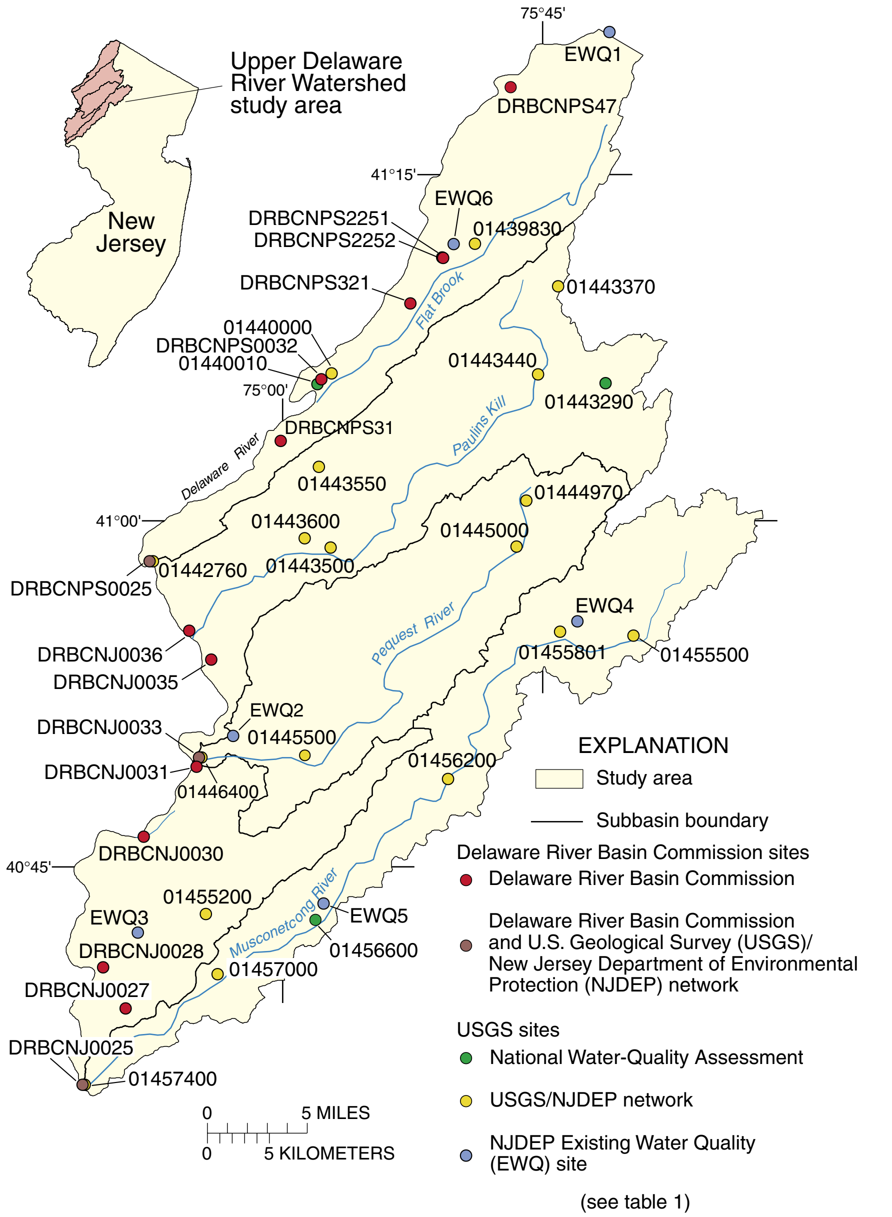

Figure 1. Location of water-quality sampling sites in the Upper Delaware River Basin study area, New Jersey.

The U.S. Geological Survey (USGS), in cooperation with the New Jersey Department of Environmental Protection (NJDEP) and North Jersey Resource Conservation and Development Council, evaluated the quality of surface water in Watershed Management Area 1 (WMA1), a 746-mi^2 (square miles) area in northwestern New Jersey that covers the Upper Delaware River watershed (fig. 1). Study results can be used for watershed-management planning and as background data for a planned preliminary assessment of the nonpoint- and point-source loads to streams in the study area. This Fact Sheet summarizes data on the quality of water in the tributaries to the Upper Delaware River in the study area with respect to instream reference levels, trends at sampling sites, variability with season and flow condition, relation to land use in the drainage areas upstream from the sites, comparison with data from statewide sampling networks, and changes in water quality along stream reaches.

Description of Study Area

The Upper Delaware River study area (fig. 1) consists of approximately 744 mi^2 in parts of Hunterdon, Morris, Sussex, and Warren Counties in northwestern New Jersey and an additional 2 mi^2 of the Clove Brook subwatershed in New York State. The study area contains 14 tributaries whose drainage areas cover more than 2 mi^2 that drain to the Delaware River in WMA1 from the Musconetcong River north to the New York State border. The largest of these tributaries are the Paulins Kill, Pequest River, and Musconetcong River.

The Upper Delaware River drains parts of two physiographic provinces (fig. 2). The New England Province covers the southeastern one-third of the study area. This area is underlain predominantly by granite, gneiss, and small amounts of marble, all of which are resistant to erosion. Limestone underlies the valley areas. The Valley and Ridge Province covers approximately the northwestern two-thirds of the study area. The area is underlain by faulted and folded sedimentary layers of sandstone, shale, and limestone. Alternating belts of erosion-resistant sandstone and easily eroded shale and limestone create the long, parallel, northeast-southwest-trending ridges and valleys that are characteristic of the province (N.J. Department of Environmental Protection, 1992).

Table 1. Surface-water-quality sites in the U.S. Geological Survey (USGS)/New Jersey Department of Environmental Protection (NJDEP), USGS National Water Quality Assessment program, and Delaware River Basin Commission (DRBC) networks sampled during 1984-2000, and NJDEP Existing Water Quality (EWQ) sites sampled in 2001, Upper Delaware River Basin, New Jersey
[Sites with eight-digit numbers are USGS or USGS/NJDEP sites; site numbers preceded by “DRBC” and “EWQ” are DRBC and EWQ sites, respectively]

Site number (see figure 1)	Site name
01439830, EWQ7	BIG FLAT BROOK AT TUTTLES CORNER, N.J.
01440000	FLAT BROOK NEAR FLATBROOKVILLE, N.J.
01440010	FLAT BROOK AT FLATBROOKVILLE, N.J.
01442760, DRBCNJ0038	DUNNFIELD CREEK AT DUNNFIELD, N.J.
01443290	PAULINS KILL UPSTREAM FROM NJ ROUTE 15 AT LAFAYETTE, N.J.
01443370, EWQ8	DRY BROOK AT COUNTY ROUTE 519 NEAR BRANCHVILLE, N.J.
01443440, EWQ9	PAULINS KILL AT BALESVILLE, N.J.
01443500	PAULINS KILL AT BLAIRSTOWN, N.J.
01443550	JACKSONBURG CREEK NEAR MILLBROOK, N.J.
01443600	JACKSONBURG CREEK NEAR BLAIRSTOWN, N.J.
01444970	PEQUEST RIVER AT ROUTE 206 BELOW SPRINGDALE, N.J.
01445000, EWQ10	PEQUEST RIVER AT HUNTSVILLE, N.J.
01445500, EWQ11	PEQUEST RIVER AT PEQUEST, N.J.
01446400, DRBCNJ0033	PEQUEST RIVER AT BELVIDERE, N.J.
01455200, EWQ14	POHATCONG CREEK AT NEW VILLAGE, N.J.
01455500	MUSCONETCONG RIVER AT OUTLET OF LAKE HOPATCONG, N.J.
01455801	MUSCONETCONG RIVER AT LOCKWOOD, N.J.
01456200, EWQ15	MUSCONETCONG RIVER AT BEATTYSTOWN, N.J.
01456600	MUSCONETCONG RIVER AT HAMPTON, N.J
01457000	MUSCONETCONG RIVER NEAR BLOOMSBURY, N.J.
01457400, DRBCNJ0025	MUSCONETCONG RIVER AT RIEGELSVILLE, N.J.
DRBCNPS0047	SHIMERS BROOK AT ROUTE 521 AT MONTAGUE, N.J.
DRBCNPS2251	LITTLE FLAT BROOK AT PETERS VALLEY, N.J.
DRBCNPS2252	BIG FLAT BROOK AT PETERS VALLEY, N.J.
DRBCNPS0321	FLAT BROOK AT WALPACK CENTER, N.J.
DRBCNPS0032	FLAT BROOK AT OLD MINE ROAD AT FLATBROOKVILLE, N.J.
DRBCNPS0031	VANCAMPENS BROOK AT OLD MINE ROAD NEAR MILLBROOK, N.J.
DRBCNJ0036	PAULINS KILL AT ROUTE 46 BRIDGE AT COLUMBIA, N.J.
DRBCNJ0035	DELAWANNA CREEK AT ROUTE 46 AT KNOWLTON TOWNSHIP, N.J.
DRBCNJ0031	POPHANDUSING BROOK AT SPRING STREET AT BELVIDERE, N.J.
DRBCNJ0030, EWQ12	BUCKHORN CREEK AT HUTCHINSON, N.J.
DRBCNJ0028	LOPATCONG CREEK AT MAIN STREET AT PHILLIPSBURG, N.J.
DRBCNJ0027, EWQ13	POHATCONG CREEK AT ROUTE 519 AT POHATCONG TOWNSHIP, N.J.
EWQ1	CLOVE BROOK AT DUTTONVILLE, N.J.
EWQ2	BEAVER BROOK AT SAREPTA, N.J.
EWQ3	LOPATCONG CREEK AT PORT WARREN, N.J.
EWQ4	LUBBERS RUN AT LOCKWOOD, N.J.
EWQ5	MUSCONETCONG RIVER AT NEW HAMPTON, N.J.
EWQ6	LITTLE FLAT BROOK AT SANDYSTON TOWNSHIP, N.J.

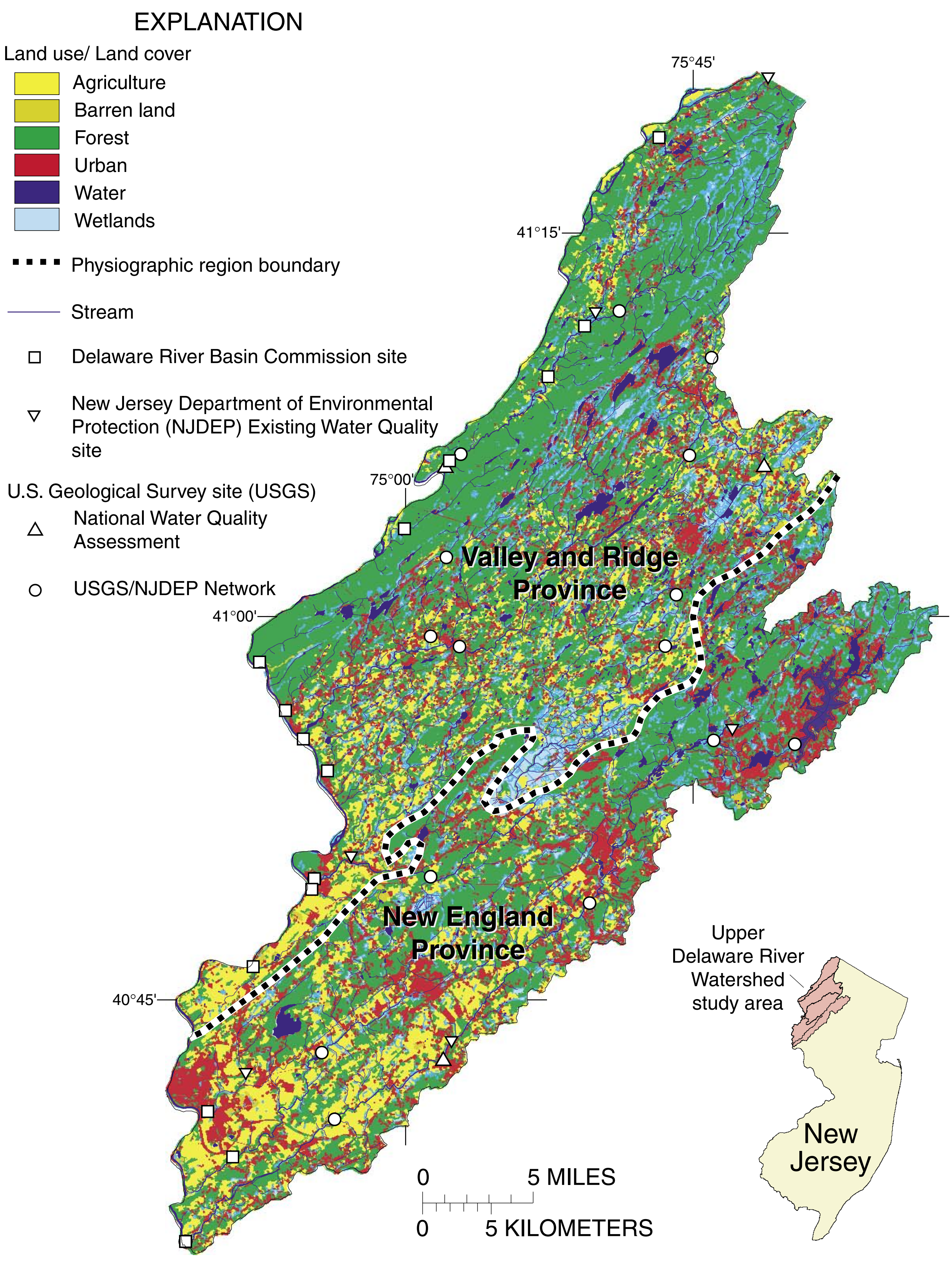

Figure 2. 1995/97 land use and physiographic provinces in the Upper Delaware River Basin study area, New Jersey.

Sixty-seven percent of the land in WMA1 is undeveloped (N.J. Department of Environmental Protection, 2000). Forested areas account for 53.3 percent; reservoirs, lakes, and ponds, 10.3 percent; wetlands, 3.0 percent; and barren areas, 0.7 percent. Nearly 33 percent of the study area is developed; 19.0 percent is used for agricultural purposes; and 13.6 percent is urban land used for residential, commercial, and industrial purposes. The Dunnfield Creek, Vancampens Brook, Flat Brook, and Shimers Brook watersheds in the northwestern part of the study area are the least developed (84.6-99.9 percent undeveloped land) (fig. 1).

The largest areas of urban land use are found in the vicinity of Lake Hopatcong and Hackettstown in the upper portions of the Musconetcong River watershed, near Washington in the headwaters of the Pohatcong Creek watershed, near Newton Borough in the Paulins Kill watershed, and in the Phillipsburg area in the downstream part of the Lopatcong Creek watershed. Agricultural land use is most prevalent (30-46 percent of the total land area) in the Pophandusing Brook, Delawanna Creek, Lopatcong Creek, Pohatcong Creek, and Buckhorn Creek subwatersheds.

Thirty-nine water-quality sites, (table 1) including 18 USGS/NJDEP cooperative network sites, 15 Delaware River Basin Commission (DRBC) sites sampled during 1985-2001, 3 USGS National Water-Quality Assessment Program (NAWQA) sites sampled in 1997, and 15 NJDEP Existing Water Quality (EWQ) sites sampled in 2001 (fig. 1) are located throughout the study area. (Three sites are in both the USGS/NJDEP and DRBC networks, and nine EWQ sites coincide with sites in the other networks.) Sampling sites are located in 12 of the 14 major subwatersheds. White Brook, with the smallest subwatershed (2.09 mi^2), and Stony Brook (4.08 mi^2) are the only tributaries to the Delaware River in the study area whose drainage areas are larger than 2 mi^2 for which no water-quality data are available for the constituents and properties studied. Thirty sites drain watersheds located entirely in one province--18 in the Valley and Ridge and 12 in the New England Province. Nine sites drain watersheds that include parts of both provinces (fig. 2). Water draining from 549 mi^2, or 74 percent of the area covered by WMA1, flows past the USGS/NJDEP network sites. Water draining from 648 mi^2, or 87 percent of WMA1, flows past the DRBC sites.

Permitted municipal and industrial point sources discharge effluent to streams upstream from sampling sites in the Musconetcong River, Paulins Kill, Pequest River, Lopatcong Creek, Pohatcong Creek, and Pophandusing Creek watersheds (table 1). The Musconetcong River, Paulins Kill, and Pequest River receive discharge from 15, 11, and 10 permitted point sources, respectively, upstream from the sampling sites. The Lopatcong and Pohatcong Creeks and Pophandusing Brook each receive discharge from two permitted point sources. Flow data from municipal facilities for 1994-99 indicate that the following amount of effluent is discharged upstream from sampling sites in each watershed: 5.8 ft^3/s to the Musconetcong River, 1.7 ft^3/s to the Paulins Kill, 1.0 ft^3/s to Pohatcong Creek, and 0.9 ft^3/s to the Pequest River.

Methods of Study

Constituents and Properties

Analyses of water samples collected at the 39 sampling sites for nine constituents and properties that are considered to be important indicators of the quality of water in the Upper Delaware River watershed were studied. The constituents and properties selected are temperature, pH, dissolved oxygen, dissolved-solids, suspended solids, nitrate plus nitrite, un-ionized ammonia, total phosphorus, and fecal coliform bacteria. Un-ionized ammonia is the component of aqueous ammonia that is most toxic to aquatic life (Schornick and Fischel, 1980). Dissolved oxygen is affected by the physical, chemical, and biological characteristics of the stream, and adequate concentrations promote the health of aquatic ecosystems. Dissolved-solids are an important constituent to water purveyors and users because costly treatment may be required when concentrations are elevated. Levels of fecal coliform bacteria are a measure of the sanitary quality of the water; when these levels are high, streams may be unsuitable for swimming or other uses. Nitrate and nitrite are the oxidized forms of nitrogen in the stream. Concentrations greater than 10 mg/L (milligrams per liter) can cause methemoglobinemia ("blue-baby syndrome") in infants (Walton, 1951). Nitrogen is a primary nutrient for rooted aquatic plants and algae and, therefore, can stimulate excessive growth of aquatic vegetation. The pH of water is a measure of its acidity or alkalinity. A pH in the range of 6.5 to 8.5 is considered most conducive to aquatic health. The total phosphorus concentration is an important indicator of stream condition, as phosphorus, another primary nutrient for aquatic plants and algae, can stimulate excessive growth. Suspended solids are an important indicator of the presence of nonpoint-source contaminants. The primary sources of suspended solids in streams are storm runoff, instream erosion, and resuspension of sediment. Water temperature affects the chemical and biological processes that occur in a stream. Water temperature is determined by the amount of sunlight reaching the stream, rainfall, air temperature, the amount of ground water discharging to the stream, and the presence of thermal point sources.

Data Review and Analysis

All data were reviewed extensively for quality-assurance purposes. Water-quality data from each USGS/NJDEP and USGS NAWQA site were plotted against streamflow, plotted by season, and compared with measured levels of other constituents. The review resulted in fewer than 0.1 percent of the values being changed or removed from the study database. Some measurements of nitrate plus nitrite and phosphorus derived from field-kit determination were not included in the statistical analyses.

Statistical tests were used to summarize and compare data, examine changes in water quality over time, and examine relations between water quality and land use. Data from each network were evaluated with respect to instream reference levels based on instream water-quality standards for the State of New Jersey. The USGS/NJDEP and DRBC sites for which a sufficient number of samples were available were evaluated for (1) trends during the study period, (2) variability in water quality with season and flow condition, (3) variability among all sites in the study area, (4) variability among sites along stream reaches, (5) relation between water quality and land use, and (6) comparison with data from statewide sampling networks.

Water samples were categorized by season and by the hydrologic condition when they were collected. Samples collected when flow was less than the median for the study period are classified as low-flow samples; those collected when flow was greater than the median are classified as high-flow samples. The period from April through October is designated the growing season and the period from November through March is designated the non-growing season (Ruffner and Bair, 1977).

Statistics including minimum, maximum, median, 25th and 75th percentiles, and standard deviation were used to analyze the distribution of concentrations, fecal coliform counts, pH values, and temperatures in the data set. A percentile is a value that indicates the percentage of samples for which the associated

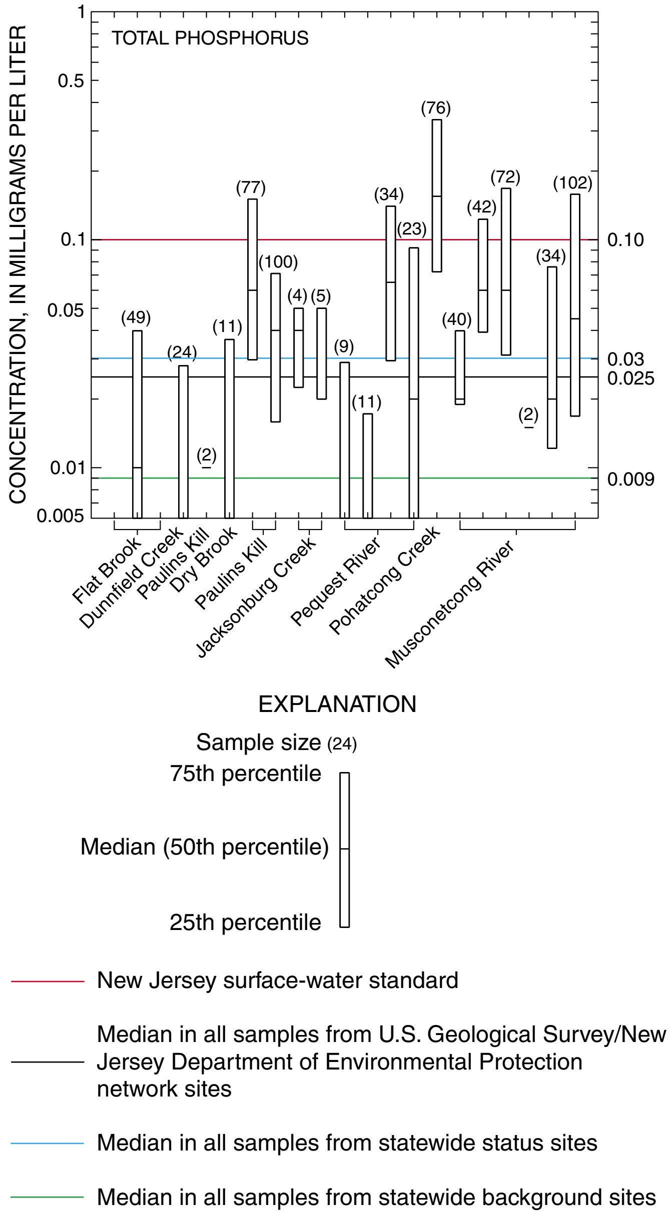

Figure 3. Boxplots showing distribution of total phosphorus concentrations in samples from 21 USGS/NJDEP network sites, and median concentrations in all samples from Statewide status and Statewide background sites.

measurements are less than or equal to it. The median value is the 50th percentile. The analysis of variance and Wilcoxan rank sum tests were used to test for significant differences in the means of two or more data sets (Helsel and Hirsch, 1992). Median values of the nine constituents and properties were evaluated with respect to land use at the 12 sites for which 12 or more measurements were available by using least-squares regression (Ott, 1988). The seasonal Kendall test (Helsel and Hirsch, 1992) was used to test data from 1985 through 2000 for trends.

Boxplots, such as the boxplot of total phosphorus concentrations shown in figure 3, were used to show the distribution of the central 50 percent of the data for each site. Streams are shown from left to right in downstream order by subwatershed. The horizontal line through the middle of the box represents the median value at the site, the horizontal line at the top of the box indicates the 75th percentile (75 percent of the data are less than this value), and the horizontal line at the bottom of the box represents the 25th percentile (25 percent of the data are less than this value). The median of the total phosphorus concentrations at each study site was compared to the median of the medians at all sites, to the median at statewide and background sites, and to the New Jersey surface-water standard (fig. 3)

Cumulative probability curves (fig. 4) are another tool for analyzing the distribution of data at each site. Curves with steep slopes indicate a large range in values; curves with a flat slope indicate a small range in values. The y-axis spans the range of values covering all the samples analyzed. The x-axis represents the percentage of time that measurements are below a given value. The red horizontal lines represent the instream water-quality standard. The intersection of the curve with the red line indicates the percentage of the samples from each site for which the associated measurement meets the standard.

Comparison to Statewide Water Quality

In general, streamwater quality in the study area compares favorably to water quality in streams throughout New Jersey. Water-quality data from sites on streams in WMA1 indicate a lower median concentration of suspended solids, total phosphorus, and nitrate plus nitrite, lower median water temperature, and a lower median count of fecal coliform bacteria, but a higher median concentration of dissolved oxygen and a higher median pH, than data from sites in the USGS/NJDEP statewide network of 109 randomly chosen sites on streams across the State. With respect to these seven constituents and properties, therefore, the quality of streamwater in WMA1 was better than that in the State as a whole. Dissolved-solids concentrations were higher, most likely because of the bedrock in the area. Dissolved-solids concentrations were highest during low flow in the summer and are not a result of the application of road salt during winter storms. Un-ionized ammonia concentrations were higher in WMA1 than at randomly selected sites across New Jersey; however, median concentrations were low, less than 0.001 milligrams per liter in both data sets.

Water-quality data for the study area were compared with data collected at the six USGS/NJDEP network background sites--sites draining predominantly undeveloped areas. In general, water quality at the statewide background sites is better than the water quality in WMA1 (fig. 3). Dissolved oxygen is the only constituent whose median value is indicative of better water quality in the study area than at statewide background sites. Median values for all constituents and properties at sites draining predominantly undeveloped areas in the Dunnfield Creek and Flat Brook watersheds (except for dissolved-solids in the Flat Brook watershed) are statistically equal to or lower than those at sites draining undeveloped areas statewide (fig. 3).

Comparison to Water-Quality Criteria

The New Jersey instream water-quality standards (New Jersey Department of Environmental Protection, 1998) for some of the constituents and properties studied do not apply to instantaneous values derived from one sample. The un-ionized ammonia standard of 0.02 mg/L (milligrams per liter) for trout sites and 0.05 mg/L for nontrout sites is for a 24-hour average concentration. The standard for fecal coliform bacteria is that the count is to exceed neither a geometric mean of 200/100 mL nor 400/100 mL in 10 or more percent of the total number of samples collected in a 30-day period (New Jersey Department of Environmental Protection, 1998). For water temperature, thermal alterations from point-source discharges should not raise the ambient stream temperature more than 0.6-2.8 °C (degrees Celsius), or to a temperature that is higher than the maximum level consistent

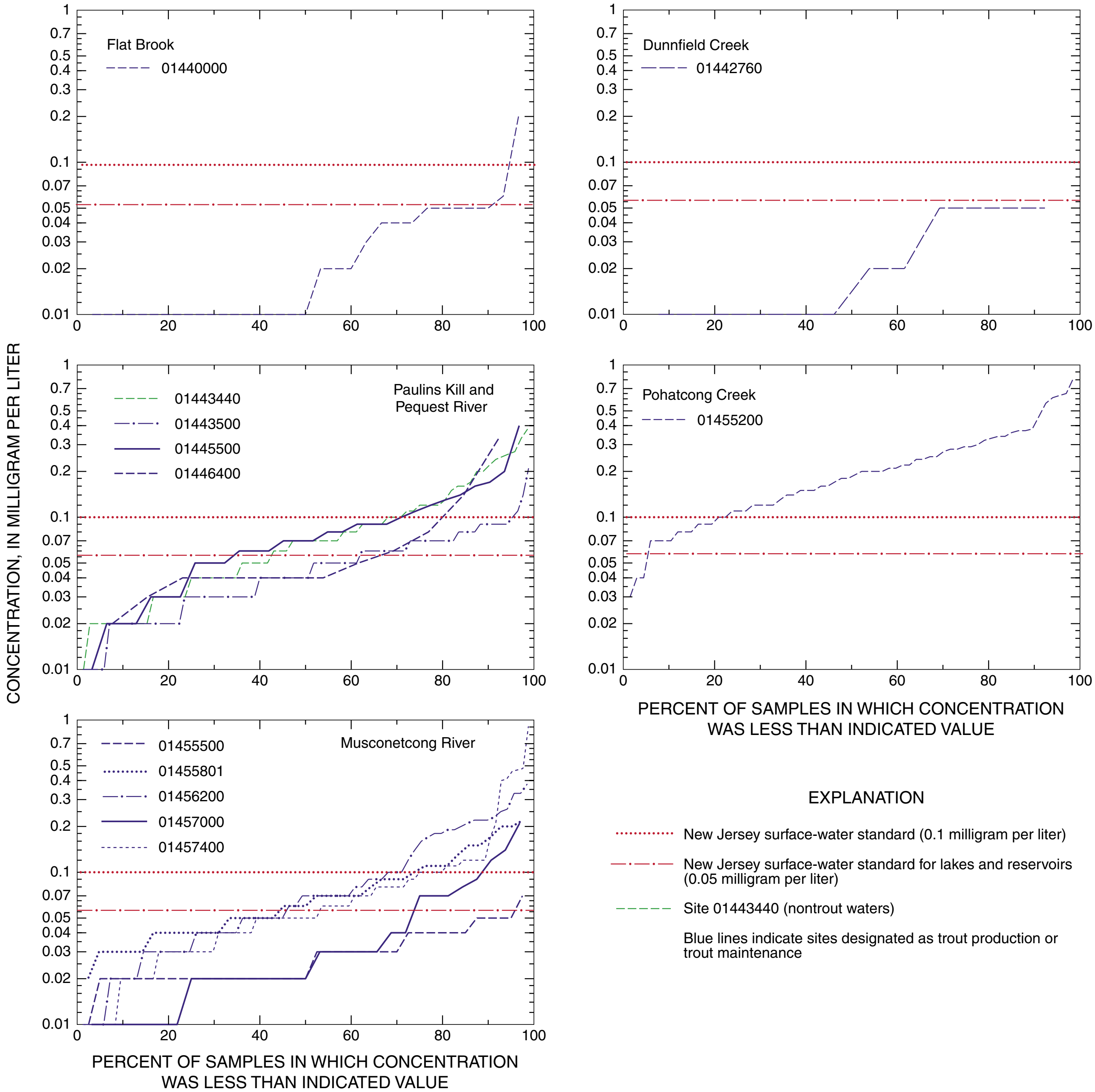

Figure 4. Cumulative probability curves for total phosphorus concentrations in samples collected at 12 USGS/NJDEP network sites during 1985-2000.

with the protection of aquatic life. The instream criteria for these constituents were used only as a level of reference for evaluating water-quality conditions in the study area. The drinking-water standard (New Jersey Department of Environmental Protection, 1989; Shelton and Lance, 1997) set by USEPA and NJDEP for nitrate plus nitrite concentrations (10 mg/L) was used as a reference level in the absence of surface-water-quality criteria. (A surface-water-quality standard is in effect for nitrate only (New Jersey Department of Environmental Protection, 1998).)

The constituents and properties most commonly found to exceed instream reference levels at USGS/NJDEP and DRBC sampling sites were fecal coliform bacteria (> 400 counts/100 mL (milliliters) in 23 percent of samples); total phosphorus (> 0.1 mg/L in 22 percent of samples); water temperature (>20 °C at trout sites in 21 percent of samples); and pH (>8.5 or <6.5 in 13 percent of samples). At sites in nontrout waters, the percentage of samples in which counts of fecal coliform bacteria and total phosphorus concentrations did not meet reference levels was 51 and 31 percent, respectively. All constituents and properties studied (except nitrate plus nitrite concentrations) exceeded reference levels in at least one sample collected at one or more sites in the study area.

The number of constituents that did not meet reference levels was higher at sites on the Musconetcong River and Pohatcong Creek than at sites on other streams; values of six of the nine constituents and properties exceeded the reference levels in one or more samples. Total phosphorus concentrations exceeded 0.1 mg/L in 80 percent of all samples at Pohatcong Creek at New Village (fig. 4). Concentrations exceeded that level in 97 percent of samples at low flow, indicating a constant base-flow or point source. At other sites, phosphorus concentrations exceeded 0.1 mg/L in less than 35 percent of the samples. Fecal coliform bacteria counts exceeded the 400/100mL reference level in more than half the samples at 11 of the 33 sampling sites, including the 2 sites on the Pohatcong River and the 2 sites farthest downstream on the Musconetcong River. Most exceedences at the USGS/NJDEP sites occurred during low-flow conditions. Counts of fecal coliform bacteria exceeded 400/100mL in 82 percent of the samples collected from the Pohatcong River during low flow.

The sites on Dunnfield Creek (station 01442760) and Jacksonburg Creek (station 01443550) are the only sites where the pH was less than 6.4. The pH of 65 percent of the DRBC samples and 33 percent of the USGS/NJDEP samples collected at the Dunnfield Creek site, and 25 percent of the samples collected at the site farthest upstream on Jacksonburg Creek, was less than the instream reference level of 6.5. The watersheds upstream from both sites are more than 94 percent undeveloped and contain no agricultural land. Both sites drain steep, mountainous terrain along the Kittatinny Mountain ridge. The bedrock upstream from these sites consists of erosion-resistant layers of sandstone and siltstone unique in WMA1 to the Kittatinny Mountain and Walpack Ridges. Soil pH in this area ranges from extremely acid to moderately acid (U.S. Department of Agriculture, 2002), with values ranging from 3.5 to 5.5 (Christine Hall, Natural Resource Conservation Service, written commun., 2002). At a sampling site farther downstream on Jacksonburg Creek, pH ranged from 7.5 to 8.1 because the area upstream from this site through which the stream flows is underlain by limestone bedrock.

Trends in Water Quality

Measurements of chemical constituents and properties were sufficient to conduct trend tests at 10 of the 21 USGS/NJDEP sites. No significant trend was found for most of the constituents and properties at most of the sites; however, some significant trends were observed. Concentrations of un-ionized ammonia and total phosphorus decreased at some sites on the Musconetcong River, Pohatcong Creek, and Paulins Kill. The sites on the Musconetcong River and Pohatcong Creek with the highest median concentrations are among those where concentrations of these constituents decreased. Water temperature decreased at the site farthest downstream on both the Musconetcong River and Paulins Kill, and pH decreased at a site on the Pequest River. Dissolved oxygen concentration increased at Musconetcong River at the outlet of Lake Hopatcong, the site with the lowest median value. Concentrations of nitrate plus nitrite and dissolved-solids, however, increased at some sites on the Musconetcong River and Pohatcong Creek. The median concentration of nitrate plus nitrite (1.93 mg/L) was highest at Pohatcong Creek, but the highest values at the site still were substantially lower than the instream reference level. Because the rate of increase was small, upward trends in concentrations of nitrate plus nitrite do not appear to be an indication that the instream reference level (10 mg/L) will be approached.

Relation of Water Quality to Land Use

Median concentrations of all constituents and properties except dissolved oxygen were significantly related to the land use upstream from USGS/NJDEP sampling sites. Sampling sites on streams draining areas containing more than 78 percent forested land (fig. 5) were associated with significantly lower median values of six of the nine measures studied and higher median concentrations of dissolved oxygen than sites draining areas containing less forested land. Median values for fecal coliform bacteria, dissolved solids, and total phosphorus were significantly higher at agricultural sites than at urban and undeveloped sites. Median values for water temperature, pH, nitrate plus nitrite, un-ionized ammonia, and suspended solids were not significantly different at agricultural and urban sites.

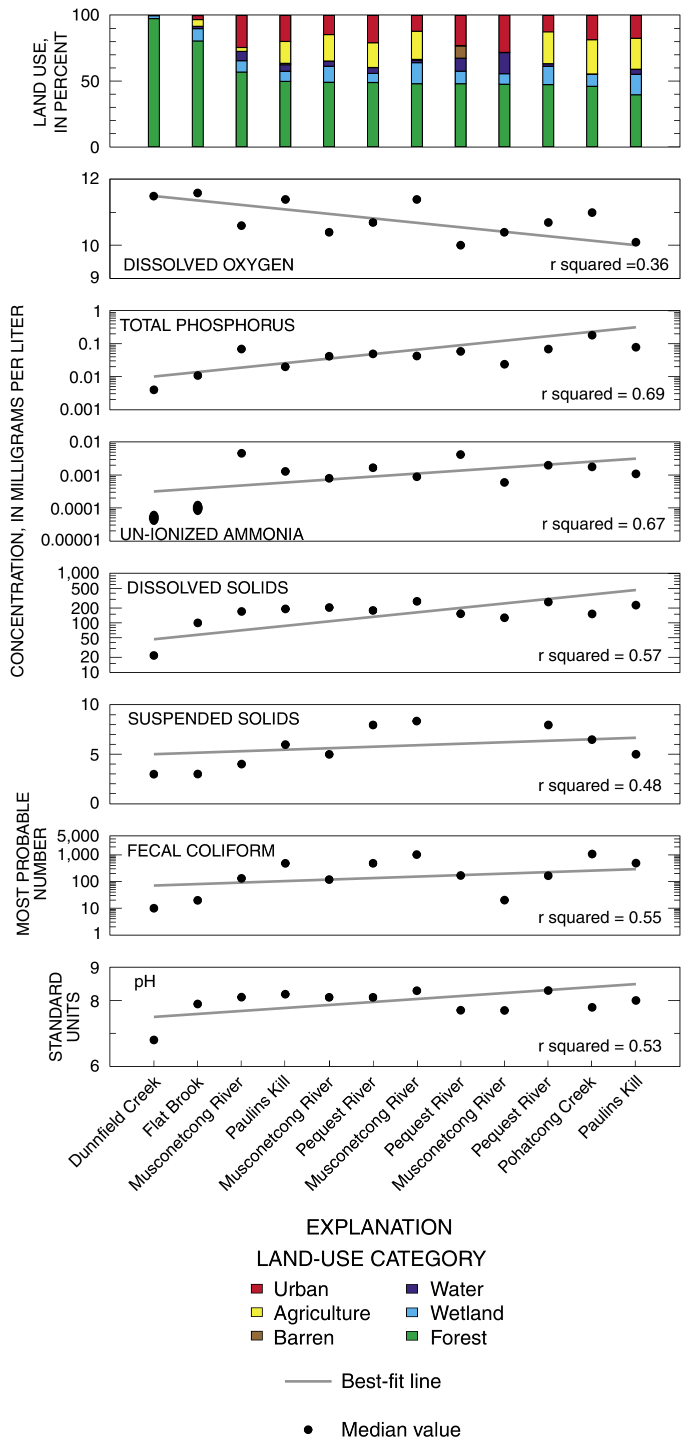

Figure 5. Relation of median concentrations, fecal coliform counts, and pH units for samples collected during 1985-2000 at the USGS/NJDEP network sites to percent of forested land use in the watershed. (Six of the nine constituents and properties studied increase, and one (dissolved oxygen) decreased with a decrease in forested land use.)

Variability of Water Quality in the Study Area

Variability of water quality at a site is related to changes in season and (or) flow condition. Values of the following constituents and properties were significantly higher in the growing season than in the non-growing season at one or more sites: water temperature, fecal coliform count, pH, and concentrations of total phosphorus, un-ionized ammonia, and dissolved solids. Values of the following constituents were significantly higher in the non-growing season than in the growing season at one or more sites: pH, and concentrations of dissolved oxygen and nitrate plus nitrite. Values of six constituents and properties were significantly higher at low flow than at high flow at one or more sites; concentrations of dissolved oxygen, suspended solids, and nitrate plus nitrite were significantly higher at high flow at some sites.

Water quality varied significantly among sites (fig. 3). Sites on the Musconetcong River and Pohatcong Creek were among those with the lowest median dissolved oxygen concentration and the highest median values of six of the remaining eight constituents and properties. Sites on the Pequest River were among those with the highest median values for four constituents and properties. In contrast, sites on Flat Brook and Dunnfield Creek were associated with some of the highest dissolved oxygen concentrations and the lowest values of the remaining eight constituents and properties. Median values of five constituents and properties were among the lowest at the site on Vancampens Brook.

Water quality also varied among the five sampling sites with sufficient data for comparison along the Musconetcong River and between the two sites sampled along both the Pequest River and Paulins Kill. Few significant differences were observed between median values for the Pequest River sites at Pequest (upstream site) and Belvidere (downstream site), which are approximately 6 miles apart. Fecal coliform counts were significantly higher at Belvidere, and concentrations of suspended solids were significantly higher at Pequest. Land use is similar in both watersheds, and no municipal point sources discharge to the river between the sites. Values of five constituents and properties were significantly different between the site at Balesville (the farthest upstream) and the site at Blairstown (the farthest downstream) on the Paulins Kill, which are approximately 15 miles apart. The Balesville site is associated with higher concentrations of total phosphorus, dissolved solids, and nitrate plus nitrite, and higher counts of fecal coliform bacteria than the Blairstown site. The median pH, however, is higher at Blairstown than at Balesville. Higher percentages of agricultural and urban land and a larger percentage of instream flow from municipal point sources upstream from Balesville may contribute to these differences.

Sites along the Musconetcong River were among those with both the highest and lowest values of pH and concentrations of nitrate plus nitrite, total phosphorus, suspended solids, and dissolved oxygen in the study area (fig. 4). pH and concentrations of dissolved oxygen, nitrate plus nitrite, and suspended solids were lower at the upstream sites than at the downstream sites. Total phosphorus concentrations were among the lowest on the Musconetcong River at the outlet of Lake Hopatcong (station 01455500) and at Bloomsbury (station 01457000), and among the highest at Beattystown (station 01456200) (fig. 1). The increase in median total phosphorus concentration between the outlet of Lake Hopatcong and Beattystown may result from the presence of point-source discharges between Bloomsburg and Beattystown and the proximity of the Beattystown site to the urban area in and around Hackettstown.

Median concentrations of dissolved solids and nitrate plus nitrite and median counts of fecal coliform bacteria increased progressively and significantly from upstream to downstream along the Musconetcong River. Suspended solids concentrations for the two upstream sites are not available; however, median concentrations at the other sites increased progressively with distance downstream, doubling from the Beattystown to Reigelsville sites. Median pH values were significantly lower at the two sites in the upper part of the watershed than at the three sites farthest downstream. Concentrations of un-ionized ammonia and total phosphorus were equally low at the upstream site and the Bloomsbury site; concentrations at the other three sites were significantly higher. Significant increases in constituent concentrations and pH from the upstream to the downstream sampling sites may result in part from the presence of permitted point sources and higher percentages of agricultural land in the lower parts of the watershed.

—Robert G. Reiser

References Cited

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: New York, Elsevier Science Publishing Company, Inc., 522 p.

New Jersey Department of Environmental Protection, 1989, Safe Drinking Water Act: New Jersey Administrative Code, 7:10-1 through 16.12.

_____1998, Surface water quality standards: New Jersey Administrative Code 7:9B: Trenton, N.J., New Jersey Department of Environmental Protection, April 1998, 122 p.

_____2000, Land use/land cover and impervious surfaces for Watershed Management Area 1, 1995/97: New Jersey Department of Environmental Protection, Bureau of Geographic Information and Analysis. (Accessed December 1, 2000, on the World Wide Web at URL http://www.state.nj.us/dep/gis/digidownload/zips/lulc95/w011u95.zip)

New Jersey Department of Environmental Protection and Energy, 1992, Geologic map of New Jersey: Trenton, N.J., New Jersey Department of Environmental Protection and Energy, New Jersey Geological Survey, scale 1:1,000,000.

Ott, L., 1988, An introduction to statistical methods and data analysis: Boston, Mass., PWS-Kent Publishing Company, 835 p.

Ruffner, J.A., and Bair, F.E., eds., 1977, The weather almanac (2d ed.): New York, Avon Books, 35 p.

Schornick, J.C., and Fischel, D.K., 1980, Effects of storm runoff on water quality in the Mill Creek drainage basin, Willingboro, New Jersey: U.S. Geological Survey Water Resources Investigations Report 80-98, 111 p.

Shelton, T.B., and Lance, S.E., 1997, Interpreting drinking water quality analysis: What do the numbers mean? (5th ed.): New Brunswick, New Jersey, Rutgers Cooperative Extension, 63 p.

U.S. Department of Agriculture, 2002, Official soil series description data for the Arnot, Lackawanna, Lordstown, and Oquaga soil series, Natural Resource Conservation Service, Soil Survey Division. (Accessed April 18, 2002, on the World Wide Web at URL http://www.statlab.iastate.edu/soils/osd/)

Walton, G., 1951, Survey of literature relating to infant methemoglobinemia due to nitrate-contaminated water: American Journal of Public Health, v. 41, p. 986-996.

Contact for additional information:

U.S. Geological Survey
Water Resources Division
810 Bear Tavern Road, Suite 206
West Trenton, NJ 08628