science for a changing world

National Water-Quality Assessment Program

Trends In Nutrient and Sediment Concentrations and Loads In Major River Basins of the South-Central United States, 1993-2004

Scientific Investigations Report 2007–5090

U.S. Department of the Interior
U.S. Geological Survey

Trends In Nutrient and Sediment Concentrations and Loads In Major River Basins of the South-Central United States, 1993-2004

By Richard A. Rebich and Dennis K. Demcheck

Scientific Investigations Report 2007–5090

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia: 2007

For product and ordering information:
World Wide Web: http://www.usgs.gov/pubprod
Telephone: 1-888-ASK-USGS

For more information on the USGS--the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment:
World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Suggested citation:
Rebich, R.A., and Demcheck, D.K., 2007, Trends in nutrient and sediment concentrations and loads in major river basins of the south-central United States, 1993-2004: U.S. Geological Survey Scientific Investigations Report 2007-5090, 112 p.

FOREWORD

The U.S. Geological Survey (USGS) is committed to providing the Nation with accurate and timely scientific information that helps 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 suitable for industry, irrigation, and habitat for fish and wildlife. Population growth and increasing demands for water make the availability of that water, now 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 condition of our Nation's streams and ground water? How are conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, 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 1991-2001, 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).

In the second decade of the Program (2002–2012), a major focus is on regional assessments of water-quality conditions and trends. These regional assessments extend the findings in the Study Units by filling critical gaps in characterizing the flow and quality of surface water and ground water, and by determining trends at sites that have been consistently monitored for more than a decade. In addition, the regional assessments continue to 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. Many of the regional assessments employ modeling and other scientific tools, developed on the basis of data collected at individual sites, to help extrapolate and forecast conditions in unmonitored, yet comparable areas within the regions. The models thereby enhance the value of our existing data and our understanding of the hydrologic system. In addition, the models are useful in evaluating various resource-management scenarios and to predict how our actions, such as by adjusting nonpoint and point sources of contamination, converting land use, and altering flow and (or) pumping regimes, are likely to affect water conditions within a region.

Other activities planned during the second decade include continuing national syntheses of information on pesticides, volatile organic compounds (VOCs), nutrients, and selected trace elements; and continuing national topical studies on the fate of agricultural chemicals, effects of urbanization on stream ecosystems, nutrient enrichment, bioaccumulation of mercury in aquatic organisms, and transport of contaminants to public-supply wells.

The USGS aims to disseminate credible, timely, and relevant science information to inform 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.

Robert M. Hirsch
Associate Director for Water

Contents

Figures

Figures (continued)

Tables

Tables (continued)

CONVERSION FACTORS, ABBREVIATIONS, AND ACRONYMS

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
cubic kilometer per year (km^3/yr)	1,119.82	cubic foot per second (ft^3/s)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)
metric ton (T)	1.102	ton (t)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Trends In Nutrient and Sediment Concentrations and Loads In Major River Basins of the South-Central United States, 1993-2004

By Richard A. Rebich and Dennis K. Demcheck

ABSTRACT

Nutrient and sediment data collected at 115 sites by Federal and State agencies from 1993 to 2004 were analyzed by the U.S. Geological Survey to determine trends in concentrations and loads for selected rivers and streams that drain into the northwestern Gulf of Mexico from the south-central United States, specifically from the Lower Mississippi, Arkansas-White-Red, and Texas-Gulf Basins. Trends observed in the study area were compared to determine potential regional patterns and to determine cause-effect relations with trends in hydrologic and human-induced factors such as nutrient sources, streamflow, and implementation of best management practices. Secondary objectives included calculation of loads and yields for the study period as a basis for comparing the delivery of nutrients and sediment to the northwestern Gulf of Mexico from the various rivers within the study area. In addition, loads were assessed at seven selected sites for the period 1980-2004 to give hydrologic perspective to trends in loads observed during 1993-2004.

Most study sites (about 64 percent) either had no trends or decreasing trends in streamflow during the study period. The regional pattern of decreasing trends in streamflow during the study period appeared to correspond to moist conditions at the beginning of the study period and the influence of three drought periods during the study period, of which the most extreme was in 2000.

Trend tests were completed for ammonia at 49 sites, for nitrite plus nitrate at 69 sites, and for total nitrogen at 41 sites. For all nitrogen constituents analyzed, no trends were observed at half or more of the sites. No regional trend patterns could be confirmed because there was poor spatial representation of the trend sites. Decreasing trends in flow-adjusted concentrations of ammonia were observed at 25 sites. No increasing trends in concentrations of ammonia were noted at any sites. Flow-adjusted concentrations of nitrite plus nitrate decreased at 7 sites and increased at 14 sites. Flow-adjusted concentrations of total nitrogen decreased at 2 sites and increased at 12 sites. Improvements to municipal wastewater treatment facilities contributed to the decline of ammonia concentrations at selected sites. Notable increasing trends in nitrite plus nitrate and total nitrogen at selected study sites were attributed to both point and nonpoint sources. Trend patterns in total nitrogen generally followed trend patterns in nitrite plus nitrate, which was understandable given that nitrite plus nitrate loads generally were 70-90 percent of the total nitrogen loads at most sites. Population data were used as a surrogate to understand the relation between changes in point sources and nutrient trends because data from wastewater treatment plants were inconsistent for this study area. Although population increased throughout the study area during the study period, there was no observed relation between increasing trends in nitrogen in study area streams and increasing trends in population. With respect to other nitrogen sources, statistical results did suggest that increasing trends in nitrogen could be related to increasing trends in nitrogen from either commercial fertilizer use and/or land application of manure.

Loads of ammonia, nitrite plus nitrate, and total nitrogen decreased during the study period, but some trends in nitrogen loads were part of long-term decreases since 1980. For example, ammonia loads were shown to decrease at nearly all sites over the past decade, but at selected sites, these decreasing trends were part of much longer trends since 1980. The Mississippi and Atchafalaya Rivers contributed the highest nitrogen loads to the northwestern Gulf of Mexico as expected; however, nitrogen yields from smaller rivers had similar or higher yields than yields from the Mississippi River.

Trend tests were completed for orthophosphorus at 34 sites and for total phosphorus at 52 sites. No trends were observed in about 57 percent of all phosphorus trend analyses attempted. Similar to nitrogen, no regional patterns could be confirmed because there was poor spatial representation of the trends sites. Flow-adjusted concentrations of orthophosphorus decreased at 10 sites and increased at 7 sites. Flow-adjusted concentrations of total phosphorus decreased at 6 sites and increased at 17 sites. It was understandable that trend patterns in total phosphorus did not follow trend patterns in orthophosphorus given that orthophosphorus loads accounted for about only 20-30 percent of the total phosphorus load at comparable sites. Trends in population data were inversely related to trends in flow-adjusted total phosphorus; therefore, trends in population were not considered a controlling factor to explain trends in total phosphorus. No relation was observed between phosphorus from fertilizer use and either orthophosphorus or total phosphorus trends. However, statistical results did sug-

gest that increasing trends in both orthophosphorus and total phosphorus could be related to increasing trends in phosphorus from land application of manure.

There were more decreasing trends than increasing trends in phosphorus loads during the past decade, most of which were unique to the recent decade and not part of long-term decreases since 1980. Similar to nitrogen loads, the Mississippi and Atchafalaya Rivers contributed the highest phosphorus loads to the northwestern Gulf of Mexico as expected; however, phosphorus yields from smaller rivers were similar to or higher than yields from the Mississippi River.

Trend analyses of suspended-sediment data were attempted at 39 sites. No trends were observed at about 71 percent of the sites. Remaining results indicated primarily decreasing trends in suspended sediment data. Most of the decreasing trends occurred on mainstem sites for the Mississippi, Arkansas, Red, and Atchafalaya Rivers, which are all regulated with reservoirs, locks and dams, and other erosion or flood-control structures that trap and prevent sediment from being transported downstream. Large decreases in suspended sediment in the Mississippi River Basin began in the 1950s when large reservoirs were constructed in the Missouri and Arkansas Rivers, which were considered the largest sources of sediment at the time. Because the Mississippi River and its major tributaries have continued to be modified and improved since 1990, it is suggested that declines in suspended sediment observed along the mainstem sites during the study period are related to ongoing watershed and channel modifications.

INTRODUCTION

The U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program is conducting regional assessments of water-quality conditions and trends in 16 principal aquifers and eight major river basins (fig. 1) (Hamilton and others, 2005). These assessments build on the NAWQA studies conducted from 1991 to 2001 in 51 river basins (fig. 1). Regional assessments in the eight major river basins focus on chemicals in water, such as trends in nutrients,

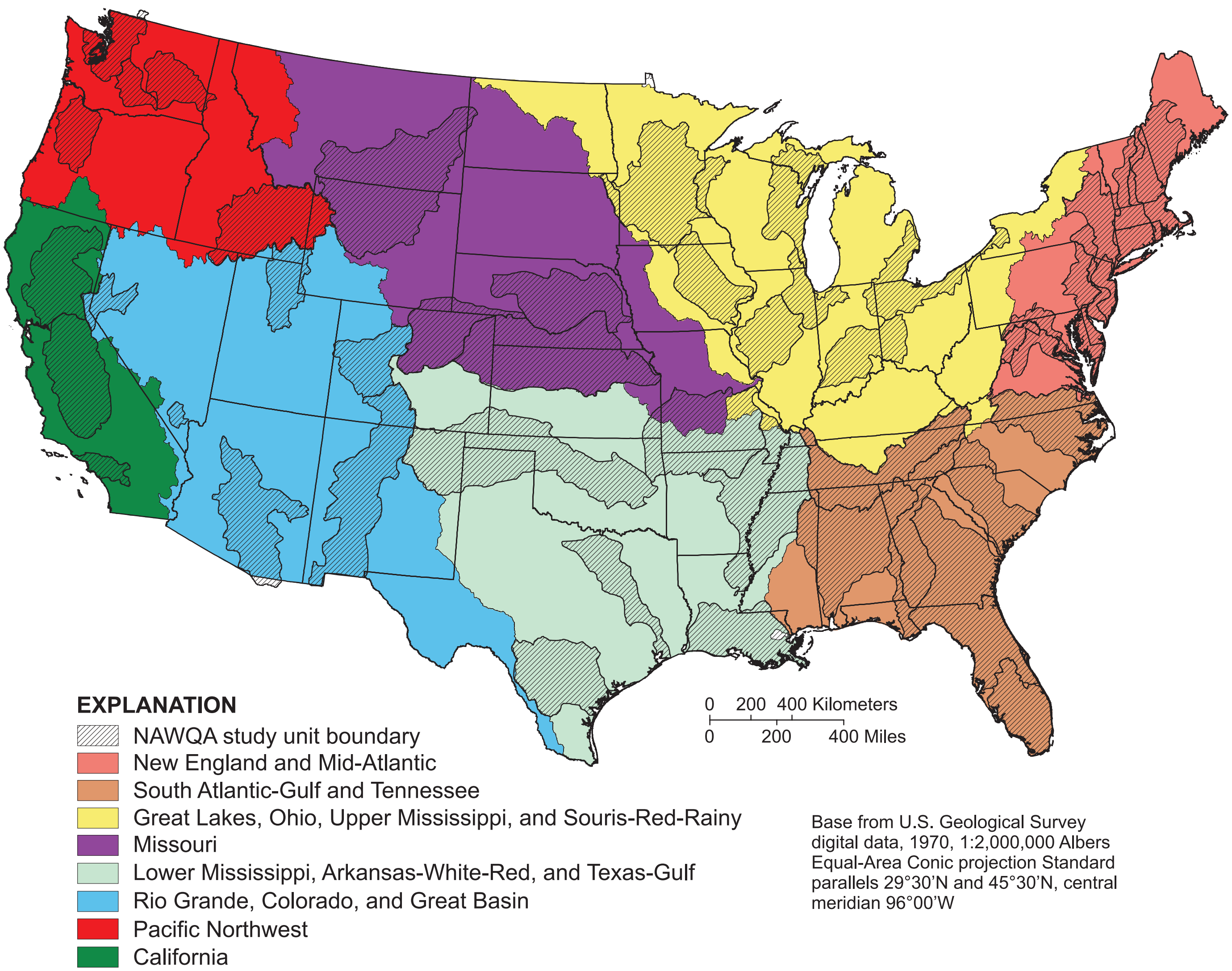


Figure 1. Locations of major river basin (MRB) and National Water-Quality Assessment (NAWQA) study areas.

sediment, and pesticides, and other relevant water-quality issues, such as trends in biological-response data (chlorophyll, algae). Each basin comprises more than one NAWQA study unit, and data used for trend testing includes data from NAWQA studies supplemented with data from other USGS studies, as well as available data collected by other agencies.

One of these regional assessments explores trends in nutrient and suspended-sediment concentrations and loads for rivers in the south-central United States, which is defined as the Lower Mississippi, Arkansas-White-Red, and Texas-Gulf Basin (hereafter referred to as the Lower-Mississippi-Texas Basin, or LMT Basin, fig. 2). The LMT Basin includes all of Arkansas and Oklahoma; nearly all of Louisiana and Texas; and parts of Colorado, Kansas, Kentucky, Mississippi, Missouri, New Mexico, and Tennessee. Major cities include Little Rock, Ark.; Tulsa and Oklahoma City, Okla.; Baton Rouge and New Orleans, La.; Dallas, Fort Worth, Houston, and San Antonio, Tex.; Colorado Springs, Colo.; Wichita, Kan.; Springfield, Mo.; and Memphis, Tenn. Major rivers include the lower Mississippi, Yazoo, Canadian, Cimarron, Arkansas, White, Red, Trinity, Brazos, Colorado, and Guadalupe.

The geological features of the LMT Basin vary considerably from rugged mountains to rolling hills, flat plains, and backwater swamps. The LMT Basin encompasses six physiographic provinces (from east to west): the Coastal Plain, which includes the East Gulf Coastal Plain, Mississippi Alluvial Plain, and West Gulf Coastal Plain sections; the Ozark Plateaus, which includes the Springfield-Salem Plateaus and the Boston “Mountains”; the Ouachita, which includes the Arkansas Valley and the Ouachita Mountains; the Osage Plains section of the Central Lowlands; the Great Plains, which includes the Colorado Piedmont, Raton, Pecos Valley, High Plains, Plains Border, Edwards Plateau, and Central Texas sections; and a small part of the Southern Rocky Mountains (U.S. Geological Survey, 2003, fig. 3). Dominating the discharge of water and nutrients into the northern Gulf of Mexico is the Mississippi Alluvial Plain section within the Coastal Plain province. The Mississippi River drains 41 per-

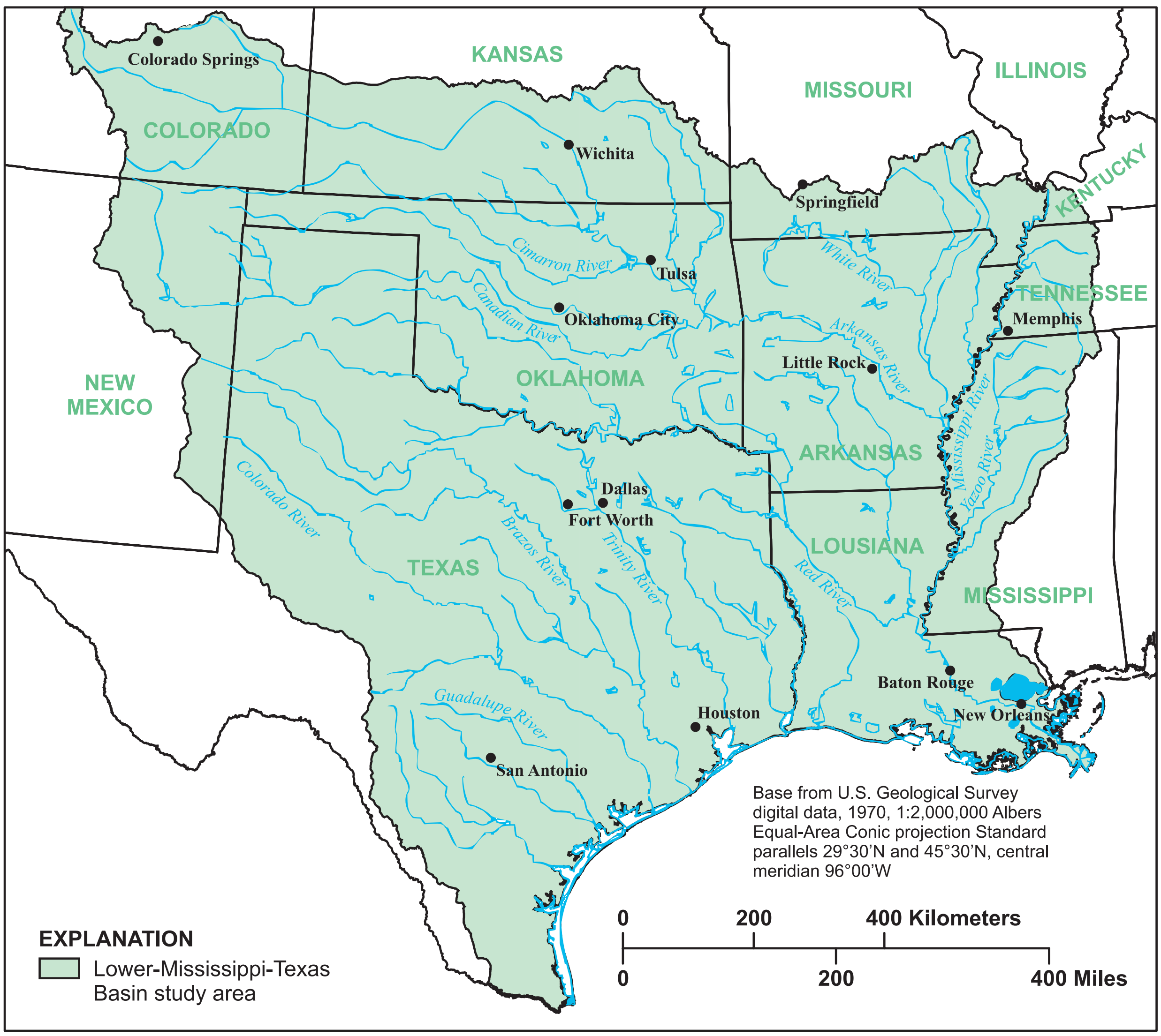


Figure 2. States, cities, and major rivers in the study area, south-central United States.

cent of the conterminous United States, and its two outlets (the lower Mississippi River and the Atchafalaya River) deliver a combined average of 580 km3/yr of freshwater to the Gulf of Mexico (Meade, 1995). Created by flow and flooding of the Mississippi River during the past 2 million years or more, the Mississippi River Alluvial Plain has an average slope of about 9.5 cm/km towards the Gulf of Mexico (Kleiss and others, 2000). One of the distinct features of the Mississippi Alluvial Plain is the formation of natural levees along the banks of the rivers, and the associated back-swamp deposits.

Extending to the west and south in the LMT Basin is the West Gulf Coastal Plain section of the Coastal Plain province (fig. 3). This area varies from rolling hills and prairie grass to piney woods and coastal prairie as one approaches the Gulf of Mexico in southwestern Louisiana and southeastern Texas, an area that is extensively cultivated for growing rice (Land and others, 1998). In southwestern Louisiana, the West Gulf Coastal Plain section is divided into a series of broad, flat areas separated by bottomland hardwood riparian corridors, which vary in width from only a few hundred meters to several kilometers (Demcheck and others, 2004).

To the northwest of the Coastal Plain province are the Ozark Plateaus and Ouachita Provinces. These areas are fairly rugged, mountainous areas that are predominantly pasture, grassland, and forest. Although mining plays a large role in local industry in these two provinces, they are also known for their beautiful and scenic landscapes that support tourism (Adamski and others, 1994).

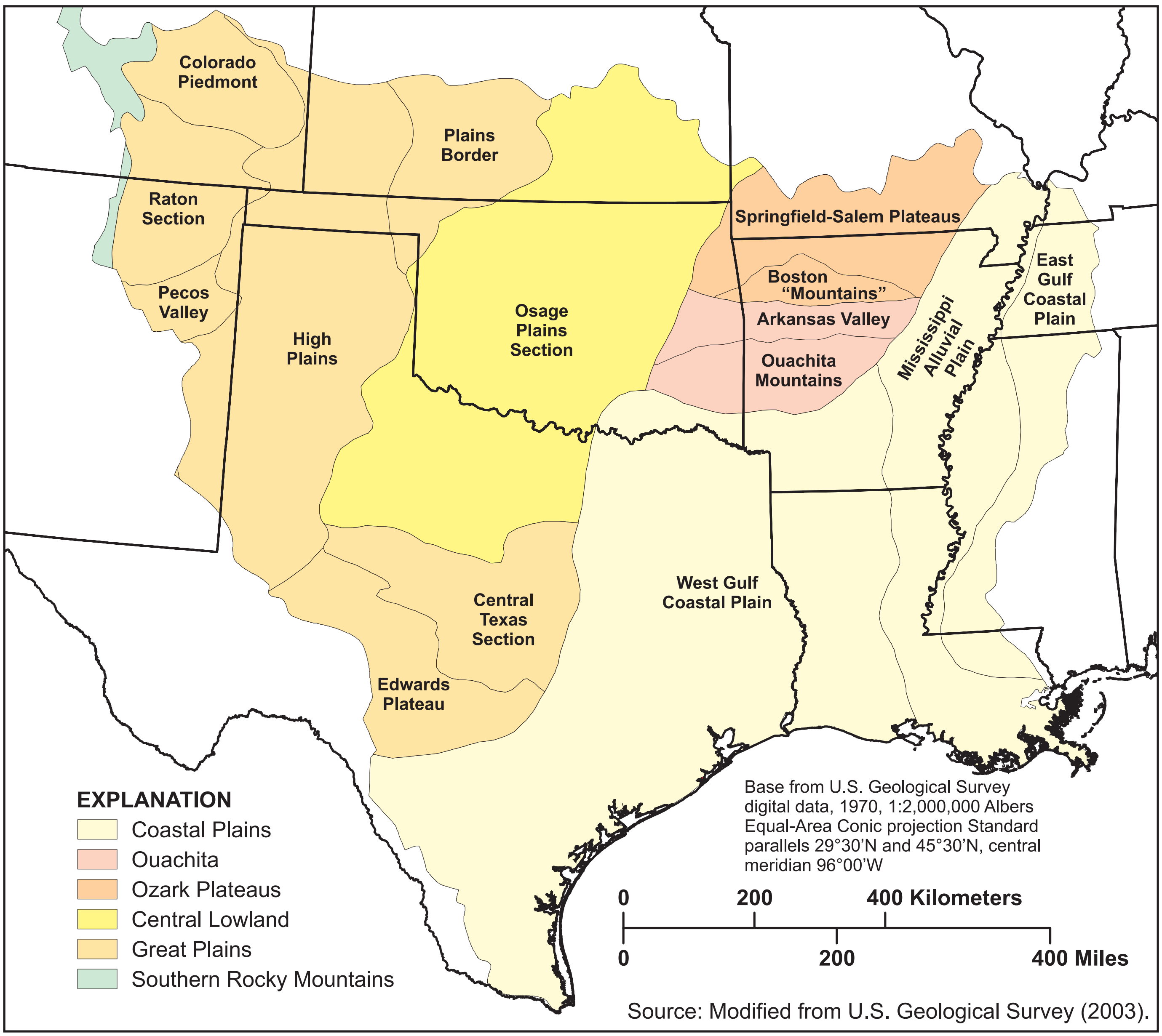


Figure 3. Physiographic provinces within the study area.

To the west, the headwaters of the Trinity and other smaller rivers drain the southern end of the Osage Plains section of the Central Lowlands physiographic province into the Gulf of Mexico. The Osage Plains section is characterized by prairie grasses, shrubs, and some forest in southern Kansas, Oklahoma, and northern Texas. Much of the area supports corn and soybean production or has been converted to pasture and hay to support cattle production (Fitzgerald and others, 2000).

Farther to the west, the remaining land area of the LMT Basin is in the Great Plains province, except for a small part in the Southern Rocky Mountains province (fig. 3). The Great Plains province is quite diverse. From the rugged sections of the Colorado Piedmont, which lies on the eastern side of the Rocky Mountains, to the volcanic formations of the Raton section, the Great Plains extends southward and eastward to include the flat, prairie areas of the Plains Border and High Plains sections (Trimble, 1980). Farther south, the Pecos Valley section of the Great Plains is dominated by karst topography, and the rugged (but picturesque) Edwards Plateau section, which is a fairly sparse area, is suited for oil and gas production as well as cattle farming (Trimble, 1980; Bush and others, 2000).

Precipitation varies considerably across the LMT Basin, generally following a decreasing pattern from the southeast to northwest, from more than 152 cm per year in southeastern Louisiana to less than 41 cm per year in Colorado. The western part is fairly arid (annual rainfall less than about 64 cm total per year [Owenby and others, 2001]) and is fairly rural with few large cities. Land use in the western part is primarily grass and fallow land with some row and small grain crops (fig. 4). Water-resource issues in the western part are related to water use, water rights, and irrigation as much as they are related to water quality. The eastern part has a humid, subtropical climate with annual rainfall amounts ranging from 100 to greater than 130 cm per year (Owenby and others, 2001); subsequently, water resources are fairly abundant. Land use in the eastern part is primarily forest and pasture land; however, row crops are abundant in the fertile Mississippi River Alluvial Valley. The eastern part is fairly rural with respect to land area but is the more populous area and contains many of the previously mentioned cities (fig. 2). With the extreme variations in geology, geography, hydrology, and land use, it is expected that trends in concentrations and loads of nutrients and sediment in surface waters within the LMT Basin will also vary considerably.

Several reports describe trends in nutrient and sediment data for the LMT Basin. For example, studies by Van Metre and Reutter (1995), Demcheck and others (2004), Davis and Bell (1998), and Coupe (2002) document trends in concentrations and loads of nutrients or sediments for statewide assessments or for selected rivers. National studies, such as work by Mueller and others (1995), include assessments of nutrient data from both ground-water wells and surface-water data-collection sites. Studies summarized by Goolsby and Battaglin (2000), Meade (1995), and Turner and Rabalais (2004) assess nutrient concentrations and loads delivered by the Mississippi River to the Gulf of Mexico; although these studies include data and results from the LMT Basin, most focus on the Upper Mississippi River Basin upstream from the LMT Basin. The U.S. Environmental Protection Agency (USEPA) recently released results from its Nutrient Pilot Study, which included an assessment of nutrient concentration and loads from coastal or near-coastal waters draining into the northern Gulf of Mexico from Louisiana, Mississippi, and Alabama (U.S. Environmental Protection Agency, 2004a). This assessment is unique and timely in that it primarily focuses on the entire LMT Basin, not just parts of the basin.

Purpose and Scope

This report presents trends observed in nutrient and sediment concentrations and loads during the period 1993-2004 for selected rivers and streams in the LMT Basin that drain into the northwestern Gulf of Mexico. Trends are computed for streamflow, ammonia, nitrite plus nitrate, total nitrogen, orthophosphorus, total phosphorus, and suspended sediment. Trends observed in the LMT Basin are compared spatially to determine potential regional patterns and are compared with trends in hydrologic and human-induced factors such as nutrients sources, streamflow, and implementation of best management practices to determine potential cause and effect relations.

This report also presents loads and yield estimates for the study period as a basis for comparing the delivery of nutrients and sediment to the northwestern Gulf of Mexico from the various drainage basins within the LMT Basin. In addition, load estimates at a few selected sites for the period 1980-2004 are presented to give hydrologic perspective to trends in loads observed during 1993-2004.

Acknowledgments

The authors wish to thank the following USGS personnel: Dave Lorenz, for technical input with trend testing and load calculations; Greg Schwarz, for help with completion of the non-flow-adjusted trend analyses; Naomi Nakagaki, for ancillary data compilations; Kirsten Tighe and Trent Snellings, for GIS-technical support; and Patty Ging and Brent Aulenbach for technical reviews.

APPROACH

This section documents sources of data used in this analysis, protocols used for site selection and data screening, methods used for trend and load calculation, and methods used for analysis of nutrient-source data and landscape attributes.

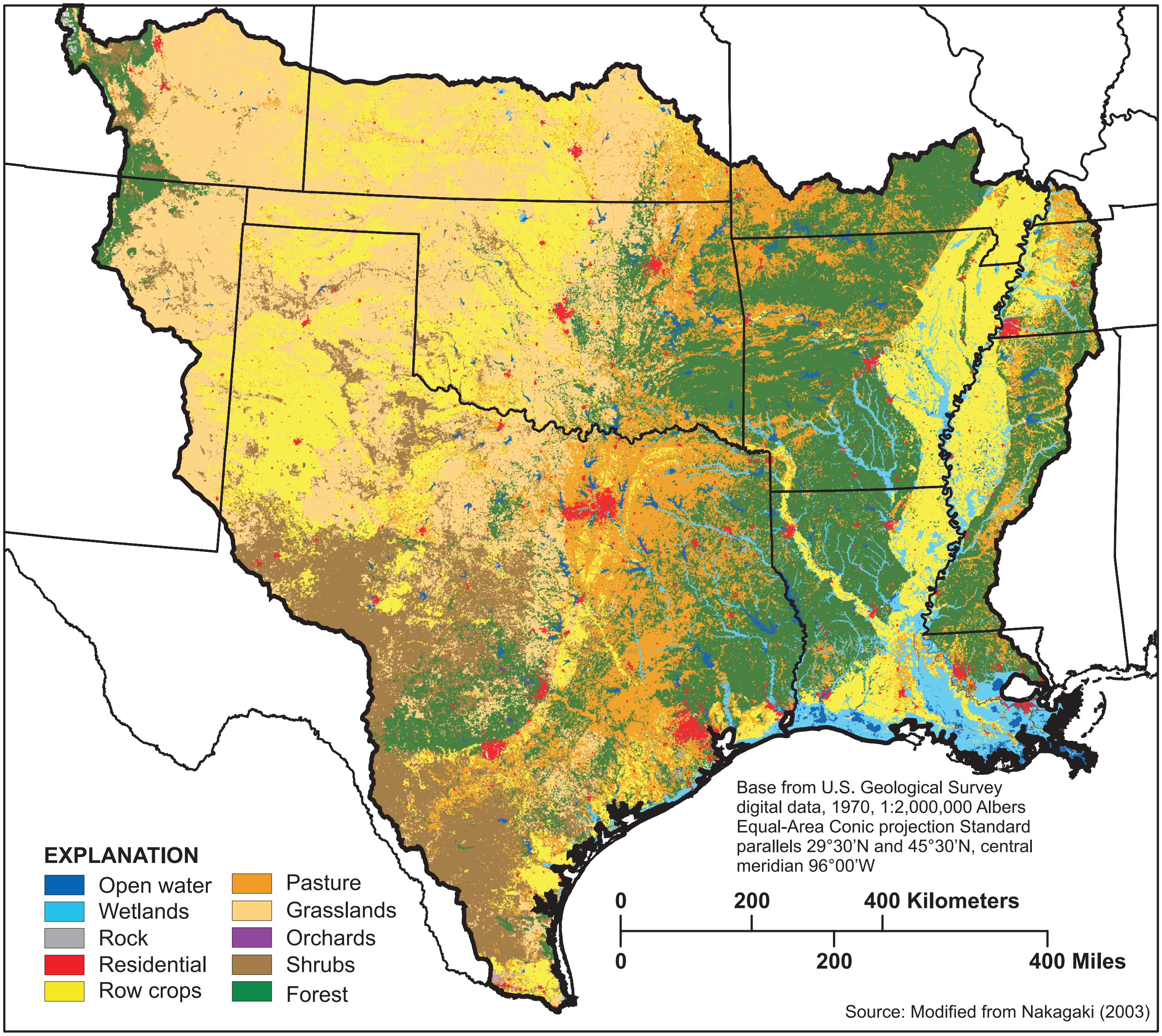


Figure 4. Land use within the study area.

Sources of Data

Two types of data were assembled for analysis in this study: water-chemistry and flow data used for trend and load analyses, and spatial data such as nutrient sources and landscape attributes used to explain identified trends. Data are stored and archived locally in the databases of the USGS Mississippi Water Science Center and nationally as part of the NAWQA Program.

The primary source of water-chemistry and flow data for this assessment was data collected by the USGS. Since the early 1970s, the USGS has collected water-quality information from major river basins throughout the United States as part of three national programs: the Hydrologic Benchmark Network (HBN), the National Stream Quality Accounting Network (NASQAN), and the NAWQA Program. In addition, other long-term water-quality monitoring stations operate as part of USGS cooperative projects in various States. All data from these USGS efforts have been compiled and are available to the public by means of the Internet as part of the National Water Information System Web Interface (NWISWeb) accessible at http://waterdata.usgs.gov/nwis/qw.

Another source of water-chemistry data was data collected by State agencies within the LMT Basin as part of ambient data-collection programs. Environmental agencies in Arkansas and Missouri have partnered in the past with USGS to acquire certification for their respective laboratories through the USGS Laboratory Evaluation Project, which is under the direction of the USGS Branch of Quality Systems (http://bqs.

usgs.gov/lep/index.html); therefore, all of the data approved for these two State agency laboratories have been entered into the national USGS database and are available to the public through the NWISWeb previously mentioned. In addition, nutrient and sediment data were requested and received from the States of Louisiana, Mississippi, Tennessee, and Texas. The final source of water-quality data considered for analysis was from the USEPA Legacy Data Center (LDC) and the Storage and Retrieval (STORET) database (U.S. Environmental Protection Agency, 2004b).

In order to explain trends in surface water-quality data, it is important to identify and understand temporal and spatial patterns in source data and landscape attributes. Geographic information system (GIS) software (ESRI, 2005) was used to automatically delineate drainage-area boundaries and create digital polygons for most sites included in the trend analyses. Sites excluded from drainage area delineation were sites that were extremely large, such as sites on the mainstem of the Mississippi River, or sites where drainage area delineations were indeterminate, such as marsh areas along the coast where flows intermingle. Once the drainage areas were delineated, their corresponding digital polygons were overlain on thematic maps of county-level nutrient source and landscape data pertinent to this study. Source data were then summed for a particular site's drainage area on a temporal basis. The nutrient source and landscape data included in this analysis were fertilizer use for nitrogen and phosphorus (annual data for the entire study period), manure generation for nitrogen and phosphorus (available for 1992, 1997, and 2002), atmospheric deposition for nitrogen (annual data for the entire study period), population density (1990 and 2000 census data), and management practices information (including irrigation type and conservation practices for 1992 and 1997). Where drainage areas extended only partly into one or more counties, the source or landscape data were apportioned according to the amount of agricultural or urban land contained within the drainage area, as described by Nakagaki and Wolock (2005).

Site Selection and Water-Quality Data Screening

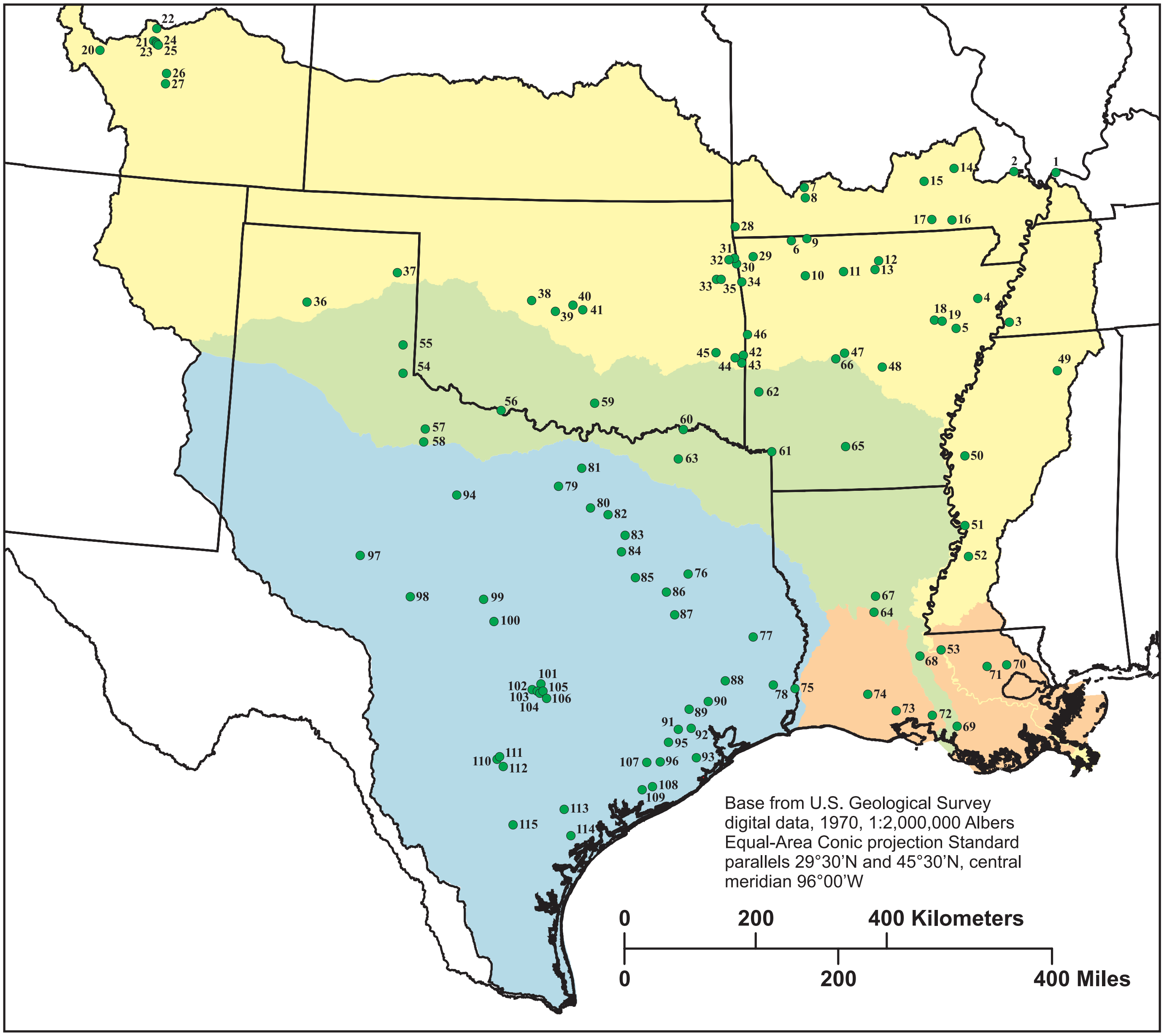
Sites were selected for analysis of trends from the USGS NWISWeb, USEPA-LDC and STORET, and State ambient databases for water years 1993-2004 (October 1, 1992, through September 30, 2004). A few sites were included in this study that had sampling periods that started after October 1, 1992, or ended prior to September 20, 2004, because of their importance relative to location or land-use type. Other than a few exceptions, most sites were selected for trend analysis based on the following minimum criteria:

- Period of record with a beginning year of 1993 or earlier and an ending year of 2004 or later;
- At least quarterly sampling each year;
- Data gaps no longer than 2 years and only during the middle part of the study period;
- Representative coverage of samples over the complete range in flow for the study period to avoid bias toward low or high values;
- Representative coverage over all seasons to avoid bias towards certain times of the year; and
- Continuous mean daily streamflow data at the trend site or an alternate site nearby that could be used as a substitute (for example, a streamflow site located downstream from the trend site would be appropriate if no major tributaries enter the stream between the streamflow site and the trend site).

Based on these criteria, there were 115 sites selected for trend analysis that had an adequate amount of data of at least one of the nutrient constituents or suspended sediment (table 1 and fig. 5). Because site-selection criteria were based primarily on data availability, spatial representation of the selected sites within the LMT Basin was considered fair to poor because there were areas that were underrepresented, such as in southern Kansas, most of Oklahoma, and parts of Texas and Louisiana (fig. 5). Lack of spatial representation, as well as other issues such as a wide range of drainage area sizes and multiple sites located on the same stream (nesting), could cause problems when interpreting trend results in a regional context.

Although there were areas within the LMT Basin that were underrepresented spatially, nearly all of the major rivers and streams that drain directly into the Gulf of Mexico had trend sites that were included in the study. The exceptions were the Guadalupe River in Texas (however, sites on the San Antonio River, which is a major tributary of the Guadalupe River, were included) and the Calcasieu River in Louisiana; neither of these two rivers had sites with enough water-quality or flow data required for analysis. The Ohio River at Dam 53 near Grand Chain, Illinois (site 1, table 1), and the Mississippi River at Thebes, Illinois (site 2, table 1), were outside of the study area but were included for analysis in order to document nutrient and sediment loadings entering the study area.

As a basis for comparing trend, load, and yield results, the trend sites were then grouped into four primary systems of rivers as follows: the Mississippi, Atchafalaya, Louisiana-Gulf/Pontchartrain, and Texas-Gulf systems (highlighted in yellow, green, orange, and blue, respectively, in tables and figures throughout this report). In most recent studies, the Mississippi and Atchafalaya systems typically are grouped together because nearly all of the water in the Atchafalaya River comes from diversion of about 25 percent of the flow from the Mississippi River (about 4,350 m3/s average annual flow; Goolsby and others, 1999). The remaining flow in the Atchafalaya River comes from the Red and Ouachita Rivers, which have combined average annual flow of about 1,020 m3/s. Because the Atchafalaya River is a separate entry point from the Mis-



EXPLANATION

Mississippi system

Atchafalaya system

Louisiana-Gulf/Pontchartrain system

Texas-Gulf system

115 Sampling site and map number from Table 1.

Figure 5. Sites selected for trend analyses and load calculations in the study area for the period, 1993-2004.

sissippi River into the Gulf of Mexico, results were grouped separately for the Atchafalaya River in this study.

Sites with small drainage areas were not eliminated, although their overall contributions of nutrient and sediment loads were potentially insignificant within the drainage area of a large river basin. These sites were important as they provided valuable information related to specific land-use types. For example, sites that were part of localized urban studies, such as near Colorado Springs, Colo. (sites 21-27, table 1), and near Austin, Tex. (sites 101-106, table 1), were included to understand trends in nutrient and sediment data from urban runoff as opposed to other areas in the LMT Basin that were forested or agricultural. Also, inclusion of sites with smaller drainage areas provided the opportunity to document potentially dramatic changes in water quality over the past decade that were due to management changes or restoration activities.

Data were compiled separately for ammonia, nitrite plus nitrate, total nitrogen, orthophosphorus, total phosphorus, and suspended sediment. For data compiled from NWISWeb, previous comparisons of paired filtered (dissolved) and unfiltered (total) samples for ammonia, nitrite plus nitrate, and orthophosphorus at the USGS National Water Quality Laboratory (NWQL) in Denver, Colo., indicated that analytical results were virtually indistinguishable nationally (U.S. Geological Survey, 1992). Comparisons were made for this study and study period for data compiled from NWISWeb. Similar results were observed when filtered nitrite plus nitrate data were compared to unfiltered data; however, differences were observed when comparing filtered and unfiltered ammonia and orthophosphorus. Therefore, filtered and unfiltered results for nitrite plus nitrate were combined, but only filtered ammonia and orthophosphorus were used for analysis in this study for data compiled from NWISWeb.

When a direct measurement of total nitrogen was unavailable, it was calculated as the sum of unfiltered ammonia plus organic nitrogen (hereafter referred to as Kjeldahl nitrogen) and nitrite plus nitrate data. If either Kjeldahl nitrogen or nitrite plus nitrate data were missing, then total nitrogen was not calculated. If either Kjeldahl nitrogen or nitrite plus nitrate data were less than their respective reporting levels (hereafter referred to as censored values or results), then the value for total nitrogen was calculated as follows:

- If both Kjeldahl nitrogen and nitrite plus nitrate data were censored, then total nitrogen was censored to the sum of both censoring levels;

- If Kjeldahl nitrogen was not censored, but nitrite plus nitrate was censored, then total nitrogen was calculated as the sum of the Kjeldahl nitrogen value plus half of the censored value for nitrite plus nitrate; and

- If Kjeldahl nitrogen was censored, but nitrite plus nitrate was not censored, then total nitrogen was calculated as the sum of the nitrite plus nitrate value plus half of the censored value for Kjeldahl nitrogen.

Once the data sets for the sites considered in this study were compiled, additional censoring adjustments were necessary prior to analysis. Before the late 1990s, the NWQL censored data at the minimum reporting level (MRL), which is the smallest measurement of concentration that can be measured by using a particular analytical method (Oblinger-Childress and others, 1999). Establishment of MRLs has been inconsistent across methods, inadequately defined, and generally undocumented. In 1992, the NWQL began adopting the USEPA method detection limit (MDL) procedure for establishing censoring levels for two pesticide methods. The MDL method is described as the minimum concentration of a substance that can be measured when the risk of a false positive detection is no more than 1 percent (Oblinger-Childress, 1999). Because the risk of a false negative at the MDL can be as much as 50 percent, the NWQL formed a team to better define censoring levels at higher levels. As a result, the NWQL began to censor data at the laboratory reporting level (LRL), a value generally twice the MDL (actually the LRL is twice the long-term MDL [LT-MDL], which is a modification of the USEPA MDL designed to capture more method variability). This practice was implemented in 1999 for Kjeldahl nitrogen, in 2000 for total phosphorus, and in 2001 for ammonia, nitrite plus nitrate, and orthophosphorus. Values measured less than the LT-MDL were reported as less than the LRL, and values measured between the LT-MDL and LRL were reported as estimated.

Using the LRL can result in upward bias during statistical analyses of censored data (which are used in this study) because the probability that an observation might fall between the LT-MDL and LRL is likely overstated (Helsel, 2005). The possibility of the occurrence of a few false negatives is less of a concern than the problems caused by such a bias (Mueller and Spahr, 2005). As a result, all data analyzed by the NWQL and used in this study were recensored from the LRL to the associated LT-MDL reported by the NWQL for a given constituent during a given time period. A small number of the samples had been diluted, and resulting LRL values had been multiplied by the dilution factor; for these samples, values were recensored to the MDL multiplied by the dilution factor. Recensoring of the NWQL data took place prior to calculation of total nitrogen previously discussed.

Trend and Load Calculations

A trend is defined as a systematic change in a water-quality constituent over time (D.L. Lorenz, U.S. Geological Survey, written commun., 2004). To complete trend tests for water-quality data, one must understand the complexities and processes that influence water-quality conditions in surface waters. Natural influences include climate, hydrology, precipitation, soil erosion, chemical reactions, and biological activities. Human influences include chemical applications, flow regulation, addition or removal of wastewater treatments plants, and land-use changes. The difficulty in interpreting trends in water-quality data is the ability to separate actual trends in the data from natural variability, as well as from artificial trends (for example, trends resulting from changes in sample collection, sample processing, and laboratory analytical methods over time).

It is important to decide if flow adjustment is necessary in trend testing. If trends tests are used to determine effects on aquatic communities, then flow adjustment may not be important. For example, total ammonia (NH3 plus NH4+) exceeds chronic criterion for aquatic organisms for concentrations above about 2.1 milligrams per liter (mg/L) when pH is within the range of 6.5 to 9.0 and temperature from 0 to 30 degrees Celsius (Mueller and others, 1995). To determine the effects on a particular ecosystem, it is not pertinent that increases in streamflow were the primary cause for the increases in total ammonia over time, but simply that ammonia concentrations increased and exceeded the criterion. If, however, it is important to understand why ammonia concentrations exceeded the criterion over time, then the trend test should be adjusted for flow to determine if the trend is retained. Flow adjustment is a technique used to understand actual changes in a water-quality constituent without influence of trends in flow. Data are adjusted for flow by establishing a relation between flow and the water-quality constituent prior to trend testing. If the trend in ammonia was retained when flow adjusted, then the increase may have been caused by a human-related action, such as an increase in fertilizer usage.

For this study, it was important to estimate both unadjusted (hereafter referred to as total trends in concentration) and flow-adjusted trends to understand the overall picture of what was happening in relation to nutrient and sediment concentrations within the LMT Basin. Other important trends to consider were trends in load, which provide a direct measure of the effect of nutrients and sediment discharging on the northwestern Gulf of Mexico, and trends in flow, which will improve interpretation of water-quality trends by understanding how flow has changed over time. The following sections describe methods used to calculate (1) total trends in concentration and load; (2) trends in flow-adjusted concentration; (3) interpretation of trend results; and (4) annual load calculations.

Total trends in concentration and load

Determination of total trends in concentration and load was attempted for all six constituents at each site listed in table 1 for the study period. Total trend in concentration and trend in load are defined as the percent changes in model-estimated, smoothed trend in concentration and load over the period of the water-quality record, divided by the length of the record (trend is, therefore, represented as percent change per year). The model-estimated trend in concentration and load is determined by combining separate trend models for streamflow and water-quality concentration. The streamflow model, estimated from all daily streamflow measurements available over the study period, relates the daily streamflow to an intercept, a linear trend term (measured by time expressed as a decimal), and sine and cosine seasonal factors (also functions of decimal time). The water-quality model is represented by the following equation:

$$c_t = b_0 + m(q_t)b_q + h(T_t)b_T + x_t b_x + e_t\,, \qquad (1)$$

where:

c_t	=	the logarithm of constituent concentration in period t;
b_o	=	an intercept value;
q_t	=	the logarithm of streamflow;
T_t	=	decimal time;
x_t	=	vectors of ancillary predictors such as sine and cosine functions of decimal time to account for seasonality;
b_q, b_T, b_x	=	coefficients determined from model fitting;
$m(q_t)b_q$	=	multi-element vector function consisting of the logarithm of streamflow and the square of the natural logarithm of streamflow;
$h(T_t)b_T$	=	multi-element vector function consisting of the second order polynomial of decimal time; and
e_t	=	random error term.

The smoothed trend in water-quality concentration is determined by the streamflow and time trend components of the water-quality model, where the smoothed trend in streamflow is substituted for the actual streamflow in the streamflow component (the smoothing of streamflow is a linear fit over logarithmic space). The smoothed trend in streamflow is given by the following equation (which is a form of the linear relation y = b + mx):

$$\tilde{q}_t = \overline{q} + a(T_t - \overline{T}), \qquad (2)$$

where:

$\tilde{q}_t$	=	smoothed trend in the logarithm of flow in the period t;
$\overline{q}$	=	average of the logarithm of flow over the trend period;
T_t	=	decimal time;
$\overline{T}$	=	average, or midpoint, of the decimal time over the trend period; and
a	=	coefficient determined from the model fitting.

Total trend in concentration is obtained by transforming the water-quality trend from logarithm space to real space, computing the percent change corresponding to the first and last dates of the water-quality record period, and dividing by the decimal time length of the study period. Trend in load is computed similarly, except the smoothed trend in streamflow is added to the smoothed trend in water-quality prior to retransformation to real space. The appendix contains a detailed description of this method, with additional discussion of the estimation of the streamflow and water-quality models and an explanation of the associated statistical tests for trend.

Flow-adjusted trends in concentration and trends in flow

The estimation of flow-adjusted trend in concentration is similar to the estimation method for total trend. The only difference is that the streamflow component of the water-quality model is not included in the determination of the smoothed water-quality trend. The estimation of the trend in streamflow is based on the smoothed streamflow trend corresponding to the simple linear function of decimal time previously described. The conversion of this smoothed trend to a trend estimate follows the same procedure described for total trend, the only difference being that the period of the trend is defined by the beginning and ending dates for the flow record within the analysis period rather than the beginning and ending dates of the water-quality record.

Interpretation of trend results

Each trend analysis produced an associated estimate of probability, or p-value, which is the probability of attaining a specified significance level (Helsel and Hirsch, 1992). P-values were compared to a significance level, or, of 0.05 (5 percent), which meant that there was less than a 5-percent chance of errors in test results. Trend results presented in this report were considered statistically significant when p-values were less than 0.05. In addition, diagnostic plots (such as a plot of actual versus predicted values) and standard error of prediction (SEP) estimates were examined to determine overall model "fit." Models and subsequent trend results were rejected if problems were observed in diagnostic plots (such as predicted values were much higher or lower than actual values) or if a model produced large, unacceptable SEP estimates.

Trend results were reported as a percent per year change; however, it was important to understand these percent changes in terms of original units, such as milligrams per liter for concentration data. Reference concentrations and loads were computed for each statistically significant trend. Reference concentrations and loads are best explained as the "starting point" of a trend line drawn through the data with a slope equal to the trend estimate. A reference concentration is obtained by evaluating the water-quality model at reference conditions consistent with the trend in water quality at the beginning of the water-quality period of record. These conditions include setting streamflow equal to its smoothed trend value corresponding to the first day of the water-quality period, setting the trend term to the decimal equivalent of the first day of the water-quality period, and setting the sine and cosine seasonal factors to their average values over the full water-quality period. The value of the reference concentration is transformed to real space, and a multiplicative retransformation factor is applied to correct for statistical bias arising from sample error in the water-quality model coefficients (see the appendix for additional details). The reference load is computed similarly, except that streamflow trend as determined by the streamflow equation evaluated at the starting date of the water-quality period, is added to the reference concentration prior to transformation to real space; also, a multiplicative constant is applied to convert the result to appropriate load units.

When there is no trend in streamflow over time, total trend and flow-adjusted trends are basically equivalent. Because the water-quality model used to derive these trends includes streamflow as a predictor, the estimates of trend are immune to bias arising from preferential water-quality sampling during high-streamflow events. Care should be taken, however, in interpolating or extrapolating these trend estimates within or beyond a site's period of record, or in making comparisons of trend across sites that have different periods of record. Because of the possible nonlinearity of trend, as arising from nonlinear specifications of the water-quality model streamflow or trend components, trends within the water-quality period or trends experienced outside this period could be quite different from the trends reported here. It also should be recognized that the method used to evaluate trend is insensitive to changes in the variability of streamflow or to changes in the unexplained variability of water quality, both changes potentially resulting in trends in water quality arising from nonlinearity in the specification of the water-quality model. Accommodation of this type of uncertainty awaits future research.

Load calculations

Annual load and yield calculations were attempted for all six constituents at each site listed in table 1 for each water year in the study period. The statistical program LOADEST (Runkel and others, 2004) was used to calculate annual loads. The specific software used was S-LOADEST, which is a "USGS plug-in" version of LOADEST in S-PLUS (version 7.0), a PC-based statistical software package (Insightful, 2005). LOADEST uses a seven-parameter linear regression model that incorporates flow, time, and seasonal terms to estimate loads of concentration over time for specific time periods (annual, monthly, or daily loads). The calibration and estimation procedures within LOADEST are based on three statistical estimation methods. The first two methods, maximum likelihood estimation (MLE) and adjusted maximum likelihood estimation (AMLE) are appropriate when the calibration model residuals are normally distributed. Of the two, AMLE is more appropriate when the calibration data set (time series of streamflow and concentration data) contains censored data; otherwise, MLE and AMLE give the same results when there are no censored data present. The third method, Least Absolute Deviation, is an alternative to AMLE when residuals are not normally distributed (Runkel and others, 2004).

One load model was developed for the entire study period for each constituent at each study site (in other words, the study period was not subdivided into smaller periods of time). Daily mean values of streamflow were used in the calibration data set for each site for each sample date. A LOADEST option was chosen that automatically selected a "best-fit" load model by using the Akaike Information Criterion (Akaike, 1981) associated with each of the eight subsets of the seven-parameter regression equation. The AMLE method was used to estimate the coefficients of the dependent variables in the best-fit regression model equation in LOADEST because censored data were present in nearly all data sets. The AMLE procedure also corrects for first-order bias in the regression coefficients and minimizes other biases that can occur when estimated logarithms of load are retransformed to original units (Cohn, 1988; Cohn and others, 1992).

Two fundamental assumptions of linear models are homoscedasticity, which means that the variance about a regression line is similar for all predictor variables, and normality, which is an assumption that model residuals follow a normal (or even) distribution. Residuals were plotted in a variety of ways such as quantile plots, residuals versus streamflow, residuals versus decimal time, and so forth. The plots were examined for homoscedasticity and normality; for example, residuals are considered to be normally distributed if they plot evenly above and below a "zero" horizontal line in a residuals versus decimal time plot. If either assumption was violated, the model was rejected. If the best-fit model did not meet the linearity assumptions, the next step was to explore a custom model with user-specified variables. Independent variables available for consideration in custom models were reciprocal transform of streamflow, reciprocal transform of streamflow squared, one or two breakpoints in streamflow, and seasonal periods that were a series of months defined by the user. Residuals from the resultant custom models were similarly examined for homoscedasticity and normality, and the optimal model was selected. If this step failed to produce an acceptable model, then the constituent at that site was excluded from load calculations.

Once calibrated, daily mean values of streamflow were used as independent variables in a prediction data set to estimate annual loads. Average annual loads were calculated by dividing the total load for the study period by the number of years of estimated loads for that site. Average annual yields at each site were then calculated by dividing the average annual load by the site's drainage area.

An attempt was made to provide hydrologic perspective to selected trends in loads from this study. In other words, were trends in loads observed in this study part of much longer trends or were they more indicative of the most recent decade? Sites 1, 2, 48, and 53 in the Mississippi system, and sites 64 and 68 in the Atchafalaya system are part of the USGS NASQAN Program and were selected to provide hydrologic perspective because they have long-term concentration and flow data. Annual nitrogen and phosphorus loads have been computed for these sites for their periods of record (early 1960s to present) by using LOADEST software and a 5-year "moving window" approach (Aulenbach and others, 2007). These annual loads were plotted for the time period 1980-2004 along with a corresponding locally weighted scatterplot smooth (LOWESS; Helsel and Hirsch, 1992) line drawn to indicate variability in the data over the longer time period. Although suspended sediment load calculations were not available in Aulenbach and others (2007), suspended sediment loads at these six sites were computed by using the 5-year moving window approach for the 1980-2004 time period and were graphed similarly. (Note: Annual loads of ammonia, orthophosphorus, and suspended sediment were not computed for site 64 for the period 1980-2004 by either Aulenbach and others (2007) or the authors of this study because of lack of concentration or flow data.)

Site 112 in the Texas-Gulf system was also selected to provide hydrologic perspective because it has long-term concentration and flow data, and it represents a river system other than the Mississippi and Atchafalaya. Annual loads were computed by using the 5-year moving window approach for the period 1980-2004 for nitrite plus nitrate, total nitrogen, and total phosphorus data from site 112 and then were graphed similarly to those previously mentioned with a corresponding LOWESS line. Other nutrient constituent and suspended-sediment loads were not calculated for the 1980-2004 period at site 112 because of lack of concentration or flow data prior to 1993. (Note: average annual streamflows for the period 1980-2004 for the same seven sites mentioned here were also graphed with a LOWESS line to give hydrologic perspective to trends in streamflow calculated for the study period.)

Analysis of Source Data and Landscape Attributes

Trends in nonpoint and point sources of nutrients were related to trends in nitrogen and phosphorus data estimated for this study. Trends in nonpoint sources of nitrogen and phosphorus included fertilizer, manure, and atmospheric deposition (nitrogen) data, as previously mentioned. Nitrogen and phosphorus fertilizer data were available for both agricultural and urban settings. These data were combined to create a single nitrogen and phosphorus fertilizer data set. Similarly, nitrogen and phosphorus data from manure were available for both confined and unconfined animal feeding operations, which were combined to create a single nitrogen and phosphorus manure data set. Data for nitrogen in atmospheric deposition were based on data from the USGS National Atmospheric Deposition Program / National Trends Network, accessible at http://bqs.usgs.gov/acidrain/. Fertilizer, manure, and atmospheric nitrogen data were expressed, in terms of mass, as total kilograms of nitrogen or phosphorus summed for the drainage area at a particular site. More detail on fertilizer, manure, and atmospheric deposition data generation can be found in Ruddy and others (2006).

Information about point-source loadings of nutrients was obtained from State management agencies, with additional information obtained from the USEPA Permit Compliance System (http://www.epa.gov/compliance/data/systems/water/pcssys.html). Unfortunately, information for point-source loadings from these two sources were inconsistent for the study area; therefore, population data were used as a “surrogate” to make inferences regarding point-source loadings as a means of interpreting trend results. The population data were derived from a 30-m resolution grid of census block groups and population counts based on the 1990 and 2000 Census of Population and Housing (U.S. Census Bureau, 1991; U.S. Census Bureau, 2000). Population data also were used to explain trends in suspended sediment; for example, increases in population could imply increases in urbanization, which in turn could cause increases in sediment in streams due to clear-cutting of trees for new subdivisions, increase in impervious area, and so forth. In terms of density, population data were expressed as number of persons per square kilometer.

To relate trends in water quality to the source data, the source data were reduced to a single value of trend at each site where source data were available. If there were more than two points of time with data, such as the fertilizer data which was generated on an annual basis, a Theil slope was computed. The Theil slope is the median of all pairwise slopes (Helsel and Hirsch, 1992) and is expressed as the amount of increase or decrease in the source data per year. The Theil slope computed at each site was then normalized by dividing by the drainage area of the site. Because the population data had data for only two points in time and were already expressed in terms of drainage area, the trend in population was simply calculated as the difference in densities from 1990 to 2000.

Weighted-least-squares (WLS) regression was used to determine if there were statistically significant regional patterns by comparing water-quality trend results to corresponding trends in source data. The reduced results (trends) of the source data were the independent variables in the WLS regression. Water-quality trend values were the dependent variables in the WLS regression, and each was weighted so that values that were known with more confidence (those with lower variances) had a greater weight in the regression than values that were known with less confidence (Helsel and Hirsch, 1992). Because weights were used, all water-quality trend values (coefficients of time) were included in the WLS regression, even those that were not considered statistically significant. Weights were based on the inverse of the variance from the trend estimates for each constituent at each site. Statistically significant regression results were those that had p-values greater than 0.05 (or there was less than a 5-percent chance that a result was not statistically significant).

Water-quality trend results were also compared to trends in management practices at each site. The management practice data were derived from selected 1992 and 1997 National Resources Inventory (NRI) data compiled by the Natural Resources Conservation Service (NRCS; U.S. Department of Agriculture, 1995; U.S. Department of Agriculture, 2001). These data were categorized into two primary groups – areas with irrigation and areas with conservation practices. These data were aggregated in areas with agricultural land use at the county level and then summed within the drainage area for each site. Irrigated areas were further divided into four subgroups: areas that used well water as the irrigation source; areas that used surface water (ponds, lakes, reservoirs, streams, ditches and canals) as the irrigation source; areas that used lagoons or other wastewaters, or a combination of sources; and areas that used gravity, pressure, or a combination of gravity or pressure as a means of irrigation-water delivery. Conservation practices data were further divided into three subgroups: areas that used contour farming and land leveling; areas that used tail-water recovery; and areas that had surface drainage. All management practices data were expressed, in terms of area (square kilometers), as the amount of land in the drainage area of a study site that contained that particular practice.

Management practice categories used in this study were the only ones where data were available in both 1992 and 1997 so that trends could be calculated. Unfortunately, several potentially influential data sets were not included in the 1997 NRI series such as conservation tillage, irrigation land management, irrigation land leveling, and subsurface drains. The data that were not included, particularly the conservation practice data, may have had a substantial influence on water-quality trends in streams in the LMT Basin, and these possible influences are not reflected in the analysis of management practices in this report.

For these reasons, WLS regression analysis techniques presented previously were not used with respect to the management practices data. Instead, potential trends in the management practices data were determined by subtracting the amount of land in a particular practice in 1992 from the amount of land in that same practice in 1997. The results were then normalized by dividing the difference by the drainage area of the study site and then multiplying by 100. The resulting value represented the change in the amount of a particular management practice expressed as a percentage of the total drainage area of a study site. In most cases, the change in amount of management practices from 1992 to 1997 represented a very small percentage of the total drainage area of a particular site (most less than 1 percent); only values greater than 1 percent (representing an increase in the amount of management practices) or values less than -1 percent (representing a decrease in the amount of management practices) were reported in this study.

RESULTS

Results of this study are presented in the following four sections: streamflow, nitrogen, phosphorus, and suspended sediment. Although specific trend results are presented in tables, they are also plotted to provide the reader visual detail. Annual loads are tabled where applicable. To maintain minimal text interruptions, all tables are presented at the end of the report.

Explanations of detected trends on a regional scale were problematic due to limited nutrient source, land use, and management-practice explanatory data. However, explanations of notable trends at some locations are discussed in each section where supported by literature. These trend explanations are general and are not intended to be definitive. A more detailed scientific investigation at each site would be necessary to provide a complete explanation as to the cause of a particular trend.

Streamflow

Trend analyses of streamflow data were attempted for all study sites in the four primary river systems (table 2, fig. 6). Trend results were rejected for five sites because of poor model fit. Of the remaining 110 sites where trend analyses were attempted and results were considered acceptable, there were 70 sites (about 64 percent) where no significant trends in streamflow were observed during the study period (table 2). Decreasing trends in streamflow were observed at 38 sites ranging from -8.2 to -2.2 percent per year during the study period (table 2, fig. 6).

For the study area, moist conditions prevailed at the beginning of the study period through about 1996 as observed from monthly Palmer Hydrologic Drought Index maps (National Oceanic Atmospheric Administration, 2006). Severe to extreme drought conditions occurred three different times during the study period–1996, 1998, and 2000–with the most extreme drought conditions occurring from October 1999 through November 2000 (National Oceanic Atmospheric Administration, 2006). Although there are many factors that could influence trends in streamflow, such as changes in land use, urbanization, and gain/loss of riparian zone wetlands, it is believed that the overall decreasing trends in streamflow for the study area during the study period likely were due to moist conditions occurring at the beginning of the study period and the influence of three drought periods near the middle and end of the study period (with the most extreme occurring in 2000).

In looking at streamflow data at selected sites for the period 1980-2004 (fig. 7), the decreasing trends in streamflow at sites 2, 48, 64, and 68 were specific to the study period and were not part of long-term trends. There was a slight decreasing trend (-2.2 percent per year) at site 53, which is barely noticeable in the streamflow data for the time period 1980-2004 at site 53 in figure 7. There were no trends in streamflow in either the current study period or the period 1980-2004 at site 1 (table 2, fig. 7).

Only two sites had significantly increasing trends in streamflow. Increasing trends in streamflow of 7.9 and 10 percent per year at sites 112 and 113 (fig. 6), respectively, on the San Antonio River in the Texas-Gulf system were observed during the study period. After the drought of 2000 subsided, moist conditions returned to south-central Texas, and conditions have been considered extremely moist since late 2002 with Palmer Hydrologic Drought indices consistently at or above about 4.00 (National Oceanic Atmospheric Administration, 2006). Moist conditions returning to southern Texas after the drought of 2000, coupled with recent increases in urbanization and impervious surfaces within the San Antonio River Basin (as suggested by Sahoo and Haan, 2005), are likely contributors to the increasing trends in streamflow during the study period at these two sites. In addition, the increasing trends in streamflow for the San Antonio River Basin for the study period were not part of long-term increases but appear to be part of a recent decadal trend that started about 1995 (based on average annual flows assembled for site 112 in figure 7).

Nitrogen

Specific details about trend, load, and yield results for ammonia, nitrite plus nitrate, and total nitrogen data are discussed at the beginning of this section. These results are then related to potential trends in nutrient sources and landscape attributes. Finally, some general conclusions about nitrogen trend and load results are discussed at the end of this section.

Ammonia trends, loads, and yields

Trend analyses of ammonia data were attempted for 93 study sites in three of the four river systems, with the exception of the Louisiana-Gulf/Pontchartrain system, which had no sites with an adequate amount of ammonia data to attempt trend analyses (table 3). Trend results were rejected for 44 of the 93 sites because of poor model fit (represented as N/A in table 3).

Of the remaining 49 sites where trend results were considered acceptable, there were 25 sites (about 51 percent) where no total trends in concentration were observed during the study period (table 3). Decreasing total trends in concentration were observed at the remaining 24 sites ranging from -8.9 to -3.8 percent per year during the study period (table 3, fig. 8). There were 24 sites (about 49 percent) where no flow-adjusted trends in concentration were observed during the study period (table 3, fig. 9). Decreasing flow-adjusted trends in concentration were observed at the remaining 25 sites ranging from-8.9 to -4.1 percent per year.

Either no trends or decreasing trends in ammonia data were evident across land-use types, physiographic regions, and three of the four river systems represented in the study area. Decreasing total trends results for ammonia were similar to decreasing trends in flow; however, decreasing flow-adjusted trend results were also observed, thus indicating that decreasing trends in ammonia data throughout the study area were not simply related to trends in streamflow but could be caused by decreases in ammonia sources or changes in management practices.

Improvements to municipal wastewater treatment facilities could be contributing to decreasing trends in ammonia at selected sites in the study area. For example, ammonia concentrations and loads decreased about 7.5 percent per year on average at sites 25, 26, and 27 during the study period. These three sites are located downstream of a large municipal wastewater treatment facility (site 25 is the nearest to the facility located only about 1.5 km downstream). The treatment facility was upgraded to advanced treatment during the mid-1990’s to reduce high ammonia concentrations and biochemical oxygen demand (BOD) in effluent discharged to Fountain Creek.

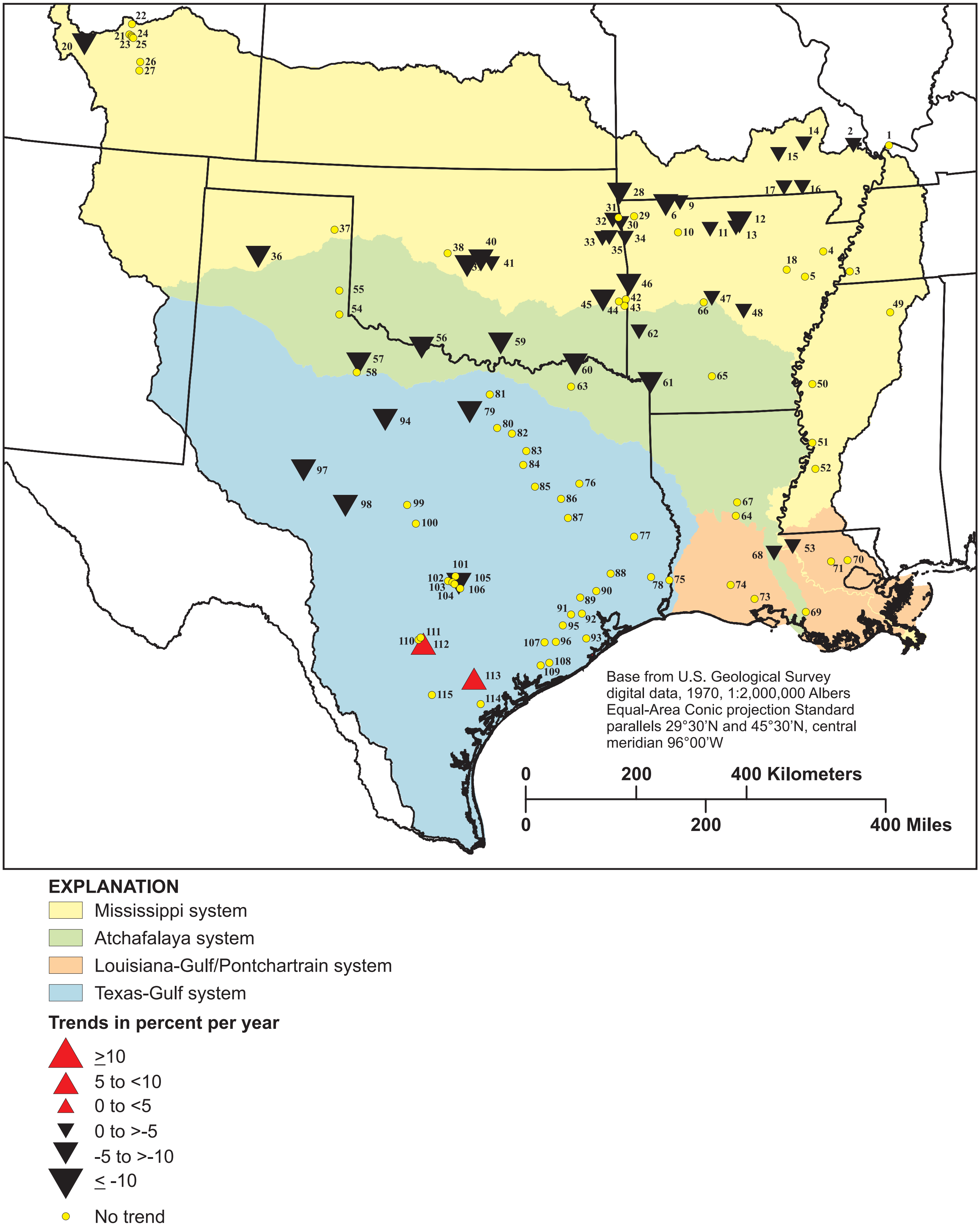


Figure 6. Trends in streamflow at study sites, 1993-2004.

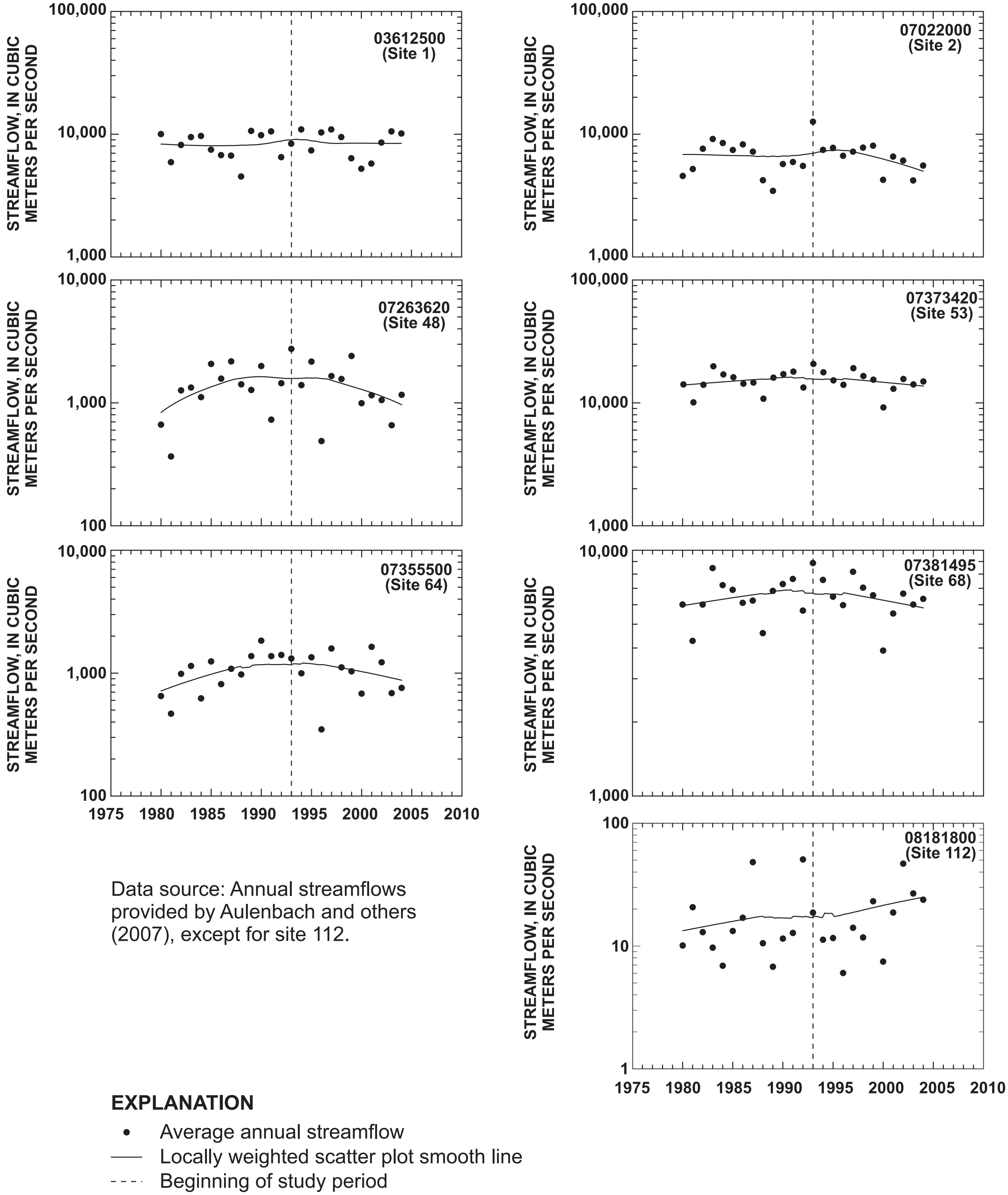


Figure 7. Average annual streamflow for selected study sites, 1980-2004.

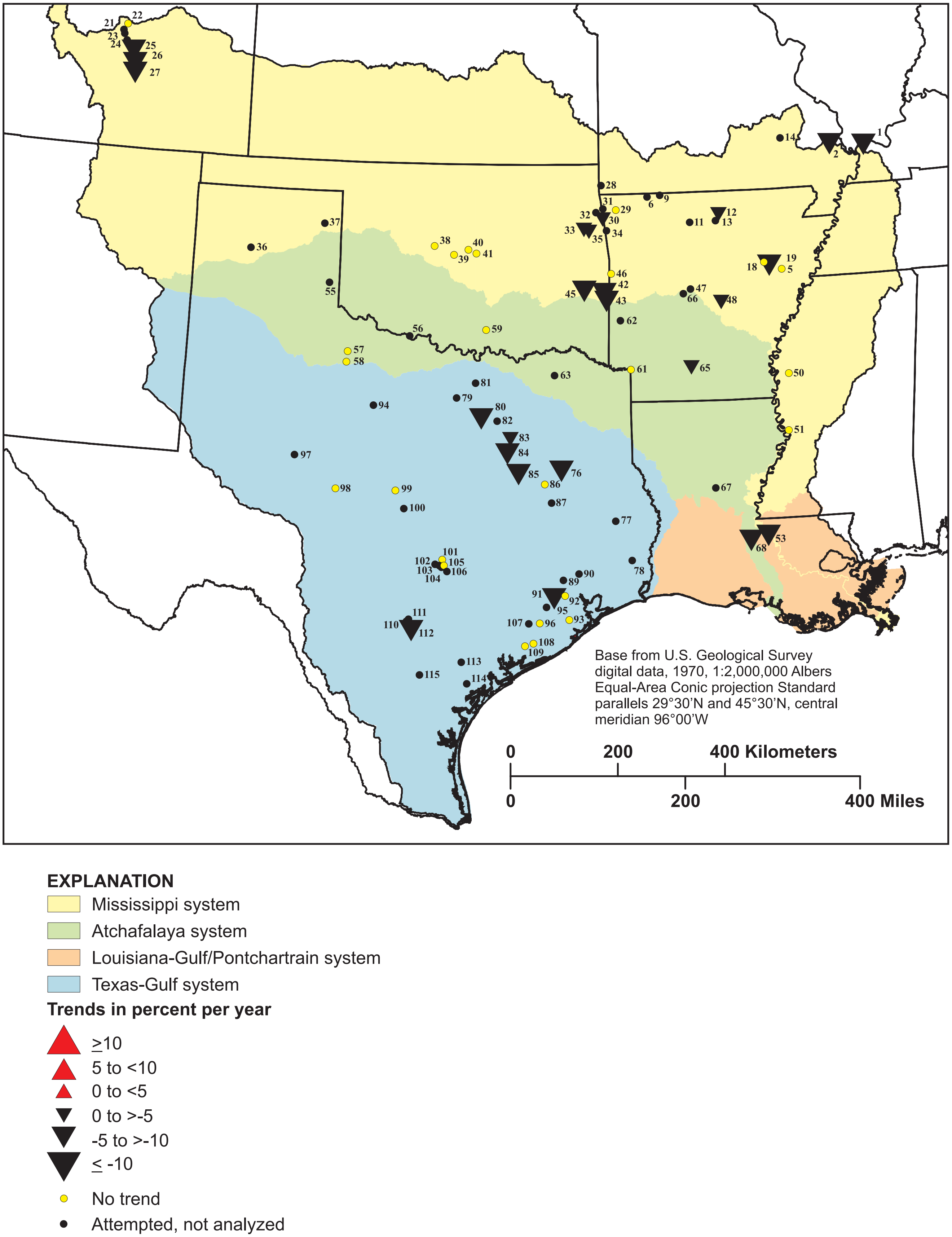
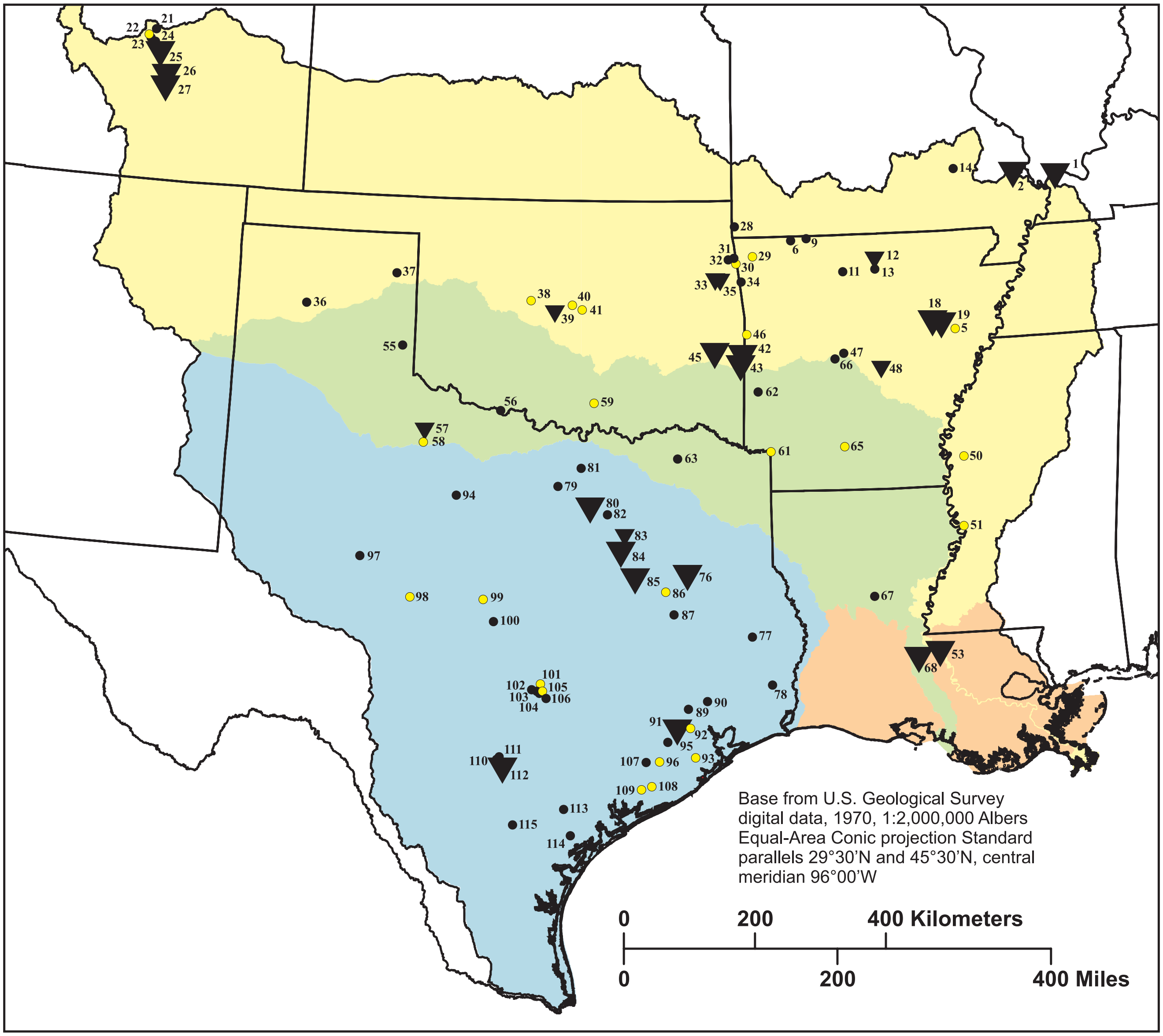


Figure 8. Total trends in ammonia concentrations at study sites, 1993-2004.



EXPLANATION

Mississippi system

Atchafalaya system

Louisiana-Gulf/Pontchartrain system

Texas-Gulf system

Trends in percent per year

≥10

5 to <10

0 to <5

0 to >-5

-5 to >-10

≤ -10

No trend

Attempted, not analyzed

Figure 9. Flow-adjusted trends in ammonia concentrations at study sites, 1993-2004.

Facility upgrades included retrofitting activated sludge tanks to advanced waste treatment for increased nitrification (addition of diffuser system), adding an anoxic zone for denitrification, increased blower sizes for nitrification to convert ammonia, and conversion of primary clarifiers to secondary clarifiers (Ginny Johnson, Colorado Springs Utilities, written commun., December 5, 2007). Effluent from the facility accounts for 40-70 percent of the total flow at site 25 (Patrick Edelmann, U.S. Geological Survey, written commun., October 10, 2006). The decreasing trends in ammonia at sites 25, 26, and 27 were likely due to the improvements in the wastewater treatment facility located upstream.

Similar results were observed for trends in ammonia loads in which 23 sites (about 47 percent) indicated no trends in load, but decreasing trends in load were observed at the remaining 26 sites, ranging from -9.4 to -5.3 percent per year (table 3, fig. 10). These trends in ammonia loads appear to be part of a longer trend in ammonia loads as seen in figure 11, which shows decreasing trends at sites 1, 2, 48, 53, and 68 since the early 1980s.

Ammonia load calculations were attempted for 37 study sites in three of the four river systems with the exception of the Louisiana-Gulf/Pontchartrain system, which had no sites with an adequate amount of ammonia or flow data to attempt load calculations (table 4). As expected, average annual ammonia loads were highest for the Mississippi system sites when compared to loads from the other two systems. Average annual ammonia loads for some of the major drainages (not necessarily the most downstream) into the northwestern Gulf of Mexico were as follows: 13,600 metric tons (T) for the Mississippi River (site 53); 7,100 T for the Atchafalaya River (site 68); and 23 T for the Neches (site 76), 317 T for the Trinity (site 86), and 115 T for the Colorado Rivers (site 108) in the Texas-Gulf system (table 4). For these same sites, however, the highest yield was 0.0294 metric tons per square kilometer per year (T·km-2·yr-1) for the Atchafalaya River, followed by yields for the Trinity, Neches, Mississippi, and Colorado Rivers, which were 0.00955, 0.00761, 0.00465, and 0.00105 T·km-2·yr-1, respectively (table 4). Load and yield data indicate that although loads are greatest from the Mississippi River, other smaller river systems can yield as much, if not more, ammonia on a per-square-kilometer basis as the Mississippi River.

Nitrite plus nitrate trends, loads, and yields

Trend analyses of nitrite plus nitrate data were attempted for 90 study sites in all four river systems (table 5). Trend results were rejected for 21 sites because of poor model fit (represented as N/A in table 5). Of the remaining 69 sites where trend results were considered acceptable, there were 47 sites (about 68 percent) where no total trends in concentration were observed during the study period (table 5). Decreasing total trends in concentration were observed at 12 sites ranging from -9.3 to -1.7 percent per year during the study period (table 5, fig. 12). Increasing total trends in concentration were observed at 10 sites, ranging from 4.2 to 39 percent per year during the study period (table 5, fig. 12). There were 48 sites (about 70 percent) where no flow-adjusted trends in concentration were observed during the study period (table 5). Decreasing flow-adjusted trends in concentration were observed at seven sites, ranging from -8.8 to -3.0 percent per year (table 5, fig. 13). Increasing flow-adjusted trends in concentration were observed at 14 sites, ranging from 2.4 to 57 percent per year during the study period (table 5, fig. 13).

Sites 16, 38, and 39 in the Mississippi system, sites 59, 61, and 64 in the Atchafalaya system, and site 71 in the Louisiana-Gulf/Pontchartrain system indicated decreases in the total trends in nitrite plus nitrate concentration results. National “background” concentration estimates of selected nutrient constituents are reported in a U.S. Geological Survey Circular (1999). Waters with concentrations of nutrients that exceeded these background levels were considered to be affected by human activities from a variety of land uses. The national background concentration for nitrite plus nitrate is about 0.6 mg/L (U.S. Geological Survey, 1999); because all of the reference concentrations at these seven sites were less than 0.6 mg/L, decreasing trends at these sites were considered negligible. Also, trends at most of these seven sites were not retained when the effects of streamflow were removed (no flow-adjusted trends found except for sites 39 and 64), which indicated that trends likely were related to decreasing trends in streamflow (table 2).

Sites 2, 26, 27, and 53 in the Mississippi system and site 98 in the Texas-Gulf system indicated decreases in total trends in nitrite plus nitrate concentration results for the study period, and reference concentrations were all greater than about 1.5 mg/L. Sites 2 and 53 did not retain trends when the effects of streamflow were removed; thus, the decreasing total trends at these two sites were likely related to decreasing trends in streamflow. Decreasing trends were retained when adjusted for streamflow at sites 26, 27, and 98, potentially indicating that management practices improved water quality or sources of nitrite plus nitrate decreased at these sites during the study period. The decreasing trends at sites 26, 27, and 98 could not be explained at this time.

Site 50 in the Mississippi system and site 75 in the Texas-Gulf system indicated no total trends in nitrite plus nitrate concentrations for the study period, but decreasing trends were observed in flow-adjusted concentrations (table 5). Reference concentrations were 0.53 and 0.08 mg/L, respectively, and consequently, less than the 0.6 mg/L national background concentration for nitrite plus nitrate (U.S. Geological Survey, 1999); thus, decreasing trends in nitrite plus nitrate at sites 50 and 75 were considered negligible.

Sites 19, 36, and 49 in the Mississippi system and site 103 in the Texas-Gulf system indicated an increase in nitrite plus nitrate for the study period in both the total and flow-adjusted trends in concentration (table 5). Reference concentrations at these four sites were all less than about 0.2 mg/L. If trends are applied to the reference concentrations at these four sites, nitrite plus nitrate concentrations would exceed the

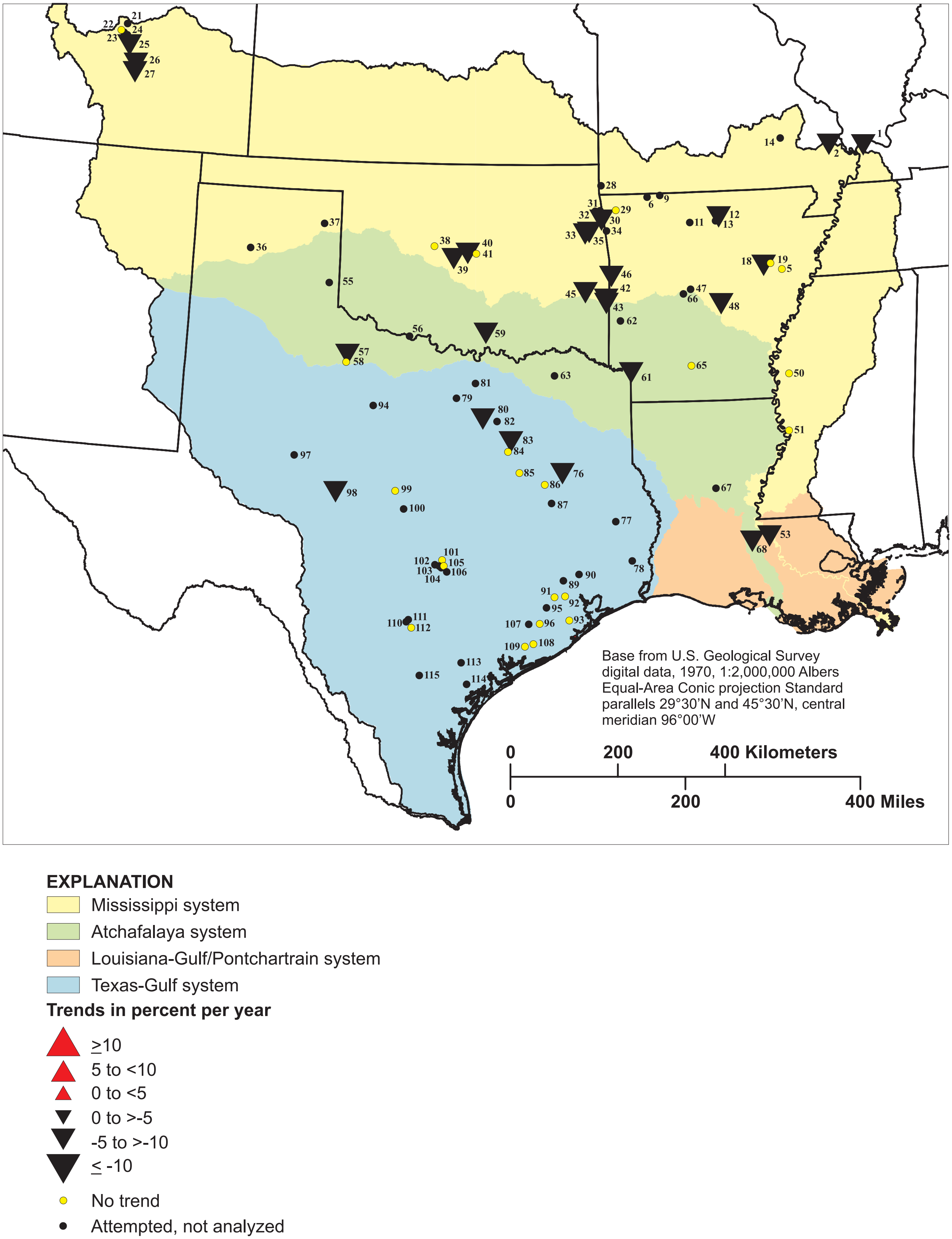


Figure 10. Trends in ammonia loads at study sites, 1993-2004.

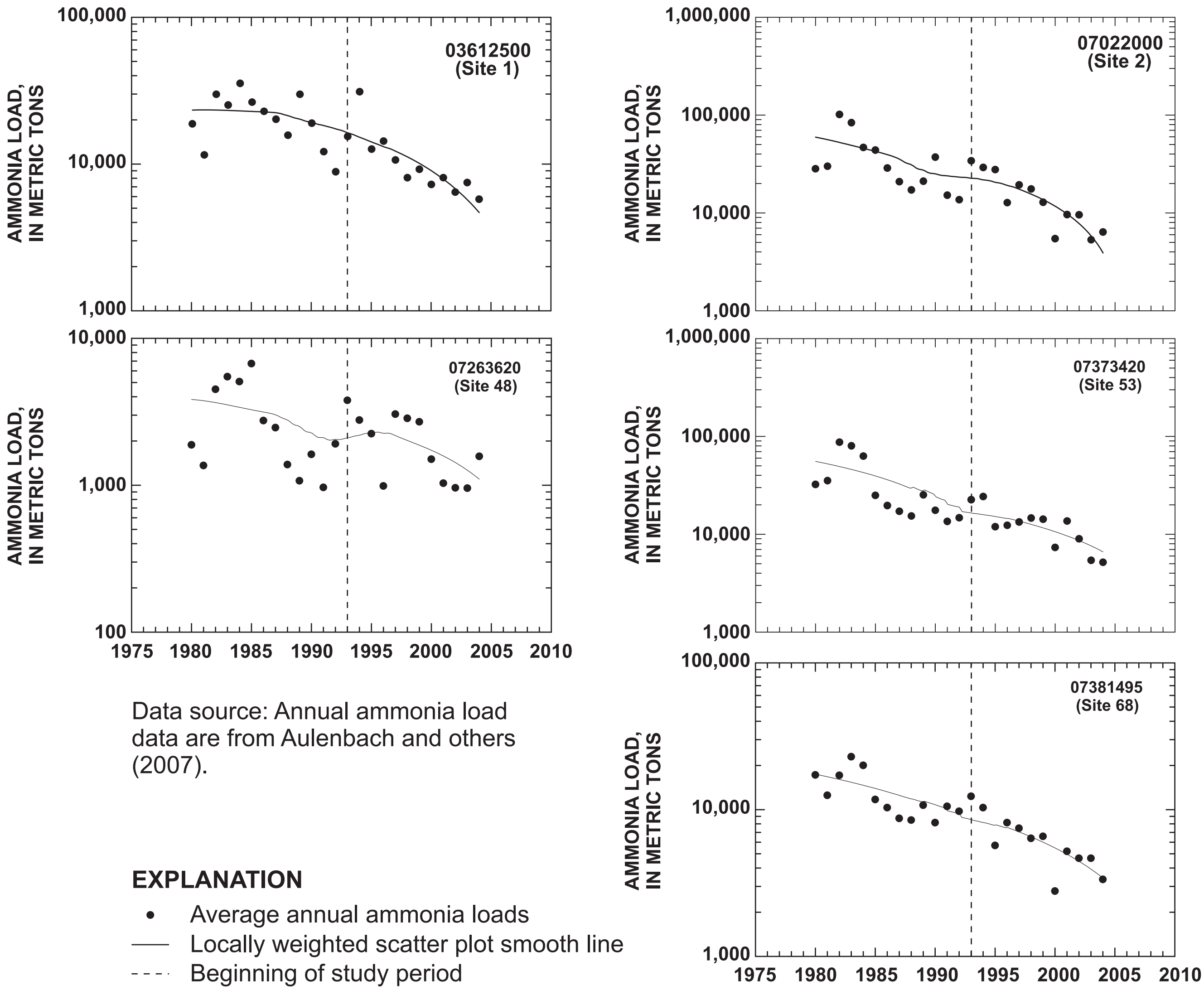
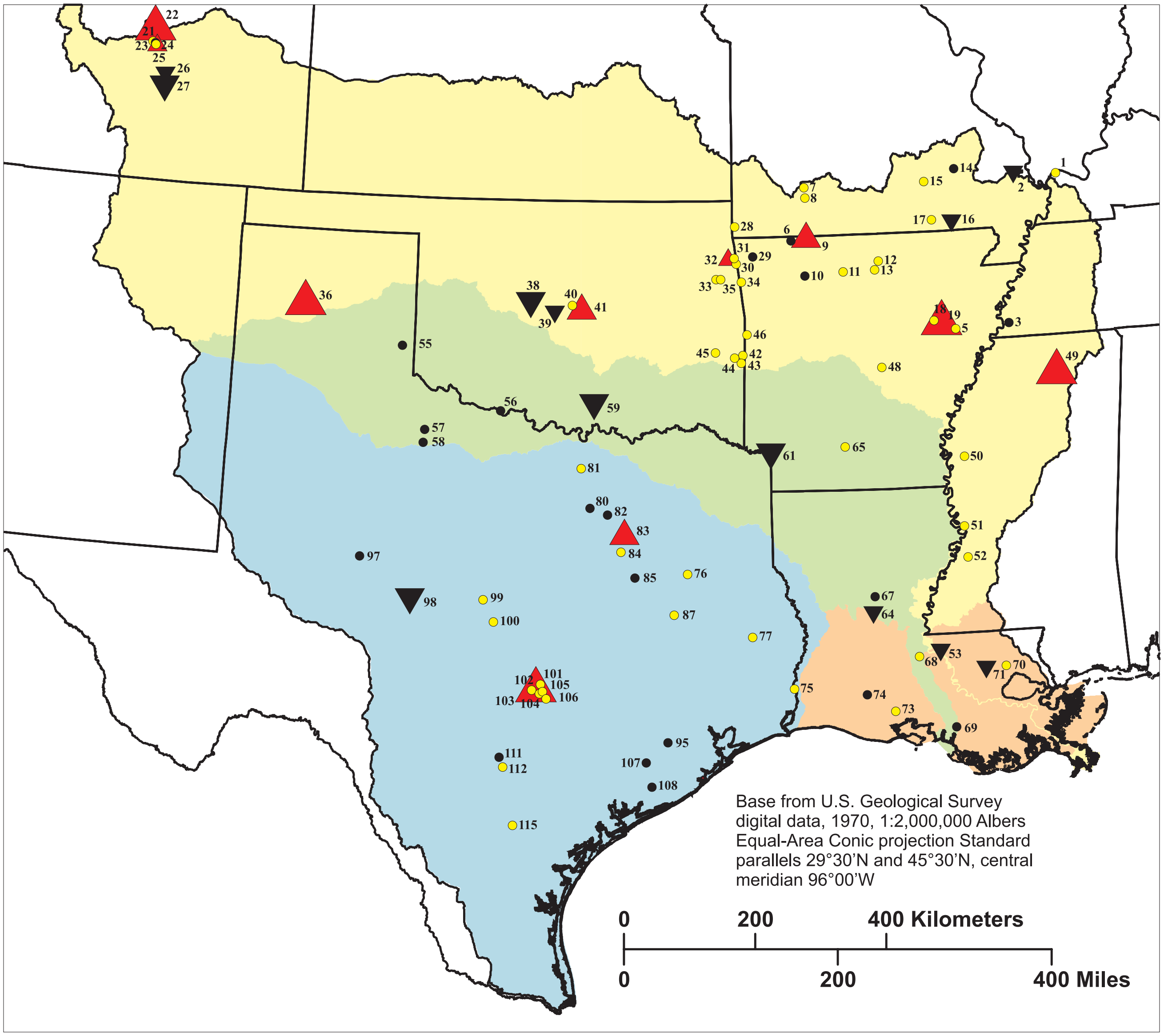


Figure 11. Annual ammonia loads for selected study sites, 1980-2004.

national background concentration of 0.6 mg/L for nitrite plus nitrate (U.S. Geological Survey, 1999) at only site 36 during the study period (the reference concentration at site 36 was 0.16 mg/L; with about a 40 percent per year increase over the 12-year study period, the reference concentration would increase to about 0.9 mg/L in 2004). Increasing trends at these four sites were thus considered negligible during the study period.

Sites 9, 25, 32, and 41 in the Mississippi system and site 83 in the Texas-Gulf system also indicated an increase in nitrite plus nitrate for the study period in both total and flow-adjusted trends (except for site 41, which did not indicate a flow-adjusted trend), and reference concentrations for these five sites were all greater than 1 mg/L (table 5). Because trends remained when the effect of streamflow was removed at sites 9, 25, 32, and 83, the trends were likely caused by influences other than streamflow, such as changes in management practices or in nitrogen sources in these basins during the study period.

Site 9 is located on Yocum Creek near Oak Grove, Ark. No recent references were available to explain the increasing trend in nitrite plus nitrate at site 9. Davis and Bell (1998) reported in their study that nitrite plus nitrate concentrations were higher in the Yocum Creek Basin than in surrounding basins due to a higher percentage of agricultural land use in the basin, and the type of land use included intensive poultry farming and application of poultry wastes to pastures. The increase in nitrite plus nitrate at site 25 (Fountain Creek below Janitell Road below Colorado Springs, Colo.) could be related to advanced treatment at the wastewater treatment plant previously mentioned. In typical advanced treatment systems, most of the conversion of nitrogen occurs in the aerobic zone (for example, conversion of ammonia to nitrate); however, reduction of nitrate is limited to that which is returned to the



EXPLANATION

Mississippi system

Atchafalaya system

Louisiana-Gulf/Pontchartrain system

Texas-Gulf system

Trends in percent per year

≥10

5 to <10

0 to <5

0 to >-5

-5 to >-10

≤ -10

No trend

Attempted, not analyzed

Figure 12. Total trends in nitrite plus nitrate concentrations at study sites, 1993-2004.

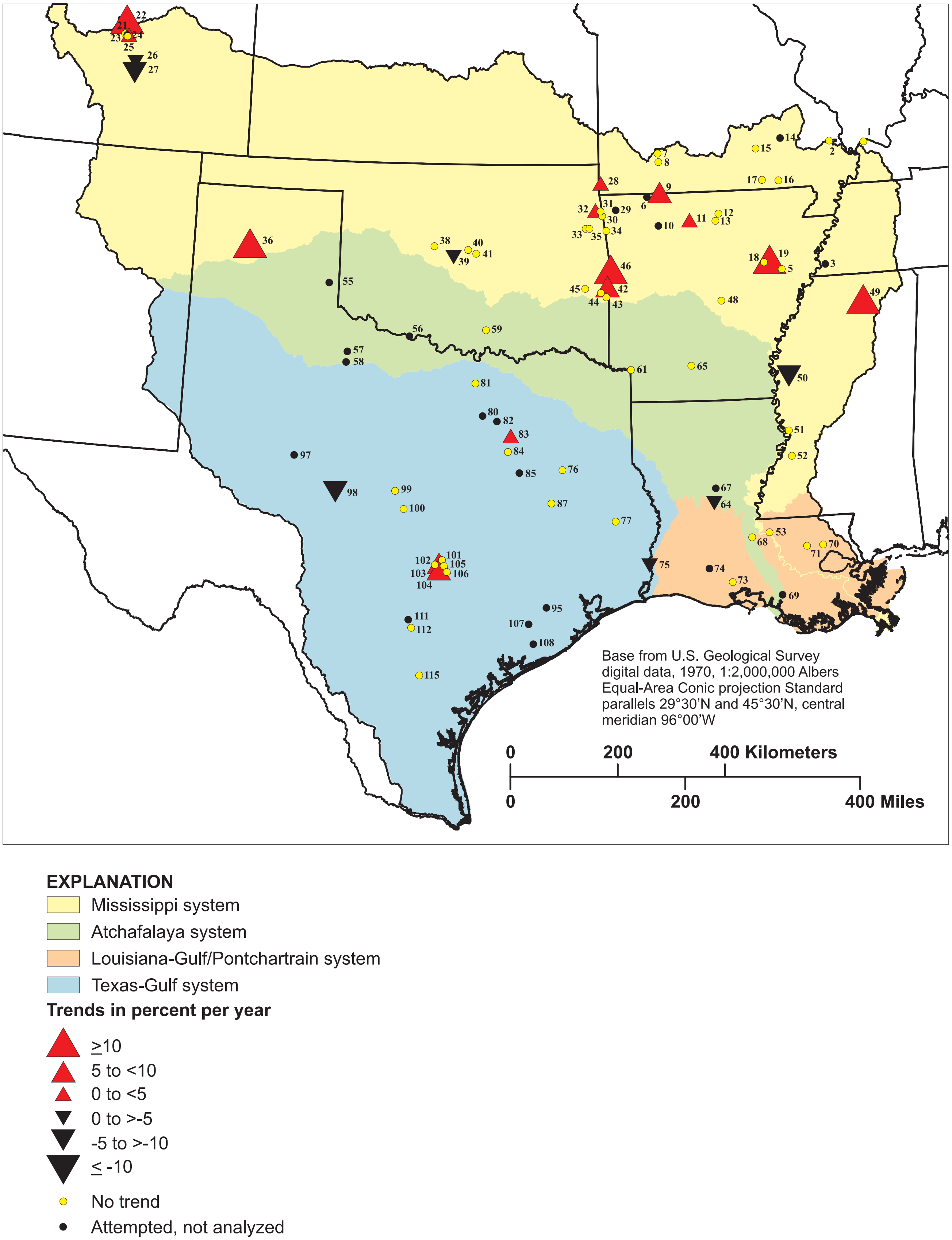


Figure 13. Flow-adjusted trends in nitrite plus nitrate concentrations at study sites, 1993-2004.

process influent and denitrified in the anoxic zone (Viessman and Hammer, 1985). The increase in nitrate in the plant's effluent, and ultimately Fountain Creek at site 25, could be a by-product of the advanced waste treatment process to reduce ammonia. Site 32 is located on Flint Creek in Oklahoma and is part of the Oklahoma Scenic Rivers Program (Oklahoma Office of the Secretary of the Environment, 2003). A segment of Flint Creek is listed as impaired due, in part, to "nitrates;" however, the official source of the impairment is unknown (Oklahoma Department of Environmental Quality, 2004). No references were found in the literature to explain increases in nitrite plus nitrate at site 83.

There were no trends observed in nitrite plus nitrate loads at 42 sites (about 61 percent) during the study period (table 5, fig. 14). Decreasing trends in loads were observed at 23 sites during the study period, ranging from -9.4 to -3.2 percent per year (table 5, fig. 14). Increasing trends in loads were observed at only four sites during the study period, ranging from 5.5 to 52 percent per year (table 5, fig. 14).

In looking at trends in nitrite plus nitrate loads for the period 1980-2004 for sites 2, 48, and 64 (fig. 15), it appears that loads peaked near the beginning of the study period in the early to mid-1990s [as also seen for sites 2 and 48 in the report by Goolsby and others (1999)]. Similar decreasing trends since the mid 1990s were also observed at sites 53 and 68, although the magnitudes of the recent trend at these two sites were lower than sites 2, 48, and 64 (table 5, fig. 15). Therefore, decreasing trends reported in this study for the past decade at these five sites likely reflect decreases in loads unique to only the last decade and do not appear to be part of a longer trend in load, unlike that observed in long-term ammonia loads.

No trends in nitrite plus nitrate loads were observed at site 1 (table 5) for the study period. No trend is apparent in the annual load data for the period 1980-2004 (fig. 15) at site 1 either, although there appears to be a slight "bump" at about 1993 in the LOWESS line (which is attributed to scale in figure 15). The increasing trend in nitrite plus nitrate loads observed at site 112 during this study (table 5) is part of a longer term increasing trend as seen in figure 15.

Annual loads, average annual load, and yield calculations for nitrite plus nitrate were attempted for 56 study sites in all four river systems (table 6). Nitrite plus nitrate loads were at least one order of magnitude greater than ammonia loads where site-by-site comparisons could be made. Average annual nitrite plus nitrate loads for some of the major drainages (not necessarily the most downstream) into the northwestern Gulf of Mexico were as follows: 707,000 T for the Mississippi River (site 53); 224,000 T for the Atchafalaya River (site 68); 322 and 68 T for the Tangipahoa River (site 70) and Tickfaw River (site 71), respectively, which empty into Lake Pontchartrain; and 220 T for the Neches River (site 77), 11,700 T for the Trinity River (site 87), 2,970 T for the San Antonio River (site 112), and 111 T for the Nueces River (site 115) from the Texas-Gulf system. If loads were summed for these eight sites, the Mississippi River would account for about 75 percent and the Atchafalaya River would account for about 24 percent of the total nitrite plus nitrate load entering the northwestern Gulf of Mexico. For these same sites, however, the top four highest yields were 0.927 T·km-2·yr-1 for the Atchafalaya River followed by 0.658, 0.325, and 0.242 T·km-2·yr-1 for the San Antonio, the Trinity, and the Mississippi Rivers, respectively. Nitrite plus nitrate loads indicated that although loads were greatest from the Mississippi River, smaller rivers yielded as much nitrite plus nitrate on a per-square-kilometer basis as the Mississippi River, similar to ammonia yield results.

Nitrite plus nitrate loads and yields for selected sites on the Mississippi, Arkansas, and Atchafalaya Rivers from this study for the period 1993-2004 were compared to loads and yields calculated by Goolsby and others (1999) for the period 1980-96. The mean annual nitrate loads for sites 1, 2, 48, 53, and 68 were 324,000; 537,000; 18,800; 732,000; and 221,000 T, respectively (Goolsby and others, 1999). Nitrate loads calculated from this study for the same sites were 337,000; 534,000; 27,100; 707,000; and 224,000 T (table 6), respectively, and thus were comparable to the previous study results. Nitrate yields from the study by Goolsby and others (1999) were 0.62, 0.29, 0.05, and 0.3 T·km-2·yr-1 for sites 1, 2, 48, and the combined Mississippi and Atchafalaya Rivers (sites 53 and 68). For this study, yields were 0.640 (site 1), 0.289 (site 2), 0.0662 (site 48), and 0.294 T·km-2·yr-1 (sites 53 and 68 combined), which were comparable to the previous study results.

Total nitrogen trends, loads, and yields

Trend analyses of total nitrogen data were attempted for 61 study sites (table 7). Trend results were rejected for 20 sites because of poor model fit (represented as N/A in table 7). Of the remaining 41 sites where trend results were considered acceptable, there were 35 sites (about 85 percent) where no total trends in concentration were observed during the study period (table 7). Decreasing total trends in concentration were observed at two sites, which were -2.3 and -1.8 percent per year for site 16 in the Mississippi system and site 73 in the Louisiana-Gulf/Pontchartrain system, respectively, during the study period (table 7, fig. 16). Increasing total trends in concentration were observed at four sites, which were 7.0 and 4.1 percent per year for sites 9 and 32, respectively, in the Mississippi system, and 6.8 and 3.8 percent per year for sites 61 and 65, respectively, in the Atchafalaya system during the study period (table 7, fig. 16). There were 27 sites (about 66 percent) where no flow-adjusted trends in concentration were observed during the study period (table 7). Decreasing flow-adjusted trends in concentration were observed at two sites, which were -1.5 and -1.8 percent per year for sites 16 and 73, respectively, for the study period (table 7, fig. 17). Increasing flow-adjusted trends in concentration were observed at 12 sites, ranging from 1.8 to 14 percent per year during the study period (table 7, fig. 17).

Decreasing total and flow-adjusted trends in total nitrogen concentrations were observed at site 16 in the Mississippi

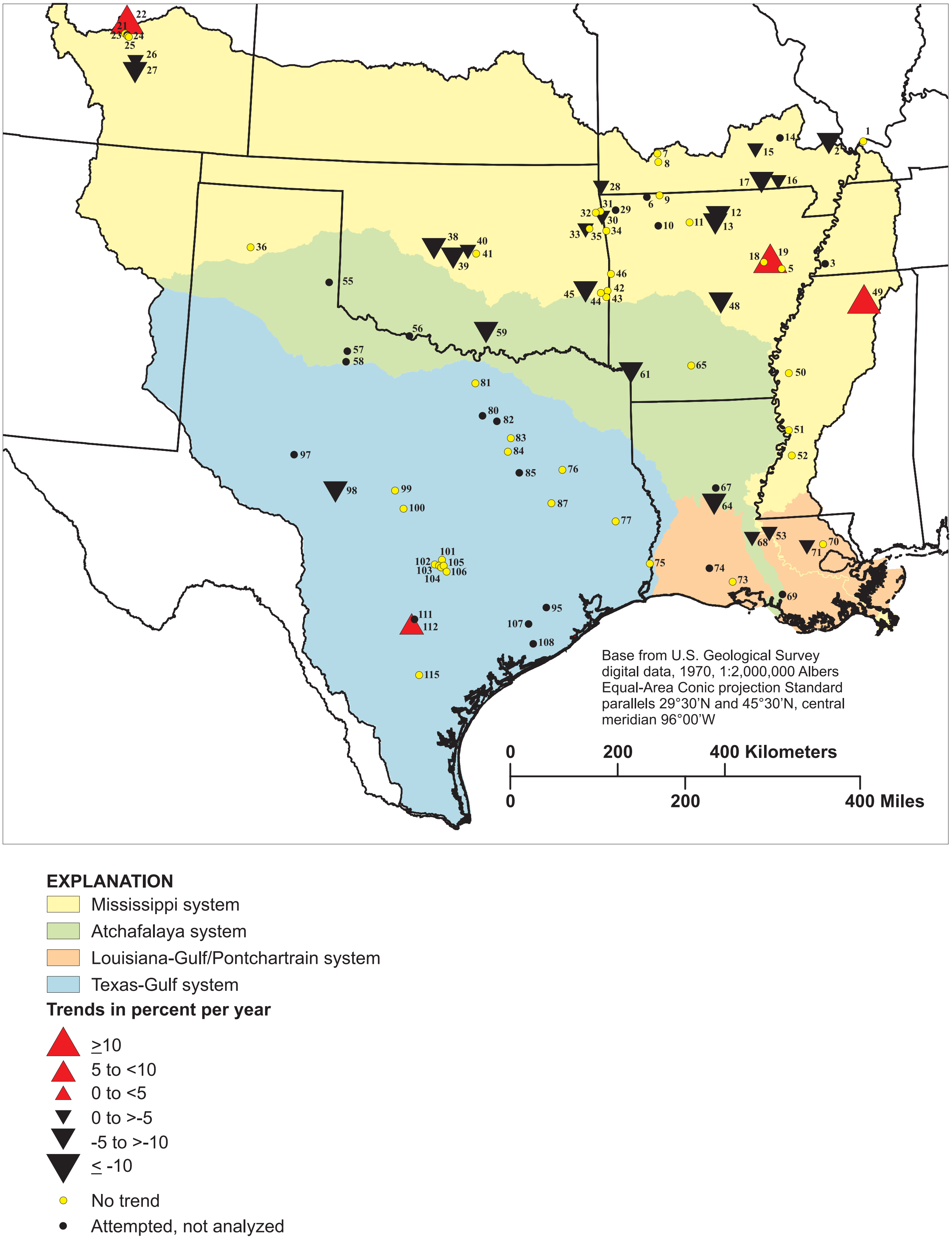


Figure 14. Trends in nitrite plus nitrate loads at study sites, 1993-2004.

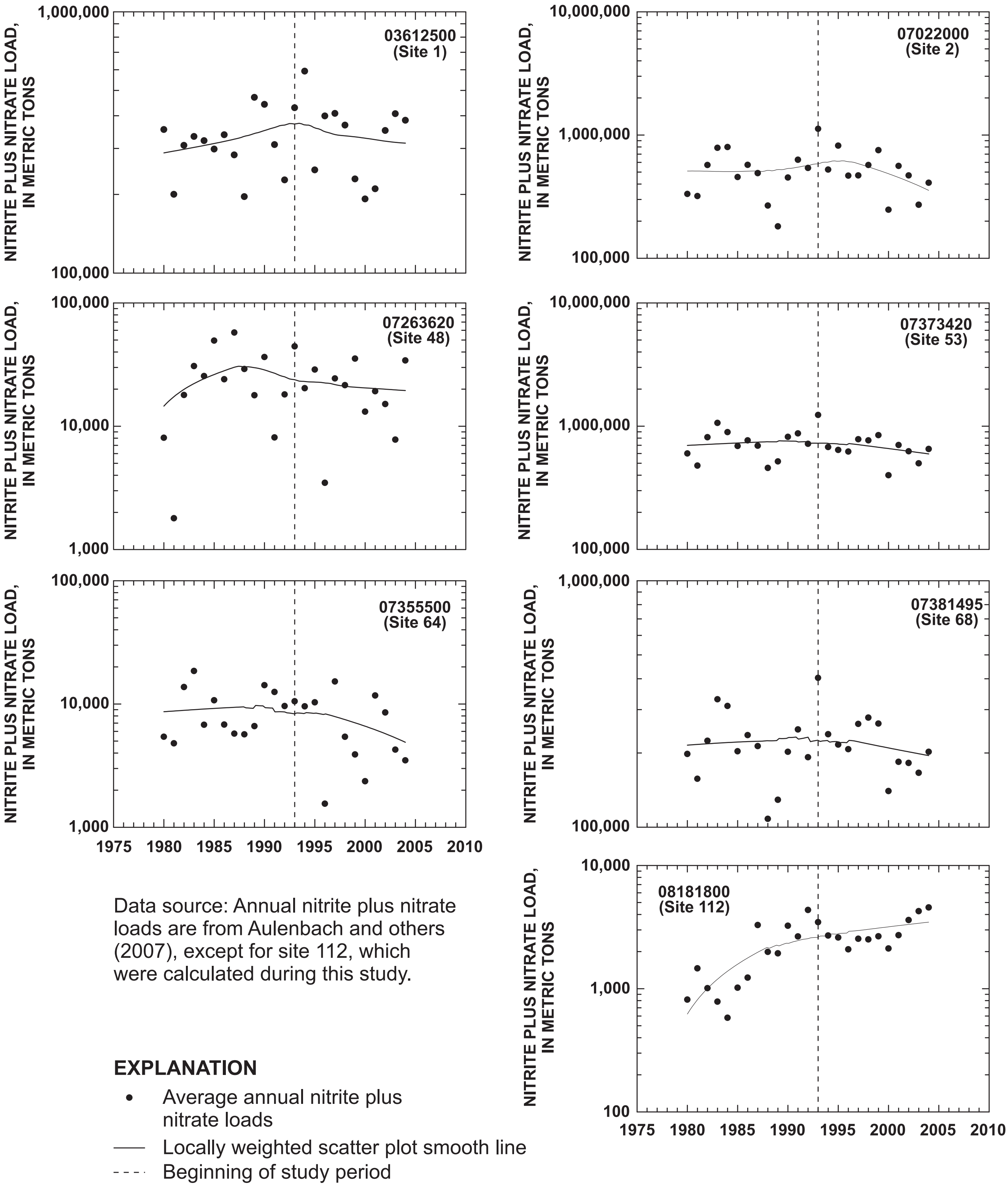


Figure 15. Annual nitrite plus nitrate loads for selected study sites, 1980-2004.

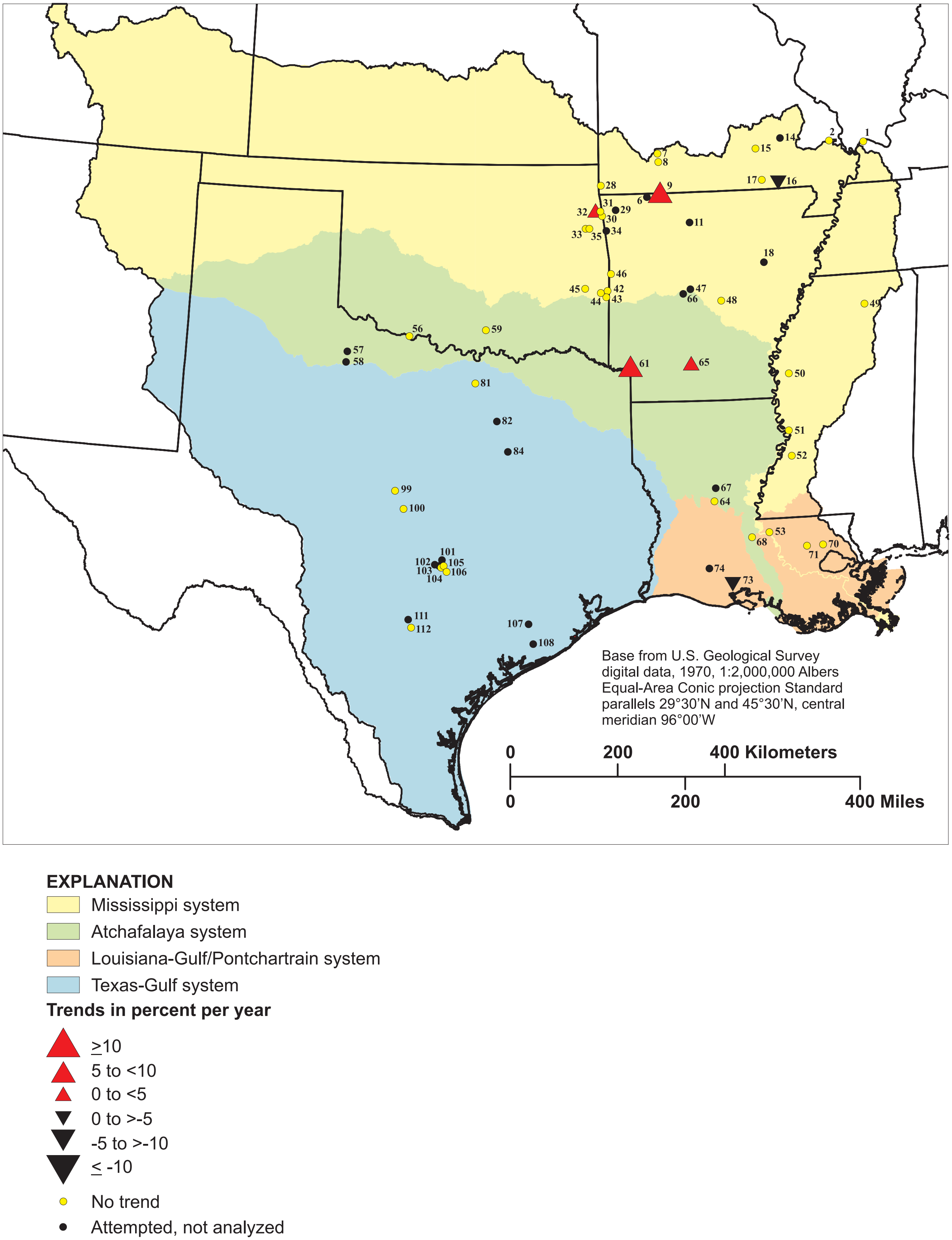


Figure 16. Total trends in total nitrogen concentrations at study sties, 1993-2004.

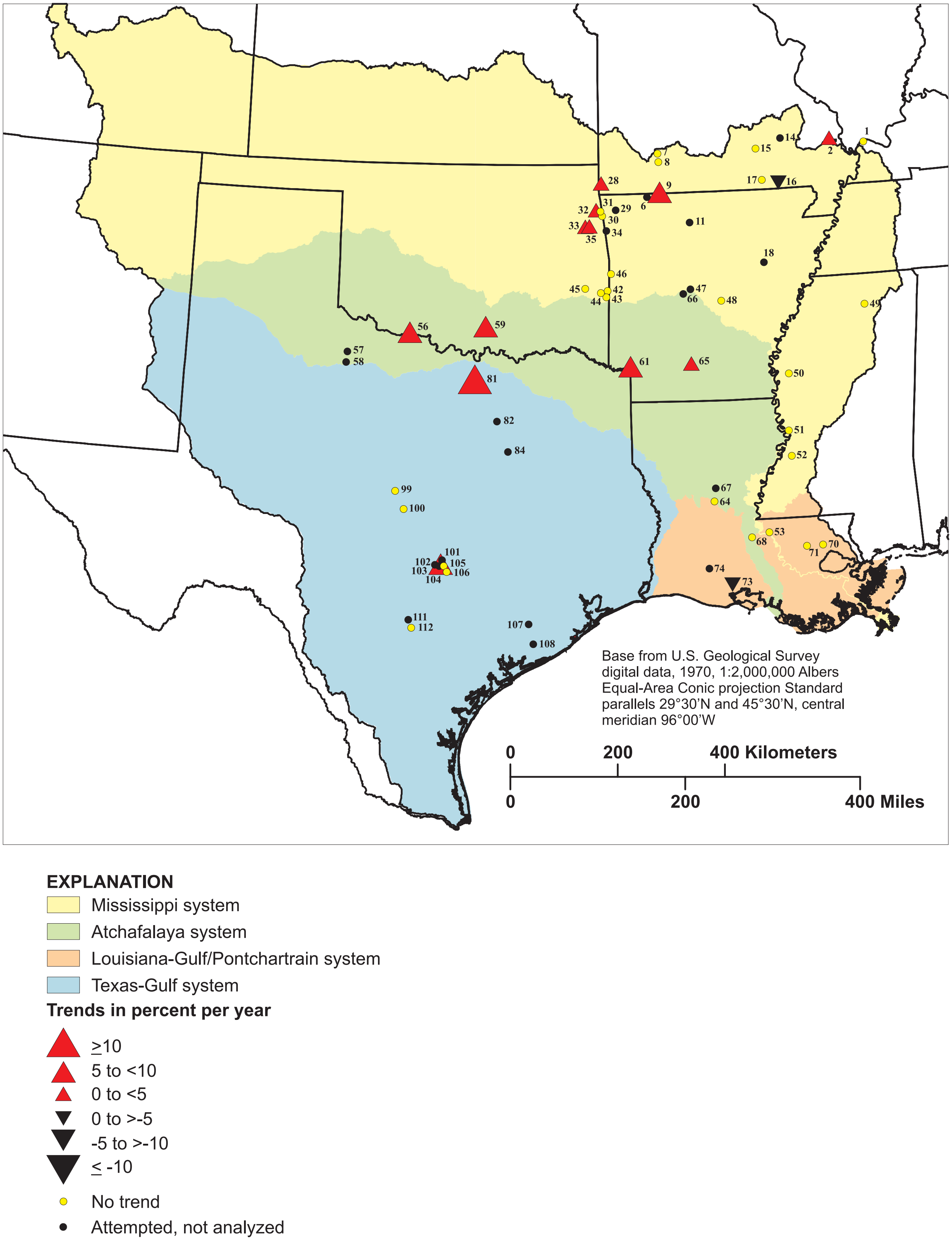


Figure 17. Flow-adjusted trends in total nitrogen concentrations at study sites, 1993-2004.

system and site 73 in the Louisiana-Gulf/Pontchartrain system indicating that the trends were not simply related to decreasing trends in streamflow, but could be caused by management changes or changes in nitrogen sources within the drainage areas at these two sites. For site 16, the decreasing trend was slight (about 2 percent), and the reference total nitrogen concentration was low (0.41 mg/L, table 7). The national background concentration for total nitrogen is 1 mg/L (U.S. Geological Survey, 1999). Also, the USEPA has developed nutrient criteria recommendations for rivers and streams in 14 nutrient “ecoregions” (U.S. Environmental Protection Agency, 2007). Site 16 is located in Nutrient Ecoregion XI (central and eastern forested uplands), and the USEPA recommendation for a total nitrogen criteria aggregated for this ecoregion is 0.31 mg/L (U.S. Environmental Protection Agency, 2000b). The reference concentration for total nitrogen at site 16 was less than the national background concentration, and total nitrogen concentrations should approach or fall below the recommended USEPA ecoregion criteria by 2004 if the trend is applied. Thus, the decreasing trend at site 16 was considered negligible. No references were found in the literature to explain the decrease in total nitrogen at site 73.

Sites 9 and 32 in the Mississippi system and sites 61 and 65 in the Atchafalaya system indicated increases in total nitrogen in both the total and flow-adjusted trends in concentration; therefore, trends were not influenced by streamflow patterns, but could indicate changes in management practices or increases in nitrogen sources in these watersheds. Increases in total nitrogen were similar to increases in nitrite plus nitrate at site 9, which is located on Yocum Creek in Arkansas. As previously mentioned, site 9 was included in a study by Davis and Bell (1998), however, their study did not include analysis of total nitrogen. No other references were found in the literature to explain the increase in total nitrogen at site 9. Similarly, no references were found in the literature to explain the increases in total nitrogen at sites 32 or 61 [however, as previously stated, site 32 is located on Flint Creek in Oklahoma, and a segment of Flint Creek is listed as impaired due to nitrates (Oklahoma Department of Environmental Quality, 2004)]. The reference concentration at site 65 was less than the national background concentration of 1 mg/L for total nitrogen (U.S. Geological Survey, 1999). Site 65 is located in Nutrient Ecoregion IX (southeastern temperate forested plains and hills), and the USEPA recommendation for a total nitrogen criteria aggregated for this ecoregion is 0.69 mg/L (U.S. Environmental Protection Agency, 2000a). Because the total nitrogen reference concentration at site 65 was less than the national background concentration, and concentrations of total nitrogen are not projected to exceed the recommended USEPA ecoregion criteria in 2004 if the trend is applied, the trend at site 65 is considered negligible.

Increasing flow-adjusted trends in total nitrogen concentration were observed at sites 2, 28, 33, and 35 in the Mississippi system, sites 56 and 59 in the Atchafalaya system, and sites 81 and 104 in the Texas-Gulf system; therefore, these trends could indicate changes in management practices or increases in nitrogen sources at these sites during the study period. Reference concentrations at sites 81 and 104 were low (less than 0.3 mg/L). USEPA recommended ecoregion total nitrogen criteria for sites 81 and 104 are 0.69 and 0.56 mg/L, respectively (U.S. Environmental Protection Agency, 2000a and 2001). If trends were applied to reference concentrations at sites 81 and 104, total nitrogen concentrations likely would not exceed the national background concentration nor associated ecoregion criteria by 2004; thus, increasing trends at these two sites were considered negligible. The drainage area for site 2 includes the upper Mississippi and Missouri Rivers; thus, an explanation for the increasing trend in total nitrogen at this site is beyond the scope of this report.

The flow-adjusted trend for total nitrogen increased at site 28 along the Elk River in Missouri during the study period. The Elk River is listed as an impaired waterbody because of nitrogen concentrations that were shown to be increasing over the past 35 years (Missouri Department of Natural Resources, 2004). Although there could be other factors that contribute to increasing nitrogen, recent TMDL and watershed restoration proposals indicate the most significant contribution of nitrogen is attributed to the poultry industry as there are approximately 275 poultry AFOs within the Elk River watershed (Missouri Department of Natural Resources, 2004 and 2006). These reports state that the increase is related to point sources, due to population increases caused by availability of more jobs in the poultry industry, and to nonpoint sources, due to application of poultry litter on agricultural fields. No references were found in the literature to explain the increases in total nitrogen at sites 33, 35, 56, and 59.

There were no trends observed in total nitrogen loads at 28 sites (about 68 percent) during the study period (table 7). Decreasing trends in total nitrogen loads were observed at 12 sites during the study period and ranged from -7.3 to -2.7 (2 sites) percent per year (fig. 18). Increasing trends in total nitrogen loads were observed only at site 112 located on the San Antonio River in the Texas-Gulf system during the study period (about a 5-percent per year increase in total nitrogen load).

The recent decreasing trends at sites 2, 48, 53, and 68 (table 7) appear to be part of longer decreasing trends observed since the early 1980s at these four sites (fig. 19). No trends in total nitrogen loads were observed at site 1 in both the current study period (table 7) and the 1980-2004 time period (fig. 19). No trend in total nitrogen loads was observed at site 64 for the study period, which is in contrast to annual loads plotted since 1980 that seem to indicate a slight decreasing over time (fig. 19); however, annual loads plotted in figure 19 since 1993 are scattered, thus validating the no-trend result for the study period.

The recent increasing trend in load at site 112 (table 7) is a recent trend, as total nitrogen loads at this site have been stable from 1980 to about 1997 (fig. 19). There were no total or flow-adjusted trends in concentration observed at site 112 for the study period; however, there was a 7.9 percent per year increase in flow observed at site 112 for the study period. The

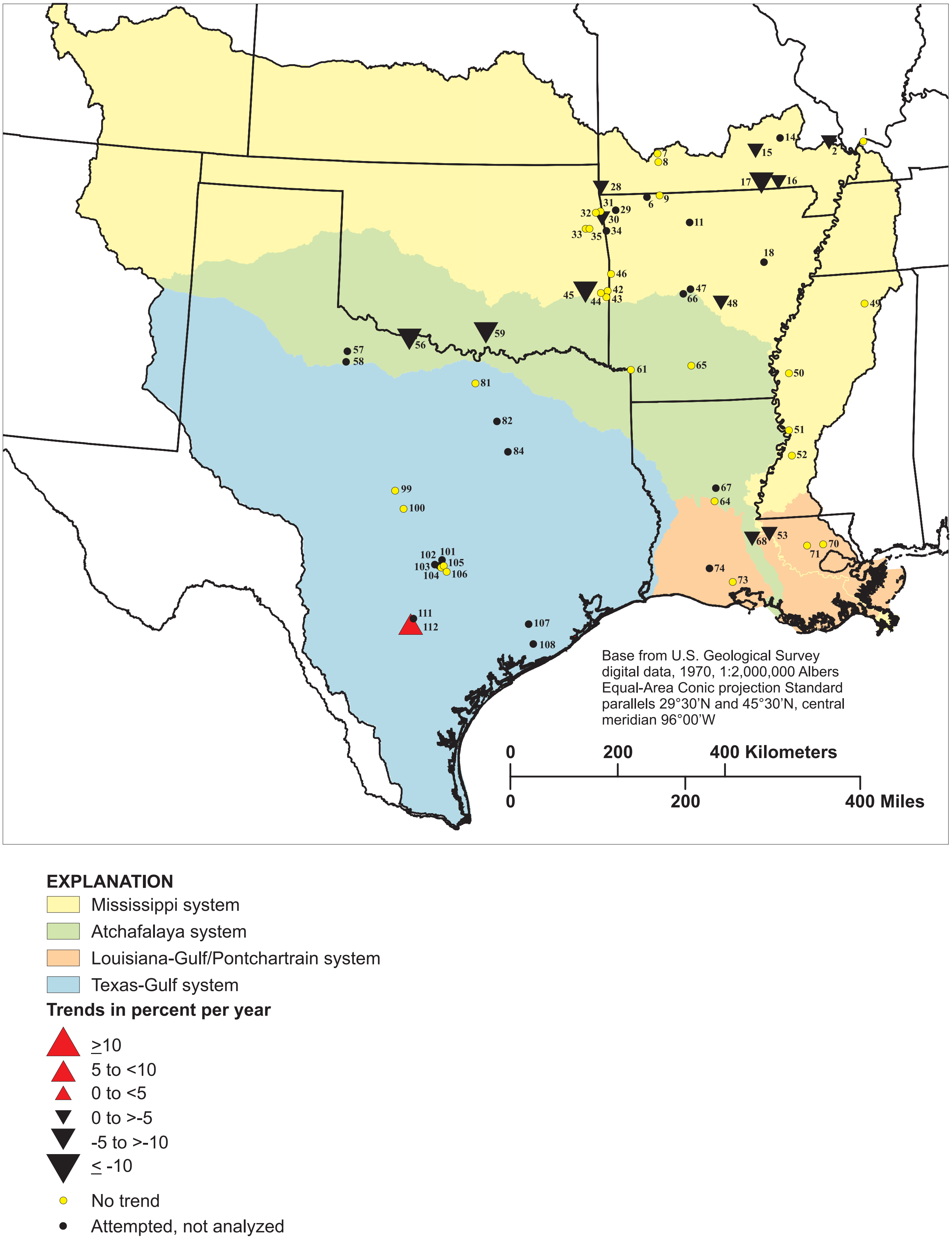
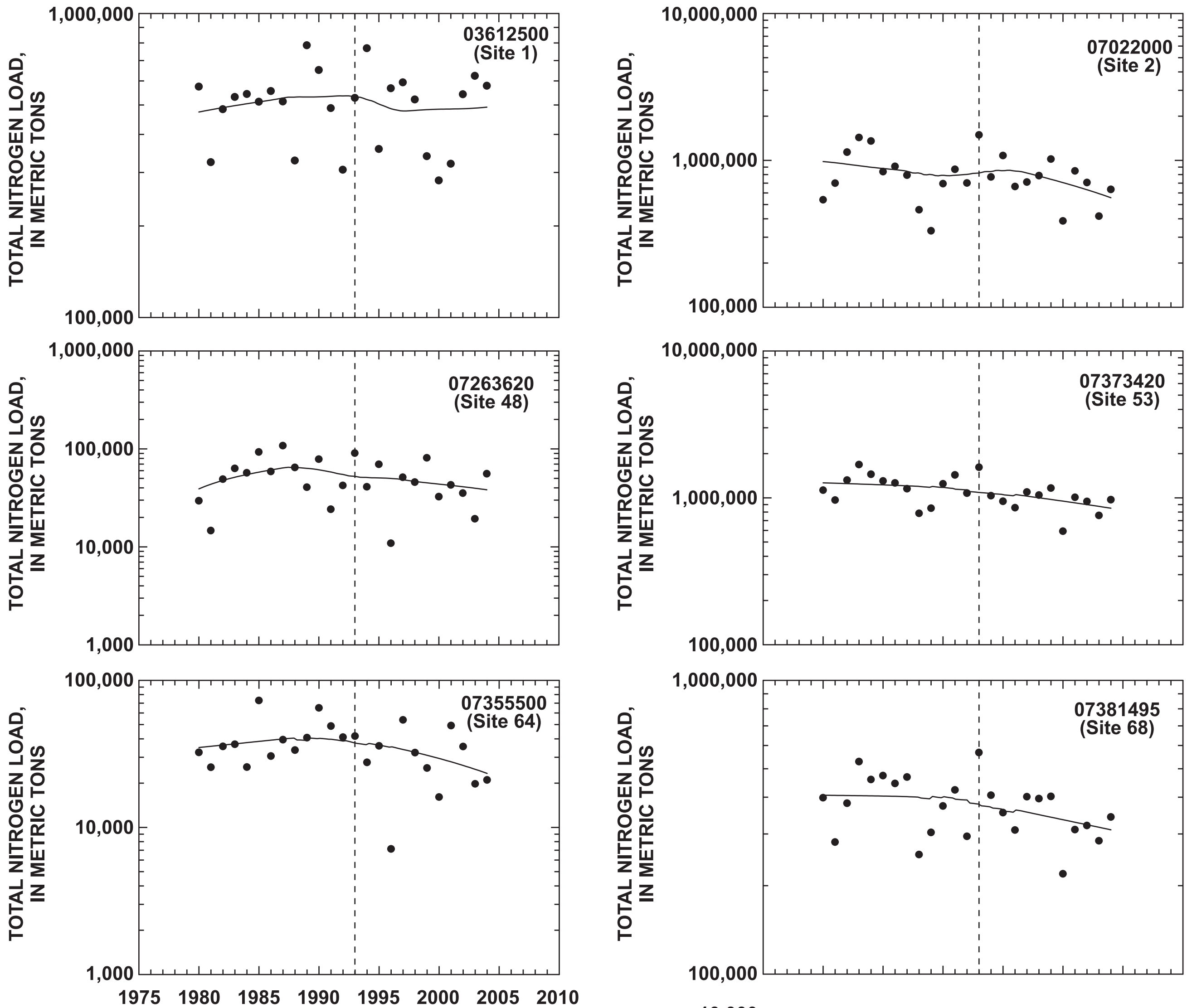
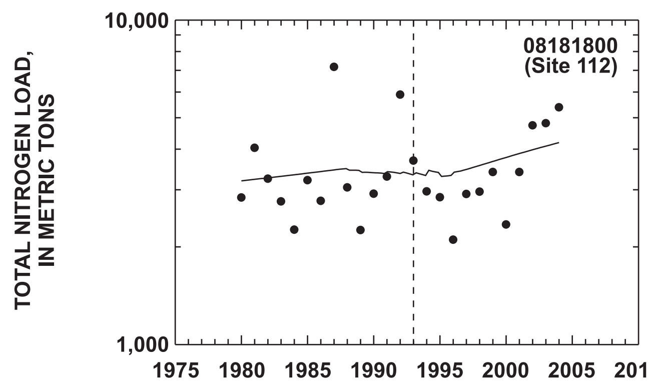


Figure 18. Trends in total nitrogen loads at study sites, 1993-2004



Data source: Annual total nitrogen loads calculated from nitrite plus nitrate and total Kjeldahl nitrogen loads from Aulenbach and others (2007), except for site 112, which were calculated during this study.



EXPLANATION

- • Average annual total nitrogen loads
- —— Locally weighted scatter plot smooth line
- - - - Beginning of study period

Figure 19. Annual total nitrogen loads for selected study sites, 1980-2004.

recent increasing trend in total nitrogen load at site 112 likely is related to an increase in streamflow at this site.

Annual loads, average annual load, and yield calculations for total nitrogen were attempted for 35 study sites in all four river systems (table 8). When total nitrogen, ammonia, and nitrite plus nitrate loads were compared at key sites in the four river systems, the nitrite plus nitrate loads accounted for about 70-90 percent of the total nitrogen loads (tables 4, 6, and 8). Average annual total nitrogen loads for some of the major drainages (not necessarily the most downstream) into the northwestern Gulf of Mexico were as follows: 992,000 T for the Mississippi River (site 53); 355,000 T for the Atchafalaya River (site 68); 1,150 T for the Tangipahoa River (site 70) and 300 T for Tickfaw River (site 71), both of which empty into Lake Pontchartrain; and 507 T for the Colorado River (site 100) and 3,450 T for the San Antonio River (site 112) from the Texas-Gulf system. Again, the Mississippi and Atchafalaya systems account for nearly all of the total nitrogen load into the northwestern Gulf of Mexico. Yields for these same sites, in order of magnitude, were 1.47, 0.764, 0.690, 0.469, 0.340, and 0.00627 T·km-2·yr-1 for the Atchafalaya, San Antonio, Tangipahoa, Tickfaw, Mississippi, and Colorado Rivers, respectively. Similar to ammonia and nitrite plus nitrate yield observations, total nitrogen yields from smaller rivers generally were as large or larger than yields from the Mississippi River.

Total nitrogen loads and yields for selected sites on the Mississippi, Arkansas, and Atchafalaya Rivers from this study for the period 1993 to 2004 were compared to loads and yields calculated by Goolsby and others (1999) for the period 1980 to 1996. The mean annual total nitrogen loads from sites 1, 2, 48, 53, and 68 from Goolsby and others (1999) were 496,000, 841,000, 54,900, 1,180,000, and 386,000 T, respectively. Total nitrogen loads for the same sites calculated from this study were 480,000, 770,000, 45,900, 992,000, and 355,000 T (table 8), respectively, which were all slightly lower than the previous study results, reflecting decreasing trends in streamflow at all of these sites during the last decade. Total nitrogen yields from Goolsby and others (1999) were 0.94, 0.46, 0.13, and 0.49 T·km-2·yr-1 for sites 1, 2, 48, and the combined Mississippi and Atchafalaya Rivers (sites 53 and 68). For this study, total nitrogen yields were 0.912, 0.417, 0.112, and 0.427 T·km-2·yr-1 for the same sites, respectively, which were comparable to the previous study results.

Relation of trends in nitrogen to trends in source data and landscape attributes

There were some statistically significant results from the WLS regression analyses where trends in nitrogen-source data and landscape attributes were compared to trends in nitrogen constituents from this study (table 9). Coefficients of determination (R2) for the statistically significant results were all less than about 0.3 indicating that very little of the variance was explained, and relations were considered poor. Therefore, statistically significant results of the WLS regression analyses are presented in this section relative to nitrogen trends, but the reader is cautioned against over-interpretation of the results.

Population throughout most of the study area either remained the same or increased during the study period (fig. 20). Such increasing trends could explain increasing trends in nitrite plus nitrate and total nitrogen observed near urban areas (point sources) or where drainages included a combination of urban and agricultural areas. Results of the WLS regression analyses did not indicate any statistically significant results where trends in population were compared to trends in nitrogen constituents observed at study sites (table 9).

Nitrogen from atmospheric deposition generally increased for locations in the center part of the study area from southeastern Colorado through central Oklahoma and northern and eastern Texas during the study period (fig. 21). Nitrogen from atmospheric deposition decreased in south-central Texas, eastern Oklahoma, northwestern Arkansas, and southwestern Missouri during the study period (fig. 21). Weighted-least-squares regression results indicated a potential inverse relation between trends in nitrogen from atmospheric deposition and flow-adjusted trends in nitrite plus nitrate at study sites (table 9), which indicated that at locations where atmospheric deposition increased, there were decreasing trends in flow-adjusted nitrite plus nitrate during the study period. Trends in atmospheric deposition were, therefore, not the controlling factor on trends in nitrite plus nitrate.

Increased trends in nitrogen from fertilizer were observed at sites in north-central Texas, eastern Oklahoma, northern Arkansas, and southern Missouri (fig. 22). Weighted-least-squares regression results suggest that increasing trends in nitrogen from fertilizer could be related to increasing flow-adjusted trends in nitrite plus nitrate at study sites (table 9). Increasing trends in nitrogen from manure were observed at some of the same sites as were trends in fertilizer (figs. 22 and 23). Weighted-least-squares regression results suggest that increasing trends in nitrogen from land application of manure could be related to increasing trends in both total and flow-adjusted trends in nitrite plus nitrate and total nitrogen at study sites (table 9).

There were only seven sites where management practices increased or decreased more than 1 percent of their total drainage areas from 1992 to 1997 (table 10). Of these seven sites, only one corresponded to any trends in nitrogen data for the study period: there was a slight increase in both total and flow-adjusted trends in nitrite plus nitrate for the study period at site 103. During the period 1992-1997, conservation practices (contour farming or terracing) decreased by 9.6 percent of the total drainage area for site 103. Because WLS regression analyses could not be completed by using the conservation practices data and trends in nitrite plus nitrate, it is unknown if the increasing trend in nitrite plus nitrate actually was affected by the decrease in conservation practices at site 103.

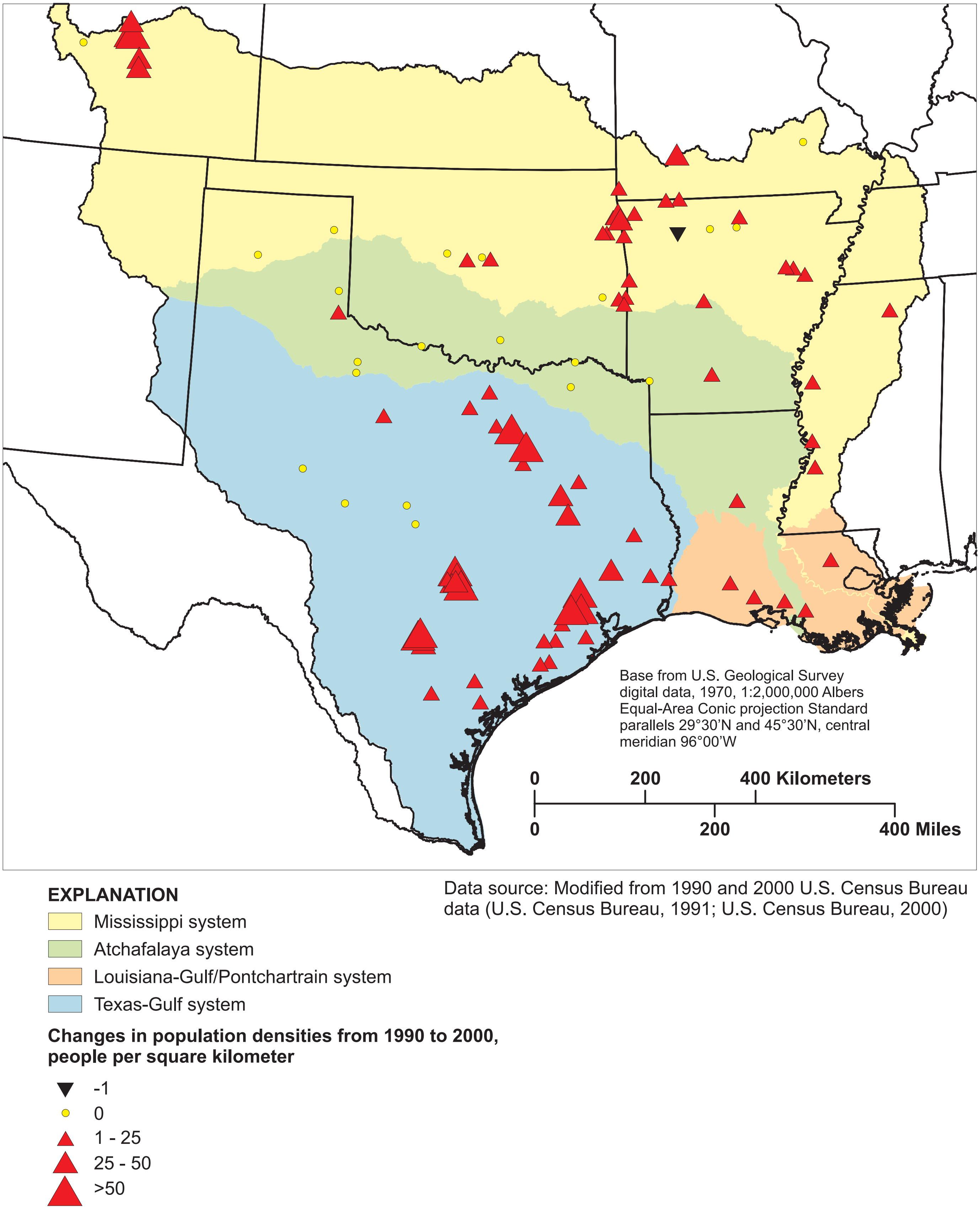
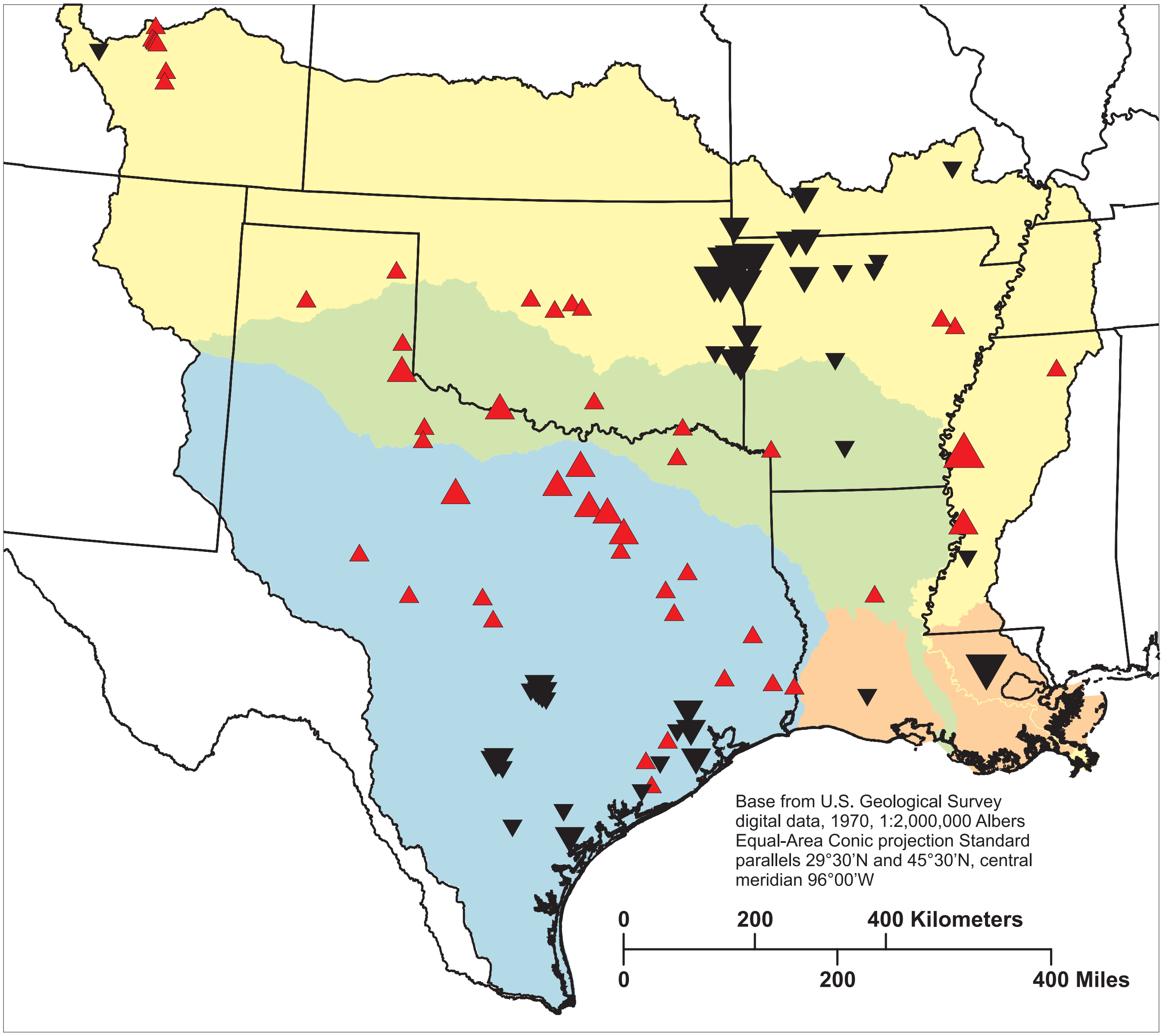


Figure 20. Trends in population densities at study sites from 1990-2000.



Data source: Modified from annual atmospheric deposition nitrogen data, 1993 - 2004 (U. S. Geological Survey National Atmospheric Deposition Program/National Trends Network, accessible at http://bqs.usgs.gov/acidrain/.)

EXPLANATION

Mississippi system

Atchafalaya system

Louisiana-Gulf/Pontchartrain system

Texas-Gulf system

Annual change in nitrogen from atmospheric deposition, 1993 to 2004, kilograms per year per square kilometers.

≥10

5 to <10

0 to <5

0 to >-5

-5 to >-10

≤ -10

Figure 21. Trends in nitrogen from atmospheric deposition at study sites, 1993-2004.

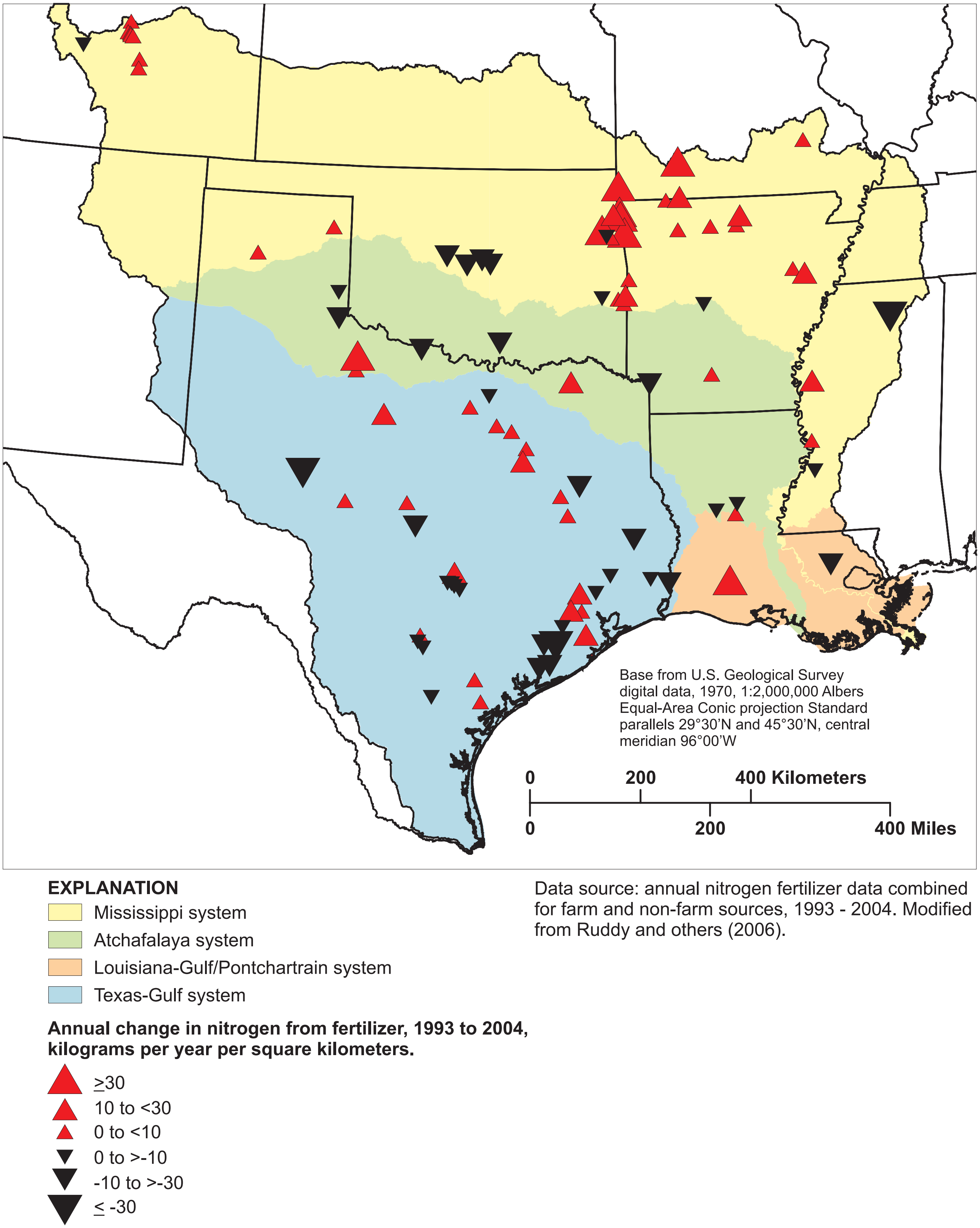


Figure 22. Trends in nitrogen from fertilizer at study sites, 1993-2004.

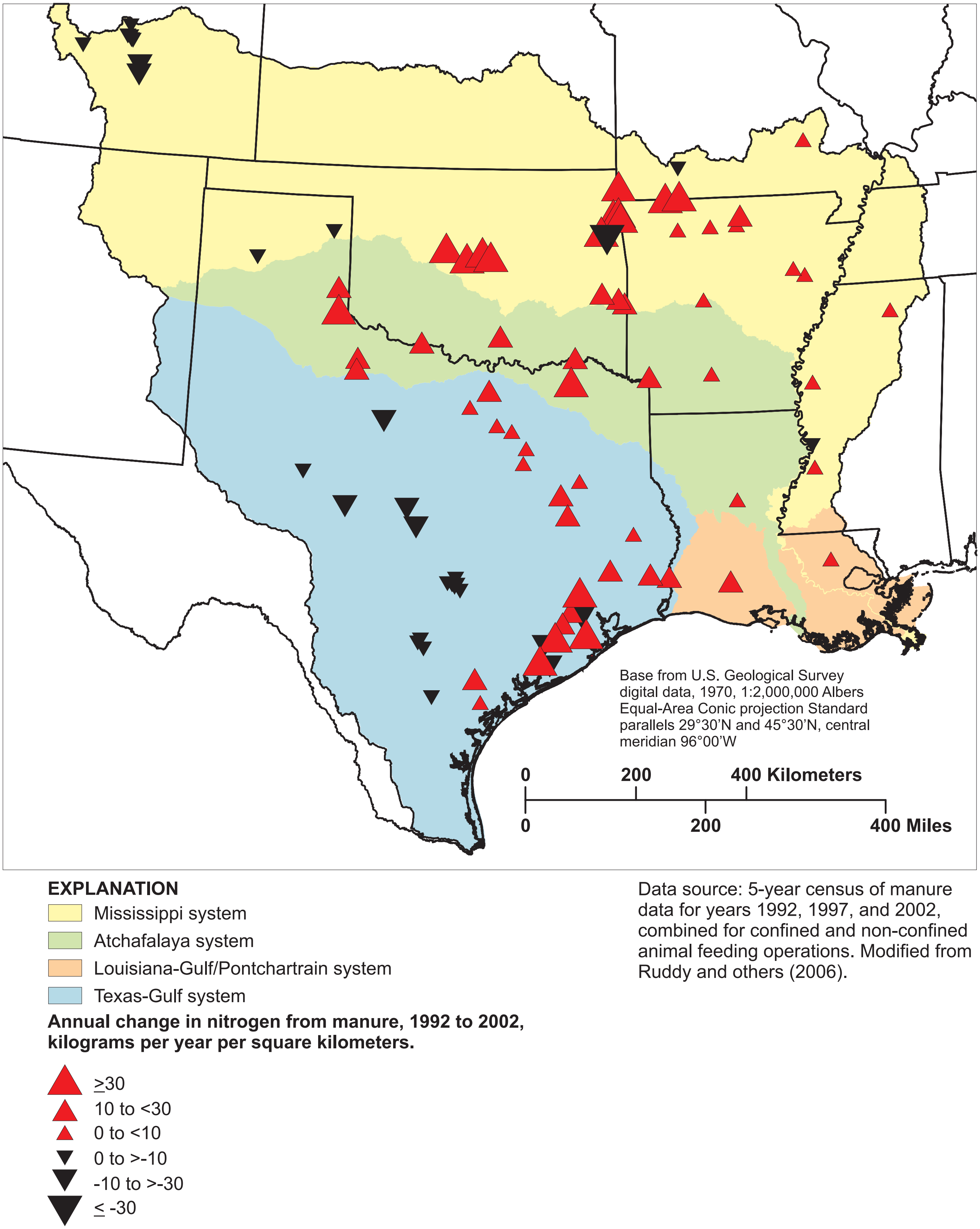


Figure 23. Trends in nitrogen from manure at study sites, 1992-2002.

Overall conclusions about nitrogen trends and loads for the study area

In general, there were few trends observed in the nitrogen data at study sites during the study period; no trends were observed in about 63 percent of all nitrogen trend analyses attempted. Although some patterns in the nitrogen data did exist where trends were attempted, no regional patterns could be confirmed because of poor spatial representation of the trends sites.

Decreasing trends in flow-adjusted concentrations of ammonia were observed at 25 sites. No increasing trends in concentrations of ammonia were noted at any sites. Flow-adjusted concentrations of nitrite plus nitrate decreased at 7 sites and increased at 14 sites. Flow-adjusted concentrations of total nitrogen decreased at 2 sites and increased at 12 sites. Improvements to municipal wastewater treatment facilities contributed to the decline of ammonia concentrations at selected sites. Notable increasing trends in nitrite plus nitrate and total nitrogen at selected study sites were attributed to both point and nonpoint sources. Trend patterns in total nitrogen generally followed trend patterns in nitrite plus nitrate, which was understandable given that nitrite plus nitrate loads generally were 70-90 percent of the total nitrogen loads at most sites. Although population increased throughout the study area during the study period, there was no observed relation between increasing trends in nitrogen in study area streams and increasing trends in population. With respect to other nitrogen sources, statistical results did suggest that increasing trends in nitrogen could be related to increasing trends in nitrogen from either commercial fertilizer use and/or land application of manure.

Loads of ammonia, nitrite plus nitrate, and total nitrogen decreased during the study period, but some trends in nitrogen loads were part of long-term decreases since 1980. For example, ammonia loads were shown to decrease at nearly all sites over the past decade, but at selected sites, these decreasing trends were part of much longer trends since 1980. The Mississippi and Atchafalaya Rivers contributed the highest nitrogen loads to the northwestern Gulf of Mexico as expected; however, nitrogen yields from smaller rivers had similar or higher yields than from the Mississippi River.

Phosphorus

Specific details about trend, load, and yield results for orthophosphorus and total phosphorus data are discussed at the beginning of this section. These results are then related to potential trends in source and landscape attributes. Finally, some general conclusions about phosphorus trend and load results are discussed at the end of this section.

Orthophosphorus trends, loads, and yields

Trend analyses of orthophosphorus data were attempted for 68 study sites in three of the four river systems, with the exception of the Louisiana-Gulf/Pontchartrain system, which had no sites with an adequate amount of orthophosphorus data to attempt trend analyses (table 11). Trend results were rejected for 34 sites because of poor model fit (represented as N/A in table 11). Of the remaining 34 sites where trend results were considered acceptable, there were 17 sites (50 percent) where no total trends in concentration were observed during the study period (table 11). Decreasing total trends in concentration were observed at 11 sites ranging from -7.2 to -2.6 percent per year during the study period (table 11, fig. 24). Increasing total trends in concentration were observed at six sites, ranging from 2.5 to 15 percent per year during the study period (table 11, fig. 24). There were 17 sites (50 percent) where no flow-adjusted trends in concentration were observed during the study period (table 11). Decreasing flow-adjusted trends in concentration were observed at 10 sites, ranging from -7.3 to -2.5 percent per year (table 11, fig. 25). Increasing flow-adjusted trends in concentration occurred at seven sites, ranging from 3.0 to 13 percent per year during the study period (table 11, fig. 25).

Decreasing total trends in orthophosphorus concentrations were observed at sites 1, 38, 39, 42, 45 in the Mississippi system, and sites 59 and 61 in the Atchafalaya system during the study period; reference concentrations at these seven sites were less than about 0.1 mg/L. Although there are no secondary water-quality standards for orthophosphorus, the USEPA recommends that total phosphates should not exceed 0.05 mg/L in a stream where it enters a lake or reservoir (U.S. Environmental Protection Agency, 1986). If trends are applied to the reference concentrations at these seven sites, orthophosphorus concentrations would likely approach or fall below the recommended USEPA concentration during the study period. Decreasing trends at these seven sites were, therefore, considered negligible. In addition, trends at site 38 and 59 were not retained when the effects of streamflow were removed; therefore, total trends at these two sites likely were related to decreasing trends in streamflow.

Decreasing total trends in orthophosphorus concentration were also observed at sites 25, 26, 27 in the upper Mississippi system, and 112 in the Texas-Gulf system, and reference concentrations were all greater than about 1 mg/L. In addition, decreasing trends were retained when the effects of streamflow were removed at these four sites (table 11), indicating that the trends were not simply influenced by decreasing trends in streamflow. Sites 25, 26, and 27 were located downstream from the wastewater treatment plant previously mentioned. Although upgrades installed in the mid-1990's at this particular plant targeted ammonia and BOD removal, decreases in orthophosphorus at these three sites could be a secondary benefit of advanced waste treatment and clarifier improvements, which are also processes that can be used for phosphorus removal (Viessman and Hammer, 1985). Site 112 is located on the San Antonio River. The San Antonio River Authority (2003) reported that reductions in phosphorus levels and improvements in water quality in the San Antonio River

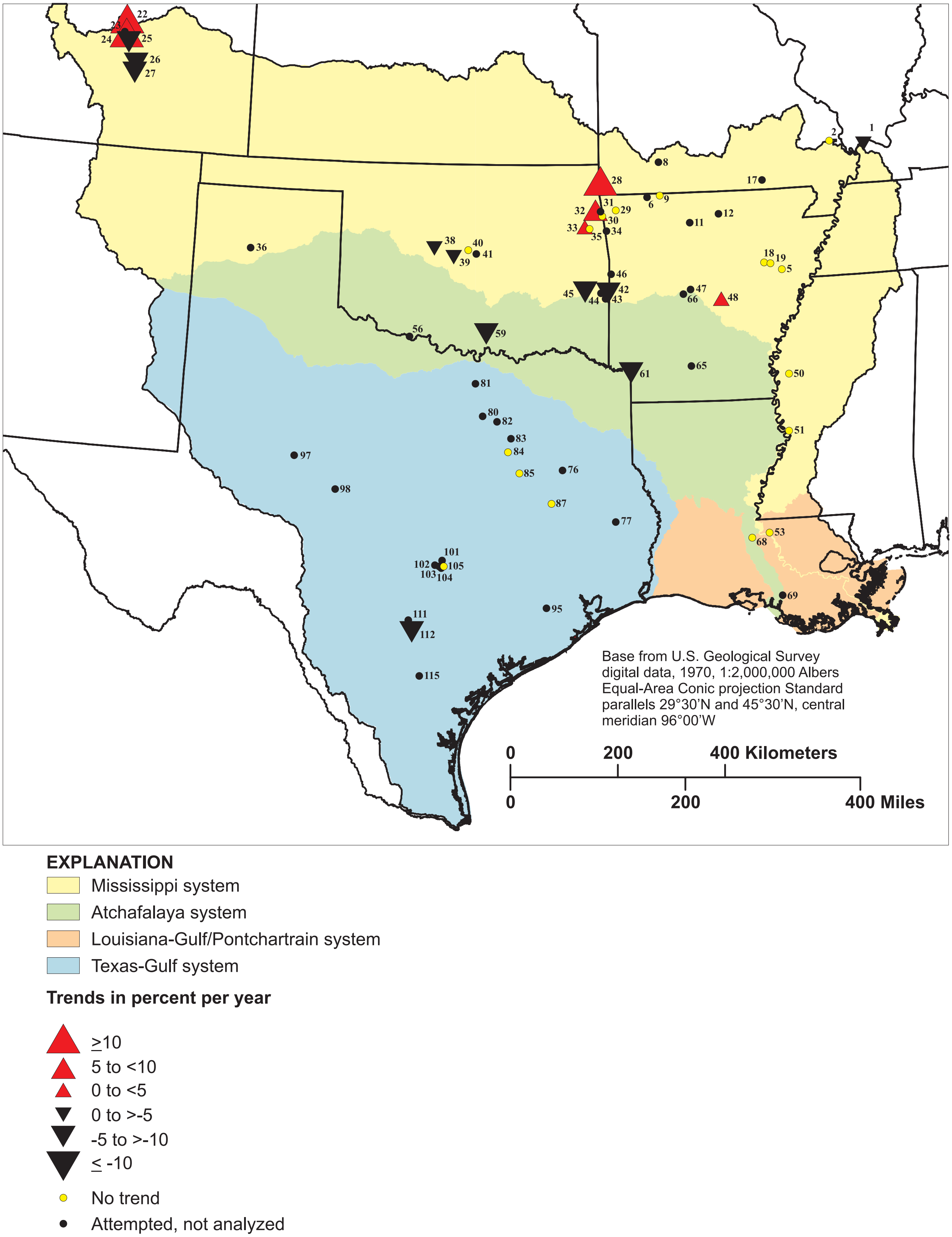


Figure 24. Total trends in orthophosphorus concentrations at study sites, 1993-2004.

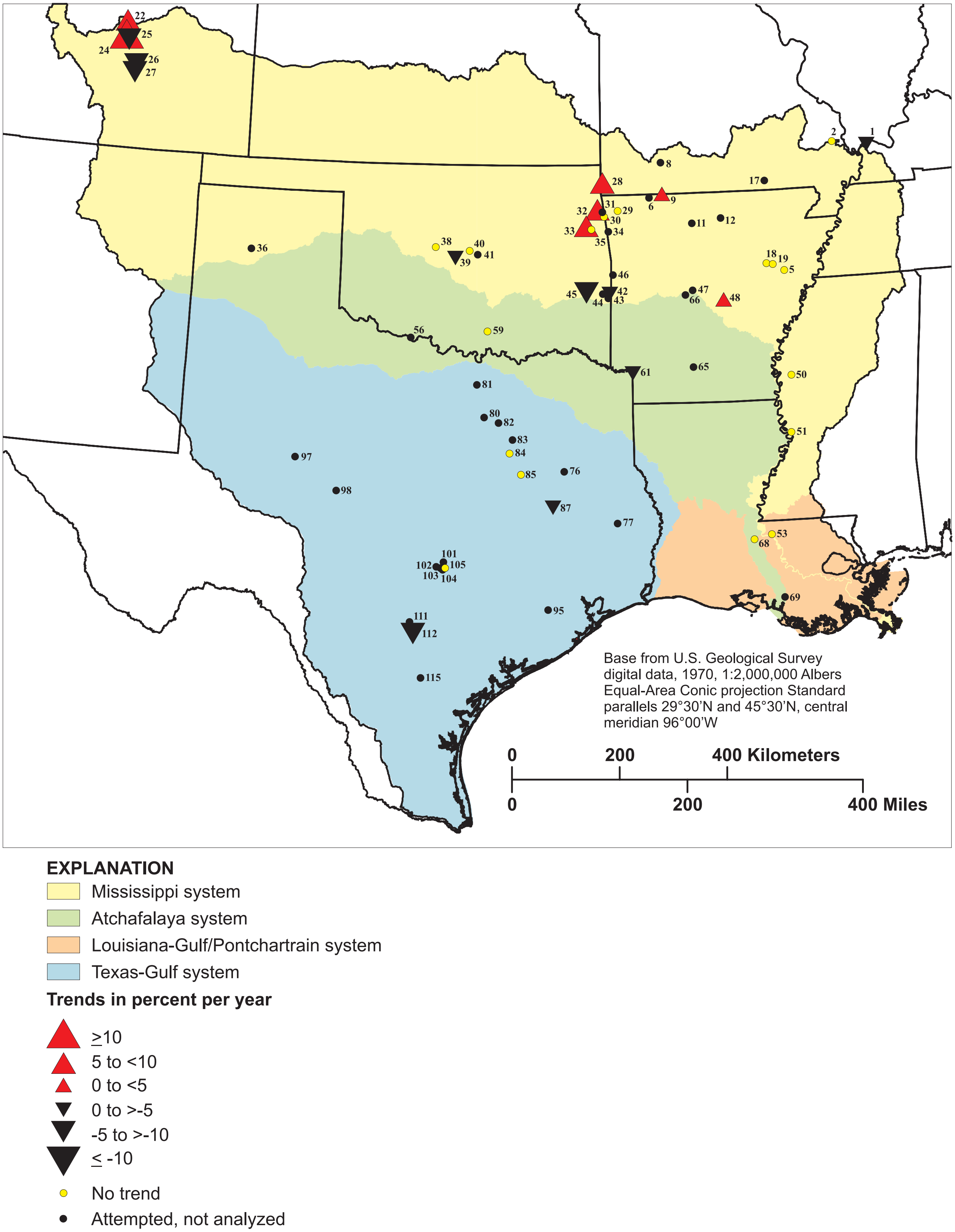


Figure 25. Flow-adjusted trends in orthophosphorus concentrations at study sites, 1993-2004.

were related to improvements in municipal wastewater treatment.

Decreasing trends in flow-adjusted orthophosphorus were observed at site 87 on the Trinity River in the Texas-Gulf system (although there were no total trends in concentration). In the mid-1990's, Van Metre and Reutter (1995) reported a decreasing trend in phosphorus loads at the same site (located about 160 miles downstream from the City of Dallas) for data collected prior to 1991, but the cause of the decreasing trend was not determined.

Increasing total and flow-adjusted trends in orthophosphorus were observed at sites 24, 28, 33, and 48 – all in the Mississippi system (table 11). Reference concentrations at these four sites were all lower than the USEPA recommendation of 0.05 mg/L orthophosphorus. If trends were applied to reference concentrations at these four sites, orthophosphorus concentrations would remain below or barely exceed 0.05 mg/L; thus, trends at these four sites were considered negligible. An increasing flow-adjusted trend in orthophosphorus occurred at site 9 in the Mississippi system (although there were no total trends in concentration). The reference concentration was 0.03 mg/L and would not exceed the USEPA recommendation of 0.05 mg/L during the study period; thus, the trend at site 9 was also considered negligible.

Increasing total and flow-adjusted trends were observed at sites 22 and 32 in the Mississippi system (table 11) indicating that trends were not influenced by streamflow but could be caused by changes in management practices or sources of phosphorus at this site. Site 22 is located on Monument Creek near the United States Air Force Academy in Colorado. The increasing trends in orthophosphorus at site 22 during this study period could not be explained at this time. Results from a study by Edelmann and others (2002) indicated that orthophosphorus concentrations tended to be higher during storm flows than during base flows for a location near site 22, but their results did not provide an overall trend for their study period, which was 1981 through 2001. Site 32 is located on Flint Creek in Oklahoma, and a segment of Flint Creek is listed as impaired due, in part, to total phosphorus; however, the official source of the impairment is unknown (Oklahoma Department of Environmental Quality, 2004).

There were no trends observed in orthophosphorus loads at 15 sites (about 44 percent) during the study period (table 11). Decreasing trends in orthophosphorus loads were observed at 17 sites for the study period (fig. 26), ranging from -7.9 to -2.5 percent per year (table 11). There were increasing trends in orthophosphorus loads observed at two sites. An increase of 37 percent per year was observed at site 19, and an increase of 7.6 percent per year was observed at site 22; however, reference loads at these two sites were 12 and 8 kg/day, respectively, and trends in orthophosphorus loads were considered negligible.

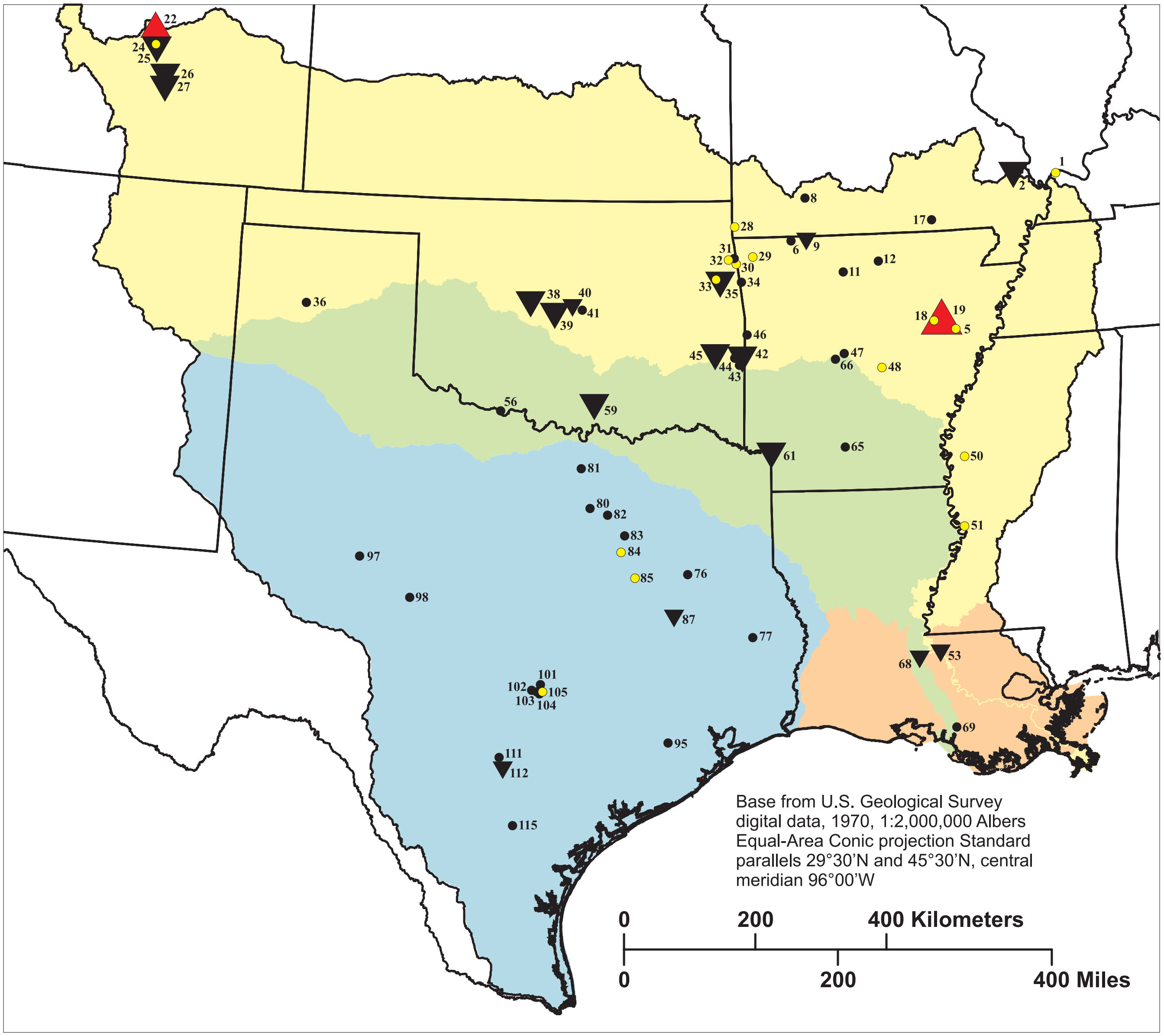
Decreasing trends in orthophosphorus loads at sites 2, 53, and 68 during the study period cannot be completely confirmed in looking at annual load data for the time period 1980-2004 plotted in figure 27. There is a lengthy gap in the annual load data at site 2 from about 1987 to 1995; load data plotted after 1995 appear to be decreasing but are also scattered (fig. 27). The decreasing trends in orthophosphorus loads at sites 53 and 68 appear to be decreasing since 1980, but the decrease is very slight (fig. 27). No trends were observed in orthophosphorus loads at sites 1 and 48 during the study period. These results appear to be confirmed in looking at annual loads plotted at site 1 for the period 1980-2004 in figure 27. Although there appears to be a decreasing trend in annual loads plotted for site 48 since 1980 (LOWESS line, site 48, fig. 27), the data are scattered, likely indicating no trend since 1980.

Annual loads, average annual load, and yield calculations for orthophosphorus were attempted for 29 study sites in three of the four river systems, with the exception being the Louisiana-Gulf/Pontchartrain system, which had no sites that had an adequate amount of orthophosphorus data to attempt load and yield calculations (table 12). Average annual orthophosphorus loads for some of the major drainages (not necessarily the most downstream) into the northwestern Gulf of Mexico were as follows: 30,100 T for the Mississippi River (site 53); 11,900 T for the Atchafalaya River (site 68); and 1,290 T and 323 T for the Trinity River (site 87) and the San Antonio River (site 112), respectively, in the Texas-Gulf system. Again, the Mississippi and Atchafalaya systems account for nearly all of the orthophosphorus load into the northwestern Gulf of Mexico. Yields for these same sites, in order of magnitude, were 0.0716, 0.0491, 0.0357, and 0.0103 T·km-2·yr-1 for the San Antonio, Atchafalaya, Trinity, and Mississippi Rivers, respectively. Similar to other yield observations, orthophosphorus yields from smaller rivers were equal to or greater than yields from the Mississippi River.

Orthophosphorus loads and yields for selected sites on the Mississippi, Arkansas, and Atchafalaya Rivers from this study for the period 1993-2004 were compared to loads and yields calculated by Goolsby and others (1999) for the period 1980-96. The mean annual orthophosphorus loads from sites 1, 2, 48, 53, and 68 from Goolsby and others (1999) were 11,200; 19,100; 1,900; 30,800; and 11,000 T, respectively. Orthophosphorus loads for the same sites calculated from this study were 10,800; 21,900; 1,980; 30,100; and 11,900 T (table 12), respectively, which were comparable to the previous study. Orthophosphorus yields from Goolsby and others (1999) were 0.021, 0.01, 0.005, and 0.013 T·km-2·yr-1 for sites 1, 2, 48, and the combined Mississippi and Atchafalaya Rivers (sites 53 and 68). For this study, orthophosphorus yields were nearly identical to the previous study results (table 12).

Total phosphorus trends, loads, and yields

Trend analyses of total phosphorus data were attempted for 80 study sites in all four river systems (table 13). Trend results were rejected for 28 sites because of poor model fit (represented as N/A in table 13). Of the remaining 52 sites where trend results were considered acceptable, there were 32 sites (about 62 percent) where no total trends in concentration



EXPLANATION

Mississippi system

Atchafalaya system

Louisiana-Gulf/Pontchartrain system

Texas-Gulf system

Trends in percent per year

≥10

5 to <10

0 to <5

0 to >-5

-5 to >-10

≤ -10

No trend

Attempted, not analyzed

Figure 26. Trends in orthophosphorus loads at study sites, 1993-2004.

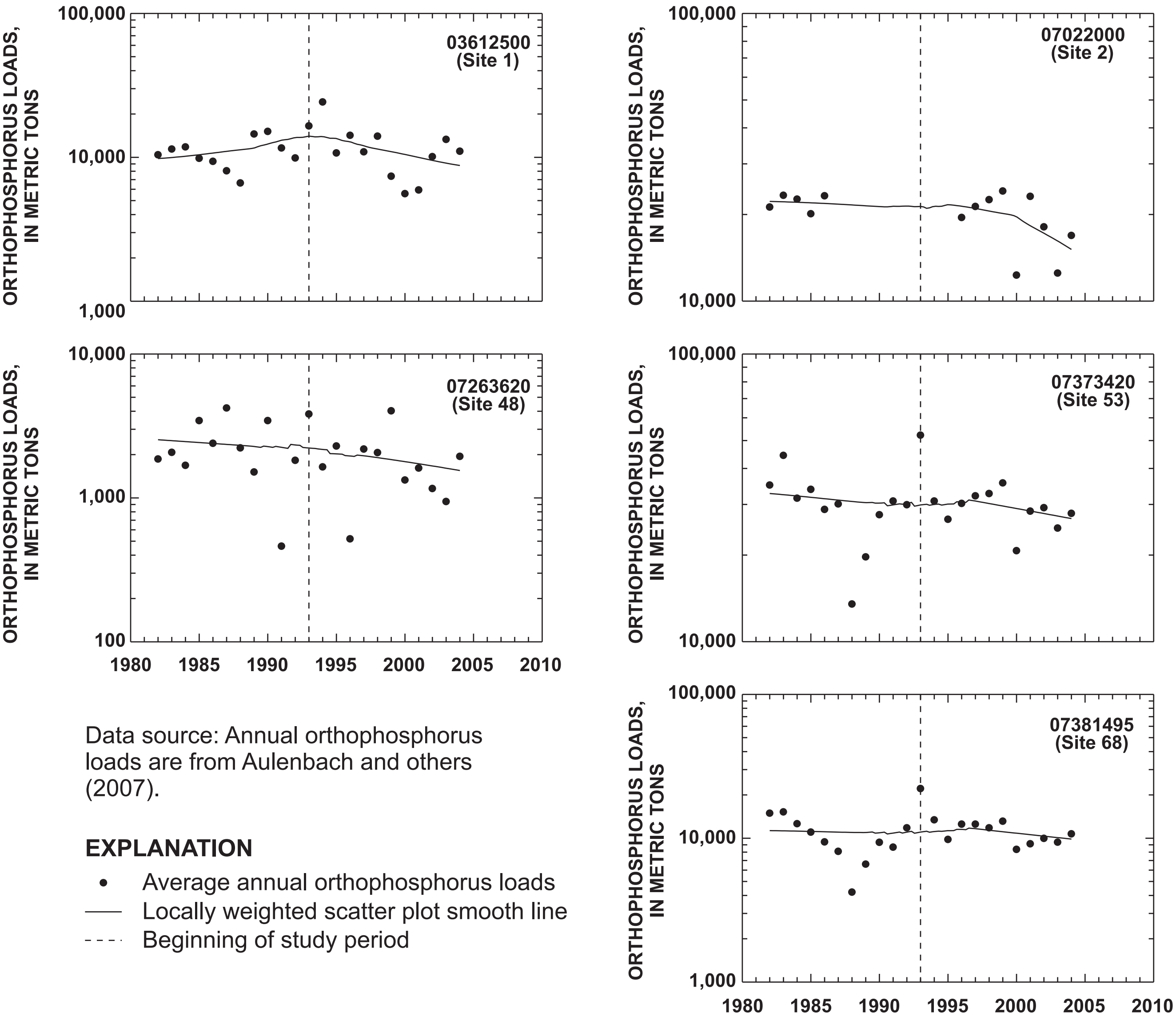


Figure 27. Annual orthophosphorus loads for selected study sites, 1980-2004.

were observed during the study period (table 13). Decreasing total trends in concentration were observed at six sites ranging from -8.8 to -5.0 percent per year during the study period (table 13, fig. 28). Increasing total trends in concentration occurred at 14 sites ranging from 4.1 to 13 percent per year during the study period (table 13, fig. 28). There were 29 sites (about 56 percent) where no flow-adjusted trends in concentration were observed during the study period (table 13). Decreasing flow-adjusted trends in concentration were observed at six sites ranging from -9.0 to -3.9 percent per year (table 13, fig. 29). Increasing flow-adjusted trends in concentration occurred at 17 sites, ranging from 3.0 to 56 percent per year during the study period (table 13, fig. 29).

Decreasing total and flow-adjusted trends in total phosphorus occurred at sites 34 and 46 in the Mississippi system and sites 89, 106, 112, and 113 in the Texas-Gulf system (table 13, figs. 28 and 29), indicating that the decreasing trends were not related to decreasing trends in streamflow but could be caused by changes in management practices or sources of phosphorus within the drainage areas of these sites. Reference concentrations at sites 34, 46, and 106 were less than 0.1 mg/L (table 13). The national background concentration for total phosphorus is 0.1 mg/L (U.S. Geological Survey, 1999). Site 34 is located in nutrient ecoregion XI (central and eastern forested uplands), and the USEPA recommendation for total phosphorus criteria aggregated for this ecoregion is 0.01 mg/L (U.S. Environmental Protection Agency, 2000b). Site 46 is located in nutrient ecoregion IX (southeastern temperate forested plains and hills), and the USEPA recommendation for total phosphorus criteria aggregated for this ecoregion is 0.037 mg/L (U.S. Environmental Protection Agency, 2000a). Site 106 is located in nutrient ecoregion IV (Great Plains grass and shrublands), and the USEPA recommendation for total phosphorus criteria aggregated for this ecoregion is 0.023 mg/

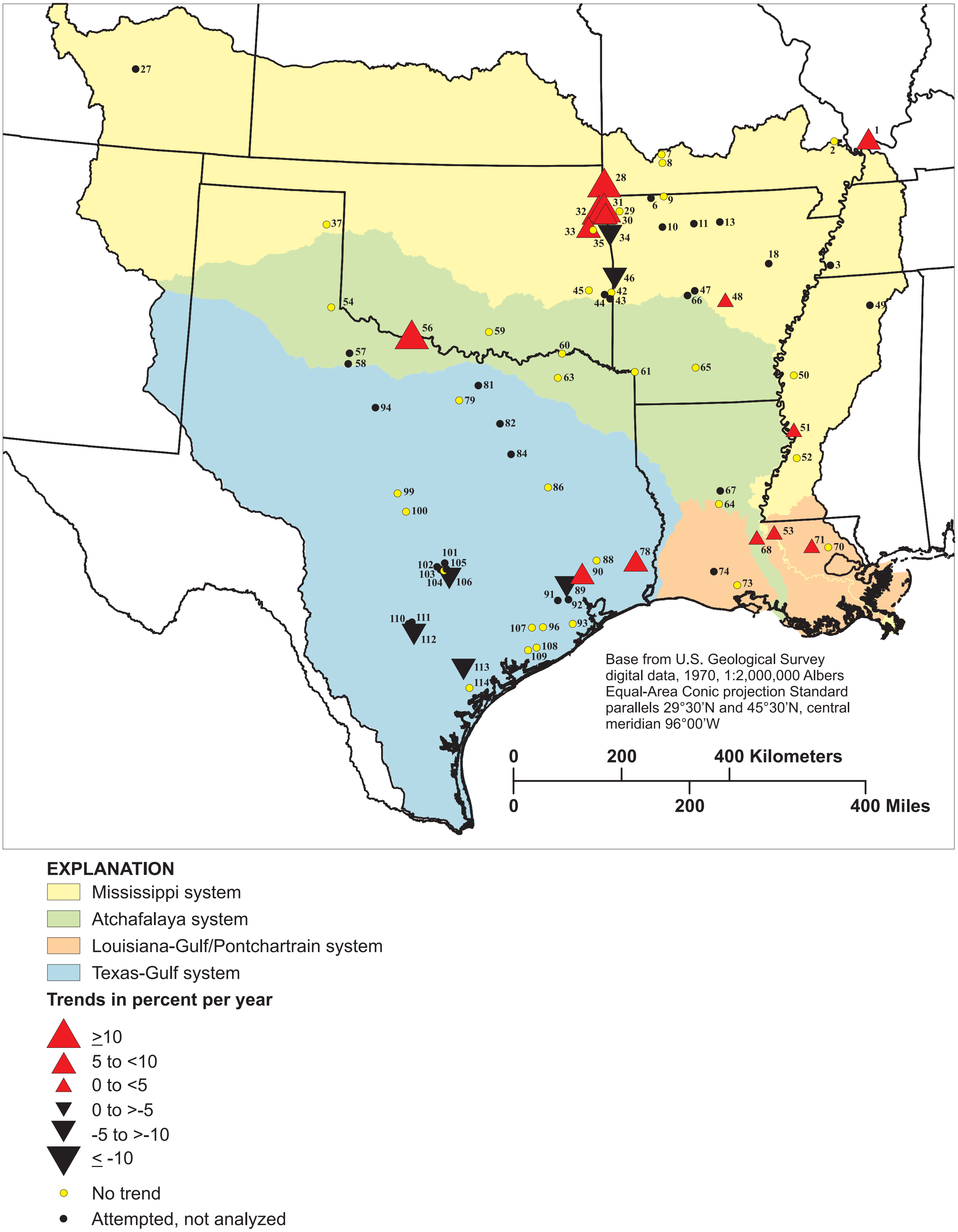


Figure 28. Total trends in total phosphorus concentrations at study sites, 1993-2004.

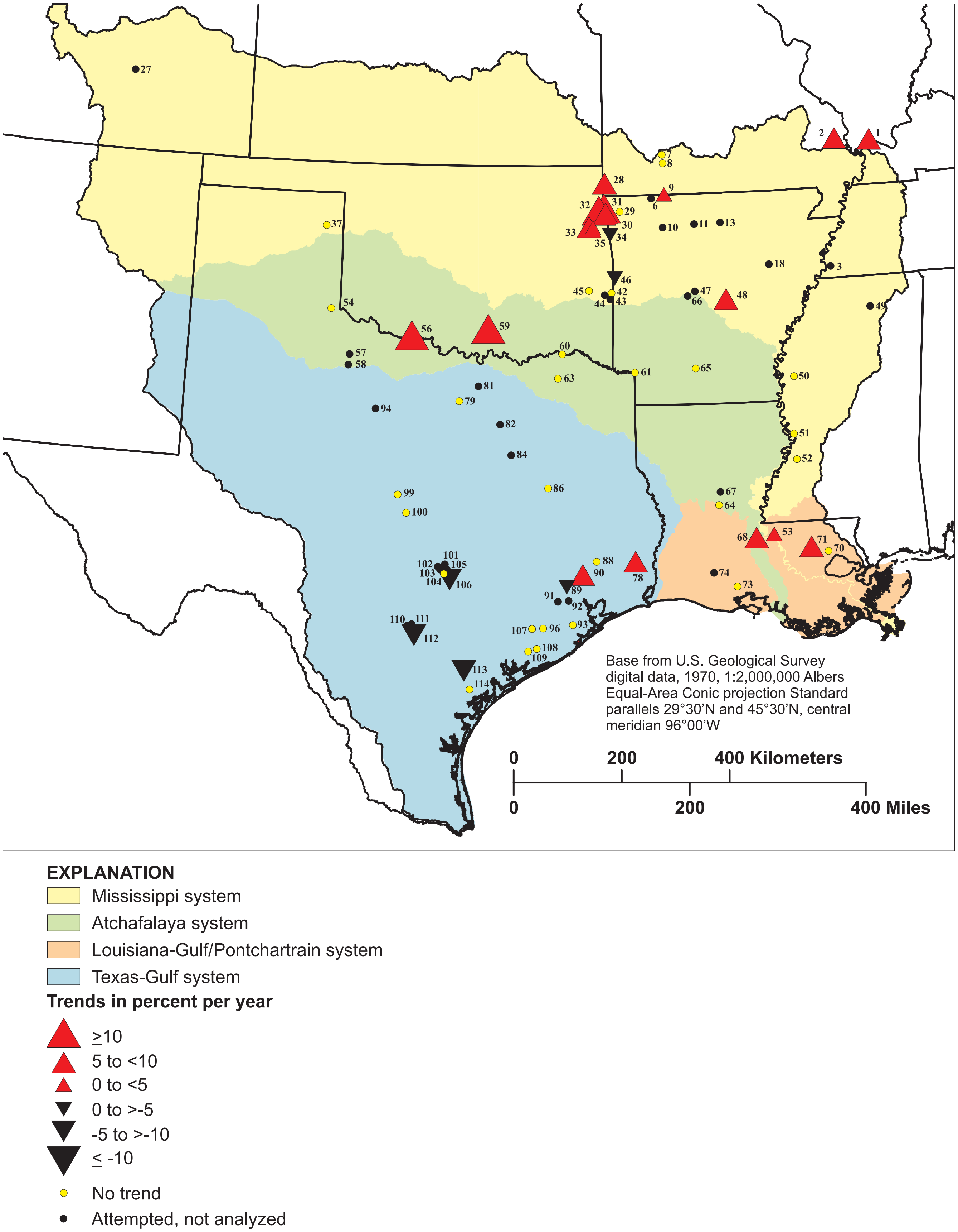


Figure 29. Flow-adjusted trends in total phosphorus concentrations at study sites, 1993-2004.

L (U.S. Environmental Protection Agency, 2001). Because reference concentrations for these three sites were less than the national background concentration, and concentrations were projected to be lower or approach associated ecoregion criteria recommendations in 2004 if trends are applied, the decreasing trends at sites 34, 46, and 106 were considered negligible.

Reference concentrations were about 1 mg/L or greater at sites 89, 112, and 113. Decreasing trends in total phosphorus at site 89 could not be explained at this time. The magnitude of decreasing trends in total phosphorus at site 112 were similar to the magnitude of decreasing orthophosphorus trends at this site (tables 11 and 13; note: site 113 is also located on the San Antonio River downstream of site 112). As discussed earlier, the San Antonio River Authority (2003) reported that reductions in phosphorus levels and improvements in water quality in the San Antonio River were related to improvements in municipal wastewater treatment.

Increasing total and flow-adjusted trends in total phosphorus occurred at sites 1, 28, 30, 31, 32, 33, 48, 53 in the Mississippi system, sites 56 and 68 in the Atchafalaya system, site 71 in the Louisiana-Gulf/Pontchartrain system, and sites 78 and 90 in the Texas-Gulf system (table 13, figs. 28 and 29) indicating that trends were not influenced by streamflow but could be caused by changes in phosphorus sources or management practices. Reference concentrations at most of these 13 sites were less than or only slightly greater than 0.1 mg/L (table 13, except for site 31, which had a reference concentration of about 0.5 mg/L). If trends are applied to the reference concentrations at these 13 sites, then total phosphorus concentrations in 2004 are projected to approach or exceed the national background concentration (U.S. Geological Survey, 1999) and associated USEPA ecoregion criteria recommendations for total phosphorus at each site (U.S. Environmental Protection Agency, 2007).

It is important to note that total phosphorus increased at sites 1, 48, 53, 56, and 68, which are mainstem sites on the Mississippi, Arkansas, Red, and Atchafalaya Rivers. The drainage areas for these five sites are extremely large and complex, thus, an explanation as to the increase in total phosphorus at these five sites is beyond the scope of this report.

Sites 30 and 33 are located on the Illinois River, and site 32 is located on Flint Creek in Oklahoma. The Illinois River and Flint Creek are part of the Oklahoma Scenic Rivers Program (Oklahoma Office of the Secretary of the Environment, 2003). Segments of these two streams are listed as impaired because of phosphorous (as well as pathogens), but the official sources of those impairments are listed as unknown (Oklahoma Department of Environmental Quality, 2004). Site 31 is located on Sager Creek, which is a tributary of Flint Creek in the Illinois River Basin. Sager Creek is not listed as impaired due to phosphorus (Oklahoma Department of Environmental Quality, 2004), but is part of the Scenic Rivers monitoring program that includes the Illinois River and Flint Creek (Oklahoma Office of the Secretary of the Environment, 2003).

Increasing trends in total phosphorus at sites 28 and 78 could not be explained at this time. Site 71 is located on the Tickfaw River in Louisiana. Although the increasing trends in total phosphorus at site 71 could not be explained at this time, phosphorus is listed as an impairment in parts of this watershed because of infiltration and outflows from failing wastewater collection systems, according to a report by the Louisiana Department of Environmental Quality (2000).

No explanation for an increasing trend in total phosphorus at site 90, located on the East Fork San Jacinto River in Texas, was found in the literature. Sneck-Fahrer and others (2005) sampled inflows into Lake Houston near Houston, Tex., for the period 2000-04. In their report, the East Fork San Jacinto River represented the eastern part of the Lake Houston watershed, which is less densely populated than the western part of the watershed. Sneck-Fahrer and others (2005) reported a decreasing trend in dissolved phosphorus data for a sampling site on the eastern part of Lake Houston itself, but not specifically at site 90.

Site 51 indicated an increasing trend in total phosphorus for the study period (total trend only, table 13). Site 51 is located near the mouth of the Yazoo River in the Mississippi system downstream from some of the most intense row-crop agricultural production areas in the United States. Although the increasing trend in total phosphorus at site 51 could be related to agriculture, Kleiss and others (2000) pointed out that phosphorus is used less in the Yazoo River Basin than in many parts of the Midwest. Another possible explanation for the increasing trend in total phosphorus is related to sediment in the Yazoo River (Coupe, 2002). Phosphorus binds to sediment, especially to fine clays, which are prevalent in streams of the Yazoo River Basin; however, an increasing trend in suspended sediment was not observed at site 51 during the study period (sediment trend results are presented in the next section). Thus, the increasing trend in total phosphorus at site 51 for the study period cannot be explained at this time.

Although there were no total trends in total phosphorus concentrations at sites 2, 9, and 35 in the Mississippi system and site 59 in the Atchafalaya system, there were increasing flow-adjusted trends observed at these four sites, possibly indicating changes in management practices or increases in phosphorus sources during the study period. The drainage area at site 2 is large and complex; thus, an explanation for an increasing flow-adjusted trend at this site is beyond the scope of this report. The increasing trend in total phosphorus at site 9 is not entirely known at this time; however, this site was included in a study by Davis and Bell (1998) that reported total phosphorus concentrations were slightly higher for site 9 than for surrounding basins due to the amount of and type of agricultural land use (poultry farming). Site 35 is located on the Baron Fork River in Oklahoma; no stream segments on the Baron Fork River are currently listed (2007) as impaired due to phosphorus (Oklahoma Department of Environmental Quality, 2004). However, a segment of the Baron Fork River has been included in the 2006 Draft 303d list for streams in Oklahoma as impaired due, in part, to phosphorus [Oklahoma

Department of Environmental Quality, 2006 (draft)]. Site 59 is located on the Washita River in Oklahoma, and the increasing trends in total phosphorus at site 59 cannot be explained at this time.

There were no trends observed in total phosphorus loads at 42 sites (about 81 percent) during the study period (table 13). Decreasing trends in total phosphorus loads were observed at nine sites for the study period, ranging from -7.8 to -3.9 percent per year (table 13, fig. 30). There was an increasing trend in total phosphorus loads observed at one site; an increase of 11 percent per year at site 31 on Sager Creek, which is a tributary of Flint Creek in the Illinois River Basin.

No trends in total phosphorus loads were observed at sites 1, 2, 48, 53, 64, and 68 during the study period (table 13). Similarly, no trends in total phosphorus loads were observed during the period 1980-2004 at sites 2, 48, 53, and 68 as plotted in figure 31. Although LOWESS lines for sites 1 and 64 indicate increasing and decreasing trends, respectively, for the period 1980-2004 (fig. 31), the scatter of the data in these plots clearly supports no trends in total phosphorus loads at these two sites (table 13, fig. 31). The decreasing trend in total phosphorus loads at site 112 on the San Antonio River is part of a much longer decreasing trend in loads that has been occurring since 1980 (fig. 31), likely due to improvements in municipal wastewater treatment facilities as previously presented (San Antonio River Authority, 2003).

Annual loads, average annual load, and yield calculations for total phosphorus were attempted for 35 study sites in all four river systems (table 14). When orthophosphorus and total phosphorus loads were compared at key sites in the four river systems, the orthophosphorus loads accounted for only about 20-30 percent of the total phosphorus loads (tables 12 and 14). Average annual total phosphorus loads for some of the major drainages (not necessarily the most downstream) into the northwestern Gulf of Mexico were as follows: 101,000 T for the Mississippi River (site 53); 40,200 T for the Atchafalaya River (site 68); 206 T for the Tangipahoa River (site 70) in the Louisiana-Gulf/Pontchartrain system; and 2,870 T and 998 T for the Trinity River (site 86) and the Colorado River (site 108), respectively, in the Texas-Gulf system. Again, the Mississippi and Atchafalaya systems accounted for most of the total phosphorus load into the northwestern Gulf of Mexico. Yields for these same sites, in order of magnitude, were 0.166, 0.123, 0.0862, 0.0347, and 0.00912 T·km-2·yr-1 for the Atchafalaya, Tangipahoa, Trinity, Mississippi, and Colorado Rivers, respectively. Similar to other yield observations, total phosphorus yields from smaller rivers were equal to or greater than yields from the Mississippi River.

Total phosphorus loads and yields for selected sites on the Mississippi, Arkansas, and Atchafalaya Rivers from this study for the period 1993-2004 were compared to loads and yields calculated by Goolsby and others (1999) for the period 1980-96. The mean annual total phosphorus loads from sites 1, 2, 48, 53, and 68 from Goolsby and others (1999) were 39,400; 68,700; 5,100; 97,000; and 39,500 T, respectively. Total phosphorus loads for the same sites calculated from this study were 48,800; 78,600; 5,020; 101,000; and 40,200 T (table 14), respectively, indicating higher loads of total phosphorus in the Ohio and Upper Mississippi Rivers (sites 1 and 2, respectively) calculated for this study than in the previous study. Total phosphorus yields from Goolsby and others (1999) were 0.075, 0.037, 0.013, and 0.042 T·km-2·yr-1 for sites 1, 2, 48, and the combined Mississippi and Atchafalaya Rivers (sites 53 and 68). For this study, total phosphorus yields for the same sites were 0.0928, 0.0425, 0.0122, and 0.0447, T·km-2·yr-1 indicating higher yields from the Ohio and Upper Mississippi Rivers (sites 1 and 2, respectively) calculated for this study than in the previous study (table 14).

Relation of trends in phosphorus to trends in source data and landscape attributes

There were some statistically significant results from the WLS regression analyses where trends in phosphorus-source data and landscape attributes were compared to trends in phosphorus constituents from this study (table 9). Coefficients of determination (R2) for the statistically significant results were all less than about 0.3, indicating that little of the variance was explained, and relations were considered poor. Statistically significant results of the WLS regression analyses are presented in this section relative to phosphorus trends; however, the reader is cautioned against over-interpretation of the results.

Population throughout most of the study area either remained the same or increased during the study period (fig. 20). Such increasing trends could explain increasing trends in orthophosphorus and total phosphorus observed near urban areas (point sources) or where drainages included a combination of urban and agricultural areas. However, results of the WLS regression analyses indicated an inverse relation between population and flow-adjusted trends in total phosphorus (table 9), which was a result that was unexpected. Therefore, trends in population were not considered a controlling factor to explain trends in total phosphorus (nor could trends in population be used to explain trends in phosphorus from point sources).

Increasing trends in phosphorus from fertilizer were observed in southeastern Colorado, eastern Oklahoma, Arkansas, and southern Missouri (fig. 32). Results of the WLS regression analyses did not indicate any statistically significant results between trends in phosphorus from fertilizer and trends in orthophosphorus or total phosphorus observed at study sites (table 9). There were more increasing trends in phosphorus from manure than were increasing trends in phosphorus from fertilizer (figs. 32 and 33). Weighted-least-squares regression results did suggest that increasing trends in phosphorus from land application of manure could be related to increasing total and flow-adjusted trends in both orthophosphorus and total phosphorus at study sites (table 9).

There were only seven sites where management practices increased or decreased more than 1 percent of their total drainage areas from 1992 to 1997 (table 10). Of these seven

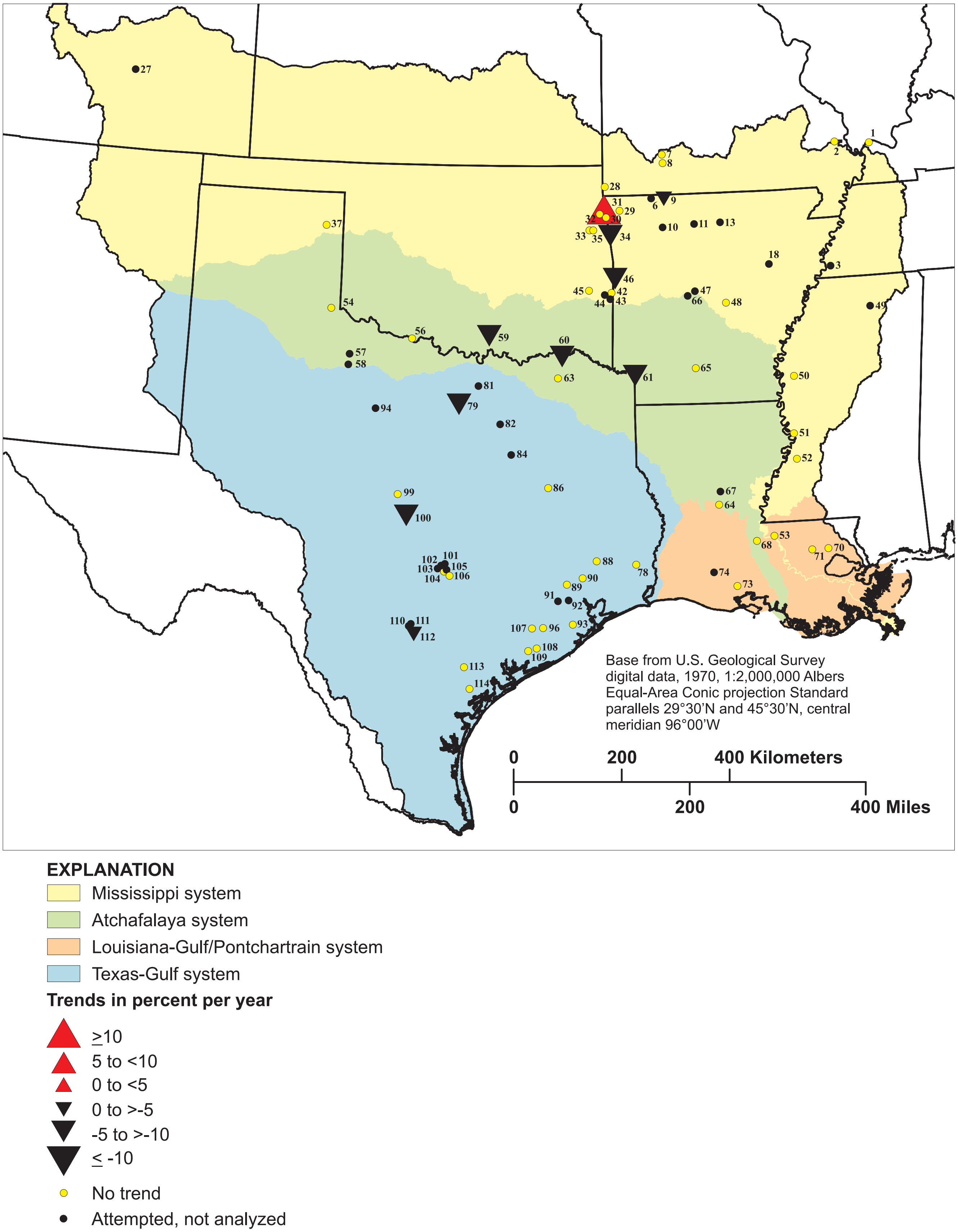


Figure 30. Trends in total phosphorus loads at study sites, 1993-2004.

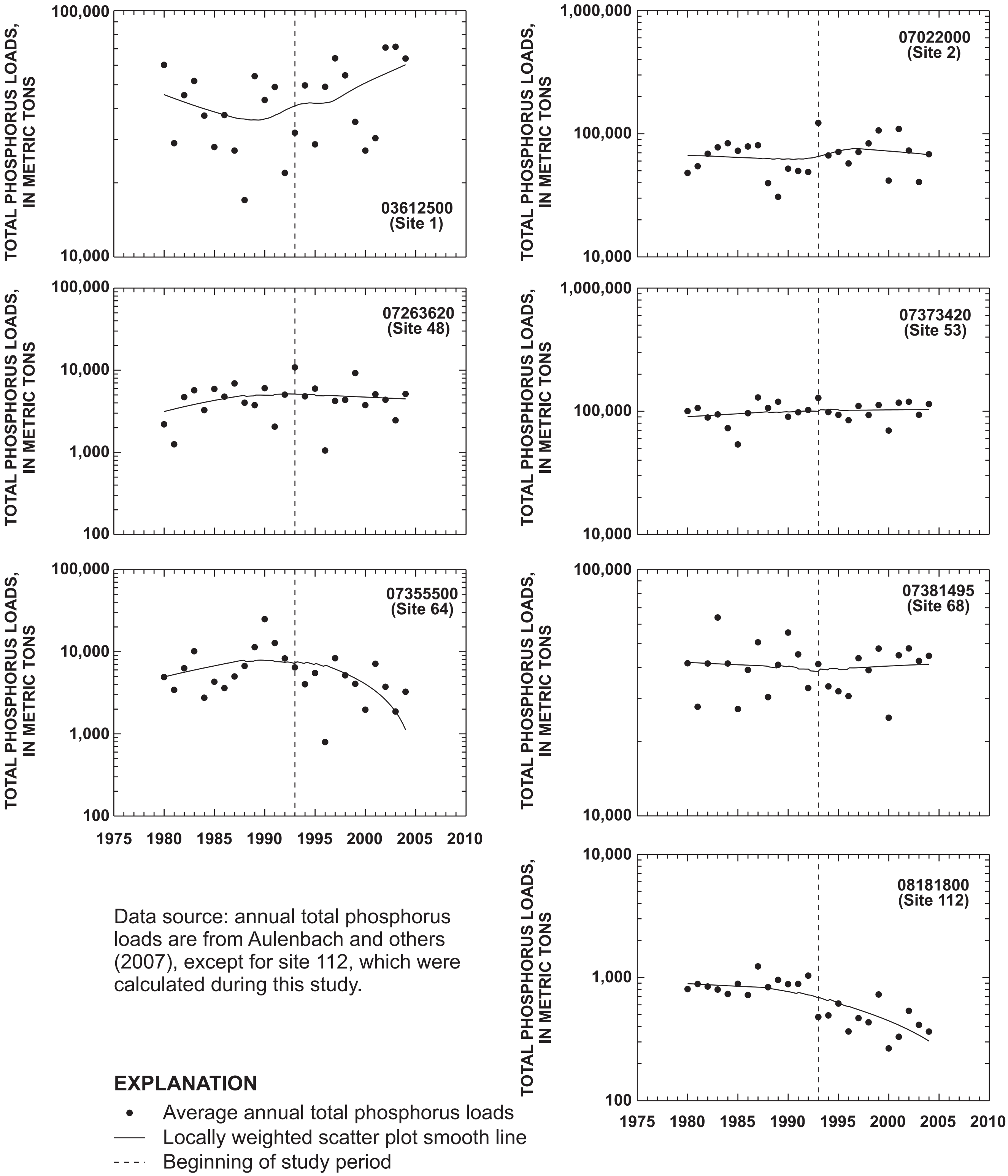
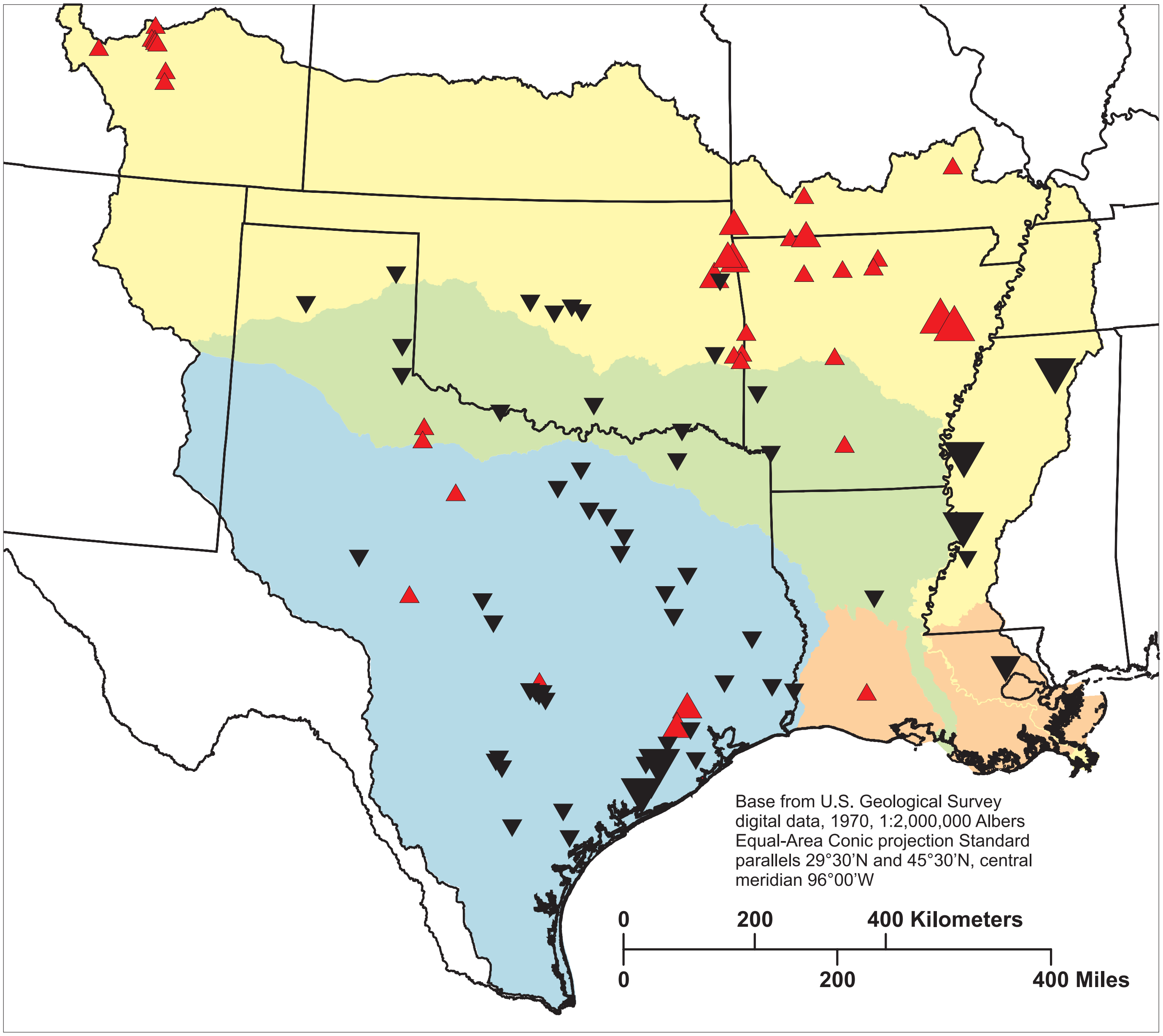


Figure 31. Annual total phosphorus loads for selected study sites, 1980-2004.



EXPLANATION

- Mississippi system
- Atchafalaya system
- Louisiana-Gulf/Pontchartrain system
- Texas-Gulf system

Annual change in phosphorus from fertilizer, 1993-2004, in kilograms per year per square kilometers

- ≥10
- 5 to <10
- 0 to <5
- 0 to >-5
- -5 to >-10
- ≤ -10

Data source: annual fertilizer data combined from farm and non-farm sources, 1993-2004 Modified from Ruddy and others (2006).

Figure 32. Trends in phosphorus from fertilizer at study sites, 1993-2004.

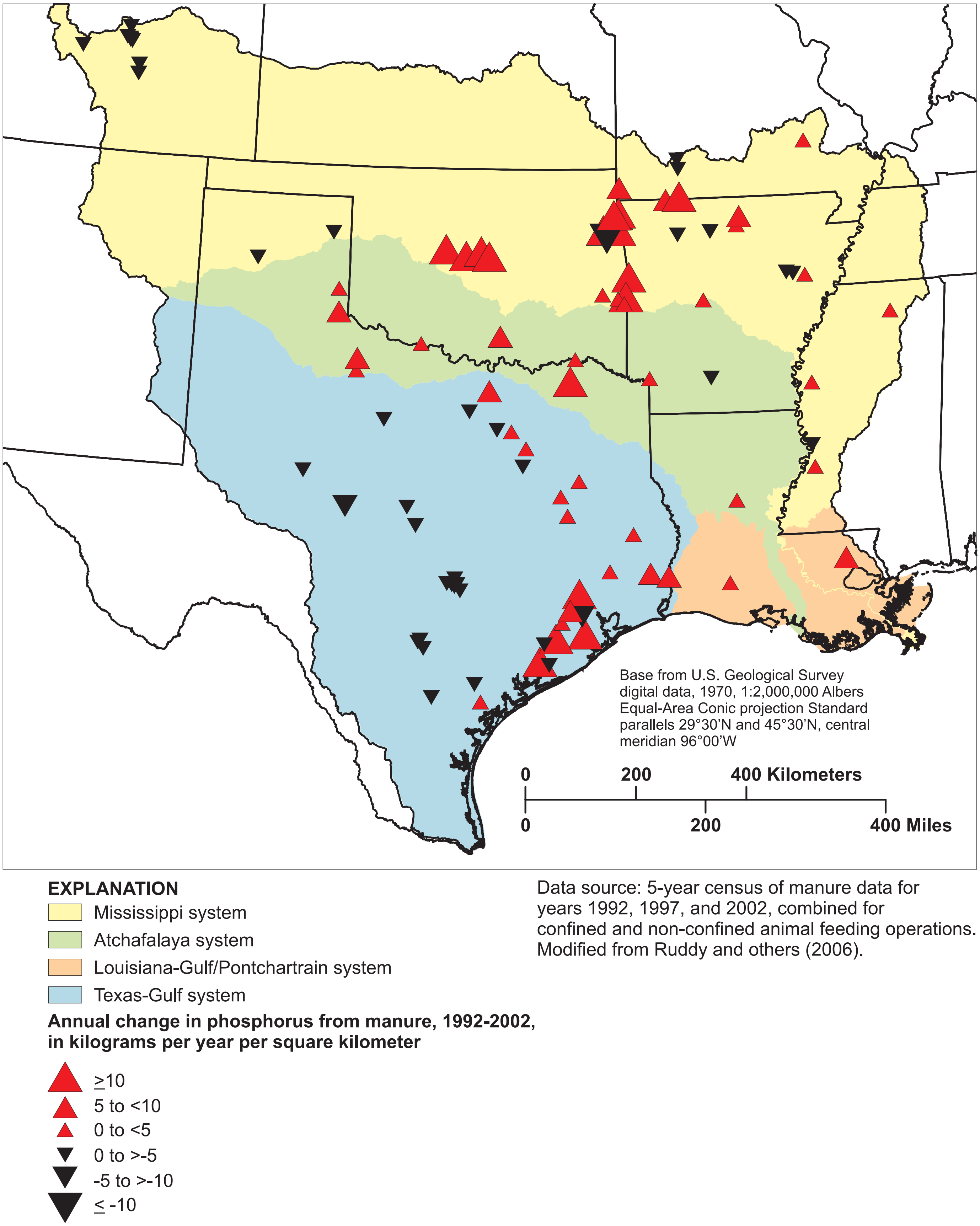


Figure 33. Trends in phosphorus from manure at study sites, 1992-2002.

sites, only one corresponded to any trends in phosphorus data for the study period. There was a decrease in both total and flow-adjusted trends in total phosphorus for the study period at site 89. During the period 1992-97, conservation practices (contour farming or terracing) decreased by 1.3 percent of the total drainage area for site 89. It is unlikely that the decrease in total phosphorus was related to the decrease in the amount of land in contour farming or terracing; rather, the decrease in total phosphorus at site 89 was affected more by changes in the wastewater treatment plant located near this site (Texas Natural Resource Conservation Commission, 2000).

Overall conclusions about phosphorus trends and loads for the study area

Similar to results for nitrogen, there were few trends observed in the phosphorus data at study sites during the study period; no trends were observed in about 57 percent of all phosphorus trend analyses attempted. Although some patterns in the phosphorus data did exist where trend analyses were attempted, no regional patterns could be confirmed because of poor spatial representation of the trends sites.

Flow-adjusted concentrations of orthophosphorus decreased at 10 sites and increased at 7 sites. Flow-adjusted concentrations of total phosphorus decreased at 6 sites and increased at 17 sites. It was understandable that trend patterns in total phosphorus did not follow trend patterns in orthophosphorus given that orthophosphorus loads accounted for only about 20-30 percent of the total phosphorus load at comparable sites. Trends in population data were inversely related to trends in flow-adjusted total phosphorus; therefore, trends in population were not considered a controlling factor to explain trends in total phosphorus. No relation was observed between phosphorus from fertilizer use and either orthophosphorus or total phosphorus trends. However, statistical results did suggest that increasing trends in both orthophosphorus and total phosphorus could be related to increasing trends in phosphorus from land application of manure.

There were more decreasing trends than increasing trends in phosphorus loads during the past decade, most of which were unique to the recent decade and not part of long-term decreases since 1980. Similar to nitrogen loads, the Mississippi and Atchafalaya Rivers contributed the highest phosphorus loads to the northwestern Gulf of Mexico as expected; however, phosphorus yields from smaller rivers were similar to or higher than yields from the Mississippi River.

Suspended Sediment

Specific details about suspended-sediment trend, load, and yield results are discussed at the beginning of this section. These results are then related to potential trends in source and landscape attributes. Finally, some general conclusions about suspended-sediment trend and load results are discussed at the end of this section.

Suspended-sediment trends, loads, and yields

Trend analyses in suspended-sediment data were attempted for 39 study sites in three of the four river systems, with the exception of the Louisiana-Gulf/Pontchartrain system, which had no sites with an adequate amount of suspended-sediment data to attempt trend analyses (table 15). Trend results were rejected for 11 sites because of poor model fit (represented as N/A in table 15). Of the remaining 28 sites where trend results were considered acceptable, there were 19 sites (about 68 percent) where no total trends in concentration were observed during the study period (table 15). Decreasing total trends in concentration were observed at eight sites ranging from -7.6 to -3.0 percent per year during the study period (table 15, fig. 34). Increasing total trends in concentration occurred at only site 9, which had a 9.5 percent per year increase during the study period (table 15, fig. 34). There were 21 sites (75 percent) where no flow-adjusted trends in concentration were observed during the study period (table 15). Decreasing flow-adjusted trends in concentration were observed at five sites, ranging from -7.6 to -2.2 percent per year (table 15, fig. 35). Increasing flow-adjusted trends in concentration occurred at two sites, sites 1 and 9, which had increases of 5.7 and a 10 percent per year, respectively, during the study period (table 15, fig. 35).

Decreasing total trends in suspended-sediment concentration were observed at sites 2, 5, 10, 46, 48, and 53 in the Mississippi system, and sites 61 and 68 in the Atchafalaya system. Decreasing trends were not retained at sites 2, 46, 61, and 68 when the effects of streamflow were removed, indicating that trends at these four sites were likely related to decreasing trends in streamflow. Decreasing trends were not retained at site 10 either, but there was no trend in streamflow at this site; therefore, the decreasing total trend in suspended sediment at site 10 cannot be explained at this time because of multiple factors that may be occurring.

Decreasing trends were retained at sites 5, 48, and 53 when the effects of streamflow were removed, indicating possible improvements in management practices or decreases in sediment sources during the study period at these three sites. The decrease in suspended sediment at site 5 cannot be explained at this time. Sites 48 and 53 are mainstem sites on the Mississippi and Arkansas Rivers. An explanation as to the decreases in suspended sediment at these two sites is beyond the scope of this report because of the size and complexity of their associated drainage areas; however, these sites are highly regulated throughout their drainage areas for navigation, hydroelectric power, and other erosion-control or flood-control purposes – the majority of which were built after the 1930s. Meade (1995) reported that reservoirs built during the 1950s on the Missouri and Arkansas Rivers, which were the largest sources of sediment to the Mississippi River Basin at the time, caused large decreases in suspended sediment because of their trapping and settling effects. Decreasing trends in sediment continued to be observed through the early 1990s (Meade, 1995).

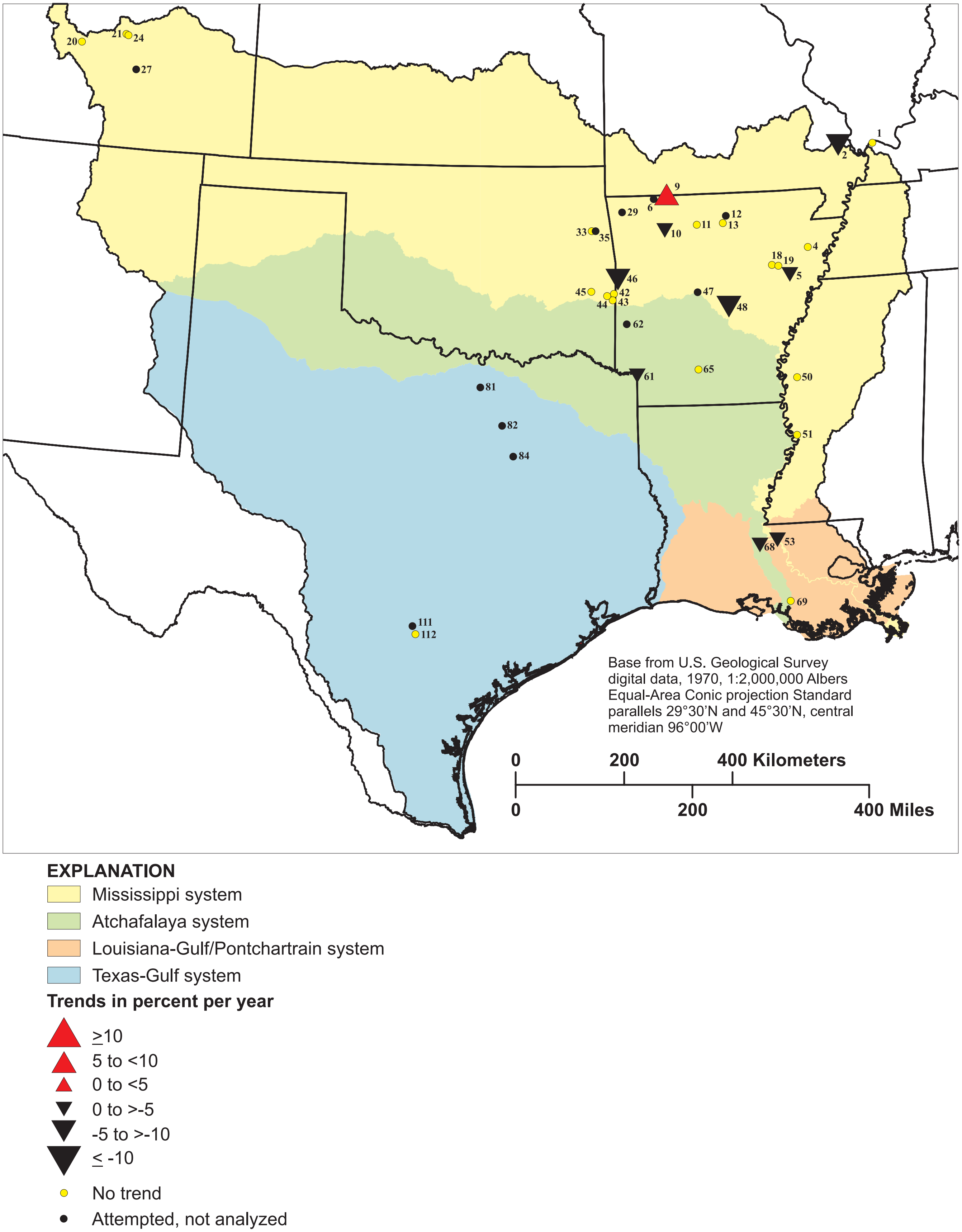
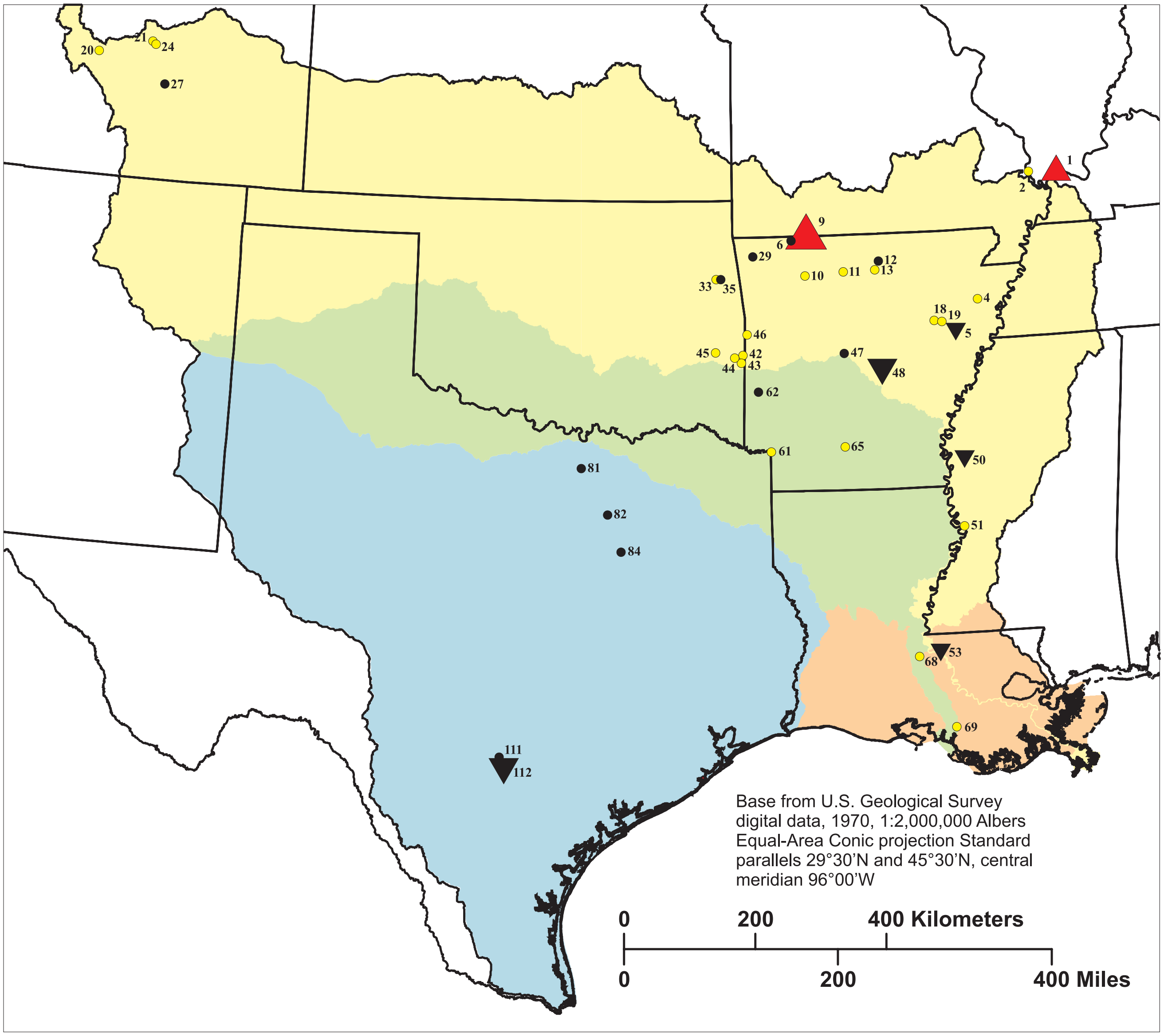


Figure 34. Total trends in suspended-sediment concentrations at study sites, 1993-2004.



EXPLANATION

- Mississippi system
- Atchafalaya system
- Louisiana-Gulf/Pontchartrain system
- Texas-Gulf system

Trends in percent per year

- ≥10
- 5 to <10
- 0 to <5
- 0 to >-5
- -5 to >-10
- ≤ -10
- No trend
- Attempted, not analyzed

Figure 35. Flow-adjusted trends in suspended-sediment concentrations at study sites, 1993-2004.

Decreasing total trends in suspended sediment were not observed at sites 50 and 112; however, decreasing flow-adjusted trends were observed at these two sites, indicating possible decreases in sediment sources within the drainage areas of these sites during the study period. Site 50 is located on the Bogue Phalia in the Yazoo River Basin in Mississippi. Land use within the drainage area of site 50 primarily is row crop production (cotton, soybean, and corn). Recent trends in tillage practices have indicated an increase in no-till or reduced tillage practices within Midsouth States since 1998 (Delta Farm Press, 2003). Although the decreasing flow-adjusted trends in suspended sediment at site 50 cannot be explained at this time, the decreasing trend could be influenced by recent shifts in row-crop agricultural practices from conventional tillage to no-till or reduced tillage.

Site 112 is located on the San Antonio River where multiple restoration and channel improvement projects have been completed since the mid- to late-1990s (for example, as documented in U.S. Army Corps of Engineers, 2004). These projects include flood control, ecological restorations, and recreational improvements. Decreases in suspended sediment at site 112 could, therefore, be a result of these restoration and improvement projects.

Increasing total and flow-adjusted trends in suspended-sediment concentration occurred at site 9 in the Mississippi system. Again, there were no recent references in literature explaining the increase at site 9. Davis and Bell (1998) state that a large percentage of the drainage area for site 9 is agricultural land use. The median suspended-sediment concentration listed in their report for site 9 was about 20 mg/L, which was similar in magnitude to the reference concentration listed in this study (about 12 mg/L, table 15).

Although increasing total trends in suspended sediment were not observed at site 1, increasing flow-adjusted trends were observed. Because of the size and complexity of the drainage area for site 1, an explanation as to the increase in flow-adjusted suspended sediment is beyond the scope of this report.

There were no trends observed in suspended-sediment loads at 20 sites (about 71 percent) during the study period (table 15). There were decreasing trends in suspended-sediment loads observed at eight sites for the study period, ranging from -8.8 to -4.4 percent per year (table 15, fig. 36). There were no increasing trends in suspended-sediment loads at study sites during the study period (table 15, fig. 36).

No trends in suspended-sediment loads were observed at site 1 for the study period (table 15) or for the period 1980-2004 (fig. 37). The decreasing trends in suspended-sediment loads at sites 2 and 48 in the Mississippi system and at site 61 in the Atchafalaya system appear to be part of recent trends during the last decade that began in the mid-1990s (fig. 37). The decreasing trends in suspended-sediment loads at site 53 in the Mississippi system and at site 68 in the Atchafalaya system are part of a much longer decreasing trend in loads that has been occurring since 1980 (fig. 37).

Annual loads, average annual load, and yield calculations for suspended sediment were attempted for 24 study sites in two of the four river systems, the Mississippi and the Atchafalaya systems (table 16). Load calculations were not attempted for sites in the Louisiana-Gulf/Pontchartrain or the Texas-Gulf systems because there was an inadequate amount of data to attempt calculations, or poor model fit associated with the results. Suspended-sediment loads and yields for selected sites on the Mississippi, Arkansas, and Atchafalaya Rivers from this study for the period 1993-2004 were compared to loads and yields calculated by Kelly and others (2001) for the period 1996-2000 [suspended-sediment loads and yields from Kelly and others (2001) were used here as a basis for comparison because Goolsby and others (1999) did not include sediment data]. The mean annual suspended-sediment loads from sites 1, 2, 48, 53, and 68 from Kelly and others (2001) were 28,200,000; 89,400,000; 4,470,000; 94,400,000; and 41,400,000 T, respectively. Suspended-sediment loads for the same sites calculated from this study were 29,200,000; 110,000,000; 5,890,000; 100,000,000; and 48,500,000 T (table 16), respectively, indicating higher loads of suspended sediment for this study, which had a study period that was longer, more recent, and included the previous study period. Suspended-sediment yields calculated from Kelly and others (2001) were 53.5, 48.4, 10.9, 32.4, and 171 T·km-2·yr-1 for sites 1, 2, 48, 53, and 68. For this study, suspended-sediment yields for the same sites were 55.6, 59.8, 14.4, 34.3, and 201 T·km-2·yr-1 indicating higher yields calculated for this study than those calculated in the previous study (table 4).

Relation of trends in suspended-sediment to trends in source data and landscape attributes

Population throughout most of the study area either remained the same or increased during the study period (fig. 20). Such increasing trends would imply increasing trends in suspended-sediment data as forested areas are converted to urban areas to accommodate suburban expansion; however, results of the WLS regression indicated no statistically significant relation between trends in suspended-sediment data and regional patterns in population at the study sites (table 9). Results of the WLS regression likely are influenced more by the lack of sites analyzed for suspended-sediment trends than any other factor, as most of the trends in suspended sediment were observed at large sites that could mask any trends in population or other landscape changes.

There were no sites in which trends in conservation-practices data could be compared to trends in suspended sediment (table 10). Specifically, the lack of conservation tillage information for 1997 was especially critical because increases in acreages of conservation tillage in agricultural areas could cause decreasing trends in suspended sediment at those locations as is implied by the decreasing flow-adjusted trend at site 50, previously mentioned.

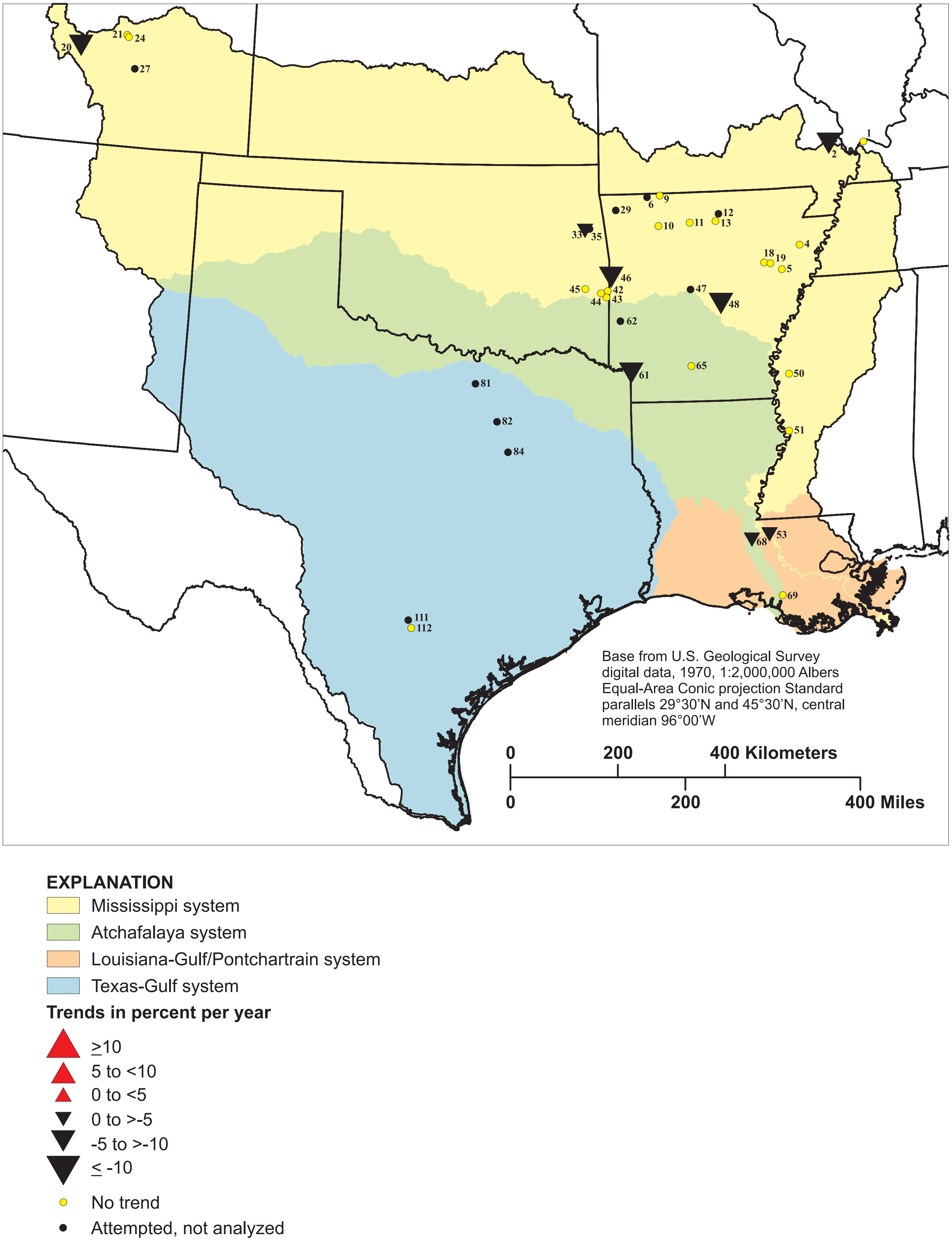


Figure 36. Trends in suspended-sediment loads at study sites, 1993-2004.

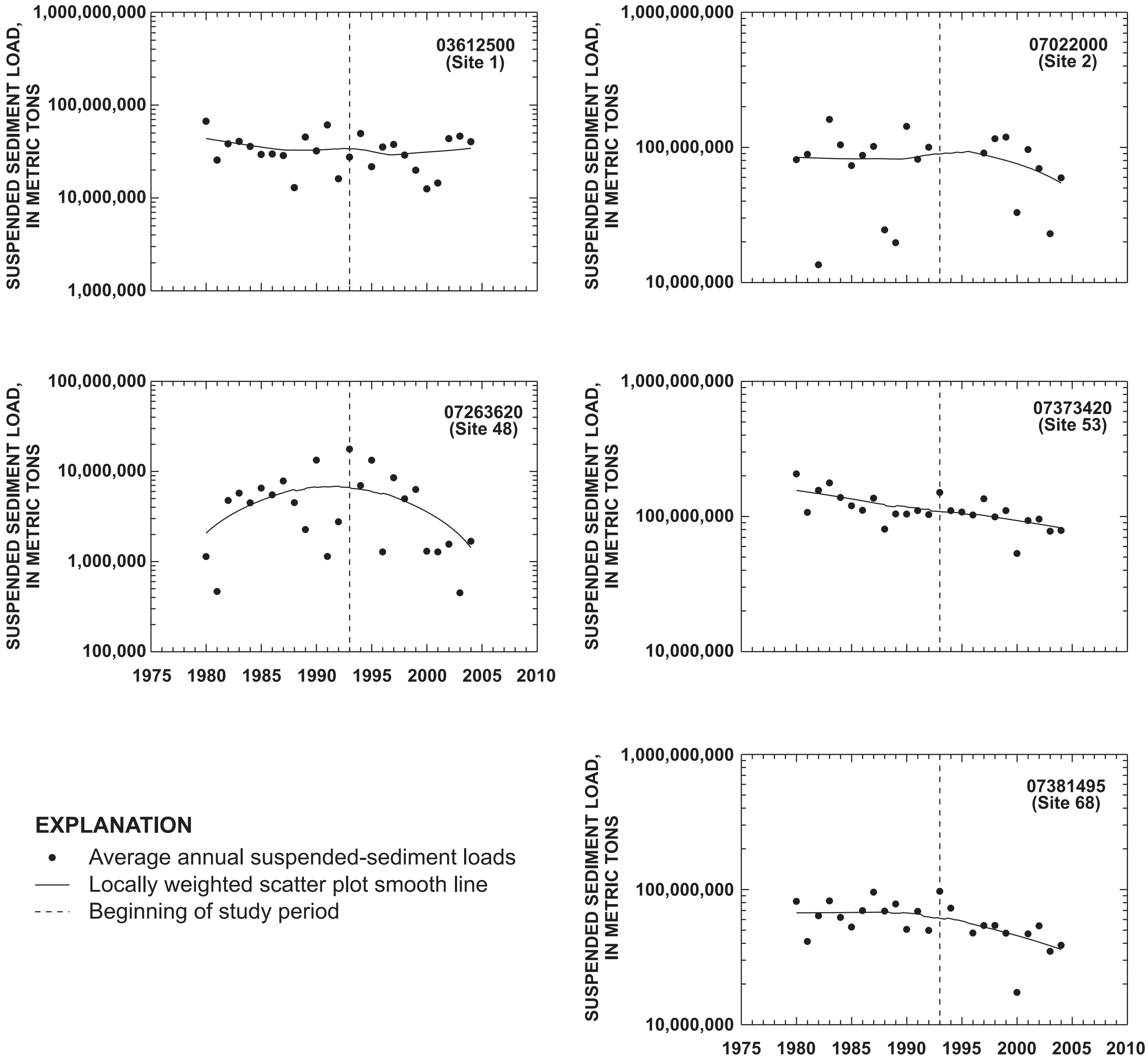


Figure 37. Annual suspended-sediment loads for selected study sites, 1980-2004.

Overall conclusions about suspended-sediment trends and loads for the study area

Trend analyses of suspended-sediment data were attempted at 39 sites. No trends were observed at about 71 percent of the sites. Remaining results indicated primarily decreasing trends in suspended sediment data. Most of the decreasing trends occurred on mainstem sites for the Mississippi, Arkansas, Red, and Atchafalaya Rivers, which are all regulated with reservoirs, locks and dams, and other erosion or flood-control structures that trap and prevent sediment from being transported downstream. Large decreases in suspended sediment in the Mississippi River basin began in the 1950s when large reservoirs were constructed in the Missouri and Arkansas Rivers, which were considered the largest sources of sediment at the time. Because the Mississippi River and its major tributaries have continued to be modified and improved since 1990, it is suggested that declines in suspended sediment observed along the mainstem sites during the study period are related to ongoing watershed and channel modifications.

It is important to note that, for this report, only suspended-sediment data were used in the analyses, and that few trend analyses were attempted because of lack of available data. Many agencies do not presently collect nor have historically collected suspended-sediment samples, but analyze water samples for total suspended solids (TSS). As pointed out by

Gray and others (2000), suspended sediment and TSS data are not comparable and should not be used interchangeably. Thus, additional sites where only TSS data were available were not included in this study. Sediment is considered one of the top three pollutants in streams and rivers in the United States (U.S. Environmental Protection Agency, 2006). Adoption of suspended sediment or TSS as the “analysis-of-choice” by agencies collecting sediment-related data would provide a consistent dataset to assess issues such as continued degradation or improvements due to restoration activities.

SUMMARY

The USGS-NAWQA Program is conducting regional assessments in eight major river basins focusing on chemicals in water, such as trends in nutrients, sediment, and pesticides, and other relevant water-quality issues, such as trends in biological-response data (chlorophyll, algae). This regional assessment explores trends in nutrient and suspended-sediment concentrations and loads for rivers in the south-central United States, which is the Lower Mississippi, Arkansas-White-Red, and Texas-Gulf Basin.

The primary source of water-chemistry and flow data for this study was data collected by the USGS. Since the early 1970s, the USGS has collected water-quality information from major river basins throughout the United States as part of three national programs. In addition, other long-term water-quality monitoring stations operate as part of USGS cooperative projects in the various States. Other sources of water-chemistry data were data collected by State agencies within the study area as part of ambient data-collection programs. The final source of water-quality data considered for analysis was from the U.S. Environmental Protection Agency Legacy Data Center and the Storage and Retrieval database.

To explain trends in surface water-quality data, it was important to identify and understand temporal and spatial patterns in source data and landscape attributes. The nutrient source and landscape data included in this study were annual fertilizer-use data for nitrogen and phosphorus, 5-year compilations of manure-generation data for nitrogen and phosphorus, annual data for atmospheric deposition of nitrogen, population density data from the 1990 and 2000 census, and management practice information (including irrigation type and conservation practices for 1992 and 1997).

Based on specific selection criteria, 115 sites were selected for trend analysis for water years 1993-2004 (water year begins October 1 and ends September 30). There were sites that were included in this study that had sampling periods that started after October 1, 1992, or ended prior to September 20, 2004. These sites were included in this study because of their importance relative to location or land-use type. Because site-selection criteria were primarily based on data availability, spatial representation of the selected sites was considered fair to poor in that there were areas that were under-represented such as in southern Kansas, most of Oklahoma, and parts of Texas and Louisiana. The selected sites were then grouped according to the four primary river systems in this study: Mississippi, Atchafalaya, Louisiana-Gulf/Pontchartrain, and the Texas-Gulf systems. These groupings were used as a basis for comparing trend, load, and yield results for major drainages entering the northwestern Gulf of Mexico.

Most rivers that empty into the Gulf of Mexico had sites that were included in this study with the exceptions of the Guadalupe River in Texas and the Calcasieu River in Louisiana. Two sites, one on the upper Mississippi River that included the Missouri River and another on the Ohio River, were outside of the study area but were included for analysis in order to document nutrient and sediment loadings entering the study area. Sites with small drainage areas were not discarded, although their overall contribution of nutrient and sediment loads was potentially insignificant within the drainage area of a large river basin. These sites were important because they provided valuable information related to specific land-use types. Also, sites with smaller drainage areas would provide the opportunity to document potentially dramatic changes in water quality over the past decade due to management changes or restoration activities.

For this study, both the total trend (not adjusted for flow) and a flow-adjusted trend were estimated to understand the overall picture of what was happening in relation to nutrient and sediment concentrations within the study area. Total trends could be used to determine impacts to aquatic communities. Flow-adjusted trends were estimated by removing the effects of streamflow on the trends in order to determine if changes in water quality were caused by something other than flow, such as landscape changes or changes in source. Other trend analyses completed were trends in load, which provided a direct measure of the effect of nutrients and sediment discharging to the northwestern Gulf of Mexico, and trends in flow, which improved interpretation of water-quality trends by understanding how flow has changed over time. Reference concentrations and loads were also computed for each statistically significant trend (reference concentrations and loads are best explained as the “starting point” of a trend line drawn through the data with a slope equal to the trend estimate).

The majority of study sites either had no trends (about 64 percent of all trend analyses attempted) or decreasing trends in streamflow during the study period. The regional pattern of decreasing trends in streamflow during the study period appeared to correspond to moist conditions at the beginning of the study period and the influence of three drought periods during the study period, with the most extreme in 2000. Decreasing trends in streamflow at mainstem sites on the Mississippi River, Arkansas, Red, and Atchafalaya Rivers were specific to the study period and were not part of long-term trends. Increasing trends in streamflow at sites on the San Antonio River in the Texas-Gulf system were observed and likely were caused by moist conditions returning to southern Texas after the drought of 2000, coupled with increased urbanization and impervious surfaces during the study period. The increase in streamflow for the San Antonio River during the study period appears to part of a recent decadal trend that started about 1997.

In general, there were few trends observed in the nitrogen data at study sites during the study period; no trends were observed in about 63 percent of all nitrogen trend analyses attempted. Although some patterns in the nitrogen data did exist where trends were attempted, no regional patterns could be confirmed because of poor spatial representation of the trends sites.

Decreasing trends in flow-adjusted concentrations of ammonia were observed at 25 sites. No increasing trends in concentrations of ammonia were noted at any sites. Flow-adjusted concentrations of nitrite plus nitrate decreased at 7 sites and increased at 14 sites. Flow-adjusted concentrations of total nitrogen decreased at 2 sites and increased at 12 sites. Improvements to municipal wastewater treatment facilities contributed to the decline of ammonia concentrations at selected sites. Notable increasing trends in nitrite plus nitrate and total nitrogen at selected study sites were attributed to both point and nonpoint sources. Trend patterns in total nitrogen generally followed trend patterns in nitrite plus nitrate, which was understandable given that nitrite plus nitrate loads generally were 70-90 percent of the total nitrogen loads at most sites. Although population increased throughout the study area during the study period, there was no observed relation between increasing trends in nitrogen in study area streams and increasing trends in population. With respect to other nitrogen sources, statistical results did suggest that increasing trends in nitrogen could be related to increasing trends in nitrogen from either commercial fertilizer use or land application of manure.

Loads of ammonia, nitrite plus nitrate, and total nitrogen decreased during the study period, but some trends in nitrogen loads were part of long-term decreases since 1980. For example, ammonia loads were shown to decrease at nearly all sites over the past decade, but at selected sites, these decreasing trends were part of much longer trends since 1980. The Mississippi and Atchafalaya Rivers contributed the highest nitrogen loads to the northwestern Gulf of Mexico as expected; however, nitrogen yields from smaller rivers had similar or higher yields than from the Mississippi River.

Similar to results for nitrogen, there were few trends observed in the phosphorus data at study sites during the study period; no trends were observed in about 57 percent of all phosphorus trend analyses attempted. Although some patterns in the phosphorus data did exist where trend analyses were attempted, no regional patterns could be confirmed because of poor spatial representation of the trends sites.

Flow-adjusted concentrations of orthophosphorus decreased at 10 sites and increased at 7 sites. Flow-adjusted concentrations of total phosphorus decreased at 6 sites and increased at 17 sites. It was understandable that trend patterns in total phosphorus did not follow trend patterns in orthophosphorus given that orthophosphorus loads accounted for only about 20-30 percent of the total phosphorus load at comparable sites. Trends in population data were inversely related to trends in flow-adjusted total phosphorus; therefore, trends in population were not considered a controlling factor to explain trends in total phosphorus. No relation was observed between phosphorus from fertilizer use and either orthophosphorus or total phosphorus trends. However, statistical results did suggest that increasing trends in both orthophosphorus and total phosphorus could be related to increasing trends in phosphorus from land application of manure.

There were more decreasing trends than increasing trends in phosphorus loads during the past decade, most of which were unique to the recent decade and not part of long-term decreases since 1980. Similar to nitrogen loads, the Mississippi and Atchafalaya Rivers contributed the highest phosphorus loads to the northwestern Gulf of Mexico as expected; however, phosphorus yields from smaller rivers were similar to or higher than yields from the Mississippi River.

Trend analyses of suspended-sediment data were attempted for 39 sites. No trends were observed at about 71 percent of the sites. Remaining results indicated primarily decreasing trends in suspended sediment data. Most of the decreasing trends occurred on mainstem sites for the Mississippi, Arkansas, Red, and Atchafalaya Rivers, which are all regulated with reservoirs, locks and dams, and other erosion or flood-control structures that trap and prevent sediment from being transported downstream. Large decreases in suspended sediment in the Mississippi River basin began in the 1950s when large reservoirs were constructed in the Missouri and Arkansas Rivers, which were considered the largest sources of sediment at the time. Because the Mississippi River and its major tributaries have continued to be modified and improved since 1990, it is suggested that declines in suspended sediment observed along the mainstem sites during the study period are related to ongoing watershed and channel modifications.

REFERENCES

Adamski, J.C., Peterson, J.C., Friewald, D.A., and Davis, J.V., 1994, Environmental and hydrologic setting of the Ozark Plateaus study unit, Arkansas, Kansas, Oklahoma, and Missouri: U.S. Geological Survey Water-Resources Investigations Report 94-4022, 69 p.

Akaike, H., 1981, Likelihood of a model and information criterion: Journal of Econometrics, V. 16, P. 3-14.

Aulenbach, B.T., Buxton, H.T., Battaglin, W.A., and Coupe, R.H., 2007, Streamflow and nutrient fluxes of the Mississippi-Atchafalaya River Basin and subbasins for the period of record through 2005: U.S. Geological Survey Open-File Report 2007-1080, accessed on March 30, 2007 at URL http://toxics.usgs.gov/pubs/of-2007-1080/index.html.

Bush, P.W., Ardis, A.F., Fahlquist, Lynne, Ging, P.B., Hornig, C.E., and Lanning-Rush, Jennifer, 2000, Water quality in south-central Texas, 1996-98: U.S. Geological Survey Circular 1212, 32 p.

Cohn, T.A., 1988, Adjusted maximum likelihood estimation of the moments of lognormal populations from Type I censored samples: U.S. Geological Survey Open-File Report 88-350, 34 p.

Cohn, T.A., Gilroy, E.J., and Baier, W.G., 1992, Estimating fluvial transport of trace constituents using a regression model with data subject to censoring, in Proceedings of the Section on Statistics and the Environment: American Statistical Association, Boston, Mass., August 9-13, 1992, p. 142-151.

Coupe, R.H., 2002, Nitrogen and phosphorus concentrations and fluxes of streams in the Mississippi Embayment study unit, 1996-1998: U.S. Geological Survey Water-Resources Investigations Report 01-4024, 65 p.

Davis, J.V., and Bell, R.W., 1998, Water-quality assessment of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma – nutrients, bacteria, organic carbon, and suspended sediment in surface water, 1993-1995: U.S. Geological Survey Water-Resources Investigations Report 98-4164, 56 p.

Delta Farm Press, 2003, Farmers reducing tillage across Cotton Belt, accessed on October 16, 2006, at URL http://deltafarmpress.com/news/farming_farmers_reducing_tillage/index.html.

Demcheck, D.K, Tollett, R.W., Mize, S.V., Skrobialowski, S.C., Fendick, R.B., Jr., Swarzenski, C.M., and Porter, Stephen, 2004, Water quality in the Acadian-Pontchartrain drainages, Louisiana and Mississippi, 1999-2001: U.S. Geological Survey Circular 1232, 41 p.

Edelman, Patrick, Ferguson, S.A., Stogner, R.W., August, Marianne, Payne, W.F., and Bruce, J.F., 2002, Evaluation of water quality, suspended sediment, and stream morphology with an emphasis on effects of stormflow on Fountain and Monument Creek basins, Colorado Springs and vicinity, Colorado, 1981 through 2001: U.S Geological Survey Water-Resource Investigations Report 02-4104, 59 p.

ESRI, 2005, ArcGIS, version 9.1: Redlands, Calif., ESRI.

Fitzgerald, J., Busby, B., Howery, M., Klataske, R., Reinking, D., and Pashley, D., 2000, Partners in flight bird conservation plan for the Osage Plains (physiographic province 33): American Bird Conservancy, v.1.0, 60 p.

Goolsby, D.A., and Battaglin, W.A., 2000, Nitrogen in the Mississippi River Basin–estimating sources and predicting flux to the Gulf of Mexico: U.S. Geological Survey Fact Sheet 135-00, 6 p.

Goolsby, D.A., Battaglin, W.A., Lawrence, G.B., Artz, R.S., Aulenbach, B.T., Hooper, R.P., Kenney, D.R., and Stensland, G.J., 1999, Flux and sources of nutrients in the Mississippi-Atchafalaya River Basin: Topic 3 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico, NOAA Coastal Ocean Program Decision Analysis Series No. 17, NOAA Coastal Ocean Program, Silver Spring, MD , 130 p.

Gray, J.R., Glysson, G.D., Turcios, L.M. and Schwarz, G.E., 2000, Comparability of suspended-sediment concentration and total suspended solids data: U.S. Geological Survey Water-Resources Investigation Report 00-4191, 20 p.

Hamilton, P.A., Myers, D.N, and Erwin, M.L, 2005, National Water-Quality Assessment Program, cycle II - regional assessments of aquifers and streams and rivers: U.S. Geological Survey Fact Sheet 2005-3013, 6 p.

Helsel, D.R., 2005, Nondetects and data analysis–Statistics for censored environmental data: New York, John Wiley and Sons, 250 p.

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

Insightful Corporation, 2005, S-PLUS 7.0 for Windows Professional Developer: Seattle, Wash., Insightful Corporation.

Kelly, V.J., Hooper, R.P., Aulenbach, B.T. and Janet, Mary, 2001, Concentrations and annual fluxes for selected water-quality constituents from the USGS National Stream Quality Accounting Network (NASQAN), 1996-2000: U.S. Geological Survey Water-Resources Investigations Report 01-4255, available at URL http://pubs.usgs.gov/wri/wri014255/.

Kleiss, B.A., Coupe, R.H., Gonthier, G.J., and Justus, B.G., 2000, Water quality in the Mississippi Embayment, Mississippi, Louisiana, Arkansas, Missouri, Tennessee, and Kentucky, 1995-1998: U.S. Geological Survey Circular 1208, 36 p.

Land, L.F., Moring, J.B., Van Metre, P.C., Reutter, D.C., Mahler, B.J., Shipp, A.A., and Ulery, R.L., 1998, Water quality in the Trinity River Basin, 1992-2995: U.S. Geological Survey Circular 1171, 39 p.

Louisiana Department of Environmental Quality, 2000, Watershed Protection Programs – Lake Pontchartrain Basin, accessed on October 16, 2006 at URL http://nps.ldeq.org/99manplan/99lake.pdf.

Meade, R.H., ed., 1995, Contaminants in the Mississippi River, 1987-92: U.S. Geological Survey Circular 1133, 140 p.

Missouri Department of Natural Resources, 2004, Total maximum daily load information sheet: Elk River Basin, accessed on October 16, 2006, at URL http://www.dnr.mo.gov/env/wpp/tmdl/info/3246-elk-r-basin-info.pdf.

Missouri Department of Natural Resources, 2006, Section 319 nonpoint source (NPS) implementation plan for MOA-2002 Elk River watershed poultry manure composting project, accessed on October 16, 2006, at URL http://dnr.missouri.gov/env/wpp/nps/MOA-2002.htm.

Mueller, D.K., and Spahr, N.E., 2005, Water-quality, streamflow, and ancillary data for nutrients in streams and ricers across the Nation, 1992-2001: U.S. Geological Survey Data Series 152, accessed on October 16, 2006 at URL http://pubs.usgs.gov/ds/2005/152/.

Mueller, D.K., Hamilton, P.A., Helsel, D.R, Hitt, K.J., and Ruddy, B.C., 1995, Nutrients in ground water and surface water of the United States – an analysis of data through 1992: U.S. Geological Survey Water-Resources Investigations Report 95-4031, 74 p.

Nakagaki, Naomi, and Wolock, D.M., 2005, Estimation of agricultural pesticide use in drainage basins using land cover maps and county pesticide data: U.S. Geological Survey Open-File Report 2005-1188, 46 p.

National Oceanic and Atmospheric Administration, 2006, Historic Palmer drought indices: Accessed on January 4, 2007, at URL http://lwf.ncdc.noaa.gov/oa/climate/research/drought/palmer-maps/.

Oblinger-Childress, C.J., Foreman, W.T., Connor, B.F., and Maloney, T.J., 1999, New reporting procedures based on long-term method detection levels and some considerations for interpretations of water-quality data provided by the U.S Geological Survey National Water Quality Laboratory: U.S. Geological Survey Open-File Report 99-193, 19p.

Oklahoma Department of Environmental Quality, 2004, The State of Oklahoma 2004 Water Quality Assessment Integrated Report, approved by the U.S. Environmental Protection Agency on October 10, 2006, accessed at URL: http://www.deq.state.ok.us/WQDnew/305b_303d/2004_integrated_report_final.pdf .

Oklahoma Department of Environmental Quality, 2006 draft, The State of Oklahoma 2006 Water Quality Assessment Integrated Report, accessed at URL: http://www.deq.state.ok.us/WQDnew/305b_303d/2006_integrated_report_entire_document.pdf .

Oklahoma Office of the Secretary of the Environment, 2003, Coordinated watershed restoration and protection strategy for Oklahoma's impaired scenic rivers, accessed on October 16, 2006, at URL http://www.ose.state.ok.us/documents/SB972/SB972report_31Jan03.pdf.

Owenby, J., Heim, R., Jr., Burgin, M., and Ezell, D., 2001, Climatography of the U.S., no. 81 - Supplement 3 – maps of annual 1961-1990 normal temperature, precipitation and degree days: National Oceanic and Atmospheric Administration, National Climatic Data Center, accessed April 2005 at URL http://www.ncdc.noaa.gov/oa/documentlibrary/clim81supp3/clim81.html

Ruddy, B.C., Lorenz, D.L., and Mueller, D.K., 2006, County-level estimates of nutrient inputs to the land surface of the conterminous United States, 1982–2001: U.S. Geological Survey Scientific Investigations Report 2006-5012, 17 p.

Runkel, R.L., Crawford, C.G., and Cohn, T.A., 2004, Load Estimator (LOADEST):A FORTRAN Program for estimating constituent loads in streams and rivers: U.S. Geological Survey Techniques and Methods Book 4, Chapter A5, 69 p.

Sahoo, D., and Haan, P., 2005, Time series analysis of freshwater inflows in an urbanizing coastal river basin, American Geophysical Union, Fall Meeting 2005, abstract #H21A-1309, accessed on 1/9/07 at URL http://adsabs.harvard.edu/abs/2005AGUFM.H21A1309S .

San Antonio River Authority, 2003, Basin summary report for the San Antonio River Basin: Texas Clean Rivers Program, Texas Commission on Environmental Quality, accessed on October 16, 2006, at URL http://www.sara-tx.org/site/water_quality/water_qual_mon/clean_rivers/Basin_Reports/completereport.pdf.

Sneck-Fahrer, D.A, Milburn, M.S., East, J.W., Oden, J.H., 2005, Water-quality assessment of Lake Houston near Houston, Texas, 200-2004: U.S. Geological Survey Scientific Investigations Report 2005-5241, 64 p.

Texas Natural Resource Conservation Commission, 2000, Cypress Creek Basin summary report – final report, accessed on 1/9/07 at URL http://www.netmwd.com/reports/bsr/commentedBSreport.pdf.

Trimble, D.E., 1980, The geologic story of the Great Plains: U.S. Geological Survey Bulletin 1493, accessed on 1/9/07 at URL: http://www.lib.ndsu.nodak.edu/govdocs/text/greatplains/text.html.

Turner, R.E., and Rabalais, N.N., 2004, Suspended sediment, C, N, P, and Si yields from the Mississippi River Basin: Hydrobiologia, 511, p. 79-89.

U.S. Army Corps of Engineers, 2004, San Antonio River, San Antonio, Texas, channel improvement project ecosystem restoration and recreation – general reevaluation report and integrated environmental assessment, accessed on October 16, 2006, at URL http://www.swf.usace.army.mil/pubdata/notices/sanantonio-rcip-grr/cover3.pdf.

U.S. Census Bureau, 1991, Census of population and housing, 1990: U.S. Census Bureau Technical Documentation Public Law 84-71, digital tabular data on CD-ROM: accessed on January 23, 2006, and URL http://www.census.gov/main/www/cen1990.html.

U.S. Census Bureau, 2000, Census 2000 Redistricting Data Summary File: U.S. Census Bureau Technical Documentation Public Law 94-171, 223 p.

U.S. Department of Agriculture, 1995, National Resources Inventory [CD-ROM reissued May 1995]: Washington, D.C., Natural Resources Conservation Service, and Ames, Iowa, Statistical Laboratory, Iowa State University.

U.S. Department of Agriculture, 2001, 1997 National Resources Inventory (revised December 2000) [CD-ROM, Version 1]: Washington D.C., Natural Resources Conservation Service, and Ames, Iowa, Statistical Laboratory, Iowa State University.

U.S Environmental Protection Agency, 1986, Quality criteria for water 1986: Washington, D.C., U.S Environmental Protection Agency Report 440/5-86-001, Office of Water [variously paginated].

U.S. Environmental Protection Agency, 2000a, Ambient water quality criteria recommendations, information supporting the development of State and tribal nutrient criteria – rivers and streams in nutrient ecoregion IX, U.S. Environmental Protection Agency Report 822-B-00-019, 108 p.

U.S. Environmental Protection Agency, 2000b, Ambient water quality criteria recommendations, information supporting the development of State and tribal nutrient criteria – rivers and streams in nutrient ecoregion XI, U.S. Environmental Protection Agency Report 822-B-00-020, 99 p.

U.S. Environmental Protection Agency, 2001, Ambient water quality criteria recommendations, information supporting the development of State and tribal nutrient criteria – rivers and streams in nutrient ecoregion IV, U.S. Environmental Protection Agency Report 822-B-00-013, 159 p.

U.S. Environmental Protection Agency, 2004a, A scientific assessment of nutrient concentrations, loads, and biological response in the northern Gulf of Mexico: EPA contract no. 68-C-03-041, work assignment no. 1-01 task 5, prepared by Battelle Corporation, Massachusetts, August 2004, accessed April 2005 at URL http://www.epa.gov/gmpo/pdf/npilot-study-final04.pdf, 41 p.

U.S. Environmental Protection Agency, 2004b, STORET: accessed April 2005 at URL http://www.epa.gov/STORET/index.html.

U.S. Environmental Protection Agency, 2006, Total maximum daily loads national section 303(d) list fact sheet, accessed on October 16, 2006, at URL http://oaspub.epa.gov/waters/national_rept.control#TOP_IMP.

U.S. Environmental Protection Agency, 2007, Water quality criteria for nitrogen and phosphorus pollution – ecoregional nutrient criteria documents for rivers and streams, accessed on October 15, 2007 at URL http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/index.html .

U.S. Geological Survey, 1992, Analytical methods–discontinuation of the National Water-Quality Laboratory determinations for “total” nitrite, “total” nitrite plus nitrate, “total” ammonia, and “total” orthophosphorus (using the four-channel analyzer): U.S Geological Survey Office of Water Quality Technical Memorandum 93.04, 5 p.

U.S. Geological Survey, 1999, The quality of our nation’s waters – nutrients and pesticides: U.S. Geological Survey Circular 1225, 82 p.

U.S. Geological Survey, 2003, A tapestry of time and terrain – the union of two maps, geology and topography, accessed on January 12, 2007, at URL http://tapestry.usgs.gov/physiogr/physio.html.

Van Metre, P.C., and Reutter, D.C., 1995, Water-quality assessment of the Trinity River Basin, Texas – analysis of available information on nutrients and suspended sediments, 1974-1991: U.S. Geological Survey Water-Resources Investigations Report 94-4086, 71 p.

Viessman, Warren, and Hammer, M.J., 1985, Water supply and pollution control: 4th ed., New York, Harper and Row Publishers, 797 p.

APPENDIX

Appendix. Methodology for estimation of total trend and flow-adjusted trends in concentration, trends in streamflow, and trends in load

Based on written communication from Greg Schwarz, U.S. Geological Survey, July 24, 2006

Total trend in concentration and trends in streamflow. The proposed estimates for total trend in concentration were derived from parameter estimates, and associated co-variances, obtained from a linear model of streamflow and an optimal model of water-quality concentration with both models being estimated in natural logarithm space.

The model of streamflow consisted of an intercept, a linear trend term (decimal time), sine and cosine functions of decimal time (the seasonal component of streamflow), and a serially correlated error term; the streamflow residual was assumed to follow an autoregressive process of order 20 [AR(20)]. The streamflow model was estimated by using maximum likelihood methods as employed by the AUTOREG procedure in SAS 9, version 1, release 2 (SAS institute Inc., 2004). For some sites, serial correlation in the residuals was not fully removed by the AR(20) model. Significant residual serial correlation could invalidate the standard error of the streamflow trend coefficient, although the practical importance of this effect for the statistical significance of the total trend was likely to be small.

The water-quality model related the logarithm of nutrient or suspended sediment concentrations to various functions of streamflow, decimal time, and season as previously described. An abstract representation of the model is given by

$$c_t = b_0 + m(q_t)b_q + h(T_t)b_T + x_t b_x + e_t\,, \tag{1}$$

where

c_t is the natural logarithm of contaminant concentration in period t;

q_t is natural logarithm of streamflow;

T_t is decimal time;

x_t is a vector of ancillary predictors such as the sine and cosine functions of decimal time;

e_t is an independent and identically normally distributed random error;

$m(\cdot)$ and $h(\cdot)$ are multi-element vector functions of q and T; and

b_0,b_q, b_T, and b_x are associated coefficients to be estimated.

The multi-element vector function of the logarithm of streamflow, $m(\cdot)$, consisted of the logarithm of streamflow and the square of the logarithm of streamflow; $h(\cdot)$ the multi-element vector function of decimal time consisted of second-order polynomial terms.

The water-quality model was estimated by using either ordinary least squares if the water-quality data contained no censored observations or the maximum likelihood method if censored observations were present. The maximum likelihood bias adjustment required estimates of the detection level even for uncensored observations; the detection level was set equal to the maximum of the median detection level for all censored observations across all stations or the reported uncensored value.

The estimate of total trend in concentration was based on the streamflow and time-trend coefficients from the water-quality model (b_q and b_T), and the coefficient on decimal time in the streamflow model, subsequently denoted as a. The trend in the logarithm of streamflow during period t (between t_1, the beginning of the streamflow analysis period in 1993, and t_2, the end of the streamflow analysis period in 2004), $\tilde{q}_t$, was defined as:

$$\tilde{q}_t = \overline{q} + a(T_t - \overline{T}), \tag{2}$$

where $\overline{q}$ and $\overline{T}$ were the means of the logarithm of streamflow and decimal time over the analysis period. If streamflow was upward trending, then a was positive and trend in the logarithm of streamflow was below the mean value of the logarithm of streamflow for the first half of the analysis period and above the mean value thereafter. Note that the average of the logarithm of streamflow, $\overline{q}$, implicitly accounted for the intercept and average of the seasonal terms that are included in the streamflow model but not otherwise apparent in the formulation of equation (2).

Total trend in water-quality concentrations in period t, (between t_1, the beginning of the streamflow analysis period in 1993, and t_2, the end of the streamflow analysis period in 2004), $\tilde{c}_t$, was defined as:

$$\tilde{c}_t = m(\tilde{q}_t)b_q + h(T_t)b_T\,. \tag{3}$$

Only terms involving trend were included in equation (3). Note that in forming this estimate, the trend in the logarithm of streamflow was substituted for the actual logarithm of flow in the function $m(\cdot)$. This substitution implies that variations in streamflow not reflected in the trend did not determine the proposed measure of total trend in water quality. Because of the nonlinearity of the function $m(\cdot)$, this might have led to a bias in the evaluation of full water-quality trend if flows were becoming more or less variable over time. The streamflow and concentration trends may have been calculated for slightly different periods because these analyses were completed as part of a larger national analysis that required flexibility in the streamflow period. The difference in the final total trend results from different streamflow periods and the streamflow period 1993 to 2004 likely is small.

The total trend in water-quality concentration over the analysis period, τ_c, is given by

$$\tau_c = \tilde{c}_{t_2} - \tilde{c}_{t_1} = (m(\tilde{q}_{t_2}) - m(\tilde{q}_{t_1}))b_q + (h(T_{t_2}) - h(T_{t_1}))b_T$$
$$= (m(\overline{q} + a(T_{t_2})) - m(\overline{q} + a(T_{t_1})))b_q + (h(T_{t_2}) - h(T_{t_1}))b_T . \quad (4)$$

The total trend in water-quality concentration depends on the trend and streamflow coefficients from the water-quality model, b_q and b_T, as well as the trend coefficient a from the streamflow model.

The total trend, expressed as the average percent change per year, is given by

$$\text{Percent Trend/year} = 100 \, \frac{(\exp(\tau)-1)}{T_{t_2} - T_{t_1}} \quad (5)$$

where τ is τ_c.

The estimate of total trend was obtained by substituting sample estimates for the population values of a, b_q and b_T in equation (4). The standard error of the resulting estimate was complicated to derive owing to the nonlinear manner in which the streamflow trend coefficient and the water-quality and streamflow coefficients interact in the determination of total trend. An approximation to the standard error suitable for large samples was obtained by taking a first-order Taylor approximation of the total trend estimate from equation (4) with respect to the streamflow and water-quality model coefficients. The vector of combined streamflow and trend coefficients from the water-quality model was represented by $b = \{b_q' \;\; b_T'\}'$, and V_b represented the covariance matrix of this vector. Under the plausible assumption that streamflow was exogenous with respect to water quality, meaning that changes in streamflow caused changes in water quality but changes in water quality did not cause changes in streamflow, the covariance between the estimated values of a and b was zero. Consequently, the standard error of τ_c, denoted σ_c, was defined as:

$$\sigma_c = \sqrt{V_a \left(\frac{\partial \Delta m}{\partial a} b_q \right)^2 + A V_b A'} \quad (6)$$

where
V_a is the variance of the estimated flow trend coefficient, a;

$$\frac{\partial \Delta m}{\partial a} = \frac{\partial m(\overline{q} + a(T_{t_2} - \overline{T}))}{\partial a} - \frac{\partial m(\overline{q} + a(T_{t_1} - \overline{T}))}{\partial a} \text{ ; and} \quad (7)$$

$$A = \{m(\overline{q} + a(T_{t_2} - \overline{T})) \;\; h(T_{t_2})\} - \{m(\overline{q} + a(T_{t_1} - \overline{T})) \;\; h(T_{t_1})\}. \quad (8)$$

In large samples, the t-statistics τ_c/σ_c was distributed standard normal; therefore, the two-sided p-value for significance of trend is given by

$$p = 2(1 - \Phi(|\tau/\sigma|)) \quad (9)$$

where
τ/σ was τ_c/σ_c, and
$\Phi(\cdot)$ is the standard normal cumulative distribution.

Trend results were considered statistically significant if the p-value was less than or equal to 0.05.

Trends in flow-adjusted concentration. The estimation of flow-adjusted trend in concentration is similar to total trend, the only difference being that the streamflow component of the water-quality model in equation (2) is not included in the determination of the smoothed water-quality trend; otherwise, the estimation methods are the same.

Trends in load. The trend in load, τ_L, is defined similarly to total trend in concentration as seen in equation (4) but includes an additional term to reflect the direct effect streamflow has on the determination of load as follows:

$$\tau_L = a(T_{t_2} - T_{t_1}) + (m(\overline{q} + a(T_{t_2}))$$
$$- m(\overline{q} + a(T_{t_1})))b_q + (h(T_{t_2}) - h(T_{t_1}))b_T . \quad (10)$$

The full trend in load, expressed in percent per year, is given by equation (5) where τ is τ_L.

The standard error of τ_L, denoted by σ_L, was defined as:

$$\sigma_L = \sqrt{V_a \left(\frac{\partial \Delta m}{\partial a} b_q + (T_{t_2} - T_{t_1}) \right)^2 + A V_b A'} , \quad (11)$$

where V_a is the variance of the estimated flow trend coefficient, a, from equation (7), and A is estimated from equation (8).

The two-sided p-value for significance of trend in load is defined from equation (9) where τ/σ is τ_L/σ_L, and $\Phi(\cdot)$ is the standard normal cumulative distribution.

TABLES

Table 1. Stream sites in south-central United States selected for trend and load computations of nutrient and sediment data

[Water-quality data are provided by the U.S. Geological Survey except those highlighted in **bold**, which are provided by State agencies; dates listed are water years]

Map number (fig. 5)	Water-quality station number	Stream-flow station number	Station name	Drainage area, square kilometers	Trends calculated, 1993-2004	Loads and yields, calculated and tabled, 1993-2004	Loads, calculated and graphed, 1980-2004
			Mississippi system				
1	03612500	03611500	Ohio River at Dam 53 near Grand Chain, Ill.	526,000	x	x	x
2	07022000	07022000	Mississippi River at Thebes, Ill.	1,847,000	x	x	x
3	**07031740**	07031740	Wolf River at Hollywood Street at Memphis, Tenn.	2,041	x		
			St. Francis River				
4	07047810	07047810	St. Francis River Floodway near Marked Tree, Ark.	12,050	x	x	
5	07047942	07047942	L'Anguille River near Colt, Ark.	1,386	x	x	
			White River				
6	**07050500**	07050500	Kings River near Berryville, Ark.	1,365	x		
7	07052152	07052152	Wilson Creek near Brookline, Mo.	102	x		
8	07052250	07052250	James River near Boaz, Mo.	1,197	x		
9	07053250	07053250	Yocum Creek near Oak Grove, Ark.	137	x	x	
			Buffalo River				
10	07055646	07055646	Buffalo River near Boxley, Ark.	149	x		
11	**07056000**	07056000	Buffalo River near St. Joe, Ark.	2,147	x	x	
12	07060500	07060500	White River at Calico Rock, Ark.	25,840	x	x	
13	07060710	07060710	North Sylamore Creek near Fifty Six, Ark.	150	x	x	
			Black River				
14	07061600	07061500	Black River below Annapolis, Mo.	1,277	x		
			Current River				
15	07066110	07066000	Jacks Fork above Two River, Mo.	1,101	x	x	
16	07068000	07068000	Current River at Doniphan, Mo.	5,278	x	x	
17	07071500	07071500	Eleven Point River near Bardley, Mo.	2,054	x	x	
18	07077500	07077500	Cache River at Patterson, Ark.	2,686	x	x	
19	07077700	07077700	Bayou DeView near Morton, Ark.	1,090	x	x	
			Arkansas River				
			Arkansas River Headwater Tributaries in Colorado				
20	07093740	07093740	Badger Creek, upper station, near Howard, Colo.	275	x		
21	07103700	07103700	Fountain Creek near Colorado Springs, Colo.	267	x	x	
22	07103780	07103780	Monument Creek above North Gate Boulevard at USAF Academy, Colo.	212	x	x	

Table 1. Stream sites in south-central United States selected for trend and load computations of nutrient and sediment data--Continued

Map number (fig. 5)	Water-quality station number	Stream-flow station number	Station name	Drainage area, square kilometers	Trends calculated, 1993-2004	Loads and yields, calculated and tabled, 1993-2004	Loads, calculated and graphed, 1980-2004
23	07104905	07104905	Monument Creek at Bijou Street at Colorado Springs, Colo.	609	x		
24	07105500	07105500	Fountain Creek at Colorado Springs, Colo.	1,015	x	x	
25	07105530	07105530	Fountain Creek below Janitell Road below Colorado Springs, Colo.	1,070	x	x	
26	07106300	07106300	Fountain Creek near Pinion, Colo.	2,209	x	x	
27	07106500	07106500	Fountain Creek at Pueblo, Colo.	2,398	x		
28	07189000	07189000	Elk River near Tiff City, Mo.	2,258	x	x	
			Illinois River				
29	**07195000**	07195000	Osage Creek near Elm Springs, Ark.	337	x		
30	07195500	07195500	Illinois River near Watts, Okla.	1,645	x	x	
31	07195865	07195865	Sager Creek near West Siloam Springs, Okla.	49	x	x	
32	07196000	07196000	Flint Creek near Kansas, Okla.	285	x	x	
33	07196500	07196500	Illinois River near Tahlequah, Okla.	2,484	x	x	
34	**07196900**	07196900	Baron Fork at Dutch Mills, Ark.	105	x	x	
35	07197000	07197000	Baron Fork at Eldon, Okla.	795	x	x	
			Canadian River				
36	07227500	07227500	Canadian River near Amarillo, Tex.	50,360	x		
37	**07228000**	07228000	Canadian River near Canadian, Tex.	59,220	x		
38	07239450	07239450	North Canadian River near Calumet, Okla.	33,570	x	x	
39	07241000	07241000	North Canadian River below Lake Overholser near Oklahoma City, Okla.	34,240	x	x	
40	07241520	07241520	North Canadian River at Britton Road at Oklahoma City, Okla.	34,740	x		
41	07241550	07241550	North Canadian River near Harrah, Okla.	34,970	x		
			Poteau River				
42	07247015	07247015	Poteau River at Loving, Okla.	697	x	x	
43	07247250	07247250	Black Fork below Big Creek near Page, Okla.	193	x	x	
44	07247345	07247250	Black Fork at Hodgen, Okla.	464	x	x	

Table 1. Stream sites in south-central United States selected for trend and load computations of nutrient and sediment data--Continued

Map number (fig. 5)	Water-quality station number	Stream-flow station number	Station name	Drainage area, square kilometers	Trends calculated, 1993-2004	Loads and yields, calculated and tabled, 1993-2004	Loads, calculated and graphed, 1980-2004
45	07247650	07247500	Fourche Maline near Leflore, Okla.	699	x	x	
46	**07249400**	07249400	James Fork near Hackett, Ark.	381	x	x	
47	07263295	07263295	Maumelle River at Williams Junction, Ark.	119	x		
48	07263620	07263450	Arkansas River at David D. Terry Lock and Dam below Little Rock, Ark.	410,000	x	x	x
			Yazoo River				
49	**07268000**	07268000	Little Tallahatchie River at Etta, Miss.	1,362	x	x	
50	07288650	07288650	Bogue Phalia near Leland, Miss.	1,254	x	x	
51	07288955	07288955	Yazoo River below Steele Bayou near Long Lake, Miss.	34,590	x	x	
52	**07290650**	07290650	Bayou Pierre near Willows, Miss.	1,694	x	x	
53	07373420	07295100*	Mississippi River near St. Francisville, La.	2,915,000	x	x	x
			Atchafalaya system				
			Red River				
54	**07299540**	07299540	Prairie Dog Town Fork Red River near Childress, Tex.	20,010	x		
55	07300000	07300000	Salt Fork Red River near Wellington, Tex.	3,165	x		
56	07308500	07308500	Red River near Burkburnett, Tex.	53,280	x	x	
			Wichita River				
57	07311700	07311700	North Wichita River near Truscott, Tex.	2,427	x	x	
58	07311800	07311800	South Wichita River near Benjamin, Tex.	1,513	x	x	
59	07331000	07331000	Washita River near Dickson, Okla.	18,650	x	x	
60	**07335500**	07335500	Red River at Arthur City, Tex.	115,300	x	x	
61	07337000	07337000	Red River at Index, Ark.	124,400	x	x	
62	07340300	07340300	Cossatot River near Vandervoort, Ark.	232	x		
63	**07343000**	07343000	North Sulphur River near Cooper, Tex.	715	x		
64	07355500	07355500	Red River at Alexandria, La.	174,800	x	x	x
			Ouachita River				
65	07362000	07362000	Ouachita River at Camden, Ark.	13,880	x	x	
66	07362587	07362587	Alum Fork Saline River near Reform, Ark.	70	x		
67	07373000	07373000	Big Creek at Pollock, La.	132	x		

Table 1. Stream sites in south-central United States selected for trend and load computations of nutrient and sediment data--Continued

Map number (fig. 5)	Water-quality station number	Stream-flow station number	Station name	Drainage area, square kilometers	Trends calculated, 1993-2004	Loads and yields, calculated and tabled, 1993-2004	Loads, calculated and graphed, 1980-2004
68	07381495*	07381490*	Atchafalaya River at Melville, La.	241,700	x	x	x
69	07381600	07381600	Lower Atchafalaya River at Morgan City, La.	indeterminate	x	x	
			Louisiana-Gulf/Pontchartrain system				
70	**07375500**	07375500	Tangipahoa River at Robert, La.	1,673	x	x	
71	**07376000**	07376000	Tickfaw River at Holden, La.	640	x	x	
72	**07385765**	07385765	Bayou Teche at Adeline Bridge near Jeanerette, La.	indeterminate	x	x	
73	**07386980**	07386980	Vermilion River at Perry, La.	indeterminate	x		
74	**08012150**	08012150	Mermentau River at Mermentau, La.	3,577	x		
			Texas-Gulf system				
75	**08030500**	08030500	Sabine River near Ruliff, Tex.	24,160	x		
			Neches River				
76	08032000	08032000	Neches River near Neches, Tex.	2,966	x	x	
77	08033500	08033500	Neches River near Rockland, Tex.	9,417	x	x	
78	**08041000**	08041000	Neches River at Evadale, Tex.	20,590	x	x	
			Trinity River				
79	**08044500**	08044500	West Fork Trinity River near Boyd, Tex.	4,468	x		
80	08049500	08049500	West Fork Trinity River at Grand Prairie, Tex.	7,938	x		
81	08051500	08051500	Clear Creek near Sanger, Tex.	764	x	x	
82	08057410	08057410	Trinity River below Dallas, Tex.	16,260	x		
83	08062500	08062500	Trinity River near Rosser, Tex.	21,100	x	x	
84	08064100	08064100	Chambers Creek near Rice, Tex.	2,090	x	x	
85	08064700	08064700	Tehuacana Creek near Streetman, Tex.	368	x	x	
86	**08065000**	08065000	Trinity River near Oakwood, Tex.	33,240	x	x	
87	08065350	08065350	Trinity River near Crockett, Tex.	36,030	x	x	
88	**08066500**	08066500	Trinity River at Romayor, Tex.	44,510	x		
89	**08069000**	08069000	Cypress Creek near Westfield, Tex.	738	x		
90	**08070200**	08070200	East Fork San Jacinto River near New Caney, Tex.	1,005	x		
91	**08073500**	08073500	Buffalo Bayou near Addicks, Tex.	759	x		

Table 1. Stream sites in south-central United States selected for trend and load computations of nutrient and sediment data--Continued

Map number (fig. 5)	Water-quality station number	Stream-flow station number	Station name	Drainage area, square kilometers	Trends calculated, 1993-2004	Loads and yields, calculated and tabled, 1993-2004	Loads, calculated and graphed, 1980-2004
92	**08074500**	08074500	Whiteoak Bayou at Houston, Tex.	224	x	x	
93	**08078000**	08078000	Chocolate Bayou near Alvin, Tex.	227	x	x	
			Brazos River				
94	**08085500**	08085500	Clear Fork Brazos River at Ft. Griffin, Tex.	10,330	x		
95	08114000	08114000	Brazos River at Richmond, Tex.	116,800	x		
96	**08117500**	08117500	San Bernard River near Boling, Tex.	1,883	x	x	
			Colorado River				
97	08123850	08123850	Colorado River above Silver, Tex.	38,620	x		
98	08136500	08136500	Concho River at Paint Rock, Tex.	17,030	x	x	
99	**08143600**	08143600	Pecan Bayou near Mullin, Tex.	5,369	x		
100	**08147000**	08147000	Colorado River near San Saba, Tex.	80,850	x	x	
			Colorado River tributaries near Austin, Tex.				
101	08154700	08154700	Bull Creek at Loop 360 near Austin, Tex.	58	x	x	
102	08155200	08155200	Barton Creek at State Highway 71 near Oak Hill, Tex.	232	x	x	
103	08155240	08155240	Barton Creek at Lost Creek Boulevard near Austin, Tex.	277	x	x	
104	08155300	08155300	Barton Creek at Loop 360, Austin, Tex.	300	x	x	
105	08156800	08156800	Shoal Creek at West 12th Street, Austin, Tex.	32	x	x	
106	**08159000**	08159000	Onion Creek at US Hwy 183, Austin, Tex.	831	x		
107	**08162000**	08162000	Colorado River at Wharton, Tex.	108,800	x	x	
108	**08162500**	08162500	Colorado River near Bay City, Tex.	109,400	x	x	
109	**08162600**	08162600	Tres Palacios River near Midfield, Tex.	376	x		
			San Antonio River				
110	**08178565**	08178565	San Antonio River at Loop 410, San Antonio, Tex.	324	x		
111	08178800	08178800	Salado Creek at Loop 13 at San Antonio, Tex.	490	x		
112	08181800	08181800	San Antonio River near Elmendorf, Tex.	4,514	x	x	x
113	**08188500**	08188500	San Antonio River at Goliad, Tex.	10,160	x		
114	**08189500**	08189500	Mission River at Refugio, Tex.	1,787	x		
115	08210000	08210000	Nueces River near Three Rivers, Tex.	39,960	x	x	

* Site operated by U.S. Army Corps of Engineers

Table 2. Analytical results for trends in daily streamflow for sites in the Lower-Mississippi-Texas Basin for water years 1993-2004

Map number (fig. 5)	Station number	Trend in daily flow begin date	Trend in daily flow end date	Trend in flow, percent per year	Trend in flow, p-value
			Mississippi system		
1	03612500	10/1/1992	9/30/2004	no trend	0.80
2	07022000	10/1/1992	9/30/2004	-4.3	0.000
3	07031740	2/1/1995	9/30/2004	no trend	0.57
4	07047810	10/1/1992	9/30/2004	no trend	0.18
5	07047942	10/1/1992	9/30/2004	no trend	0.41
6	07050500	10/1/1992	9/30/2004	-5.2	0.002
9	07053250	4/15/1993	9/30/2004	-4.8	0.000
10	07055646	4/17/1993	9/26/2004	no trend	0.44
11	07056000	10/1/1992	9/30/2004	-4.0	0.043
12	07060500	10/1/1992	9/30/2004	-5.2	0.001
13	07060710	10/1/1992	9/30/2004	-4.7	0.001
14	07061600	10/1/1992	9/30/2004	-3.5	0.003
15	07066110	10/1/1992	9/30/2004	-3.8	0.003
16	07068000	10/1/1992	9/30/2004	-3.6	0.000
17	07071500	10/1/1992	9/30/2004	-4.5	0.004
18	07077500	10/1/1996	9/30/2004	no trend	0.31
20	07093740	10/1/1992	9/30/2003	-7.0	0.000
21	07103700	10/1/1992	9/30/2004	no trend	0.21
22	07103780	10/1/1992	9/30/2004	no trend	0.38
24	07105500	10/1/1992	9/30/2004	no trend	0.32
25	07105530	10/1/1992	9/30/2004	no trend	0.47
26	07106300	10/1/1992	9/30/2004	no trend	0.87
27	07106500	10/1/1992	9/30/2004	no trend	0.74
28	07189000	10/1/1992	9/30/2004	-5.0	0.001
29	07195000	7/13/1995	9/30/2004	no trend	0.82
30	07195500	10/1/1992	9/30/2004	-3.9	0.004
31	07195865	9/12/1996	9/30/2004	no trend	0.83
32	07196000	10/1/1992	9/30/2004	-3.5	0.049
33	07196500	10/1/1992	9/30/2004	-3.8	0.010
34	07196900	10/1/1992	9/30/2004	-4.5	0.046
35	07197000	10/1/1992	9/30/2004	-4.5	0.006
36	07227500	10/1/1992	9/30/2004	-6.6	0.020
37	07228000	10/1/1992	9/30/2004	no trend	0.30
38	07239450	10/1/1992	9/30/2004	no trend	0.19
39	07241000	10/1/1992	9/30/2004	-7.3	0.014

Table 2. Analytical results for trends in daily streamflow for sites in the Lower-Mississippi-Texas Basin for water years 1993-2004--Continued

Map number (fig. 5)	Station number	Trend in daily flow begin date	Trend in daily flow end date	Trend in flow, percent per year	Trend in flow, p-value
40	07241520	10/1/1992	9/30/2004	-6.0	0.011
41	07241550	10/1/1992	9/30/2004	-4.8	0.008
42	07247015	10/1/1992	9/30/2004	no trend	0.088
43	07247250	10/1/1992	9/30/2004	no trend	0.12
44	07247345	10/1/1992	9/30/2004	no trend	0.12
45	07247650	10/1/1992	9/30/2004	-5.6	0.023
46	07249400	10/1/1992	9/30/2004	-5.8	0.001
47	07263295	11/11/1992	9/29/2004	-4.8	0.030
48	07263620	10/1/1992	9/30/2004	-4.9	0.019
49	07268000	10/1/1992	9/30/2004	no trend	0.96
50	07288650	10/1/1995	9/30/2004	no trend	0.18
51	07288955	10/1/1995	9/30/2004	no trend	0.17
52	07290650	10/1/1992	9/30/2004	no trend	0.41
53	07373420	10/1/1992	9/30/2004	-2.2	0.039
Atchafalaya system					
54	07299540	10/1/1992	9/30/2004	no trend	0.44
55	07300000	10/1/1992	9/30/2004	no trend	0.40
56	07308500	10/1/1992	9/30/2004	-7.3	0.000
57	07311700	10/1/1992	9/30/2004	-6.0	0.000
58	07311800	10/1/1992	9/30/2004	no trend	0.063
59	07331000	10/1/1992	9/30/2004	-6.6	0.000
60	07335500	10/1/1992	9/30/2004	-5.9	0.000
61	07337000	10/1/1992	9/30/2004	-5.8	0.000
62	07340300	10/1/1992	9/30/2004	-3.0	0.021
63	07343000	10/1/1992	9/19/2004	no trend	0.48
64	07355500	10/1/1992	9/30/2004	no trend	0.44
65	07362000	10/1/1992	9/30/2004	no trend	0.69
66	07362587	10/1/1992	9/13/2004	no trend	0.34
67	07373000	10/1/1992	9/30/2004	no trend	0.60
68	07381495	10/1/1992	9/30/2004	-2.2	0.030
69	07381600	10/1/1995	9/30/2004	no trend	0.74
Louisiana-Gulf/Pontchartrain system					
70	07375500	10/1/1992	9/30/2004	no trend	0.19
71	07376000	10/1/1992	9/30/2004	no trend	0.066
73	07386980	10/1/1992	9/30/2004	no trend	0.46
74	08012150	10/1/1992	9/29/2004	no trend	0.26

Table 2. Analytical results for trends in daily streamflow for sites in the Lower-Mississippi-Texas Basin for water years 1993-2004--Continued

Map number (fig. 5)	Station number	Trend in daily flow begin date	Trend in daily flow end date	Trend in flow, percent per year	Trend in flow, p-value
			Texas-Gulf system		
75	08030500	10/1/1992	9/30/2004	no trend	0.86
76	08032000	10/1/1992	9/30/2004	no trend	0.39
77	08033500	10/1/1992	9/30/2004	no trend	0.93
78	08041000	10/1/1992	9/30/2004	no trend	0.82
79	08044500	10/1/1992	9/30/2004	-5.2	0.004
80	08049500	10/1/1992	9/30/2004	no trend	0.20
81	08051500	10/1/1992	9/30/2004	no trend	0.070
82	08057410	10/1/1992	9/30/2004	no trend	0.25
83	08062500	10/1/1992	9/30/2004	no trend	0.16
84	08064100	10/1/1992	9/30/2004	no trend	0.81
85	08064700	10/1/1992	9/30/2004	no trend	0.69
86	08065000	10/1/1992	9/30/2004	no trend	0.28
87	08065350	10/1/1992	9/30/2004	no trend	0.15
88	08066500	10/1/1992	9/30/2004	no trend	0.63
89	08069000	10/1/1992	9/30/2004	no trend	0.10
90	08070200	10/1/1992	9/30/2004	no trend	0.76
91	08073500	10/1/1992	9/30/2004	no trend	0.63
92	08074500	10/1/1992	9/30/2004	no trend	0.12
93	08078000	10/1/1992	9/30/2004	no trend	0.72
94	08085500	10/1/1992	9/30/2004	-7.0	0.003
95	08114000	10/1/1992	9/30/2004	no trend	0.94
96	08117500	10/1/1992	9/30/2004	no trend	0.69
97	08123850	10/1/1992	9/30/2004	-6.9	0.004
98	08136500	10/1/1992	9/30/2004	-8.2	0.0
99	08143600	10/1/1992	9/30/2004	no trend	0.59
100	08147000	10/1/1992	9/30/2004	no trend	0.15
101	08154700	10/1/1992	9/30/2004	no trend	0.61
102	08155200	10/1/1992	9/30/2004	no trend	0.26
103	08155240	10/1/1992	9/30/2004	no trend	0.29
104	08155300	11/19/1992	8/5/2004	no trend	0.36
105	08156800	10/7/1992	9/18/2004	-5.7	0.008
106	08159000	10/1/1992	9/27/2004	no trend	0.35
107	08162000	10/1/1992	9/30/2004	no trend	0.62
108	08162500	10/1/1992	9/30/2004	no trend	0.83
109	08162600	10/1/1992	9/30/2004	no trend	0.77

Table 2. Analytical results for trends in daily streamflow for sites in the Lower-Mississippi-Texas Basin for water years 1993-2004--Continued

Map number (fig. 5)	Station number	Trend in daily flow begin date	Trend in daily flow end date	Trend in flow, percent per year	Trend in flow, p-value
110	08178565	10/1/1992	9/30/2004	no trend	0.37
111	08178800	10/1/1992	9/30/2004	no trend	0.63
112	08181800	10/1/1992	9/30/2004	7.89	0.037
113	08188500	10/1/1992	9/30/2004	10	0.026
114	08189500	10/1/1992	9/30/2004	no trend	0.25
115	08210000	10/1/1992	9/30/2004	no trend	0.11

Table 3. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for ammonia data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[mg/L, milligrams per liter; kg/day, kilograms per day; N/A, analysis attempted but results not available because of poor model fit or incomplete datasets; reference concentrations and loads are left blank where trend results are "no trend;" p-values and reference concentrations and loads are blank where trend results are "N/A;" there were no sites in the Louisiana-Gulf/Pontchartrain river system with an adequate amount of ammonia data to complete trend analyses]

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
							Mississippi system							
1	03612500	10/20/1992	9/1/2004	147	61	-6.3	3.9E-10	0.06	-6.3	3.5E-9	0.06	-6.4	2.5E-7	34,300
2	07022000	7/20/1993	9/1/2004	141	55	-6.9	1.3E-8	0.08	-6.6	3.3E-6	0.08	-7.9	5.2E-12	52,600
5	07047942	11/11/1992	9/1/2004	71	6	no trend	0.14		no trend	0.16		no trend	0.50	
6	07050500	4/28/1993	8/31/2004	69	31	N/A			N/A			N/A		
9	07053250	4/26/1993	8/25/2004	136	85	N/A			N/A			N/A		
11	07056000	5/6/1993	3/23/2004	126	97	N/A			N/A			N/A		
12	07060500	11/17/1992	8/25/2004	71	32	-4.0	0.017	0.02	-4.3	0.021	0.02	-6.8	2.7E-5	505
13	07060710	11/17/1992	8/24/2004	120	85	N/A			N/A			N/A		
14	07061600	5/12/1993	9/7/2004	0	0	N/A			N/A			N/A		
18	07077500	11/10/1992	9/1/2004	92	10	no trend	0.076		-7.7	0.044	0.04	-9.2	0.022	57
19	07077700	11/11/1992	9/1/2004	75	5	-8.9	0.011	0.14	-8.9	0.020	0.14	no trend	0.99	
21	07103700	1/28/1993	8/4/2004	99	61	N/A			N/A			N/A		
22	07103780	1/27/1993	10/28/2003	89	19	no trend	0.87		no trend	0.86		no trend	0.58	
23	07104905	1/27/1993	8/23/2004	92	33	N/A			N/A			N/A		
24	07105500	1/28/1993	8/4/2004	116	32	N/A			N/A			N/A		
25	07105530	1/28/1993	8/4/2004	106	2	-8.6	0.00	N/A	-8.6	0.00	N/A	-8.6	0.00	N/A
26	07106300	3/26/1993	7/22/2004	56	18	-7.4	0.008	0.05	-7.4	0.009	0.05	-7.4	0.009	15
27	07106500	1/29/1993	7/22/2004	105	29	-6.8	0.001	0.06	-6.7	0.001	0.06	-7.0	0.007	21
28	07189000	4/27/1993	9/14/2004	111	77	N/A			N/A			N/A		
29	07195000	8/3/1995	9/1/2004	49	17	no trend	0.12		no trend	0.13		no trend	0.14	

Table 3. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for ammonia data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
30	07195500	10/7/1992	8/17/2004	111	35	-4.4	0.017	0.03	no trend	0.070		-6.3	0.001	42
31	07195865	10/6/1992	8/18/2004	87	40	N/A			N/A			N/A		
32	07196000	10/6/1992	8/18/2004	108	49	N/A			N/A			N/A		
33	07196500	10/14/1992	8/17/2004	127	66	-4.8	0.001	0.01	-4.4	0.005	0.01	-6.5	0.000	25
34	07196900	6/28/1995	9/1/2004	50	23	N/A			N/A			N/A		
35	07197000	10/13/1992	8/17/2004	114	54	-4.2	0.040	0.01	-4.9	0.011	0.01	-6.5	0.000	8
36	07227500	1/13/1993	8/5/2004	62	33	N/A			N/A			N/A		
37	07228000	11/16/1992	4/8/2003	0	0	N/A			N/A			N/A		
38	07239450	11/17/1992	9/8/2004	143	47	no trend	0.27		no trend	0.42		no trend	0.12	
39	07241000	10/14/1992	9/8/2004	144	19	no trend	0.33		-4.7	0.022	0.08	-7.7	0.001	54
40	07241520	10/14/1992	9/7/2004	132	20	no trend	0.43		no trend	0.15		-6.6	0.003	86
41	07241550	10/14/1992	9/7/2004	142	26	no trend	0.87		no trend	0.81		no trend	0.058	
42	07247015	10/13/1992	8/24/2004	91	26	-6.7	1.7E-9	0.04	-6.5	1.0E-7	0.04	-7.6	2.6E-5	7
43	07247250	10/15/1992	8/24/2004	80	36	-7.4	1.0E-8	0.03	-7.3	3.5E-7	0.03	-8.0	7.2E-5	4
44	07247345	10/14/1992	8/25/2004	78	30	N/A			N/A			N/A		
45	07247650	10/14/1992	8/25/2004	79	20	-6.0	5.1E-5	0.05	-5.8	0.000	0.05	-7.6	0.000	6
46	07249400	6/27/1995	9/7/2004	56	17	no trend	0.20		no trend	0.30		-8.2	0.003	2
47	07263295	12/15/1992	8/2/2004	57	28	N/A			N/A			N/A		
48	07263620	12/17/1992	9/7/2004	102	21	-4.1	0.018	0.06	-5.0	0.001	0.06	-6.6	4.8E-5	5,590
50	07288650	2/16/1996	9/8/2004	100	18	no trend	0.25		no trend	0.11		no trend	0.79	
51	07288955	2/14/1996	9/10/2004	148	34	no trend	0.68		no trend	0.63		no trend	0.42	
53	07373420	10/14/1992	9/14/2004	151	80	-5.3	9.3E-7	0.03	-5.4	5.3E-6	0.03	-6.1	1.5E-7	44,400

Table 3. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for ammonia data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
Atchafalaya system														
55	07300000	1/12/1993	8/12/2004	48	7	N/A			N/A			N/A		
56	07308500	11/18/1992	8/20/2004	103	36	N/A			N/A			N/A		
57	07311700	1/15/1993	9/14/2004	118	9	no trend	0.40		-4.0	0.015	0.08	-6.6	4.8E-7	8
58	07311800	1/15/1993	9/9/2004	96	14	no trend	0.43		no trend	0.60		no trend	0.24	
59	07331000	10/21/1992	9/1/2004	111	40	no trend	0.42		no trend	0.99		-7.1	0.001	163
61	07337000	11/17/1992	8/17/2004	66	9	no trend	0.56		no trend	0.79		-5.3	0.011	1,120
62	07340300	11/18/1992	8/18/2004	58	32	N/A			N/A			N/A		
63	07343000	10/27/1992	3/10/2003	0	0	N/A			N/A			N/A		
65	07362000	11/17/1992	8/17/2004	66	13	-3.7	0.048	0.03	no trend	0.056		no trend	0.12	
66	07362587	12/15/1992	8/2/2004	61	27	N/A			N/A			N/A		
67	07373000	10/27/1992	2/23/2004	0	0	N/A			N/A			N/A		
68	07381495	2/23/1993	9/13/2004	152	70	-6.1	4.1E-7	0.04	-6.2	1.5E-6	0.04	-6.8	3.2E-8	22,200
Texas-Gulf system														
76	08032000	1/21/1993	9/13/2004	70	23	-5.5	0.002	0.04	-5.4	0.003	0.04	-6.4	0.011	42
77	08033500	1/22/1993	9/2/2004	70	36	N/A			N/A			N/A		
78	08041000	6/16/1993	4/23/2003	0	0	N/A			N/A			N/A		
79	08044500	10/1/1992	2/19/2003	42	13	N/A			N/A			N/A		
80	08049500	2/9/1993	9/14/2004	64	10	-5.8	0.002	0.04	-5.9	0.002	0.04	-6.6	0.001	55
81	08051500	2/8/1993	8/18/2004	100	57	N/A			N/A			N/A		
82	08057410	4/21/1993	8/17/2004	85	14	N/A			N/A			N/A		
83	08062500	1/19/1993	9/8/2004	60	5	-4.9	0.015	0.07	-4.9	0.014	0.07	-6.1	0.006	523
84	08064100	4/20/1993	9/15/2004	126	63	-5.7	1.3E-5	0.02	-5.8	1.7E-6	0.02	no trend	0.52	
85	08064700	1/27/1993	9/9/2004	53	17	-5.4	0.005	0.04	-5.4	0.006	0.04	no trend	0.38	

Table 3. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for ammonia data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
86	08065000	11/12/1992	4/8/2003	72	23	no trend	0.44		no trend	0.39		no trend	0.83	
87	08065350	1/20/1993	9/13/2004	73	30	N/A			N/A			N/A		
89	08069000	11/4/1992	4/9/2003	111	9	N/A			N/A			N/A		
90	08070200	1/14/1993	4/28/2003	126	93	N/A			N/A			N/A		
91	08073500	11/19/1992	4/1/2003	98	20	-5.2	0.031	0.24	-5.1	0.038	0.24	no trend	0.20	
92	08074500	11/19/1992	4/29/2003	135	17	no trend	0.20		no trend	0.20		no trend	0.093	
93	08078000	12/7/1992	2/12/2003	38	16	no trend	0.31		no trend	0.30		no trend	0.47	
94	08085500	11/5/1992	2/4/2003	35	16	N/A			N/A			N/A		
95	08114000	1/26/1993	9/25/2002	44	23	N/A			N/A			N/A		
96	08117500	12/9/1992	4/9/2003	51	24	no trend	0.60		no trend	0.62		no trend	0.52	
97	08123850	11/3/1992	9/2/2003	55	16	N/A			N/A			N/A		
98	08136500	1/19/1993	6/24/2003	58	20	no trend	0.36		no trend	0.62		-9.4	5.2E-8	3
99	08143600	11/18/1992	4/16/2003	55	25	no trend	0.48		no trend	0.47		no trend	0.79	
100	08147000	11/18/1992	4/16/2003	54	35	N/A			N/A			N/A		
101	08154700	1/14/1993	4/6/2004	45	21	no trend	0.89		no trend	0.95		no trend	0.63	
102	08155200	1/25/1993	4/6/2004	86	51	N/A			N/A			N/A		
103	08155240	11/20/1992	6/9/2004	77	37	N/A			N/A			N/A		
104	08155300	11/20/1992	3/4/2004	48	30	N/A			N/A			N/A		
105	08156800	12/14/1992	12/23/2002	38	10	no trend	0.61		no trend	0.58		no trend	0.36	
106	08159000	10/13/1992	4/24/2003	0	0	N/A			N/A			N/A		
107	08162000	10/14/1992	4/2/2003	55	35	N/A			N/A			N/A		
108	08162500	10/14/1992	2/4/2003	55	24	no trend	0.62		no trend	0.62		no trend	0.76	
109	08162600	6/8/1993	3/25/2003	60	18	no trend	0.22		no trend	0.34		no trend	0.28	

Table 3. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for ammonia data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
110	08178565	10/20/1992	4/24/2003	75	18	N/A			N/A			N/A		
111	08178800	1/11/1993	9/9/2004	129	48	N/A			N/A			N/A		
112	08181800	2/9/1993	9/9/2004	134	27	-6.4	5.0E-6	0.07	-6.3	1.5E-5	0.07	no trend	0.079	
113	08188500	10/15/1992	4/21/2003	78	21	N/A			N/A			N/A		
114	08189500	10/14/1992	4/22/2003	37	13	N/A			N/A			N/A		
115	08210000	10/13/1992	9/23/2004	48	7	N/A			N/A			N/A		

Table 4. Ammonia annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[All values in table are loads in metric tons unless otherwise noted; blanks appear in table for water years at specific sites where load calculations could not be completed because of poor model fit or incomplete data sets; there were no sites in the Louisiana-Gulf/Pontchartrain river system that had an adequate amount of ammonia data to complete load calcuations]

Map Number (fig. 5)	Station number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load	Average annual yield, metric tons/ square kilometers/ year
Mississippi river system															
1	03612500	21,500	24,000	14,000	16,500	16,800	11,800	8,550	5,600	5,650	7,180	7,420	6,890	12,200	0.023
2	07022000	43,900	26,900	20,300	14,900	19,300	17,100	15,900	6,320	9,510	7,600	4,210	5,430	15,900	0.009
5	07047942	44	80	48	33	74	42	38	27	36	55	41	28	45	0.033
12	07060500	320	277	230	100	236	161	124	64	63	144	61	92	156	0.006
18	07077500					9	53	40	30	30	41	27		33	0.012
19	07077700						47	36	23	34	52	55	23	39	0.035
22	07103780	0.5	1	1	1	1	1		1	1	0.4	1		1	0.004
25	07105530	1,080	864	825	438	317	242	151	91	45	20	11	8	341	0.319
26	07106300	11	11	13	10	9	9	8	7	5	3	2	2	8	0.003
30	07195500	68	33	45	17	30	26	35	32	16	25	7	21	30	0.018
33	07196500	53	28	45	16	34	31	38	50	20	20	5	16	30	0.012
35	07197000	20	9	15	9	15	13	9	13	6	6	1	6	10	0.013
38	07239450	23	11	16	8	45	36	35	21	24	3	11	11	20	0.001
39	07241000	61	20	40	19	56	43	38	21	18	3	8	6	28	0.001
42	07247015	18	18	22	8	25	14	15	6	9	12	2	2	13	0.018
43	07247250	10	6	7	2	8	4	5	2	2	3	0.4	1	4	0.022
45	07247650	35	22	26	15	22	16	24	4	18	16	2	4	17	0.024
48	07263620	5,060	2,790	3,420	1,050	2,590	2,410	2,930	1,370	1,530	1,310	838	1,210	2,210	0.005
50	07288650				36	97	66	52	73	98	66	66		69	0.055
51	07288955				648	1,460	1,120	1,170	562	1,100	1,610	1,500	1,050	1,140	0.033
53	07373420	26,200	22,000	16,100	13,600	18,400	14,200	12,500	6,440	8,790	9,510	7,610	7,400	13,600	0.005
Atchafalaya river system															
57	07311700	5	3	6	3	4	3	3	2	2	2	2	1	3	0.002
58	07311800	1	1	2	1	2	1	1	0.4	1	1	1	1	1	0.001
59	07331000	271	91	202	67	169	153	59	40	145	55	35	35	110	0.006

Table 4. Ammonia annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map Number (fig. 5)	Station number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load	Average annual yield, metric tons/ square kilometers/ year
61	07337000	838	546	721	296	751	686	384	218	758	559	275	215	520	0.004
65	07362000	201	232	203	66	221	154	165	76	163	158	112	112	155	0.011
68	07381495	14,900	12,200	8,720	7,290	9,640	7,330	6,280	3,180	4,270	4,510	3,520	3,350	7,100	0.029
							Texas-Gulf river system								
76	08032000	43	29	51	5	27	20	23	11	28	14	11	9	23	0.008
83	08062500	412	397	798	151	683	554	363	445	271	148	135		396	0.019
84	08064100	20	22	58	0.4	42	32	27	9	17	9	3	7	21	0.010
85	08064700	2	3	3	0.1	6	2	5	1	4	1	2	1	3	0.007
86	08065000	314	365	573	72	436	331	335	151	405	316	223	288	317	0.010
92	08074500	40	27	40	25	50	41	37	21	55	34	44	56	39	0.175
98	08136500	3	2	4	1	3		1	1	1	1	2	0.3	2	0.000
101	08154700	1	0.2	1	0.2	1	0.3	1		1	1	0.4	1	1	0.008
105	08156800	0.4	0.3	1	0.4	0.5	0.3		0.2	1		0.4	1	1	0.017
108	08162500	139	45	136	42	237	115	155	26	105	130	150	105	115	0.001

Table 5. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for nitrite plus nitrate data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[mg/L, milligrams per liter; kg/day, kilograms per day; N/A, analysis attempted but reults not available because of poor model fit or incomplete datasets; reference concentrations and loads are blank where trend results are “no trend;” p-values and reference concentrations and loads are blank where trend results are “N/A”]

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
							Mississippi system							
1	03612500	10/20/1992	9/1/2004	147	0	no trend	0.42		no trend	0.43		no trend	0.54	
2	07022000	11/11/1992	9/1/2004	158	1	-2.0	0.031	2.3	no trend	0.92		-5.4	7.5E-5	1,720,000
3	07031740	2/2/1993	6/2/2004	43	1	N/A			N/A			N/A		
5	07047942	11/11/1992	9/1/2004	71	3	no trend	0.053		no trend	0.076		no trend	0.51	
6	07050500	10/13/1992	8/31/2004	83	2	N/A			N/A			N/A		
7	07052152	11/24/1993	7/22/2004	69	0	no trend	0.85		no trend	0.83		no trend	0.71	
8	07052250	11/17/1992	7/21/2004	71	0	no trend	0.14		no trend	0.15		no trend	0.23	
9	07053250	4/26/1993	8/25/2004	136	2	7.9	1.3E-5	2.3	9.6	4.5E-6	2.3	no trend	0.56	
10	07055646	4/28/1993	8/25/2004	80	55	N/A			N/A			N/A		
11	07056000	10/27/1992	3/23/2004	144	42	no trend	0.61		4.3	0.041	0.06	no trend	0.30	
12	07060500	11/17/1992	8/25/2004	71	2	no trend	0.14		no trend	0.46		-6.0	0.004	6,910
13	07060710	11/17/1992	8/24/2004	120	30	no trend	0.21		no trend	0.59		-5.4	0.002	4
14	07061600	1/5/1993	9/7/2004	68	4	N/A			N/A			N/A		
15	07066110	11/12/1992	9/7/2004	83	0	no trend	0.18		no trend	0.12		-3.2	0.039	326
16	07068000	11/12/1992	9/15/2004	144	1	-1.8	0.010	0.27	no trend	0.52		-4.7	0.000	2,080
17	07071500	8/25/1993	9/15/2004	68	0	no trend	0.26		no trend	0.28		-5.1	0.013	1,220
18	07077500	11/10/1992	9/1/2004	92	5	no trend	0.45		no trend	0.38		no trend	0.18	
19	07077700	11/11/1992	9/1/2004	75	6	12	0.042	0.15	13	0.042	0.15	52	0.008	27
21	07103700	10/15/1992	8/4/2004	106	0	no trend	0.93		no trend	0.32		no trend	0.14	
22	07103780	10/14/1992	10/28/2003	92	8	39	1.4E-5	N/A	33	3.5E-5	N/A	24	0.003	2

Table 5. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for nitrite plus nitrate data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
23	07104905	10/14/1992	8/23/2004	100	0	N/A			N/A			N/A		
24	07105500	10/15/1992	8/4/2004	122	0	no trend	0.49		no trend	0.68		no trend	0.28	
25	07105530	10/15/1992	8/4/2004	111	0	4.5	0.000	1.7	3.7	1.3E-5	1.7	no trend	0.24	
26	07106300	12/18/1992	7/22/2004	57	0	-4.3	2.2E-9	5.1	-4.3	1.3E-7	5.1	-4.5	0.039	1,550
27	07106500	10/16/1992	7/22/2004	114	0	-5.1	0.00	5.4	-5.1	0.00	5.4	-5.5	0.001	1,770
28	07189000	11/18/1992	9/14/2004	117	0	no trend	0.44		4.7	3.4E-6	1.6	-4.7	0.040	2,620
29	07195000	10/13/1992	9/1/2004	69	1	N/A			N/A			N/A		
30	07195500	10/7/1992	8/17/2004	111	0	no trend	0.24		no trend	0.32		-4.7	0.003	3,350
31	07195865	10/6/1992	8/18/2004	87	0	no trend	0.074		no trend	0.058		no trend	0.30	
32	07196000	10/6/1992	8/18/2004	109	0	4.2	4.6E-11	1.9	4.7	5.5E-12	1.9	no trend	0.67	
33	07196500	10/14/1992	8/17/2004	127	0	no trend	0.19		no trend	0.40		-4.6	0.023	3360
34	07196900	11/3/1992	9/1/2004	67	1	no trend	0.96		no trend	0.44		no trend	0.17	
35	07197000	10/13/1992	8/17/2004	114	0	no trend	0.94		no trend	0.056		no trend	0.052	
36	07227500	11/17/1992	8/5/2004	63	10	30	0.004	0.16	57	0.000	0.16	no trend	1.0	
38	07239450	11/17/1992	9/8/2004	143	69	-5.8	0.029	N/A	no trend	0.077		-7.2	0.048	40
39	07241000	10/14/1992	9/8/2004	144	26	-4.6	0.014	0.26	-4.8	0.009	0.26	-7.9	0.001	169
40	07241520	10/14/1992	9/7/2004	132	6	no trend	0.099		no trend	0.80		-4.4	0.029	648
41	07241550	10/14/1992	9/7/2004	142	0	7.5	0.021	1.1	no trend	0.74		no trend	0.30	
42	07247015	10/13/1992	8/24/2004	91	17	no trend	0.16		5.9	0.048	0.09	no trend	0.53	
43	07247250	10/15/1992	8/24/2004	80	21	no trend	0.48		no trend	0.050		no trend	0.37	
44	07247345	10/14/1992	8/25/2004	78	27	no trend	0.41		no trend	0.10		no trend	0.41	
45	07247650	10/14/1992	8/25/2004	79	19	no trend	0.19		no trend	0.84		-6.6	0.030	9
46	07249400	10/20/1992	9/7/2004	76	33	no trend	0.62		18	0.009	0.05	no trend	0.19	

Table 5. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for nitrite plus nitrate data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
48	07263620	12/17/1992	9/7/2004	102	14	no trend	0.10		no trend	0.23		-6.3	0.009	32,000
49	07268000	11/2/1992	12/5/2001	59	1	21	0.002	0.08	21	0.003	0.08	20	0.044	42
50	07288650	2/16/1996	9/8/2004	100	13	no trend	0.10		-6.1	0.022	0.53	no trend	0.92	
51	07288955	2/14/1996	9/10/2004	149	0	no trend	0.40		no trend	0.36		no trend	0.43	
52	07290650	11/2/1992	12/5/2001	77	23	no trend	0.68		no trend	0.39		no trend	0.86	
53	07373420	10/14/1992	9/14/2004	153	0	-1.7	0.015	1.6	no trend	0.068		-3.5	0.007	2,100,000
Atchafalaya system														
55	07300000	11/16/1992	8/12/2004	49	0	N/A			N/A			N/A		
56	07308500	11/18/1992	8/20/2004	103	44	N/A			N/A			N/A		
57	07311700	11/13/1992	9/14/2004	119	62	N/A			N/A			N/A		
58	07311800	11/13/1992	9/9/2004	97	45	N/A			N/A			N/A		
59	07331000	10/21/1992	9/1/2004	111	21	-5.0	0.037	0.36	no trend	0.60		-7.7	0.000	2,200
61	07337000	11/17/1992	8/17/2004	66	34	-5.8	0.031	0.14	no trend	0.57		-7.7	0.003	5,110
64	07355500	10/27/1992	9/23/2004	135	36	-4.3	0.002	0.16	-4.0	0.002	0.16	-5.2	0.037	11,200
65	07362000	11/17/1992	8/17/2004	66	8	no trend	0.75		no trend	0.80		no trend	0.64	
67	07373000	10/27/1992	2/23/2004	27	8	N/A			N/A			N/A		
68	07381495	11/19/1992	9/13/2004	155	0	no trend	0.072		no trend	0.19		-3.3	0.011	649,000
69	07381600	10/28/1992	9/8/2004	68	0	N/A			N/A			N/A		
Louisiana-Gulf/Pontchartrain system														
70	07375500	10/12/1992	8/24/2004	144	3	no trend	0.055		no trend	0.17		no trend	0.094	
71	07376000	11/16/1992	8/24/2004	110	2	-2.8	0.009	0.3	no trend	0.067		-4.7	0.022	197
73	07386980	10/12/1992	9/1/2004	112	1	no trend	0.48		no trend	0.60		no trend	0.97	
74	08012150	11/17/1992	9/1/2004	53	2	N/A			N/A			N/A		
Texas-Gulf system														
75	08030500	10/15/1992	4/9/2003	114	45	no trend	0.088		-3.0	0.047	0.08	no trend	0.18	
76	08032000	1/21/1993	9/13/2004	70	10	no trend	0.84		no trend	0.71		no trend	0.36	

Table 5. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for nitrite plus nitrate data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
77	08033500	1/22/1993	9/2/2004	70	15	no trend	0.59		no trend	0.57		no trend	0.80	
80	08049500	11/23/1992	9/14/2004	65	0	N/A			N/A			N/A		
81	08051500	11/2/1992	8/18/2004	102	28	no trend	0.16		no trend	0.72		no trend	0.085	
82	08057410	11/2/1992	8/17/2004	86	1	N/A			N/A			N/A		
83	08062500	11/4/1992	9/8/2004	61	0	6.1	0.019	2.8	2.4	0.012	2.8	no trend	0.41	
84	08064100	10/20/1992	9/15/2004	127	27	no trend	0.96		no trend	0.66		no trend	0.88	
85	08064700	10/21/1992	9/9/2004	54	36	N/A			N/A			N/A		
87	08065350	1/20/1993	9/13/2004	72	1	no trend	0.84		no trend	0.49		no trend	0.15	
95	08114000	1/26/1993	9/25/2002	44	16	N/A			N/A			N/A		
97	08123850	11/3/1992	9/2/2003	55	32	N/A			N/A			N/A		
98	08136500	11/5/1992	6/24/2003	59	5	-9.3	7.5E-14	11.6	-8.8	9.8E-5	11.6	-9.4	2.2E-16	1,640
99	08143600	11/18/1992	4/16/2003	50	14	no trend	0.68		no trend	0.59		no trend	0.97	
100	08147000	11/18/1992	4/16/2003	48	5	no trend	0.81		no trend	0.23		no trend	0.53	
101	08154700	11/19/1992	4/6/2004	48	9	no trend	0.57		no trend	0.79		no trend	0.57	
102	08155200	1/25/1993	4/6/2004	86	31	no trend	0.083		no trend	0.19		no trend	0.17	
103	08155240	11/19/1992	6/9/2004	79	10	12	0.009	0.06	7.1	0.007	0.06	no trend	0.14	
104	08155300	11/19/1992	3/4/2004	49	2	no trend	0.15		6.4	0.042	0.11	no trend	0.68	
105	08156800	12/14/1992	12/23/2002	38	1	no trend	0.42		no trend	0.45		no trend	0.22	
106	08159000	2/15/1994	4/17/2003	40	9	no trend	0.98		no trend	0.65		no trend	0.56	
107	08162000	2/16/1994	4/2/2003	46	2	N/A			N/A			N/A		
108	08162500	2/16/1994	4/2/2003	47	3	N/A			N/A			N/A		
111	08178800	10/28/1992	9/9/2004	131	2	N/A			N/A			N/A		
112	08181800	10/21/1992	9/9/2004	137	1	no trend	0.51		no trend	0.075		5.5	0.006	5,470
115	08210000	10/13/1992	9/23/2004	48	7	no trend	0.59		no trend	0.98		no trend	0.20	

Table 6. Nitrite plus nitrate annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[All values in table are loads in metric tons unless otherwise noted; blanks appear in table for water years at specific sites where load calculations could not be completed because of poor model fit or incomplete data sets]

Map Number (fig. 5)	Station Number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load	Average annual yield, metric tons/square kilometers/year
Mississippi system															
1	03612500	327,000	445,000	281,000	412,000	428,000	376,000	252,000	199,000	213,000	338,000	399,000	372,000	337,000	0.640
2	07022000	970,000	570,000	593,000	505,000	574,000	626,000	644,000	270,000	521,000	453,000	274,000	409,000	534,000	0.289
5	07047942	131	178	107	82	134	81	81	65	79	121	113	96	106	0.076
9	07053250		190	161	132	226	262	151	123	113	312	89	239	182	1.33
11	07056000	174	142	326	129	390	191	171	101	117	313	69	111	186	0.087
12	07060500	4,440	4,160	3,750	1,440	4,120	2,710	2,200	1,130	1,030	3,420	1,220	2,180	2,650	0.103
13	07060710	6	4	4	2	6	3	2	3	2	8	2	3	4	0.025
15	07066110	171	210	178	147	206	167	175	78	84	178	118	177	157	0.143
16	07068000	847	1,019	828	629	811	750	694	315	302	824	444	670	678	0.128
17	07071500	507	665	548	347	556	351	291	152	121	437	230	387	383	0.186
18	07077500					32	356	249	233	196	373	351		256	0.095
19	07077700						103	86	56	111	212	259	135	137	0.126
21	07103700	8	11	20	12	20	17	23	12	8	5	6	9	13	0.047
22	07103780	1	3	5	5	7	13	12	14	10	6	7		8	0.036
24	07105500	56	87	161	104	154	154	223	125	95	56	55	63	111	0.109
25	07105530	146	206	361	270	380	394	524	362	306	237	219	236	303	0.284
26	07106300	374	498	734	563	630	646	686	507	384	251	223	261	480	0.217
28	07189000	2,720	1,870	1,910	446	1,540	1,480	1,800	829	940	1,660	556	1,450	1,430	0.634
30	07195500	2,400	1,680	1,720	800	1,590	1,540	1,630	931	1,180	1,530	687	1,090	1,400	0.850
31	07195865					92	91	113	111	100	126	82	141	107	2.18

Table 6. Nitrite plus nitrate annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map Number (fig. 5)	Station Number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load	Average annual yield, metric tons/square kilometers/ year
32	07196000	365	256	338	103	289	252	353	235	285	260	118	294	262	0.920
33	07196500	3,170	1,950	2,130	755	1,930	1,810	1,920	1,290	1,600	1,730	606	1,530	1,700	0.685
34	07196900	349	169	200	117	193	195	167	108	112	157	33	112	159	1.51
35	07197000	901	557	709	338	749	765	693	389	553	565	139	440	566	0.712
38	07239450	111	67	64	23	201	201	139	84	90	6	34		93	0.003
39	07241000	237	56	129	61	237	231	139	54	69	11	33	15	106	0.003
39	07241000	879	190	473	186	360	404	302	182	230	123	161	187	307	0.009
39	07241000	1,010	632	912	661	950	977	868	672	759	572	596	597	767	0.022
42	07247015	67	68	82	26	114	88	76	34	93	149	26	40	72	0.103
48	07263620	54,200	27,300	34,700	6,570	30,800	37,000	41,300	15,900	25,800	20,300	9,990	21,700	27,100	0.066
49	07268000	27	43	162	325	225	231	55	165	266				167	0.122
50	07288650				350	893	501	358	469	581	362	332		481	0.383
51	07288955				4,853	10,130	6,803	7,338	4,545	6,740	9,795	9,758	7,616	7,509	0.217
52	07290650	115	150	102	103	121	136	75	19	105	108	126	135	108	0.064
53	07373420	1,020,000	844,000	740,000	676,000	870,000	757,000	699,000	393,000	565,000	661,000	610,000	644,000	707,000	0.242
							Atchafalaya system								
56	07308500	2,700	320	1,530	1,560	4,070	6,240	685	632	2,250	327	450		1,890	0.035
59	07331000	3,580	1,110	2,640	1,160	2,650	1,920	716	458	2,410	670	473	414	1,520	0.081
61	07337000	7,240	3,730	5,400	902	6,240	5,950	1,780	443	6,540	3,940	926	439	3,630	0.029
64	07355500	13,200	8,530	11,100	1,490	13,800	9,890	7,110	3,010	11,800	7,740	3,370	3,130	7,850	0.045
65	07362000	936	1,090	1,010	301	1,240	899	988	423	1,070	1,080	767	832	886	0.064
68	07381495	312,000	248,000	229,000	213,000	267,000	242,000	219,000	128,000	183,000	219,000	206,000	222,000	224,000	0.927
							Louisiana-Gulf/Pontchartrain system								
70	07375500	436	358	399	277	422	366	168	56	281	279	490	327	322	0.192
71	07376000	103	85	95	59	91	69	45	12	60	48	85	64	68	0.106
72	07385765						149	97	44	136	110	124	193	122	---

Table 6. Nitrite plus nitrate annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map Number (fig. 5)	Station Number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load	Average annual yield, metric tons/square kilometers/ year
							Texas-Gulf system								
76	08032000	89	60	122	23	57	62	88	34	90	70	58	42	66	0.022
77	08033500	254	243	303	86	246	185	265	104	276	209	237	232	220	0.023
81	08051500	326	194	284	2	421	106	8	0.3	443	109	14	126	170	0.222
83	08062500	8,100	8,660	11,200	7,420	11,700	10,800	10,500	11,700	10,400	8,900	9,170		9,870	0.468
84	08064100	1,100	1,050	3,030		2,380	1,580	897	647	1,350	528	263	1,260	1,280	0.612
87	08065350	9,590	11,900	17,400	7,610	15,700	13,800	15,500	8,600	14,400	10,600	8,510	7,010	11,700	0.325
102	08155200	3	0.1	5		11	5	8	0.1	7	17	7	3	6	0.024
103	08155240	4	0.1	8	0.1	19	9	15	1	13	29	14	7	10	0.036
104	08155300	2		9	0.1	18	7	22	0.4	10	32	13	7	11	0.034
105	08156800	3	2	6	2	3	2	4	2	5	5	3	4	4	0.111
112	08181800	2,920	2,490	2,520	2,080	2,570	2,710	3,080	2,390	3,180	3,850	3,980	3,900	2,970	0.658
115	08210000	70	84	93	74	123	83	157	21	72		170	269	111	0.003

Table 7. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for total nitrogen data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[mg/L, milligrams per liter; kg/day, kilograms per day; N/A, analysis attempted but results not available because of poor model fit or incomplete datasets; reference concentrations and loads are blank where trend results are "no trend;" p-values and reference concentrations and loads are blank where trend results are "N/A"]

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
							Mississippi system							
1	03612500	10/20/1992	9/1/2004	139	0	no trend	0.12		no trend	0.093		no trend	0.71	
2	07022000	11/11/1992	9/1/2004	156	0	no trend	0.38		1.8	0.030	3.2	-4.7	0.001	2,320,000
6	07050500	4/28/1993	8/31/2004	70	1	N/A			N/A			N/A		
7	07052152	11/24/1993	7/22/2004	64	0	no trend	0.68		no trend	0.69		no trend	0.98	
8	07052250	11/17/1992	7/21/2004	66	0	no trend	0.11		no trend	0.13		no trend	0.21	
9	07053250	4/26/1993	9/3/2003	125	2	7.0	1.4E-6	2.5	8.7	1.9E-7	2.5	no trend	0.44	
11	07056000	5/6/1993	3/23/2004	126	61	N/A			N/A			N/A		
14	07061600	1/5/1993	9/7/2004	63	35	N/A			N/A			N/A		
15	07066110	11/12/1992	9/7/2004	76	2	no trend	0.68		no trend	0.98		-4.0	0.005	512
16	07068000	11/12/1992	9/15/2004	130	6	-2.3	0.001	0.41	-1.5	0.039	0.41	-4.9	2.4E-5	3,140
17	07071500	11/10/1993	9/15/2004	60	0	no trend	0.18		no trend	0.95		-5.3	0.007	1,450
18	07077500	10/12/1994	9/1/2004	59	0	N/A			N/A			N/A		
28	07189000	11/18/1992	9/14/2004	108	0	no trend	0.55		3.8	3.3E-5	1.7	-4.8	0.028	2,860
29	07195000	8/3/1995	9/1/2004	49	0	N/A			N/A			N/A		
30	07195500	10/7/1992	8/17/2004	110	1	no trend	0.74		no trend	0.53		-4.1	0.014	3,520
31	07195865	10/6/1992	8/18/2004	87	0	no trend	0.062		no trend	0.053		no trend	0.35	
32	07196000	10/6/1992	8/18/2004	109	0	4.1	2.5E-10	1.9	4.8	8.5E-13	1.9	no trend	0.66	
33	07196500	10/14/1992	8/17/2004	127	0	no trend	0.75		2.0	0.007	1.7	no trend	0.058	
34	07196900	6/28/1995	9/1/2004	50	2	N/A			N/A			N/A		
35	07197000	10/13/1992	8/17/2004	114	0	no trend	0.72		3.1	0.017	1	no trend	0.068	

Table 7. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for total nitrogen data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
42	07247015	10/13/1992	8/24/2004	91	1	no trend	0.39		no trend	0.19		no trend	0.20	
43	07247250	10/15/1992	8/24/2004	80	26	no trend	0.29		no trend	0.45		no trend	0.090	
44	07247345	10/14/1992	8/25/2004	77	22	no trend	0.50		no trend	0.90		no trend	0.12	
45	07247650	10/14/1992	8/25/2004	78	0	no trend	0.82		no trend	0.67		-5.7	0.032	65
46	07249400	6/27/1995	9/7/2004	56	13	no trend	0.58		no trend	0.091		no trend	0.066	
47	07263295	12/15/1992	8/2/2004	57	24	N/A			N/A			N/A		
48	07263620	12/17/1992	9/7/2004	102	0	no trend	0.45		no trend	0.13		-4.7	0.048	81,500
49	07268000	11/2/1992	12/5/2001	73	3	no trend	0.13		no trend	0.11		no trend	0.41	
50	07288650	2/16/1996	9/5/2003	92	2	no trend	0.18		no trend	0.057		no trend	0.66	
51	07288955	2/14/1996	9/9/2003	136	0	no trend	0.66		no trend	0.99		no trend	0.19	
52	07290650	11/2/1992	12/5/2001	77	10	no trend	0.52		no trend	0.66		no trend	0.36	
53	07373420	10/14/1992	9/14/2004	149	0	no trend	0.30		no trend	0.54		-2.7	0.033	2,830,000
Atchafalaya system														
56	07308500	11/18/1992	8/20/2004	103	0	no trend	0.73		7.5	0.004	1.4	-7.3	0.001	4,190
57	07311700	11/13/1992	9/14/2004	96	28	N/A			N/A			N/A		
58	07311800	11/13/1992	9/9/2004	79	20	N/A			N/A			N/A		
59	07331000	10/21/1992	9/1/2004	111	1	no trend	0.37		6.0	0.000	1	-6.4	0.001	6,250
61	07337000	11/17/1992	8/17/2004	66	2	6.8	2.6E-5	0.67	8.3	4.5E-6	0.67	no trend	0.11	
64	07355500	10/27/1992	9/23/2004	134	0	no trend	0.39		no trend	0.10		no trend	0.64	
65	07362000	11/17/1992	8/17/2004	66	11	3.8	0.041	0.32	3.9	0.041	0.32	no trend	0.49	
66	07362587	12/15/1992	8/2/2004	61	32	N/A			N/A			N/A		
67	07373000	10/27/1992	2/23/2004	27	7	N/A			N/A			N/A		
68	07381495	2/23/1993	9/13/2004	149	0	no trend	0.32		no trend	0.70		-2.7	0.031	1,020,000

Table 7. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for total nitrogen data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
Louisiana-Gulf/Pontchartrain system														
70	07375500	10/12/1992	8/24/2004	143	6	no trend	0.050		no trend	0.14		no trend	0.090	
71	07376000	11/16/1992	8/24/2004	109	8	no trend	0.19		no trend	0.95		no trend	0.084	
73	07386980	10/12/1992	9/1/2004	112	0	-1.8	0.014	1.9	-1.8	0.019	1.9	no trend	0.76	
74	08012150	11/17/1992	9/1/2004	53	0	N/A			N/A			N/A		
Texas-Gulf system														
81	08051500	11/2/1992	7/15/2003	90	13	no trend	0.19		14	8.1E-6	0.3	no trend	0.27	
82	08057410	11/2/1992	9/8/2003	71	0	N/A			N/A			N/A		
84	08064100	10/20/1992	7/1/2003	89	0	N/A			N/A			N/A		
99	08143600	11/18/1992	4/16/2003	49	1	no trend	0.24		no trend	0.27		no trend	0.84	
100	08147000	11/18/1992	4/16/2003	48	2	no trend	0.74		no trend	0.36		no trend	0.44	
101	08154700	11/19/1992	4/6/2004	36	7	N/A			N/A			N/A		
102	08155200	1/25/1993	4/6/2004	86	47	N/A			N/A			N/A		
103	08155240	11/19/1992	6/9/2004	78	26	N/A			N/A			N/A		
104	08155300	11/19/1992	3/4/2004	48	10	no trend	0.21		8.5	0.040	0.23	no trend	0.73	
105	08156800	12/14/1992	12/23/2002	34	1	no trend	0.42		no trend	0.14		no trend	0.25	
106	08159000	2/15/1994	4/17/2003	36	4	no trend	0.36		no trend	0.20		no trend	0.72	
107	08162000	2/16/1994	4/2/2003	42	0	N/A			N/A			N/A		
108	08162500	2/16/1994	4/2/2003	42	0	N/A			N/A			N/A		
111	08178800	10/28/1992	9/10/2003	104	0	N/A			N/A			N/A		
112	08181800	10/21/1992	9/10/2003	111	0	no trend	0.48		no trend	0.23		5.4	0.019	6,110

Table 8. Total nitrogen annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[All values in table are loads in metric tons unless otherwise noted; blanks appear in table for water years at specific sites where load calculations could not be completed because of poor model fit or incomplete data sets]

Map Number (fig. 5)	Station Number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load	Average annual yield, metric tons/square kilometers/year
Total nitrogen															
Mississippi system															
1	03612500	432,000	606,000	380,000	572,000	609,000	532,000	354,000	278,000	304,000	503,000	610,000	579,000	480,000	0.912
2	07022000	1,370,000	767,000	829,000	703,000	803,000	897,000	936,000	395,000	783,000	697,000	420,000	638,000	770,000	0.417
9	07053250		195	164	134	232	268	151	123	113	312	88	237	183	1.34
15	07066110	348	417	272	222	300	232	249	98	110	299	157	302	250	0.227
16	07068000	1,560	1,960	1,380	1,040	1,300	1,230	1,070	482	476	1,490	606	1,010	1,130	0.214
17	07071500	634	855	678	427	687	431	352	192	157	603	278	481	481	0.234
28	07189000	3,010	2,060	2,110	487	1,650	1,580	1,940	899	1,010	1,760	593	1,530	1,550	0.687
30	07195500	3,320	2,100	2,290	998	2,080	1,970	2,140	1,310	1,450	1,980	766	1,440	1,820	1.11
31	07195865					103	101	128	128	111	143	84	163	120	2.45
32	07196000	456	300	410	112	352	293	431	343	341	289	124	359	317	1.11
33	07196500	4,180	2,400	2,760	919	2,490	2,390	2,640	1,840	2,090	2,440	733	2,200	2,260	0.909
35	07197000	1,240	672	943	510	1,070	1,060	886	703	708	769	147	675	782	0.983
42	07247015	243	254	325	109	464	327	297	132	312	486	77	111	261	0.375
43	07247250	96	69	73	22	116	63	86	43	67	109	21	30	66	0.344
44	07247345	289	200	215	56	367	182	249	118	195	345	54	78	196	0.422
45	07247650	336	247	301	174	317	299	367	75	378	372	65	105	253	0.362
46	07249400	259	164	323	109	437	358	279	63	264	664	35		269	0.706
48	07263620	85,500	42,300	65,800	13,400	51,700	52,700	76,900	30,500	38,800	34,400	20,000	38,600	45,900	0.112
49	07268000	156	385	1,140	2,240	1,080	1,250	245	918	2,380				1,090	0.799
50	07288650				911	2,640	1,960	1,120	2,220	3,020	1,590	1,460		1,860	1.49

Table 8. Total nitrogen annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map Number (fig. 5)	Station Number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load	Average annual yield, metric tons/square kilometers/year
51	07288955				14,800	34,800	23,800	25,200	14,500	23,700	35,700	34,700	25,300	25,800	0.747
52	07290650	934	1,890	1,070	932	1,300	1,730	621	211	1,490	1,530	1,560	1,580	1,240	0.730
53	07373420	1,330,000	1,120,000	986,000	919,000	1,200,000	1,070,000	992,000	573,000	834,000	990,000	914,000	982,000	992,000	0.340
Atchafalaya system															
56	07308500	3,970	909	8,110	3,410	7,710	4,710	1,970	1,320	2,780	750	946	1,370	3,160	0.059
59	07331000	7,480	3,050	9,280	3,060	7,110	5,370	2,890	2,170	6,000	2,540	1,520	1,780	4,350	0.233
61	07337000	16,800	10,500	18,000	5,980	18,500	15,000	8,910	4,530	21,000	16,300	6,160	5,520	12,300	0.099
64	07355500	38,500	28,300	39,400	8,180	49,900	35,300	31,000	18,500	53,300	39,300	20,300	22,100	32,000	0.132
65	07362000	2,440	3,160	2,850	989	4,330	3,000	3,410	1,590	4,310	4,600	3,080	3,220	3,080	0.222
68	07381495	483,000	398,000	357,000	332,000	426,000	382,000	352,000	205,000	296,000	351,000	327,000	352,000	355,000	1.47
Louisiana-Gulf/Pontchartrain system															
70	07375500	1,550	1,150	1,490	870	1,490	1,400	564	151	1,040	943	1,910	1,290	1,150	0.690
71	07376000	430	347	401	229	412	337	174	39	266	214	437	313	300	0.469
72	07385765						828	395	165	610	509	573	867	564	
Texas-Gulf system															
81	08051500	244	162	247	5	358	124	16	1	553	178	40	265	183	0.239
100	08147000	409	537	568	411	1,394	452	165	137	556	535	325	600	507	0.006
112	08181800	3,850	3,010	2,990	2,260	2,990	3,050	3,630	2,450	3,580	4,720	4,540	4,290	3,450	0.764

Table 9. Analytical results of weighted-least-squares regression comparing flow-adjusted and total trends in nutrient and suspended-sediment concentrations for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[P-value, probability value; items in **bold** are statistically significant trends (p-values less than value of significance of 0.05)]

		Population Density			Atmospheric Deposition			Fertilizer			Manure		
Trend type	Parameter	Model coeffi-cient	P-value	Coefficient of deter-mination (R2)	Model co-efficient	P-value	Coefficient of deter-mination (R2)	Model co-efficient	P-value	Coefficient of deter-mination (R2)	Model co-efficient	P-value	Coefficient of deter-mination (R2)
Total trend	Ammonia	0.018	0.13	0.057	0.15	0.094	0.070	-0.022	0.39	0.019	-0.012	0.59	0.008
Total trend	Nitrite plus nitrate	-0.021	0.49	0.009	-0.19	0.11	0.048	0.056	0.18	0.032	**0.031**	**0.011**	**0.11**
Total trend	Total nitrogen	0.011	0.77	0.003	-0.036	0.70	0.006	0.027	0.38	0.028	**0.023**	**0.030**	**0.16**
Total trend	Orthophosphorus	0.021	0.70	0.006				0.18	0.20	0.066	**0.13**	**0.059**	**0.14**
Total trend	Total phosphorus	-0.017	0.74	0.003				0.13	0.097	0.069	**0.15**	**0.002**	**0.21**
Total trend	Suspended sediment	-0.046	0.55	0.020									
Flow-adjusted trend	Ammonia	-0.013	0.26	0.032	0.057	0.47	0.013	0.001	0.97	0.000	0.015	0.33	0.025
Flow-adjusted trend	Nitrite plus nitrate	-0.038	0.074	0.058	**-0.34**	**0.000**	**0.23**	**0.092**	**0.007**	**0.12**	**0.050**	**8.3E-6**	**0.31**
Flow-adjusted trend	Total nitrogen	0.003	0.94	0.000	0.019	0.85	0.001	0.024	0.35	0.031	**0.024**	**0.013**	**0.21**
Flow-adjusted trend	Orthophosphorus	-0.064	0.18	0.073				0.19	0.24	0.057	**0.18**	**0.011**	**0.24**
Flow-adjusted trend	Total phosphorus	**-0.092**	**0.037**	**0.11**				0.11	0.25	0.034	**0.20**	**0.001**	**0.24**
Flow-adjusted trend	Suspended sediment	-0.023	0.64	0.012									

Table 10. Sites in the Lower-Mississippi-Texas Basin where the amount of conservation practices increased or decreased by more than one percent of the total drainage area, water years 1993-2004

[All data are from the National Resources Inventories of 1992 and 1997 compiled by the U.S. Department of Agriculture, Natural Resources Conservation Service (U.S. Department of Agriculture, 1995; U.S. Department of Agriculture, 2001); blank cells in the table indicate less than a 1 percent change rather than missing data]

Map number (fig. 5)	Station number	Drainage area, square kilometers	Irrigation source: wells, difference from 1992-1997 divided by drainage area, in percent	Irrigation type: gravity, pressure, or combination, difference from 1992-1997 divided by drainage area, in percent	Conservation practice: contour farming or terrace, difference from 1992-1997 divided by drainage area, in percent	Conservation practice: surface drainage, difference from 1992-1997 divided by drainage area, in percent
74	08012150	3,577				-3.1
89	08069000	738			-1.3	
91	08073500	759			-1.3	
101	08154700	58	1.6	1.6	-11	
103	08155240	277	1.8	1.6	-9.6	
110	08178565	324	1.4	1.2	-9.9	
111	08178800	490			-6.6	

Table 11. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for orthophosphorus data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[mg/L, milligrams per liter; kg/day, kilograms per day; N/A, analysis attempted but results not available because of poor model fit or incomplete datasets; reference concentrations and loads are blank where trend results are "no trend;" p-values and reference concentrations and loads are blank where trend results are "N/A;" there were no sites in the Louisiana-Gulf/Pontchartrain river system with an adequate amount of orthophosphorus data to complete trend analyses]

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
Mississippi system														
1	03612500	10/20/1992	9/1/2004	147	1	-2.6	0.007	0.04	-2.5	0.006	0.04	no trend	0.13	
2	07022000	7/20/1993	9/1/2004	141	2	no trend	0.11		no trend	0.92		-5.4	0.000	72,900
5	07047942	11/11/1992	9/1/2004	71	0	no trend	0.77		no trend	0.77		no trend	0.39	
6	07050500	4/28/1993	8/31/2004	69	2	N/A			N/A			N/A		
8	07052250	5/24/1994	7/21/2004	44	1	N/A			N/A			N/A		
9	07053250	4/26/1993	8/25/2004	136	2	no trend	0.29		4.2	0.003	0.03	-4.2	0.027	2
11	07056000	5/6/1993	3/23/2004	126	100	N/A			N/A			N/A		
12	07060500	11/17/1992	8/25/2004	71	53	N/A			N/A			N/A		
17	07071500	8/25/1993	9/15/2004	0	0	N/A			N/A			N/A		
18	07077500	11/10/1992	9/1/2004	92	1	no trend	0.72		no trend	0.73		no trend	0.29	
19	07077700	11/11/1992	9/1/2004	75	0	no trend	0.28		no trend	0.37		37	0.044	12
21	07103700	1/28/1993	8/4/2004	98	69	N/A			N/A			N/A		
22	07103780	1/27/1993	10/28/2003	85	0	15	0.004	0.39	9.1	1.3E-7	0.39	7.6	9.7E-5	8
23	07104905	1/27/1993	8/23/2004	0	0	N/A			N/A			N/A		
24	07105500	1/28/1993	8/4/2004	113	2	14	1.4E-13	0.04	13	1.4E-11	0.03	no trend	0.18	
25	07105530	1/28/1993	8/4/2004	104	0	-7.2	8.4E-8	2.5	-7.3	6.5E-8	2.5	-7.5	9.2E-8	735
26	07106300	3/26/1993	7/22/2004	52	0	-5.9	1.6E-9	1.2	-6.0	6.2E-8	1.2	-6.1	0.001	372
27	07106500	1/29/1993	7/22/2004	104	0	-6.2	0.00	1.1	-6.2	0.00	1.1	-6.5	0.000	349
28	07189000	4/27/1993	9/14/2004	111	2	11	0.000	0.03	6.9	0.008	0.03	no trend	0.78	
29	07195000	6/29/1995	9/1/2004	49	1	no trend	0.52		no trend	0.54		no trend	0.56	

Table 11. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for orthophosphorus data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
30	07195500	10/7/1992	8/17/2004	111	2	no trend	0.51		no trend	0.82		no trend	0.12	
31	07195865	10/6/1992	8/18/2004	85	0	N/A			N/A			N/A		
32	07196000	10/6/1992	8/18/2004	109	0	7.1	5.4E-11	0.09	8.2	1.2E-12	0.09	no trend	0.80	
33	07196500	10/14/1992	8/17/2004	127	0	3.3	0.017	0.05	5.4	6.6E-5	0.05	no trend	0.38	
34	07196900	6/28/1995	9/1/2004	50	14	N/A			N/A			N/A		
35	07197000	10/13/1992	8/17/2004	114	3	no trend	0.38		no trend	0.51		-5.1	0.020	14
36	07227500	1/13/1993	8/5/2004	62	36	N/A			N/A			N/A		
38	07239450	11/17/1992	9/8/2004	143	20	-4.8	0.026	0.05	no trend	0.059		-6.7	0.043	20
39	07241000	10/14/1992	9/8/2004	144	2	-4.0	0.005	0.12	-4.7	0.000	0.12	-7.8	0.001	80
40	07241520	10/14/1992	9/7/2004	132	0	no trend	0.17		no trend	0.072		-4.8	0.001	208
41	07241550	10/14/1992	9/7/2004	142	0	N/A			N/A			N/A		
42	07247015	10/13/1992	8/24/2004	91	4	-5.1	0.002	0.04	-4.7	0.008	0.04	-6.8	0.004	7
43	07247250	10/15/1992	8/24/2004	80	50	N/A			N/A			N/A		
44	07247345	10/14/1992	8/25/2004	78	56	N/A			N/A			N/A		
45	07247650	10/14/1992	8/25/2004	79	41	-6.9	1.3E-7	0.01	-6.7	6.3E-6	0.01	-7.9	9.7E-6	2
46	07249400	6/27/1995	9/7/2004	56	37	N/A			N/A			N/A		
47	07263295	12/15/1992	8/2/2004	57	35	N/A			N/A			N/A		
48	07263620	12/17/1992	9/7/2004	101	0	2.5	0.049	0.03	3.0	0.025	0.03	no trend	0.14	
50	07288650	2/16/1996	9/8/2004	100	4	no trend	0.62		no trend	0.15		no trend	0.42	
51	07288955	2/14/1996	9/10/2004	148	3	no trend	0.80		no trend	0.50		no trend	0.29	
53	07373420	10/14/1992	9/14/2004	144	0	no trend	0.52		no trend	0.71		-2.5	0.042	80,600

Table 11. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for orthophosphorus data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
						Atchafalaya system								
56	07308500	11/18/1992	8/20/2004	102	63	N/A			N/A			N/A		
59	07331000	10/21/1992	9/1/2004	111	22	-5.4	0.004	0.05	no trend	0.47		-7.8	6.3E-6	282
61	07337000	11/17/1992	8/17/2004	66	20	-5.5	0.000	0.01	-4.1	0.030	0.01	-7.6	1.2E-5	546
65	07362000	11/17/1992	8/17/2004	66	39	N/A			N/A			N/A		
66	07362587	12/15/1992	8/2/2004	60	43	N/A			N/A			N/A		
68	07381495	2/23/1993	9/13/2004	148	1	no trend	0.17		no trend	0.36		-3.2	0.021	34,700
69	07381600	10/28/1992	9/8/2004	61	0	N/A			N/A			N/A		
						Texas-Gulf system								
76	08032000	1/21/1993	9/13/2004	70	49	N/A			N/A			N/A		
77	08033500	1/22/1993	9/2/2004	70	25	N/A			N/A			N/A		
80	08049500	2/9/1993	9/14/2004	64	0	N/A			N/A			N/A		
81	08051500	2/8/1993	8/18/2004	100	66	N/A			N/A			N/A		
82	08057410	4/21/1993	8/17/2004	85	1	N/A			N/A			N/A		
83	08062500	1/19/1993	9/8/2004	60	0	N/A			N/A			N/A		
84	08064100	4/20/1993	9/15/2004	126	81	no trend	0.94		no trend	0.90		no trend	0.84	
85	08064700	1/27/1993	9/9/2004	53	15	no trend	0.46		no trend	0.30		no trend	0.97	
87	08065350	1/20/1993	9/13/2004	73	1	no trend	0.54		-3.4	0.028	0.31	-4.5	0.007	3,720
95	08114000	1/26/1993	9/25/2002	44	10	N/A			N/A			N/A		
97	08123850	11/3/1992	9/2/2003	0	0	N/A			N/A			N/A		
98	08136500	1/19/1993	6/24/2003	0	0	N/A			N/A			N/A		
101	08154700	1/14/1993	4/6/2004	45	24	N/A			N/A			N/A		
102	08155200	1/25/1993	4/6/2004	86	67	N/A			N/A			N/A		
103	08155240	11/20/1992	6/9/2004	78	52	N/A			N/A			N/A		

Table 11. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for orthophosphorus data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
104	08155300	11/20/1992	3/4/2004	48	31	N/A			N/A			N/A		
105	08156800	12/14/1992	12/23/2002	38	3	no trend	0.93		no trend	0.84		no trend	0.088	
111	08178800	1/11/1993	9/9/2004	111	12	N/A			N/A			N/A		
112	08181800	2/9/1993	9/9/2004	119	2	-6.3	9.0E-7	1.5	-5.0	1.7E-6	1.5	-4.2	0.000	1,010
115	08210000	10/13/1992	9/23/2004	48	3	N/A			N/A			N/A		

Table 12. Orthophosphorus annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[All values in table are loads in metric tons unless otherwise noted; blanks appear in table for water years at specific sites where load calculations could not be completed because of poor model fit or incomplete data sets; there were no sites in the Louisiana-Gulf/Pontchartrain system that had an adequate amount of orthophosphorus data to complete load calcuations]

Map Number (fig. 5)	Station number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load, metric tons	Average annual yield, metric tons/square kilometers/year
Mississippi system															
1	03612500	12,000	16,100	9,670	14,000	15,100	11,600	7,290	5,370	5,960	9,580	11,900	11,400	10,800	0.021
2	07022000	39,000	24,700	23,900	21,400	23,000	24,600	26,900	12,800	19,200	18,000	12,100	17,200	21,900	0.012
5	07047942	20	56	29	18	59	30	27	20	30	65	46	25	35	0.026
9	07053250		6	5	3	10	21	3	3	1	10	1	21	8	0.056
18	07077500					27	71	52	40	45	103	73		59	0.022
19	07077700						25	23	14	32	70	64	38	38	0.035
22	07103780	3	3	4	4	4	5	5	5	5	5	8		4	0.021
24	07105500	1	2	5	2	5	5	11	4	4	2	3	4	4	0.004
26	07106300	98	86	87	59	53	49	44	37	32	24	26	37	53	0.024
26	07106300	85	82	88	51	49	46	46	35	28	20	22	32	49	0.022
28	07189000	82	60		24	72	67	98	57	51	75	26	51	60	0.027
30	07195500	204	116	140	71	128	115	128	119	88	121	50	107	116	0.070
32	07196000	25	14	20	5	15	11	21	29	16	15	7	28	17	0.061
33	07196500	150	81	115	47	109	92	128	158	87	112	33	118	102	0.041
35	07197000	42	17	23	18	26	20	15	36	11	15	2	23	21	0.026
38	07239450	32	14	21	9	49	37	33	18	19	3	8	7	21	0.001
39	07241000	79	19	60	21	66	46	42	20	16	3	7	6	32	0.001
39	07241000	166	53	116	57	94	86	79	52	57	34	40	45	73	0.002
42	07247015	22	25	34	11	46	33	27	10	22	23	4	3	22	0.031
48	07263620	3,440	1,680	2,880	606	2,290	2,090	3,550	1,380	1,620	1,500	949	1,770	1,980	0.005

Table 12. Orthophosphorus annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map Number (fig. 5)	Station number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load, metric tons	Average annual yield, metric tons/square kilometers/year
50	07288650				26	73	56	27	76	115	65	54		61	0.049
51	07288955				460	1,029	679	691	406	654	1,031	1,056	771	753	0.022
53	07373420	40,300	35,500	31,500	29,500	35,300	31,400	29,800	21,000	25,600	28,200	26,400	27,000	30,100	0.010
							Atchafalaya system								
59	07331000	237	85	216	107	193	113	61	42	157	52	39	39	112	0.006
61	07337000	399	278	473	149	527	389	173	61	361	196	58	29	258	0.002
68	07381495	17,300	13,200	12,300	11,300	14,000	12,500	11,400	6,740	9,340	11,300	11,200	12,000	11,900	0.049
							Texas-Gulf system								
87	08065350	1,720	1,650	2,080	885	1,480	1,280	1,340	808	1,310	1,040	939	914	1,290	0.036
105	08156800	0.3	0.2	1	0.3	0.4	0.3	1	0.2	1	1	0.3	0.4	0.4	0.013
112	08181800	518	415	383	301	324	311	317	234	270	288	273	243	323	0.072

Table 13. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for total phosphorus data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[mg/L, milligrams per liter; kg/day, kilograms per day; N/A, analysis attempted but results not available because of poor model fit or incomplete datasets; reference concentrations and loads are blank where trend results are "no trend;" p-values and reference concentrations and loads are blank where trend results are "N/A"]

Map number (fig. 5)	Station Number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
Mississippi system														
1	03612500	10/20/1992	9/1/2004	139	0	5.6	0.001	0.08	6.0	1.4E-7	0.08	no trend	0.16	
2	07022000	11/11/1992	9/1/2004	156	0	no trend	0.097		8.9	1.1E-8	0.23	no trend	0.11	
3	07031740	5/4/1993	6/2/2004	43	1	N/A			N/A			N/A		
6	07050500	10/13/1992	8/31/2004	86	7	N/A			N/A			N/A		
7	07052152	11/24/1993	7/22/2004	64	0	no trend	0.48		no trend	0.46		no trend	0.37	
8	07052250	11/17/1992	7/21/2004	69	1	no trend	0.74		no trend	0.73		no trend	0.73	
9	07053250	4/26/1993	8/25/2004	136	34	no trend	0.36		3.1	0.021	0.04	-4.4	0.015	4
10	07055646	4/28/1993	8/25/2004	79	39	N/A			N/A			N/A		
11	07056000	10/27/1992	3/23/2004	145	55	N/A			N/A			N/A		
13	07060710	11/17/1992	8/24/2004	120	92	N/A			N/A			N/A		
18	07077500	10/12/1994	9/1/2004	59	0	N/A			N/A			N/A		
27	07106500	10/20/1992	7/22/2004	36	0	N/A			N/A			N/A		
28	07189000	11/18/1992	9/14/2004	108	3	11	3.7E-6	0.03	8.5	0.000	0.03	no trend	0.77	
29	07195000	10/13/1992	9/1/2004	70	0	no trend	0.94		no trend	0.98		no trend	0.97	
30	07195500	10/7/1992	8/17/2004	111	1	5.4	0.012	0.12	6.5	0.003	0.12	no trend	0.67	
31	07195865	10/6/1992	8/18/2004	86	0	12	0.016	0.51	11	0.005	0.51	11	0.009	17
32	07196000	10/6/1992	8/18/2004	108	0	8.3	3.9E-9	0.09	10	2.1E-12	0.09	no trend	0.64	
33	07196500	10/14/1992	8/17/2004	127	5	5.4	0.001	0.07	9.4	4.4E-9	0.07	no trend	0.75	
34	07196900	11/3/1992	9/1/2004	69	9	-5.1	0.001	0.08	-4.9	0.003	0.08	-6.9	0.001	4
35	07197000	10/13/1992	8/17/2004	114	37	no trend	0.70		5.0	0.036	0.03	no trend	0.14	

Table 13. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for total phosphorus data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station Number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
37	07228000	11/16/1992	4/8/2003	43	7	no trend	0.058		no trend	0.12		no trend	0.088	
42	07247015	11/18/1992	8/24/2004	95	0	no trend	0.50		no trend	0.81		no trend	0.094	
43	07247250	10/15/1992	8/24/2004	83	45	N/A			N/A			N/A		
44	07247345	1/6/1993	8/25/2004	74	37	N/A			N/A			N/A		
45	07247650	10/14/1992	8/25/2004	78	4	no trend	0.73		no trend	0.11		no trend	0.069	
46	07249400	10/20/1992	9/7/2004	75	25	-5.7	3.2E-5	0.06	-3.9	0.008	0.06	-7.6	1.6E-5	8
47	07263295	12/15/1992	8/2/2004	57	21	N/A			N/A			N/A		
48	07263620	12/17/1992	9/7/2004	102	0	4.0	0.000	0.08	7.4	1.6E-8	0.08	no trend	0.38	
49	07268000	11/2/1992	12/5/2001	60	4	N/A			N/A			N/A		
50	07288650	2/16/1996	9/8/2004	99	1	no trend	0.45		no trend	0.14		no trend	0.38	
51	07288955	2/14/1996	9/10/2004	146	0	4.3	0.030	0.19	no trend	0.097		no trend	0.075	
52	07290650	11/2/1992	12/5/2001	78	4	no trend	0.37		no trend	0.48		no trend	0.28	
53	07373420	10/14/1992	9/14/2004	154	0	4.1	0.000	0.18	4.4	0.000	0.18	no trend	0.65	
Atchafalaya system														
54	07299540	8/25/1993	3/4/2003	47	12	no trend	0.28		no trend	0.34		no trend	0.21	
56	07308500	11/18/1992	8/20/2004	104	5	13	0.032	0.07	56	1.4E-6	0.07	no trend	0.15	
57	07311700	11/13/1992	9/14/2004	97	68	N/A			N/A			N/A		
58	07311800	11/13/1992	9/9/2004	79	36	N/A			N/A			N/A		
59	07331000	10/21/1992	9/1/2004	110	0	no trend	0.88		12	5.1E-5	0.22	-6.5	0.005	1,310
60	07335500	8/23/1993	4/22/2003	35	0	no trend	0.64		no trend	0.84		-7.1	0.014	3,150
61	07337000	11/17/1992	8/17/2004	66	0	no trend	0.77		no trend	0.071		-5.7	0.017	4,170
63	07343000	10/27/1992	3/10/2003	37	9	no trend	0.26		no trend	0.33		no trend	0.26	
64	07355500	10/27/1992	9/23/2004	133	2	no trend	0.35		no trend	0.58		no trend	0.37	

Table 13. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for total phosphorus data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station Number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
65	07362000	11/17/1992	8/17/2004	66	22	no trend	0.55		no trend	0.59		no trend	0.51	
66	07362587	12/15/1992	8/2/2004	61	28	N/A			N/A			N/A		
67	07373000	10/27/1992	2/23/2004	0	0	N/A			N/A			N/A		
68	07381495	11/19/1992	9/13/2004	157	0	4.8	2.1E-6	0.15	6.0	2.80E-9	0.15	no trend	0.50	
Louisiana-Gulf/Pontchartrain system														
70	07375500	10/12/1992	8/24/2004	142	0	no trend	0.94		no trend	0.52		no trend	0.36	
71	07376000	11/16/1992	8/24/2004	107	0	4.5	0.010	0.07	5.2	0.004	0.07	no trend	0.95	
73	07386980	10/12/1992	9/1/2004	112	0	no trend	0.96		no trend	0.78		no trend	0.56	
74	08012150	11/17/1992	9/1/2004	55	0	N/A			N/A			N/A		
Texas-Gulf system														
78	08041000	1/19/1993	4/23/2003	53	1	6.0	0.028	0.05	6.2	0.024	0.05	no trend	0.12	
79	08044500	10/1/1992	2/19/2003	41	1	no trend	0.96		no trend	0.88		-5.6	0.043	34
81	08051500	11/2/1992	8/18/2004	97	31	N/A			N/A			N/A		
82	08057410	11/2/1992	8/17/2004	79	0	N/A			N/A			N/A		
84	08064100	10/20/1992	8/16/2004	97	13	N/A			N/A			N/A		
86	08065000	11/12/1992	4/8/2003	56	0	no trend	0.52		no trend	0.93		no trend	0.36	
88	08066500	10/20/1992	3/20/2003	101	5	no trend	0.89		no trend	0.93		no trend	0.64	
89	08069000	11/4/1992	1/22/2003	74	0	-5.5	0.006	1.5	-4.2	0.032	1.5	no trend	0.16	
90	08070200	6/2/1993	1/22/2003	85	0	6.6	0.010	0.07	6.4	0.011	0.07	no trend	0.14	
91	08073500	11/19/1992	1/30/2003	37	0	N/A			N/A			N/A		
92	08074500	11/19/1992	1/30/2003	42	0	N/A			N/A			N/A		
93	08078000	12/7/1992	2/12/2003	38	1	no trend	0.56		no trend	0.42		no trend	1.0	
94	08085500	11/5/1992	2/4/2003	35	0	N/A			N/A			N/A		
96	08117500	12/9/1992	4/9/2003	50	0	no trend	0.70		no trend	0.79		no trend	0.64	
99	08143600	11/18/1992	4/16/2003	55	1	no trend	0.96		no trend	1.0		no trend	0.65	

Table 13. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for total phosphorus data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station Number	Water-quality data start date	Water-quality data end date	Number of obser-vations	Number of cen-sored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concen-tration, mg/L	Flow-ad-justed trend, percent per year	Flow-ad-justed trend, model p-value	Flow-adjusted trend reference concen-tration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Refer-ence load, kg/day
100	08147000	11/18/1992	4/16/2003	58	12	no trend	0.058		no trend	0.072		-7.8	0.020	40
101	08154700	11/19/1992	4/6/2004	36	15	N/A			N/A			N/A		
102	08155200	1/25/1993	4/6/2004	86	62	N/A			N/A			N/A		
103	08155240	11/19/1992	6/9/2004	79	53	N/A			N/A			N/A		
104	08155300	11/19/1992	3/4/2004	49	20	no trend	0.75		no trend	0.36		no trend	0.63	
105	08156800	12/14/1992	12/23/2002	34	3	N/A			N/A			N/A		
106	08159000	10/13/1992	4/24/2003	56	22	-8.9	0.000	0.08	-9.0	0.001	0.08	no trend	0.15	
107	08162000	10/14/1992	4/2/2003	70	0	no trend	0.85		no trend	0.79		no trend	0.76	
108	08162500	10/14/1992	4/2/2003	55	1	no trend	0.42		no trend	0.39		no trend	0.82	
109	08162600	6/8/1993	3/25/2003	56	0	no trend	0.80		no trend	0.66		no trend	0.98	
110	08178565	10/20/1992	4/24/2003	93	10	N/A			N/A			N/A		
111	08178800	10/28/1992	9/9/2004	115	11	N/A			N/A			N/A		
112	08181800	10/21/1992	9/9/2004	121	0	-6.1	1.1E-9	1.5	-5.3	2.6E-9	1.6	-3.9	0.008	1,050
113	08188500	10/15/1992	4/21/2003	91	0	-5.0	7.4E-8	0.93	-5.0	8.2E-7	0.93	no trend	0.85	
114	08189500	10/14/1992	4/22/2003	40	5	no trend	0.45		no trend	0.50		no trend	0.18	

Table 14. Total phosphorus annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[All values in table are loads in metric tons unless otherwise noted; blanks appear in table for water years at specific sites where load calculations could not be completed because of poor model fit or incomplete data sets]

Map Number (fig. 5)	Station number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load	Average annual yield, metric tons/square kilometers/year
Mississippi system															
1	03612500	34,200	60,300	30,400	54,000	68,200	50,400	34,500	21,500	25,600	59,000	75,100	72,700	48,800	0.093
2	07022000	147,000	64,500	79,200	64,800	72,800	89,200	97,800	37,100	87,000	82,000	44,900	76,600	78,600	0.043
9	07053250		7	5	3	9	21	3	3	2	11	1	21	8	0.058
28	07189000	99	73	116	28	84	80	120	71	64	97	32	68	78	0.034
30	07195500	294	144	199	106	209	168	213	296	135	229	70	240	192	0.117
31	07195865					12	11	14	38	18	18	11	29	19	0.383
32	07196000	37	18	28	6	21	14	30	66	22	18	8	47	26	0.092
33	07196500	323	132	202	78	181	157	205	423	161	210	48	335	205	0.082
34	07196900	16	6	7	5	6	6	4	5	2	3	1	3	5	0.051
35	07197000	101	31	55	62	72	52	37	217	30	48	4	127	70	0.088
42	07247015	62	60	70	21	91	67	55	24	63	99	16	24	54	0.078
45	07247650	49	35	44	28	49	43	61	10	63	69	9	16	39	0.056
46	07249400	47	26	49	17	54	36	33	7	20	52	2	53	33	0.087
48	07263620	9,110	3,980	7,020	1,150	5,370	5,190	8,930	3,260	4,220	4,030	2,430	5,570	5,020	0.012
50	07288650				133	417	370	222	421	582	314	304		345	0.275
51	07288955				2,390	7,610	5,670	6,360	3,640	6,420	10,300	9,270	5,660	6,370	0.184
52	07290650	248	605	297	261	370	569	165	55	473	548	499	456	379	0.224
53	07373420	111,000	98,200	89,300	85,800	114,000	105,000	104,000	61,600	92,900	114,000	112,000	125,000	101,000	0.035
Atchafalaya system															
56	07308500	654	99	4,570	725	2,490	1,050	536	384	750	211	286	619	1,030	0.019
59	07331000	2,580	863	3,190	689	1,710	1,320	638	501	1,630	748	381	672	1,240	0.067

Table 14. Total phosphorus annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map Number (fig. 5)	Station number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load	Average annual yield, metric tons/ square kilome-ters/year
60	07335500	2,680	1,330	3,020	734	2,130	1,820	800	400	1,950	1,220	606	402	1,430	0.012
61	07337000	3,710	2,040	3,640	943	3,570	2,860	1,380	592	3,720	2,740	759	647	2,220	0.018
64	07355500	6,010	4,160	5,990	840	8,040	5,580	4,390	2,230	8,320	5,820	2,590	2,690	4,720	0.020
65	07362000	290	408	336	95	485	317	346	142	422	438	273	261	318	0.023
68	07381495	44,400	38,600	33,800	32,300	47,700	42,700	41,200	22,500	36,700	47,700	44,500	50,400	40,200	0.166
Louisiana-Gulf/Pontchartrain system															
70	07375500	300	188	269	137	246	236	102	32	192	169	351	249	206	0.123
71	07376000	55	40	55	29	53	47	26	8	47	35	70	64	44	0.069
72	07385765						203	76	29	135	109	125	200	125	
Texas-Gulf system															
78	08041000	469	336	705	171	418	454	547	169	574	419	490	454	434	0.021
86	08065000	3,180	3,020	4,560	1,220	3,670	3,000	2,950	1,700	3,610	2,810	2,150	2,530	2,870	0.086
93	08078000	41	29	48	19	43	35	21	3	34	40	35	38	32	0.141
96	08117500	338	104	203	78	272	176	325	34	195	169	253	213	197	0.104
98	08136500	12	56	43	10	136	32	7	5	19	83	29	46	40	0.002
107	08162000	812	303	995	279	1,970	809	1,190	199	768	1,020	1,160	726	853	0.008
108	08162500	1,150	295	1,250	283	2,240	943	1,530	162	823	1,110	1,320	870	998	0.009
112	08181800	907	631	574	380	462	425	478	269	376	465	395	325	474	0.105

Table 15. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for suspended-sediment data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[mg/L, milligrams per liter; kg/day, kilograms per day; N/A, analysis attempted but results not available because of poor model fit or incomplete datasets; reference concentrations and loads are blank where trend results are "no trend;" p-values and reference concentrations and loads are blank where trend results are "N/A;" there were no sites in the Louisiana-Gulf/Pontchartrain system with an adequate amount of suspended-sediment data to complete trend analyses]

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
Mississippi system														
1	03612500	10/20/1992	9/1/2004	138	0	no trend	0.081		5.7	0.002	33	no trend	0.34	
2	07022000	11/6/1995	9/1/2004	123	0	-6.5	9.20E-5	287	no trend	0.41		-8.5	1.30E-5	174,000,000
4	07047810	10/14/1992	6/8/2004	98	0	no trend	0.18		no trend	0.49		no trend	0.14	
5	07047942	11/11/1992	9/1/2004	184	0	-3.9	3.80E-5	155	-3.8	6.70E-5	155	no trend	0.35	
6	07050500	4/28/1993	8/31/2004	62	0	N/A			N/A			N/A		
9	07053250	4/26/1993	8/25/2004	137	0	9.5	0.006	12	10	0.006	12	no trend	0.85	
10	07055646	4/28/1993	8/25/2004	80	0	-4	0.045	9	no trend	0.067		no trend	0.16	
11	07056000	5/6/1993	3/23/2004	126	0	no trend	0.5		no trend	0.14		no trend	0.41	
12	07060500	11/17/1992	8/25/2004	71	0	N/A			N/A			N/A		
13	07060710	11/17/1992	8/24/2004	120	0	no trend	0.056		no trend	0.064		no trend	0.46	
18	07077500	11/10/1992	9/1/2004	91	0	no trend	0.88		no trend	0.99		no trend	0.41	
19	07077700	11/11/1992	9/1/2004	71	0	no trend	0.94		no trend	0.75		no trend	0.14	
20	07093740	10/7/1992	9/11/2003	109	0	no trend	0.17		no trend	0.32		-7.7	0.001	240
21	07103700	11/12/1992	8/4/2004	156	0	no trend	0.23		no trend	0.77		no trend	0.2	
24	07105500	10/15/1992	9/27/2004	166	0	no trend	0.4		no trend	0.98		no trend	0.34	
27	07106500	10/20/1992	8/31/2004	78	0	N/A			N/A			N/A		
29	07195000	8/3/1995	9/1/2004	54	0	N/A			N/A			N/A		
33	07196500	4/29/1993	8/17/2004	103	0	no trend	0.38		no trend	0.8		-4.9	0.047	34,000
35	07197000	5/17/1994	8/17/2004	75	0	N/A			N/A			N/A		
42	07247015	10/13/1992	8/24/2004	94	0	no trend	0.23		no trend	0.66		no trend	0.082	

Table 15. Analytical results and reference values for trends in flow-adjusted concentrations, total trend in concentrations, and trends in loads for suspended-sediment data for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004--Continued

Map number (fig. 5)	Station number	Water-quality data start date	Water-quality data end date	Number of observations	Number of censored values	Total trend, percent per year	Total trend, model p-value	Total trend reference concentration, mg/L	Flow-adjusted trend, percent per year	Flow-adjusted trend, model p-value	Flow-adjusted trend reference concentration, mg/L	Trend in load, percent per year	Trend in load, model p-value	Reference load, kg/day
43	07247250	10/15/1992	8/24/2004	82	0	no trend	0.82		no trend	0.52		no trend	0.2	
44	07247345	10/14/1992	8/25/2004	77	0	no trend	0.98		no trend	0.5		no trend	0.21	
45	07247650	10/14/1992	8/25/2004	79	0	no trend	0.63		no trend	0.055		no trend	0.1	
46	07249400	6/27/1995	9/7/2004	56	0	-5.8	0.016	41	no trend	0.094		-8.8	0.000	4,180
47	07263295	12/15/1992	8/2/2004	54	0	N/A			N/A			N/A		
48	07263620	12/17/1992	9/7/2004	99	0	-7.6	9.70E-13	87	-7	1.20E-10	87	-8.1	5.90E-7	8,370,000
50	07288650	1/23/1996	9/8/2004	99	0	no trend	0.14		-3.3	0.047	211	no trend	0.59	
51	07288955	2/14/1996	9/10/2004	148	0	no trend	0.41		no trend	1		no trend	0.21	
53	07373420	10/14/1992	9/14/2004	150	0	-3	0.001	239	-2.2	0.016	239	-4.4	0.002	322,000,000
Atchafalaya system														
61	07337000	11/17/1992	8/17/2004	66	0	-4.7	0.018	445	no trend	1		-7.3	0.001	16,200,000
62	07340300	11/18/1992	8/18/2004	58	0	N/A			N/A			N/A		
65	07362000	11/17/1992	8/17/2004	66	0	no trend	0.13		no trend	0.15		no trend	0.25	
68	07381495	2/23/1993	9/13/2004	132	0	-3.2	0.032	211	no trend	0.41		-4.6	0.021	121,000,000
69	07381600	10/28/1992	9/8/2004	200	0	no trend	0.54		no trend	0.22		no trend	0.86	
Texas-Gulf system														
81	08051500	10/21/1993	8/18/2004	74	0	N/A			N/A			N/A		
82	08057410	4/21/1993	8/17/2004	57	0	N/A			N/A			N/A		
84	08064100	4/20/1993	8/16/2004	81	0	N/A			N/A			N/A		
111	08178800	4/22/1996	9/9/2004	87	0	N/A			N/A			N/A		
112	08181800	4/16/1996	9/9/2004	102	0	no trend	0.16		-7.6	0.001	64	no trend	0.94	

Table 16. Suspended-sediment annual loads, average annual load, and average annual yield for sites in the Lower-Mississippi-Texas Basin, water years 1993-2004

[All values in table are loads in metric tons unless otherwise noted; blanks appear in table for water years at specific sites where load calculations could not be completed because of poor model fit or incomplete data sets; there were no sites in the Louisiana-Gulf/Pontchartrain and Texas-Gulf systems that had an adequate amount of suspended-sediment data to complete load calcuations]

Map Number (fig. 5)	Station number	1993 Water Year	1994 Water Year	1995 Water Year	1996 Water Year	1997 Water Year	1998 Water Year	1999 Water Year	2000 Water Year	2001 Water Year	2002 Water Year	2003 Water Year	2004 Water Year	Average annual load	Average annual yield, metric tons/square kilometers/ year
Mississippi system															
1	03612500	19,900,000	39,300,000	17,600,000	34,300,000	43,100,000	31,400,000	19,800,000	11,000,000	12,700,000	36,400,000	45,200,000	40,300,000	29,200,000	55.6
2	07022000					94,300,000	117,000,000	118,000,000	28,100,000	92,900,000	84,200,000	30,000,000	58,400,000	77,900,000	59.8
4	07047810	581,000	928,000	603,000	303,000	1,170,000	780,000	741,000	240,000	256,000	1,350,000	744,000	489,000	682,000	56.6
5	07047942	54,800	117,000	69,200	46,200	121,000	64,400	60,000	39,800	56,000	88,200	62,300	36,800	68,000	49.1
9	07053250		1,480	1,800	1,770	3,490	3,860	2,520	2,400	1,510	3,760	856	1,620	2,280	16.7
11	07056000	138,000	72,000	294,000		259,000	90,000	54,900	118,000	70,400	445,000	48,100		159,000	74.0
13	07060710	900	889	1,390	999	2,890	1,620	1,380		912	3,590	729	1,030	1,480	9.86
18	07077500					32,200	145,000	107,000	84,000	93,300	165,000	134,000		109,000	40.4
19	07077700						84,100	67,700	32,800	75,100	134,000	113,000	54,900	80,200	73.6
24	07105500	11,400	52,200	295,000	23,500	207,000	63,100	1,130,000	29,600	30,600	12,700	12,600	34,200	158,000	156
33	07196500	198,000	69,300	151,000	58,800	135,000	124,000	147,000	505,000	112,000	109,000	13,600	161,000	149,000	59.9
42	07247015	36,900	34,300	45,300	11,900	66,300	37,100	32,200	14,400	35,300	74,600	5,620	13,600	34,000	48.7
43	07247250	6,250	3,980	4,490	957	8,190	3,580	5,330	2,480	3,920	7,980	901	1,540	4,130	21.4
44	07247345	13,400	8,710	9,620	2,250	15,900	8,680	10,100	4,720	9,520	17,200	2,270	3,130	8,790	18.9
45	07247650	50,800	35,000	45,000	29,000	52,200	46,000	62,500	8,010	69,400	85,100	8,620	15,100	42,200	60.4
46	07249400	29,000	19,500	27,500	11,100	27,200	20,200	21,900	4,790	14,200	25,700	2,260	20,100	18,600	48.9
48	07263620	23,100,000	7,460,000	12,800,000	971,000	6,060,000	5,670,000	7,540,000	1,770,000	2,150,000	1,500,000	498,000	1,240,000	5,890,000	14.4
50	07288650				118,000	359,000	296,000	181,000	306,000	396,000	210,000	200,000		258,000	206
51	07288955				2,630,000	8,160,000	5,700,000	5,750,000	2,580,000	5,500,000	10,200,000	9,440,000	5,380,000	6,150,000	178
53	07373420	157,000,000	131,000,000	105,000,000	92,800,000	128,000,000	108,000,000	100,000,000	46,900,000	75,600,000	90,900,000	79,900,000	86,500,000	100,000,000	34.3
Atchafalaya system															
61	07337000	23,400,000	10,400,000	19,600,000	3,260,000	18,000,000	14,800,000	4,670,000	1,500,000	17,100,000	11,900,000	1,770,000	1,390,000	10,600,000	85.5
65	07362000	374,000	487,000	396,000	117,000	578,000	337,000	370,000	167,000	429,000	442,000	274,000	257,000	352,000	25.4
68	07381495	75,900,000	63,500,000	43,700,000	37,400,000	70,300,000	54,100,000	49,300,000	16,700,000	35,900,000	51,100,000	39,700,000	44,300,000	48,500,000	201
69	07381600				25,500,000	59,200,000	34,200,000	38,900,000	21,700,000					35,900,000	

Rebich, R.A., and Demcheck, D.K.—**Trends In Nutrient and Sediment Concentrations and Loads In Major River Basins of the South-Central United States, 1993-2004**—USGS Scientific Investigations Report 2007-5090

Printed on recycled paper