

What are the history, status, and likely future of water quality in southern watersheds?

## Chapter 19: Water Quality in the South

*Ben West*  
Region 4, U.S. Environmental  
Protection Agency

### Key Findings

- Significant water-quality impairment, forest loss, and wetland loss have occurred in the South since the time of European settlement; however, water quality has generally improved since the passage of the Clean Water Act in 1972.
- Based on a national watershed characterization program, approximately 30 percent of the South has relatively good water quality, 36 percent has moderate water-quality problems, and 15 percent has more serious water-quality problems; approximately 19 percent of the South, primarily in western Texas, does not have sufficient information to provide a characterization of the status of water quality.
- The leading causes (pollutants) of water-quality impairment in the South from 1988 to 1998 were siltation (sedimentation), pathogens (bacteria), and nutrients (nitrogen and phosphorous).
- The leading sources of water-quality impairment in the South from 1988 to 1998 were agriculture and urbanization; silviculture ranked 9<sup>th</sup> out of the 10 major sources of impairment during this time.
- Approximately 70 percent of all pollution came from nonpoint sources.
- Southern forests are a vital factor in maintaining and improving water quality in the South. Forested watersheds have consistently been shown to have lower sediment and nutrient yields with better

aquatic biological conditions than nonforested watersheds.

- The primary factor affecting the future of water quality in the South is control of nonpoint-source pollution from agriculture and urbanization, primarily urban sprawl.

- The future of water quality in the South is highly dependent on the success of future mandates and programs such as the Clean Water Action Plan and Unified Watershed Assessment restoration priorities, as well as citizen involvement in watershed protection, including public education and voluntary initiatives.

- Agencies responsible for monitoring water quality in the South should develop standard assessment and reporting criteria for determining the causes and sources of impairment and describing the level of confidence in the classification.

### Introduction

Approximately 935,000 miles of rivers and streams flow across the South. These waterways are important in defining the landscape and in providing habitat for many of the South's plants and animals. They also have significant economic values that are of great importance but are often overlooked. Rivers, lakes, estuaries, and wetlands provide flood protection and support industry. Recreation activities such as fishing, boating, and rafting generate jobs, economic benefits, and tax revenue to the region. In addition, much of the South's drinking water is obtained from surface-water sources.

As the South continues to enjoy strong economic growth, increasing demands and threats are placed upon our river systems. These threats directly affect the natural and historical heritage of our rivers, and, ultimately, public health and quality of life. Threats are varied and include pollution and impacts from many sources, including residential development, construction, municipal and industrial stormwater runoff, agricultural runoff (containing sediments, pesticides, herbicides, and fertilizers), deforestation, impoundments, channel alteration, and introduction of exotic species.

In recognition of these threats, there is a growing public awareness of the importance of aquatic resources and the need to manage land to protect, maintain, and restore water quality. All Southern States have adopted a watershed-based approach to controlling water pollution and improving water quality. A watershed is an area of land in which water flows across the land surface and drains into a particular marsh, stream, river, or lake. Watersheds can vary in size from a few acres to thousands of acres (U.S. Environmental Protection Agency 2001d). A watershed management approach accounts for a watershed's unique needs and recognizes that water quality is a function of not just one stream, but rather the entire watershed.

This chapter provides an overview of the history, status, regulatory controls, and likely future of water quality in southern watersheds. The relative impacts of land uses on water quality over time are evaluated, as are the ways in which point and nonpoint sources of pollution have influenced water quality. The original intent of this chapter was

to describe water quality only in forested watersheds. However, in order to address the range of topics described previously and to respond to specific public comments about this chapter, all watersheds are included in this evaluation. The result is a more comprehensive overview of water quality in the South. A discussion of the role of forests in protecting water quality in the South is also included in the section: "Role of forests in protecting water quality."

## Methods

Information presented is limited to published literature, other regulatory reports, and personal interviews conducted with water-quality experts in the South. The status of water quality was examined and reported at various scales across the South, including the whole region, individual States, ecological regions, and individual watersheds.

There are numerous linkages and areas of overlap between this chapter and other chapters in this Assessment. To avoid redundancy and enhance integration with other Assessment questions, the reader is referred to other chapters where information is presented in greater detail.

## Data Sources

### Spatial Data

The United States is divided and subdivided into successively smaller hydrologic units. Four levels are recognized: (1) regions, (2) subregions, (3) accounting units, and (4) cataloging units. These hydrologic units are arranged within each other, from the smallest (cataloging units) to the largest (regions). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification (U.S. Geological Survey 2001a).

Individual watersheds were delineated using the U.S. Geological Survey (USGS) cataloging unit classification system, or eight-digit HUC, in which the last digit represents the smallest consistent watershed size throughout the South. Watershed information was summarized for all watersheds that are

wholly or partially located in the 13-State study area. Using this system, the South is divided into 672 watersheds. The average size of these watersheds at this scale is approximately 810,000 acres.

Ecological regions were delineated at the ecological province, following the National Hierarchical Framework of Ecological Units (ECOMAP 1993). There are 11 ecological provinces in the South. A complete description of the ecological provinces in the South is included in chapter 16.

### Land Use Data

The primary source of land use data, particularly forest cover, for this chapter was the Forest Inventory and Analysis (FIA) plot-level data assembled for this Assessment (U.S. Department of Agriculture, Forest Service 2001). Information contained in the FIA database is derived from a series of permanent plots across the South and is typically reported at the State and county level. A complete discussion of the FIA Eastwide database is provided by Hansen and others (1992).

The most current survey data from each State were aggregated across the South to create a current survey for the South (representing the 1990s). Information on the most recent survey for each State is included in chapter 16. Individual plots were assigned an eight-digit HUC and aggregated at the watershed level. Land uses from the FIA database representing forested land were selected and summarized by individual watershed to determine the percentage of forest in each watershed. That percentage was calculated by dividing the forest area by the total watershed area.

### Water-Quality Data

The following sources of water-quality data were used to compile this chapter:

- Literature surveys.
- Interviews with The University of Georgia (UGA) staff.
- U.S. Environmental Protection Agency (USEPA) National Water Quality Inventories, in reports to Congress.
- USEPA Index of Watershed Indicators.
- Unified Watershed Assessment data from each of the 13 Southern States.

■ USGS National Water Quality Assessment (NAWQA) Program Studies.

## Results

### History of Water-Quality Conditions in the South

This section is confined to key points about the history of water quality in the South. A discussion of the history of southern forests and land use change in the South is included in chapters 6 and 24.

Little information is available on water quality in the South prior to the 20<sup>th</sup> century. Erosion resulting from Native American transportation and agricultural practices has been characterized as minimal (Binkley and Brown 1993, Sedjo 1991). Causes of erosion during this period included fires, mass soil movement, natural stream erosion, and animal trails. For example, migration of buffalo was correlated with an increase in stream turbidity (Trimble 1974).

Early descriptions repeatedly characterized streams as clear and dark as opposed to the brown or red color that now dominates southern streams (Trimble 1974). Early explorers described a shiny substance in streams, which may have indicated the presence of mica (Trimble 1974). Mica is no longer abundant in the majority of streams in the Southeast, presumably due to manmade erosion of upland soils into streams. The average soil loss in the North Carolina Piedmont was less than one-tenth inch per 1,000 years prior to European settlement. Current rates of soil loss from clean cultivated land are 80 to 300 inches per 1,000 years (Trimble 1974).

Settlement by Europeans resulted in large-scale ecological changes that continue to affect water quality (Trimble 1974). Throughout the early settlement period, water quality declined as land cover shifted from mature forests to agricultural fields (Trimble 1974). Sedimentation and erosion were the primary causes of water-quality impairment. It has been estimated that an average of 5.9 inches (15 cm) of soil have been lost in the Southeast due to erosion since the time of European settlement (Binkley and Brown 1993). Cotton, tobacco, and small plots of

corn dominated agricultural crops through 1860. Cotton plantations were the primary source of water-quality impairment during this period (Trimble 1974).

The period between 1860 and 1920 was the most destructive in the South with regard to water quality due to widespread clearing of forests for fuel, timber, wood products, and crops (Trimble 1974). Forest clearing without erosion control measures resulted in increased sedimentation and severe water-quality impairment (Mac and others 1998). Logging activities peaked in 1909 and remained high until 1920. By 1920, only a small area of virgin forest remained. After the Civil War, agriculture continued to be the most important land use in the South. Increased soil erosion rates due to inadequate conservation practices and increased use of fertilizers accelerated the degradation of water quality (Trimble 1974). Southern rivers filled with sediments from upland soils.

Comprehensive water-resource research was largely initiated during this period. The first watershed experiment, called the Wagon Wheel Gap study, was conducted in 1909. This Colorado study focused on the effects of deforestation on the volume and timing of streamflow, soil erosion, and sediment loading (Megahan and Hornbeck 2000).

Between 1920 and 1972, people migrated to cities as industry became the dominant force in the United States economy. Less wood was used for fuel and roads, resulting in a decrease in the demand for wood (Sedjo 1991). Due to this decreased demand, logging and land-clearing activities were significantly reduced. Therefore, adverse effects on water quality from these activities also declined.

The effect of agricultural land use practices became evident in the 1930s with the onset of the Great Depression (Mac and others 1998). Losses of fertile soil due to the intensity and types of agriculture practices, as well as drought conditions, resulted in the Dust Bowl of the 1930s and the abandonment of farmland (Meyer 1995). Soil erosion during this time period adversely affected water quality, primarily due to sedimentation of rivers and streams.

Draining of wetlands, which serve as filters for surface-water runoff, was

another contributing factor to water-quality impairment. Between 1950 and 1970, 11 million acres of wetlands were lost in the United States (Meyer 1995). A complete discussion of the history of forested wetlands in the South is provided in chapter 20. Flooding was also a problem during this period, and the Flood Control Act of 1936 brought about the modification of major rivers, such as the Mississippi. River channels were widened and dredged to facilitate navigation. These practices had devastating effects on many aquatic species, by removing or covering benthic habitat. A complete discussion of aquatic species and habitats is included in chapter 23.

In the late 19<sup>th</sup> and early 20<sup>th</sup> centuries, waterborne disease occurred in urban centers as populations came into contact with water bodies contaminated with sewage. Diseases such as cholera were transmitted through inadequate disposal of human waste, and typhoid fever outbreaks occurred as cities began to develop (Chase 1952, Cowdrey 1996). As a result, sanitary engineering (later called environmental engineering) developed technologies to reduce waterborne illnesses by treating sewage prior to discharging it into water bodies (Chase 1952). Industrialization in the South also created water-quality problems during this period. The petrochemical, paper, and automotive industries are a few of the industries that impacted water quality by discharging industrial wastes directly into water bodies (Cowdrey 1996).

Pesticide use increased dramatically after World War II. Overspraying resulted in numerous instances of harmful levels of pesticides in soil and water. Toxic compounds such as dichlorodiphenyltrichloroethane (DDT) were used without restrictions. In 1962, Rachel Carson's "Silent Spring" highlighted the effects of DDT, which include contamination of water supplies and thinning of predatory bird eggshells. In 1972, the use of DDT was banned (Cowdrey 1996).

As a better understanding of the interdependence of water quality and land use practices was developed, legislation at local, regional, and national levels was passed to address the management and preservation of natural resources. According to the USEPA, only a third of the Nation's waters were safe for fishing and

swimming in 1972 (U.S. Environmental Protection Agency 2001a). In response to the situation, the Federal Water Pollution Control Act, or Clean Water Act (CWA), was passed in 1972. This act significantly changed the way the Federal Government and individual States regulated and reported on water quality. In addition, State and local mandates were developed to regulate sources and causes of water-quality impairment on a local level. Land-disturbance activities and urban development are subject to regulations and guidelines at the State and local level via sedimentation and erosion-control management plans, zoning, permits, and implementation of best management practices (BMPs). The CWA and other laws and regulations that affect water quality in the United States are summarized and discussed in detail in chapter 8, primarily as they relate to silvicultural practices.

Subsequent to the passage of the CWA, a comprehensive analysis of water quality in rivers was conducted (Smith and others 1987). This study utilized data from the National Stream Quality Accounting Network (NASQAN) and the National Water Quality Surveillance System (NWQSS). In general, results of this study indicated that point-source pollution had decreased on a national scale, and nonpoint-source pollution had increased since passing of the CWA (Smith and others 1987). A complete discussion of point and nonpoint sources of pollution is included in the section "National Water Quality Inventories: leading sources of impairment (1988-98)."

In the South, decreases in bacteria associated with municipal wastewater discharges were noted, especially in parts of the Gulf of Mexico, central Mississippi, and Arkansas. However, localized increases in bacteria were noted in association with point-source livestock waste discharges. A dramatic increase in suspended sediment, nutrients, phosphorous, and nitrate was observed due to increased fertilizer applications, other agricultural practices, and high soil erosion rates. In addition, atmospheric deposition was positively correlated with increases in nitrate concentrations, especially in forested basins. In contrast, a decrease in phosphorous concentrations was noted in the upper Mississippi Valley.

An increase in contaminants such as metals was observed primarily due to fossil fuel combustion, metal manufacturing, pesticides, and herbicides. However, a widespread decrease in lead concentrations was observed due to a 67-percent drop in leaded gasoline consumption (Smith and others 1987).

## Current Status of Water Quality in the South

Concerns about water quality in the South have engendered proactive research, monitoring, and control programs. In addition, public and private stakeholders are supporting the development of comprehensive watershed assessments and related studies. The goal of these programs and studies is to assess and improve water quality in the United States, including the South. Two primary programs have been developed to report information on water quality: (1) National Water Quality Inventories, and (2) USEPA Index of Watershed Indicators (IWI). The National Water Quality Inventories provide information at the regional and State levels, and the IWI program provides information about water quality in individual watersheds (USGS eight-digit HUC). These and other regional assessment programs such as the USGS NAWQA and Southern Appalachian Assessment are summarized in this section.

**National Water Quality Inventories**—To assess progress toward the goals of the CWA, States, tribes, and other jurisdictions adopt water-quality standards, which must be approved by the USEPA. Water-quality standards have three elements (U.S. Environmental Protection Agency 2000b):

1. Designated uses: All waters of the United States are required by law to be designated for beneficial uses. Examples include drinking water supply, contact recreation (swimming), and support of warm- and coldwater fisheries. States are responsible for assigning designations and can designate multiple uses for the same water body.
2. Criteria: Scientists establish criteria necessary to protect the designated uses. Criteria can include chemical-specific thresholds that protect fish and humans from adverse health

effects as well as biological and habitat conditions.

3. Antidegradation policy: The antidegradation policy is intended to prevent waters from deteriorating from their current conditions. Therefore, States cannot change a water body's designated use(s) to lower water-quality standards without extensive justification.

The status of the Nation's waters is determined by assessing the degree to which the States' water-quality standards are met (U.S. Environmental Protection Agency 1994). States, tribes, and other jurisdictions are required and/or encouraged, under Section 305(b) of the CWA, to submit a report to the USEPA on the status of their water bodies. For purposes of this section, discussion is limited to State 305(b) reports and does not include reports from tribes or other jurisdictions. States are required to submit updated 305(b) reports once every 2 years. According to Section 305(b) of the CWA, reports should include the following:

- A description of water quality for all navigable waters in the State.
- An analysis of the extent to which all navigable waters in the State provide for the protection and propagation of shellfish, fish, and wildlife, and allow recreational activities in and on the water.
- An analysis of the extent to which the elimination of the pollutants has been or will be achieved to meet water-quality standards.
- Recommendations of actions needed to achieve the water-quality standard.
- An estimate of the extent of environmental impact and the economic and social costs and benefits associated with achieving the water-quality standard, and the date by which the water-quality standard will be achieved.
- A description of the nature and extent of nonpoint sources of pollutants and recommendations of programs to control these sources, including costs to implement such controls.

The CWA requires States to assess the degree to which waters meet adopted water-quality standards. In order to meet this requirement, States examine two types of data: monitored data and evaluated data. Monitored data supply quantitative information including field

measurements that are not more than 5 years old, such as biological, habitat, toxicity, and/or physical/chemical conditions in water bodies, sediments, and fish tissues. Evaluated data are quantitative and/or qualitative information frequently used to fill data gaps. Evaluated data include field measurements that are more than 5 years old, estimates generated using land use and source information, predictive models, and surveys from fish and game biologists (U.S. Environmental Protection Agency 2000b). An example of this process follows: The degree to which the Georgia water-quality standard for streams classified as fishable must be assessed. The standard is that fishable streams must contain less than 1,000 fecal coliform bacteria per 100 ml of water for the months of November through April (Georgia Water Quality Control Act 391-3-6.03). If monitored or evaluated data indicate that fecal coliform exceeds this standard, the fishable use criterion is not supported.

Depending on the degree to which designated uses are supported, States place assessed waters into the following categories (U.S. Environmental Protection Agency 2000b):

1. Fully supporting overall use: A water body that meets all of the established criteria for designated beneficial uses.
2. Threatened overall use: A water body that fully supports all of its designated beneficial uses but is in danger of not fully supporting one or more of the uses.
3. Partially supporting overall use: A water body that does not meet all of the established criteria for one or more of its designated beneficial uses.
4. Not supporting overall use: A water body that does not meet any of the established criteria for one or more of its designated beneficial uses.
5. Not attainable: A water body for which one or more designated beneficial uses is not achievable due to natural conditions or human activity that cannot be reversed without imposing widespread economic and social impacts. This category is derived by a State-conducted use-attainability study.

Impaired waters are defined as any water body that is classified as partially supporting or not supporting overall use. Impaired water bodies are

summed, and the State reports the amount of total impaired waters.

The USEPA compiles the information in State 305(b) reports and submits a summary report entitled “National Water Quality Inventory Report to Congress” (National 305(b) Reports). These reports are the principal vehicle for informing Congress and the public about general water-quality conditions in the United States. Discussions and data for this chapter are based on the information included in the National 305(b) Reports.

**National Water Quality Inventories: general trends in water quality (1988-98)**—The National 305(b) Reports from 1988 to 1998 were evaluated to identify recent trends in water quality in the South (U.S. Environmental Protection Agency 1990, 1992, 1994, 1996, 1998a, 2000b). These reports include summaries of water quality for rivers and streams, lakes, reservoirs, ponds, tidal estuaries, shoreline waters, coral reefs, wetlands, and ground water in individual States. In this chapter, only water quality of rivers and streams in the South is reported. The National 305(b) Reports do not describe the health of all rivers and streams in the South because the States have not comprehensively assessed all their waters. Due to funding and monitoring constraints, States only assess a subset of total waters. Therefore, the health of only those portions of rivers and streams assessed and reported in individual State water-quality inventories are summarized in this chapter.

Southern States assessed a total of approximately 149,260 river miles in 1988 and approximately 231,600 river miles in 1998 (U.S. Environmental Protection Agency 1990, 2000b). The term “river miles” is used interchangeably with “river and stream miles” in this chapter. Assessed river miles increased by 55 percent over this 10-year period. The 231,600 assessed river miles in 1998 represent approximately 25 percent of the South’s total river and stream miles, which is consistent with the percent assessed nationwide in 1998. This amount is considerable because only approximately 470,000 river miles in the South are perennial waters (flow year round). The remaining 463,000 river miles are intermittent or ephemeral,

which means they are dry for some or most of the year.

As described previously, each State reports the assessed river miles as fully supporting, partially supporting, or not supporting overall use. The last two categories represent impaired river miles. From 1988 to 1998, 9 of the 13 Southern States reported an increase in impaired river miles. The percentage of river miles that were impaired rose from 26 to 45 during the 10-year period. In 1998, Southern States reported that 55 percent of the 231,600 assessed river miles fully support all of their uses. This percentage is slightly lower than the nationwide percentage in 1998 (65 percent). Of the fully supporting river miles, 10 percent (approximately 23,700 river miles) were considered threatened. These threatened waters may need special attention and additional monitoring to prevent further deterioration. Some form of pollution or habitat degradation impairs the remaining 45 percent (103,441 river miles) of the assessed river miles.

The designation of river miles as being impaired is a complicated process that varies among reporting cycles and States. In many cases, States do not use directly comparable criteria and

monitoring strategies to measure their water quality. Therefore, States with strict criteria for defining healthy waters are more likely to report that a high percentage of their waters are not fully supporting designated uses. Similarly, States with comprehensive monitoring programs are more likely to identify more water-quality problems. Because of these issues, it is likely that the increase in impaired miles from 1988 to 1998 is related to the overall increase in assessed river miles. As a result, one cannot assume that water quality is worse now than in 1988 just because an individual State reports a higher number or percentage of impaired waters. A more thorough discussion of the data limitations of the 305(b) reports is included in section “National Water Quality Inventories: Limitations of the National 305(b) Reports.”

**National Water Quality Inventories: leading causes of impairment (1988-98)**—Each State identifies causes and sources of impairment of rivers and streams in order to determine where improvements are needed, and to assess the effectiveness of current water-quality programs and protection policies. Causes of impairment are pollutants, practices, or processes that

**Table 19.1—Common causes of pollution summarized from National Water Quality Inventory Reports**

Cause of impairment	Description of cause
Nutrients	Nitrates found in sewage and fertilizers and phosphates found in detergents and fertilizers.
Siltation (sedimentation)	Wash off plowed fields, construction and logging sites, urban areas, strip-mined land, and eroded stream banks.
Pathogens (bacteria)	Inadequately treated sewage, storm water drains, septic systems, runoff from livestock pens, and boats that dump sewage.
Organic material	Sewage, leaves and grass clippings, and runoff from livestock feedlots and pastures.
Metals	Industrial discharges, runoff from city streets, mining activities, and leachate from landfills.
Pesticides and herbicides	Runoff from croplands, lawns, and termite control.
Habitat modification	Grazing, farming, channelization, dam construction, and dredging.

Source: U.S. Environmental Protection Agency 1994.

result in numeric or narrative support criteria being exceeded. Specific causes of impairment may include chemical contaminants (such as polychlorinated biphenyls, dioxin, and metals), physical conditions (such as temperature), and biological conditions (such as aquatic weeds) (U.S. Environmental Protection Agency 1998a). A water body may be affected by multiple causes. Descriptions of the common causes of pollution included in the National 305(b) Reports are provided in table 19.1. The leading causes of pollution in southern rivers and streams from 1988 to 1998 were siltation (sedimentation), pathogens (bacteria), nutrients, and organic enrichment.

**National Water Quality Inventories: leading sources of impairment (1988-98)**—Once the cause of impairment is identified, the States report the estimated source of the impairment. There are two broad categories of sources of pollution: (1) point-source pollution and (2) nonpoint-source pollution. The fundamental difference between these two categories is the manner in which the pollutant reaches the water body, which is often directly related to land use. The current statutory definition of a point source is as follows (Water Quality Act, Sec. 502-514, U.S. Congress, 1987):

The term “point source” means any discernible, confined, and discrete conveyance, including, but not limited to any pipe, ditch, channel, tunnel, conduit, well discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.

Research conducted in the late 1970s indicated that over half of all water pollution was due to nonpoint sources (Neary and others 1989). Therefore, the CWA was amended in 1987 to place more emphasis on proactive approaches for controlling nonpoint-source pollution (Novotny and Olem 1994). Nonpoint-source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, or seepage. Descriptions of the common point and nonpoint sources of pollution identified in the National 305(b) Reports are provided in table 19.2. As is the case

**Table 19.2—Common sources of pollution summarized from National Water Quality Inventory Reports**

Source of impairment	Description of source
Point sources	
Municipal	Publicly owned sewage treatment plants that may receive indirect discharges from industrial facilities or businesses.
Storm sewers/urban runoff <sup>a</sup>	Runoff from impervious surfaces including streets, buildings, lawns, and other paved areas that enters a sewer, pipe, or ditch before discharge into surface waters.
Industrial	Pulp and paper mills, chemical manufacturers, steel plants, textile manufacturers, and food processing plants.
Land disposal <sup>a</sup>	Leachate or discharge from septic tanks, landfills, and hazardous waste sites.
Nonpoint sources	
Agriculture	Crop production, pastures, rangeland, feedlots, and other animal holding areas.
Hydrologic/habitat modification	Channelization, dredging, dam construction, flow regulation; removal of riparian vegetation, streambank modification, drainage/filling of wetlands.
Resource extraction	Mining, petroleum-drilling, runoff from mine tailing sites.
Construction	Land development, road construction.
Silviculture	Forest management, tree harvesting, logging road construction.
Natural	Non-man-induced impacts, such as floods, hurricanes, leachate from naturally occurring metals, and wildlife.

<sup>a</sup> Storm sewers/urban runoff and land disposal include both point and nonpoint sources. Source: U.S. Environmental Protection Agency 1998a.

with causes of impairment, a river mile or water body may be affected by multiple sources.

A source of pollution is often the land use practice that generates a reported cause of impairment; therefore, causes and sources of impairment are interlinked. One particular cause may originate from multiple sources. For example, sedimentation can originate from agricultural practices, urban stormwater runoff, and/or road construction sites. Similarly, one particular source may generate multiple causes or pollutants. For example, silvicultural practices can generate

sedimentation, nutrient loading, and pesticide inputs. The interconnection between causes and sources is summarized in table 19.3.

The 10 leading point and nonpoint sources of impairment for rivers and streams in the South from 1988 to 1998 are depicted in figure 19.1. The relative contributions of point and nonpoint sources of pollution in rivers and streams in each of the Southern States are shown in figure 19.2. During this time, nonpoint sources contributed annually almost 70 percent of the total pollution to impaired rivers

**Table 19.3—Interrelationship between common sources and causes of pollution**

Source of impairment	Siltation (sediment)	Pathogens (bacteria)	Nutrients <sup>a</sup>	Organic enrichment	Pesticides	Metals	Habitat modification
Point sources							
Municipal		X	X	X		X	
Storm sewers/urban runoff <sup>b</sup>	X				X	X	
Industrial	X	X	X	X	X	X	X
Land disposal <sup>b</sup>		X	X	X		X	
Nonpoint sources							
Agriculture	X	X	X	X	X		X
Hydrologic/habitat modification	X		X	X	X		X
Resource extraction	X					X	X
Construction	X						
Silviculture	X		X	X	X		X
Natural	X	X	X	X		X	X

<sup>a</sup> Nutrients include nitrogen and phosphorus.

<sup>b</sup> Storm sewers/urban runoff and land disposal include both point and nonpoint sources.

Source: U.S. Environmental Protection Agency 2000b.

Figure 19.1—Annual average contribution of point and nonpoint sources of pollution to impaired river miles from 1988 to 1998 in the South (U.S. Environmental Protection Agency 1990, 1992, 1994, 1996, 1998a, 2000b).

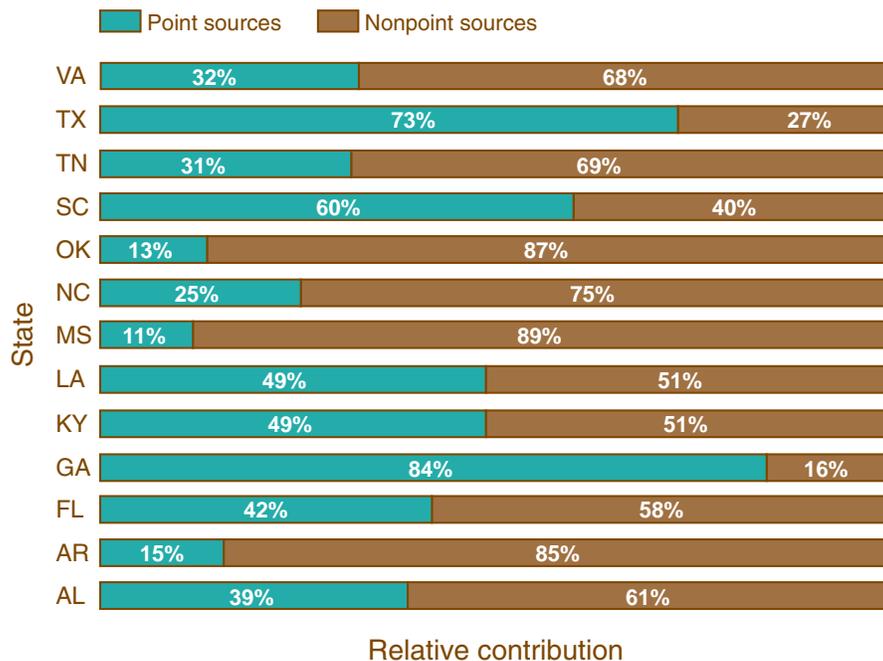
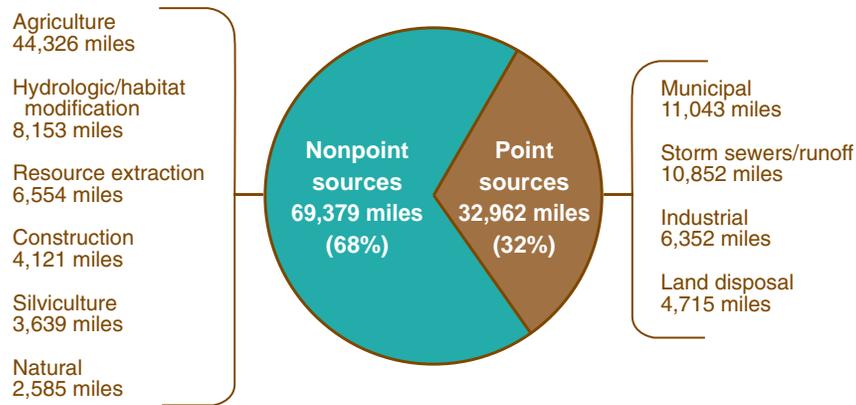


Figure 19.2—Relative percent contribution of point and nonpoint sources of pollution to impaired river miles from 1988 to 1998 (U.S. Environmental Protection Agency 1990, 1992, 1994, 1996, 1998a, 2000b).

and streams. In the South, as well as nationwide, agricultural activities, such as crop production and animal operations, were the most widespread sources of pollution in assessed rivers and streams. Agriculture accounted for almost half of the total pollution, greater than all point-source discharges combined. After agriculture, the States reported that municipal treatment plants, storm sewers/urban runoff, and hydrologic/habitat modification were the most common sources of impairment during this 10-year timeframe. Silviculture ranked 9<sup>th</sup> out of the 10 major sources of impairment during this time. Each of the leading sources of impairment is grouped into major land use practices, and the impacts of these practices are discussed in the section “Land Use Impacts on Water Quality.”

The leading sources of impairment for rivers and streams in individual Southern States from 1988 to 1998 are shown in figure 19.3 and reported in table 19.4. With the exception of Georgia and Texas, agricultural activities were the leading sources of pollution in each State during this time. Storm sewer discharges and urban runoff were the largest sources of pollutants in Georgia, and municipal discharges were the largest source of pollutants in Texas. The designation of river miles as being impaired by a specific source is a complicated process that varies among reporting cycles and States. Data limitations of the 305(b)

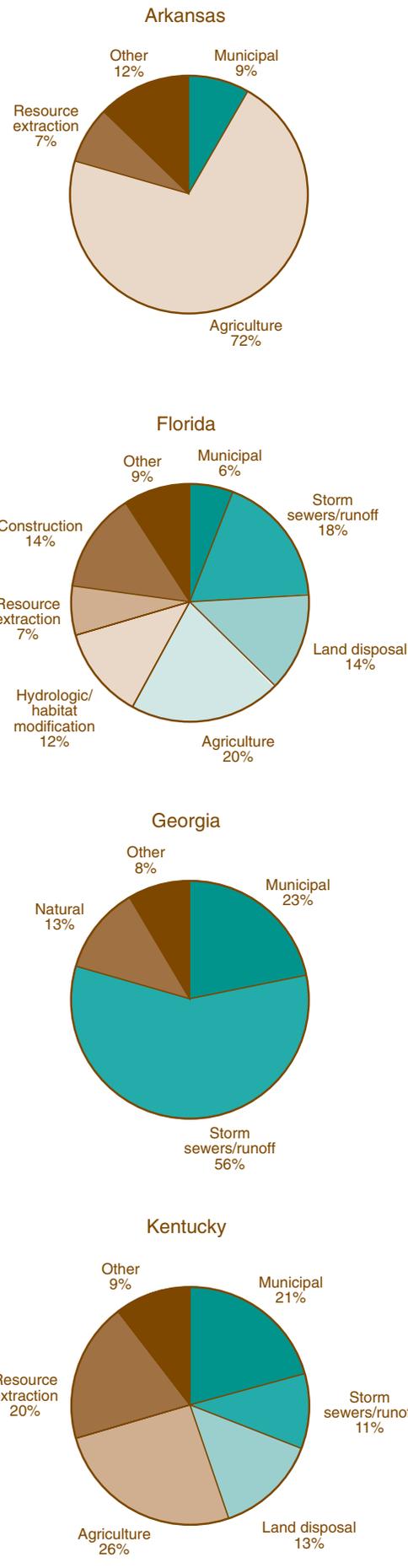
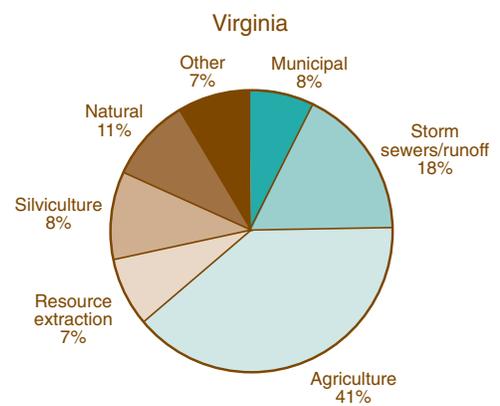
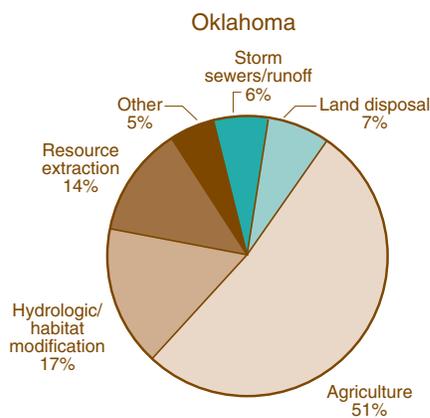
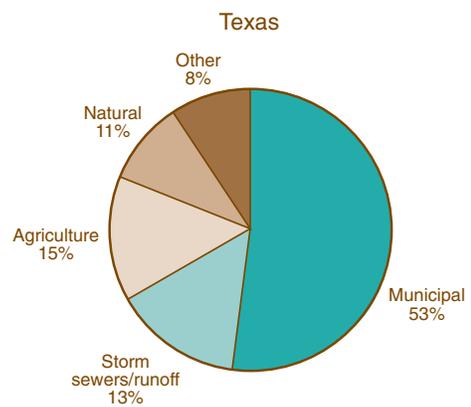
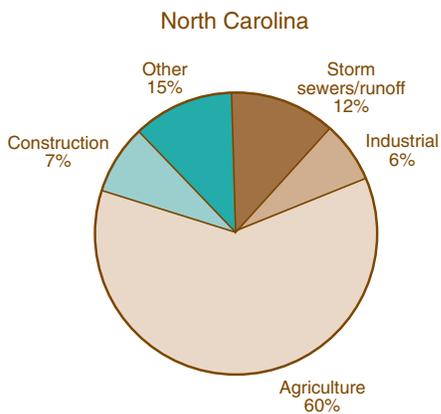
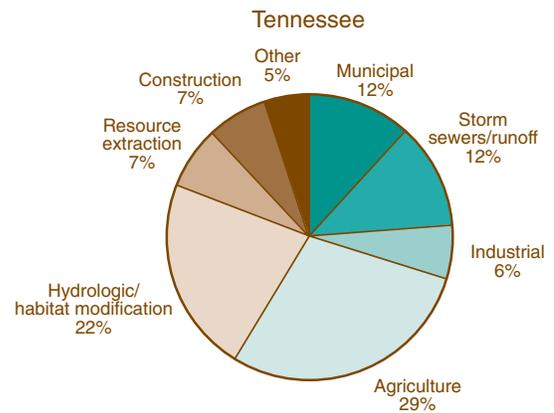
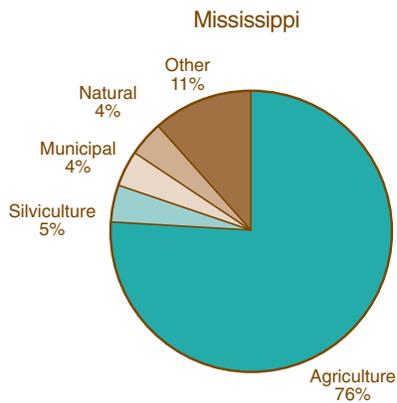
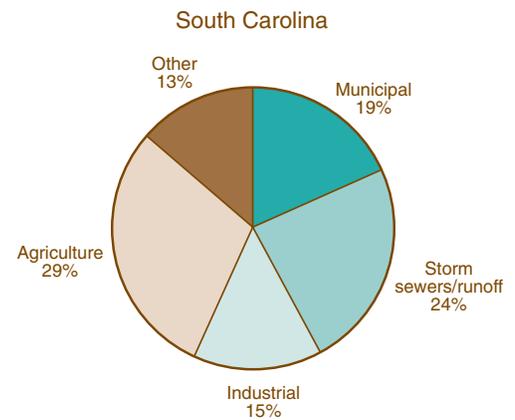
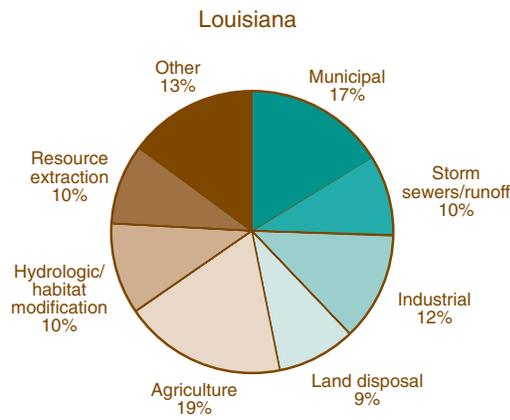


Figure 19.3—Leading sources of impairment of rivers and streams in Southern States from 1988 to 1998 (U.S. Environmental Protection Agency 1990, 1992, 1994, 1996, 1998a, 2000b).

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**Table 19.4—Leading sources of impairment of rivers and streams in Southern States from 1988 to 1998**

Source of impairment <sup>a</sup>	AL	AR	FL	GA	KY	LA	MS	NC	OK	SC	TN	TX	VA
----- Annual average impaired miles <sup>b,c</sup> -----													
<b>Point sources</b>													
Municipal	642	318	575	468	1,149	3,335	1,076	296	0	974	1,994	1,522	211
Storm sewers/runoff <sup>d</sup>	260	40	1,775	1,162	599	1,880	605	898	513	1,251	1,995	375	472
Industrial	321	184	476	99	217	2,432	952	496	14	804	1,023	123	143
Land disposal <sup>d</sup>	69	27	1,364	1	731	1,847	272	260	515	105	270	78	40
<b>Total</b>	<b>1,292</b>	<b>569</b>	<b>4,190</b>	<b>1,730</b>	<b>2,696</b>	<b>9,494</b>	<b>2,905</b>	<b>1,950</b>	<b>1,042</b>	<b>3,133</b>	<b>5,282</b>	<b>2,099</b>	<b>866</b>
<b>Nonpoint sources</b>													
Agriculture	969	2,662	2,033	16	1,447	3,816	19,408	4,647	4,000	1,540	4,874	428	1,106
Hydrologic/habitat modification	288	14	1,244	33	186	2,022	488	279	1,339	98	3,640	27	27
Resource extraction	459	248	688	5	1,107	1,875	419	114	1,126	22	1,269	0	177
Construction	123	26	1,372	0	37	691	49	572	179	96	1,178	0	0
Silviculture	138	154	563	1	78	984	1,216	206	120	193	188	0	209
Natural	70	0	0	271	2	691	994	0	62	172	376	331	281
<b>Total</b>	<b>2,047</b>	<b>3,103</b>	<b>5,901</b>	<b>326</b>	<b>2,857</b>	<b>10,078</b>	<b>22,574</b>	<b>5,818</b>	<b>6,826</b>	<b>2,122</b>	<b>11,524</b>	<b>785</b>	<b>1,800</b>

<sup>a</sup> Table does not include all sources of impairment for all years, only major sources; impaired miles can be affected by multiple sources.  
<sup>b</sup> An impaired river mile is a river mile that is classified as partially supporting overall use or not supporting overall use.  
<sup>c</sup> Annual average impaired miles from 1988 to 1998 is defined as the total of impaired miles for each source for the years that data was reported divided by the number of years for which data was reported; for example, in Alabama, municipal sources contributed annually, on average, to the impairment of 642 river miles from 1988 to 1998.  
<sup>d</sup> Storm sewers/runoff and land disposal include both point and nonpoint sources.  
 Source: U.S. Environmental Protection Agency 1990, 1992, 1994, 1996, 1998a, 2000b.

reports are discussed more thoroughly in the following section.

**National Water Quality Inventories: limitations of the National 305(b) Reports**—The National 305(b) Reports provide snapshots of water quality, as assessed by individual States. The reports are not recommended for determining statistically significant trends concerning our Nation’s water resources (U.S. Environmental Protection Agency 1992). Some other limitations on use of these reports that have been identified include:

- Inconsistent data reporting over time (Society of American Foresters 2000).
- Variability among States regarding the compilation of reports (Society of American Foresters 2000, U.S. Environmental Protection Agency 1994).
- Insufficient water-quality data to make accurate designations in assessed waters (Society of American Foresters 2000).
- Conditions in assessed waters cannot always be extrapolated to estimate conditions in nonassessed waters; information provided by

States generally reflects monitoring and evaluation efforts that have been focused within problem areas of individual waters (U.S. Environmental Protection Agency 1994).

- In some instances in the past, impaired waters were overestimated by States to qualify for greater Federal funding to address potential impairment problems, as opposed to actual impairments (Society of American Foresters 2000).

Based on these limitations, reliance on data from these reports for statistical numeric trends over time or for specific comparisons between States is not recommended. However, despite these limitations, this information represents the most comprehensive set of current water-quality data available for the South. These reports were used in this chapter to identify general trends over time and the major causes and sources of impairment to rivers and streams in the South. For each individual State, the most significant information from figure 19.3 and table 19.4 is the relative contribution of each source.

**Index of watershed indicators (IWI)**—The USEPA introduced the IWI

program in October 1997 to increase public awareness about the health of the Nation’s watersheds. The primary objectives of the IWI program are to:

- Develop a consistent, descriptive technique for characterizing the condition and vulnerability of individual watersheds across the Nation.
- Make this information available in a way that informs and inspires Americans to learn more about their water resources, what affects those resources, and how to protect and restore them.
- Help water-quality management professionals make better decisions on strategies and priorities for environmental programs.
- Establish a national baseline on the condition and vulnerability of aquatic resources that could be used over time to help measure progress toward the goal that all watersheds be healthy and productive.

In order to achieve these objectives, 15 individual indicators of condition and vulnerability of aquatic systems in each of the 2,262 watersheds in the 50

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States and Puerto Rico were developed and used to rank each watershed (U.S. Environmental Protection Agency 2001e). These 15 indicators are listed and discussed in “The Index of Watershed Indicators” (U.S. Environmental Protection Agency 1997). Watersheds are delineated using the USGS eight-digit HUC classification system, as described in the preceding section “Spatial Data.” Federal and State agencies, stakeholders, and other organizations contribute to the information gathered for the IWI. After making an assessment of condition, vulnerability, and data sufficiency, the condition of the watershed is scored and assigned one of the following general categories: (1) better water quality, (2) water quality with less serious problems, (3) water quality with more serious problems, and (4) insufficient data (U.S. Environmental Protection Agency 2001e).

The most recent IWI information (September 1999) was compiled to provide a current characterization of water quality in individual watersheds in the South. Figure 19.4 provides a graphic representation of this information. Table 19.5 summarizes this

information at the State level. Based on these data, 188 individual watersheds (USGS eight-digit HUCs) are characterized as having relatively good water quality; these represent 30 percent of the land area in the South. Two hundred forty-one individual watersheds (36 percent of the land area) are characterized as having moderate water-quality problems, and 115 individual watersheds (15 percent of the land area) are classified as having more serious water-quality problems. One hundred twenty-eight individual watersheds (19 percent of the land area) do not have enough information to provide an overall characterization (fig. 19.4).

The majority of more serious water-quality problems are located in Louisiana, Mississippi, South Carolina, and Oklahoma. Watersheds characterized by less serious water-quality problems are scattered throughout the region, with concentrations in Georgia, South Carolina, and southern Florida. States with higher percentages of better water quality include Virginia, North Carolina, Alabama, and Arkansas. Significant areas of Texas, particularly

watersheds in the western portion of the State, do not have enough information to provide an adequate characterization of water quality (table 19.5).

Table 19.6 presents the same information as table 19.5, except the IWI information is aggregated by ecological province. A complete description of the ecological provinces in the South is included in chapter 16. The best water quality is generally found in the Central Appalachian Broadleaf Forest and the Ozark Broadleaf Forest. Ecological provinces with more serious water-quality problems include the Lower Mississippi Riverine Forest and the Outer Coastal Plain Mixed Forest.

Through the “Surf Your Watershed” Internet feature on the USEPA Web page (U.S. Environmental Protection Agency 2001d), the public can access information about a watershed of interest, as well as view the IWI data for that watershed. IWI represents a focused, long-term reporting tool that may assist in pinpointing specific problems in a watershed, and in providing improved assessment of current watershed conditions and

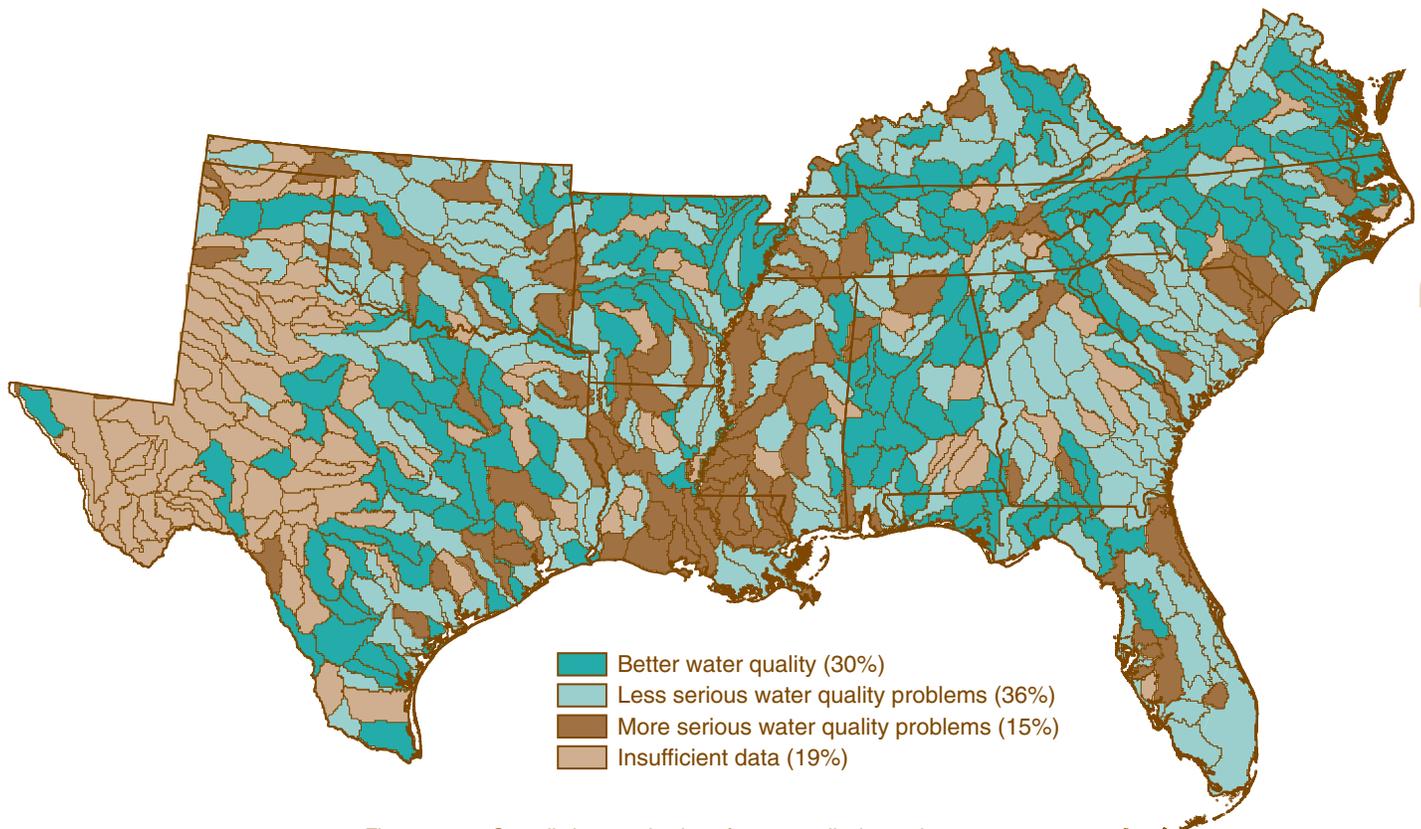


Figure 19.4—Overall characterization of water quality in southern watersheds [index of watershed indicators data (U.S. Environmental Protection Agency 1999)].

**Table 19.5—Overall watershed characterization in Southern States using Index of Watershed Indicators data**

State	Total watersheds		Better water quality	Less serious water quality	More serious water quality	Insufficient data
	No.	Acres	----- Number of watersheds (percent of acres) -----			
Alabama	53	(33,090,082)	22 (50.54)	19 (25.12)	5 (10.00)	7 (14.34)
Arkansas	59	(33,924,530)	27 (50.98)	20 (28.70)	7 (10.38)	5 (9.94)
Florida	54	(35,401,487)	16 (24.76)	16 (57.70)	9 (16.24)	4 (1.30)
Georgia	53	(37,512,562)	16 (14.98)	28 (66.47)	4 (6.52)	5 (12.03)
Kentucky	47	(25,747,680)	15 (36.57)	23 (53.11)	8 (9.94)	1 (0.34)
Louisiana	58	(29,554,483)	5 (5.07)	19 (35.25)	29 (50.79)	5 (8.89)
Mississippi	56	(30,461,735)	8 (8.37)	20 (42.15)	25 (45.11)	3 (4.37)
North Carolina	57	(31,387,170)	32 (59.76)	16 (26.86)	6 (9.75)	3 (3.63)
Oklahoma	70	(44,743,486)	8 (11.64)	37 (58.40)	17 (24.47)	8 (5.49)
South Carolina	36	(19,759,604)	8 (13.09)	18 (62.07)	9 (24.81)	1 ( .02)
Tennessee	62	(26,992,715)	29 (43.91)	20 (33.16)	8 (15.98)	5 (6.96)
Texas	206	(168,984,378)	48 (28.64)	47 (19.15)	22 (7.05)	89 (45.15)
Virginia	54	(25,615,321)	26 (59.92)	23 (33.76)	0 (0)	5 (6.32)

Source: U.S. Environmental Protection Agency 1997, 1999.

future trends (U.S. Environmental Protection Agency 2001e).

**Other water-quality assessment programs: NAWQA program—**

USGS established the NAWQA program in 1991 to assess and provide past, present, and future water-quality conditions in 60 river basins and aquifers nationwide. The NAWQA program is a long-term comparative study of the relationship between human impact and natural factors and the resulting water-quality condition within an area. NAWQA studies focus on region-specific factors that affect aquatic habitat.

The assessed areas, referred to as study units, account for 60 to 70 percent of the Nation's water use, and cover about one-half of the land area of the United States (U.S. Geological Survey 2001b). Assessments were initiated in 20 study units in 1991, 20 in 1993, and 20 in 1997, and data were collected by Federal, State, and local agencies, as well as universities and environmental groups. The 16 NAWQA study units for the South are presented in table 19.7. Due to the number of individual basin reports, specific findings for each study unit are not summarized in this report; however, some key findings from several of the basin studies are discussed in individual sections following as they relate to the effects of various land uses on water quality. Additional information on each of the

southern study units, including specific reports and key study findings, can be accessed via the USGS Internet site at <http://water.usgs.gov/nawqa/nawqamap.html>.

**Other water-quality assessment programs: Southern Appalachian assessment—**A recent study conducted in the Southern Appalachians indicates that overall water quality has improved slightly since passage of the CWA (Southern Appalachian Man and the Biosphere 1996). The Southern Appalachians include an area of approximately 37.4 million acres of mountains, foothills, and valleys stretching from northern Virginia and eastern West Virginia to northwestern South Carolina, northern Georgia, and northern Alabama. Other key findings included in this study were:

- Population growth and landscape alterations have resulted in water-quality degradation.
- The Tennessee River and Alabama River Basins are the most significantly impacted watersheds in the Southern Appalachians.
- Acidity of some streams in the area is increasing.
- Mining, urbanization, and dams have the largest effects on regional hydrology.
- Two-thirds of the reported localized water-quality impacts were a result of nonpoint-source pollution, including agricultural runoff, storm-water discharge, and landfill and mining leachate.

■ Mining impacts on water quality occur in the Tennessee River Basin and southwestern Virginia.

**Land Use Impacts on Water Quality**

**Role of forests in protecting water quality—**According to Sedell and others (2000), 80 percent of the freshwater resources in the United States originate in forests. Therefore, having healthy forests is critical to having clean water. The quality of water draining from forested watersheds is typically the highest in the country (Binkley and Brown 1993, Clark and others 2000). Undisturbed forests or woodlands generally provide the best protection of land and water from sedimentation and other pollutants. The tree canopy and litter layer dissipate the energy contained in raindrops. Also, a continuous litter layer maintains a porous soil surface and high water infiltration rates; consequently, overland flow is minimized in the forest. Forests slow stormwater runoff and provide watershed stability and critical habitat for fish and wildlife (Sedell and others 2000).

The body of literature that examines the role of forests, as compared to other land uses, in protecting water quality is significant. This section summarizes some of the key findings from various studies throughout the Nation and the South related to sediment yield,

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**Table 19.6—Watershed characterization of ecological provinces in the South using Index of Watershed Indicators data**

Ecological Province <sup>a</sup>	Total watersheds		Better water quality	Less serious water quality	More serious water quality	Insufficient data	
	No.	Acres	----- Number of watersheds (percent of acres) -----				
E. Broadleaf (Oceanic) (221)	41	(12,011,675)	17 (40.43)	17 (42.78)	2 (9.02)	5 (7.77)	
Central Appalachian (M221)	52	(20,960,016)	23 (55.19)	23 (39.37)	4 (1.52)	2 (3.92)	
E. Broadleaf (Contl.) (222)	76	(41,470,850)	29 (42.33)	30 (41.86)	14 (12.79)	3 (3.01)	
Ozark Broadleaf (M222)	15	(4,136,528)	8 (52.34)	4 (22.38)	2 (14.39)	1 (10.89)	
Southeastern Mixed (231)	199	(112,330,643)	65 (35.11)	73 (39.22)	43 (17.56)	18 (8.12)	
Ouachita Mixed (M231)	18	(7,153,279)	8 (38.65)	5 (24.37)	4 (30.98)	1 (6.00)	
Outer Coastal Plain (232)	216	(126,888,978)	54 (24.02)	93 (45.90)	48 (21.51)	21 (8.57)	
Lower Miss. Riverine (234)	87	(27,494,018)	17 (27.39)	31 (36.60)	36 (31.89)	3 (4.12)	
Prairie Parkland (Temp.) (M251)	12	(2,571,329)	2 (2.29)	9 (75.21)	1 (22.50)	0 (0)	
Prairie Parkland (Subtrop.) (255)	113	(55,793,413)	35 (37.52)	49 (39.69)	16 (16.18)	13 (6.61)	
Everglades (411)	6	(5,253,389)	0 (0)	4 (91.07)	1 (7.18)	1 (1.75)	

<sup>a</sup>Bailey's ecological provinces, represented by three digit codes; leading "M" indicates mountainous topography. Source: U.S. Environmental Protection Agency 1997, 1999.

nutrient yield, and biological conditions in forested versus nonforested watersheds. A number of these reports have been completed as part of the NAWQA program described in the preceding section.

Patric and others (1984) and Yoho (1980) compiled the range of sediment yields from several small watershed studies throughout the Nation and the South, respectively. Both of these reviews concluded that forested lands produced a small fraction of the sediment yielded by more intensive land uses. Periodic timber harvesting activities occurred in many of the forested watersheds. Even with a wide diversity of forest types, geology, climate, and physiography, forested watersheds yielded far less sediment than areas where nonforest land uses occurred (Patric and others 1984). In the upper Mississippi River Basin, sediment yield increased 150-fold from the forested headwaters to downstream areas dominated by other land uses, including agriculture (Mack 1967).

Runoff and annual sediment yields were greatest from agricultural lands compared to pine plantations and mature pine-hardwoods in small watersheds in northern Mississippi (Ursic and Dendy 1963).

Faye and others (1980) compared erosion and suspended sediment yields in nine watersheds in the upper Chattahoochee River Basin, GA, and reported the greatest suspended sediment yields from urban areas, compared with forested and agricultural lands. In a land use study in Virginia, Jones and Holmes (1985) compared the effects of urban, agricultural, and forested land uses (silvicultural activities) on water resources. They concluded that forestry practices contributed little sediment; agriculture was an important source, and urban development contributed the most sediment (as well as other pollutants).

In a nationwide review of watershed characteristics and stream nutrient levels, Omernik (1977) found that streams draining agricultural water-

sheds had, on average, considerably higher nutrient concentrations than those draining forested watersheds. Nutrient concentrations were generally proportional to the percent of land in agriculture and inversely proportional to the percent of land in forest (Omernik 1977).

Spruill and others (1998) conducted a water-quality assessment of the four river basins in the Albemarle-Pamlico Drainage Basin—the Chowan, Roanoke, Tar, and Neuse. Highest nitrogen and phosphorous yields occurred in the highly agricultural and urbanized Neuse Basin, and lowest nutrient yields occurred in streams of the forested Chowan Basin. In a study of the upper Tennessee River, Hampson and others (2000) found that sampling stations in forested watersheds had the lowest concentrations of total nitrogen, whereas stations in agricultural areas had the highest. Concentrations of nitrogen in urban and mixed land use areas were significantly greater than in forested watersheds but were some-

**Table 19.7—National Water Quality Assessment Program study units in the South**

Study year	Study unit	States
1991	Potomac River Basin	Virginia
1991	Albemarle-Pamlico Drainage	North Carolina, Virginia
1991	Apalachicola-Chattahoochee-Flint River Basin	Alabama, Florida, Georgia
1991	Georgia-Florida Coastal Plain	Georgia, Florida
1991	Ozark Plateaus	Arkansas, Oklahoma
1991	Trinity River Basin	Texas
1991	Rio Grande Valley	Texas
1994	South Central Texas	Texas
1994	Mississippi Embayment	Arkansas, Kentucky, Louisiana, Mississippi, Tennessee
1994	Southern Florida	Florida
1994	Kanawha-New River Basin	Virginia, North Carolina
1994	Upper Tennessee River Basin	Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia
1994	Santee Basin and coastal drainages	South Carolina, North Carolina
1997	Lower Tennessee River Basin	Tennessee, Alabama, Georgia
1997	Acadian-Pontchartrain	Louisiana, Mississippi
1997	Mobile River and tributaries	Mississippi, Alabama, Georgia

Source: U.S. Geological Survey 2001b.

what less than nitrogen concentrations in agricultural watersheds. As with total nitrogen, the lowest phosphorous concentrations were detected at sites in predominantly forested watersheds, whereas sites in urban and agricultural areas had the highest phosphorous concentrations (Hampson and others 2000).

In an assessment of biological indicators of the Apalachicola-Chattahoochee-Flint (ACF) River Basin, streams with forested land use had the best biological condition as shown by the Index of Biotic Integrity (Frick and others 1998). Lenat and Crawford (1994) conducted a study on the effects of land use on aquatic biota in three small catchment basins (forested, agricultural, and urban) in the Piedmont of North Carolina. Biological measurements showed large and consistent between-stream

differences in the different watersheds. Invertebrate taxa richness criteria and biotic index criteria indicated good water quality, fair water quality, and poor water-quality classifications in the forested, agricultural, and urban catchments, respectively (Lenat and Crawford 1994). For the purposes of this report, a Geographic Information System (GIS) analysis was conducted to determine if a positive relationship could be demonstrated between water quality and forest cover for watersheds. The three general IWI categories, “better water quality,” “less serious water-quality problems,” and “more serious water-quality problems,” were compared with percent forest cover for each of the southern watersheds. Percent forest cover was derived from the USDA Forest Service FIA data for each State and aggregated by watershed. However,

because of the scale of the analysis (size of the watersheds) and other limitations in the use of the water-quality data at this scale, regional trends relating forest cover and water quality were not identified.

In addition, water-quality impairment based on IWI classification accounts for multiple factors and conditions that may have a greater impact on water quality than forest cover alone. Recent studies have concluded that the effects of human actions on nutrient loads may be disproportionately greater than the actual amount of anthropogenic cover in a watershed. Hession and others (1996) found that 80 percent of lake phosphorous load was attributable to agriculture, which accounted for only 25 percent of the watershed area. Nutrient export from agriculture was determined to be disproportionately greater than its area within a watershed. Although urban and suburban land use accounts for only 5 percent of the ACF River Basin, it has the most significant effect on streamwater quality (Frick and others 1998).

The scale of any watershed analysis is critical to determining specific relationships between land uses and water quality. Effects of land uses, including silvicultural practices, on water quality and aquatic biota are best studied and summarized at much smaller scales. This level of analysis was not possible for this report.

**Specific land uses affecting water quality in the South**—Based on a nationwide study of streams draining forested land, Patric and others (1984) concluded that land use has more influence on average sediment concentration in watersheds than does any other single factor. Land uses (practices) that are major sources of water-quality impairment in the South, and the pollutants that they may generate, are discussed in this section. Figure 19.1 displays the leading point and nonpoint sources of pollution from 1988 to 1998. Figure 19.3 displays this information by State. Primary land use practices (or types) affecting water-quality impairment in the South can be grouped into five broad categories: (1) agriculture, (2) urbanization, (3) resource extraction, (4) hydrologic/habitat modification, and (5) silviculture. At the local and regional level, land use practices can dramatically affect soil condition and water quality,

as well as water supply. Factors that affect land use change include economic growth, population density, social development, political structure, attitudes and values, and technology (Turner and others 1993). Five major land use categories are discussed in the subsections that follow.

■ **Agriculture:** From 1988 to 1998, agriculture was identified as the primary source of water-quality impairment in the South. It accounted for a majority of the pollution impacting rivers and streams in the South (fig. 19.1). An annual average of approximately 44,326 miles of rivers and streams was impacted by agricultural activities during this period. Until the 1950s, the growth of agricultural land use generally kept pace with population increases (Novotny and Olem 1994). The majority of farming was conducted on small family farms without excessive use of chemicals. Since then, farming has shifted from family farms to larger corporate enterprises. Concurrently, farming began to rely on chemical fertilizers to increase plant yields, and on pesticides for insect and weed control. In general, as environmental awareness has increased, modern day agricultural practices have begun to incorporate techniques that reduce potential environmental impacts.

Despite these advances, agricultural practices continue to be the primary source of water-quality impairment in the South (U.S. Environmental Protection Agency 2000b). For example, in North Carolina construction activities typically cause the highest erosion rates, but agriculture is the most common source of sediment problems because of the large amount of agricultural land use (Lenat and Crawford 1994). Agricultural activities such as field tillage, pesticide and fertilizer applications, drainage, irrigation, grazing, and feedlot operations are sources of significant nonpoint-source pollution (Neary and others 1989). Major pollutants associated with agriculture include sedimentation; nitrogen and phosphorous loading; changes in soil salinity; and introduction of pesticides, other toxins, bacteria, and pathogens. Agricultural practices are more likely to contribute certain pollutants than other land use practices. Agricultural land cover is considered one of the

principal sources of excess loads of nitrogen and phosphorous in receiving waters (Parry 1998).

Concentrated animal operations (CAOs) are a major agricultural practice that contributes significant amounts of pollutants to rivers and estuaries in the South (Burkholder and others 1997, Mallin 2000). For example, North Carolina experienced a rapid increase in CAOs between 1980 and 1990. The CAOs were exempt from land zoning laws and mandatory inspection programs. The waste lagoons were not required to have impermeable liners, and some were even constructed below the water table (Burkholder and others 1997). During heavy rainfall events, the waste lagoons overflowed, resulting in an increase in biochemical oxygen demand, fecal coliform, and nutrients and a decrease in dissolved oxygen, possibly resulting in fish kills (Burkholder and others 1997). Typical

agricultural practices and associated pollutants are summarized in table 19.8 (Novotny and Olem 1994).

■ **Urbanization:** Urbanization is defined as land use conversion caused by increased population density and activities associated with the creation of infrastructure to support populations, primarily within cities. Features of urbanization addressed in this chapter include construction of homes and other buildings, infrastructure development such as municipal wastewater treatment plants and storm sewer systems, construction of industrial plants, urban sprawl, and creation of extended transportation routes, including mass transit.

Urban areas account for a small percentage of land in the South, but their effects on water resources have been severe. Urbanization represents the second overall leading source of impairment to water quality.

**Table 19.8—Agricultural land use practices and associated pollutants**

Agricultural land use practices	Pollutants (causes)
Nonirrigated cropland	Sedimentation, nutrients, pesticides, streambank destabilization, removal of riparian vegetation.
Irrigated crop production	Sedimentation, nutrients, pesticides, traces of certain metals, salts, bacteria, viruses.
Rangeland	Bacteria, nutrients, sedimentation, pesticides, streambank destabilization, flow alteration, removal of riparian vegetation, increases in water temperature, reductions in dissolved oxygen concentrations.
Pasture land	Bacteria, nutrients, sedimentation, pesticides, streambank destabilization, flow alteration, removal of riparian vegetation, increases in water temperature, reductions in dissolved oxygen concentrations.
Feedlots	Bacteria, viruses, nutrients, sedimentation, organic material, salts and metals.
Animal holding areas	Bacteria, viruses, nutrients, sedimentation, organic material, salts and metals.
Animal operations	Bacteria, viruses, nutrients, sedimentation, organic material, salts and metals.

Source: U.S. Environmental Protection Agency 1998a, Novotny 1994.

Urbanization not only affects local rivers; it also contributes to water-quality impacts far downstream. According to National 305(b) Reports from 1988 to 1998, 5 of the 11 leading sources of water-quality impairment in the South were due to urbanization (fig. 19.1). These include both point and nonpoint sources of runoff in the categories of: (1) municipal (wastewater treatment plants), (2) storm sewer/urban runoff, (3) industrial discharges, (4) land disposal (landfills), and (5) construction activities. These five sources impacted an annual average of approximately 37,083 miles of rivers and streams during this time.

In the first half of the 20<sup>th</sup> century, deterioration of water quality due to urbanization was primarily associated with point sources from industrial and commercial operations and treated and untreated domestic sewage. Point sources continue to contribute to water-quality impairment. It was not until 1970 that urban nonpoint sources of pollution were also recognized as contributing a significant portion of water-quality impacts. The following point and nonpoint sources of water-quality impairment are considered to be a result of urbanization.

■ **Point sources of pollution:** Treated sewage discharges; industrial discharges; storm sewer outflows in urban centers, including pollutants such as car oil, detergents, and other household and commercial solvents and chemicals; spills or releases from petroleum tankers, railcars, etc; unpermitted discharges from industrial or municipal sources.

■ **Nonpoint sources of pollution:** Runoff (sedimentation and erosion) from construction activities; runoff from roads and road construction; sediment and contaminant transport from other impervious surfaces such as parking lots; runoff from the application of pesticides and fertilizers; runoff and leachate from landfills and septic tank systems; leaking underground storage tanks and other improperly contained hazardous material storage tanks; combined sewer overflows.

Other impacts to water quality due to urbanization include reduced flow in rivers and streams caused by increased demand for water resources, such as drinking water and extensive land use changes due to urban sprawl.

■ **Hydrologic/habitat modification:** Hydrologic modification is the alteration of the flow of water, which changes water depth, stream velocity, and amount of discharge. Habitat modification is the removal of riparian vegetation, streambank modification, and drainage/filling of wetlands (U.S. Environmental Protection Agency 2000b). Throughout the history of modern civilization, sources of water have been modified to exploit available resources. As populations have increased, modification of nearby streams, rivers, wetland areas, and lakes has increased accordingly. Traditionally, activities such as the draining of wetlands for agricultural purposes and the development of urban centers along rivers and streams have been encouraged and considered to be signs of progress and economic growth (Mac and others 1998).

Hydrologic/habitat modification has been one of the leading causes of water-quality impairment in the South from 1988 to 1998. These activities impacted an annual average of approximately 8,153 river miles during this time (fig. 19.1) and were the third leading source of water-quality impairment, behind agriculture and urbanization. Hydrologic/habitat modification includes the following activities (specific literature citations for water-quality impacts are included):

■ **Dredging:** The excavation of bottom sediment to increase water depth and subsequent disposal of dredged material (Burke and Engler 1978, U.S. Army Corp of Engineers 1989).

■ **Channelization:** The alteration of stream morphology for human beneficial uses, such as flood control and irrigation (Crance and Masser 1996, Mac and others 1998).

■ **Damming/flow regulation:** A barrier preventing and regulating the flow of water for the purpose of flood control, power generation, and water resources (Federal Interagency Restoration Working Group 1998, Mac and others 1998).

■ **Drainage of wetlands and swamps:** The act of removing water from wetlands by altering the land for purposes such as conversion to farmland and urban development (see chapter 20).

■ **Resource extraction:** Resource extraction, as reported in the National 305(b) Reports, includes mining,

petroleum drilling, and runoff from mine tailing sites (U.S. Environmental Protection Agency 2000b). It was one of the top five sources of water-quality impairment in the South from 1988 to 1998 (fig. 19.1). The most common minerals extracted by mining are coal and metallic ores (Novotny and Olem 1994). Nonpoint sources of pollution associated with resource extraction include mineral and sediment discharges from inactive mining operations, sedimentation and erosion runoff from roads, old tailings, and spoil pile leaching of contaminants. In addition, acid mine drainage can severely impact water quality by altering pH levels of rivers and streams.

A national stream survey by the USEPA reported that 10 percent of the streams in the northern Appalachians were acidic due to acid mine drainage during spring baseflow (Mac and others 1998). Active mines are considered point sources of pollution, and a discharge permit is required for their operation. Nonpoint-pollution sources such as erosion and sedimentation are associated with almost every abandoned surface mine (Novotny and Olem 1994). Although mining is not as widespread as agriculture, water-quality impairment is often severe.

■ **Silviculture:** Silviculture is “the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis” (Society of American Foresters 1994). It includes the application of scientific agricultural practices to grow trees for use as lumber or other products. The majority of forested land in the South has been subject to historical silvicultural activities of some type or extent. According to the National 305(b) Reports, silvicultural activities impacted annually an average of approximately 3,639 miles of rivers and streams in the South from 1988 to 1998 (fig. 19.1). Table 21.1 in chapter 21 provides a breakout of this information by State.

Silviculture ranks low among water-impairing land use activities in the South. Nevertheless, impacts from silvicultural activities can be considerable if BMPs are not applied. The major potential nonpoint-source pollutant resulting from silvicultural activities is sediment from roads and skid trails.

Other minor nonpoint-source impacts on water quality include short-term increases in peak flows during storms, short-term increases in base flows, short-term increases in nutrient concentrations (primarily nitrogen and phosphorous), short-term increases in herbicides/fertilizers and derivative products, and thermal pollution (increased stream temperature). Elevated levels of organics and nutrients may result from leaching of disturbed or exposed soils. Fertilizer applications may alter stream chemistry in managed forests, depending on the type of fertilizer used and how it is applied (Society of American Foresters 2000). In comparison, pollutant loads from properly managed areas are considered negligible (Novotny and Olem 1994). Chapter 21 provides a complete discussion of the potential effects of silvicultural activities on water quality.

### The Likely Future of Water Quality in the South

The population of the United States is expected to reach nearly 400 million people by the year 2050, and Texas and Florida are among the States with the fastest growing populations in the country (U.S. Census Bureau 1997). Suburbs and rural areas are expanding. As a result, the needs for recreation, timber, clean water, and other forest benefits are also increasing. Although the current trend is generally toward improved water quality in the United States, uncontrolled land use practices may alter this trend. Loss of wildlife and vegetation, erosion of soils, and nonpoint-source pollution of ground water and surface water will result in a trend of degrading water quality. According to the study “Status and Trends of the Nation’s Biological Resources,” “there are enough scientifically documented declines of species abundances and extinctions of aquatic species that are direct results of human activity to indicate that present water-use and development practices cannot continue” (Mac and others 1998). It should also be noted that although this chapter did not focus on estuarine and coastal resources, a number of studies indicate that due to population increases, water quality in coastal regions is likely to significantly degrade in a number of areas, including the South (Dame and others 2000, Mallin and others 2000). Understanding

cumulative downstream impacts is essential to assessing the likely future of water quality, especially in these coastal regions.

The likely future of water quality in the South depends on the success of future mandates, specific programs, and initiatives to promote water-quality improvements. Some of the major programs are described in the following sections.

**Clean Water Action Plan (CWAP)**—In 1998, President Clinton announced a new clean water initiative to speed the restoration of the Nation’s waterways. This initiative, called the Clean Water Action Plan (CWAP), aims to achieve clean water by strengthening public health protection, targeting community-based watershed protection efforts, and providing communities with new resources to control polluted runoff. The intended purpose of CWAP is a reemphasis of the original goal of the CWA, which was to achieve “fishable and swimmable water for every American” (Clean Water Action Plan 2001). The CWAP builds on existing programs and proposes new efforts that support partnerships between Federal, State, and local levels. These efforts include financial assistance and incentives to aid in the restoration of aquatic systems within watersheds. Four areas identified as imperative to the success of CWAP include: (1) a watershed approach, (2) strong Federal and State standards, (3) natural resource stewardship, and (4) informed citizens and officials.

**Unified Watershed Assessment (UWA)**—One of the key objectives of CWAP was to encourage States and tribes to work together with the public to identify watersheds that do not meet water quality and other natural resource goals and watersheds that are in the most critical need of restoration and protection. This objective would be accomplished through the conduct of UWAs. UWAs represent some of the first coordinated efforts to develop common priorities to restore and protect water quality. The designation of these watersheds would use common criteria within one of four categories, as described following (Clean Water Action Plan 2001).

■ Watersheds in need of restoration: These watersheds do not meet clean water goals, and are considered priorities for restoration. States and

tribes have developed subcategories to further prioritize watersheds in need of restoration based on the degree of vulnerability or threat to water-quality conditions. These include: (1) highest restoration priority—those watersheds determined by States to be most in need of restoration, and (2) other restoration needed—the remaining watersheds in need of restoration.

■ Watersheds meeting goals, including those needing actions to sustain water quality: These watersheds meet clean water and other natural resource goals and standards and support healthy aquatic systems.

■ Watersheds with pristine/sensitive aquatic system conditions on land administered by Federal, State, or tribal governments: These watersheds contain pristine water quality, other sensitive aquatic system conditions, and drinking water sources that are located on land administered by Federal, State, or tribal governments. These areas include currently designated and potential candidate wilderness areas, outstanding natural resource waters, and wild and scenic rivers.

■ Watersheds with insufficient data to make an assessment: These watersheds lack significant information or the critical data elements needed to make a reasonable assessment.

Once prioritized, each State and tribe must develop restoration action strategies, a long-term schedule, and a description of the information used to base priority decisions through their UWA. States that share a watershed, such as in the ACF River Basin in Georgia, Alabama, and Florida, are encouraged to exchange information and work closely to reach common goals (Natural Resource Conservation Service 2001).

The UWA designations for individual watersheds (eight-digit HUCs) in the South were compiled to identify the specific watershed restoration and protection priorities based on certain factors such as water quality. Figure 19.5 provides a graphic representation of this information. Table 19.9 summarizes this information at the State level. The information that is presented in figure 19.5 is similar to that shown in figure 19.4 (IWI data), but UWA data focuses on restoration

priorities of watersheds established by individual States.

Based on the results of the UWA characterization, 391 individual watersheds, which represent approximately 59 percent of the land area in the South, have been categorized as in need of some level of restoration. Of these, 148 watersheds (25 percent of the land area) are designated as the highest restoration priority, and 243 watersheds

(34 percent of the land area) are classified as "other restoration needed." One hundred ninety-four individual watersheds (29 percent of the land area) are classified as meeting standards, and two individual watersheds (less than 1 percent of the land area) are considered very high quality. The two very high-quality watersheds are in Mississippi and North Carolina. For 85 individual watersheds (12 percent of the land

area), information is insufficient for overall characterization (fig. 19.5). Georgia has the highest percentage of watershed acreage designated as having the highest restoration priority (22 individual watersheds), followed by Louisiana and Virginia (table 19.9).

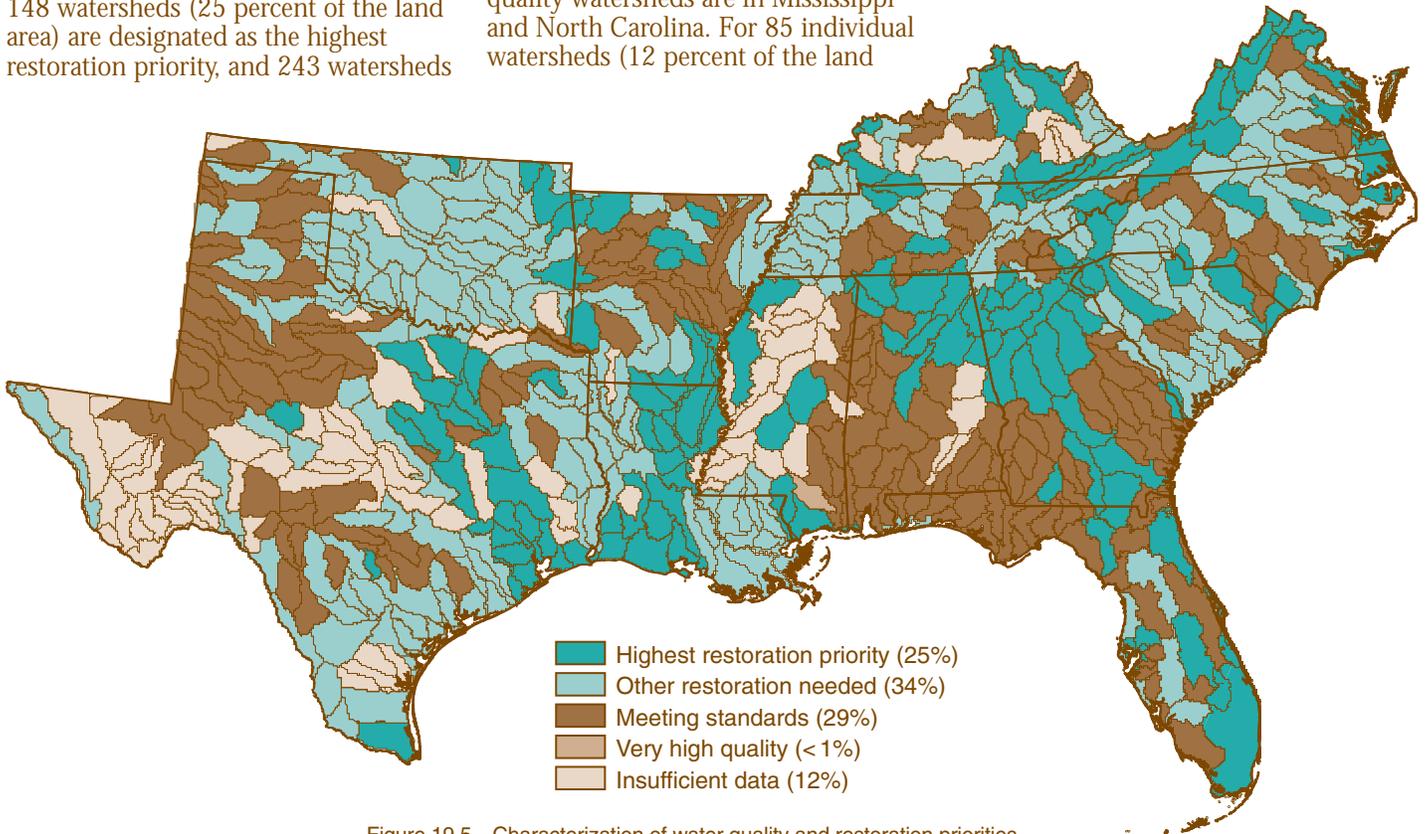


Figure 19.5—Characterization of water quality and restoration priorities of southern watersheds [unified watershed assessment data (U.S. Environmental Protection Agency 1998b)].

Table 19.9—Overall watershed characterization in Southern States using Unified Watershed Assessment criteria

State	Total watersheds		Very high quality		Meeting standards		Other restoration needed		Highest restoration priority		Insufficient data	
	No.	Acres	----- Number of watersheds (percent of acres) -----									
Alabama	53	(33,090,082)	0	(0)	34	(59.21)	2	(0.33)	12	(30.58)	5	(9.88)
Arkansas	59	(33,924,530)	0	(0)	20	(42.76)	22	(31.69)	13	(23.76)	4	(1.78)
Florida	54	(35,401,487)	0	(0)	35	(51.02)	7	(15.11)	12	(33.87)	0	(0)
Georgia	53	(37,512,562)	0	(0)	27	(44.69)	4	(4.43)	22	(50.88)	0	(0)
Kentucky	47	(25,747,680)	0	(0)	6	(12.61)	20	(32.60)	13	(31.72)	8	(23.07)
Louisiana	58	(29,554,483)	0	(0)	0	(0)	27	(46.70)	21	(47.77)	10	(5.54)
Mississippi	56	(30,461,735)	1	(2.72)	14	(19.92)	11	(6.27)	9	(26.57)	21	(44.51)
North Carolina	57	(31,387,170)	1	(1.29)	15	(29.80)	27	(45.73)	14	(23.18)	0	(0)
Oklahoma	70	(44,743,486)	0	(0)	9	(7.47)	48	(77.49)	9	(8.30)	4	(6.74)
South Carolina	36	(19,759,604)	0	(0)	7	(13.43)	21	(60.55)	8	(26.02)	0	(0)
Tennessee	62	(26,992,715)	0	(0)	11	(28.92)	34	(51.91)	17	(19.17)	0	(0)
Texas	206	(168,984,378)	0	(0)	58	(31.05)	76	(33.30)	26	(12.91)	46	(22.74)
Virginia	54	(25,615,321)	0	(0)	6	(14.82)	23	(39.08)	24	(46.11)	1	(0)

Source: U.S. Environmental Protection Agency 1998b.

AQUATIC

**Table 19.10—Watershed characterization of ecological provinces in the South using Unified Watershed Assessment criteria**

Ecological Province <sup>a</sup>	Total watersheds		Very high quality		Meeting standards		Other restoration needed		Highest restoration priority		Insufficient data	
	No.	Acres	----- Number of watersheds (percent of acres) -----									
E. Broadleaf (Oceanic) (221)	41	(12,011,675)	0	(0)	8	(18.11)	16	(40.13)	12	(27.45)	5	(14.31)
Central Appalachian (M221)	52	(20,960,016)	0	(0)	6	(14.08)	19	(24.69)	25	(59.82)	2	(1.41)
E. Broadleaf (Contl.) (222)	76	(41,470,850)	0	(0)	18	(22.58)	36	(37.93)	17	(30.03)	5	(9.47)
Ozark Broadleaf (M222)	15	(4,136,528)	0	(0)	5	(35.03)	6	(21.32)	4	(43.64)	0	(0)
Southeastern Mixed (231)	199	(112,330,643)	0	(0)	51	(23.23)	68	(32.47)	59	(34.40)	21	(9.89)
Ouachita Mixed (M231)	18	(7,153,279)	0	(0)	8	(25.31)	7	(45.16)	2	(20.41)	1	(9.12)
Outer Coastal Plain (232)	216	(126,888,978)	2	(0.97)	82	(42.92)	62	(24.45)	54	(25.91)	16	(5.75)
Lower Miss. Riverine (234)	87	(27,494,018)	0	(0)	10	(18.88)	39	(32.81)	21	(35.20)	17	(13.11)
Prairie Parkland (Temp.) (M251)	12	(2,571,329)	0	(0)	0	(0)	9	(82.18)	3	(17.82)	0	(0)
Prairie Parkland (Subtrop.) (255)	113	(55,793,413)	0	(0)	13	(9.05)	59	(52.49)	27	(25.80)	14	(12.66)
Everglades (411)	6	(5,253,389)	0	(0)	2	(26.94)	1	(0.14)	3	(72.93)	0	(0)

<sup>a</sup>Bailey's ecological provinces, represented by three digit codes; leading "M" indicates mountainous topography. Source: U.S. Environmental Protection Agency 1998b.

Table 19.10 presents the same information as table 19.9, except the UWA information is aggregated by ecological province. A complete description of the ecological provinces in the South is included in chapter 16. The ecological province with the fewest watersheds, the Everglades, has the most need for restoration. Approximately 73 percent of the Everglades Province, which consists of some 5.25 million acres, is in the most critical need of restoration. Watersheds in the Central Appalachian Province have also been targeted for significant restoration efforts. The Outer Coast Province, which is the largest ecological province in the South, contains the highest percentage of watershed acreage categorized as meeting standards or very high quality.

**Total Maximum Daily Load (TMDL) program**—The TMDL program is identified in Section 303(d) of the CWA. It requires States to determine the TMDLs that would be necessary to bring those waters up to water-quality minimums, and allocate those loads among sources in discharge

permits and State water-quality plans. USEPA defines a TMDL as “a calculation of the maximum amount of a pollutant that a water body can receive and still meet water-quality standards, and an allocation of that amount to the pollutant’s sources” (U.S. Environmental Protection Agency 2000a). Included in this amount or “pollution budget” is a margin of safety to ensure that water bodies can be used for the State-designated uses, such as swimming, recreation, and fishing.

Under the CWA, States are required to develop TMDLs for water-quality limited water body segments and promote effective nonpoint-source controls (Boyd 2000). State regulatory agencies determine the steps needed to improve or restore the quality of impaired waters through either approved TMDL implementation plans or the continuous planning process as mandated by Section 303(e) of the CWA. The development and implementation process for TMDLs is designed to promote stakeholder consensus in technical evaluation

and development of management strategies for the identified water-quality problems. The establishment of TMDLs for specific watersheds or subwatersheds is the primary approach to watershed restoration efforts identified as part of the UWA process.

**National Pollutant Discharge Elimination System (NPDES) stormwater program**—Congress amended the CWA in 1987 to include a two-phase national program addressing stormwater discharges. Under the initial NPDES Phase 1 program, separate municipal storm sewer systems (MS4s) serving 100,000 or more people and operators of construction activities disturbing five or more acres must obtain an NPDES stormwater permit (U.S. Environmental Protection Agency 2001b). The NPDES Phase 2 program was finalized in 1999, and is scheduled for full implementation by 2003. The new requirements were established to protect water resources from stormwater runoff in regulated MS4s serving

populations less than 100,000 and construction sites that disturb from 1 to 5 acres (U.S. Environmental Protection Agency 2001b).

**Incentives and stewardship programs**—A number of stewardship programs have been established to promote good land use practices, proactive thinking on the part of companies and private landowners with regard to multiresource management, and financial incentives for participation. Specific to forestry activities, the American Forest and Paper Association (AF&PA) recently began a stewardship initiative to incorporate the protection of natural resources. Under the Sustainable Forestry Initiative (SFI) program, water-quality improvement is specifically targeted by implementation of BMPs, approved State water-quality programs, and adherence to State and Federal water-protection laws and regulations. A similar program, the Forest Stewardship Council (FSC) certification program, was established in 1993 by environmental groups, the timber industry, foresters, indigenous peoples, and community groups from 25 countries. The FSC program is designed to promote responsible forest management by certifying forest products that meet rigorous standards. The FSC certification standards encourage environmentally appropriate, socially beneficial, and economically viable management of the World's forests.

The USDA Forest Service initiated a Forest Stewardship Program, similar to the SFI program, that provides educational and technical assistance to landowners interested in active management of their forests for multiple resource benefits. Another program, the Stewardship Incentive Program (SIP), provides cost-share support for nonindustrial private forest landowners to help them develop and implement forest stewardship plans. Funding through SIP is based on landowner adherence to the plan for a minimum of 10 years. Technical and planning assistance by natural resource professionals is available through the program.

**Source Water Assessment Programs (SWAPs)**—The Safe Drinking Water Act Amendments of 1996 require States to develop and implement SWAPs. These programs are intended to address existing and potential threats to public

drinking water quality. Assessments will include drinking water sources and potential threats to drinking water quality for metropolitan areas, towns, schools, and restaurants. Currently, the USEPA has approved 52 SWAPs, which must be implemented by States within 3 years of USEPA approval (U.S. Environmental Protection Agency 2001c).

**Fishable Waters Act**—The Fishable Waters Act (FWA) of 2000 is a proposed amendment to the CWA introduced to Congress by the Clinton Administration. The objective of this act is to meet fishable and swimmable goals of the CWA. The FWA was drafted in collaboration with the Fishable Waters Coalition with the objective of restoring the physical and biological integrity of 4 million acres of public waters for fishing and recreation (Izaak Walton League of America 2001). If passed by Congress, the FWA would be a program under the CWA that would allow States to use funds in their Fisheries Habitat Account toward FWA conservation programs.

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## Discussion and Conclusions

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Although water quality has improved since the passage of the CWA, water-quality impairment is still an important concern in the South. Several watersheds and water bodies have been identified as needing improvement and/or as being impaired for designated uses. There are too many instances of insufficient data regarding the current conditions of rivers and streams in the South. It is important to understand the difficulties in identifying causes and, in particular, sources of pollution in impaired waters. Many of the monitoring and data reporting limitations have been described in previous sections. However, USEPA and the individual States are working to develop better, more consistent methods for determining the causes and sources of impairment and describing the level of confidence in the classification.

The information included in this chapter on the status of water quality has been presented at various scales: regional, State, ecological region, and individual watershed (eight-digit HUC). The leading pollutants in rivers and

streams in the South are sedimentation and pathogens (bacteria). Nonpoint-source pollution continues to degrade the overwhelming majority of rivers and streams. The primary nonpoint sources of water-quality impairment identified in the South are agriculture and urbanization. Agriculture and urbanization impact water quality by eliminating natural vegetation and replacing it with impervious surfaces or creating more readily erodible surfaces.

Therefore, preservation and restoration of forest cover are crucial to maintaining water quality in the South. Forest cover, riparian habitat, and streambank management are vital to maintaining and increasing water quality. Although the relationship is often hard to analyze statistically, loss of these habitats has had significant effects on water quality. A positive relationship between increasing forest cover and better water quality could not be identified due to problems with geographic scale and the nature of the water-quality data. In almost all instances, designation of the causes or sources of a particular water-quality impairment occurs within individual river miles. Land use, as a source of pollution, clearly plays a more significant role in degrading water quality at a local level.

Understanding land use impacts and implementation of effective management practices is the key to maintenance and improvement of water quality in the South. Sustainable land use practices are needed to maintain and improve water quality. Assessment and management issues must be addressed at regional, State, and local levels to understand the complex and interdependent relationships among natural resources and land uses. Management at the regional level is vital since impacts from land use changes are widespread and occur in different combinations and rates in different areas. As a greater understanding of cumulative downstream effects is gained, effective implementation of regional land use and watershed management programs may aid in minimizing potential water-quality impacts (Bolstad and Swank 1997).

Progress is being made to restore degraded rivers and to protect those that are still intact. The general public is becoming increasingly aware of water-quality issues. Across the South,

local communities and organizations are working with State and Federal agencies to find ways to protect our rivers without adversely impacting continued economic growth. Improved public outreach and education are needed, particularly concerning nonpoint-source pollution management, wastewater operation and maintenance, and general water quality and resource management. Future trends in water quality in the South include a variety of proactive mandates, management approaches, increased awareness and implementation of BMPs, and the use of more effective and accurate technological tools.

## Needs for Additional Research

As increasing land use demands affect water quality in the South, additional research and activities have been identified that would enhance the effectiveness of management programs, thereby improving water quality. The overall goal for water-quality management is to “protect our water sources, including groundwater, from contamination and overuse, and commit to maintaining or continuing to restore degraded aquatic systems, riparian forests, and natural resources” (Mac and others 1998). Recommendations and additional research needs necessary to accomplish this goal are:

- Research and develop standard assessment and reporting criteria among States for the National 305(b) Reports to Congress.
- Develop watershed assessment methods that consider costs and benefits of land use at large watershed and regional scales.
- Develop and integrate standardized tools for water-quality assessment, including modeling, use and interpretation of satellite imagery, and remote sensing.
- Develop methods to identify priority natural areas for protection and restoration as part of land management planning efforts.
- Investigate whole ecosystem impacts in restoration efforts.
- Research and incorporate downstream cumulative impacts in watershed assessment and management.

- Examine the effects historical disturbances have on current water quality.
- Investigate the long-term effects of BMPs and forest harvesting activities on sediment production.
- Research urbanization effects on forest ecosystem function and structure.

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The southern forest resource assessment provides a comprehensive analysis of the history, status, and likely future of forests in the Southern United States. Twenty-three chapters address questions regarding social/economic systems, terrestrial ecosystems, water and aquatic ecosystems, forest health, and timber management; 2 additional chapters provide a background on history and fire. Each chapter surveys pertinent literature and data, assesses conditions, identifies research needs, and examines the implications for southern forests and the benefits that they provide.

**Keywords:** Conservation, forest sustainability, integrated assessment.

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