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National Water-Quality Assessment Program

Nitrate Loads and Concentrations in Surface-Water Base Flow and Shallow Groundwater for Selected Basins in the United States, Water Years 1990–2006

Scientific Investigations Report 2010–5098

U.S. Department of the Interior
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Foreword

The U.S. Geological Survey (USGS) is committed to providing the Nation with reliable scientific information that helps to enhance and protect the overall quality of life and that facilitates effective management of water, biological, energy, and mineral resources (*http://www.usgs.gov/*). Information on the Nation's water resources is critical to ensuring long-term availability of water that is safe for drinking and recreation and is suitable for industry, irrigation, and fish and wildlife. Population growth and increasing demands for water make the availability of that water, measured in terms of quantity and quality, even more essential to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to support national, regional, State, and local information needs and decisions related to water-quality management and policy (*http://water.usgs.gov/nawqa)*. The NAWQA Program is designed to answer: What is the quality of our Nation's streams and groundwater? How are conditions changing over time? How do natural features and human activities affect the quality of streams and groundwater, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. From 1991 to 2001, the NAWQA Program completed interdisciplinary assessments and established a baseline understanding of water-quality conditions in 51 of the Nation's river basins and aquifers, referred to as Study Units (*http://water.usgs.gov/nawqa/studyu.html*).

National and regional assessments are ongoing in the second decade (2001–2012) of the NAWQA Program as 42 of the 51 Study Units are selectively reassessed. These assessments extend the findings in the Study Units by determining water-quality status and trends at sites that have been consistently monitored for more than a decade, and filling critical gaps in characterizing the quality of surface water and groundwater. For example, increased emphasis has been placed on assessing the quality of source water and finished water associated with many of the Nation's largest community water systems. During the second decade, NAWQA is addressing five national priority topics that build an understanding of how natural features and human activities affect water quality, and establish links between ***sources*** of contaminants, the ***transport*** of those contaminants through the hydrologic system, and the potential ***effects*** of contaminants on humans and aquatic ecosystems. Included are studies on the fate of agricultural chemicals, effects of urbanization on stream ecosystems, bioaccumulation of mercury in stream ecosystems, effects of nutrient enrichment on aquatic ecosystems, and transport of contaminants to public-supply wells. In addition, national syntheses of information on pesticides, volatile organic compounds (VOCs), nutrients, trace elements, and aquatic ecology are continuing.

The USGS aims to disseminate credible, timely, and relevant science information to address practical and effective water-resource management and strategies that protect and restore water quality. We hope this NAWQA publication will provide you with insights and information to meet your needs, and will foster increased citizen awareness and involvement in the protection and restoration of our Nation's waters.

The USGS recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for cost-effective management, regulation, and conservation of our Nation's water resources. The NAWQA Program, therefore, depends on advice and information from other agencies—Federal, State, regional, interstate, Tribal, and local—as well as nongovernmental organizations, industry, academia, and other stakeholder groups. Your assistance and suggestions are greatly appreciated.

Matthew C. Larsen
Associate Director for Water

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Conversion Factors

Multiply	By	To obtain
mile (mi)	1.609	kilometer (km)
foot (ft)	0.3048	meter (m)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Abbreviations Used in Report

Abbreviation	Description
AMLE	Adjusted maximum-likelihood estimation
MLE	Maximum likelihood estimation
mg/L	Milligrams per liter
NAWQA	National water-quality assessment
USGS	United States Geological Survey
BFI	Base-flow index
GIS	Geographic information system
LOADEST	Load estimator
LOWESS	Locally weighted scatterplot smooth

Latitude and longitude are referenced to the North American Datum of 1983 (NAD83).

Altitude, as used in this report, refers to distance above the North American Vertical Datum of 1988 (NAVD88).

Water year is the continuous 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as water year 1980.

Nitrate Loads and Concentrations in Surface-Water Base Flow and Shallow Groundwater for Selected Basins in the United States, Water Years 1990–2006

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Abstract

Hydrograph separation was used to determine the base-flow component of streamflow for 148 sites sampled as part of the National Water-Quality Assessment program. Sites in the Southwest and the Northwest tend to have base-flow index values greater than 0.5. Sites in the Midwest and the eastern portion of the Southern Plains generally have values less than 0.5. Base-flow index values for sites in the Southeast and Northeast are mixed with values less than and greater than 0.5. Hypothesized flow paths based on relative scaling of soil and bedrock permeability explain some of the differences found in base-flow index. Sites in areas with impermeable soils and bedrock (areas where overland flow may be the primary hydrologic flow path) tend to have lower base-flow index values than sites in areas with either permeable bedrock or permeable soils (areas where deep groundwater flow paths or shallow groundwater flow paths may occur).

The percentage of nitrate load contributed by base flow was determined using total flow and base flow nitrate load models. These regression-based models were calibrated using available nitrate samples and total streamflow or base-flow nitrate samples and the base-flow component of total streamflow.

Many streams in the country have a large proportion of nitrate load contributed by base flow: 40 percent of sites have more than 50 percent of the total nitrate load contributed by base flow. Sites in the Midwest and eastern portion of the Southern Plains generally have less than 50 percent of the total nitrate load contributed by base flow. Sites in the Northern Plains and Northwest have nitrate load ratios that generally are greater than 50 percent. Nitrate load ratios for sites in the Southeast and Northeast are mixed with values less than and greater than 50 percent.

Significantly lower contributions of nitrate from base flow were found at sites in areas with impermeable soils and impermeable bedrock. These areas could be most responsive to nutrient management practices designed to reduce nutrient transport to streams by runoff. Conversely, sites with potential for shallow or deep groundwater contribution (some combination of permeable soils or permeable bedrock) had significantly greater contributions of nitrate from base flow. Effective nutrient management strategies would consider groundwater nitrate contributions in these areas.

Mean annual base-flow nitrate concentrations were compared to shallow-groundwater nitrate concentrations for 27 sites. Concentrations in groundwater tended to be greater than base-flow concentrations for this group of sites. Sites where groundwater concentrations were much greater than base-flow concentrations were found in areas of high infiltration and oxic groundwater conditions. The lack of correspondingly high concentrations in the base flow of the paired surface-water sites may have multiple causes. In some settings, there has not been sufficient time for enough high-nitrate shallow groundwater to migrate to the nearby stream. In these cases, the stream nitrate concentrations lag behind those in the shallow groundwater, and concentrations may increase in the future as more high-nitrate groundwater reaches the stream. Alternatively, some of these sites may have processes that rapidly remove nitrate as water moves from the aquifer into the stream channel.

Partitioning streamflow and nitrate load between the quick-flow and base-flow portions of the hydrograph coupled with relative scales of soil permeability can infer the importance of surface water compared to groundwater nitrate sources. Study of the relation of nitrate concentrations to base-flow index and the comparison of groundwater nitrate concentrations to stream nitrate concentrations during times when base-flow index is high can provide evidence of potential nitrate transport mechanisms. Accounting for the surface-water and groundwater contributions of nitrate is crucial to effective management and remediation of nutrient enrichment in streams.

Introduction

Knowledge of the relative sources of streamflow is important because the concentration of nutrients is often different among the various sources and determining the source of nutrient loads is critical to the development of nutrient management strategies. The amount of water flowing in a stream (streamflow) is a complex result of climatic, physiographic, surface water, groundwater, and human-induced processes.

At any given point along a stream, the source of the water can include precipitation, surface runoff, groundwater discharge, interflow (that is, shallow subsurface flow), release from watershed storages (bank storage, wetlands, lakes), and human sources (reservoirs, point discharges, return flows) each with its own chemical signature. The change in streamflow and stream chemistry over time will reflect the cumulative effects of all of these factors.

Streamflow can be partitioned into two general classes of flow: quick flow, which consists of surface runoff and rapid interflow; and base flow, which consists of groundwater discharge, release from other watershed storages, and longer-term interflow (Maidment, 1993). Base flow traditionally has been attributed in large part to groundwater discharge, but it is important to note that groundwater may be only one component of base flow.

The term base flow also can refer to lower flow periods of an annual hydrograph. Nutrient conditions during these critical low-flow periods are important to the ecological health of streams and rivers. In this report, base flow refers to the portion of streamflow that has been partitioned or separated from the quick-flow component.

This report expands on the national synthesis of nutrient data collected as part of the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) program. Mueller and Spahr (2006) describe nutrient-data collection, processing, and analysis as well as annual nutrient conditions for a group of surface-water sites that the NAWQA program refers to as the “basic fixed sites.” This report describes nitrate loads and concentrations in surface-water base flow and shallow groundwater for selected basins upstream from basic fixed sites. Methods used to characterize the base-flow component of streamflow and nitrate load for a subset of sites in the basic fixed site network are described. The spatial distributions of nitrate load contributed by base flow and the concentration of nitrate for base-flow conditions are described at national and regional scales. Where groundwater nitrate concentrations are available, a comparison of base-flow nitrate concentration to shallow groundwater concentration is presented. The period of data collection varies between groups of NAWQA sites. This analysis uses available streamflow and nitrate data collected during water years 1990–2006.

Site Selection, Data, and Methods

NAWQA stream sites within the conterminous United States having drainage-basin areas less than 500 square miles were selected as the initial group of sites for analysis. Annual streamflow hydrographs for each site were screened for issues that may affect base-flow separation such as obvious flow regulation or tidal influences. Station and basin comments provided by NAWQA study unit personnel also were reviewed to determine suitability of sites for base-flow analysis. Based on these comments, sites with potential effect from wastewater treatment facilities or impoundments were excluded from analysis. Insufficient streamflow or nitrate data excluded additional sites resulting in 148 sites available for investigation (site names and numbers, and location information are listed in table 1 in the Supplemental Information section of this report). Streamflow and nitrate concentration data presented by Mueller and Spahr (2005) were updated for the selected sites with data from the USGS National Water Information System (accessed at *http://waterdata.usgs.gov/usa/nwis/*) to include any additional data for water years 1990–2006. Sites were classified by the percentage of major land use within the upstream basin according to the following criteria:

- Agricultural: greater than 50 percent agricultural land and less than or equal to 5 percent urban land;
- Urban: greater than 25 percent urban land and less than or equal to 25 percent agricultural land;
- Undeveloped: less than or equal to 5 percent urban land and less than or equal to 25 percent agricultural land;
- Mixed: All other combinations of urban, agricultural, and undeveloped land.

Base Flow

Hydrograph separation was used to determine the base-flow component of streamflow for the 148 sites. Several computer-based methods are available to estimate the base-flow component from daily streamflow records (Rutledge, 1998; Sloto and Crouse, 1996; Arnold and others, 1995; Wahl and Wahl, 1988). The base-flow index (BFI) computer program (Wahl and Wahl, 1988) (*http://www.usbr.gov/pmts/hydraulics_lab/twahl/bfi/index.html*, accessed July 2007), a hydrograph separation technique and one of the base-flow estimation programs developed by the USGS, was selected for use in this study. The BFI routine is based on a method developed by the Institute of Hydrology, United Kingdom (1980) and has been applied in a variety of hydrologic studies (for example, see Winter and others (1998); Garg and others, 2003; Tesoriero and others, 2009). The BFI program computes estimates of daily base flow and an average annual base-flow index (the ratio of base flow to total streamflow).

Halford and Mayer (2000) give a critical review of the use of hydrograph separation techniques for determining groundwater discharge and recharge. Issues regarding hydrograph separation identified by Halford and Mayer include the inability of hydrograph separation techniques to distinguish between groundwater discharge and water discharged from bank storage, wetlands, and surface-water bodies. Suggested alternative methods include the use of geochemical tracers and groundwater-flow models. Because of the broad geographic extent of the present study, however, hydrograph separation is the only viable option. Base-flow results presented in this report may not be entirely generated by groundwater discharge. It is also important to note that even in areas where groundwater discharge is important, streams are not always gaining and preferential flow paths as well as exchange of water in the hyporheic zone are important processes.

Daily streamflow data sets with complete water-year records were used as input to the BFI routine. The routine generates daily base-flow values for each day of the input data set. The base-flow index (annual base flow divided by annual total flow) was computed for each complete water year of data for each site. The number of years of streamflow data often exceeded the number of years of nitrate data and load estimates. Average base-flow index values were computed using available streamflow data for the 1990–2006 period as well as for the nitrate load estimation period, but it was found that the average base-flow index estimates did not change significantly when different periods were analyzed (data available in table 2 in the Supplemental Information Section of this report). Therefore, only the BFI values for the nitrate load estimation period were used in subsequent analyses. Neff and others (2005, p. 6) also note the stability of base-flow index values.

Nitrate Loads

Base flow and total flow nitrate loads were determined using multiple-regression analysis as implemented in the computer program LOADEST (Runkel and others, 2004). The dependent variable in each case was the natural logarithm of nitrate load, computed as the product of a measured concentration and the mean daily streamflow (or mean daily base flow) for the date of sample collection. Nitrate samples collected at the sites were classified as either base-flow or non-base-flow samples: a base-flow sample was one that was collected on any day when the base flow was 77 percent or more of the total flow (Langland and others, 1995). All nitrate samples were used to calibrate the total flow models, whereas only base-flow samples were used to calibrate the base-flow load models.

The explanatory (independent) variables for each model were selected from a set of potential predictor variables:

- natural logarithm of streamflow, log (flow)
- log (flow) squared
- time, in decimal years
- sine of time
- cosine of time
- time squared

Models were fit using all possible combinations of these variables, and the best model was selected on the basis of the Akaike Information Criteria (Akaike, 1981). The sine and cosine terms, which account for seasonality, were always included together if either was selected.

Because nitrate concentrations included censored values (values reported as less than the laboratory reporting level), regression coefficients were determined by an adjusted maximum-likelihood estimation (AMLE) method (Cohn and others, 1992). The AMLE method corrects for bias in the standard maximum-likelihood (MLE) regression coefficients and also incorporates a factor that minimizes the bias that can occur when estimated logarithms of constituent load are retransformed to original units.

The calibrated models along with daily streamflows and base flows at each site were used to estimate daily total nitrate loads and daily base-flow nitrate loads for available water years. Mean annual total loads and mean annual base-flow loads were then computed from the daily values. The period of record for load simulation varied from 1 to 16 years with an average of 6 years. The proportion of nitrate load contributed by base flow was determined from the ratio of base-flow load to total flow load. Flow-weighted mean nitrate concentrations in milligrams per liter (mg/L) for total flow and base flow were calculated by dividing the total load over the estimation time period by the total streamflow and the total base-flow load by the total base flow. This general method of streamflow and load partitioning has been used in other studies (Jordan and others, 1997; Bachman and others, 1998; Mullaney, 2007).

Shallow Groundwater Nitrate Concentrations

The NAWQA program assessed nutrients in groundwater within specific land-use settings. Land-use studies focused on shallow groundwater primarily within agricultural, urban, or undeveloped settings. Each study involved the sampling of about 20 to 30 randomly located wells within each targeted land-use area. To identify surface-water sites suitable for comparison to groundwater data, groundwater network locations were intersected with the basin upstream from the selected surface-water sampling sites using geographic information system (GIS) tools. Groundwater networks that intersected one of the 148 drainage basins and had a similar land-use classification were selected for comparison. A single nitrate sample from each well was used to calculate the network median nitrate concentration.

Statistical Analysis

Nonparametric statistical methods were chosen to test for differences among categories of base-flow index, load ratios, and concentrations. Differences among all categories were tested by using analysis of variance on the ranks of the data (Conover and Iman, 1981). If a significant difference was indicated by this test, differences between categories were evaluated by applying Tukey's multiple-comparison test (Helsel and Hirsch, 1992, p. 196) to the rank-transformed data. The multiple comparison test results are shown in conjunction with box plots displaying the distributions of the values. Box plots identified by the same letter indicate that the distributions are not significantly different. An alpha value of 0.05 was used to evaluate the significance of the test. If two letters are listed (for example, AB), the distribution is not significantly different from other distributions identified by either one of those letters.

Spearman's rho, a rank correlation coefficient, (Helsel and Hirsch, 1992, p. 217) was used as a measure of the significance of the relation between variables. A significant result indicates that rho is different from 0 at an alpha level of 0.05. In some graphical comparisons among variables a smooth line is used to depict the general shape of the relation. Locally weighted scatterplot (LOWESS) smoothing method (Helsel and Hirsch, 1992, p. 288) was used to generate the line.

Base-Flow Index

The base-flow index calculated for the 148 streams ranges from 0.04 to 0.98 with a median of 0.48, and values showed distinctive spatial distributions (fig. 1). Sites in the Southwest and the Northwest tend to have base-flow index values greater than 0.5. Sites in the Midwest and the eastern portion of the Southern Plains generally have values less than 0.5. Base-flow index values for sites in the Southeast and Northeast are mixed with values less than and greater than 0.5. The geographic distribution generally corresponds to a national map of base-flow index produced by Santhi and others (2008) using hydrograph separation based on a recursive digital filter and streamflow data from more than 8,600 streamflow-gaging stations. Exceptions include sites in Minnesota and parts of Georgia where Santhi and others estimated values greater than 0.5, whereas data for this report indicate values less than 0.5.

Climate, hydrogeology, and physiography contribute to differences in base-flow index. The hydrologic landscapes concept (Winter, 2001) can be used to understand some aspects of the geographic pattern in base-flow index values. Using GIS and statistical tools, Wolock and others (2004) generated hydrologic landscape regions for the conterminous United States at both 1-kilometer and 100-meter resolutions (D.M. Wolock and N. Nakagaki, U.S. Geological Survey, written commun., 2008; Wolock, 2003). The 20 hydrologic landscape regions (table 3, Supplemental Information Section of this report) are based on landscape and climatic characteristics that are assumed to affect hydrologic processes. Hydrologic landscape regions are not contiguous and the same region can occur in different parts of the country. The dominant hydrologic landscape region, mapped at the 100-meter resolution scale, was determined for the basin upstream from each site. The distribution of base-flow index values for sites in each hydrologic landscape region is shown in figure 2. Individual values rather than box plots are shown for regions that have 6 or fewer sites. Multiple comparison tests were not evaluated for base-flow index among the hydrologic landscapes due to the highly variable, and often low, number of sites. However, differences in base-flow index values are apparent for some regions. Region 2, which has permeable soils and bedrock, has greater values than regions such as region 6, which have impermeable soils and bedrock. Basin relief is one of the land-surface form characteristics used in the generation of hydrologic landscape regions (Wolock and others, 2004). Santhi and others (2008) show good correspondence between basin relief and base-flow index values and this is apparent in figure 2. Hydrologic landscape regions 15 - 20 represent mountainous areas. Sites located in landscapes 15 and 20 have somewhat greater median base-flow index values than sites found in the other landscape regions (fig. 2).

The 20 hydrologic landscapes were classified into four groups based on relative scaling of soil and bedrock permeability by Wolock and others (2004), to examine hydrologic processes and potential flow paths. This classification of relative bedrock permeability is based on lithologic groups of principal aquifers and bedrock permeability classes. Areas with no principal bedrock aquifer were assigned the lowest permeability class (Wolock and others, 2004).

This classification did not consider all of the shallow aquifers of glacial origin in the northern United States. This classification represents hypothetical flow paths; overland flow in areas of impermeable soils, shallow groundwater flow in areas of permeable soils, and deeper groundwater flow in areas with permeable bedrock. Santhi and others (2008) used a national base-flow index grid to determine mean base flow for each of the 20 hydrologic landscapes regions. They compared the hydrologic response in each hydrologic landscape region to the hypothesized response for each region based on relative scaling of soil and bedrock permeability developed by Wolock and others (2004). They concluded that the hypothesized hydrologic response was reasonable for large-scale analysis but further refinement of hydrologic landscape regions may be required for local scale study.

Each site was classified using these relative permeability categories and the distribution of sites within the four categories as well as the distribution of base-flow index values within each category is shown in figure 3. Although there is significant variability, sites in areas with impermeable soils and bedrock (areas where overland flow may be the primary hydrologic flow path) tend to have lower base-flow index values than sites in areas with either permeable bedrock or permeable soils (areas where deep groundwater flow paths or shallow groundwater flow paths may occur, the second and third categories in figure 3). Within this data set, the relative rankings of bedrock and soil permeability do not differentiate the base-flow index for areas with potential deep groundwater flow from areas with potential shallow groundwater flow (the second and third categories in figure 3). The fourth category in figure 3, representing sites with potential for both shallow and deep groundwater flow paths, are not statistically different from any of the other categories. Additional basin characteristics, such as relief, refinement of permeability categories, and a much greater number of sites may be needed to further categorize the base-flow generation processes. However, areas with impermeable soils and bedrock are areas where overland flow could be the primary hydrologic flow path and groundwater/surface-water interactions may be limited.

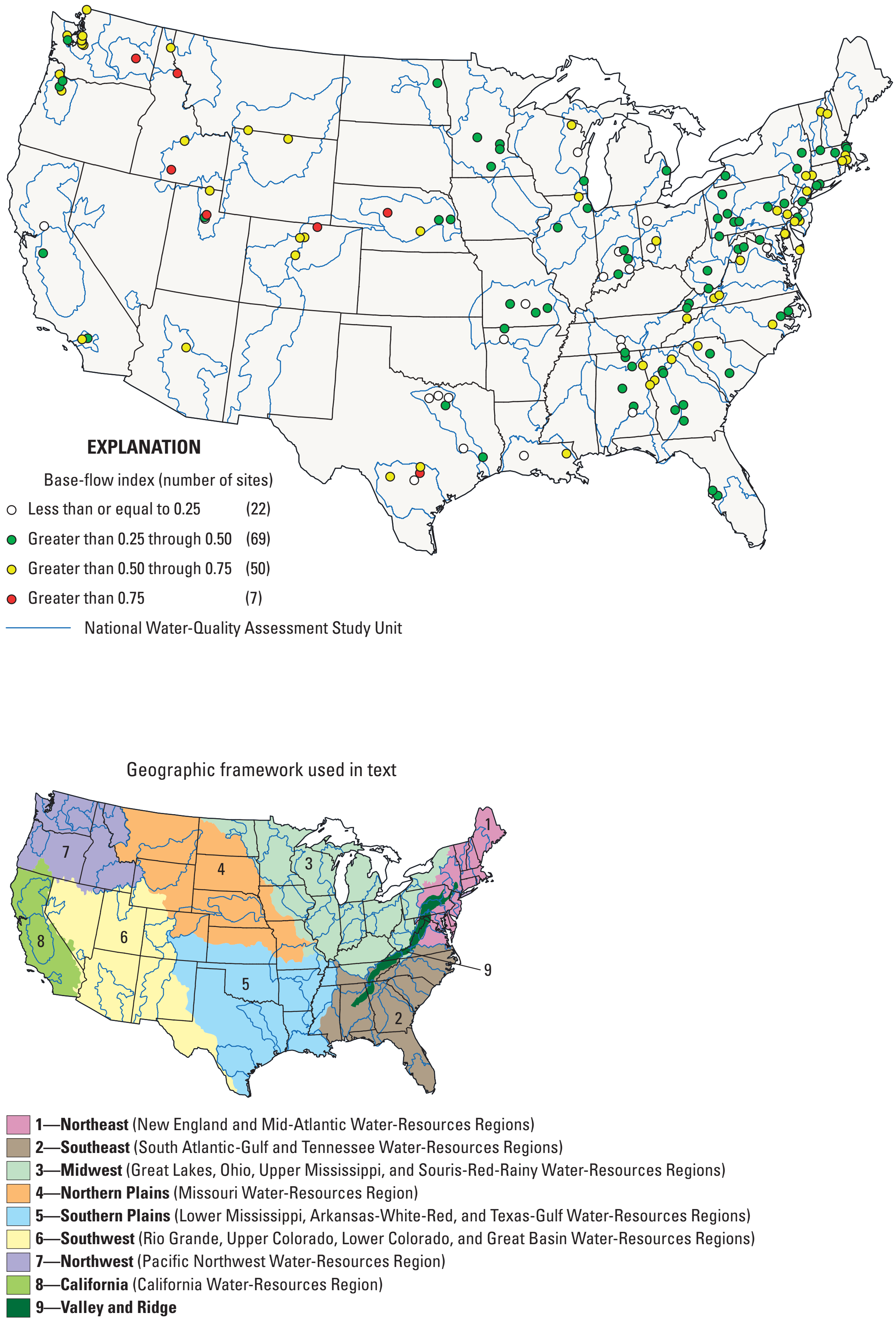

Figure 1. Base-flow index for selected National Water-Quality Assessment sampling sites.

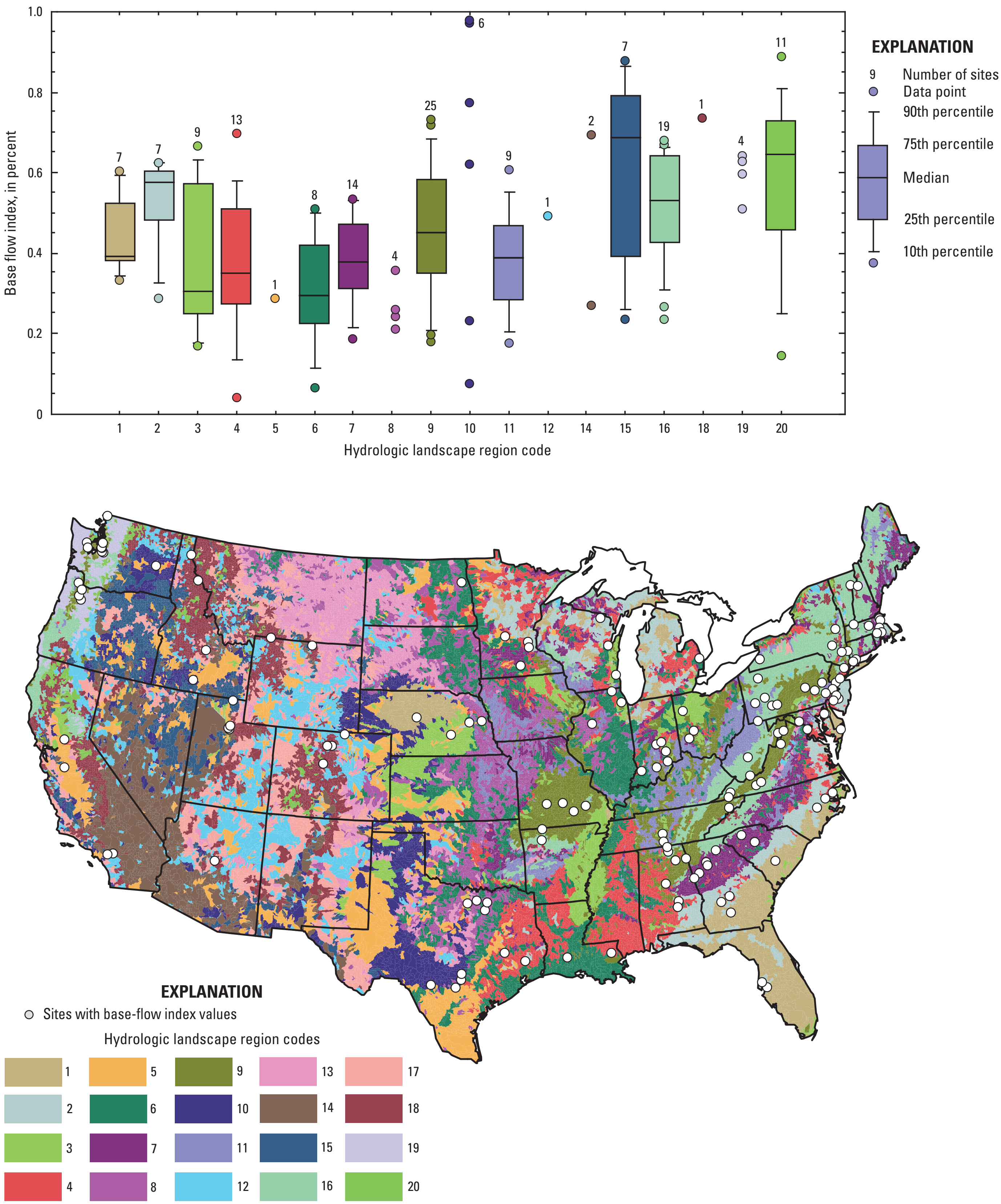

Figure 2. Distribution of base-flow index by hydrologic landscape regions.

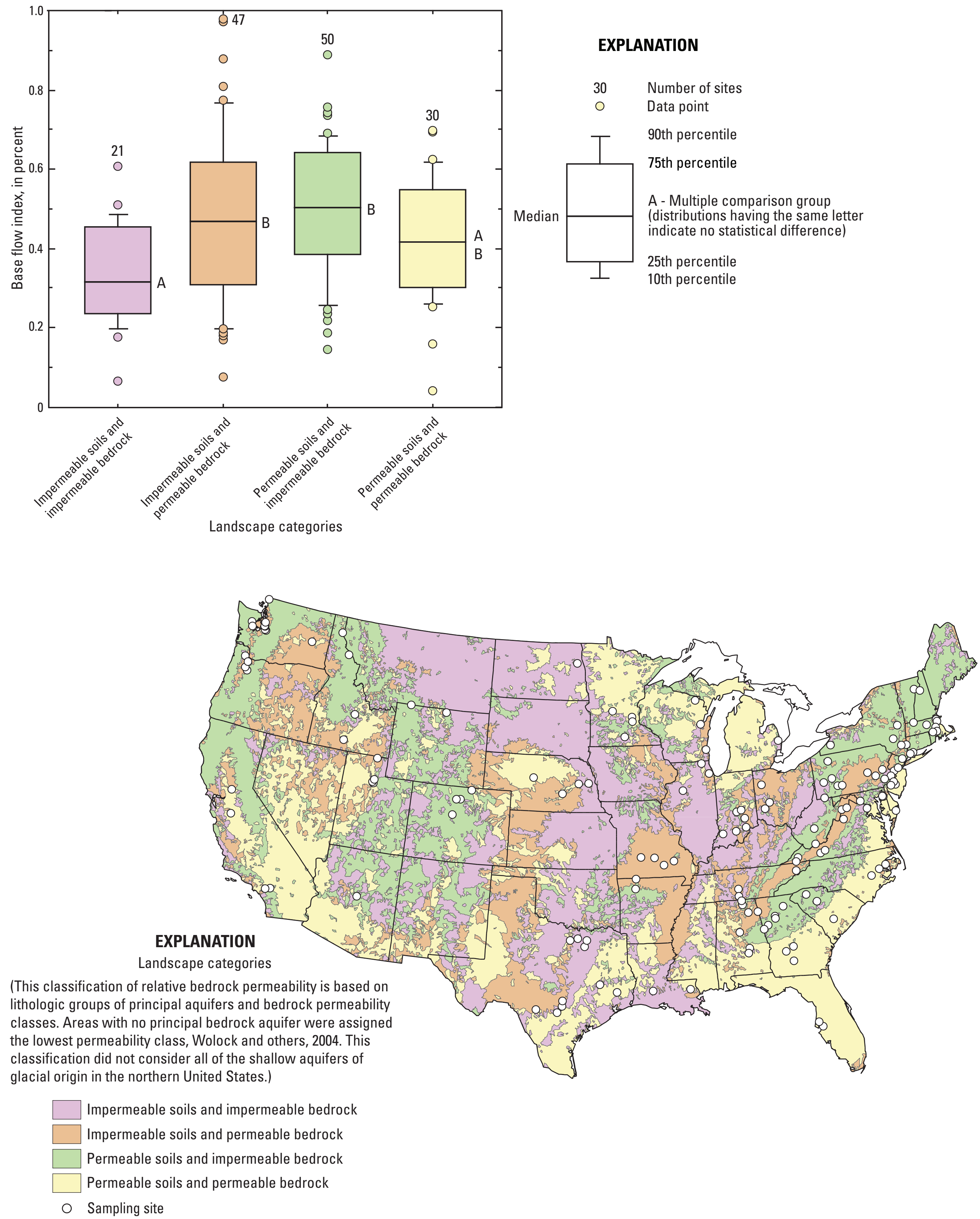

Figure 3. Distribution of base-flow index by categories of hydrologic landscape regions.

Base-Flow Nitrate Loads

The proportion of nitrate load contributed by base flow, determined as the ratio of base-flow load to total flow load multiplied by 100, ranged from about 3 to 98 percent with a median of 44 percent (nitrate load ratio data are listed in table 4 in the Supplemental Information Section of this report). The distribution of nitrate load ratios can be described spatially, and hydrologic landscape regions provide a framework to assess the observed patterns.

Geographic Distribution of Nitrate Load Ratios

Many streams in the country have a large proportion of nitrate load contributed by base flow: 40 percent of the sites have more than 50 percent of the total nitrate load contributed by base flow (fig. 4). Sites in the Midwest and eastern portion of the Southern Plains generally have less than 50 percent of the total nitrate load contributed by base flow (fig. 4). Sites in the Northern Plains and Northwest have nitrate load ratios that generally are greater than 50 percent. Nitrate load ratios for sites in the Southeast and Northeast are mixed with values less than and greater than 50 percent. Although broad regional patterns are somewhat evident, smaller cluster of sites are distinct where similar processes result in similar proportions.

Sites in the Trinity River Basin of eastern Texas typically have less than 25 percent of their nitrate load contributed by base flow (fig. 4). The low base-flow proportion at these sites results from periods of extremely low flow with low nitrate concentrations followed by short duration runoff events with greater nitrate concentrations (Land and others, 1998). The concentration discharge relation for Clear Creek (a site in the Trinity River Basin), for example, shows greater nitrate concentrations during high flows and relatively low concentrations during base-flow periods (fig. 5) Base-flow contribution to the nitrate load for Clear Creek is less than 10 percent.

Sites in the eastern portion of the Midwest (Indiana and Ohio) also have low base-flow nitrate load ratios. Five of the nine sites in Indiana and Ohio have base-flow nitrate load ratios less that 25 percent (fig. 4). Base-flow index values for these sites also are low, less than 32 percent. The relatively low contributions of groundwater to in-stream nitrate loads can result from the use of tile drains, a common agricultural practice in much of the Midwest. Fenelon (1998) describes the higher nitrate concentrations found in streams when tile drains are flowing as a result of the drainage system intercepting nitrate-rich shallow groundwater (fig. 6). The shortened flow paths, created by drainage systems, result in much of this water being proportioned into the quick-flow component during hydrograph separation. When tile drains go dry, stream nitrate concentrations in Sugar Creek reflect the typically low concentrations found in deeper aquifers contributing to base flow (Fenelon, 1998).

Seven sites located in the Valley and Ridge physiographic province running from northern Alabama through Tennessee, Virginia, Maryland, and Pennsylvania have more than 50 percent of the nitrate load contributed by base flow (fig. 4). Base-flow nitrate contribution is more than 70 percent for 4 of these sites, which are underlain by the Valley and Ridge carbonate aquifers. Although characteristics vary within the Valley and Ridge carbonate aquifers, they generally are considered unconfined with karst features including sinkholes, springs, and caverns (Lindsey and others, 2009). The karst and solution features result in aquifers that are susceptible to contamination (Hampson and others, 2000) as well as extensive interaction between groundwater and surface water. The site on Tulpehocken Creek, located in an agricultural area of eastern Pennsylvania (the northern most of the indicated Valley and Ridge sites on figure 4, part of the Delaware River Basin), has 78 percent of the nitrate load contributed by base flow, as well as, a high base-flow index of 0.73. Nitrate concentrations are relatively high and invariant at low and moderate flows, and decrease during high-flow conditions (fig. 7).

Many sites with snowmelt-dominated hydrology (such as Tongue River, Soda Butte Creek, and Big Thompson River) have base-flow nitrate load ratios greater than 50 percent (fig. 4). Nitrate concentrations at these sites typically are low (tenths of milligrams per liter) but are at least twice as large at low flow, during the non snowmelt-runoff period, than during moderate- and high-flow periods (fig. 8). The higher concentrations during base-flow periods coupled with base-flow index values greater than 50 percent results in high base-flow load percentages.

Areas where streamflow is derived principally from groundwater have a large proportion of the nitrate load contributed by base flow. The Sandhills region of central Nebraska, represented by the Dismal River (fig. 4), is an area with where little runoff occurs because nearly all of the precipitation infiltrates directly to groundwater (Frenzel and others, 1998). Streamflow is almost entirely generated by groundwater discharge resulting in a base-flow nitrate load contribution of about 98 percent. Nitrate concentrations have little variation with changes in streamflow at the Dismal River site (fig. 9). Streamflow in the Comal River, in south central Texas, primarily is from Comal Springs which discharges from the Edwards aquifer (Ging and Otero, 2003). The base-flow nitrate load ratio about 98 percent, and the relation between concentration and streamflow is also relatively invariant (fig. 9).

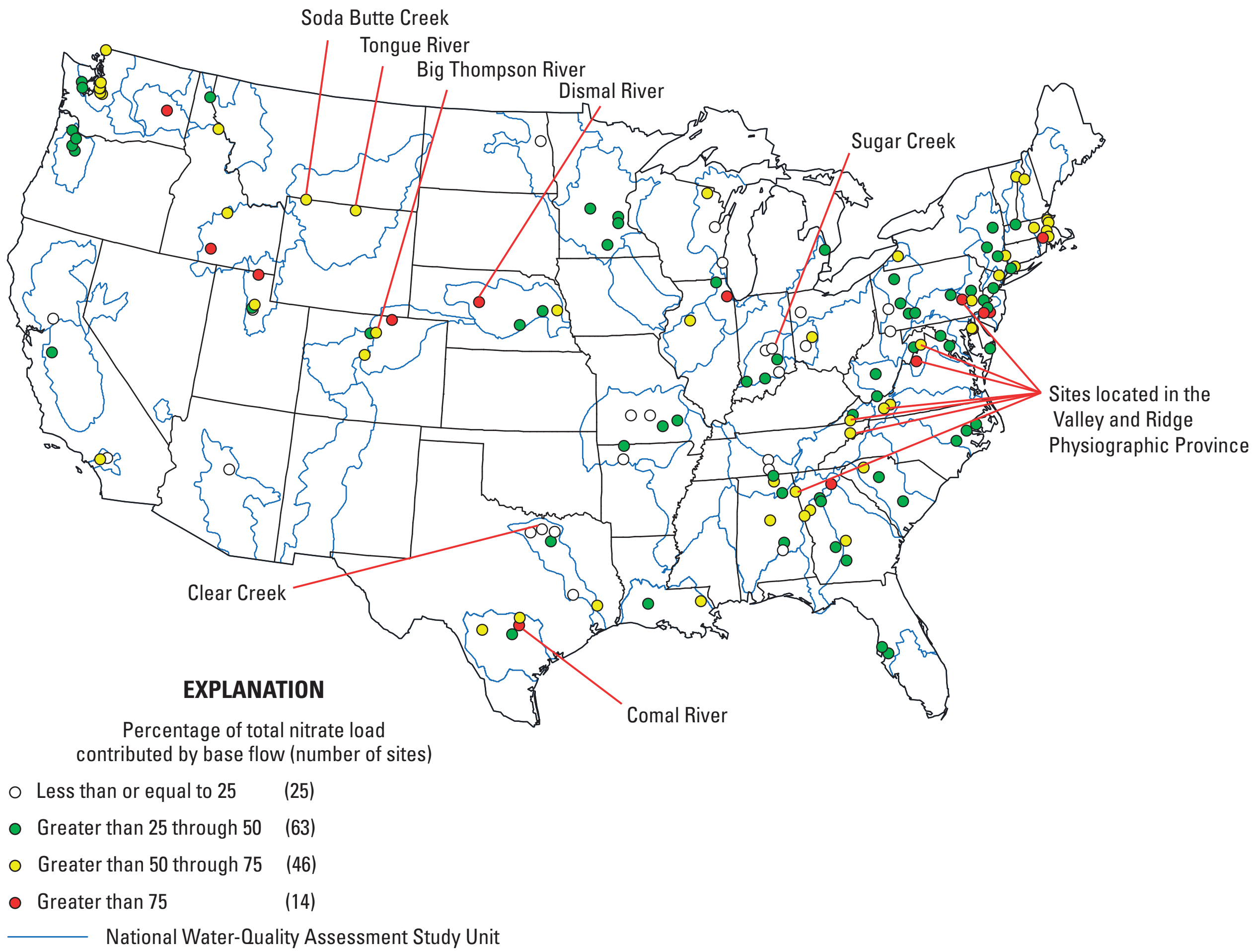

Figure 4. Percentage of total nitrate load contributed by base flow (nitrate load ratio) for selected National Water-Quality Assessment sampling sites.

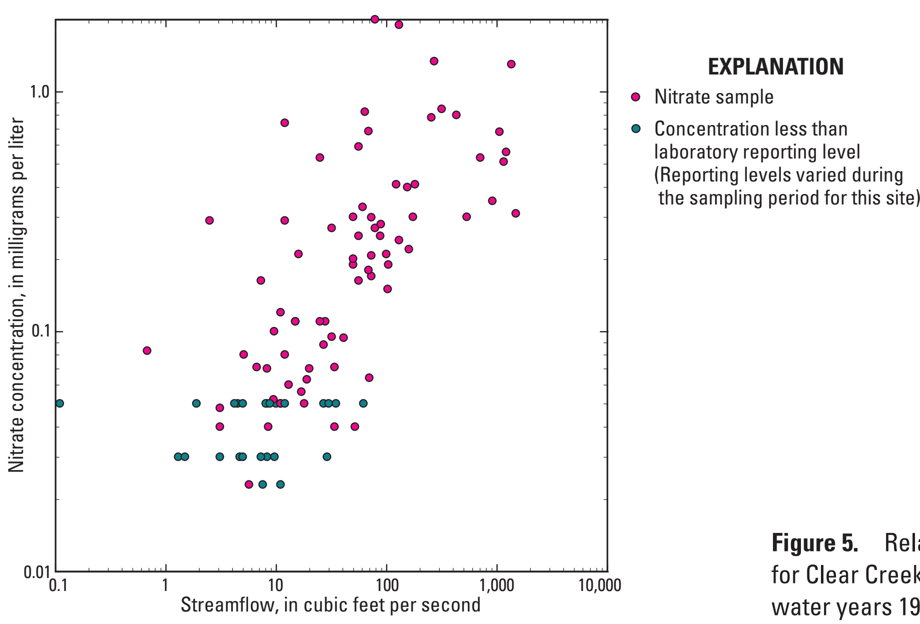

Figure 5. Relation of nitrate concentration to streamflow for Clear Creek near Sanger in the Trinity River Basin, Texas, water years 1993–2005.

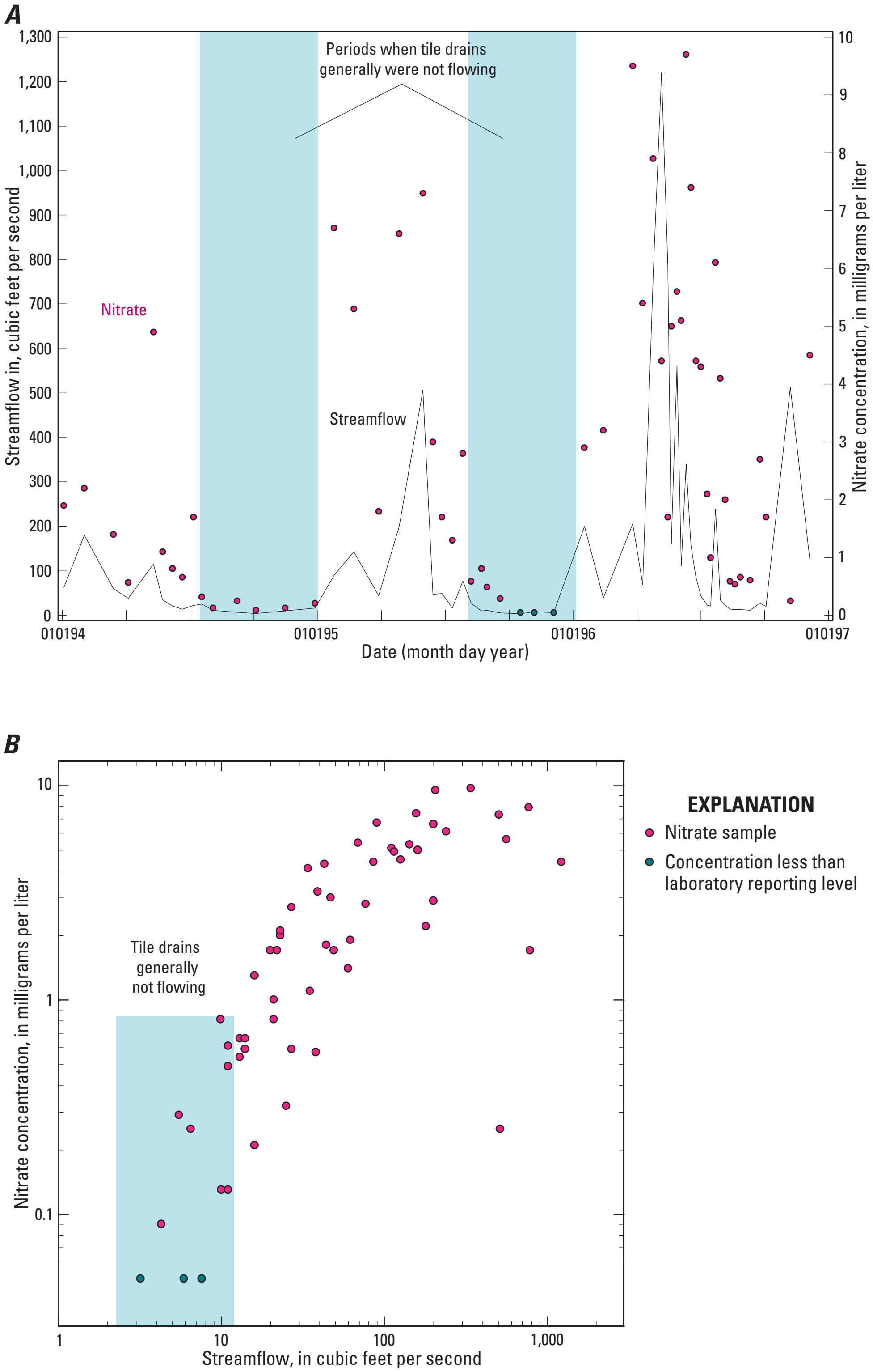

Figure 6. The relation of (*A*) streamflow and nitrate concentration to time for Sugar Creek at New Palestine, Indiana (modified from Fenelon, 1998), and (*B*) nitrate concentration and streamflow for the same time period.

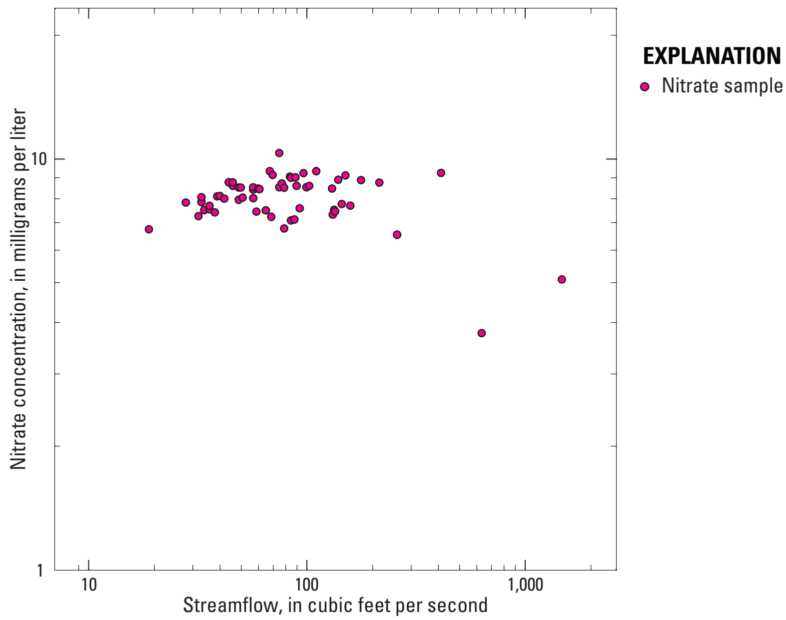

Figure 7. Relation of nitrate concentration and streamflow for Tulpehocken Creek near Bernville, Pennsylvania, where 78 percent of the nitrate load is contributed by base flow, water years 1999–2001.

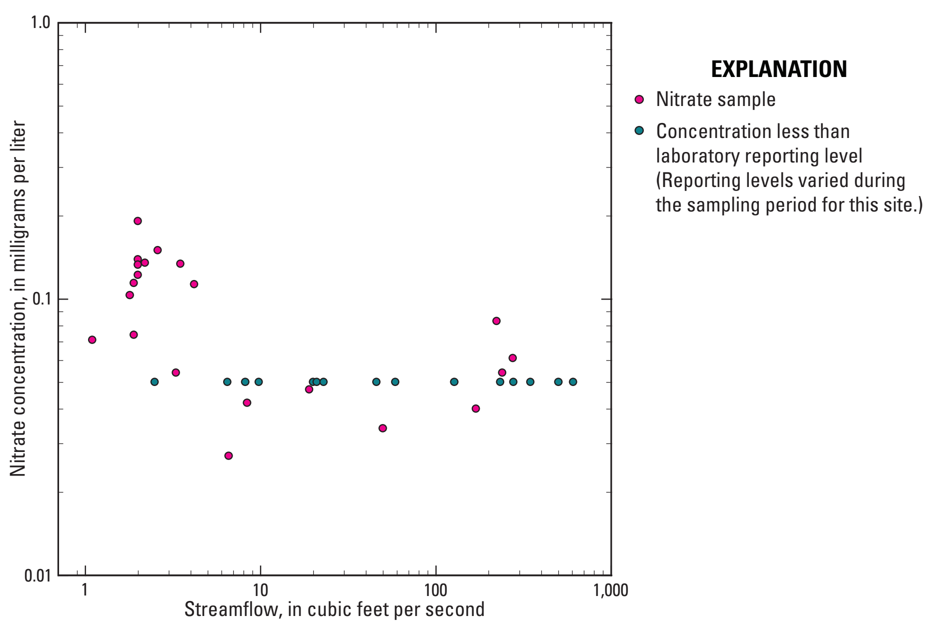

Figure 8. Relation of nitrate concentration and streamflow for Soda Butte Creek near Silvergate, Montana, a typical snowmelt-runoff site, water years 1999–2001.

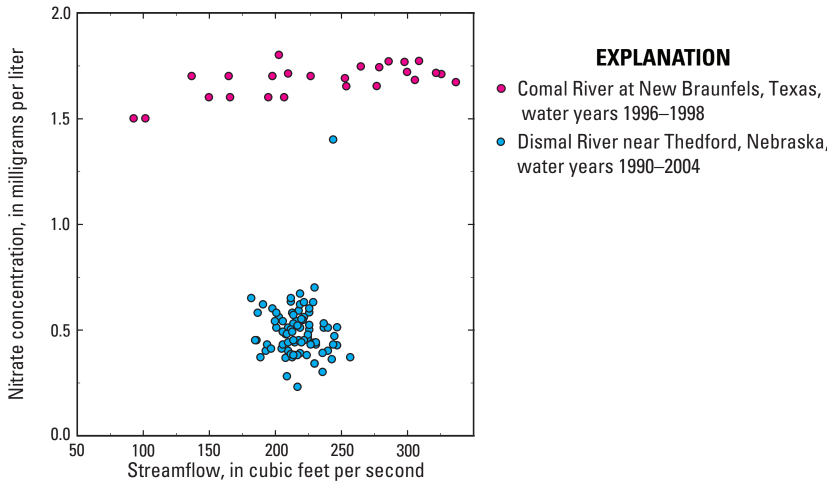

Figure 9. Relation of nitrate concentration and streamflow for two sites where streamflow and nitrate load are almost entirely contributed by groundwater discharge.

Regional Processes Affecting Base-Flow Loads

Climate, soils and bedrock permeability, and land-surface slope are among the many landscape characteristics that affect the mode of transport of nitrate from sources in a landscape to a stream. As with the base-flow index values (fig. 3), the effect of the characteristics of contrasting hydrologic landscapes on the sources of nitrate loads in streams was evaluated by grouping sites into one of four landscape categories: landscapes with permeable soils and permeable bedrock, landscapes with permeable soils and impermeable bedrock, landscapes with impermeable soils and permeable bedrock, and landscapes with impermeable soils and impermeable bedrock (Wolock and others, 2004). While there is a large amount of variability within each group, a significantly lower proportion of the nitrate load is derived from base flow at sites in areas with impermeable soils and impermeable bedrock than in the other landscapes (fig. 10). These sites tend to have lower base-flow index values as shown in figure 3. Additionally, the nitrate concentrations are lower during base-flow conditions as compared to higher flow periods for the majority of these sites.

Landscapes with impermeable soils and impermeable bedrock are areas where overland flow is the dominant mechanism of streamflow generation. Landscapes with these characteristics are common in the productive agricultural land in the Midwest and eastern portions of the Northern and Southern Plains (fig. 1). These areas, as well as similar areas where the majority of the nitrate load in streams is not delivered by base flow, could be most responsive to nutrient management practices designed to reduce nutrient transport to streams by runoff. Conversely, in areas where a large proportion of the stream nitrate load is derived from base flow, which is derived primarily from groundwater, changes in nutrient management focused on transport by runoff will have less effect on stream loads. Rather, changes in nutrient management could include consideration of contributions from groundwater in these areas, and improvements in stream nitrate concentrations will not take place until the nitrate concentration in the groundwater reaching the stream decreases. As with base-flow index, the relative ranking of bedrock and soil permeability does not differentiate nitrate base-load proportion in categories with some degree of permeable soils or bedrock (the three categories on the right in the figure 10 box plot). These categories—representing a deep groundwater component, a shallow groundwater component, and a combination of deep and shallow groundwater contributions of nitrate—are not statistically different. Refinement of permeability and landscape categories may be necessary to further categorize the base-flow nitrate load contribution.

Annual variations in streamflow (wet or dry cycles) could affect the relative proportions of the sources of streamflow and thus the nitrate load ratios. To investigate the effect of changes in streamflow volume on nitrate load ratios, Spearman correlation coefficients between annual nitrate load ratio and mean annual streamflow were determined for each of the 68 sites that had 5 or more years of simulated loads. Seventy-eight percent of these sites had no significant correlation. All but 2 of the 15 sites with statistically significant correlations between nitrate load and streamflow had negative rho values (higher streamflow periods resulted in lower proportion of nitrate contributed during base-flow periods). These 15 sites are located throughout the country and throughout the hydrologic landscape categories. While it appears that there is potential to bias load-ratio results when data only are available for wet or dry periods, the problem for this data set is not extensive.

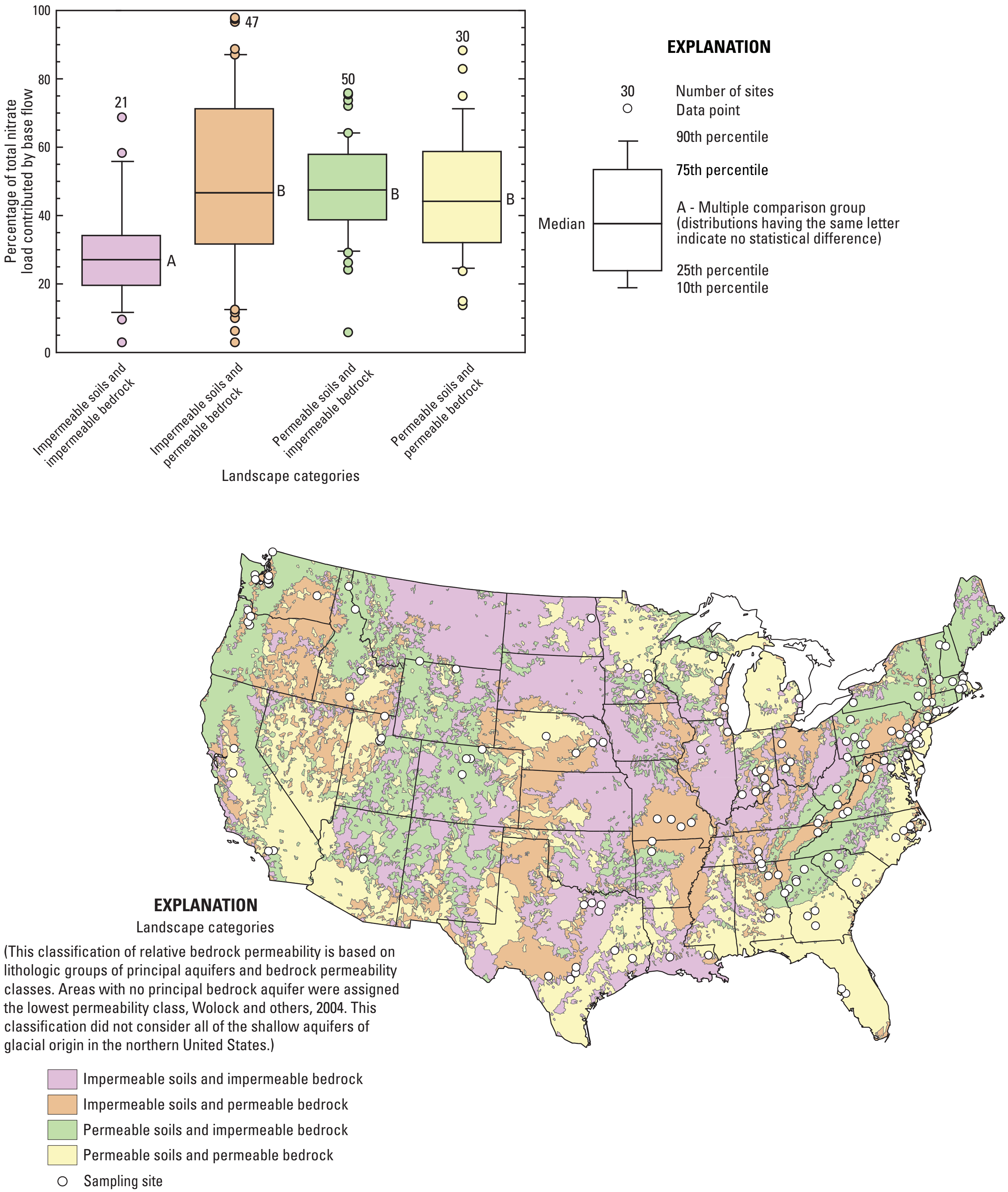

Figure 10. Distribution of nitrate load percentage by hydrologic landscape categories.

Nitrate Concentrations in Surface-Water Base Flow and Shallow Groundwater

Mean annual base-flow nitrate concentrations were determined by dividing the base-flow nitrate load for the estimation time period by the base-flow streamflow. Land use, and the associated nonpoint sources of nutrients, were used to assess the distribution of base-flow nitrate concentrations. Comparison of nitrate concentrations in surface-water base flow to shallow groundwater-nitrate concentrations can indicate potential pathways of the movement of nitrogen to streams, and illustrate the potential effect of the movement of shallow groundwater to streams.

Nitrate Concentrations in Surface-Water Base Flow

The spatial distribution of base-flow nitrate concentrations follow the same general patterns as that described for nitrogen in the Nation's streams (Mueller and Spahr, 2006) (fig. 11, concentration data are given in table 5 in the Supplemental Information Section of this report). Higher concentrations are found in areas of higher nutrient sources: the greatest concentrations of total nitrogen and nitrate nitrogen were found at agricultural sites in the Midwest, Northeast, and Northwest areas of the country, and the relatively lower concentrations were found at undeveloped sites throughout the country (Mueller and Spahr, 2006). A comparison among land-use categories shows that concentrations are greatest at agricultural sites followed by the mixed, urban, and undeveloped categories (fig. 12). Sites in undeveloped areas have significantly lower concentrations than sites located in developed areas. The relative ranking in the distributions of concentrations by land-use category is similar to that presented by Mueller and Spahr (2006, page 29). However, sites with known point source discharges were removed from the analysis in the present report resulting in lower overall distributions for the urban and mixed land-use categories. As with total flow nitrate concentrations, the distributions of base-flow concentrations depend on nutrient sources and transport mechanisms. One mechanism that can be important is surface-water/groundwater interactions.

Comparison of Nitrate Concentrations in Surface-Water Base Flow and Shallow Groundwater

Networks of monitoring wells established to investigate land-use effects on nutrient conditions in groundwater were selected to compare to surface-water conditions for 27 of the 148 sites. The mean annual base-flow nitrate concentrations were compared with the network median nitrate concentrations in shallow groundwater for these 27 sites (fig. 13, concentration data given in table 6 in the Supplemental Information Section of this report). Although the nitrate concentrations in base flow and shallow groundwater are often similar, nitrate concentrations in groundwater are more often greater than nitrate concentration in base flow for this group of sites (fig. 13). Areas where the contrast between elevated groundwater concentration and low base-flow concentration are greatest commonly have both permeable soils and permeable bedrock, conditions that enhance infiltration of water. Most of these areas also have groundwater that is predominantly oxic, the chemical environment in which nitrate is stable. These characteristics—high infiltration and oxic conditions—favor nitrate transport and persistence in groundwater. The lack of correspondingly high concentrations in the base flow of the paired surface-water sites may have multiple causes. In some settings, there has not been sufficient time for enough high-nitrate shallow groundwater to migrate to the nearby stream. In these cases, the stream nitrate concentrations lag behind those in the shallow groundwater, and concentrations may increase in the future as more high-nitrate groundwater reaches the stream. Alternatively, some of these sites may have processes that rapidly remove nitrate as water moves from the aquifer into the stream channel. For example, high denitrification rates in the riparian sediments along Fishtrap Creek remove nitrate from groundwater before it enters the stream (Tesoriero and others, 2000).

Three sites where base-flow concentrations are elevated, yet median groundwater concentrations are low, occur in areas with impermeable soils and impermeable bedrock (Black River, Kessinger Ditch, and Nippersink Creek in figure 13). These sites are in agricultural or mixed land-use areas in the Midwest with large nitrogen input from fertilizer, and with subsurface tile drainage systems (Natural Resources Conservation Service, 1995). In these areas, nitrate concentrations in groundwater are highly variable, and decrease greatly with depth from a maximum of 17 mg/L in shallow oxic groundwater near the water table, to consistently less than the laboratory reporting level in samples from greater than 25 feet below the water table. The high nitrate concentrations in the base-flow samples at these sites likely represent a combination of contributions of high nitrate water from the recession period of subsurface tile drainage during the wetter winter and spring seasons and moderate nitrate concentrations resulting from the discharge of a mixture of shallow high-nitrate groundwater and deeper low-nitrate groundwater during the drier summer and fall seasons when drains rarely flow. Despite the contribution of some nitrate load during base flow, at these sites overland flow and tile drainage is the predominant source of streamflow and nitrate load (base-flow nitrate load ratios of 44 percent or less).

Nitrate concentrations are elevated in both base flow and shallow groundwater in the vicinity of Tulpehocken Creek (fig. 13). This site is located in an agricultural area of eastern Pennsylvania with highly permeable underlying rocks (Fischer and others, 2004). Manure from livestock operations

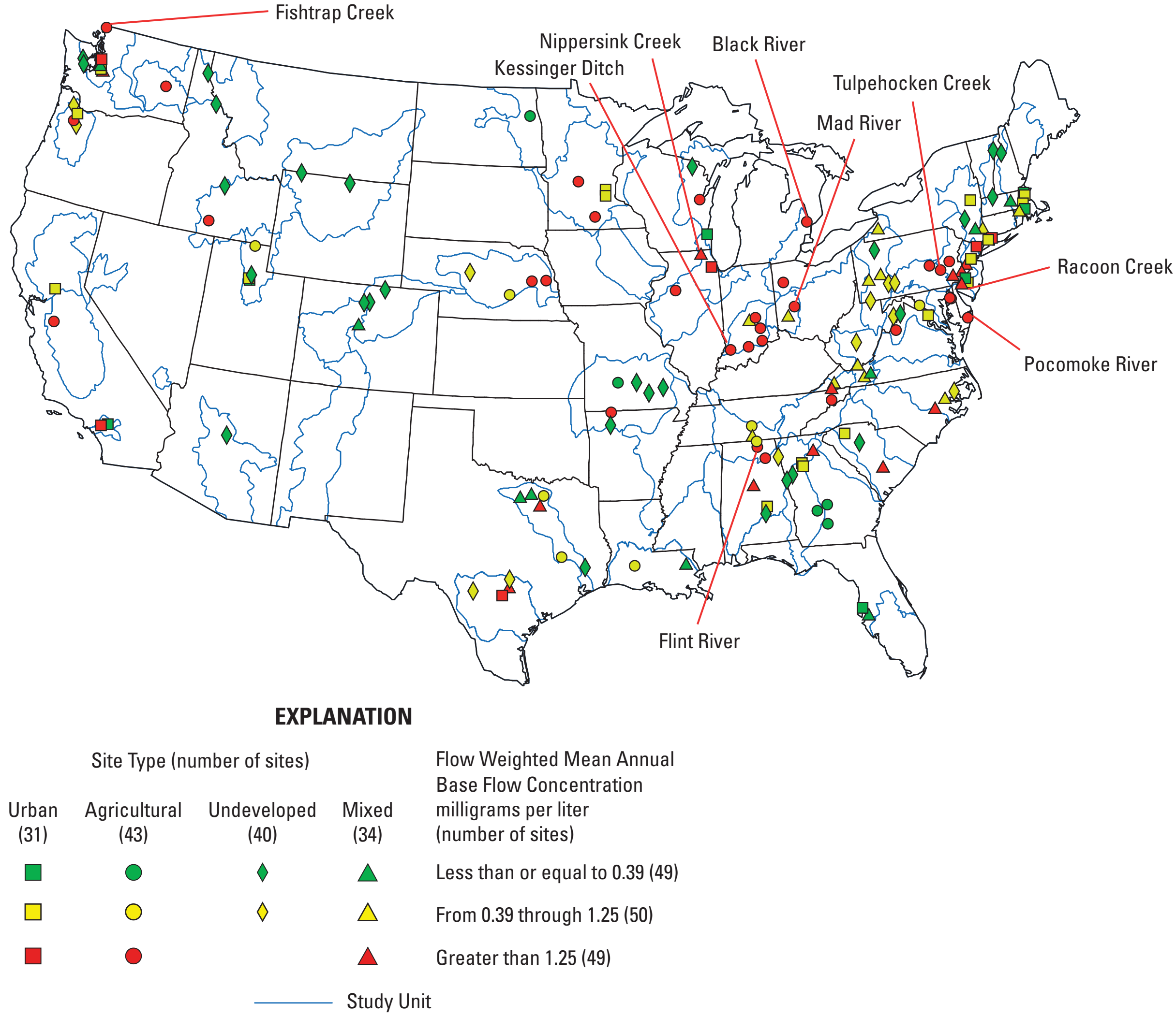

Figure 11. Spatial distribution of mean annual base-flow nitrate concentrations.

commonly is applied to farm fields in this area. Lindsey and others (1998) describe the rapid infiltration of nitrate from fertilizer and manure in other agricultural areas of Pennsylvania with similar shallow and highly permeable bedrock. The correspondence between groundwater and base-flow nitrate concentrations indicates a fairly rapid and unattenuated transport of nitrate in groundwater to this stream.

Tesoriero and others (2009) used the relation of concentration and base-flow index to identify nutrient sources. They demonstrated that for sites where base flow generates a large component of the nitrate load, a groundwater source of nitrate is indicated by the combination of a positive correlation between nitrate concentration and base-flow index corresponding to the date of sampling and the correspondence between groundwater concentrations and the concentration in streams during periods with high base-flow index values. This type of relation was observed in the current study for some sites (Tulpehocken Creek and the Flint River, fig. 14). However other types of relations also were observed. For example, the Mad River has more than 60 percent of the nitrate load contributed during base-flow conditions but concentrations of nitrogen associated with quicker-flow sources (lower base-flow index values) can have elevated concentrations. The relation can become more complex for sites with less than 50 percent of the load contributed during base-flow conditions and reverse for sites where base flow contributes a minor portion of the nitrate load (Pocomoke River and Black River, fig. 14). Stream nitrate concentrations at high base-flow index values are substantially lower than the median concentration in shallow groundwater for the Racoon Creek site (fig. 14). This lack of correspondence was noted for other sites in the Atlantic Coastal Plain and indicates denitrification in the aquifer near the streams or by in-stream processes (Ayers and others, 2000).

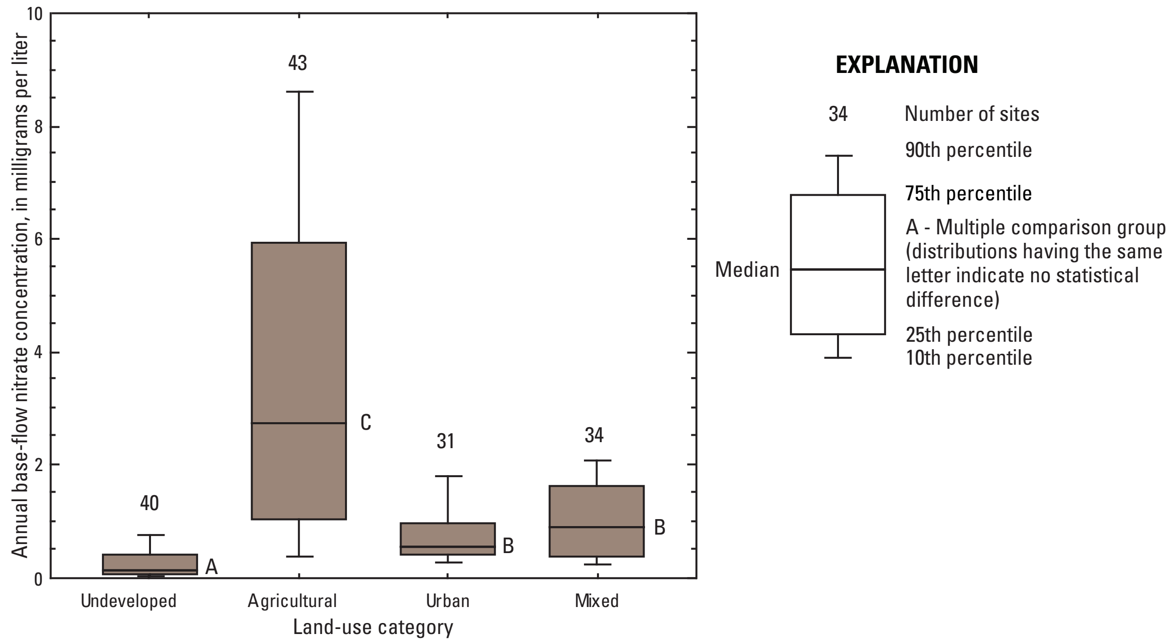

Figure 12. Distribution of surface-water base-flow nitrate concentrations by land-use category.

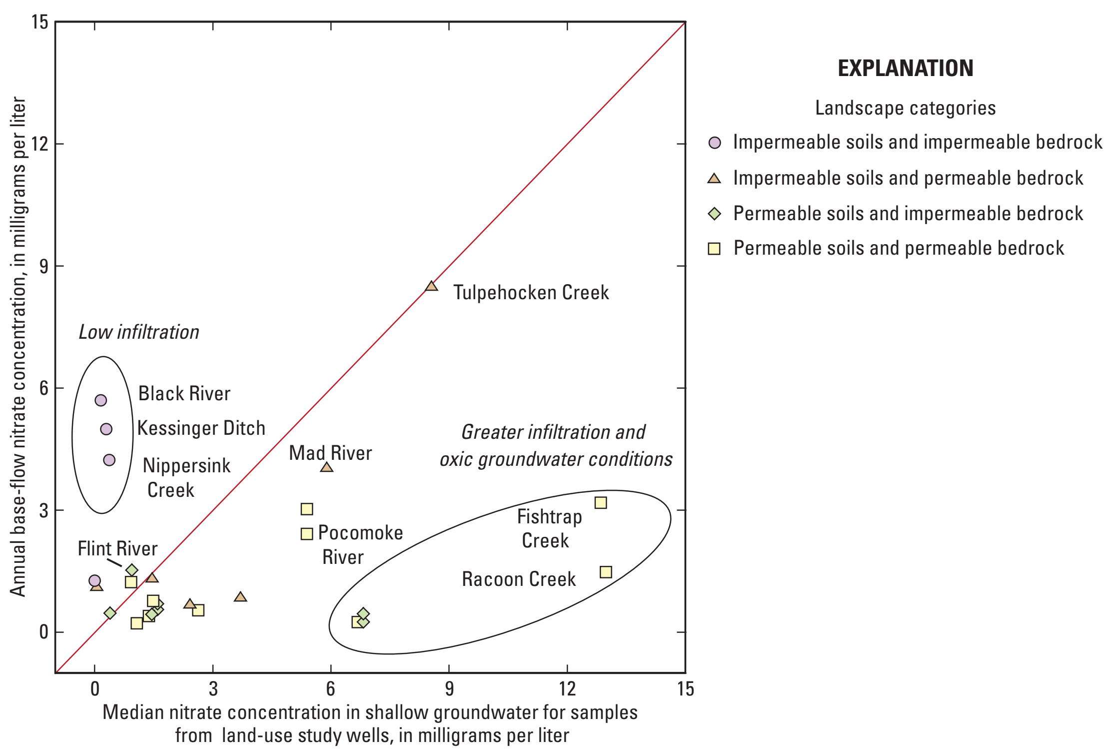

Figure 13. Comparison of nitrate concentrations in base flow and shallow groundwater for selected National Water-Quality Assessment sampling sites.

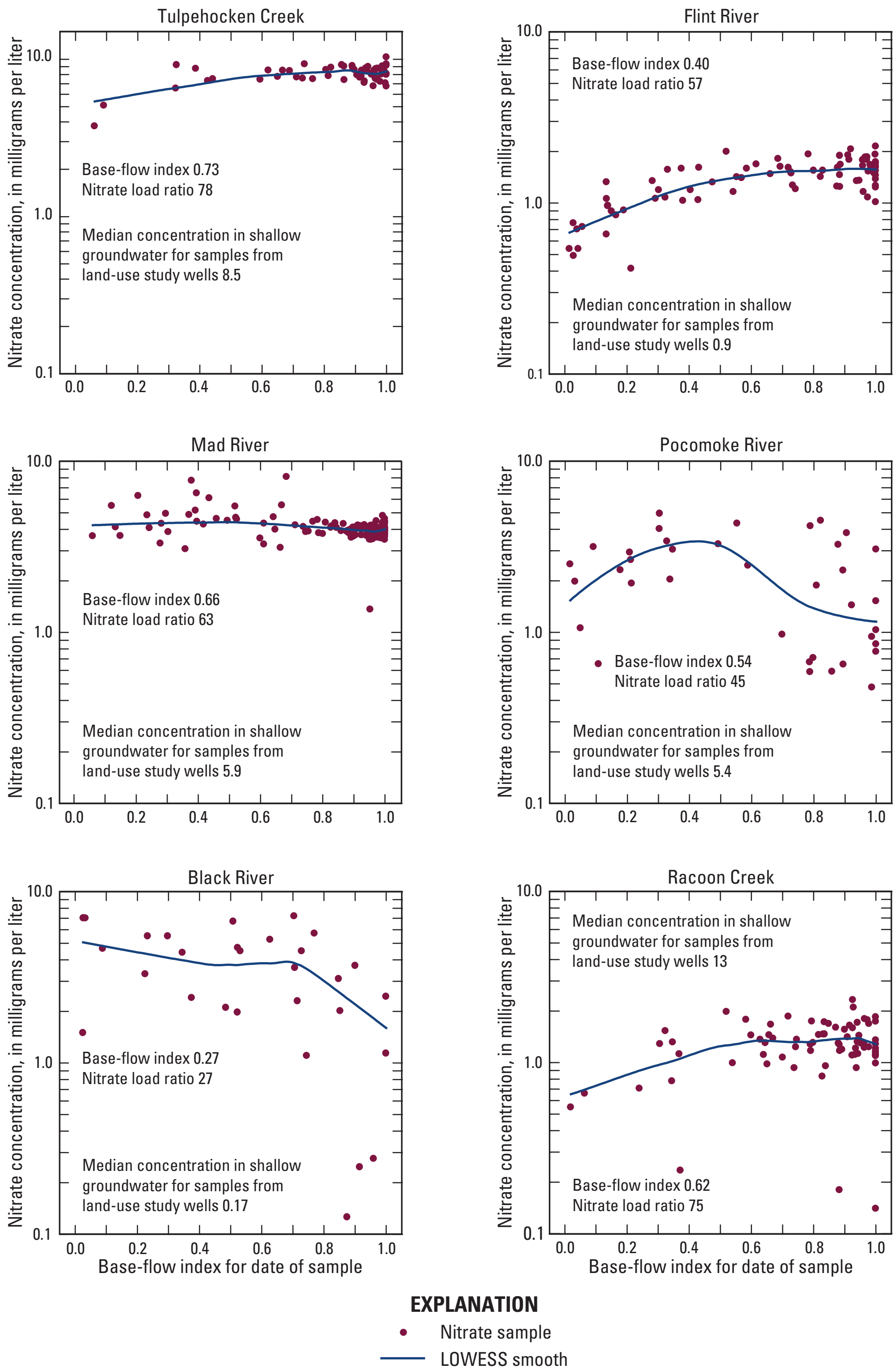

Figure 14. Relation of concentration to base-flow index corresponding to the date of sampling for selected National Water-Quality Assessment sampling sites.

Tesoriero and others (2009) further compared the concentrations near the end of these relations (high base-flow index values) to concentrations found in streambed pore water, riparian zone, and upland groundwater to infer flow-path mechanisms. The similarity in groundwater-nitrate concentrations and base-flow nitrate concentrations coupled with the lack of correspondence between base-flow nitrate concentrations and pore-water nitrate concentrations indicate preferential groundwater-flow paths as the source of nitrate during base-flow conditions (Tesoriero and others, 2000). Extensive flow-path data, such as pore-water concentrations and riparian zone concentrations, routinely were not collected as part of the NAWQA basic fixed site network and is unavailable for the current study. Groundwater-flow paths, preferential flow paths, hyporheic zone conditions, riparian zone processes, artificial drainage, runoff, biologic uptake, and nitrogen sources are among the many processes that make comparison of surface-water and groundwater nitrate concentrations a complex problem.

Partitioning streamflow and nitrate load between the quick-flow and base-flow portions of the hydrograph coupled with relative scales of soil permeability can infer the importance of surface-water compared to groundwater nitrate sources. Study of the relation of nitrate concentrations to base-flow index and the comparison of groundwater nitrate concentrations to stream nitrate concentrations during times when the base-flow index is high can provide evidence of potential nitrate transport mechanisms. These tools, regional study of the relative importance of surface-water compared to groundwater contributions of nitrate, and further integration of surface-water and groundwater data collection networks can assist in the selection of appropriate nutrient management strategies. Accounting for the surface-water and groundwater contributions of nitrate is crucial to effective management and remediation of nutrient enrichment in streams.

Summary

Concentrations of nutrients in streams vary with the source of streamflow. Knowledge of the contribution of base flow to the nutrient load can assist in determining the applicability of nutrient management strategies. Sites with drainage areas less than 500 square miles that were sampled as part of the basic-fixed site network for the NAWQA program were selected for investigation. Based on comments from NAWQA study unit personnel, sites with potential effect from wastewater treatment facilities or impoundments were excluded from analysis.

Hydrograph separation techniques were used to determine the ratio of base flow to total flow (base-flow index) for the 148 sites. Sites in the Southwest and the Northwest tend to have base-flow index values greater than 0.5. Sites in the Midwest and the eastern portion of the Southern Plains generally have values less than 0.5. Base-flow index values for sites in the Southeast and Northeast are mixed with values less than and greater than 0.5. Categories of hydrologic landscapes based on soil and bedrock permeability explain some of the differences found in base-flow index. Areas with impermeable soils and impermeable bedrock tend to have lower base-flow index values. These are areas where overland flow may be an important hydrologic flow path.

The percentage of total nitrate load contributed by base flow was determined by developing total flow and base-flow nitrate load models. These regression-based models were calibrated using available nitrate samples and total streamflow or base-flow nitrate samples and the base-flow component of total streamflow.

Many streams in the country have a large proportion of nitrate load contributed by base flow: 40 percent of sites have more than 50 percent of the total nitrate load contributed by base flow. Sites in the Northern Plains and Northwest have nitrate load ratios that generally are greater than 50 percent. Nitrate load ratios for sites in the Southeast and Northeast are mixed with values less than and greater than 50 percent. The proportion of nitrate load contributed by base flow (load ratio) generally is less than 50 percent for sites in the Midwest and eastern portion of the Southern Plains. Sites in eastern Texas have low nitrate load ratios (less than 25 percent) as a result of low nitrate concentrations during periods of low flow followed by short duration runoff events with higher nitrate concentrations. Low nitrate-load ratios also are found in streams in the eastern portion of the Midwest (Indiana and Ohio). Tile-drainage systems, common in this area, can intercept nitrate-rich shallow groundwater resulting in high nitrate concentrations when the tile drains are flowing.

Sites underlain by the Valley and Ridge carbonate aquifer in the Valley and Ridge physiographic province (northern Alabama through Tennessee, Virginia, Maryland, and Pennsylvania) have more than 70 percent of the nitrate load contributed by base flow. The shallow permeable bedrock can result in extensive interaction between surface water and groundwater.

Two sites where groundwater contributions are well documented (the Dismal River in Nebraska and the Comal River in Texas) have about 98 percent of the nitrate load contributed by base flow. The relation between nitrate concentration and streamflow at these sites is relatively invariant.

The effect of the characteristics of contrasting hydrologic landscapes on the sources of nitrate loads in streams is shown by grouping sites into one of four landscape categories: landscapes with permeable soils and permeable bedrock, landscapes with permeable soils and impermeable bedrock, landscapes with impermeable soils and permeable bedrock, and landscapes with impermeable soils and impermeable bedrock. Significantly lower contributions of nitrate from base flow were found in areas with impermeable soils and impermeable bedrock. These areas could be most responsive to nutrient management practices designed to reduce nutrient transport to streams by runoff. Conversely, sites with potential for shallow or deep groundwater contribution (some combination of permeable soils or permeable bedrock) had significantly greater contributions of nitrate from base flow. Effective nutrient management strategies would consider groundwater nitrate contributions in these areas.

Mean annual base-flow nitrate concentrations are greater at agricultural sites in the Midwest, Northeast, and Northwest areas of the country and are relatively lower at undeveloped sites throughout the country. Comparison of the distributions of base-flow nitrate concentrations by land use show that concentrations are greatest at agricultural sites followed by the mixed, urban, and undeveloped categories.

Mean annual base-flow concentrations were compared to shallow-groundwater concentrations for 27 of the 148 sites. Nitrate concentrations in groundwater tended to be greater than base-flow concentrations for this group of sites. Sites where groundwater concentrations were much greater than base-flow concentrations were found in areas of high infiltration and oxic groundwater conditions. The lack of correspondingly high concentrations in the base flow of the paired surface-water sites may have multiple causes. In some settings, there has not been sufficient time for enough high-nitrate shallow groundwater to migrate to the nearby stream. In these cases, the stream nitrate concentrations lag behind those in the shallow groundwater, and concentrations may increase in the future as more high-nitrate groundwater reaches the stream. Alternatively, some of these sites may have processes that rapidly remove nitrate as water moves from the aquifer into the stream channel.

Partitioning streamflow and nitrate load between the quick-flow and base-flow portions of the hydrograph coupled with relative scales of soil permeability can infer the importance of surface water compared to groundwater nitrate sources. Study of the relation of nitrate concentrations to base-flow index and the comparison of groundwater nitrate concentrations to stream nitrate concentrations during times when base flow index is high can provide evidence of potential nitrate transport mechanisms. Accounting for the surface-water and groundwater contributions of nitrate is crucial to effective management and remediation of nutrient enrichment in streams.

Acknowledgments

This report relies on water samples that were collected by hydrologists and hydrologic technicians in 51 NAWQA study units and analyzed by technicians at the USGS National Water Quality Laboratory in Denver, Colorado. Without all their diligent efforts, the data interpretation in this report would not have been possible.

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Supplemental Information

Table 1. Site location, drainage area, and land-use classification.

[Ag, Agriculture; Undev, undeveloped]

U.S. Geological Survey site number	Site name	Study unit identifier	Study unit name	Latitude (decimal degrees)	Longitude (decimal degrees)	Drainage area (square miles)	Land-use classification
site	**site_name**	**suid**	**su_name**	**lat**	**long**	**drain_area_sqmi**	**circular_lu**
07375050	Tchefuncte River near Covington, LA	ACAD	Acadian-Pontchartrain Drainages	30.49464	-90.16950	141	Mixed
08010000	Bayou Des Cannes near Eunice, LA	ACAD	Acadian-Pontchartrain Drainages	30.48353	-92.49040	142	Ag
02332830	West Fork Little River near Clermont, GA	ACFB	Apalachicola-Chattahoochee-Flint River Basins	34.41538	-83.82160	18	Mixed
02335870	Sope Creek near Marietta, GA	ACFB	Apalachicola-Chattahoochee-Flint River Basins	33.95399	-84.44330	31	Urban
02336300	Peachtree Creek at Atlanta, GA	ACFB	Apalachicola-Chattahoochee-Flint River Basins	33.81955	-84.40770	86	Urban
02337500	Snake Creek near Whitesburg, GA	ACFB	Apalachicola-Chattahoochee-Flint River Basins	33.52956	-84.92830	36	Undev
02338523	Hillibahatchee Creek near Franklin, GA	ACFB	Apalachicola-Chattahoochee-Flint River Basins	33.34056	-85.22694	17	Undev
02350080	Lime Creek near Cobb, GA	ACFB	Apalachicola-Chattahoochee-Flint River Basins	32.03517	-83.99240	62	Ag
02084160	Chicod Creek near Simpson, NC	ALBE	Albemarle-Pamlico Drainages	35.56322	-77.22830	42	Mixed
02084557	Van Swamp near Hoke, NC	ALBE	Albemarle-Pamlico Drainages	35.73044	-76.74660	22	Undev
0208925200	Bear Creek at Mays Store, NC	ALBE	Albemarle-Pamlico Drainages	35.27461	-77.79410	59	Mixed
03015795	East Hickory Creek near Queen, PA	ALMN	Allegheny-Monongahela River Basins	41.64201	-79.33810	20	Undev
03037350	South Branch Plum Creek at Five Points, PA	ALMN	Allegheny-Monongahela River Basins	40.71895	-79.23640	33	Mixed
03040000	Stonycreek River at Ferndale, PA	ALMN	Allegheny-Monongahela River Basins	40.28563	-78.92060	452	Undev
03049646	Deer Creek near Dorseyville, PA	ALMN	Allegheny-Monongahela River Basins	40.58257	-79.86120	27	Mixed
03072000	Dunkard Creek at Shannopin, PA	ALMN	Allegheny-Monongahela River Basins	39.75925	-79.97060	227	Undev
09505800	West Clear Creek near Camp Verde, AZ	CAZB	Central Arizona Basins	34.53864	-111.69400	237	Undev
12464770	Crab Creek near Ritzville, WA	CCYK	Central Columbia Plateau (CCPT)-Yakima River Basin (YAKI)	47.30265	-118.36900	459	Ag
06773050	Prairie Creek near Ovina, NE	CNBR	Central Nebraska Basins	40.98418	-98.41670	140	Ag
06775900	Dismal River near Thedford, NE	CNBR	Central Nebraska Basins	41.77916	-100.52500	28	Undev
06795500	Shell Creek near Columbus, NE	CNBR	Central Nebraska Basins	41.52584	-97.28230	294	Ag
06800000	Maple Creek near Nickerson, NE	CNBR	Central Nebraska Basins	41.56083	-96.54110	368	Ag
01135300	Sleepers River near St. Johnsbury, VT	CONN	Connecticut, Housatonic, and Thames River Basins	44.43450	-72.03900	43	Undev
01137500	Ammonoosuc River at Bethlehem Junction, NH	CONN	Connecticut, Housatonic, and Thames River Basins	44.26896	-71.63060	88	Undev
01170100	Green River near Colrain, MA	CONN	Connecticut, Housatonic, and Thames River Basins	42.70342	-72.67060	41	Undev
01199900	Tenmile River near Wingdale, NY	CONN	Connecticut, Housatonic, and Thames River Basins	41.66309	-73.55960	193	Mixed
01208873	Rooster River at Fairfield, CT	CONN	Connecticut, Housatonic, and Thames River Basins	41.18010	-73.21860	10	Urban
01209710	Norwalk River at Winnipauk,CT	CONN	Connecticut, Housatonic, and Thames River Basins	41.13509	-73.42660	33	Urban
01451800	Jordon Creek near Schnecksville, PA	DELR	Delaware River Basin	40.66176	-75.62690	52	Ag
01464907	Little Neshaminy Creek near Warminster, PA	DELR	Delaware River Basin	40.22927	-75.11960	28	Mixed
01467150	Cooper River at Haddonfield, NJ	DELR	Delaware River Basin	39.90317	-75.02160	18	Urban
01470779	Tulpehocken Creek near Bernville, PA	DELR	Delaware River Basin	40.41343	-76.17160	69	Ag
01472157	French Creek near Phoenixville, PA	DELR	Delaware River Basin	40.15149	-75.60130	59	Mixed
01477120	Racoon Creek near Swedesboro, NJ	DELR	Delaware River Basin	39.74123	-75.25880	26	Mixed
02215100	Tucsawhatchee Creek near Hawkinsville, GA	GAFL	Georgia-Florida Coastal Plain Drainages	32.23961	-83.50160	162	Ag
02300700	Bullfrog Creek near Wimauma, FL	GAFL	Georgia-Florida Coastal Plain Drainages	27.79197	-82.35200	29	Mixed

Table 1. Site location, drainage area, and land-use classification.—Continued

[Ag, Agriculture; Undev, undeveloped]

U.S. Geological Survey site number	Site name	Study unit identifier	Study unit name	Latitude (decimal degrees)	Longitude (decimal degrees)	Drainage area (square miles)	Land-use classification
02306774	Rocky Creek near Citrus Park, FL	GAFL	Georgia-Florida Coastal Plain Drainages	28.06556	-82.56583	20	Urban
02317797	Little River near Tifton, GA	GAFL	Georgia-Florida Coastal Plain Drainages	31.48185	-83.58410	129	Ag
10102200	Cub River near Richmond, UT	GRSL	Great Salt Lake Basins	41.92632	-111.85400	223	Ag
10167800	Little Cottonwood Creek at Crestwood Park, UT	GRSL	Great Salt Lake Basins	40.59995	-111.83400	36	Urban
10168000	Little Cottonwood Creek at Salt Lake City, UT	GRSL	Great Salt Lake Basins	40.66384	-111.90200	45	Urban
10172200	Red Butte Creek at Fort Douglas, UT	GRSL	Great Salt Lake Basins	40.77995	-111.80600	7	Undev
01356190	Lisha Kill northwest of Niskayuna, NY	HDSN	Hudson River Basin	42.78341	-73.85710	15	Urban
01362200	Esopus Creek at Allaben, NY	HDSN	Hudson River Basin	42.11703	-74.38010	65	Undev
01372051	Fall Kill at Poughkeepsie, NY	HDSN	Hudson River Basin	41.71009	-73.92620	19	Mixed
03167000	Reed Creek at Grahams Forge, VA	KANA	Kanawha-New River Basin	36.93957	-80.88670	258	Mixed
03170000	Little River at Graysontown, VA	KANA	Kanawha-New River Basin	37.03762	-80.55670	307	Mixed
03178000	Bluestone River near Spanishburg, WV	KANA	Kanawha-New River Basin	37.43345	-81.11090	200	Mixed
03191500	Peters Creek near Lockwood, WV	KANA	Kanawha-New River Basin	38.26261	-81.02320	40	Undev
04159492	Black River near Jeddo, MI	LERI	Lake Erie-Lake St. Clair Drainages	43.15253	-82.62410	462	Ag
04186500	Auglaize River near Fort Jennings, OH	LERI	Lake Erie-Lake St. Clair Drainages	40.94866	-84.26610	331	Ag
04213500	Cattaraugus Creek at Gowanda, NY	LERI	Lake Erie-Lake St. Clair Drainages	42.46395	-78.93500	436	Mixed
01390500	Saddle River at Ridgewood, NJ	LINJ	Long Island-New Jersey Coastal Drainages	40.98482	-74.09130	22	Urban
01398000	Neshanic River at Reaville, NJ	LINJ	Long Island-New Jersey Coastal Drainages	40.47177	-74.82790	25	Mixed
01403900	Bound Brook at Middlesex, NJ	LINJ	Long Island-New Jersey Coastal Drainages	40.58510	-74.50770	49	Urban
01410784	Great Egg Harbor River near Sicklerville, NJ	LINJ	Long Island-New Jersey Coastal Drainages	39.73400	-74.95100	15	Urban
05568800	Indian Creek near Wyoming, IL	LIRB	Lower Illinois River Basin	41.01837	-89.83540	63	Ag
01555400	East Mahantango Creek at Klingerstown, PA	LSUS	Lower Susquehanna River Basin	40.66342	-76.69140	45	Ag
01559795	Bobs Creek near Pavia, PA	LSUS	Lower Susquehanna River Basin	40.27258	-78.59840	17	Undev
02398300	Chattooga River above Gaylesville, AL	MOBL	Mobile River Basin	34.29037	-85.50910	366	Undev
02419977	Three Mile Branch at Montgomery, AL	MOBL	Mobile River Basin	32.42236	-86.25500	9	Urban
02421115	Pintlalla Creek near Pintlalla, AL	MOBL	Mobile River Basin	32.15292	-86.35360	59	Undev
0242354750	Cahaba Valley Creek at Pelham, AL	MOBL	Mobile River Basin	33.31345	-86.80640	26	Mixed
01095220	Stillwater River near Sterling, MA	NECB	New England Coastal Basins	42.41093	-71.79120	30	Mixed
01101500	Ipswich River at South Middleton, MA	NECB	New England Coastal Basins	42.56954	-71.02700	45	Urban
01102345	Saugus River at Saugus, MA	NECB	New England Coastal Basins	42.46954	-71.00730	23	Urban
01105000	Neponset River at Norwood, MA	NECB	New England Coastal Basins	42.17760	-71.20090	33	Urban
01109000	Wading River near Norton, MA	NECB	New England Coastal Basins	41.94760	-71.17670	44	Urban
01112900	Blackstone River at Manville, RI	NECB	New England Coastal Basins	41.97121	-71.47010	431	Mixed
12392155	Lightning Creek at Clark Fork, ID	NROK	Northern Rockies Intermontane Basins	48.15104	-116.18300	126	Undev
12413875	St. Joe River near Red Ives Work Station, ID	NROK	Northern Rockies Intermontane Basins	47.05603	-115.35300	106	Undev
06923150	Dousinbury Creek near Wall Street, MO	OZRK	Ozark Plateaus	37.59449	-92.96690	41	Ag
06929315	Paddy Creek above Slabtown Spring, MO	OZRK	Ozark Plateaus	37.55810	-92.04880	30	Undev
07053250	Yocum Creek near Oak Grove, AR	OZRK	Ozark Plateaus	36.45395	-93.35660	52	Ag

Table 1. Site location, drainage area, and land-use classification.—Continued

[Ag, Agriculture; Undev, undeveloped]

U.S. Geological Survey site number	Site name	Study unit identifier	Study unit name	Latitude (decimal degrees)	Longitude (decimal degrees)	Drainage area (square miles)	Land-use classification
07055646	Buffalo River near Boxley, AR	OZRK	Ozark Plateaus	35.94535	-93.40350	59	Undev
07061600	Black River Below Annapolis, MO	OZRK	Ozark Plateaus	37.32505	-90.76400	495	Undev
07065495	Jacks Fork River at Alley Spring, MO	OZRK	Ozark Plateaus	37.14449	-91.45760	305	Undev
01485000	Pocomoke River at Willards, MD	PODL	Potomac River Basin (POTO) & Delmarva Peninsula (DLMV)	38.38888	-75.32500	53	Ag
01493112	Chesterville Branch near Crumpton, MD	PODL	Potomac River Basin (POTO) & Delmarva Peninsula (DLMV)	39.25722	-75.94056	7	Ag
01493500	Morgan Creek near Kennedyville, MD	PODL	Potomac River Basin (POTO) & Delmarva Peninsula (DLMV)	39.28000	-76.01444	13	Ag
01608000	South Fork South Branch Potomac River near Moorefield, WV	PODL	Potomac River Basin (POTO) & Delmarva Peninsula (DLMV)	39.01233	-78.95610	277	Undev
01610400	Waites Run near Wardensville, WV	PODL	Potomac River Basin (POTO) & Delmarva Peninsula (DLMV)	39.04270	-78.59830	11	Undev
01621050	Muddy Creek at Mount Clinton, VA	PODL	Potomac River Basin (POTO) & Delmarva Peninsula (DLMV)	38.48651	-78.96090	14	Ag
01638480	Catoctin Creek at Taylorstown, VA	PODL	Potomac River Basin (POTO) & Delmarva Peninsula (DLMV)	39.25510	-77.57640	90	Ag
01654000	Accotink Creek near Annandale, VA	PODL	Potomac River Basin (POTO) & Delmarva Peninsula (DLMV)	38.81289	-77.22830	23	Urban
12056500	North Fork Skokomish River near Hoodsport, WA	PUGT	Puget Sound Drainages	47.51426	-123.33000	57	Undev
12061500	Skokomish River near Potlatch, WA	PUGT	Puget Sound Drainages	47.30982	-123.17700	131	Undev
12108500	Newaukum Creek near Black Diamond, WA	PUGT	Puget Sound Drainages	47.27566	-122.06000	27	Mixed
12112600	Big Soos Creek near Auburn, WA	PUGT	Puget Sound Drainages	47.31232	-122.16500	67	Urban
12113375	Springbrook Creek at Tukwila, WA	PUGT	Puget Sound Drainages	47.46565	-122.23300	20	Urban
12113390	Duwamish River at Tukwila, WA	PUGT	Puget Sound Drainages	47.47899	-122.25900	461	Mixed
12128000	Thornton Creek near Seattle, WA	PUGT	Puget Sound Drainages	47.69566	-122.27600	11	Urban
12212100	Fishtrap Creek at Lynden, WA	PUGT	Puget Sound Drainages	48.92650	-122.49600	38	Ag
05082625	Turtle River near Arvilla, ND	REDN	Red River of the North Basin	47.93832	-97.50040	254	Ag
11447360	Arcade Creek near Del Paso Heights, CA	SACR	Sacramento River Basin	38.64185	-121.38300	31	Urban
11274538	Orestimba Creek near Crows Landing, CA	SANJ	San Joaquin-Tulare River Basins	37.41355	-121.01600	11	Ag
021603257	Brushy Creek near Pelham, SC	SANT	Santee River Basin & Coastal Drainages	34.86317	-82.25070	14	Urban
021607224	Indian Creek Above Newberry, SC	SANT	Santee River Basin & Coastal Drainages	34.42514	-81.60480	63	Undev
02174250	Cow Castle Creek near Bowman, SC	SANT	Santee River Basin & Coastal Drainages	33.37877	-80.69980	24	Mixed
08169000	Comal River at New Braunfels, TX	SCTX	South-Central Texas	29.70606	-98.12250	132	Mixed
08171000	Blanco River at Wimberley, TX	SCTX	South-Central Texas	29.99438	-98.08890	357	Undev
08178800	Salado Creek at San Antonio, TX	SCTX	South-Central Texas	29.35718	-98.41280	195	Urban
08195000	Frio River at Concan, TX	SCTX	South-Central Texas	29.48856	-99.70480	397	Undev
11060400	Warm Creek near San Bernardino, CA	SOCA	Southern California Coastal Drainages	34.07835	-117.30000	12	Urban
11073495	Cucamonga Creek near Mira Loma, CA	SOCA	Southern California Coastal Drainages	33.98279	-117.59900	80	Urban
06753400	Lonetree Creek at Carr, CO	SPLT	South Platte River Basin	40.89832	-104.86800	169	Undev
402114105350101	Big Thompson River near Estes Park, CO	SPLT	South Platte River Basin	40.35387	-105.58400	40	Undev
03466208	Big Limestone Creek near Limestone, TN	TENN	Tennessee River Basin (UTEN & LTEN)	36.20594	-82.65040	79	Ag
03524550	Guest River near Miller Yard, VA	TENN	Tennessee River Basin (UTEN & LTEN)	36.87872	-82.40600	100	Mixed
03526000	Copper Creek near Gate City, VA	TENN	Tennessee River Basin (UTEN & LTEN)	36.67399	-82.56570	107	Mixed
03573182	Scarham Creek near McVille, AL	TENN	Tennessee River Basin (UTEN & LTEN)	34.29843	-86.11660	54	Ag
0357479650	Hester Creek near Plevna, AL	TENN	Tennessee River Basin (UTEN & LTEN)	34.96092	-86.46360	29	Ag

Table 1. Site location, drainage area, and land-use classification.—Continued

[Ag, Agriculture; Undev, undeveloped]

U.S. Geological Survey site number	Site name	Study unit identifier	Study unit name	Latitude (decimal degrees)	Longitude (decimal degrees)	Drainage area (square miles)	Land-use classification
03575100	Flint River near Brownsboro, AL	TENN	Tennessee River Basin (UTEN & LTEN)	34.74926	-86.44670	374	Ag
035825882	Cane Creek near Howell, TN	TENN	Tennessee River Basin (UTEN & LTEN)	35.22286	-86.62310	79	Mixed
03598250	North Fork Creek near Poplins Crossroads, TN	TENN	Tennessee River Basin (UTEN & LTEN)	35.58507	-86.59580	74	Ag
08044000	Big Sandy Creek near Bridgeport, TX	TRIN	Trinity River Basin	33.23178	-97.69480	334	Mixed
08051500	Clear Creek near Sanger, TX	TRIN	Trinity River Basin	33.33623	-97.17950	295	Mixed
08057200	White Rock Creek at Dallas, TX	TRIN	Trinity River Basin	32.88917	-96.75639	67	Mixed
08058900	East Fork Trinity River at McKinney, TX	TRIN	Trinity River Basin	33.24400	-96.60890	168	Ag
08065800	Bedias Creek near Madisonville, TX	TRIN	Trinity River Basin	30.88436	-95.77770	331	Ag
08066295	Menard Creek near Fuqua, TX	TRIN	Trinity River Basin	30.46187	-94.72300	107	Undev
09010500	Colorado River near Grand Lake, CO	UCOL	Upper Colorado River Basin	40.32582	-105.85700	63	Undev
09046530	French Gulch at Breckenridge, CO	UCOL	Upper Colorado River Basin	39.49305	-106.04500	11	Mixed
05531500	Salt Creek at Western Springs, IL	UIRB	Upper Illinois River Basin	41.82642	-87.90010	112	Urban
05548105	Nippersink Creek above Wonder Lake, IL	UIRB	Upper Illinois River Basin	42.38530	-88.36930	85	Mixed
05276005	North Fork Crow River above Paynesville, MN	UMIS	Upper Mississippi River Basin	45.37719	-94.78360	232	Ag
05288705	Shingle Creek at Minneapolis, MN	UMIS	Upper Mississippi River Basin	45.04996	-93.31020	28	Urban
05320270	Little Cobb River near Beauford, MN	UMIS	Upper Mississippi River Basin	43.99663	-93.90860	130	Ag
05330902	Nine Mile Creek at Bloomington, MN	UMIS	Upper Mississippi River Basin	44.80719	-93.30160	45	Urban
13092747	Rock Creek at Twin Falls, ID	USNK	Upper Snake River Basin	42.56241	-114.49500	241	Ag
13120500	Big Lost River near Chilly, ID	USNK	Upper Snake River Basin	43.99825	-114.02100	442	Undev
03267900	Mad River near Eagle City, OH	WHMI	White, Great (WHIT) & Little Miami (MIAM) River Basins	39.96423	-83.83160	310	Ag
03353637	Little Buck Creek near Indianapolis, IN	WHMI	White, Great (WHIT) & Little Miami (MIAM) River Basins	39.66671	-86.19660	17	Mixed
03360895	Kessinger Ditch near Monroe City, IN	WHMI	White, Great (WHIT) & Little Miami (MIAM) River Basins	38.57061	-87.27700	56	Ag
03366500	Muscatatuck River near Deputy, IN	WHMI	White, Great (WHIT) & Little Miami (MIAM) River Basins	38.80422	-85.67390	292	Ag
03373530	Lost River near Leipsic, IN	WHMI	White, Great (WHIT) & Little Miami (MIAM) River Basins	38.63644	-86.36530	35	Ag
391732085414401	Clifty Creek near Hartsville, IN	WHMI	White, Great (WHIT) & Little Miami (MIAM) River Basins	39.29227	-85.69550	88	Ag
393944084120700	Holes Creek at Kettering, OH	WHMI	White, Great (WHIT) & Little Miami (MIAM) River Basins	39.66228	-84.20190	20	Mixed
394340085524601	Sugar Creek at New Palestine, IN	WHMI	White, Great (WHIT) & Little Miami (MIAM) River Basins	39.72782	-85.87940	95	Ag
14200400	Little Abiqua Creek near Scotts Mills, OR	WILL	Willamette Basin	44.95568	-122.62800	10	Undev
14201300	Zollner Creek near Mt. Angel, OR	WILL	Willamette Basin	45.10040	-122.82200	15	Ag
14205400	East Fork Dairy Creek near Meachan Corner, OR	WILL	Willamette Basin	45.66667	-123.07000	34	Undev
14206950	Fanno Creek at Durham, OR	WILL	Willamette Basin	45.40345	-122.75500	31	Urban
04063700	Popple River near Fence, WI	WMIC	Western Lake Michigan Drainages	45.76357	-88.46320	140	Undev
04072050	Duck Creek near Howard, WI	WMIC	Western Lake Michigan Drainages	44.46582	-88.21900	95	Ag
040869415	Lincoln Creek at Milwaukee, WI	WMIC	Western Lake Michigan Drainages	43.09695	-87.97230	10	Urban
06187915	Soda Butte Creek near Silvergate, MT	YELL	Yellowstone River Basin	45.00299	-110.00200	28	Undev
06298000	Tongue River near Dayton, WY	YELL	Yellowstone River Basin	44.84941	-107.30500	206	Undev

Table 2. Comparison of longer-term base-flow index to load-simulation period base-flow index.

U.S. Geological Survey site number	Site name	Study unit identifier	Longer-term period				Load-simulation period			
			Base-flow index	First water year	Last water year	Number of years	Base-flow index	First water year	Last water year	Number of years
site	site_name	suid	bfi	first_wy	last_wy	n_years	bfi_sim	fsim_wy	lsim_wy	n_years_sim
07375050	Tchefuncte River near Covington, LA	ACAD	0.55	2000	2001	2	0.55	2000	2001	2
08010000	Bayou Des Cannes near Eunice, LA	ACAD	.09	1990	2006	17	.07	1999	2001	3
02332830	West Fork Little River near Clermont, GA	ACFB	.65	1994	1998	5	.65	1994	1998	5
02335870	Sope Creek near Marietta, GA	ACFB	.38	1990	2006	17	.37	1993	2005	13
02336300	Peachtree Creek at Atlanta, GA	ACFB	.27	1990	2006	17	.27	1993	2005	13
02337500	Snake Creek near Whitesburg, GA	ACFB	.67	1990	2006	17	.67	1993	2001	9
02338523	Hillibahatchee Creek near Franklin, GA	ACFB	.69	2003	2006	4	.65	2003	2005	3
02350080	Lime Creek near Cobb, GA	ACFB	.50	1994	2006	7	.48	1994	2005	6
02084160	Chicod Creek near Simpson, NC	ALBE	.25	1993	2006	14	.32	1993	1997	5
02084557	Van Swamp near Hoke, NC	ALBE	.43	1990	2006	17	.43	1993	2004	12
0208925200	Bear Creek at Mays Store, NC	ALBE	.52	1990	2006	17	.51	1993	2001	9
03015795	East Hickory Creek near Queen, PA	ALMN	.47	1997	1998	2	.47	1997	1998	2
03037350	South Branch Plum Creek at Five Points, PA	ALMN	.32	1997	1998	2	.32	1997	1998	2
03040000	Stonycreek River at Ferndale, PA	ALMN	.49	1990	2006	17	.47	1996	1998	3
03049646	Deer Creek near Dorseyville, PA	ALMN	.39	1997	1998	2	.39	1997	1998	2
03072000	Dunkard Creek at Shannopin, PA	ALMN	.31	1990	2006	17	.30	1996	1998	3
09505800	West Clear Creek near Camp Verde, AZ	CAZB	.59	1990	2006	17	.61	2001	2005	5
12464770	Crab Creek near Ritzville, WA	CCYK	.81	1994	2004	9	.81	1994	2004	9
06773050	Prairie Creek near Ovina, NE	CNBR	.43	1994	1999	3	.58	1994	1994	1
06775900	Dismal River near Thedford, NE	CNBR	.97	1990	2006	17	.97	1990	2004	15
06795500	Shell Creek near Columbus, NE	CNBR	.43	1990	2006	17	.40	1992	1995	4
06800000	Maple Creek near Nickerson, NE	CNBR	.46	1990	2006	17	.45	1990	2005	16
01135300	Sleepers River near St. Johnsbury, VT	CONN	.49	1990	2006	17	.52	1993	1995	3
01137500	Ammonoosuc River at Bethlehem Junction, NH	CONN	.49	1990	2006	17	.56	1993	1995	3
01170100	Green River near Colrain, MA	CONN	.49	1990	2006	17	.48	1993	2005	13
01199900	Tenmile River near Wingdale, NY	CONN	.58	1992	2006	15	.61	1993	1995	3
01208873	Rooster River at Fairfield, CT	CONN	.45	1990	2005	16	.49	1993	1995	3
01209710	Norwalk River at Winnipauk,CT	CONN	.49	1990	2005	16	.49	1990	2005	16
01451800	Jordon Creek near Schnecksville, PA	DELR	.39	1990	2006	17	.43	1999	2001	3
01464907	Little Neshaminy Creek near Warminster, PA	DELR	.25	2000	2006	7	.25	2000	2004	5
01467150	Cooper River at Haddonfield, NJ	DELR	.43	1990	2006	17	.40	1999	2005	7
01470779	Tulpehocken Creek near Bernville, PA	DELR	.72	1990	2006	17	.73	1999	2001	3
01472157	French Creek near Phoenixville, PA	DELR	.55	1990	2006	17	.54	1999	2005	7
01477120	Racoon Creek near Swedesboro, NJ	DELR	.63	1990	2006	17	.63	1999	2005	7
02215100	Tucsawhatchee Creek near Hawkinsville, GA	GAFL	.46	1990	2006	17	.45	1993	1996	4
02300700	Bullfrog Creek near Wimauma, FL	GAFL	.29	1990	2006	17	.33	1993	1996	4

Table 2. Comparison of longer-term base-flow index to load-simulation period base-flow index.—Continued

U.S. Geological Survey site number	Site name	Study unit identifier	Longer-term period				Load-simulation period			
			Base-flow index	First water year	Last water year	Number of years	Base-flow index	First water year	Last water year	Number of years
02306774	Rocky Creek near Citrus Park, FL	GAFL	0.34	1990	2006	17	0.39	2002	2005	4
02317797	Little River near Tifton, GA	GAFL	.29	1994	1997	4	.29	1994	1997	4
10102200	Cub River near Richmond, UT	GRSL	.73	1999	2000	2	.73	1999	2000	2
10167800	Little Cottonwood Creek at Crestwood Park, UT	GRSL	.27	1990	2001	4	.15	1999	2000	2
10168000	Little Cottonwood Creek at Salt Lake City, UT	GRSL	.36	1990	2006	9	.32	1999	2005	7
10172200	Red Butte Creek at Fort Douglas, UT	GRSL	.89	1990	2006	17	.89	1990	2005	16
01356190	Lisha Kill northwest of Niskayuna, NY	HDSN	.38	1994	2005	9	.38	1994	2005	9
01362200	Esopus Creek at Allaben, NY	HDSN	.46	1990	2006	17	.47	1993	2004	12
01372051	Fall Kill at Poughkeepsie, NY	HDSN	.53	1994	1995	2	.53	1994	1995	2
03167000	Reed Creek at Grahams Forge, VA	KANA	.59	1990	2006	17	.61	1997	1998	2
03170000	Little River at Graysontown, VA	KANA	.67	1990	2006	17	.68	1997	1998	2
03178000	Bluestone River near Spanishburg, WV	KANA	.45	1997	1998	2	.45	1997	1998	2
03191500	Peters Creek near Lockwood, WV	KANA	.40	1997	2006	5	.42	1997	1998	2
04159492	Black River near Jeddo, MI	LERI	.29	1990	2006	17	.27	1996	1998	3
04186500	Auglaize River near Fort Jennings, OH	LERI	.18	1990	2006	17	.17	1996	2005	10
04213500	Cattaraugus Creek at Gowanda, NY	LERI	.48	1990	2006	16	.47	1990	1998	9
01390500	Saddle River at Ridgewood, NJ	LINJ	.51	1990	2005	16	.53	1996	1998	3
01398000	Neshanic River at Reaville, NJ	LINJ	.24	1990	2006	17	.24	1991	2005	15
01403900	Bound Brook at Middlesex, NJ	LINJ	.32	1997	2006	4	.28	1997	1998	2
01410784	Great Egg Harbor River near Sicklerville, NJ	LINJ	.58	1997	1998	2	.58	1997	1998	2
05568800	Indian Creek near Wyoming, IL	LIRB	.49	1990	2006	17	.47	1997	1998	2
01555400	East Mahantango Creek at Klingerstown, PA	LSUS	.36	1993	2000	6	.36	1993	2000	6
01559795	Bobs Creek near Pavia, PA	LSUS	.41	1994	2000	4	.41	1994	2000	4
02398300	Chattooga River above Gaylesville, AL	MOBL	.54	1990	2006	17	.58	1999	2001	3
02419977	Three Mile Branch at Montgomery, AL	MOBL	.30	1999	2001	3	.30	1999	2001	3
02421115	Pintlalla Creek near Pintlalla, AL	MOBL	.16	1999	2001	3	.16	1999	2001	3
0242354750	Cahaba Valley Creek at Pelham, AL	MOBL	.41	1999	2006	8	.40	1999	2005	7
01095220	Stillwater River near Sterling, MA	NECB	.48	1995	2006	12	.49	1999	2004	6
01101500	Ipswich River at South Middleton, MA	NECB	.55	1990	2006	17	.49	1999	2004	6
01102345	Saugus River at Saugus, MA	NECB	.48	1995	2006	12	.47	1999	2004	6
01105000	Neponset River at Norwood, MA	NECB	.57	1990	2006	17	.53	1999	2004	6
01109000	Wading River near Norton, MA	NECB	.59	1990	2006	17	.58	1999	2004	6
01112900	Blackstone River at Manville, RI	NECB	.62	1990	2006	17	.62	1993	2002	10
12392155	Lightning Creek at Clark Fork, ID	NROK	.53	1990	2006	16	.60	1999	2001	3
12413875	St. Joe River near Red Ives Work Station, ID	NROK	.75	1999	2006	8	.76	1999	2005	7
06923150	Dousinbury Creek near Wall Street, MO	OZRK	.26	1994	1997	4	.26	1994	1997	4
06929315	Paddy Creek above Slabtown Spring, MO	OZRK	.21	1994	1997	4	.21	1994	1997	4
07053250	Yocum Creek near Oak Grove, AR	OZRK	.43	1994	2006	13	.43	1994	2005	12

Table 2. Comparison of longer-term base-flow index to load-simulation period base-flow index.—Continued

U.S. Geological Survey site number	Site name	Study unit identifier	Longer-term period				Load-simulation period			
			Base-flow index	First water year	Last water year	Number of years	Base-flow index	First water year	Last water year	Number of years
07055646	Buffalo River near Boxley, AR	OZRK	0.25	1994	2006	10	0.23	1994	2004	8
07061600	Black River Below Annapolis, MO	OZRK	.50	1990	2006	17	.50	1993	2005	13
07065495	Jacks Fork River at Alley Spring, MO	OZRK	.47	1994	2006	13	.48	1994	1997	4
01485000	Pocomoke River at Willards, MD	PODL	.51	1990	2004	15	.55	1999	2002	4
01493112	Chesterville Branch near Crumpton, MD	PODL	.71	1997	2002	6	.70	1999	2002	4
01493500	Morgan Creek near Kennedyville, MD	PODL	.53	1990	2005	16	.52	1998	2004	7
01608000	South Fork South Branch Potomac River near Moorefield, WV	PODL	.39	1990	2006	17	.36	1993	1995	3
01610400	Waites Run near Wardensville, WV	PODL	.47	2003	2006	4	.49	2003	2005	3
01621050	Muddy Creek at Mount Clinton, VA	PODL	.55	1994	2006	13	.53	1994	2002	9
01638480	Catoctin Creek at Taylorstown, VA	PODL	.44	1990	2006	17	.45	1993	1995	3
01654000	Accotink Creek near Annandale, VA	PODL	.22	1990	2006	17	.22	1993	2002	10
12056500	North Fork Skokomish River near Hoodsport, WA	PUGT	.54	1990	2006	17	.52	2001	2005	5
12061500	Skokomish River near Potlatch, WA	PUGT	.47	1990	2006	17	.45	1996	1998	3
12108500	Newaukum Creek near Black Diamond, WA	PUGT	.63	1990	2006	17	.57	1996	1998	3
12112600	Big Soos Creek near Auburn, WA	PUGT	.72	1990	2006	17	.68	1996	1998	3
12113375	Springbrook Creek at Tukwila, WA	PUGT	.39	1996	2004	7	.38	1996	1998	3
12113390	Duwamish River at Tukwila, WA	PUGT	.63	1990	2006	17	.64	1996	2004	9
12128000	Thornton Creek near Seattle, WA	PUGT	.60	1997	2006	10	.61	1997	2005	9
12212100	Fishtrap Creek at Lynden, WA	PUGT	.60	1997	1998	2	.60	1997	1998	2
05082625	Turtle River near Arvilla, ND	REDN	.41	1993	2006	14	.36	1993	2000	8
11447360	Arcade Creek near Del Paso Heights, CA	SACR	.08	1997	2006	10	.08	1997	2005	9
11274538	Orestimba Creek near Crows Landing, CA	SANJ	.28	1993	2006	14	.29	1993	2005	13
021603257	Brushy Creek near Pelham, SC	SANT	.55	1996	1997	2	.55	1996	1997	2
021607224	Indian Creek Above Newberry, SC	SANT	.35	1996	1998	3	.35	1996	1998	3
02174250	Cow Castle Creek near Bowman, SC	SANT	.47	1996	2006	11	.46	1996	2005	10
08169000	Comal River at New Braunfels, TX	SCTX	.94	1990	2006	17	.98	1996	1998	3
08171000	Blanco River at Wimberley, TX	SCTX	.61	1990	2006	17	.62	1996	1998	3
08178800	Salado Creek at San Antonio, TX	SCTX	.24	1990	2006	17	.24	1990	2005	16
08195000	Frio River at Concan, TX	SCTX	.70	1990	2006	17	.69	1993	2004	12
11060400	Warm Creek near San Bernardino, CA	SOCA	.28	1990	2006	17	.27	1999	2004	6
11073495	Cucamonga Creek near Mira Loma, CA	SOCA	.61	1990	2006	17	.69	1999	2001	3
06753400	Lonetree Creek at Carr, CO	SPLT	.77	1994	1995	2	.77	1994	1995	2
402114105350101	Big Thompson River near Estes Park, CO	SPLT	.68	1996	2006	6	.69	1996	2004	5
03466208	Big Limestone Creek near Limestone, TN	TENN	.73	1997	2005	8	.72	1997	2004	7
03524550	Guest River near Miller Yard, VA	TENN	.42	1997	1998	2	.42	1997	1998	2
03526000	Copper Creek near Gate City, VA	TENN	.50	1997	1998	2	.50	1997	1998	2
03573182	Scarham Creek near McVille, AL	TENN	.37	1999	2003	5	.35	1999	2001	3

Table 2. Comparison of longer-term base-flow index to load-simulation period base-flow index.—Continued

U.S. Geological Survey site number	Site name	Study unit identifier	Longer-term period				Load-simulation period			
			Base-flow index	First water year	Last water year	Number of years	Base-flow index	First water year	Last water year	Number of years
0357479650	Hester Creek near Plevna, AL	TENN	0.25	1999	2005	7	0.25	1999	2004	6
03575100	Flint River near Brownsboro, AL	TENN	.43	1999	2006	8	.41	1999	2004	6
035825882	Cane Creek near Howell, TN	TENN	.20	1999	2001	3	.20	1999	2001	3
03598250	North Fork Creek near Poplins Crossroads, TN	TENN	.18	1999	2005	7	.19	1999	2001	3
08044000	Big Sandy Creek near Bridgeport, TX	TRIN	.24	1990	2006	10	.23	1993	1995	3
08051500	Clear Creek near Sanger, TX	TRIN	.23	1990	2006	17	.24	1993	2005	13
08057200	White Rock Creek at Dallas, TX	TRIN	.23	1990	2006	17	.26	1995	2005	11
08058900	East Fork Trinity River at McKinney, TX	TRIN	.21	1990	2006	17	.21	1993	1995	3
08065800	Bedias Creek near Madisonville, TX	TRIN	.05	1990	2006	17	.04	1993	1995	3
08066295	Menard Creek near Fuqua, TX	TRIN	.35	1993	1995	3	.35	1993	1995	3
09010500	Colorado River near Grand Lake, CO	UCOL	.67	1990	2006	17	.65	1995	1998	4
09046530	French Gulch at Breckenridge, CO	UCOL	.75	1996	2003	8	.74	1996	1999	4
05531500	Salt Creek at Western Springs, IL	UIRB	.46	1990	2006	17	.46	1999	2006	8
05548105	Nippersink Creek above Wonder Lake, IL	UIRB	.54	1995	2001	6	.51	1999	2001	3
05276005	North Fork Crow River above Paynesville, MN	UMIS	.39	1997	1998	2	.39	1997	1998	2
05288705	Shingle Creek at Minneapolis, MN	UMIS	.38	1997	2006	7	.37	1997	2005	6
05320270	Little Cobb River near Beauford, MN	UMIS	.37	1997	2006	8	.37	1997	2005	7
05330902	Nine Mile Creek at Bloomington, MN	UMIS	.31	1997	1998	2	.31	1997	1998	2
13092747	Rock Creek at Twin Falls, ID	USNK	.88	1993	2006	14	.88	1993	2005	13
13120500	Big Lost River near Chilly, ID	USNK	.72	1990	2006	17	.74	1993	1996	4
03267900	Mad River near Eagle City, OH	WHMI	.68	1990	2006	14	.67	1999	2005	7
03353637	Little Buck Creek near Indianapolis, IN	WHMI	.23	1990	2006	17	.22	1990	2004	15
03360895	Kessinger Ditch near Monroe City, IN	WHMI	.19	1993	1998	6	.18	1993	1995	3
03366500	Muscatatuck River near Deputy, IN	WHMI	.19	1990	2006	17	.18	1993	1995	3
03373530	Lost River near Leipsic, IN	WHMI	.32	1993	2001	9	.31	1993	1995	3
391732085414401	Clifty Creek near Hartsville, IN	WHMI	.27	1990	2006	17	.29	1993	1995	3
393944084120700	Holes Creek at Kettering, OH	WHMI	.19	2000	2004	5	.19	2000	2004	5
394340085524601	Sugar Creek at New Palestine, IN	WHMI	.32	1990	2006	17	.32	1992	2005	14
14200400	Little Abiqua Creek near Scotts Mills, OR	WILL	.51	1994	2004	11	.51	1994	2004	11
14201300	Zollner Creek near Mt. Angel, OR	WILL	.31	1994	2006	13	.31	1994	2005	12
14205400	East Fork Dairy Creek near Meachan Corner, OR	WILL	.61	2003	2006	4	.63	2003	2005	3
14206950	Fanno Creek at Durham, OR	WILL	.32	1994	2006	8	.32	1994	2005	7
04063700	Popple River near Fence, WI	WMIC	.61	1990	2006	17	.61	1990	2005	16
04072050	Duck Creek near Howard, WI	WMIC	.22	1990	2006	17	.23	1993	2005	13
040869415	Lincoln Creek at Milwaukee, WI	WMIC	.27	1994	1994	1	.27	1994	1994	1
06187915	Soda Butte Creek near Silvergate, MT	YELL	.58	1999	2006	8	.68	1999	2001	3
06298000	Tongue River near Dayton, WY	YELL	.70	1990	2006	17	.65	1999	2002	4

Table 3. Description of hydrologic landscape regions.

Hydrologic landscape region	Description
1	Subhumid plains with permeable soils and bedrock
2	Humid plains with permeable soils and bedrock
3	Subhumid plains with impermeable soils and permeable bedrock
4	Humid plains with permeable soils and bedrock
5	Arid plains with permeable soils and bedrock
6	Subhumid plains with impermeable soils and bedrock
7	Humid plains with permeable soils and impermeable bedrock
8	Semiarid plains with impermeable soils and bedrock
9	Humid plateaus with impermeable soils and permeable bedrock
10	Arid plateaus with impermeable soils and permeable bedrock
11	Humid plateaus with impermeable soils and bedrock
12	Semiarid plateaus with permeable soils and impermeable bedrock
13	Semiarid plateaus with impermeable soils and bedrock
14	Arid playas with permeable soils and bedrock
15	Semiarid mountains with impermeable soils and permeable bedrock
16	Humid mountains with permeable soils and impermeable bedrock
17	Semiarid mountains with impermeable soils and bedrock
18	Semiarid mountains with permeable soils and impermeable bedrock
19	Very humid mountains with permeable soils and impermeable bedrock
20	Humid mountains with permeable soils and impermeable bedrock

Table 4. Nitrate load ratios and hydrologic landscape regions.

[Water year, the continuous 12-month period, October 1 through September 3. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as water year 1980.]

U.S. Geological Survey site number	Site name	Study unit identifier	First water year of load simulation	Last water year of load simulation	Number of years of load simulation	Base-flow index	Nitrate load ratio	Dominant hydrologic landscape region (table 3)	Hydrologic landscape region category
site	site_name	suid	fsim_wy	lsim_wy	n_years_sim	bfi_sim	load_ratio	hlr_dom	hlr_category
07375050	Tchefuncte River near Covington, LA	ACAD	2000	2001	2	0.55	52	4	Permeable soils and permeable bedrock
08010000	Bayou Des Cannes near Eunice, LA	ACAD	1999	2001	3	.07	30	6	Impermeable soils and impermeable bedrock
02332830	West Fork Little River near Clermont, GA	ACFB	1994	1998	5	.65	76	16	Permeable soils and impermeable bedrock
02335870	Sope Creek near Marietta, GA	ACFB	1993	2005	13	.37	41	16	Permeable soils and impermeable bedrock
02336300	Peachtree Creek at Atlanta, GA	ACFB	1993	2005	13	.27	33	16	Permeable soils and impermeable bedrock
02337500	Snake Creek near Whitesburg, GA	ACFB	1993	2001	9	.67	62	16	Permeable soils and impermeable bedrock
02338523	Hillibahatchee Creek near Franklin, GA	ACFB	2003	2005	3	.65	52	16	Permeable soils and impermeable bedrock
02350080	Lime Creek near Cobb, GA	ACFB	1994	2005	6	.48	39	2	Permeable soils and permeable bedrock
02084160	Chicod Creek near Simpson, NC	ALBE	1993	1997	5	.32	26	4	Permeable soils and permeable bedrock
02084557	Van Swamp near Hoke, NC	ALBE	1993	2004	12	.43	31	4	Permeable soils and permeable bedrock
0208925200	Bear Creek at Mays Store, NC	ALBE	1993	2001	9	.51	38	4	Permeable soils and permeable bedrock
03015795	East Hickory Creek near Queen, PA	ALMN	1997	1998	2	.47	45	9	Impermeable soils and permeable bedrock
03037350	South Branch Plum Creek at Five Points, PA	ALMN	1997	1998	2	.32	27	11	Impermeable soils and impermeable bedrock
03040000	Stonycreek River at Ferndale, PA	ALMN	1996	1998	3	.47	47	11	Impermeable soils and impermeable bedrock
03049646	Deer Creek near Dorseyville, PA	ALMN	1997	1998	2	.39	17	11	Impermeable soils and impermeable bedrock
03072000	Dunkard Creek at Shannopin, PA	ALMN	1996	1998	3	.30	25	11	Impermeable soils and impermeable bedrock
09505800	West Clear Creek near Camp Verde, AZ	CAZB	2001	2005	5	.61	23	11	Impermeable soils and impermeable bedrock
12464770	Crab Creek near Ritzville, WA	CCYK	1994	2004	9	.81	79	15	Impermeable soils and permeable bedrock
06773050	Prairie Creek near Ovina, NE	CNBR	1994	1994	1	.58	46	3	Impermeable soils and permeable bedrock
06775900	Dismal River near Thedford, NE	CNBR	1990	2004	15	.97	98	10	Impermeable soils and permeable bedrock
06795500	Shell Creek near Columbus, NE	CNBR	1992	1995	4	.40	47	9	Impermeable soils and permeable bedrock
06800000	Maple Creek near Nickerson, NE	CNBR	1990	2005	16	.45	58	11	Impermeable soils and impermeable bedrock
01135300	Sleepers River near St. Johnsbury, VT	CONN	1993	1995	3	.52	58	16	Permeable soils and impermeable bedrock
01137500	Ammonoosuc River at Bethlehem Junction, NH	CONN	1993	1995	3	.56	51	16	Permeable soils and impermeable bedrock
01170100	Green River near Colrain, MA	CONN	1993	2005	13	.48	37	16	Permeable soils and impermeable bedrock
01199900	Tenmile River near Wingdale, NY	CONN	1993	1995	3	.61	66	9	Impermeable soils and permeable bedrock
01208873	Rooster River at Fairfield, CT	CONN	1993	1995	3	.49	72	7	Permeable soils and impermeable bedrock
01209710	Norwalk River at Winnipauk,CT	CONN	1990	2005	16	.49	47	12	Permeable soils and impermeable bedrock
01451800	Jordon Creek near Schnecksville, PA	DELR	1999	2001	3	.43	47	9	Impermeable soils and permeable bedrock
01464907	Little Neshaminy Creek near Warminster, PA	DELR	2000	2004	5	.25	40	7	Permeable soils and impermeable bedrock
01467150	Cooper River at Haddonfield, NJ	DELR	1999	2005	7	.40	26	4	Permeable soils and permeable bedrock
01470779	Tulpehocken Creek near Bernville, PA	DELR	1999	2001	3	.73	78	9	Impermeable soils and permeable bedrock
01472157	French Creek near Phoenixville, PA	DELR	1999	2005	7	.54	58	16	Permeable soils and impermeable bedrock
01477120	Racoon Creek near Swedesboro, NJ	DELR	1999	2005	7	.63	75	2	Permeable soils and permeable bedrock

Table 4. Nitrate load ratios and hydrologic landscape regions.—Continued

[Water year, the continuous 12-month period, October 1 through September 3. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as water year 1980.]

U.S. Geological Survey site number	Site name	Study unit identifier	First water year of load simulation	Last water year of load simulation	Number of years of load simulation	Base-flow index	Nitrate load ratio	Dominant hydrologic landscape region (table 3)	Hydrologic landscape region category
02215100	Tucsawhatchee Creek near Hawkinsville, GA	GAFL	1993	1996	4	0.45	52	7	Permeable soils and impermeable bedrock
02300700	Bullfrog Creek near Wimauma, FL	GAFL	1993	1996	4	.33	34	1	Permeable soils and permeable bedrock
02306774	Rocky Creek near Citrus Park, FL	GAFL	2002	2005	4	.39	41	1	Permeable soils and permeable bedrock
02317797	Little River near Tifton, GA	GAFL	1994	1997	4	.29	33	2	Permeable soils and permeable bedrock
10102200	Cub River near Richmond, UT	GRSL	1999	2000	2	.73	87	15	Impermeable soils and permeable bedrock
10167800	Little Cottonwood Creek at Crestwood Park, UT	GRSL	1999	2000	2	.15	24	20	Permeable soils and impermeable bedrock
10168000	Little Cottonwood Creek at Salt Lake City, UT	GRSL	1999	2005	7	.32	44	20	Permeable soils and impermeable bedrock
10172200	Red Butte Creek at Fort Douglas, UT	GRSL	1990	2005	16	.89	58	20	Permeable soils and impermeable bedrock
01356190	Lisha Kill northwest of Niskayuna, NY	HDSN	1994	2005	9	.38	37	7	Permeable soils and impermeable bedrock
01362200	Esopus Creek at Allaben, NY	HDSN	1993	2004	12	.47	26	20	Permeable soils and impermeable bedrock
01372051	Fall Kill at Poughkeepsie, NY	HDSN	1994	1995	2	.53	44	7	Permeable soils and impermeable bedrock
03167000	Reed Creek at Grahams Forge, VA	KANA	1997	1998	2	.61	51	9	Impermeable soils and permeable bedrock
03170000	Little River at Graysontown, VA	KANA	1997	1998	2	.68	54	16	Permeable soils and impermeable bedrock
03178000	Bluestone River near Spanishburg, WV	KANA	1997	1998	2	.45	44	9	Impermeable soils and permeable bedrock
03191500	Peters Creek near Lockwood, WV	KANA	1997	1998	2	.42	37	16	Permeable soils and impermeable bedrock
04159492	Black River near Jeddo, MI	LERI	1996	1998	3	.27	27	6	Impermeable soils and impermeable bedrock
04186500	Auglaize River near Fort Jennings, OH	LERI	1996	2005	10	.17	12	3	Impermeable soils and permeable bedrock
04213500	Cattaraugus Creek at Gowanda, NY	LERI	1990	1998	9	.47	69	11	Impermeable soils and impermeable bedrock
01390500	Saddle River at Ridgewood, NJ	LINJ	1996	1998	3	.53	63	16	Permeable soils and impermeable bedrock
01398000	Neshanic River at Reaville, NJ	LINJ	1991	2005	15	.24	25	11	Impermeable soils and impermeable bedrock
01403900	Bound Brook at Middlesex, NJ	LINJ	1997	1998	2	.28	38	4	Permeable soils and permeable bedrock
01410784	Great Egg Harbor River near Sicklerville, NJ	LINJ	1997	1998	2	.58	88	2	Permeable soils and permeable bedrock
05568800	Indian Creek near Wyoming, IL	LIRB	1997	1998	2	.47	54	6	Impermeable soils and impermeable bedrock
01555400	East Mahantango Creek at Klingerstown, PA	LSUS	1993	2000	6	.36	32	9	Impermeable soils and permeable bedrock
01559795	Bobs Creek near Pavia, PA	LSUS	1994	2000	4	.41	41	9	Impermeable soils and permeable bedrock
02398300	Chattooga River above Gaylesville, AL	MOBL	1999	2001	3	.58	71	9	Impermeable soils and permeable bedrock
02419977	Three Mile Branch at Montgomery, AL	MOBL	1999	2001	3	.30	43	4	Permeable soils and permeable bedrock
02421115	Pintlalla Creek near Pintlalla, AL	MOBL	1999	2001	3	.16	15	4	Permeable soils and permeable bedrock
0242354750	Cahaba Valley Creek at Pelham, AL	MOBL	1999	2005	7	.40	65	9	Impermeable soils and permeable bedrock
01095220	Stillwater River near Sterling, MA	NECB	1999	2004	6	.49	63	16	Permeable soils and impermeable bedrock
01101500	Ipswich River at South Middleton, MA	NECB	1999	2004	6	.49	61	2	Permeable soils and permeable bedrock
01102345	Saugus River at Saugus, MA	NECB	1999	2004	6	.47	51	7	Permeable soils and impermeable bedrock
01105000	Neponset River at Norwood, MA	NECB	1999	2004	6	.53	62	7	Permeable soils and impermeable bedrock
01109000	Wading River near Norton, MA	NECB	1999	2004	6	.58	55	2	Permeable soils and permeable bedrock
01112900	Blackstone River at Manville, RI	NECB	1993	2002	10	.62	75	16	Permeable soils and impermeable bedrock

Table 4. Nitrate load ratios and hydrologic landscape regions.—Continued

[Water year, the continuous 12-month period, October 1 through September 3. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as water year 1980.]

U.S. Geological Survey site number	Site name	Study unit identifier	First water year of load simulation	Last water year of load simulation	Number of years of load simulation	Base-flow index	Nitrate load ratio	Dominant hydrologic landscape region (table 3)	Hydrologic landscape region category
12392155	Lightning Creek at Clark Fork, ID	NROK	1999	2001	3	0.60	37	19	Permeable soils and impermeable bedrock
12413875	St. Joe River near Red Ives Work Station, ID	NROK	1999	2005	7	.76	51	20	Permeable soils and impermeable bedrock
06923150	Dousinbury Creek near Wall Street, MO	OZRK	1994	1997	4	.26	12	9	Impermeable soils and permeable bedrock
06929315	Paddy Creek above Slabtown Spring, MO	OZRK	1994	1997	4	.21	13	9	Impermeable soils and permeable bedrock
07053250	Yocum Creek near Oak Grove, AR	OZRK	1994	2005	12	.43	39	9	Impermeable soils and permeable bedrock
07055646	Buffalo River near Boxley, AR	OZRK	1994	2004	8	.23	6	16	Permeable soils and impermeable bedrock
07061600	Black River Below Annapolis, MO	OZRK	1993	2005	13	.50	38	9	Impermeable soils and permeable bedrock
07065495	Jacks Fork River at Alley Spring, MO	OZRK	1994	1997	4	.48	43	9	Impermeable soils and permeable bedrock
01485000	Pocomoke River at Willards, MD	PODL	1999	2002	4	.55	45	1	Permeable soils and permeable bedrock
01493112	Chesterville Branch near Crumpton, MD	PODL	1999	2002	4	.70	83	4	Permeable soils and permeable bedrock
01493500	Morgan Creek near Kennedyville, MD	PODL	1998	2004	7	.52	67	4	Permeable soils and permeable bedrock
01608000	South Fork South Branch Potomac River near Moorefield, WV	PODL	1993	1995	3	.36	47	15	Impermeable soils and permeable bedrock
01610400	Waites Run near Wardensville, WV	PODL	2003	2005	3	.49	55	15	Impermeable soils and permeable bedrock
01621050	Muddy Creek at Mount Clinton, VA	PODL	1994	2002	9	.53	89	9	Impermeable soils and permeable bedrock
01638480	Catoctin Creek at Taylorstown, VA	PODL	1993	1995	3	.45	30	16	Permeable soils and impermeable bedrock
01654000	Accotink Creek near Annandale, VA	PODL	1993	2002	10	.22	29	7	Permeable soils and impermeable bedrock
12056500	North Fork Skokomish River near Hoodsport, WA	PUGT	2001	2005	5	.52	39	20	Permeable soils and impermeable bedrock
12061500	Skokomish River near Potlatch, WA	PUGT	1996	1998	3	.45	44	20	Permeable soils and impermeable bedrock
12108500	Newaukum Creek near Black Diamond, WA	PUGT	1996	1998	3	.57	60	3	Impermeable soils and permeable bedrock
12112600	Big Soos Creek near Auburn, WA	PUGT	1996	1998	3	.68	68	9	Impermeable soils and permeable bedrock
12113375	Springbrook Creek at Tukwila, WA	PUGT	1996	1998	3	.38	46	1	Permeable soils and permeable bedrock
12113390	Duwamish River at Tukwila, WA	PUGT	1996	2004	9	.64	62	19	Permeable soils and impermeable bedrock
12128000	Thornton Creek near Seattle, WA	PUGT	1997	2005	9	.61	71	9	Impermeable soils and permeable bedrock
12212100	Fishtrap Creek at Lynden, WA	PUGT	1997	1998	2	.60	62	1	Permeable soils and permeable bedrock
05082625	Turtle River near Arvilla, ND	REDN	1993	2000	8	.36	9	8	Impermeable soils and impermeable bedrock
11447360	Arcade Creek near Del Paso Heights, CA	SACR	1997	2005	9	.08	3	10	Impermeable soils and permeable bedrock
11274538	Orestimba Creek near Crows Landing, CA	SANJ	1993	2005	13	.29	46	5	Permeable soils and permeable bedrock
021603257	Brushy Creek near Pelham, SC	SANT	1996	1997	2	.55	64	16	Permeable soils and impermeable bedrock
021607224	Indian Creek Above Newberry, SC	SANT	1996	1998	3	.35	32	7	Permeable soils and impermeable bedrock
02174250	Cow Castle Creek near Bowman, SC	SANT	1996	2005	10	.46	46	1	Permeable soils and permeable bedrock
08169000	Comal River at New Braunfels, TX	SCTX	1996	1998	3	.98	98	10	Impermeable soils and permeable bedrock
08171000	Blanco River at Wimberley, TX	SCTX	1996	1998	3	.62	56	10	Impermeable soils and permeable bedrock
08178800	Salado Creek at San Antonio, TX	SCTX	1990	2005	16	.24	32	15	Impermeable soils and permeable bedrock
08195000	Frio River at Concan, TX	SCTX	1993	2004	12	.69	72	15	Impermeable soils and permeable bedrock
11060400	Warm Creek near San Bernardino, CA	SOCA	1999	2004	6	.27	14	14	Permeable soils and permeable bedrock

Table 4. Nitrate load ratios and hydrologic landscape regions.—Continued

[Water year, the continuous 12-month period, October 1 through September 3. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as water year 1980.]

U.S. Geological Survey site number	Site name	Study unit identifier	First water year of load simulation	Last water year of load simulation	Number of years of load simulation	Base-flow index	Nitrate load ratio	Dominant hydrologic landscape region (table 3)	Hydrologic landscape region category
11073495	Cucamonga Creek near Mira Loma, CA	SOCA	1999	2001	3	0.69	53	14	Permeable soils and permeable bedrock
06753400	Lonetree Creek at Carr, CO	SPLT	1994	1995	2	.77	86	10	Impermeable soils and permeable bedrock
402114105350101	Big Thompson River near Estes Park, CO	SPLT	1996	2004	5	.69	64	20	Permeable soils and impermeable bedrock
03466208	Big Limestone Creek near Limestone, TN	TENN	1997	2004	7	.72	73	9	Impermeable soils and permeable bedrock
03524550	Guest River near Miller Yard, VA	TENN	1997	1998	2	.42	41	16	Permeable soils and impermeable bedrock
03526000	Copper Creek near Gate City, VA	TENN	1997	1998	2	.50	52	9	Impermeable soils and permeable bedrock
03573182	Scarham Creek near McVille, AL	TENN	1999	2001	3	.35	43	7	Permeable soils and impermeable bedrock
0357479650	Hester Creek near Plevna, AL	TENN	1999	2004	6	.25	29	4	Permeable soils and permeable bedrock
03575100	Flint River near Brownsboro, AL	TENN	1999	2004	6	.41	57	7	Permeable soils and impermeable bedrock
035825882	Cane Creek near Howell, TN	TENN	1999	2001	3	.20	12	9	Impermeable soils and permeable bedrock
03598250	North Fork Creek near Poplins Crossroads, TN	TENN	1999	2001	3	.19	13	3	Impermeable soils and permeable bedrock
08044000	Big Sandy Creek near Bridgeport, TX	TRIN	1993	1995	3	.23	6	10	Impermeable soils and permeable bedrock
08051500	Clear Creek near Sanger, TX	TRIN	1993	2005	13	.24	3	8	Impermeable soils and impermeable bedrock
08057200	White Rock Creek at Dallas, TX	TRIN	1995	2005	11	.26	28	8	Impermeable soils and impermeable bedrock
08058900	East Fork Trinity River at McKinney, TX	TRIN	1993	1995	3	.21	13	8	Impermeable soils and impermeable bedrock
08065800	Bedias Creek near Madisonville, TX	TRIN	1993	1995	3	.04	24	4	Permeable soils and permeable bedrock
08066295	Menard Creek near Fuqua, TX	TRIN	1993	1995	3	.35	65	4	Permeable soils and permeable bedrock
09010500	Colorado River near Grand Lake, CO	UCOL	1995	1998	4	.65	39	20	Permeable soils and impermeable bedrock
09046530	French Gulch at Breckenridge, CO	UCOL	1996	1999	4	.74	74	18	Permeable soils and impermeable bedrock
05531500	Salt Creek at Western Springs, IL	UIRB	1999	2006	8	.46	81	3	Impermeable soils and permeable bedrock
05548105	Nippersink Creek above Wonder Lake, IL	UIRB	1999	2001	3	.51	44	6	Impermeable soils and impermeable bedrock
05276005	North Fork Crow River above Paynesville, MN	UMIS	1997	1998	2	.39	32	1	Permeable soils and permeable bedrock
05288705	Shingle Creek at Minneapolis, MN	UMIS	1997	2005	6	.37	43	7	Permeable soils and impermeable bedrock
05320270	Little Cobb River near Beauford, MN	UMIS	1997	2005	7	.37	31	6	Impermeable soils and impermeable bedrock
05330902	Nine Mile Creek at Bloomington, MN	UMIS	1997	1998	2	.31	48	7	Permeable soils and impermeable bedrock
13092747	Rock Creek at Twin Falls, ID	USNK	1993	2005	13	.88	97	15	Impermeable soils and permeable bedrock
13120500	Big Lost River near Chilly, ID	USNK	1993	1996	4	.74	55	20	Permeable soils and impermeable bedrock
03267900	Mad River near Eagle City, OH	WHMI	1999	2005	7	.67	63	3	Impermeable soils and permeable bedrock
03353637	Little Buck Creek near Indianapolis, IN	WHMI	1990	2004	15	.22	20	6	Impermeable soils and impermeable bedrock
03360895	Kessinger Ditch near Monroe City, IN	WHMI	1993	1995	3	.18	29	11	Impermeable soils and impermeable bedrock
03366500	Muscatatuck River near Deputy, IN	WHMI	1993	1995	3	.18	23	9	Impermeable soils and permeable bedrock
03373530	Lost River near Leipsic, IN	WHMI	1993	1995	3	.31	43	9	Impermeable soils and permeable bedrock
391732085414401	Clifty Creek near Hartsville, IN	WHMI	1993	1995	3	.29	30	3	Impermeable soils and permeable bedrock
393944084120700	Holes Creek at Kettering, OH	WHMI	2000	2004	5	.19	24	7	Permeable soils and impermeable bedrock
394340085524601	Sugar Creek at New Palestine, IN	WHMI	1992	2005	14	.32	21	6	Impermeable soils and impermeable bedrock

Table 4. Nitrate load ratios and hydrologic landscape regions.—Continued

[Water year, the continuous 12-month period, October 1 through September 3. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as water year 1980.]

U.S. Geological Survey site number	Site name	Study unit identifier	First water year of load simulation	Last water year of load simulation	Number of years of load simulation	Base-flow index	Nitrate load ratio	Dominant hydrologic landscape region (table 3)	Hydrologic landscape region category
14200400	Little Abiqua Creek near Scotts Mills, OR	WILL	1994	2004	11	0.51	39	19	Permeable soils and impermeable bedrock
14201300	Zollner Creek near Mt. Angel, OR	WILL	1994	2005	12	.31	25	3	Impermeable soils and permeable bedrock
14205400	East Fork Dairy Creek near Meachan Corner, OR	WILL	2003	2005	3	.63	43	19	Permeable soils and impermeable bedrock
14206950	Fanno Creek at Durham, OR	WILL	1994	2005	7	.32	32	9	Impermeable soils and permeable bedrock
04063700	Popple River near Fence, WI	WMIC	1990	2005	16	.61	59	2	Permeable soils and permeable bedrock
04072050	Duck Creek near Howard, WI	WMIC	1993	2005	13	.23	19	6	Impermeable soils and impermeable bedrock
040869415	Lincoln Creek at Milwaukee, WI	WMIC	1994	1994	1	.27	10	3	Impermeable soils and permeable bedrock
06187915	Soda Butte Creek near Silvergate, MT	YELL	1999	2001	3	.68	53	20	Permeable soils and impermeable bedrock
06298000	Tongue River near Dayton, WY	YELL	1999	2002	4	.65	58	16	Permeable soils and impermeable bedrock

Table 5. Base-flow nitrate concentrations.

[Ag, Agriculture; Undev, undeveloped]

U.S. Geological Survey site number	Site name	Study unit identifier	Land-use classification	Mean annual base-flow nitrate concentration (milligrams per liter)
site	**site_name**	**suid_2**	**circular_lu**	**bf_no3_mg_l**
07375050	Tchefuncte River near Covington, LA	ACAD	Mixed	0.25
08010000	Bayou Des Cannes near Eunice, LA	ACAD	Ag	1.15
02332830	West Fork Little River near Clermont, GA	ACFB	Mixed	1.69
02335870	Sope Creek near Marietta, GA	ACFB	Urban	.56
02336300	Peachtree Creek at Atlanta, GA	ACFB	Urban	.70
02337500	Snake Creek near Whitesburg, GA	ACFB	Undev	.15
02338523	Hillibahatchee Creek near Franklin, GA	ACFB	Undev	.14
02350080	Lime Creek near Cobb, GA	ACFB	Ag	.38
02084160	Chicod Creek near Simpson, NC	ALBE	Mixed	.85
02084557	Van Swamp near Hoke, NC	ALBE	Undev	.86
0208925200	Bear Creek at Mays Store, NC	ALBE	Mixed	2.36
03015795	East Hickory Creek near Queen, PA	ALMN	Undev	.22
03037350	South Branch Plum Creek at Five Points, PA	ALMN	Mixed	1.00
03040000	Stonycreek River at Ferndale, PA	ALMN	Undev	.80
03049646	Deer Creek near Dorseyville, PA	ALMN	Mixed	.40
03072000	Dunkard Creek at Shannopin, PA	ALMN	Undev	.42
09505800	West Clear Creek near Camp Verde, AZ	CAZB	Undev	.02
12464770	Crab Creek near Ritzville, WA	CCYK	Ag	1.70
06773050	Prairie Creek near Ovina, NE	CNBR	Ag	.63
06775900	Dismal River near Thedford, NE	CNBR	Undev	.50
06795500	Shell Creek near Columbus, NE	CNBR	Ag	4.31
06800000	Maple Creek near Nickerson, NE	CNBR	Ag	6.43
01135300	Sleepers River near St. Johnsbury, VT	CONN	Undev	.34
01137500	Ammonoosuc River at Bethlehem Junction, NH	CONN	Undev	.12
01170100	Green River near Colrain, MA	CONN	Undev	.09
01199900	Tenmile River near Wingdale, NY	CONN	Mixed	.85
01208873	Rooster River at Fairfield, CT	CONN	Urban	2.36
01209710	Norwalk River at Winnipauk,CT	CONN	Urban	.51
01451800	Jordon Creek near Schnecksville, PA	DELR	Ag	4.04
01464907	Little Neshaminy Creek near Warminster, PA	DELR	Mixed	1.62
01467150	Cooper River at Haddonfield, NJ	DELR	Urban	.27
01470779	Tulpehocken Creek near Bernville, PA	DELR	Ag	8.48
01472157	French Creek near Phoenixville, PA	DELR	Mixed	1.43
01477120	Racoon Creek near Swedesboro, NJ	DELR	Mixed	1.46
02215100	Tucsawhatchee Creek near Hawkinsville, GA	GAFL	Ag	.32
02300700	Bullfrog Creek near Wimauma, FL	GAFL	Mixed	.25
02306774	Rocky Creek near Citrus Park, FL	GAFL	Urban	.09
02317797	Little River near Tifton, GA	GAFL	Ag	.23
10102200	Cub River near Richmond, UT	GRSL	Ag	.99
10167800	Little Cottonwood Creek at Crestwood Park, UT	GRSL	Urban	.26
10168000	Little Cottonwood Creek at Salt Lake City, UT	GRSL	Urban	.45
10172200	Red Butte Creek at Fort Douglas, UT	GRSL	Undev	.03
01356190	Lisha Kill northwest of Niskayuna, NY	HDSN	Urban	.47
01362200	Esopus Creek at Allaben, NY	HDSN	Undev	.16
01372051	Fall Kill at Poughkeepsie, NY	HDSN	Mixed	.34
03167000	Reed Creek at Grahams Forge, VA	KANA	Mixed	.75
03170000	Little River at Graysontown, VA	KANA	Mixed	.36
03178000	Bluestone River near Spanishburg, WV	KANA	Mixed	.59
03191500	Peters Creek near Lockwood, WV	KANA	Undev	.43

Table 5. Base-flow nitrate concentrations.—Continued

[Ag, Agriculture; Undev, undeveloped]

U.S. Geological Survey site number	Site name	Study unit identifier	Land-use classification	Mean annual base-flow nitrate concentration (milligrams per liter)
04159492	Black River near Jeddo, MI	LERI	Ag	5.69
04186500	Auglaize River near Fort Jennings, OH	LERI	Ag	9.21
04213500	Cattaraugus Creek at Gowanda, NY	LERI	Mixed	1.25
01390500	Saddle River at Ridgewood, NJ	LINJ	Urban	1.46
01398000	Neshanic River at Reaville, NJ	LINJ	Mixed	1.63
01403900	Bound Brook at Middlesex, NJ	LINJ	Urban	1.00
01410784	Great Egg Harbor River near Sicklerville, NJ	LINJ	Urban	.52
05568800	Indian Creek near Wyoming, IL	LIRB	Ag	11.44
01555400	East Mahantango Creek at Klingerstown, PA	LSUS	Ag	6.04
01559795	Bobs Creek near Pavia, PA	LSUS	Undev	1.17
02398300	Chattooga River above Gaylesville, AL	MOBL	Undev	.49
02419977	Three Mile Branch at Montgomery, AL	MOBL	Urban	.76
02421115	Pintlalla Creek near Pintlalla, AL	MOBL	Undev	.07
0242354750	Cahaba Valley Creek at Pelham, AL	MOBL	Mixed	1.35
01095220	Stillwater River near Sterling, MA	NECB	Mixed	.21
01101500	Ipswich River at South Middleton, MA	NECB	Urban	.30
01102345	Saugus River at Saugus, MA	NECB	Urban	.62
01105000	Neponset River at Norwood, MA	NECB	Urban	.43
01109000	Wading River near Norton, MA	NECB	Urban	.20
01112900	Blackstone River at Manville, RI	NECB	Mixed	.95
12392155	Lightning Creek at Clark Fork, ID	NROK	Undev	.10
12413875	St. Joe River near Red Ives Work Station, ID	NROK	Undev	.01
06923150	Dousinbury Creek near Wall Street, MO	OZRK	Ag	.21
06929315	Paddy Creek above Slabtown Spring, MO	OZRK	Undev	.04
07053250	Yocum Creek near Oak Grove, AR	OZRK	Ag	3.56
07055646	Buffalo River near Boxley, AR	OZRK	Undev	.02
07061600	Black River Below Annapolis, MO	OZRK	Undev	.12
07065495	Jacks Fork River at Alley Spring, MO	OZRK	Undev	.16
01485000	Pocomoke River at Willards, MD	PODL	Ag	2.40
01493112	Chesterville Branch near Crumpton, MD	PODL	Ag	6.35
01493500	Morgan Creek near Kennedyville, MD	PODL	Ag	3.01
01608000	South Fork South Branch Potomac River near Moorefield, WV	PODL	Undev	1.11
01610400	Waites Run near Wardensville, WV	PODL	Undev	.27
01621050	Muddy Creek at Mount Clinton, VA	PODL	Ag	7.76
01638480	Catoctin Creek at Taylorstown, VA	PODL	Ag	.92
01654000	Accotink Creek near Annandale, VA	PODL	Urban	.96
12056500	North Fork Skokomish River near Hoodsport, WA	PUGT	Undev	.03
12061500	Skokomish River near Potlatch, WA	PUGT	Undev	.09
12108500	Newaukum Creek near Black Diamond, WA	PUGT	Mixed	2.16
12112600	Big Soos Creek near Auburn, WA	PUGT	Urban	.98
12113375	Springbrook Creek at Tukwila, WA	PUGT	Urban	.51
12113390	Duwamish River at Tukwila, WA	PUGT	Mixed	.38
12128000	Thornton Creek near Seattle, WA	PUGT	Urban	1.27
12212100	Fishtrap Creek at Lynden, WA	PUGT	Ag	3.16
05082625	Turtle River near Arvilla, ND	REDN	Ag	.26
11447360	Arcade Creek near Del Paso Heights, CA	SACR	Urban	.67
11274538	Orestimba Creek near Crows Landing, CA	SANJ	Ag	2.26
021603257	Brushy Creek near Pelham, SC	SANT	Urban	.70
021607224	Indian Creek Above Newberry, SC	SANT	Undev	.07
02174250	Cow Castle Creek near Bowman, SC	SANT	Mixed	2.08

Table 5. Base-flow nitrate concentrations.—Continued

[Ag, Agriculture; Undev, undeveloped]

U.S. Geological Survey site number	Site name	Study unit identifier	Land-use classification	Mean annual base-flow nitrate concentration (milligrams per liter)
08169000	Comal River at New Braunfels, TX	SCTX	Mixed	1.69
08171000	Blanco River at Wimberley, TX	SCTX	Undev	.44
08178800	Salado Creek at San Antonio, TX	SCTX	Urban	1.31
08195000	Frio River at Concan, TX	SCTX	Undev	.72
11060400	Warm Creek near San Bernardino, CA	SOCA	Urban	.38
11073495	Cucamonga Creek near Mira Loma, CA	SOCA	Urban	4.09
06753400	Lonetree Creek at Carr, CO	SPLT	Undev	.23
402114105350101	Big Thompson River near Estes Park, CO	SPLT	Undev	.11
03466208	Big Limestone Creek near Limestone, TN	TENN	Ag	2.03
03524550	Guest River near Miller Yard, VA	TENN	Mixed	.47
03526000	Copper Creek near Gate City, VA	TENN	Mixed	1.26
03573182	Scarham Creek near McVille, AL	TENN	Ag	3.50
0357479650	Hester Creek near Plevna, AL	TENN	Ag	1.22
03575100	Flint River near Brownsboro, AL	TENN	Ag	1.53
035825882	Cane Creek near Howell, TN	TENN	Mixed	.79
03598250	North Fork Creek near Poplins Crossroads, TN	TENN	Ag	.86
08044000	Big Sandy Creek near Bridgeport, TX	TRIN	Mixed	.06
08051500	Clear Creek near Sanger, TX	TRIN	Mixed	.26
08057200	White Rock Creek at Dallas, TX	TRIN	Mixed	2.04
08058900	East Fork Trinity River at McKinney, TX	TRIN	Ag	.99
08065800	Bedias Creek near Madisonville, TX	TRIN	Ag	.86
08066295	Menard Creek near Fuqua, TX	TRIN	Undev	.10
09010500	Colorado River near Grand Lake, CO	UCOL	Undev	.04
09046530	French Gulch at Breckenridge, CO	UCOL	Mixed	.09
05531500	Salt Creek at Western Springs, IL	UIRB	Urban	8.29
05548105	Nippersink Creek above Wonder Lake, IL	UIRB	Mixed	4.22
05276005	North Fork Crow River above Paynesville, MN	UMIS	Ag	1.27
05288705	Shingle Creek at Minneapolis, MN	UMIS	Urban	.44
05320270	Little Cobb River near Beauford, MN	UMIS	Ag	2.36
05330902	Nine Mile Creek at Bloomington, MN	UMIS	Urban	.51
13092747	Rock Creek at Twin Falls, ID	USNK	Ag	1.81
13120500	Big Lost River near Chilly, ID	USNK	Undev	.04
03267900	Mad River near Eagle City, OH	WHMI	Ag	4.03
03353637	Little Buck Creek near Indianapolis, IN	WHMI	Mixed	.82
03360895	Kessinger Ditch near Monroe City, IN	WHMI	Ag	4.98
03366500	Muscatatuck River near Deputy, IN	WHMI	Ag	1.50
03373530	Lost River near Leipsic, IN	WHMI	Ag	7.49
391732085414401	Clifty Creek near Hartsville, IN	WHMI	Ag	8.25
393944084120700	Holes Creek at Kettering, OH	WHMI	Mixed	1.15
394340085524601	Sugar Creek at New Palestine, IN	WHMI	Ag	2.73
14200400	Little Abiqua Creek near Scotts Mills, OR	WILL	Undev	.39
14201300	Zollner Creek near Mt. Angel, OR	WILL	Ag	1.95
14205400	East Fork Dairy Creek near Meachan Corner, OR	WILL	Undev	.50
14206950	Fanno Creek at Durham, OR	WILL	Urban	.85
04063700	Popple River near Fence, WI	WMIC	Undev	.08
04072050	Duck Creek near Howard, WI	WMIC	Ag	3.62
040869415	Lincoln Creek at Milwaukee, WI	WMIC	Urban	.35
06187915	Soda Butte Creek near Silvergate, MT	YELL	Undev	.04
06298000	Tongue River near Dayton, WY	YELL	Undev	.07

Table 6. Base-flow nitrate concentration and associated land-use study network median nitrate concentration.

U.S. Geological Survey site number	Site name	Study unit identifier	Drainage area (square kilometers)	Hydrologic landscape category	Median nitrate concentration for land-use study well network (milligrams per liter)	Mean annual base-flow nitrate concentration (milligrams per liter)	Nitrate load ratio	Base-flow index
site	**site_name**	**suid**	**drain_area_sqkm**	**hlr_category**	**gw_net_median**	**bf_no3_mg_l**	**load_ratio**	**bfi_sim**
01109000	Wading River near Norton, MA	NECB	113	Permeable soils and permeable bedrock	1.09	0.20	55	0.58
01199900	Tenmile River near Wingdale, NY	CONN	499	Impermeable soils and permeable bedrock	3.70	.85	66	.61
01356190	Lisha Kill northwest of Niskayuna, NY	HDSN	40	Permeable soils and impermeable bedrock	.39	.47	37	.38
01410784	Great Egg Harbor River near Sicklerville, NJ	LINJ	39	Permeable soils and permeable bedrock	2.65	.52	88	.58
01470779	Tulpehocken Creek near Bernville, PA	DELR	179	Impermeable soils and permeable bedrock	8.55	8.48	78	.73
01477120	Racoon Creek near Swedesboro, NJ	DELR	67	Permeable soils and permeable bedrock	13.00	1.46	75	.63
01485000	Pocomoke River at Willards, MD	PODL	138	Permeable soils and permeable bedrock	5.41	2.40	45	.55
01493500	Morgan Creek near Kennedyville, MD	PODL	33	Permeable soils and permeable bedrock	5.41	3.01	67	.52
01608000	South Fork South Branch Potomac River near Moorefield, WV	PODL	718	Impermeable soils and permeable bedrock	.05	1.11	47	.36
02317797	Little River near Tifton, GA	GAFL	335	Permeable soils and permeable bedrock	6.70	.23	33	.29
02335870	Sope Creek near Marietta, GA	ACFB	80	Permeable soils and impermeable bedrock	1.60	.56	41	.37
02336300	Peachtree Creek at Atlanta, GA	ACFB	222	Permeable soils and impermeable bedrock	1.60	.70	33	.27
02350080	Lime Creek near Cobb, GA	ACFB	162	Permeable soils and permeable bedrock	1.40	.38	39	.48
02419977	Three Mile Branch at Montgomery, AL	MOBL	23	Permeable soils and permeable bedrock	1.51	.76	43	.30
03267900	Mad River near Eagle City, OH	WHMI	802	Impermeable soils and permeable bedrock	5.89	4.03	63	.67
03360895	Kessinger Ditch near Monroe City, IN	WHMI	146	Impermeable soils and impermeable bedrock	.31	4.98	29	.18
0357479650	Hester Creek near Plevna, AL	TENN	76	Permeable soils and permeable bedrock	.94	1.22	29	.25
03575100	Flint River near Brownsboro, AL	TENN	969	Permeable soils and impermeable bedrock	.94	1.53	57	.41
04159492	Black River near Jeddo, MI	LERI	1198	Impermeable soils and impermeable bedrock	.17	5.69	27	.27
05288705	Shingle Creek at Minneapolis, MN	UMIS	73	Permeable soils and impermeable bedrock	1.45	.44	43	.37
05548105	Nippersink Creek above Wonder Lake, IL	UIRB	219	Impermeable soils and impermeable bedrock	.39	4.22	44	.51
08010000	Bayou Des Cannes near Eunice, LA	ACAD	369	Impermeable soils and impermeable bedrock	.05	1.15	30	.07
08178800	Salado Creek at San Antonio, TX	SCTX	506	Impermeable soils and permeable bedrock	1.46	1.31	32	.24
10167800	Little Cottonwood Creek at Crestwood Park, UT	GRSL	94	Permeable soils and impermeable bedrock	6.83	.26	24	.15
10168000	Little Cottonwood Creek at Salt Lake City, UT	GRSL	117	Permeable soils and impermeable bedrock	6.83	.45	44	.32
11447360	Arcade Creek near Del Paso Heights, CA	SACR	82	Impermeable soils and permeable bedrock	2.42	.67	3	.08
12212100	Fishtrap Creek at Lynden, WA	PUGT	99	Permeable soils and permeable bedrock	12.87	3.16	62	.60

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