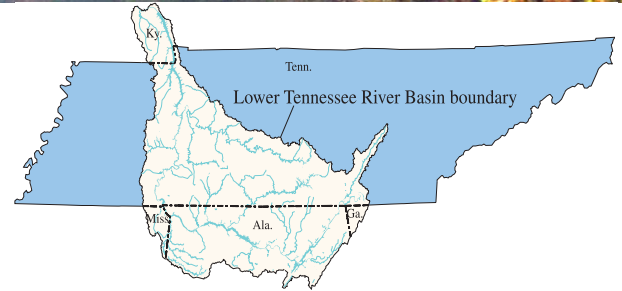


# Nutrients in Streams and Rivers in the Lower Tennessee River Basin



## INTRODUCTION

**Nitrogen and phosphorus are essential nutrients for plant and animal growth, but excessive amounts can promote nuisance growths or “blooms” of algae and other aquatic plants in streams, lakes, and estuaries.** In turn, algal blooms can impair the suitability of water for municipal supplies, recreation, fishing, and wildlife. In 1997, the U.S. Geological Survey (USGS) began an assessment of nutrients in the lower Tennessee River Basin as part of the National Water-Quality Assessment (NAWQA) Program. Initial assessments focused on nutrients

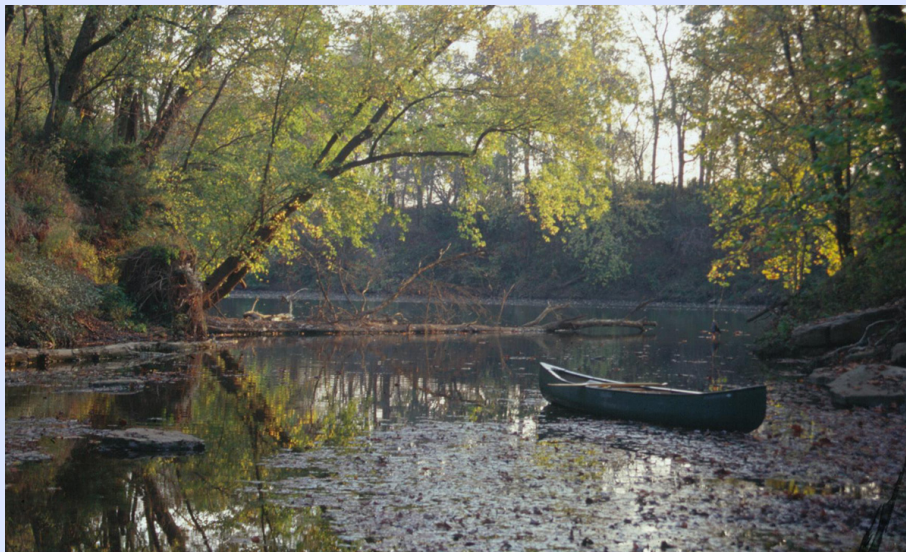
because officials from Federal, State, and local resource-management and regulatory agencies identified nutrients in surface waters as an issue of concern. In 1996, State water-quality regulatory agencies listed overenrichment of nutrients as the cause of impairment in 37 stream segments and in 2 lakes within the lower Tennessee River Basin. Understanding the relation between the source and transport of nutrients within a watershed can assist resource managers and policymakers in forming sound nutrient-management decisions. This report compares nutrient inputs from nonpoint and point sources and nutrient outputs in selected basins in the

lower Tennessee River Basin as summarized from the comprehensive report by Hoos and others (2000), which describes nutrient transport within the lower Tennessee River Basin.

## NONPOINT AND POINT SOURCES OF NUTRIENTS

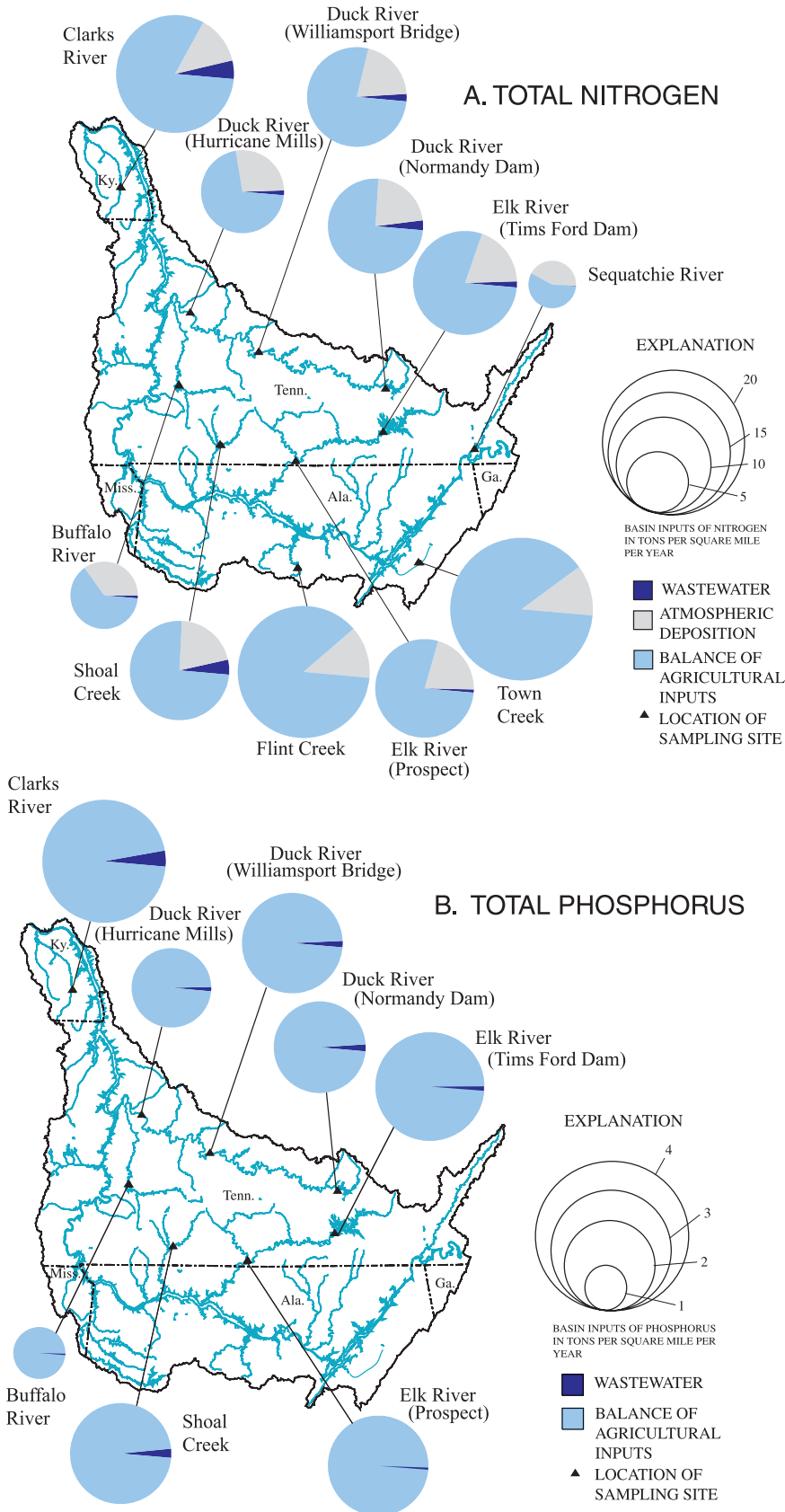
**An estimated 205,000 tons of nitrogen and 38,100 tons of phosphorus are input annually into the lower Tennessee River Basin from nonpoint and point sources.** Nonpoint sources include basinwide, diffuse inputs from fertilizers applied to crops, lawns, and golf courses, failing septic systems, livestock and pet waste, atmospheric deposition, and natural sources in the rocks and soil. Point sources of nutrients include discharges directly to streams and lakes, such as wastewater from municipal and industrial facilities. An unknown percentage of nutrients in fertilizers, livestock waste, and other basinwide inputs is transported to streams during storm events or mobilized by natural chemical processes in the soil and then transported by ground water into streams.

Nutrient inputs from nonpoint and point sources were estimated for the lower Tennessee River Basin and for 11 tributary basins (fig. 1). Basinwide information on nonpoint sources was available only for atmospheric deposition and agricultural sources, which includes commercial fertilizer inputs, nitrogen fixation by leguminous crops, and livestock



The lower Tennessee River Basin drains about 19,500 square miles, mostly in Middle Tennessee and northern Alabama, and small areas of Kentucky, Georgia, and Mississippi. The major land uses in the basin include forest (51 percent), pasture (34 percent), and cropland (6 percent). The Tennessee Valley Authority constructed six main stem reservoirs and three tributary reservoirs in the lower Tennessee River Basin for power generation, navigation, and flood control. About 1.5 million people residing in the basin rely heavily on these reservoirs for drinking-water supplies and recreational activities. Surface water is the primary source of drinking water, providing about 160 million gallons a day to about 560,000 people in the basin.

# Basin Inputs



**Figure 1.** Estimated basin inputs of (A) total nitrogen and (B) total phosphorus and the proportions of inputs from wastewater, atmospheric deposition, and the balance of agricultural inputs.

waste. **Nonpoint sources account for about 94 percent of the nitrogen inputs and 98 percent of the phosphorus inputs to the Basin.** Despite the smaller percentage of total nutrient inputs, point sources can have noticeable effects on water quality, especially when streamflows are low.

## Atmospheric Deposition

The combustion of fossil fuels, such as oil and coal, by automobiles, electric utilities, and large industries is the major source of nitrogen in atmospheric deposition. Although atmospheric deposition contributes about 34,600 tons of total nitrogen annually to the lower Tennessee River Basin, atmospheric deposition is not considered to be a significant source of phosphorus to the lower Tennessee River Basin (Kingsbury and others, 1999).

Atmospheric inputs of total nitrogen range from 1.6 to 2.0 tons per square mile per year [(tons/mi<sup>2</sup>)/yr] in the 11 basins in the lower Tennessee River Basin. Although atmospheric inputs of total nitrogen are similar among the 11 basins, the percentage of inputs from atmospheric deposition is highly variable within each basin. Only 11 percent of the nonpoint-source inputs of annual total nitrogen are from atmospheric deposition in an agricultural tributary basin (Town Creek Basin); whereas, about 43 percent of the nonpoint-source inputs of annual total nitrogen are from atmospheric deposition in the undeveloped Sequatchie River Basin (fig. 1).

## Agriculture

Inputs of nitrogen and phosphorus from fertilizers, nitrogen fixation by leguminous crops, and livestock waste contribute about 157,000 tons of nitrogen and 37,300 tons of phosphorus annually to the lower Tennessee River Basin. Inputs from



Row crops are grown predominantly along the flood plains of the major tributaries and the main stem of the Tennessee River. Cotton, corn, and soybeans are the primary row crops in the lower Tennessee River Basin.

confined animal operations. Phosphorus inputs were not estimated for Flint Creek Basin, Sequatchie River Basin, or Town Creek Basin because of limited concentration data, which prevented a comparison of inputs and outputs.

### Wastewater Discharge

Discharges from sewage treatment plants and industrial facilities contribute about 13,400 tons of nitrogen and 760 tons of phosphorus annually to the lower Tennessee River Basin. As noted previously, nutrient inputs from point sources enter streams directly. Undetermined amounts of nutrients can be assimilated in streams near discharge points and the remaining proportion of nutrients transported further downstream.

**Nutrient inputs from point sources accounted for less than 6 percent of the estimated nutrient inputs to the tributary basins.** Point-source inputs of nutrients were lowest in the Flint Creek and Town Creek Basins and highest in the Clarks River Basin. Inputs from point sources in the tributary basins ranged from 0 to 0.61 (tons/mi<sup>2</sup>)/yr for total nitrogen and 0 to 0.14 (tons/mi<sup>2</sup>)/yr for total phosphorus (fig. 1).

agricultural activities are distributed throughout the basin and the percentage of these inputs transported to streams is difficult to estimate. Accumulation and denitrification in the soil and volatilization of nitrogen in livestock waste are just a few examples of how nutrients are assimilated and made unavailable for transport to a stream. In addition, corn, soybeans, cotton, and other crops grown in the Basin incorporate nutrients into plant biomass that is removed from the Basin when a crop is harvested and exported. Estimates of nutrient inputs from agricultural activities were adjusted by subtracting crop uptake from the sum of the fertilizer application, nitrogen fixation, and livestock waste. Crop uptake accounts for about 58,000 tons of nitrogen and 7,100 tons of phosphorus annually in the lower Tennessee River Basin. Corrections for other nutrient sinks were not estimated for this report.

Agricultural inputs accounted for the largest percentage of inputs of total nitrogen and total phosphorus in all the basins evaluated. Basinwide inputs of nutrients from agricultural activities ranged from 2.4 to 15 (tons/mi<sup>2</sup>)/yr for total nitrogen

and 1.2 to 3.2 (tons/mi<sup>2</sup>)/yr for total phosphorus (fig. 1). The lowest inputs of total nitrogen and total phosphorus from agricultural activities occurred in basins where the percentage of crop and pasture land was least (Sequatchie River Basin and Buffalo River Basin). The highest agricultural inputs of total nitrogen were in the Town Creek Basin. Over 86 percent of the agricultural inputs in the Town Creek Basin are from livestock operations, mainly from



Nutrients from point sources are discharged directly into streams and can have noticeable effects on water quality, especially when streamflows are low.



Excessive amounts of nutrients can stimulate algal blooms which can impair the suitability of water for municipal supplies, recreation, fishing, and wildlife.

## QUANTIFYING NUTRIENT OUTPUTS

Estimates of annual flow-weighted mean concentrations and stream yields of nutrients provide information on nutrient outputs from streams and rivers. Estimates of annual flow-weighted mean concentrations (computed by dividing the annual nutrient load by the annual total stream discharge) are useful for evaluating average water-quality conditions at a site and for making comparisons with other streams and rivers in the Nation. Estimates of stream yields (computed by dividing the annual nutrient load by the basin area) are useful for comparing nutrient transport among basins with different areas.

## CONCENTRATIONS OF NUTRIENTS IN STREAMS VARY WITH LAND USE

**A large range in annual flow-weighted concentrations of total nitrogen in the lower Tennessee River Basin suggests that human activities have caused concentrations of total nitrogen to increase by as much as fivefold.** Flow-

weighted concentrations of total nitrogen range from about 0.5 milligrams per liter (mg/L) in a stream draining an undeveloped basin to 2.8 mg/L in a stream draining a mixture of land uses, including urban development, pasture land, and cropland. Flow-weighted concentrations of total nitrogen are low (0.55 mg/L) in the undeveloped Buffalo River Basin and similar to concentrations of total nitrogen for undeveloped basins throughout the Southeast (Clark and others, 2000). Flow-weighted concentrations also are low (0.53 mg/L) in the Duck River Basin (Normandy Dam). Denitrification within Normandy Lake during the summer when the reservoir is stratified results in lower concentrations of total nitrogen in the water discharged from the reservoir. Flow-weighted concentrations of total nitrogen are highest in the Clarks River (2.8 mg/L) and Town Creek (2.3 mg/L) Basins. The Clarks River Basin receives inputs of total nitrogen from a variety of point and nonpoint sources; whereas, the primary source of total nitrogen in the Town Creek Basin is from nonpoint sources, such as animal feeding operations, cropland, pasture, and failing

septic systems (not estimated in this report). Flow-weighted concentrations of total nitrogen in Clarks River and Town Creek also are elevated (greater than the 70<sup>th</sup> percentile) in comparison to 372 streams and rivers across the Nation (D.K. Mueller, U.S. Geological Survey, oral commun., 2000).

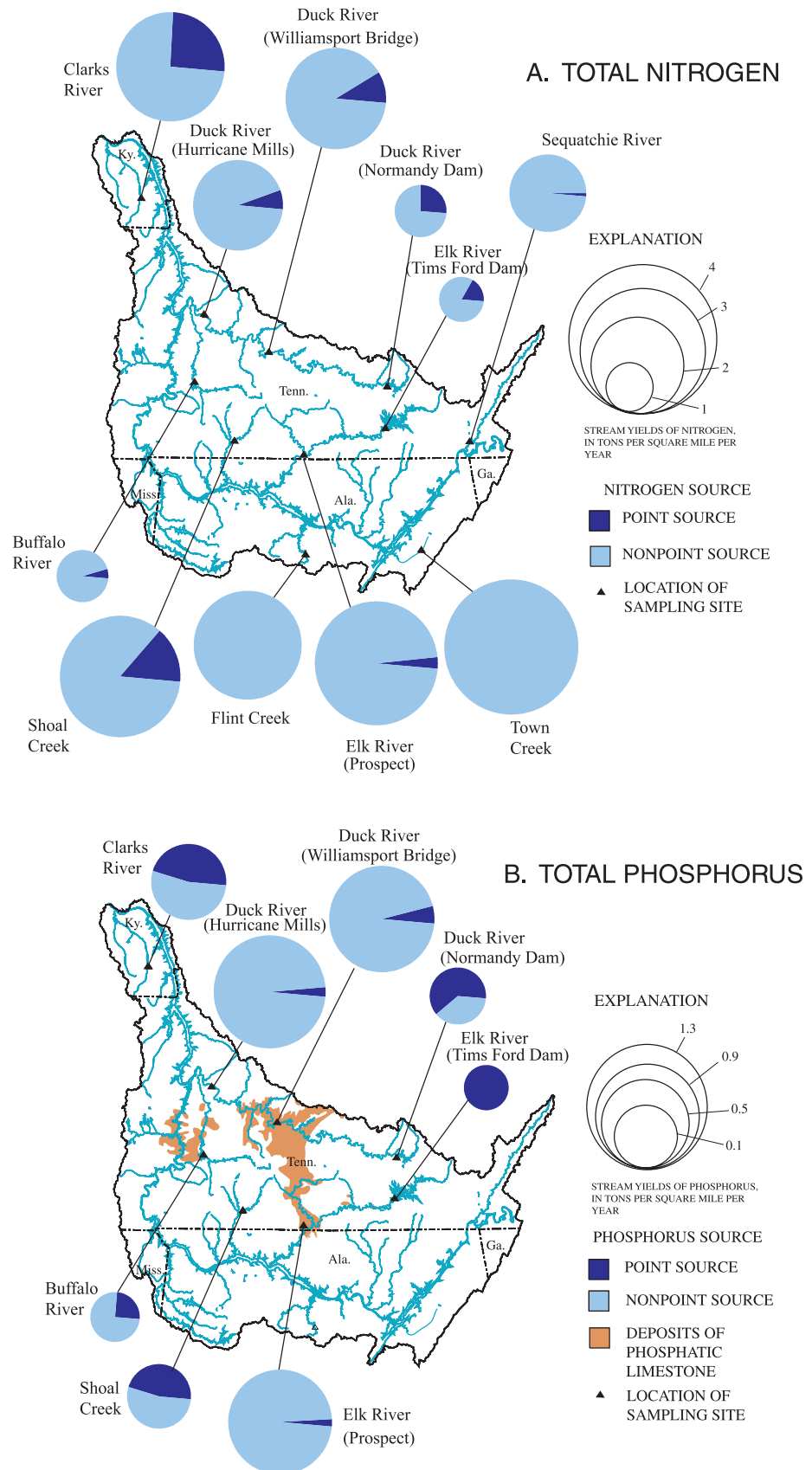
Although national water-quality criteria limiting nutrient fluxes have not been established, the National Technical Advisory Committee (1968) recommended phosphorus concentrations not exceed 0.05 mg/L for waters entering impoundments. Among the eight streams and rivers investigated in the lower Tennessee River Basin, flow-weighted concentrations of total phosphorus range from 0.02 mg/L in the undeveloped Buffalo River Basin to 0.73 mg/L in the Duck River Basin (Williamsport Bridge). **Phosphorus levels in the undeveloped Buffalo River Basin are similar to the median flow-weighted concentration of total phosphorus (0.022 mg/L) for undeveloped basins throughout the Nation (Clark and others, 2000).** Annual flow-weighted concentrations of total phosphorus in the lower Duck River (Williamsport Bridge and Hurricane Mills) and the Elk River (Prospect) Basins exceed 0.52 mg/L, which is above the 90<sup>th</sup> percentile of flow-weighted concentrations of total phosphorus among 372 streams and rivers across the Nation (D.K. Mueller, U.S. Geological Survey, oral commun., 2000). **Natural deposits of phosphatic limestones in the Duck River and Elk River Basins (fig. 2) contribute to the large variation, nearly forty-fold, in concentrations of total phosphorus throughout streams in the lower Tennessee River Basin.** The presence of phosphatic limestone is an important factor to consider as regional boundaries are established to attain region-specific water-quality criteria for total phosphorus.

## COMPARISONS OF NONPOINT AND POINT SOURCE INPUTS TO NUTRIENT YIELDS

In 11 basins in the lower Tennessee River Basin, nonpoint sources of total nitrogen account for at least 74 percent of the annual total nitrogen stream yields; point sources account for less than 26 percent of the annual total nitrogen stream yields (fig. 2). Nonpoint-source contributions to the annual nutrient stream yields were estimated by subtracting point-source inputs from stream yields. These nonpoint-source estimates are conservative because they assume that none of the nutrient inputs from point sources are assimilated or removed in the stream between the point of discharge and the point where the stream nutrient yields are estimated.

Elevated stream yields of total nitrogen occur in the Town Creek [3.5 (tons/mi<sup>2</sup>)/yr], Elk River (Prospect) [3.0 (tons/mi<sup>2</sup>)/yr], Shoal Creek [2.9 (tons/mi<sup>2</sup>)/yr], Clarks River [2.4 (tons/mi<sup>2</sup>)/yr], and the Flint Creek Basins [2.4 (tons/mi<sup>2</sup>)/yr]. Few, if any, point sources are present in the Town Creek, Flint Creek, and Elk River (Prospect) Basins, thus nonpoint sources are the primary sources contributing to the elevated annual stream yields of total nitrogen in these basins (fig. 2). Point-source inputs of total nitrogen comprise 26 percent or less of the annual total nitrogen stream yield in the Clarks River Basin and 15 percent or less of the annual total nitrogen stream yield in the Shoal Creek Basin. During periods of low streamflows, a significant correlation exists between median concentrations of total nitrogen and wastewater inputs of total nitrogen among the basins with point sources, which suggests that wastewater discharges can be significant contributors to the amount of

## Stream Yields



**Figure 2.** Estimated stream yields of (A) total nitrogen and (B) total phosphorus and the proportion of stream yield contributed by point sources and nonpoint sources.

nitrogen in transport during periods of low streamflow. In basins without any point sources, nonpoint sources, such as fertilizers applied to crops, lawns, and golf courses, failing septic systems, livestock waste, atmospheric deposition, and natural sources in the rocks and soil, are the primary sources of total nitrogen. Evaluation of nutrient-management strategies within a basin requires quantitative information on nutrient inputs and a thorough understanding of nutrient cycling and transport.

**Nonpoint sources of total phosphorus account for 52 to 98 percent of the annual total phosphorus stream yields; point sources account for less than 2 to 48 percent of the annual total phosphorus stream yields in basins unaffected by impoundments.**

Nonpoint-source inputs of total phosphorus from natural deposits of phosphatic limestone in the lower Duck River (Williamsport Bridge and Hurricane Mills) and the Elk River (Pros-

pect) Basins (fig. 2) contribute to the highest annual stream yields of total phosphorus [greater than 0.88 (tons/mi<sup>2</sup>)/yr] among the basins in the lower Tennessee River Basin. Stream yields of total phosphorus are less than 0.08 (tons/mi<sup>2</sup>)/yr in the undeveloped Buffalo River Basin and in the Elk River (Tims Ford Dam) and Duck River (Normandy Dam) Basins, where sampling sites are located directly downstream of reservoirs that act as major sinks for phosphorus. Point-source inputs of total phosphorus account for less than 48 percent of the annual total phosphorus stream yields in the Clarks River and Shoal Creek Basins. Despite the large percentage of inputs from point sources in the Clarks River and Shoal Creek Basins, annual stream yields of phosphorus are low [0.30 (tons/mi<sup>2</sup>)/yr in Clarks River Basin and 0.15 (tons/mi<sup>2</sup>)/yr in Shoal Creek Basin] when compared to yields in basins within the lower Tennessee River Basin that contain

natural deposits of phosphatic limestone.

—By Michael D. Woodside and Anne B. Hoos

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- Kingsbury, J.A., Hoos, A.B., and Woodside, M.D., 1999, Environmental setting and water-quality issues in the lower Tennessee River Basin: U.S. Geological Survey Water-Resources Investigations Report 99-4080, 44 p.
- National Technical Advisory Committee, 1968, Water-quality criteria, A report of the National Technical Advisory Committee to the Secretary of the Interior: Washington, D.C., U.S. Government Printing Office, 234 p.

## FOR MORE INFORMATION

The information summarized in this report is based on the publication:

Hoos, A.B., Robinson, J.A., Aycock, R.A., Knight, R.R., and Woodside, M.D., 2000, Sources, instream transport, and trends of nitrogen, phosphorus, and sediment in the lower Tennessee River Basin, 1980-96: U.S. Geological Survey Water-Resources Investigations Report 99-4139, 96 p.

Additional information on the lower Tennessee River Basin NAWQA study unit is available through the World Wide Web at <http://tn.water.usgs.gov/lten/lten.html>

Or contact:

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## For More Information on the National Water-Quality Assessment Program

The U.S. Geological Survey's National Water-Quality Assessment Program is building an explanation of how and why water quality varies across the United States. National and regional assessments of nutrients, pesticides, and volatile organic compounds are based on investigations in more than 50 major river and ground-water systems throughout the Nation.

Additional information on the USGS National Water-Quality Assessment Program is available through the World Wide Web at [http://water.usgs.gov/nawqa/nawqa\\_home.html](http://water.usgs.gov/nawqa/nawqa_home.html)