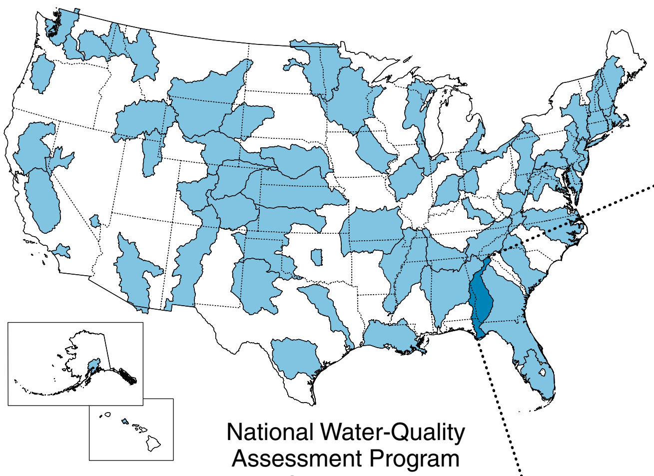
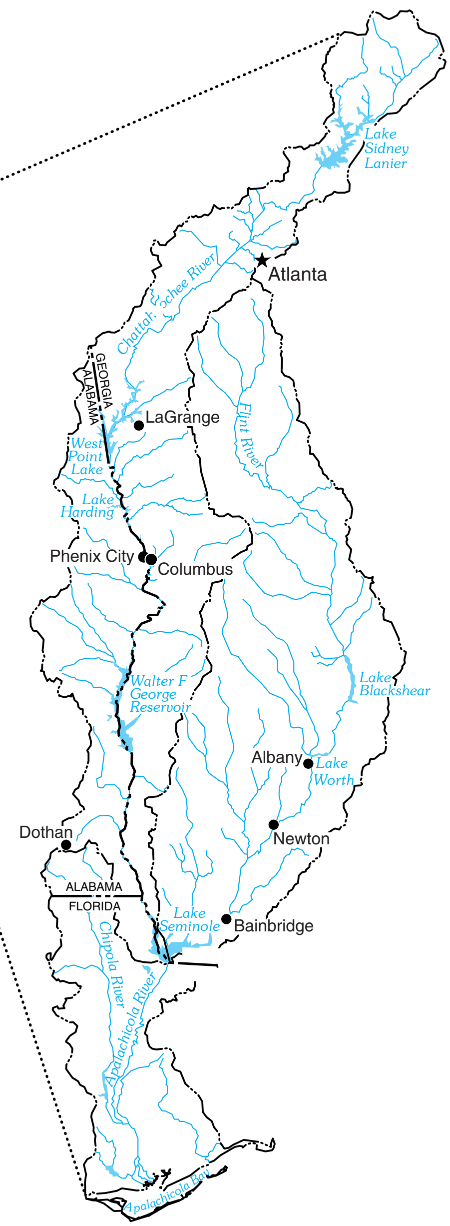
# THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM—*EXAMPLE OF STUDY UNIT DESIGN FOR THE APALACHICOLA–CHATTAHOOCHEE–FLINT RIVER BASIN IN GEORGIA, ALABAMA, AND FLORIDA, 1991-97*



National Water-Quality
Assessment Program
Study Units




**U.S. GEOLOGICAL SURVEY**
**Open-File Report 97-48**

# THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM—*EXAMPLE OF STUDY UNIT DESIGN FOR THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN IN GEORGIA, ALABAMA, AND FLORIDA, 1991–97*

By David J. Wangsness

U.S. GEOLOGICAL SURVEY

Open-File Report 97-48

National Water-Quality Assessment Program

Atlanta, Georgia
1997

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

---

For addtional information write to:

District Chief
U.S. Geological Survey
Peachtree Business Center
3039 Amwiler Road, Suite 130
Atlanta, GA 30360-2824

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Denver Federal Center
Box 25286
Denver, CO 80225-0286

## CONTENTS

## ILLUSTRATIONS



## TABLES

## FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society, we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for, and likely consequences, of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers;
- describe how water quality is changing over time; and
- improve understanding of primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Information regarding the NAWQA Program is available on the Internet via the World Wide Web. You may connect to the NAWQA Home Page using the Universal Resources Locator (URL) at:

<URL:http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html>

*This paper originally was presented at an Advanced Research Workshop sponsored by the NATO International Scientific Exchange Programmes. The workshop, entitled "Water Quality Data Sharing for the Effective Management of Danube River Basin," convened May 27–30, 1996, in Budapest, Hungary. The title of the original paper was "Design and Implementation of the National Water-Quality Assessment Program—A United States Example: Understanding the Limitations of Using Compliance-Monitoring Data to Assess the Water Quality of a Large River Basin," and was published by Kluwer Press, along with other workshop proceedings papers, in a book entitled "Protecting Danube Resources: Ensuring Access to Water Quality Data and Information."*

*The purpose for the original paper was to provide representatives from European countries within the Danube River basin with (1) a brief discussion of data limitations in the U.S. that led to the inception of the National Water Quality Assessment (NAWQA) program; (2) a description the conceptual design for the NAWQA program; and (3) a more detailed description of one study-unit design, using the Apalachicola-Chattahoochee-Flint (ACF) River basin study unit as an example. The paper has been reprinted here for distribution in the U.S. and, more specifically, to document in some detail the design for the NAWQA study conducted in the ACF River basin.*

# THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM—*EXAMPLE OF STUDY UNIT DESIGN FOR THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN IN GEORGIA, ALABAMA, AND FLORIDA, 1991–97*

By David J. Wangsness

**ABSTRACT**

Much of the water-quality monitoring conducted in the United States is designed to comply with Federal and State laws mandated primarily by the Clean Water Act of 1987 and the Safe Drinking Water Act of 1986. For example, the State of Wisconsin estimates that more than 98 percent of it's monitoring program is compliance monitoring, and Washington State estimates that 80 to 90 percent of its monitoring program is compliance monitoring. A small percentage of the water-quality data in the United States has been collected as a part of ambient monitoring programs or river-basin assessments. Monitoring programs generally focus on rivers upstream and downstream of point-source discharges and at water-supply intakes. Few data are available for aquifer systems and chemical analyses are often limited to those constituents required by law. In most cases, the majority of the available chemical and streamflow data have provided the information necessary to meet the objectives of the compliance-monitoring programs; however, do not necessarily provide the information required for basinwide assessments of water quality at the local, regional, or national scale.

During the period 1972–86, an estimated $541 billion was expended for water-pollution abatement in the United States; and in 1986, the U.S. Congress asked if the Nation's water quality was improving as a result of those expenditures. For various reasons, this basic question could not be answered satisfactorily using only existing ambient- and compliance-monitoring data. Therefore, the U.S. Geological Survey (USGS) was requested to design and implement a National Water-Quality Assessment (NAWQA) Program to address the questions related to status and trends in surface- and ground-water quality at national, regional, and local scales. The program was fully implemented in 1991.

An initial task of the NAWQA Program was to locate and evaluate existing data, and use those data to help meet as many of the program goals as possible. In general, these data are stored in computerized data bases or as paper files and are available upon request. The sharing of these data generally is not an issue within and among the various governmental agencies. Far greater issues are standardization, quality assurance, and some assurance that the shared data meet program goals and help to answer the questions being asked.

Because the existing data were not adequate to meet the goals of the NAWQA Program, the USGS has designed and is implementing water-quality monitoring networks within large river basins and major aquifer systems that, when combined with existing programs, will provide the information necessary to meet program goals. Great care has been taken to use standardized study approaches and techniques for data collection, laboratory analyses, and quality assurance so that information is comparable throughout the United States and can be compiled at various scales.

Some of the experiences gained by the USGS during the development of the NAWQA Program may be useful when developing an international data-sharing program for the effective management of Danube River basin resources. It is important for participating nations to agree upon ways to share data, but if those data are collected as part of compliance-monitoring programs, similar to those in the United States, it can not be assumed that those data alone will provide the information needed to assess the quality of the Danube River or design effective management programs. In addition to agreeing to share data, it is equally important for the participating nations to agree upon mutual goals and a valid design for the assessment program.

It is important to start by identifying questions and issues related to the water quality of a river basin; prioritize those questions and issues; and based on that prioritization, identify and prioritize a list of data and information needs. The next step is to identify and locate sources of existing data; consolidate the data; process, summarize, and evaluate the data; and share the results. This information then could be used to determine which of the priority questions could be answered using existing data, which could not be answered, and what data are necessary to fill information gaps. An assessment program then could be designed to fill the gaps; taking care to standardize approaches, techniques, and data bases; and to use new data in conjunction with existing data to address the priority questions. Standardization is critical throughout the programme so that the combined efforts of all participants will provide the information needed to answer the questions; and thereby, attain the agreed upon goals.

This evaluation is not meant to be a criticism of the available data from compliance-monitoring programs; but rather to point out that those data were collected to meet specific goals and to answer specific, short-term questions, and not for the purpose of meeting the goals of a long-term, river-basin-scale assessment. All data sets can be an important source of information for a water-quality assessment program, but their limitations need to be recognized and evaluated, and often, new data need to be collected to address specific assessment goals.

## INTRODUCTION

This report is one of several published as proceedings from a workshop entitled “An International Data-Sharing Programme for the Effective Management of Danube River Basin Resources.” The purpose of the workshop is to recommend an Action Program that will provide the framework for development of an international water-quality data-sharing programme that assures all participants access to accurate and compatible water-quality data necessary for management and protection of water resources of the Danube River Basin.

### Purpose and Scope

This report provides a brief history of United States laws related to protection of water quality, and the resulting standards, monitoring programs, and data-sharing mechanisms within the United States. But more importantly, this report describes the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program as one example of the process of planning, designing, and implementing a large-scale water-quality assessment.

### Water-Quality Legislation

Federal water-quality legislation in the United States began with the Federal Water Pollution Control Act as amended by the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), and further amended by the Clean Water Act of 1977 (PL 95-217) and the Clean Water Act Amendments of 1978 (PL 95-676). Current legislation is derived from the following:

- Clean Water Act (PL-100-4) 1987
- Safe Drinking Water Act (PL-99-339) 1986
- Superfund Amendments (PL-99-499) 1986
- Resource Conservation and Recovery Act (PL-94-580) 1976

Also included are a wide variety of other Federal and State mandates (Intergovernmental Task Force on Monitoring Water Quality, 1992). It also is important to note that the Safe Drinking Water Act was reauthorized by the U.S. Congress in August 1996.

## Standards and Guidelines

Water-quality legislation in the United States provides the basis for the development and implementation of standards and guidelines. It also designates the U.S. Environmental Protection Agency (USEPA) as the regulatory authority at the Federal level. In most cases, this authority is delegated by USEPA to state agencies that are responsible for environmental protection, provided that the state's mandates meet or exceed the Federal mandates.

National standards and guidelines for water quality are established for the United States by agencies of the U.S. Government or by the National Academy of Sciences (NAS) and National Academy of Engineering (NAE). Standards and guidelines are specific to one sampling medium (water, bed sediment, and fish and shellfish tissue) and focus on protection of one or more beneficial uses of the hydrologic system (drinking water, fish and shellfish consumption, aquatic organisms, and wildlife). The term "standard" refers to threshold values that are legally enforceable by the USEPA and/or designated state regulatory agencies. In water, USEPA maximum contaminant levels (MCLs) for drinking water; and levels of chemicals, such as pesticides, in edible fish and shellfish tissues are enforceable. The term "guideline" refers to threshold values that have no regulatory status but are issued in an advisory capacity. For instance, NAS/NAE may recommend maximum concentrations in water for protection of aquatic life that often become precursors to USEPA aquatic-life criteria or guidelines, but are not considered standards until the recommendations have undergone notice and comment procedures under the Administrative Procedures Act. Many states use Federal guidelines as the basis for state standards.

The USGS is the Federal government's earth-science agency and has no regulatory authority; however, the agency does conduct studies that are jointly funded by various levels of government. These studies provide data that are used to directly support Federal and State requirements, as well as providing interpretive information that helps water-resource managers understand their hydrologic systems. Standards and guidelines are useful tools in water-quality studies, since they provide a measure for comparison. However, valid use of a given standard or guideline requires an understanding of its technical basis and underlying assumptions. Several detailed references describe the technical basis and underlying assumptions, and provide lists of current standards and guidelines (see Camp Dresser & McKee, Inc., 1986; National Academy of Sciences and National Academy of Engineering, 1973; Nowell and Resek, 1994; U.S. Environmental Protection Agency, 1993, 1994, and 1995). Updated information is available at the USEPA home page on the World Wide Web (WWW) at **http://www.epa.gov.**

## Water-Quality Monitoring Programs

One of the greatest challenges faced by water-resource scientists is acquiring reliable data and information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by many local, State, and Federal agencies and academic institutions in the United States that collect and store water-quality data as a part of routine compliance-monitoring, water-quality assessment or ambient monitoring programs, and research activities in response to Federal and State laws mandated primarily by the Clean Water Act of 1987 and the Safe Drinking Water Act of 1986. An additional use of water-quality data and information is to provide a basis on which regional and national-level policy decisions can be based. Informed decisions must be based on sound information. As a society, we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the effectiveness of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

Much of the surface-water monitoring conducted in the United States is compliance monitoring and focuses on chemical concentrations and flows discharged from point sources, locations upstream and downstream of those sources, and water-supply intakes (see Intergovernmental Task Force on Monitoring Water Quality (1992) and Powell (1995)).

For example, the State of Wisconsin estimates that more than 98 percent of it's monitoring program is compliance monitoring; and Washington State estimates that 80 to 90 percent of its monitoring program is compliance monitoring.The goal of compliance-monitoring programs is to determine whether or not a given discharger, such as a municipal wastewater treatment facility, is in compliance with its discharge permit. Water samples are periodically collected from both the effluent and the receiving water body, and are analyzed for concentrations of selected constituents to determine if a concentration exceeds a water-quality standard or limit defined in the discharge permit. A large percentage of the water-quality data in the United States has been collected as a part of compliance-monitoring programs.

Ambient-monitoring and water-quality assessment programs generally focus on issues related to water-resource management of a river basin for multiple uses. There generally are multiple goals for these programs, such as: (1) describing the current status and historical trends in water quality, (2) comparing and contrasting the effects of point-source and nonpoint-source inputs, and (3) providing clear and concise summaries of sound scientific interpretations and recommendations to land- and water-resource managers. A small percentage of the water-quality data in the United States have been collected as a part of ambient monitoring programs or river-basin assessments.

In most cases, the majority of the available chemical and flow data have provided the information necessary to meet the objectives of the compliance-monitoring programs, but do not necessarily provide the information required for basinwide assessments of water quality at the local, regional, or national scale. Therefore, the majority of existing data have provided some of the information necessary to satisfactorily support some of the short- and long-term decisions concerning water-resources management in the United States.

In general, these data are stored in computerized data bases or as paper files and are available upon request, provided one knows they exist and where they are located. The sharing of these data generally is not an issue within and among the various governmental agencies. Far greater issues are standardization, quality assurance, and some assurance that the shared data meet program goals and help to answer the questions being asked.

## THE NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

During the period 1972-86, an estimated $541 billion was expended for water-pollution abatement in the United States (Intergovernmental Task Force on Monitoring Water Quality, 1992); and in 1985, the U.S. Congress asked if the Nation's water quality was improving as a result of those expenditures. For various reasons, this question could not be answered satisfactorily using existing water-quality information. Therefore, the U.S. Congress appropriated funds in 1986 for the USGS to design and implement a program to address questions related to status and long-term trends in surface- and ground-water quality at national, regional, and local scales. The USGS began a pilot program in seven project areas to develop and refine a plan for the National Water-Quality Assessment (NAWQA) Program (Hirsch and others, 1988). In 1991, the USGS began full implementation of the program (Leahy and others, 1990). The NAWQA program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA program are to:

- describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers;
- describe how water quality is changing over time; and
- improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems (referred to as study units). These study units are distributed throughout the Nation (fig. 1) and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within these study units and more than two-thirds of the people served by public water-supply systems live within their boundaries. The 60 study units have been divided into three groups of 20 study units each, and the intensive data-collection phases have been staggered to allow efficient and effective use of funds and human resources. The first 20 studies began in 1991, the second group began in 1994, and the third group is planned to begin in 1997. The first group of 20 study units is planned to begin a second cycle of study in the year 2000, and the cycle is intended to continue into the future, so as to provide both short-term information necessary for today's water-resource management decisions, and the long-term information needed for policy decisions.

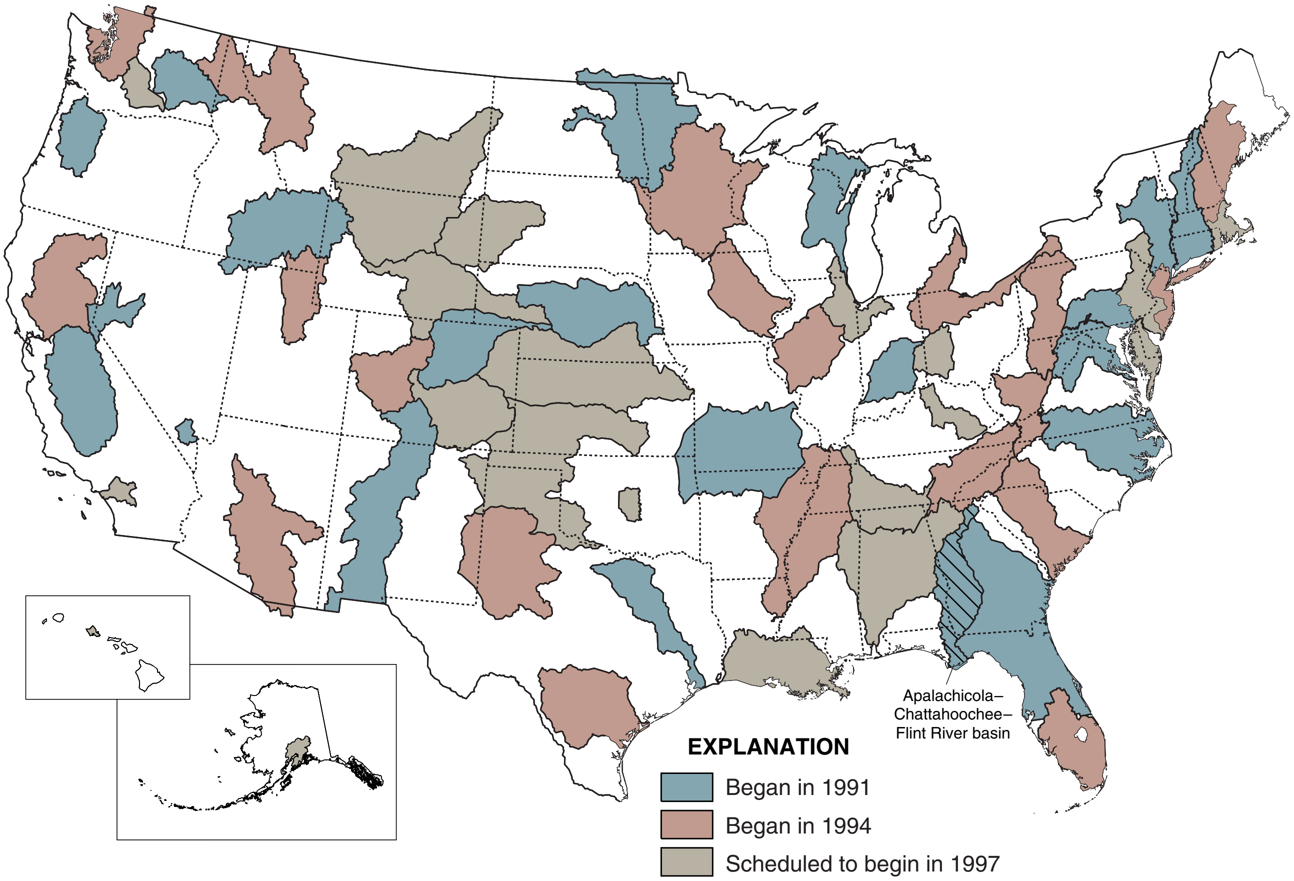



**Figure 1.** National Water-Quality Assessment Program study units.

## The National Water-Quality Assessment Program Design

Study-unit investigations are conducted at the river-basin or aquifer-system scale, and will comprise the foundation on which national and regional assessments will be based. National and regional synthesis of data, based on analyses of an aggregation of comparable information obtained from the study units, is a major component of the program (Leahy and others, 1990). This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides and the nitrogen and phosphorus nutrients, followed by volatile organic compounds, and aquatic biology as additional topics. Discussions of these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

Study-unit investigations consist of four phases. The first phase, *planning and study design*, and the second phase, *analysis of existing data*, have considerable overlap. The third phase, the implementation of the study design, is a *three-year period of intensive data collection*. The fourth phase is a period of *intensive data analysis, interpretation, and report production*; coincident with *low-intensity monitoring* meant to provide a link between high-intensity periods. Throughout all phases of the study, and at all levels of the program, emphasis is placed on using nationally consistent study designs and approaches, and sampling and analytical techniques to provide nationally consistent information that will address a pertinent set of questions. The approaches being used by all study-unit teams include conducting retrospective analyses of existing data; establishing a nationwide, long-term-monitoring network designed to assess existing water-quality conditions and provide a data base for trend analyses; and conducting process-oriented studies designed to provide a better understanding of the relation between land- and water-use activities and water-quality conditions.

### *Planning and Study Design*

Planning and study design was the initial task for the 20 study-unit teams that were formed in 1991. This was an iterative process that included addressing local issues, and at the same time assuring that the information provided by each study unit could ultimately be aggregated to address issues at the regional and national scale. To assure compatibility at all scales, standard lists of constituents were chosen, study approaches were designed, protocols for collecting and processing samples were developed, a quality-assurance plan was designed and implemented, and it was decided that all samples would be analyzed by one centralized laboratory using standardized analytical techniques. Compatible computerized data bases and geographic information systems (GIS) also were designed to be a part of a distributed-information system. To assure local involvement, liaison committees comprised of representatives from local, state, and Federal governmental agencies; environmental groups; and universities; were formed to provide a routine exchange of ideas and information.

### *Analysis of Existing Data*

The second phase for each study unit has been the analyses of existing data. In most study units much of the data for retrospective analyses were obtained from the USEPA's Water Storage and Retrieval (STORET) data base and from the USGS's National Water Information System (NWIS) data base. The STORET data base is available to all data-collection agencies for the storage and retrieval of those agencies' data, as well as the data of others. However, USEPA relies on each contributing agency to enter and quality assure their own data. Agency-specific data bases are not readily available, or are not yet automated, so STORET remains the best source for water-quality data. The NWIS data base is managed by the USGS and data inputs are strictly quality assured. The data are public information and available to users upon request, but direct access to the data base is limited. Private industries also monitor water quality but not all their data are available; in particular, the ground-water-quality data.

Each study-unit team compiled and analyzed existing water-quality data from water-resource agencies at all governmental levels. Those analyses determined the extent to which NAWQA goals could be met using existing data, and pointed out issues and areas that needed additional study. Because the types, amounts, and quality of data varied between study units, the retrospective analyses were a critical part of the iterative design process for the NAWQA Program as each study unit developed a plan to fill data gaps in a nationally consistent manner.

To meet the goals of assessing the Nation's water quality, the following were needed:

- long-term monitoring sites spatially distributed throughout a river basin and representative of a composite of upstream inputs;
- long-term data sets that included a broad list of constituents, including stream flow, that were temporally distributed throughout a year and were representative of all hydrologic conditions, including extremes such as droughts and floods;
- computerized data sets available in standard and easily readable formats;
- computerized data sets that were complete and accurate -- that is, a minimum standard set of data fields having data that were quality assured (checked and verified);
- assurance that the same or similar sample-collection techniques and laboratory analytical techniques were used, and that all techniques were well documented; and
- computerized data sets containing ancillary data that could be used to help explain water-quality information.

In general, the following were available:

- compliance-monitoring sites that often were poorly distributed spatially and heavily influenced by a point-source inputs and regulated flows;
- data sets having sites that were active during varying time periods, that included a minimum list of constituents based on the water-quality standards that apply to a particular site and often were collected from an inappropriate sample medium (such as, analysis of hydrophobic compounds in samples of open water), and generally do not include streamflow;
- some computerized data sets, but in varying formats and languages (much of the data were "available" in paper files that required data entry);
- incomplete data sets (empty fields) containing errors that caused all data to be of questionable quality;
- inadequately documented sample-collection techniques and laboratory analytical techniques that made it difficult to determine if the techniques used were the same or similar; and
- few ancillary data sets that contained current information at the appropriate spatial or temporal scale.

Because the existing data were not adequate to meet the goals of the NAWQA program, the study-unit teams designed surface- and ground-water-quality monitoring networks within large river basins that, when combined with existing programs, will provide the information necessary to meet the program goals.

It is important to note that the comparison of monitoring programs is not meant to be a criticism of the available data from compliance-monitoring programs; but, rather, to point out that those data were collected to meet specific goals and to answer specific, short-term questions, and not for the purpose of meeting the goals of a long-term, river-basin-scale assessment. All data sets can be an important source of information for a water-quality assessment program, but their limitations need to be recognized and evaluated, and often, new data need to be collected to specifically address assessment goals.

### *Intensive Data Collection*

The third phase for each study unit was implementation of the three-year intensive data-collection component of the study design. Each study unit design included the standardized approaches and data collection, quality assurance, and analysis techniques agreed upon during the planning and design phase (Gilliom and others, 1995). Great care was taken to consistently use those approaches and techniques so that information can be compiled at various scales. For the NAWQA Program to succeed at the regional and national levels, there must be a high level of assurance that data were collected and analyzed in a consistent manner to minimize differences due to data collection and analysis procedures. A chemical concentration measured in a water sample from one study unit must be directly comparable with a chemical concentration from any other study unit.

Sample sites were chosen based on a study-unit stratification process, whereby basins were subdivided by major features such as physiographic provinces or major aquifer systems that may influence water quality; and further subdivided by predominant land uses. Because of limited resources (funds, personnel, and time), a small number of sampling locations needed to be selected from a large list of potential sites that met the stratification criteria within each basin. Care was taken during the selection of sample sites to assure that data collected from each site helped to address questions and issues at local, regional, and national scales. Also, sample sites needed to be typical of the larger, surrounding area so that information gained through intensive monitoring could be transferred to adjacent locations that were monitored less frequently, and ultimately provide a description of water quality for the study unit.

#### *Surface-Water Monitoring Network*

A surface-water monitoring network was developed based on a nested design that included 50 to 100 sample sites spatially distributed throughout each study unit. Sample sites were chosen to represent various land uses, upstream and downstream of known point- and nonpoint-source inputs, and various scales ranging from small subbasins to large tributaries, and then to mainstem rivers. Sample frequency ranged from infrequent sampling of the complete network of sites to determine occurrence and distribution of selected chemicals and compounds in water, sediments, and biota; to a smaller network of fixed monitoring sites that were sampled monthly and during extreme high and low flows; and finally, to a subset of the fixed monitoring sites that were sampled weekly during periods of intensive application of nutrients and pesticides. In general, because of analytical costs, samples collected from the larger network were analyzed for a shorter list of constituents than samples collected from the few intensive monitoring sites. The following provides a brief description of types of monitoring sites, their intended purpose, sample frequency, and a list of constituents.

##### *Integrator Sites*

A small number (2 to 4) of fixed monitoring sites were located at continuous streamflow gaging stations on mainstem rivers that generally have large drainage areas and mixed land uses. These sites serve as *integrators* of upstream water quality. Water samples are collected monthly and an attempt is made to collect samples during extreme high and low flows (Shelton, 1994). Samples are analyzed for concentrations of nutrients, major ions, suspended sediment, and organic carbon. On-site measurements of flow and field parameters (pH, dissolved oxygen, specific conductance, water temperature, and alkalinity) are made during each site visit. Data from these sites, which often supplement existing monitoring programs supported by other agencies, form the core of the national network and will provide the data necessary to analyze for long-term trends.

*Indicator Sites*

A second group of 6 to 10 fixed monitoring sites were located at gaged sites (if a site did not have a gage, one was constructed so that a continuous-stream-flow record was available) in small watersheds (20 to 100 square miles [$mi^2$]) and serve as *indicators* of the effects of the predominant land use within that watershed. The same sample frequency and constituent list was employed at indicator sites as at the integrator sites. In addition, samples of the fish (Meador and others, 1993a), macroinvertebrate (Cuffney and others, 1993a,b), and benthic algal communities (Porter and others, 1993) were collected annually and a series of physical measurements were made to describe terrestrial and in-stream habitat (Meador and others, 1993b). Data from these sites form the core of the national network that will provide information on the effects of land use on water quality at various scales and in different hydrologic settings throughout the United States.

*Intensive Sites*

A subset of indicator sites (1 to 4 sites) was selected for *intensive* sampling during periods of heavy application of nutrients and pesticides, primarily in agricultural and urbanized watersheds. Depending on the study unit, samples were collected weekly from one to several months. Samples were analyzed for concentrations of nutrients, major ions, suspended sediment, organic carbon, and pesticides. On-site measurements of streamflow and field parameters were made during each site visit. These sites form the core of the national network that will provide estimates of flux from different land uses, and insights on the seasonal occurrence and magnitude of sampled constituents that are vital for development of more efficient and effective sampling designs.

*Comparison Sites*

Because in some study units the core of fixed monitoring sites represented only a small part of the total land area within the river basin there was concern about the level of confidence in the data, and that without a measure of variability, the information from these sites may have limited transferability to other sites, and to the study unit as a whole. Therefore, additional sites were selected for *comparison* with the indicator sites to help define variability between sites that had been chosen to represent a predominant land use. Generally, 2 to 4 comparison sites were paired with each of the indicator sites. Comparison sites met the same site-selection criteria as the indicator sites, but were sampled only 1 to 2 times per year. Samples were analyzed for the same list of constituents as the indicator sites, but with fewer biological analyses. In addition, 2 to 3 comparison sites were selected within each indicator basin to help define within-basin variability. Data from these sites are important at the study-unit scale because they provide a level of confidence about transferability of information to the larger scale; however, they are not part of a regional or National network.

*Synoptic Sites*

Additional sites were selected to provide a more complete spatial coverage of the river basin. These sites represented large tributaries that did not meet the criteria listed above, but represented large areas of mixed land use and provided substantial inputs to mainstem rivers. Sites on mainstem rivers that were not selected to be fixed monitoring sites also were a part of this network and represented locations upstream and downstream of major inputs or major influences, such as lakes and reservoirs. This group of sites, when combined with all sites described above, became the study unit's *synoptic* network. All sites in the network were sampled 1 to 2 times per year during a short period of time (2 to 3 weeks) by a large number of field crews. Samples were analyzed for the core list of chemical parameters and field measurements (some study units included pesticide analyses) in order to provide a spatial "snapshot" of the water quality within the basin at that time. Because all other monitoring sites were nested within this synoptic network, the data provided each study-unit team a means of putting individual sites in perspective within the basin, and provided some level of confidence about the transferability of information from an intensive site to a larger land area that the site was chosen to represent.

*Bed-Sediment and Tissue Surveys*

Each study-unit team selected 20 to 40 sites from the synoptic network for a survey of metals and hydrophobic organic compounds that may have accumulated in bed sediments and bioaccumulated in tissues. Fine-grained, surficial sediments representing recent deposition were collected—a subsample of the <63 μ fraction was analyzed for metals and a subsample of the <2mm fraction was analyzed for organochlorine compounds, semivolatile organic compounds, and organic carbon (Shelton and Capel, 1994). Whole-body tissue samples were analyzed for metals and organochlorine compounds (Crawford and Luoma, 1993). The tissue analyses were intended to provide information on occurrence and spatial distribution of chemicals and compounds that could be used to identify potential problem areas and help to develop the study design, and were not intended to be used for comparison with health-related standards. Target species were prioritized in an attempt to provide standardization nationally. The asiatic clam *Corbicula fluminea* was the first choice. If *Corbicula fluminea* was not present or in low abundance, benthic-feeding fish such as carp, catfish, or suckers were the second choice, followed by species of macroinvertebrates such as caddis flies.

*Ground-Water Monitoring Networks*

Ground-water monitoring networks were designed using three approaches that provided information at three scales: 1) a survey of wells and springs distributed throughout the study unit or a major aquifer system; 2) a survey of wells and springs representing the effects of specific land uses on the surficial aquifer system(s); and 3) surveys of transects of wells, springs, and seeps representing localized, small-scale flow systems (Lapham and others, 1995). The objectives of these surveys and the emphasis placed on each approach varied depending on the hydrogeology of the study unit. Generally, sample sites that were part of large-scale surveys were sampled once to determine occurrence and distribution of a large suite of chemicals and compounds (Koterba and others, 1995). Sample sites that were part of small-scale flow-system studies were sampled more frequently for a smaller suite of chemicals and compounds to provide understanding of processes that influence their fate and transport from specific land uses.

*Study-Unit Survey*

As a part of the retrospective analysis of existing data, the locations and physical descriptions of existing wells were incorporated into the study unit data base. That list then was sorted to provide a subset of 40 to 60 wells that met specific criteria such as: well constructed to avoid localized contamination; open interval represented the aquifer of interest; and well could be sampled using field techniques required for quality assurance. The intent of the survey was to describe water quality of a shallow aquifer or aquifer system that may be used for water supply and may be susceptible to contamination. Generally, the available wells were observation wells that had been installed during previous studies or domestic wells. In areas where few wells were available, springs were used to supplement the monitoring network. In study units having a large number of wells and springs, a standardized computer program developed by Scott (1990) was used to randomly select spatially distributed wells for sampling to assure statistical validity of the data.

*Land-Use Studies*

Land-use studies were designed to determine the effects of a specific land uses on the surficial aquifer system(s). Often, the surficial aquifers do not provide water supplies but their water quality is of interest to determine any effects of overlying land uses, and to provide an early warning of potential contamination of underlying aquifer systems. Generally, the target land uses were urban and agricultural. The standardized computer program by Scott (1990) was used to randomly select 20 to 40 sample locations. If existing wells and springs were in close proximity to the selected locations and met the study criteria, they were used as sample sites. Otherwise, shallow wells were installed. The preferred approach was to install wells to ensure consistency in well construction and materials. In general, this was feasible and cost effective in agricultural areas. However, in urban areas it was difficult to obtain permission to install monitoring wells, so sampling sites were limited to existing wells and springs that met the established criteria.

*Flow-System Studies*

Ground-water flow-system studies were designed with the intent of tracking specific chemicals or compounds applied at land surface, through the shallow ground-water system to an area of surface-water discharge. Studies generally focused on transport of nutrients and pesticides applied in agricultural and urban settings, and represented varying hydrogeologic and geographic settings. Unlike the approaches described above, these studies characterize local flow systems that are subject to possible ground-water contamination from land-use practices. A series of nested wells were installed along a transect believed to parallel the ground-water flow path from the source of contamination to the area of discharge to surface water. Springs, seeps, and drains within the study area often were used as sample points to supplement information from the wells and to gain a better understanding of the flow system. Samples were collected at varying frequencies, but generally collected to represent seasonal conditions.

*<u>Ancillary Data</u>*

Each study-unit team acquired ancillary data sets consisting of information that would help to describe and explain the water quality within the study unit. This information included—but was not limited to—soils, geology, population, land use and land cover, climatic data, and agricultural statistics such as crop types and acreages, fertilizer and pesticide usage, and numbers and types of animals produced in a given area. Much of these data were included in GIS coverages to assist with numeric and graphical evaluation.

<u>*Special Studies*</u>

Each study-unit team had the flexibility to conduct special studies that addressed issues critical to the river basin or major aquifer system, provided the core monitoring networks produced information necessary for regional and national syntheses. Several study-unit teams expanded their study designs by adding sample locations, adding or modifying approaches, or addressing water-quality topics beyond the national focus.

*Analysis, Interpretation, and Reports Publication*

The fourth phase of the NAWQA Program is data analysis, interpretation, and production of technical reports and other products such as briefing papers and educational materials. The 20 study-unit teams that began work in 1991 currently (1997) are in the fourth phase of the study. Each study-unit team is preparing topical reports that describe results and conclusions, and are archiving all information for future reference. Teams of scientists at the regional and national level are compiling data and interpretive information from the 20 study units, combining it with data and information from other sources, and will conduct regional and national syntheses that address issues related to nutrients, pesticides, volatile organic compounds, and aquatic biota.

Currently (1997), teams of scientists from the first group of 20 study units are collecting samples at a subset of monitoring sites as part of a low-intensity phase of study that is designed to provide a link between the high-intensity phases that will occur in 10-year cycles, and provide a better understanding of long-term trends that may occur. The second group of 20 study-unit teams began the planning phase in 1994, the retrospective analyses of existing data in 1995, and the three-year intensive data-collection phase in 1996. The third and final group of 20 study units are scheduled to begin the planning phase in 1997, the retrospective analysis phase in 1998, and the three-year intensive data-collection phase in 1999 (fig. 2). This staggered schedule allows the centralized laboratory to receive a consistent sample load, and allows the NAWQA Program to utilize funds and human resources efficiently and effectively. By the time the third group has completed the intensive data-collection phase (2001), the teams from the first group of study units will have evaluated the initial study designs, modified them to accommodate new or evolving issues, and will be prepared to begin a second cycle of intensive data collection. The NAWQA Program is intended to continue to provide water-resource information at the local, regional, and national level indefinitely.

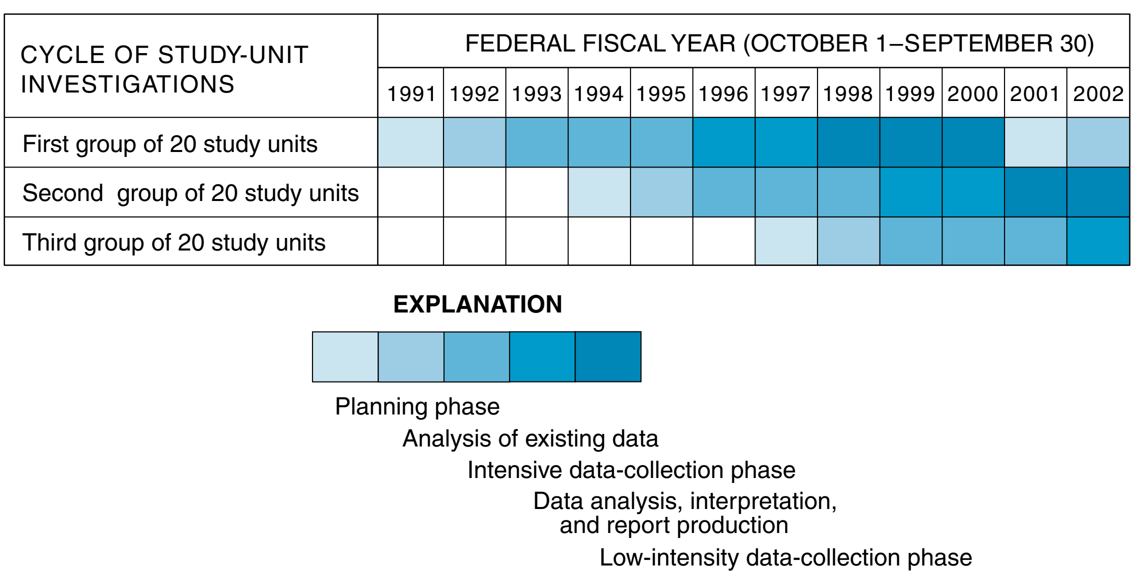



**Figure 2.** Schedule of first cycle of National Water-Quality Assessment study-unit investigations, by activity.

Some of the data collected during the first cycle of intensive data collection have been summarized and are described in reports that have been produced by teams at the study-unit and national level. Other data are being analyzed, interpreted, and documented in topical reports that will be produced during 1996-97. A list of reports published by the NAWQA Program, along with other information, is available at the USGS home page on the WWW at **http://www.usgs.gov.**

**Example of Study-Unit Design for the Apalachicola-Chattahoochee-Flint River basin**

The following section describes the integrated study design used to assess the physical, chemical, and biological quality of surface and ground water as it relates to point- and nonpoint-source contributions from various land uses within a typical NAWQA study unit. The design components for each study unit are very similar; and the study approaches and sampling and analytical techniques used are identical. Numbers of surface- and ground-water sampling sites vary somewhat between study units, but each study unit supports a minimum core of sites so that data can be compiled and synthesized at the regional and national levels.

The Apalachicola-Chattahoochee-Flint (ACF) River basin, located in the southeastern United States (fig. 1), was among the first 20 NAWQA study units selected for study in 1991 (Wangsness and Frick, 1991). The ACF River basin drains about 19,800 $mi^2$ in western Georgia, eastern Alabama, and the Florida panhandle, and is comprised of the Chattahoochee and Flint Rivers that converge at Lake Seminole to form the Apalachicola River (fig. 3). The Apalachicola River flows south through the Florida panhandle into Apalachicola Bay, which discharges into the Gulf of Mexico. Basin hydrology is influenced by 16 reservoirs that cause about 50 percent of the mainstem river miles to be in backwater, and play a major role in controlling flow and influencing the quality of water in the basin. The basin is underlain by five major aquifer systems; crystalline rock aquifers in the Blue Ridge and Piedmont physiographic provinces in the northern part of the basin, and four aquifers in the Coastal Plain physiographic province in the southern part of the basin. For more detailed information on the environmental setting of the ACF River basin, see Couch and others (1996).

The goal of the ACF River basin study design is to compare and contrast the effects of predominant land

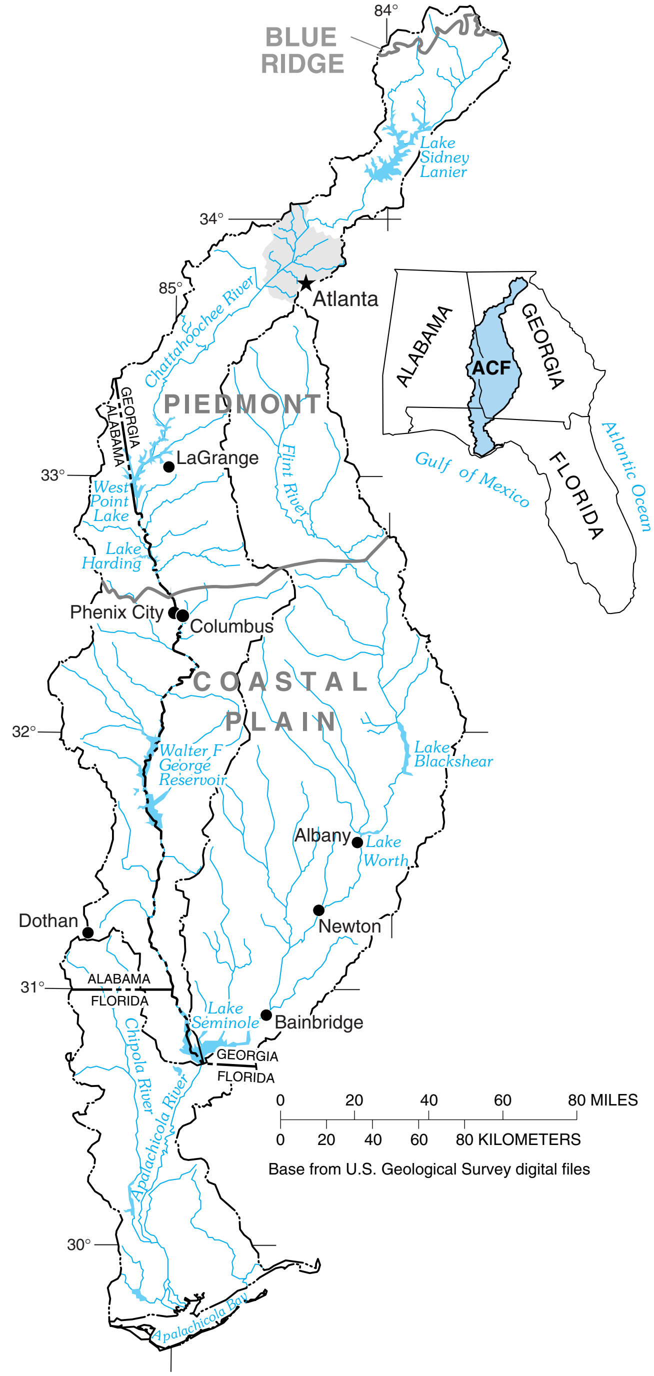



**Figure 3.** Apalachicola–Chattahoochee–Flint (ACF) River basin and physiographic provinces.

uses on surface- and ground-water quality. Forest and agriculture are dominant land uses and land covers within the ACF River basin, accounting for 59 and 29 percent of the study area, respectively (fig. 4). Most agricultural land in the upper and middle Chattahoochee and upper Flint River subbasins is used for livestock grazing and poultry production, while most agricultural land in the southern ACF River basin is used for row crops and vegetables; and to a lesser extent, orchards. Urban land use accounts for 5.3 percent of the study area. In 1990, the population of the ACF River basin was about 2.64 million people, 60 percent of which lived in the Metropolitan Atlanta area. Wetland areas account for about 5.4 percent of the entire basin. Agricultural and urban land uses are of particular interest within the ACF River basin, because they have the greatest potential impact on the physical, chemical, and biological quality of the surface- and ground-water resources.

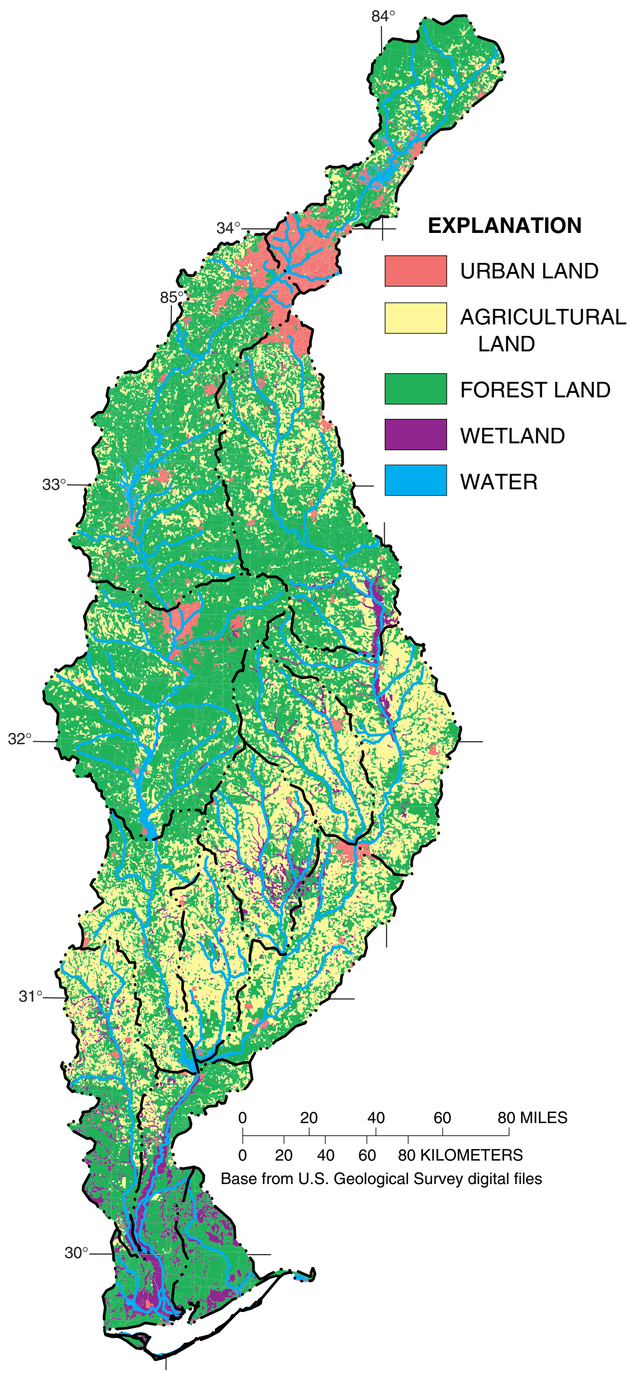



**Figure 4.** Land use in the Apalachicola–Chattahoochee–Flint River basin.

### *Planning and Retrospective Analysis Phases*

Development of a study design for the ACF River basin NAWQA Program was very much an iterative process that overlapped with the retrospective analysis phase. The study team located and assembled existing chemical and biological data, and GIS coverages that then were used to map the basin; discussed and prioritized issues and known problem areas with scientists and water-resource managers from local, state, and Federal agencies; and traveled extensively throughout the basin to inventory and evaluate potential sampling sites, and to verify maps and note changes in land uses and locations of point sources. The study team evaluated the information to determine information gaps, and then repeated the general process—searching for specific types of information, asking more specific questions of colleagues in other agencies, and narrowing the search for sample sites. The end result of this iterative process was a study design that would provide information needed to fill gaps or add to existing information, rather than duplicate information that either already existed or was being collected by other agencies, and ultimately provide a description of water quality within the ACF River basin.

Water-quality data that were available in STORET, NWIS, and other data bases were assembled, sorted, and evaluated as to their reliability and adequacy for assessing water quality within the ACF River basin. Some of the data sets contained analyses of compounds that have been banned from use in the United States, but few analyses of current-use compounds. This provided an historical summary, but no insight as to occurrence and distribution of current high-use compounds such as pesticides. Few ground-water analyses were available, and those data that were available represented localized studies that were not well distributed spatially. Biological data were limited to fish collections that were maintained by universities and often were stored as paper files that had to be computerized. Likewise, chemical and flow data from wastewater treatment facilities generally had not been entered into STORET and had to be entered into the study unit data base from paper files obtained from each facility. It was not practical to enter all data stored on paper files, however, it was decided that data from major facilities were critical for the evaluation of water quality within the ACF River basin. Once entered into the computer, these data proved to be very valuable. The most complete data set available for retrospective analysis was nutrient concentration data from a basinwide surface-water monitoring network supported by the States and the USGS. The majority of these data were collected for compliance monitoring, but the network contained adequate monitoring sites on the mainstem rivers to provide a good description of longitudinal, seasonal, and historical changes throughout much of the basin. When combined with data available from USGS streamflow gages, estimates of loads and flow-adjusted trends could be calculated. These data will provide the basis for national retrospective analyses and analysis of long-term trends during future study-unit cycles. Few monitoring sites were located on tributaries, so data interpretation was limited to a discussion of the effects of point-source inputs. Much of the existing data were used to indicate data gaps and to help develop an integrated study design. These data will be maintained as a part of the study unit and national data base for future evaluation.

*Intensive Data-Collection Phase*

Much of the historical data and current monitoring programs focus on point-source inputs and their effect on mainstem rivers. Since the effects of nonpoint-source inputs from various land uses is poorly understood, the NAWQA Program has been designed to fill that information gap. Because the ACF River basin is too large to allow for the detailed study of each stream and aquifer, several small watersheds and aquifer systems were selected to represent a predominant land use and/or physiographic area. The term predominant land use is used to describe areas of mixed land uses that are dominated by one land-use type (such as, 60 percent row-crop agriculture and a mix of other land uses), but are not homogeneous (such as, 100 percent row-crop agriculture). The ideal study design for comparison of land-use effects on water quality is a system of paired watersheds having different, homogeneous land uses. The goal of NAWQA is to describe water quality in large areas of the country; however, large areas of homogeneous land use generally do not exist in the ACF River basin. Therefore, small watersheds with no point-source inputs and having mixed land use, predominated by the target land use and typical of other small watersheds in the area, were selected for study. These small watersheds, ranging from about 20 to 100 $mi^2$ in area, represent a medium-sized scale of study that provides the link between small-scale studies (such as, farm-field level studies) and large-scale studies (such as, large tributaries and mainstem rivers draining mixed land uses and physiography, and containing point-source inputs). Because the goal of the study is to document water quality and describe the effects of land uses on water quality in the ACF River basin, it is necessary to study effects of land use at a medium scale, address some specific questions at a smaller scale, but ultimately be able to transfer what was learned at those scales to larger areas of the basin. It is this nested study design that will be described in greater detail in the following sections of this report.

During the development of the study design, the goal was to integrate surface-water, ground-water, and biological components where possible so as to be able to document the current water quality of the study area, to begin to describe the effects of predominant land uses on that water quality, and to lay the foundation for future evaluation of the surface- and ground-water resources as an integrated system. The design primarily focuses on nonpoint-source inputs of nutrients, sediment, and pesticides from agricultural, urban, and forested land uses. The primary agricultural land uses of interest are poultry production in the headwaters of the ACF River basin (Piedmont physiographic province) and production of row crops in the southern half of the basin (Coastal Plain physiographic province). The urban land uses of interest are intensive commercial areas, such as downtown Atlanta, and suburban residential areas, such as those surrounding Atlanta. In some parts of the country, forested lands represent large undisturbed areas and are suitable for collection of background information. Forested lands in the ACF River basin generally are being managed silviculturally. But even though the forested lands have been, or are being disturbed, they are the best representation of background water-quality conditions, and their effect on water quality is of value for comparison to other land uses.

*Surface-Water Design*

The surface-water system of the ACF River basin was stratified based on physiography and major land uses. Water-quality monitoring locations then were chosen to represent predominant land uses at various scales. The monitoring network reflects the nested study design described earlier, starting with a few fixed monitoring sites (integrator sites and indicator sites, a subset of which were intensive monitoring sites), adding a group of comparison sites, and finally a group of sampling sites on large tributaries and main-stem rivers. Water samples were collected at frequencies varying from hourly to annually, depending on the intended purpose. The different monitoring sites, sample types, and sample frequencies are described in the following sections. A description of surface-water monitoring sites is listed in table 1 at the back of this report. Site numbers assigned to each location are provided as a cross-reference to the locator maps. Table 2, also located at the back of this report, lists the chemicals and compounds analyzed in surface- and ground-water samples.

*Integrator Sites*

Because there already was an extensive monitoring network in the basin supported by State and Federal agencies, the NAWQA study design focused on three integrator sites located on mainstem rivers—two on the Chattahoochee River upstream and downstream of Metropolitan Atlanta, and one on the Apalachicola River near the mouth (table 1, fig. 5). The first two sites (sites 30 and 85 in table 1 and on figure 5) were selected to provide an estimate of total load of selected constituents in the Chattahoochee River upstream and downstream of a major source of point and nonpoint inputs to the river. Extensive monitoring of many point-source discharges to the river and tributaries provide data to estimate point-source loads of selected constituents and, by difference, estimate nonpoint-source loads from tributaries draining Metropolitan Atlanta. The site near the mouth of the Apalachicola River (site 139 in table 1 and on figure 5) was selected to provide an estimate of total load of selected constituents entering Apalachicola Bay. These data are valuable for comparing current and historical water-quality conditions, for documenting current water-quality conditions, and for analysis of long-term trends in the future.

*Indicator Sites*

Six indicator sites (table 1 and fig. 5) located on small streams having drainage areas ranging from about 20 to 90 $mi^2$, represent target land uses and physiography. West Fork Little River (site 15), the most upstream basin, represents water quality in an area of intensive poultry production. The primary issue is nutrient input from poultry litter that is spread on pastures surrounding the production areas. Sope Creek (site 50) and Peachtree Creek (site 70) are located within Metropolitan Atlanta and represent water quality in intensive urban and suburban watersheds, respectively. Sope Creek receives runoff from residential areas, and from suburban commercial areas and transportation networks that are less dense than areas within the City of Atlanta. Peachtree Creek receives runoff from dense commercial areas and transportation networks associated with the City of Atlanta, and inputs from combined sewer overflows. Snake Creek (site 84) receives runoff from an area that is predominantly forested. Tracts of land within the basin have been harvested for pulp and lumber and, therefore, the basin does not represent an unimpacted control watershed. However, since about 60 percent of the ACF River basin is forested, and under some type of silvicultural management, Snake Creek is typical and representative of forested basins within the study unit. Lime Creek (site 116) and Aycocks Creek (site 132) represent water quality in areas of intensive row-crop agriculture.

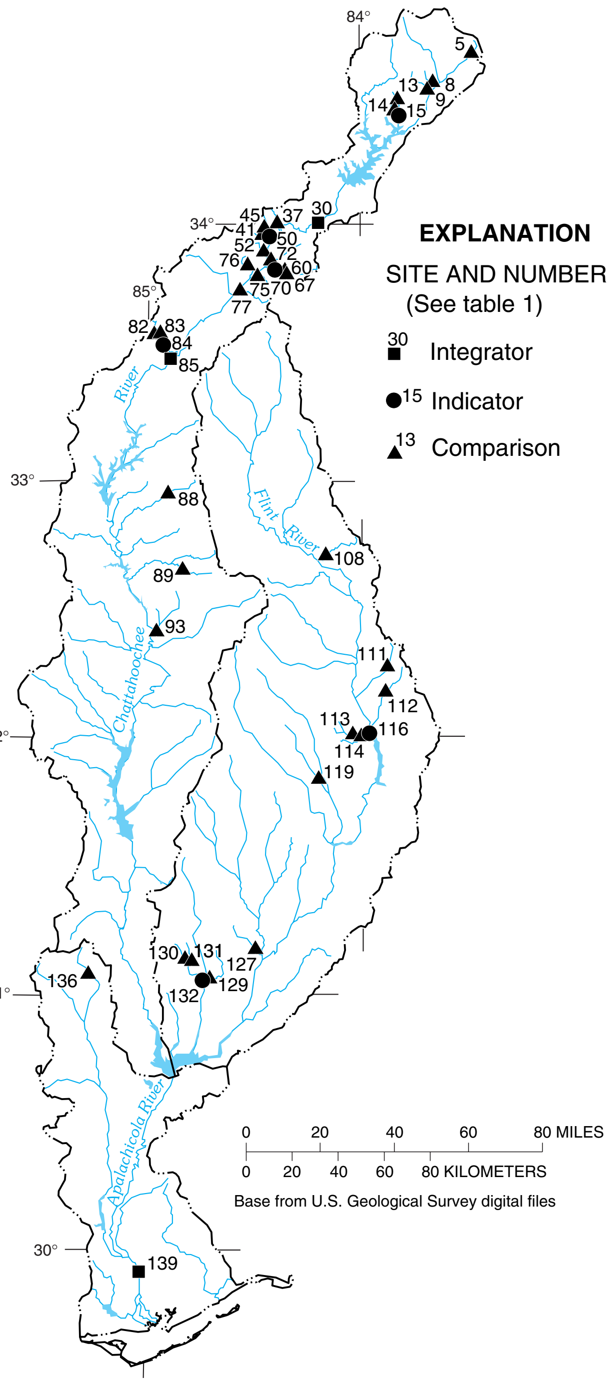



**Figure 5.** Locations of integrator, indicator, and comparison monitoring sites in the Apalachicola–Chattahoochee–Flint River basin.

Unlike parts of the United States where large, continuous tracts of land often are farmed to the stream bank, farming in the Coastal Plain of the southeastern United States is generally limited to well-drained uplands. This results in smaller and more discontinuous farm fields that do not extend to the river bank. Instead, streams generally are protected from overland runoff by natural buffers consisting of forested wetlands and floodplains. However, the potential remains high for the movement of farm chemicals to streams because the climate and availability of ground water for irrigation are favorable for multi-cropping practices that can result in the application of nutrients and pesticides to fields throughout much of the year.

*Intensive Sites*

Sampling sites on Sope, Lime, and Aycocks Creeks (table 1 and fig. 5) were selected as intensive sites and were sampled frequently during a one-year period to provide temporal data that defines the seasonal distribution of nutrients, sediment, and pesticides. Samples collected nearly once each week and several times during storm hydrographs, provided valuable information on the occurrence, magnitude, and distribution of constituents in the stream system. This information not only helps to assess the water quality of those representative basins, but also can be used to adjust future monitoring programs by targeting specific constituents and key times for conducting intensive sampling.

*Comparison Sites*

For each of the six indicator sites, 5 to 6 comparison sites were chosen (table 1 and fig. 5). Three sites were chosen for between basin comparison and 2 to 3 for within-basin comparison. Those sites chosen for between basin comparison met the same criteria as sites in the indicator basin. In theory, if data collected at all targeted land-use sites during basinwide synoptic surveys indicated that all basins had very similar water-quality characteristics, then information gained through intensive monitoring of one could be transferred to the others. Within-basin comparison sites were selected to represent inputs from tributaries or sub-basins upstream of the indicator site to help define within-basin variability.

Biological samples were collected at least once a year at each of the indicator sites and at their respective comparison sites, and a measure of terrestrial and in-stream habitat made once during the period of study. The most intensive sampling effort was conducted at the six indicator sites. A stream reach 6 to 10 times as long as the average width that contained replicate examples of the various habitats (such as pools, riffles, overhangs, and submerged logs) was defined. As cross-sectional areas for sampling were identified, care was taken to minimize disturbance of the cross section. Individual quantitative samples of macroinvertebrates and benthic algae were collected from potentially rich habitats such as cobble and gravel substrates in riffles, and depositional areas such as sand and mud in pools (table 3).

**Table 3.** Description of ecological sample types

| Type of sample | Units |
|---|---|
| **Fish assemblage** [1/] | |
| All habitats sampled | number of taxa |
| **Benthic macroinvertebrate**[2/,3/] | |
| Rich-targeted habitat (RTH) [habitat sampled—rock and snag] | number by taxon, in square meters |
| Depositional-targeted habitat (DTH) [habitat sampled—sand/silt in pools] | number by taxon, in square meters |
| Qualitative multiple habitat (QMH) [composite from all habitats] | number by taxon |
| **Benthic algae**[4/] | |
| Rich-targeted habitat (RTH) [solid substrates—rock and snag] | number by taxon, in square centimeters |
| Depositional-targeted habitat (DTH) [habitat sampled—sand/silt in pools] | number by taxon, in square centimeters |
| Qualitative multiple habitat (QMH) [composite from all habitats] | number by taxon |
| **Habitat assessment**[5/] | |
| Bank angle | degrees |
| Bank erosion | 6/ |
| Bank height | meters |
| Bank shape | 6/ |
| Bank stability | 6/ |
| Bank substrate | 6/ |
| Canopy angle | degrees |
| Channel aspect | degrees |
| Channel substrate | 6/ |
| Channel width | meters |
| Floodplain width | meters |
| Reach length | meters |
| Velocity | foot per second |

[1/]Sampling methods described in Meador and others (1993a).
[2/]Sampling methods described in Meador and others (1993a).
[3/]Sampling methods described in Cuffney and others (1993b).
[4/]Sampling methods described in Porter and others (1993).
[5/]Sampling methods described in Meador and others (1993b).
[6/]The nominal scale of classification is described in Meador and others (1993b). For example, bank stability is rated on a nominal scale of 1 to 4.

Qualitative samples were collected from these same habitats and, additionally, from other habitats such as the surfaces of living or dead vegetation, root and leaf mats, and overhanging banks in an attempt to provide data on relative abundance, and to better define a complete species list. Fish were collected using techniques such as electroshocking, seines, dip nets, or combinations of these techniques that provided the most representative sample of the fish community. Measurements of in-stream habitat included stream width, depth, and velocity; size and distribution of substrates; amount and type of submerged and emergent vegetation; and estimates of the percent of pools and riffles. Measurements of terrestrial habitat included bank slope and stability; vegetation type, size, and density; and percent of cover overhanging the stream. A less intensive sampling effort was performed at the comparison sites to conserve funds and human resources. Priority was placed on the collection of a representative sample of the fish community; single, qualitative/semiquantitative samples of macroinvertebrates and benthic algae, and measurements of in-stream habitat.

#### _Synoptic Sites_

Monitoring sites were identified near the mouths of major tributaries, upstream and downstream of major reservoirs, and at additional locations on the main-stem rivers (table 1 and fig. 6). These sites completed the surface-water monitoring network and assured a more complete spatial coverage than the sampling sites described above could provide alone. Synoptic surveys of the entire monitoring network were conducted three times during the period of study. Surveys were conducted during spring and early summer to coincide with periods of nutrient and pesticide applications to urban and agricultural lands.

#### _Bed-Sediment and Tissue Surveys_

Two bed sediment and tissue surveys were conducted early in the project to provide information useful to the overall study design. An initial survey of 31 sites consisting of integrator, indicator, selected mainstem river, and reservoir sites was conducted in 1992 to determine occurrence of organic compounds and trace metals in bed sediments and the asiatic clam *Corbicula fluminea*. A second survey that included resampling many of the same sites and adding about 15 additional sites, primarily in urban and suburban watersheds, was conducted in 1993 to better define the distribution of organic compounds and trace metals throughout the ACF River basin. Because of the basinwide distribution of *Corbicula fluminea,* it was exclusively analyzed to assess the bioaccumulation of organic compounds and trace metals in tissue, except at three locations in the Apalachicola River floodplain where *Gambusia affinis holbrooki* (mosquitofish) was used for tissue analysis.

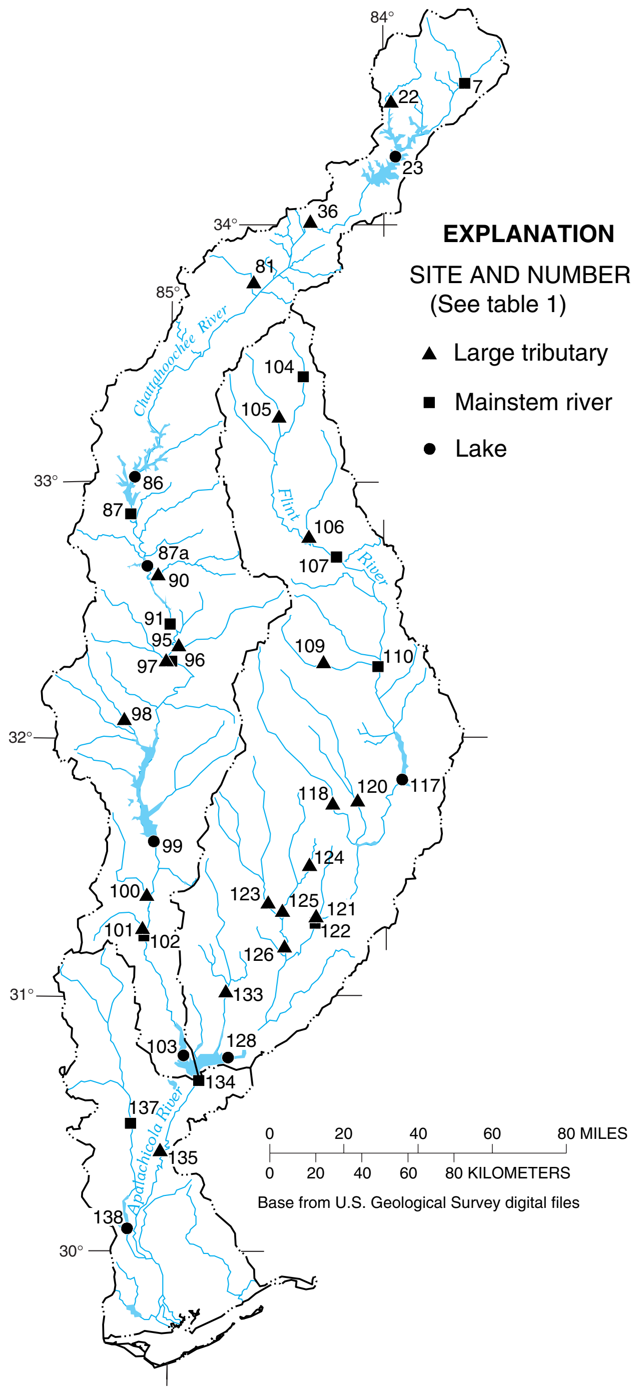



**Figure 6.** Locations of large tributary, mainstem, and lake monitoring sites in the Apalachicola–Chattahoochee–Flint River basin.

*Ground-Water Design*

Because few ground-water data existed within the ACF River basin prior to this study, the ground-water monitoring network was designed primarily to provide information on the occurrence and distribution of a large suite of chemicals and compounds that can be used to better identify problem areas, and define related questions and issues. Data collected during this first cycle of intensive data collection also will provide a valuable reference for comparison with the data collected during subsequent cycles of intensive data collection. The ground-water monitoring networks, analytical schedules, and sample frequencies are described in the following sections. Table 4 lists the numbers of sample sites and analyses performed as a part of each of the ground-water monitoring networks. Table 2 lists the chemicals and compounds analyzed in samples from surface- and ground-water monitoring sites.

**Table 4.** Description of ground-water monitoring networks in the Apalachicola-Chattahoochee-Flint River basin, and types and numbers of samples collected

| Type of network | Number of sites | Number of samples by monitoring network | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Field parameters and water level | Nutrients | Major ions and turbidity | Organic carbon | Pesticides | Trace elements | Volatile organic compounds | Tritium | Isotopes (hydrogen and oxygen) | Radon |
| **Study-unit survey** | | | | | | | | | | | |
| Wells (domestic and observation) | 26 | 26 | 25 | 26 | 26 | 26 | 26 | 26 | 26 | 22 | 26 |
| Springs | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 14 | 14 |
| **Land-use studies** | | | | | | | | | | | |
| **Agricultural land use (drilled wells)** | | | | | | | | | | | |
| Agricultural wells (low water table) | 36 | 36 | 36 | 36 | 34 | 36 | — | 28 | 17 | — | 15 |
| Reference wells (low water table) | 4 | 4 | 4 | 4 | 3 | 4 | — | 4 | — | — | 3 |
| Agricultural wells (high water table) | 27 | 27 | 27 | 27 | 26 | 27 | — | 1 | 4 | — | 19 |
| Reference wells (high water table) | 4 | 4 | 4 | 4 | 4 | 4 | — | — | — | — | 3 |
| **Urban land use** | | | | | | | | | | | |
| Wells (domestic and observation) | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | — | — | 21 |
| Springs | 19 | 19 | 19 | 19 | 18 | 17 | 19 | 19 | — | — | 18 |
| **Flow-system study** | | | | | | | | | | | |
| U.S. Geological Survey wells | 19 | 77 | 77 | 62 | 53 | 58 | — | — | — | — | — |
| Agricultural Research Service wells [1/] | 18 | 207 | 242 | 17 | — | 72 | — | — | — | — | — |
| Drains | 3 | 67 | 105 | 32 | 26 | 33 | — | — | — | — | — |
| Springs | 3 | 3 | 3 | 3 | 3 | 3 | — | — | — | — | — |
| Pore Waters | 11 | 11 | 11 | 11 | — | — | — | — | — | — | — |

[1/] Includes sample sites and data from collaborative study with U.S. Department of Agriculture, Agricultural Research Service.

*Study-Unit Survey*

The study-unit survey was designed to characterize the quality of shallow ground water within the Floridan aquifer system and to determine the effects of land use. An area of about 3,900 $mi^2$ in the southern part of the study unit, known locally as the Dougherty Plain and underlain by the Floridan aquifer system, was selected for the ground-water study-unit survey (fig. 7). The predominant land use in the Dougherty Plain is row-crop agriculture and orchards. The source of some public and most domestic water supply is the Floridan aquifer system, a highly productive fractured limestone aquifer having karst features. To establish sampling sites within the Dougherty Plain, the area was subdivided into 30 polygons of similar size and existing wells or, where present, one or two high-flow springs were chosen for sampling from each polygon. Forty two sites were selected for sampling. Depth to water in the monitoring wells ranged from 10 to 59 feet below land surface (one well was a flowing well with approximately 3 feet of head). Each site was sampled once in August or September 1995. Samples were analyzed for nutrients, pesticides, volatile organic compounds, trace metals, major ions, organic carbon, stable isotopes, and selected radionuclides. On-site measurements of ground-water levels, flow from springs, and field parameters were made at each site.

*Land-Use Studies*

The agricultural land-use study was designed to determine the chemical quality of shallow ground water that underlies agricultural areas in a 6,700 $mi^2$ area of the southern part of the ACF River basin (fig. 7). Sites for monitoring the surficial aquifer were located randomly using the computer program developed by Scott (1990), and wells were installed according to Lapham and (1995) adjacent to and downgradient of 37 farm fields. Four reference wells were installed in forested areas to represent background water-quality conditions. The depth to the water table in the surficial aquifer monitoring wells ranged from about 3 to 67 feet below land surface. Surficial aquifers were selected for sampling rather than deeper aquifer systems because surficial aquifers are the first water-bearing zones to receive recharge from infiltration, and presumably are more susceptible to contamination. Therefore, water-quality conditions in surficial aquifers may serve as an early warning of potential contamination of deeper aquifer systems that are used for drinking-water supply and irrigation. Water samples were collected from all wells during summer 1993 and from most wells during spring 1994. The sample times represented low and high water-table conditions, respectively. The samples were analyzed for nutrients, pesticides, volatile organic compounds, major ions, organic carbon, and selected radionuclides. On-site measurements of water levels and field parameters also were made at each site.

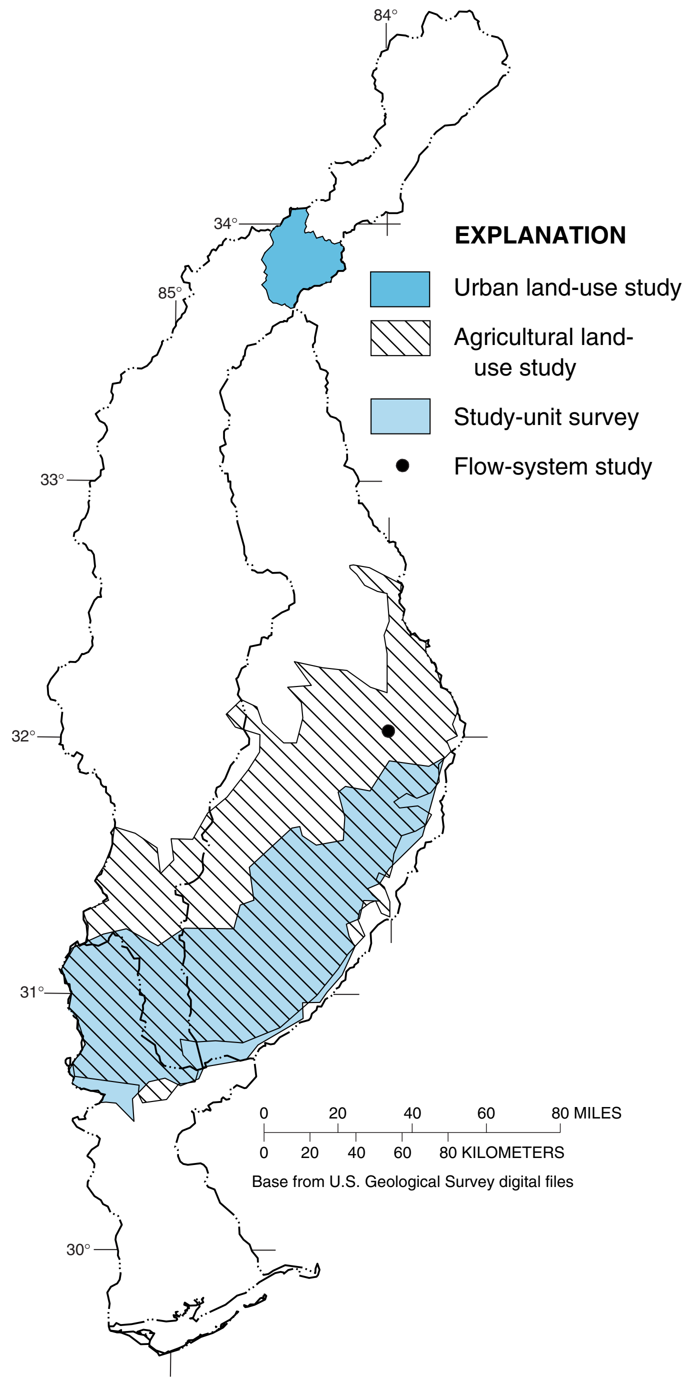



**Figure 7.** Location of ground-water study areas in the Apalachicola–Chattahoochee–Flint River basin.

The urban land-use study (fig. 7) was designed to determine the chemical quality of shallow ground water that underlies Metropolitan Atlanta within a 350 $mi^2$ area of the surficial drainage to the Chattahoochee River. Sampling sites were established by subdividing the study area into 30 polygons of equal area using the computer program developed by Scott (1990), and then selecting an existing domestic or observation well; and where present, a spring, from each polygon. Forty locations were selected as sampling sites. Depth to water in the monitoring wells ranged from 2 to 29 feet below land surface. Each site was sampled once during the period from Summer 1994 through Spring 1995. Samples were analyzed for nutrients, pesticides, volatile organic compounds, major ions, organic carbon, trace metals, and selected radionuclides. On-site measurements of water levels, flows from springs, and field parameters also were made at each site.

*Flow System Study*

The ground-water flow system study (fig. 7) was designed to track the transport of nutrients and pesticides from a field where they were applied, through the shallow flow system that underlies the field and the adjacent forested floodplain/wetland, to areas of discharge to the surface-water system. During previous studies of a 1,000-acre field, nutrients and pesticides were measured in two shallow ground-water monitoring wells adjacent to and down-gradient from the field. Three generalized flow paths were identified within the study area: (1) shallow ground water collected by a network of tile drains within the field that discharged to ditches; (2) shallow ground water flowing from the farmed upland area and discharging along the toe slope at the edge of the forested floodplain; and (3) shallow ground water flowing from the farmed upland area, through the alluvial sediments within the floodplain, and discharging directly to the stream. Sampling points were located along two transects from edge of field to stream. Shallow monitoring wells were installed at each sample point, including points adjacent to the stream and within the stream bed; lithologic information was recorded; and water samples were collected and analyzed from each well and from the stream. Based on an evaluation of those data, additional sample locations were selected to provide better characterization of the system. These included additional wells installed along the transects between existing locations, nests of wells installed at varying depths at existing locations, springs located along the base of the toe slope that separated the forested upland from the forested floodplain, and three pipes connected to a network of tile drains throughout the field that discharged into two drainage ditches that flowed through the floodplain. The complete network of sample locations included 34 wells, 3 springs, 3 drains, and 2 surface-water sites. The frequency of sample collection and the list of constituents analyzed in water samples varied, but a core of sites were sampled three times a year to represent different seasons and flow conditions. Most samples were analyzed for nutrients, pesticides, major ions, and organic carbon. On-site measurements of water levels, flows, and field parameters also were made during each visit.

*Special Studies*

The study design for the ACF River basin study unit was modified to include four special studies: (1) addition of an intensive network of synoptic sites within the urban and suburban basins; (2) analysis of sediment cores collected from six of the reservoirs within the study unit; (3) intensive sampling of the Flint River during record flooding; and (4) seasonal sampling of fish to determine community recovery following the record flooding. Each of these activities was pertinent to the assessment of water-quality conditions within the ACF River basin, and also provided information of value to both regional and national synthesis efforts.

A network of surface-water monitoring sites, which included the indicator and two comparison sites, was selected within Sope Creek (total of 14 sites) and Peachtree Creek (total of 19 sites) and sampled during one-day synoptic surveys that represented baseflow conditions. Three surveys were conducted within Sope Creek basin and one within Peachtree Creek basin. The purpose for these surveys was to locate areas of ground-water discharge that would provide the basis for a flow-system study, and to better define water quality in small basins affected by urban and suburban land uses. In-situ measurements of flow and field parameters were made, and samples were collected and analyzed for nutrients, pesticides, major ions, and organic carbon.

The system of reservoirs within the study unit provided an opportunity to evaluate land-use changes and chemical inputs within the basin, as reflected by changes in the chemical composition of sediments deposited within the reservoirs. Sediment cores were collected from six of the major reservoirs for the purpose of defining changes within each reservoir and differences between reservoirs. Each core was divided into discrete subsamples that were age dated and analyzed for a suite of organic compounds, trace metals, major ions, nitrogen, phosphorus, and carbon.

During July 1994, Tropical Storm Alberto caused record flooding in southwestern and central Georgia, southeastern Alabama, and northwestern Florida. Parts of Georgia received as much as 28 inches of rainfall during the storm. The record flooding provided a unique opportunity to measure concentrations and loads of nutrients, suspended sediments, and pesticides during extreme hydrologic conditions. Water samples were collected from several locations affected by the flood, but the most frequent data collection within the ACF River basin occurred at the Flint River at Newton, Ga., the most downstream site that was accessible throughout the flood. Nineteen samples were collected during the period July 5–26, 1994.

The record flooding also provided an opportunity to document the recovery of fish communities following the catastrophic event. The pre-flood fish community in Lime Creek, one of six indicator sites, had been documented as a part of the original study design based on samples collected in June 1993 and May 1994. To determine post-flood community structure three samples were collected during the period August 1994 through August 1995.

*Current Status of Apalachicola-Chattahoochee-Flint River Basin National Water-Quality Assessment Study*

Four monitoring sites (sites 15, 50, 70, and 84) are sampled monthly as part of a low-intensity phase of study that is designed to provide a link between high-intensity phases. Some of the data collected during the first cycle of intensive data collection have been summarized and are described in reports that have been produced by the study-unit team. Other data are being analyzed, interpreted, and documented in topical reports that will be produced during 1997. Published reports, along with maps, data, and links to other agencies and organizations are available at the ACF River basin NAWQA home page on the WWW at **http://wwwga.usgs.gov/nawqa/.** This WWW site is updated as new products become available.

## SUMMARY

In 1986, the U.S. Congress asked if the Nation’s water-quality was improving as a result of the expenditure of an estimated $541 billion for water-pollution abatement in the United States during the period 1972-86. For a number of reasons, this important question could not be answered satisfactorily using existing water-quality information. Therefore, the U.S. Geological Survey was provided funds to design and implement a National Water-Quality Assessment Program to address questions related to status and long-term trends in surface- and ground-water quality at national, regional, and local scales. Information from the NAWQA Program will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

Some of the experience gained by the USGS during the development of the NAWQA Program may be useful when developing an international data-sharing programme for the effective management of Danube River basin resources. It is important for participating nations to agree upon ways to share data, but if those data were collected as part of compliance-monitoring programs, similar to those in the United States, it cannot be assumed that those data alone will provide the information needed to assess the quality of the Danube River, or design effective management programmes. In addition to agreeing to share data, it is equally important to agree upon mutual goals and a valid design for the assessment program. It is important to start by identifying questions and issues related to the water quality of the Danube River basin. This should be an iterative process that is open to consensus building.

The next step in designing an assessment program is prioritization of the questions and issues, realizing that an assessment program may not be able to address all questions and issues, and also realizing that priorities may vary throughout a river basin as large as the Danube. Based on the priority questions and issues to be addressed, a list of data and information needs can be identified and prioritized. This would include locations of key sample sites, constituent lists, sample-collection and laboratory-analytical techniques, sample frequencies, types of ancillary data, and data-reporting criteria. The next step is to identify and locate sources of existing water-quality, water-quantity, and ancillary data; consolidate existing data; process, summarize, and evaluate the data; and share results. This information could then be used to determine which of the priority questions could be answered using existing data, which could not be answered, and what data are necessary to fill information gaps. An assessment program could then be designed to fill the gaps, taking care to standardize approaches, techniques, and data bases, and to use new data in conjunction with existing data to address the priority questions. Standardization is critical throughout the program so that the combined efforts of all participants will provide the information needed to answer the questions and, thereby, attain the agreed upon goals.

## REFERENCES CITED


Arbogast, Belinda, 1990, Quality assurance manual for the Branch of Geochemistry: U.S. Geological Survey Open-File Report 90-668, 184 p.

Camp Dresser & McKee, Inc., 1986, The Safe Drinking Water Act, as amended by the Safe Drinking Water Act Amendments of 1986: Boston, Mass., Camp Dresser & McKee, Inc., 54 p.

Couch, C.A., Hopkins, E.A., and Hardy, P.S., 1996, Influences of environmental settings on aquatic ecosystems in the Apalachicola-Chattahoochee-Flint River basin: U.S. Geological Survey Water-Resources Investigations Report 95-4278, 58 p.

Crawford, J.K., and Luoma, S.N., 1993, Guidelines for studies of contaminants in biological tissues for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 92-494, 69 p.

Cuffney, T.F., Gurtz, M.E., and Meador, M.R., 1993a, Methods for collecting benthic invertebrate samples as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 93-406, 66 p.

___1993b, Guidelines for the processing and quality assurance of benthic invertebrate samples collected as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 93-407, 80 p.

Fishman, M.J., and Friedman, L.C., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water Resources Investigations, book 5, chap. A1, 545 p.

Foreman, W.T., Conner, B.F., Furlong, E.T., Vaught, D.G., and Merten, L.M., 1995, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory—Determination of organochlorine pesticides and polychlorinated biphenyls in bottom sediment by dual capillary-column gas chromatography with electron-capture detection: U.S. Geological Survey Open-File Report 95-140, 78 p.

Furlong, E.T., Vaught, D.G., Merten, L.M., Foreman, W.T., and Gates, P.M., 1996, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory—Determination of semivolatile organic compounds in bottom sediment by solvent extraction, gel permeation chromatographic fractionation, and capillary-column gas chromatography/mass spectrometry: U.S. Geological Survey Open-File Report 95-719, 67 p.

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the National Water-Quality Assessment Program: occurrence and distribution of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.

Guy, Harold P., 1973, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. C1, 58 p.

Hirsch, R.M., Alley, W.M., and Wilber, W.G., 1988, Concepts for a National Water-Quality Assessment Program: U.S. Geological Survey Circular 1021, 42 p.

Hoffman, G.L., 1996, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory -- Preparation procedure for aquatic biological material determined for trace metals: U.S. Geological Survey Open-File Report 96-362, 42 p.

Intergovernmental Task Force on Monitoring Water Quality (ITFM), 1992, Ambient water-quality monitoring in the United States: first year review, evaluation, and recommendations: A Report to the Office of Management and Budget, Washington, D.C., 50 p.

Koterba, M.T., Wilde, F.D., and Lapham, W.W., 1995, Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program: collection and documentation of water-quality samples and related data: U.S. Geological Survey Open-File Report 95-399, 113 p.

Lapham, W.W., Wilde, F.D., and Koterba, M.T., 1995, Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program: selection, installation, and documentation of wells, and collection of related data: U.S. Geological Survey Open-File Report 95-398, 69 p.

Leahy, P.P., Rosenshein, J.S., and Knopman, D.S., 1990, Implementation plan for the National Water-Quality Assessment Program: U.S. Geological survey Open-File Report 90-174, 10 p.

Leiker, T.J., Madsen, J.E., Deacon, J.R., and Foreman, W.T., 1995, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory—Determination of chlorinated pesticides in aquatic tissue by capillary-column gas chromatography with electron-capture detection: U.S. Geological Survey Open-File Report 94-710, 42 p.

**REFERENCES CITED—Continued**

Meador, M.R., Cuffney, T.F., and Gurtz, M.E., 1993a, Methods for sampling fish communities as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 93-104, 40 p.

Meador, M.R., Hupp, C.R., Cuffney, T.F., and Gurtz, M.E., 1993b, Methods for characterizing stream habitat as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 93-408, 48 p.

National Academy of Sciences and National Academy of Engineering (NAS/NAE), 1973, Water quality criteria, 1972: U.S. Environmental Protection Agency, EPA R3-73-033, 594 p.

Nowell, L.H., and Resek, E.A., 1994, National standards and guidelines for pesticides in water, sediment, and aquatic organisms: application to water-quality assessments: Reviews in Environmental Contamination and Toxicology, v. 140, New York, Springer-Verlag, 164 p.

Porter, S.G., Cuffney, T.F., Gurtz, M.E., and Meador, M.R., 1993, Methods for collecting algal samples as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 93-409, 39 p.

Powell, Mary, 1995, Building a national water-quality monitoring program: Environmental Science & Technology, v. 29, no. 10, p. 458-463.

Rose, D.L., and Schroeder, M.P., 1995, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory—Determination of volatile organic compounds in water by purge and trap capillary gas chromatography/mass spectrometry: U.S. Geological Survey Open-File Report 94-708, 26 p.

Sandstrom, M.W., Wydoski, D.S., Schroeder, M.R., Zamboni, J.L., and Foreman, W.T., 1992, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory—Determination of organonitrogen herbicides in water by solid-phase extraction and capillary-column gas chromatography/mass spectrometry with selected-ion monitoring: U.S. Geological Survey Open-File Report 91-519, 26 p.

Scott, J.C., 1990, Computerized stratified random site-selection approaches for design of a ground-water-quality sampling network: U.S. Geological Survey Water-Resources Investigations Report 90-4101, 109 p.

Shelton, L.R., 1994, Field guide for collecting and processing stream-water samples for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 94-455, 42 p.

Shelton, L.R., and Capel, P.D., 1994, Guidelines for collecting and processing samples of stream bed sediment for analysis of trace elements and organic contaminants for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 94-458, 22 p.

Thatcher, L.L., Janzer, V.J., and Edwards, K.W., 1977, Methods for determination of radioactive substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A5, 95 p.

U.S. Environmental Protection Agency, 1993, Protection of environment, *revised* July 1, 1993: U.S. Code of Federal Regulations, title 40, parts 100 to 149, 1,053 p.

___1994, National primary drinking water standards: U.S. Environmental Protection Agency, EPA 810-F-94-001, 2 p.

___1995, Drinking water regulations and health advisories: U.S. Environmental Protection Agency, 11 p.

Wangsness, D.J., and Frick, E.A., 1991, National Water-Quality Assessment Program - The Apalachicola-Chattahoochee-Flint River basin: U.S. Geological Survey Open-File Report 91-163, 2 p.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., 1983, Methods for the determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A3, 173 p.

**Table 1.** Description of surface-water monitoring sites in the Apalachicola-Chattahoochee-Flint River basin and types and numbers of samples collected

[$mi^2$, square miles; —, no data; <, less than

| Site number (see figures 5 and 6) | Site type and name | Drainage area ($mi^2$) | Land use (in percent) | | | | | Number of samples per monitoring site | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Water column samples | | | | | | Bed sediment | | Tissue | | Ecological samples | | | |
| | | | Forest | Agriculture | Urban | Wetland | Other | Field Parameters/Flow | Nutrients/Turbidity | Major Ions | Suspended Sediment | Organic Carbon | Pesticides | Organics | Trace Metals | Organics | Trace Metals | Fish | Macro Invertebrates | Periphytic Algae | Habitat |
| | **Integrator sites** | | | | | | | | | | | | | | | | | | | | |
| 30 | Chattahoochee River near Norcross | 1,168 | 71 | 16 | 7 | — | 6 | 33 | 33 | 32 | 31 | 32 | 3 | 1 | 1 | 1 | 1 | — | — | — | — |
| 85 | Chattahoochee River near Whitesburg | 2,411 | 59 | 14 | 23 | — | 4 | 35 | 35 | 34 | 30 | 34 | 5 | 2 | 2 | — | 1 | — | — | — | — |
| 139 | Apalachicola River near Sumatra [1/] | 19,241 | 58 | 30 | 6 | 4 | 2 | 26 | 26 | 26 | 26 | 25 | 4 | 2 | 2 | 1 | 1 | — | — | — | — |
| | **Indicator and comparison sites (indented)** | | | | | | | | | | | | | | | | | | | | |
| 15 | West Fork Little River near Clermont [2/] | 18 | 57 | 42 | 1 | — | — | 47 | 47 | 43 | 44 | 42 | 2 | 1 | 1 | 1 | 1 | 7 | 17 | 12 | 1 |
| 5 | Deep Creek near Hollywood | 16 | 83 | 14 | 3 | — | — | 4 | 4 | 2 | 3 | 3 | 2 | — | — | — | — | 3 | 2 | 2 | 1 |
| 8 | White Creek near Cleveland | 8.3 | 44 | 56 | — | — | — | 4 | 4 | 2 | 3 | 3 | 2 | — | — | — | — | 3 | 2 | 2 | 1 |
| 9 | Mossy Creek near Cleveland | 28 | 74 | 24 | 1 | — | 1 | 4 | 4 | 2 | 3 | 3 | 2 | — | — | — | — | 3 | 2 | 2 | 1 |
| 13 | West Fork Little River (within basin) | 5.9 | 54 | 46 | — | — | — | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | — | 2 | — | 1 |
| 14 | Bear Creek (within basin) | 3.4 | 46 | 54 | — | — | — | 3 | 3 | 2 | 2 | 3 | 2 | — | — | — | — | — | 2 | — | 1 |
| 50 | Sope Creek near Marietta [2/] [3/] | 31 | 1 | <1 | 98 | — | <1 | 81 | 81 | 46 | 70 | 44 | 68 | 2 | 2 | 1 | 2 | 5 | 11 | 6 | 1 |
| 37 | Willeo Creek near Roswell | 16 | 25 | 3 | 71 | — | 1 | 4 | 4 | 3 | 3 | 4 | 3 | 1 | 1 | 1 | 1 | 3 | 2 | — | 1 |
| 72 | Nancy Creek at Atlanta | 35 | 6 | — | 93 | — | 1 | 4 | 4 | 3 | 3 | 4 | 3 | 1 | 1 | — | — | 2 | 2 | — | 1 |
| 76 | Nickajack Creek near Mableton | 21 | <1 | — | 99 | — | <1 | 4 | 4 | 3 | 3 | 4 | 3 | 1 | 1 | 1 | 1 | 3 | 2 | — | 1 |
| 41 | Sope Creek (within basin) | 13 | 3 | <1 | 95 | — | <1 | 7 | 7 | 6 | 2 | 7 | 6 | 1 | 1 | — | — | — | 2 | — | 1 |
| 45 | Sewell Mill Creek (within basin) | 13 | <1 | — | 99 | — | <1 | 7 | 7 | 6 | 3 | 7 | 6 | 1 | 1 | — | 1 | 3 | 2 | — | 1 |
| 70 | Peachtree Creek at Atlanta [2/] | 85 | <1 | — | 99 | — | <1 | 49 | 49 | 46 | 44 | 47 | 18 | 2 | 2 | 1 | 2 | 5 | 11 | 6 | 1 |
| 52 | Rottenwood Creek near Smyrna | 18 | 5 | — | 94 | — | <1 | 4 | 4 | 3 | 3 | 4 | 3 | 1 | 1 | — | — | 3 | 2 | — | 1 |
| 75 | Proctor Creek near Atlanta | 16 | <2 | — | 98 | — | <1 | 4 | 4 | 3 | 3 | 4 | 3 | 1 | 1 | — | — | 3 | 2 | — | 1 |
| 77 | Utoy Creek near Atlanta | 34 | 13 | 1 | 85 | — | 1 | 4 | 4 | 3 | 3 | 4 | 3 | 1 | 1 | — | — | 3 | 2 | — | 1 |
| 93 | Bull Creek at Columbus | 68 | 43 | 4 | 52 | — | 1 | 4 | 4 | 3 | 3 | 4 | 3 | 1 | 1 | 1 | 1 | — | 2 | — | 1 |
| 60 | North Fork Peachtree Creek (within basin) | 39 | <2 | — | 98 | — | <1 | 4 | 4 | 3 | 3 | 4 | 3 | 1 | 1 | — | — | — | 2 | — | 1 |
| 67 | South Fork Peachtree Creek (within basin) | 29 | <1 | — | 99 | — | <1 | 4 | 4 | 3 | 2 | 4 | 3 | 1 | 1 | — | — | — | 2 | — | 1 |
| 84 | Snake Creek near Whitesburg | 35 | 83 | 16 | <1 | — | <1 | 42 | 45 | 37 | 51 | 34 | 3 | 1 | 1 | 1 | 1 | 5 | 11 | — | 1 |
| 88 | Flat Shoal Creek near Stovall | 45 | 90 | 9 | <1 | — | — | 3 | 3 | 2 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 3 | 2 | — | 1 |
| 89 | Ossahatchie Creek near Cataula | 36 | 75 | 24 | <1 | — | — | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | 3 | 2 | — | 1 |
| 108 | Ulcohatchee Creek near Roberta | 51 | 92 | 7 | <1 | — | <1 | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | 3 | 2 | — | 1 |
| 82 | Snake Creek near Hulett (within basin) | 13 | 75 | 23 | 1 | — | 1 | 3 | 3 | 2 | 2 | 3 | 2 | — | — | — | — | — | 2 | 2 | 1 |
| 83 | Little Snake Creek near Hulett (within basin) | 3.4 | 96 | 3 | <1 | — | — | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | — | 2 | 2 | 1 |

**Table 1.** Description of surface-water monitoring sites in the Apalachicola-Chattahoochee-Flint River basin and types and numbers of samples collected—Continued

[$mi^2$, square miles; —, no data; <, less than

| Site number (see figures 5 and 6) | Site type and name | Drainage area ($mi^2$) | Land use (in percent) | | | | | Number of samples per monitoring site | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Water column samples | | | | | | Bed sediment | | Tissue | | Ecological samples | | | |
| | | | Forest | Agriculture | Urban | Wetland | Other | Field Parameters/Flow | Nutrients/Turbidity | Major Ions | Suspended Sediment | Organic Carbon | Pesticides | Organics | Trace Metals | Organics | Trace Metals | Fish | Macro Invertebrates | Periphytic Algae | Habitat |
| 116 | Lime Creek near Cobb [1/] [2/] [3/] | 62 | 28 | 67 | <1 | 4 | <1 | 83 | 83 | 39 | 71 | 40 | 73 | 2 | 2 | 1 | 1 | 5 | 12 | 6 | 1 |
| 111 | Hogcrawl Creek near Five Points | 30 | 48 | 52 | — | — | — | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | 1 | 2 | — | 1 |
| 112 | Turkey Creek at Byromville | 48 | 31 | 68 | <1 | <1 | — | 3 | 3 | 2 | 3 | 3 | 2 | 1 | 1 | — | — | 1 | 2 | — | 1 |
| 119 | Muckaloochee Creek near Smithville | 56 | 35 | 63 | 1 | <1 | <1 | 3 | 3 | 2 | 2 | 3 | 2 | — | — | — | — | — | 2 | — | 1 |
| 113 | Lime Creek near Desoto (within basin) | 36 | 36 | 60 | <1 | 3 | <1 | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | — | 2 | — | 1 |
| 114 | Dominy Branch near Cobb (within basin) | 12 | 14 | 80 | — | 6 | — | 5 | 5 | 5 | 5 | 5 | 5 | — | — | — | — | — | 2 | — | 1 |
| 132 | Aycocks Creek near Boykin [3/] | 105 | 34 | 60 | — | 6 | — | 49 | 48 | 28 | 42 | 26 | 38 | 2 | 2 | 1 | 1 | 3 | 11 | 6 | 1 |
| 127 | Big Cypress Creek near Newton | 63 | 29 | 62 | — | 9 | — | 2 | 2 | 2 | 2 | 2 | 2 | — | — | — | — | 1 | 1 | — | 1 |
| 129 | Big Drain Creek near Boykin | 43 | 26 | 70 | — | 4 | — | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | — | — | 1 | 1 | — | 1 |
| 136 | Cowarts Creek near Cottonwood | 44 | 25 | 73 | 2 | — | — | 2 | 2 | 2 | 2 | 2 | 2 | — | — | — | — | — | 1 | — | 1 |
| 130 | Aycocks Creek near Colquitt (within basin) | 47 | 39 | 55 | — | 6 | — | 2 | 2 | 2 | 2 | 2 | 2 | — | — | — | — | — | 1 | — | 1 |
| 131 | Cypress Creek near Colquitt (within basin) | 12 | 49 | 39 | — | 12 | — | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | — | — | 1 | 1 | — | 1 |
| | **Synoptic sites (mainstem river sites, reservoirs, and tributaries [indented])** | | | | | | | | | | | | | | | | | | | | |
| 7 | Chattahoochee River near Cornelia | 316 | 83 | 15 | 2 | — | <1 | 4 | 4 | 2 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | — | — | — | — |
| 22 | Chestatee River near Dahlonega | 224 | 88 | 11 | 1 | — | — | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | — | — | — | — |
| 23 | Lake Lanier [4/] | 905 | 76 | 17 | 4 | — | 3 | 1 | 1 | — | — | — | — | 1/3 | 1/14 | — | 1 | — | — | — | — |
| 35 | Big Creek near Roswell (water intakes) | 103 | 57 | 24 | 18 | — | 1 | 8 | 8 | 8 | 8 | 8 | 3 | — | — | — | — | 1 | 1 | 2 | — |
| 36 | Big Creek near Roswell | 103 | 57 | 24 | 18 | — | 1 | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | — | — | — | — |
| 81 | Sweetwater Creek near Austell | 240 | 51 | 23 | 24 | — | 2 | 5 | 5 | 4 | 5 | 5 | 4 | — | — | — | — | — | — | — | — |
| 86 | West Point Lake [4/] | 3,247 | 63 | 15 | 18 | — | 4 | 1 | 1 | — | — | — | — | 1/8 | 1/64 | — | — | — | — | — | — |
| 87 | Chattahoochee River at West Point | 3,541 | 64 | 15 | 17 | — | 4 | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | — | — | — | — |
| 87a | Lake Harding [4/] | — | — | — | — | — | — | 1 | — | — | — | — | — | —/10 | —/37 | — | — | — | — | — | — |
| 90 | Mulberry Creek near Mulberry Grove | 190 | 90 | 8 | 1 | — | 1 | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | — | — | — | — |
| 91 | Chattahoochee River at Columbus | 4,661 | 67 | 15 | 14 | — | 4 | 1 | 1 | — | — | — | — | 2 | 2 | 1 | 1 | — | — | — | — |
| 95 | Upatoi Creek at Fort Benning | 453 | 86 | 5 | 7 | 1 | 1 | 3 | 3 | 2 | 2 | 3 | 2 | — | — | — | — | — | — | — | — |
| 96 | Chattahoochee River at Fort Benning | 5,227 | 69 | 14 | 14 | <1 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | — | — | — | — |
| 97 | Uchee Creek near Fort Mitchell | 322 | 72 | 26 | 1 | <1 | <1 | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | — | — | — | — |
| 98 | North Fork Cowikee Creek near Glenville | 114 | 69 | 30 | <1 | — | <1 | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | — | — | — | — |
| 99 | Lake Walter F. George [4/] | 7,472 | 71 | 15 | 10 | <1 | 4 | 1 | 1 | — | — | — | — | 1/14 | 1/39 | — | — | — | — | — | — |

**Table 1.** Description of surface-water monitoring sites in the Apalachicola-Chattahoochee-Flint River basin and types and numbers of samples collected—Continued

[$mi^2$, square miles; —, no data; <, less than

| Site number (see figures 5 and 6) | Site type and name | Drainage area ($mi^2$) | Land use (in percent) | | | | | Number of samples per monitoring site | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Water column samples | | | | | | Bed sediment | | Tissue | | Ecological samples | | | |
| | | | Forest | Agriculture | Urban | Wetland | Other | Field Parameters/Flow | Nutrients/Turbidity | Major Ions | Suspended Sediment | Organic Carbon | Pesticides | Organics | Trace Metals | Organics | Trace Metals | Fish | Macro Invertebrates | Periphytic Algae | Habitat |
| 100 | Abbie Creek near Haleburg | 197 | 67 | 31 | 1 | <1 | <1 | 1 | 1 | — | 1 | 1 | — | — | — | — | — | — | — | — | — |
| 101 | Omusee Creek at Columbia | 179 | 33 | 62 | 5 | — | — | 3 | 3 | 2 | 2 | 3 | 2 | — | — | — | — | — | — | — | — |
| 102 | Chattahoochee River near Columbia | 8,209 | 70 | 17 | 10 | <1 | 3 | 2 | 1 | — | — | — | 2 | 2 | 2 | 1 | 1 | — | — | — | — |
| 103 | Lake Seminole (Chattahoochee River arm) | 8,623 | 68 | 19 | 9 | <1 | 4 | 1 | 1 | — | — | — | — | 1 | 1 | 1 | 1 | — | — | — | — |
| 104 | Flint River near Lovejoy | 133 | 26 | 12 | 59 | 1 | 2 | 4 | 4 | 2 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | — | — | — | — |
| 105 | Line Creek at Digby | 213 | 60 | 29 | 5 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | — | — | — | — | — | — | — | — |
| 106 | Potato Creek near Thomaston | 234 | 62 | 31 | 6 | <1 | <1 | 3 | 3 | 2 | 3 | 3 | 2 | — | — | — | — | — | — | — | — |
| 107 | Flint River near Culloden | 1,845 | 65 | 26 | 7 | 1 | 1 | 4 | 4 | 2 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | — | — | — | — |
| 109 | Buck Creek near Ellaville | 149 | 69 | 26 | <1 | 4 | <1 | 3 | 3 | 2 | 2 | 3 | 2 | — | — | — | — | — | — | — | — |
| 110 | Flint River at Montezuma [1/] | 2,630 | 65 | 25 | 5 | 4 | 1 | 4 | 4 | 3 | 4 | 4 | 3 | — | — | — | — | — | — | — | — |
| 117 | Lake Blackshear [4/] | 3,700 | 58 | 33 | 4 | 4 | 1 | 2 | 1 | — | — | — | — | 2/9 | 2/29 | 1 | 1 | — | — | — | — |
| 118 | Kinchafoonee Creek near Dawson [1/] | 522 | 62 | 32 | <1 | 5 | <1 | 5 | 5 | 3 | 3 | 4 | 3 | 2 | 2 | 1 | 1 | — | — | — | — |
| 120 | Muckalee Creek near Leesburg | 367 | 40 | 50 | 3 | 6 | 1 | 4 | 4 | 2 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | — | — | — | — |
| 121 | Cooleewahee Creek near Newton | 169 | 35 | 40 | 7 | 15 | 3 | 4 | 4 | 2 | 2 | 3 | 2 | 1 | 1 | 1 | 1 | — | — | — | — |
| 122 | Flint River at Newton [1/] [2/] | 5,768 | 53 | 38 | 4 | 4 | 1 | 22 | 21 | 20 | 20 | 18 | 22 | 2 | 2 | 1 | 1 | — | — | — | — |
| 123 | Ichawaynochaway Creek at Milford | 635 | 36 | 52 | <1 | 11 | <1 | 3 | 3 | 2 | 2 | 3 | 2 | — | — | — | — | — | — | — | — |
| 124 | Kiokee Creek near Albany | 54 | 57 | 35 | <1 | 7 | <1 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | — | — | 1 | 1 | — | 1 |
| 125 | Chickasawhatchee Creek at Elmodel [1/] | 320 | 35 | 41 | 1 | 22 | 1 | 4 | 4 | 3 | 4 | 4 | 3 | — | — | — | — | — | — | — | — |
| 126 | Ichawaynochaway Creek near Newton [1/] | 1,040 | 36 | 49 | <1 | 14 | <1 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | — | — | — | — |
| 128 | Lake Seminole (Flint River arm) [4/] | 7,661 | 50 | 41 | 3 | 5 | 1 | 2 | 1 | — | — | — | — | 2/23 | 2/78 | 1 | 1 | — | — | — | — |
| 133 | Spring Creek near Iron City [1/] | 474 | 32 | 62 | 1 | 4 | 1 | 5 | 5 | 3 | 3 | 4 | 3 | 2 | 2 | 1 | 1 | — | — | — | — |
| 134 | Apalachicola River at Chattahoochee | 17,178 | 58 | 31 | 6 | 3 | 2 | — | — | — | — | — | 2 | 2 | 2 | 1 | 1 | — | — | — | — |
| 135 | Apalachicola River near Blountstown | 17,554 | 58 | 31 | 6 | 3 | 2 | 2 | 1 | — | — | — | — | 2 | 2 | 1 | 1 | — | — | — | — |
| 137 | Chipola River near Altha | 839 | 39 | 50 | 2 | 8 | 1 | 2 | — | — | — | — | 2 | — | — | — | — | — | — | — | — |
| 138 | Dead Lake near Wewahitchka | 1,253 | 50 | 36 | 2 | 11 | 1 | 1 | 1 | — | — | — | — | 1 | 1 | — | — | — | — | — | — |

[1/] One or more samples collected during flooding caused by Tropical Storm Alberto (July 1994).

[2/] Varying number of samples collected at different stages of a storm hydrograph.

[3/] Intensive Sites.

[4/] 1/14 = Number of samples of surficial sediments from reservoirs as part of Bed-Sediment and Tissue Survey (**1**/14) and number of subsamples (1/**14**) of reservoir core.

**Table 2.** Physical and chemical constituents in surface and ground-water analyses, and minimum reporting level

[MRL, minimum reporting level; mg/L, milligrams per liter; $ft^3/s$, cubic feet per second; µg/L, micrograms per liter; µg/Kg, micrograms per kilogram]

| Constituents | MRL | Constituents | MRL | Constituents | MRL |
|---|---|---|---|---|---|
| **Field parameters** | | | | | |
| pH (standard units) | 0.05 | Dissolved oxygen (mg/L) | 0.01 | Stream discharge ($ft^3/s$) | 0.01 |
| Specific conductance (µS/cm) | 1 | DO (percent saturation) | .1 | Ground-water level (ft) | .003 |
| Alkalinity, as $CaCO_3$ (mg/L) | 1 | Air and water temperature ($^o$ C) | .1 | Spring discharge ($ft^3/s$) | — |
| Barometric pressure (mm Hg) | 1 | | | | |
| **Dissolved [D] and total [T] nutrients (in mg/L)[1/]** | | | | | |
| Nitrate+nitrite nitrogen as N [D] | 0.05 | Ammonia+organic nitrogen as N [D] | .2 | Ammonia+organic nitrogen as N [T] (surface water only) | .2 |
| Nitrite nitrogen as N [D] | .01 | Orthophosphate as P [D] | .01 | Phosphorus as P [T] ) (surface water only) | .01 |
| Ammonia nitrogen as N [D] | .01 | Phosphorus as P [D] | .01 | Turbidity (NTU) | 1 |
| **Major inorganics (in mg/L except where noted) [1/]** | | | | | |
| Alkalinity, as $CaCO_3$, (lab) | 1 | Iron (in µg/L) | 3 | Sodium | .2 |
| Bromide (ground water only) | .01 | Magnesium | .01 | Sulfate | .1 |
| Calcium | .02 | Manganese (in µg/L) | 1 | pH, (lab) (standard units) | .1 |
| Chloride | .1 | Potassium | .1 | Residue on evaporation (at 180 $^o$ C) | 1 |
| Fluoride | .1 | Silica | .01 | Specific conductance (µS/cm) | 1 |
| **Suspended sediment [2/] and organic carbon (in mg/L except where noted) [1/]** | | | | | |
| Suspended sediment | 1 | Dissolved organic carbon | .1 | | |
| Size fractionation (percent) | .1 | Suspended organic carbon | .1 | | |
| **Pesticides in water (in µg/L)[3/]** **(F = fungicide, H = herbicide, I = insecticide, M = metabolite)** | | | | | |
| Acetochlor (H) | .002 | Dieldrin (I) | .001 | Napropamide (H) | .003 |
| Acifluorfen (H) | .035 | Diethylanaline (M) | .003 | Neburon (H) | .015 |
| Alachlor (H) | .002 | Dinoseb (H) | .035 | Norflurazon (H) | .024 |
| Aldicarb (I) | .016 | Disulfoton (I) | .017 | Oryzalin (H) | .019 |
| Aldicarb sulfone (M) | .016 | Diuron (H) | .020 | Oxamyl (I) | .018 |
| Aldicarb sulfoxide (M) | .021 | DNOC (H,I) | .035 | Parathion (I) | .004 |
| Atrazine (H) | .001 | EPTC (H) | .002 | Pebulate (H) | .004 |
| Benfluralin (H) | .002 | Esfenvalerate (I) | .019 | Pendimethalin (H) | .004 |
| Bentazon (H) | .014 | Ethalfluralin (H) | .004 | *cis*-Permethrin (H) | .005 |
| Bromacil (H) | .035 | Ethoprop (I) | .003 | Phorate (I) | .002 |
| Bromoxynil (H) | .035 | Fenuron (H) | .013 | Picloram (H) | .050 |
| Butylate (H) | .002 | Fluometuron (H) | .035 | Prometon (H) | .018 |
| Carbaryl (I) | .003 | Fonofos (I) | .003 | Pronamide (H) | .003 |
| Carbofuran (I) | .003 | α-HCH (I) | .002 | Propachlor (H) | .007 |
| Chloramben (H) | .011 | γ-HCH (I) | .004 | Propanil (H) | .004 |
| Chlorothalonil (F) | .035 | 3-Hydroxycarbofuran (I) | .014 | Propargite (I) | .013 |
| Chlorpyrifos (I) | .004 | Linuron (H) | .002 | Propham (H) | .035 |
| Clopyralid (H) | .050 | Malathion (I) | .005 | Propoxur (I) | .035 |
| Cyanazine (H) | .004 | MCPA (H) | .050 | Simazine (H) | .005 |
| 2,4-D (H) | .035 | MCPB (H) | .035 | Tebuthiuron (H) | .010 |
| 2,4-DB (H) | .035 | Methiocarb (I) | .026 | Terbacil (H) | .007 |
| DCPA (H) | .002 | Methomyl (I) | .017 | Terbufos (I) | .013 |
| DCPA-monoacid (M) | .017 | Methylazinphos (I) | .001 | Thiobencarb (H) | .002 |
| *p,p*-DDE (M) | .006 | Methylparathion (I) | .006 | 2,4,5-T (H) | .035 |
| Desethylatrazine (M) | .002 | Metolachlor (H) | .002 | 2,4,5-TP (H) | .021 |

**Table 2.** Physical and chemical constituents in surface and ground-water analyses, and minimum reporting level—Continued

[MRL, minimum reporting level; mg/L, milligrams per liter; $ft^3/s$, cubic feet per second; µg/L, micrograms per liter; µg/Kg, micrograms per kilogram]

| Constituents | MRL | Constituents | MRL | Constituents | MRL |
|---|---|---|---|---|---|
| Diazinon (I) | .002 | Metribuzin (H) | .004 | Triallate (H) | .001 |
| Dicamba (H) | .035 | Molinate (H) | .004 | Triclopyr (H) | .050 |
| Dichlobenil (H) | .020 | 1-Naphthol (M) | .007 | Trifluralin (H) | .002 |
| Dichlorprop (2,4-DP) (H) | .032 | | | | |
| | | **Trace elements, dissolved in water (in µg/L) [1/]** | | | |
| Arsenic | 1 | Chromium | 1 | Nickel | 1 |
| Aluminum | 1 | Cobalt | 1 | Selenium | 1 |
| Antimony | 1 | Copper | 1 | Silver | 1 |
| Barium | 1 | Lead | 1 | Uranium | 1 |
| Beryllium | 1 | Manganese | 1 | Zinc | 1 |
| Cadmium | 1 | Molybdenum | 1 | | |
| | | **Volatile organic compounds (VOCs) (in µg/L) [4/]** | | | |
| Benzene | .2 | 1,3-Dichlorobenzene | .2 | Methyl-tert-butylether | .2 |
| Bromobenzene | .2 | 1,4-Dichlorobenzene | .2 | Naphthalene | .2 |
| Bromochloromethane | .2 | Dichlorodifluoromethane | .2 | n-Propylbenzene | .2 |
| Bromodichloromethane | .2 | 1,1-Dichloroethane | .2 | Styrene | .2 |
| 1,4-Bromofluorobenzene | .2 | 1,2-Dichloroethane | .2 | 1,1,1,2-Tetrachloroethane | .2 |
| Bromomethane | .2 | 1,1-Dichloroethene | .2 | 1,1,2,2-Tetrachloroethane | .2 |
| n-Butylbenzene | .2 | *cis*-1,2-Dichloroethene | .2 | Tetrachloroethene | .2 |
| sec-Butylbenzene | .2 | *trans*-1,2-Dichloroethene | .2 | Tetrachloromethane | .2 |
| tert-Butylbenzene | .2 | Dichloromethane | .2 | Tribromomethane | .2 |
| Chlorobenzene | .2 | 1,2-Dichloropropane | .2 | 1,2,3-Trichlorobenzene | .2 |
| Chloroethane | .2 | 1,3-Dichloropropane | .2 | 1,2,4-Trichlorobenzene | .2 |
| Chloroethene | .2 | 2,2-Dichloropropane | .2 | 1,1,1-Trichloroethane | .2 |
| Chloromethane | .2 | 1,1-Dichloropropene | .2 | 1,1,2-Trichloroethane | .2 |
| 1-Chloro-2-methylbenzene | .2 | *cis*-1,3-Dichloropropene | .2 | Trichloroethene | .2 |
| 1-Chloro-4-methylbenzene | .2 | *trans*-1,3-Dichloropropene | .2 | Trichlorofluoromethane | .2 |
| Dibromochloromethane | .2 | Ethylbenzene | .2 | Trichloromethane | .2 |
| 1,2-Dibromo-3-chloropropane | 1 | 1,1,2,3,4,4-Hexachloro-1,3-butadiene | .2 | 1,2,3-Trichloropropane | .2 |
| 1,2-Dibromoethane | .2 | Isopropylbenzene | .2 | 1,1,2-Trichloro-1,2,2-trifluoroethane | .2 |
| Dibromomethane | .2 | *p*-Isopropyltoluene | .2 | 1,2,4-Trimethylbenzene | .2 |
| 1,2-Dichlorobenzene | .2 | Methylbenzene | .2 | 1,3,5-Trimethylbenzene | .2 |
| | | **Radionuclides and stable isotopes [5/]** | | | |
| Deuterium/Hydrogen ratio (permil) | — | Oxygen 18/16 ratio (permil) | — | Radon (pCi/L) | 24 |
| | | | | Tritium (Tritium Units) | .3 |
| | | **Semivolatile organic compounds in bed sediments (in µg/Kg except where noted) [6/]** | | | |
| Acenaphthene | 50 | Dibenzothiphene | 50 | Isoquinoline | 50 |
| Acenaphthylene | 50 | 1,2-Dichlorobenzene | 50 | 2-Methylanthracene | 50 |
| Acridine | 50 | 1,3-Dichlorobenzene | 50 | 4,5-Methylenephenanthrene | 50 |
| c8-Alkyl-phenol | 50 | 1,4-Dichlorobenzene | 50 | 1-Methyl-9h-fluorene | 50 |
| Anthracene | 50 | 2,4-Dichlorophenol | 50 | 1-Methylphenanthrene | 50 |
| Anthraquinone | 50 | Diethylphthalate | 50 | 1-Methylpyrene | 50 |
| Azo-benzene | 50 | 1,2-Dimethylnaphthalene | 50 | Naphthalene | 50 |
| Benzo (a) anthracene | 50 | 1,6-Dimethylnaphthalene | 50 | Nitrobenzene | 50 |
| Benzo (b) fluoranthene | 50 | 2,6-Dimethylnaphthalene | 50 | 2-Nitrophenol | 50 |
| Benzo-C-quinoline | 50 | 3,5-Dimethylphenol | 50 | 4-Nitrophenol | 50 |
| Benzo (g,h,i) perylene | 50 | Dimethylphthalate | 50 | N-nitroso-di-n-propylamine | 50 |

**Table 2.** Physical and chemical constituents in surface and ground-water analyses, and minimum reporting level—Continued

[MRL, minimum reporting level; mg/L, milligrams per liter; $ft^3/s$, cubic feet per second; µg/L, micrograms per liter; µg/Kg, micrograms per kilogram]

| Constituents | MRL | Constituents | MRL | Constituents | MRL |
|---|---|---|---|---|---|
| Benzo (k) fluoranthene | 50 | Di-n-butylphthalate | 50 | N-nitrosodiphenylamine | 50 |
| Benzo (a) pyrene | 50 | 4,6-Dinitro-2-methylphenol | 50 | Pentachloroanisol | 50 |
| 2,2'-Biquinoline | 50 | 2,4-Dinitrophenol | 50 | Pentachloronitrobenzene | 50 |
| 4-Bromophenyl-phenylether | 50 | 2,4-Dinitrotoluene | 50 | Pentachlorophenol | 50 |
| Butylbenzylphthalate | 50 | 2,6-Dinitrotoluene | 500 | Phenanthrene | 50 |
| 9H-Carbazol | 50 | Di-n-octylphthalate | 50 | Phenanthridine | 50 |
| bis (2-Chloroethoxy) methane | 50 | bis (2-Ethylhexyl) phthalate | 50 | Phenol | 50 |
| bis (2-Chloroethyl) ether | 50 | 2-Ethylnaphthalene | 50 | Pyrene | 50 |
| bis (2-chloroisopropyl) ether | 50 | Fluoranthene | 50 | Quinoline | 50 |
| 4-Chloro-3-methylphenol | 50 | 9H-Fluorene | 50 | 2,3,5,6-Tetramethylphenol | 50 |
| 2-Chloronaphthalene | 50 | Hexachlorobenzene | 50 | 1,2,4-Trichlorobenzene | 50 |
| 2-Chlorophenol | 50 | Hexachlorobutadiene | 50 | 2,4,6-Trichlorophenol | 50 |
| 4-Chlorophenyl-phenylether | 50 | Hexachlorocyclopentadiene | 50 | 2,3,6-Trimethylnaphthalene | 50 |
| Chrysene | 50 | Hexachloroethane | 50 | 2,4,6-Trimethylphenol | 50 |
| *p*-Cresol | 50 | Indeno (1,2,3-c,d) pyrene | 50 | | |
| Dibenzo (a,h) anthracene | 50 | Isophorone | 50 | | |
| **Organochlorine compounds in bed sediments (in µg/Kg except where noted)[7/]** | | | | | |
| Aldrin | 1 | *trans*-Nonachlor | 1 | Toxaphene | 200 |
| *cis*-Chlordane | 1 | Oxychlordane | 1 | α-HCH | 1 |
| *trans*-Chlordane | 1 | *p,p'*-DDE | 1 | β-HCH | 1 |
| Chlorneb | 5 | *o,p'*-DDT | 2 | γ-HCH | 1 |
| DCPA | 5 | *p,p'*-DDT | 2 | Heptachlor | 1 |
| *o,p'*-DDD | 1 | Dieldrin | 1 | Heptachlor epoxide | 1 |
| *p,p'*-DDD | 1 | Endosulfan I | 1 | Hexachlorobenzene | 50 |
| *o,p'*-DDE | 1 | Endrin | 2 | Isodrin | 1 |
| *o,p'*-Methoxychlor | 5 | Pentachloroanisole | 50 | Inorganic Carbon | .1 |
| *p,p'*-Methoxychlor | 5 | *cis*-Permethrin | 5 | Organic Carbon | .1 |
| Mirex | 1 | *trans*-Permethrin | 5 | Total Carbon | .1 |
| *cis*-Nonachlor | 1 | Polychlorinatedbiphenyls | 50 | Moisture (percent) | .1 |
| **Organochlorine compounds in reservoir cores (in µg/Kg)[8/]** | | | | | |
| Aldrin | .1 | Endosulfan | .1 | Methoxychlor | .8 |
| Chlordane | 1 | Endrin | .1 | Mirex | .1 |
| Total DDD | .1 | γ-HCH | .1 | Perthane | 1 |
| Total DDE | .1 | Heptachlor | .1 | Polychlorinatedbiphenyls | 1 |
| Total DDT | .1 | Heptachlor epoxide | .1 | Polychlorinatednaphthalenes | 1 |
| Dieldrin | .8 | Isodrin | 1 | Toxaphene | 10 |
| **Major and trace elements in bed sediments and reservor cores (in µg/G except where noted)[9/]** | | | | | |
| Aluminum [10/] | .05 | Iron (percent) [10/] | .05 | Strontium [10/] | 2 |
| Antimony [11/] | .1 | Lanthanum [10/] | 2 | Sulfur (percent) [11/] | .05 |
| Arsenic [10/] | .1 | Lead [10/] | 4 | Tantalum [10/] | 40 |
| Barium [10/] | 1 | Lithium [10/] | 2 | Thorium [10/] | 1 |
| Beryllium [10/] | 1 | Magnesium (percent) [10/] | .005 | Tin [10/] | 10 |
| Bismuth [10/] | 10 | Manganese [10/] | 4 | Titanium (percent) [10/] | .005 |
| Cadmium [10/] | .1 | Mercury [11/] | .02 | Uranium [10/] | .05 |
| Calcium [10/] | .05 | Molybdenum [10/] | 2 | Vanadium [10/] | 2 |
| Cerium [10/] | 4 | Neodymium [10/] | 4 | Ytterbium [10/] | 1 |

**Table 2.** Physical and chemical constituents in surface and ground-water analyses, and minimum reporting level—Continued

[MRL, minimum reporting level; mg/L, milligrams per liter; ft$^3$/s, cubic feet per second; µg/L, micrograms per liter; µg/Kg, micrograms per kilogram]

| Constituents | MRL | Constituents | MRL | Constituents | MRL |
|---|---|---|---|---|---|
| Cesium (pCi/G)[12/] | .1 | Nickel [10/] | 2 | Yttrium [10/] | 2 |
| Chromium [10/] | 1 | Niobium [10/] | 4 | Zinc [10/] | 4 |
| Cobalt [10/] | 1 | Potassium (percent) [10/] | .05 | Inorganic Carbon (percent) [10/] | .01 |
| Copper [11/] | 1 | Scandium [10/] | 2 | Organic Carbon (percent) [10/] | .01 |
| Europium [10/] | 2 | Selenium [11/] | .1 | Total Carbon (percent) [10/] | .01 |
| Gallium [10/] | 4 | Silicon [12/] | .1 | Total Nitrogen (percent) [12/] | .01 |
| Gold [10/] | 8 | Silver [10/] | .005 | Total Phosphorus (percent) [10/] | .005 |
| Holmium [10/] | 4 | Sodium (percent) [10/] | | | |
| Organochlorine compounds in tissue (in µg/Kg except where noted)[13/] | | | | | |
| Aldrin | 5 | Endrin | 5 | Mirex | 5 |
| *cis*-Chlordane | 5 | α-HCH | 5 | *cis*-Nonachlor | 5 |
| *trans*-Chlordane | 5 | β-HCH | 5 | *trans*-Nonachlor | 5 |
| DCPA | 5 | δ-HCH | 5 | Oxychlordane | 5 |
| *o,p'*-DDT | 5 | γ-HCH | 5 | Pentachloroanisole | 5 |
| *p,p'*-DDT | 5 | Heptachlor | 5 | Toxaphene | 5 |
| *o,p'*-DDD | 5 | Heptachlor epoxide | 5 | Polychlorinatedbiphenyls | 5 |
| *p,p'*-DDD | 5 | Hexachlorobenzene | 5 | Lipids (percent) | .5 |
| *o,p'*-DDE | 5 | Hexachlorobutadiene | 5 | Moisture (percent) | .5 |
| *p,p'*-DDE | 5 | *o,p'*-Methoxychlor | 5 | | |
| Dieldrin | 5 | *p,p'*-Methoxychlor | 5 | | |
| **Trace elements in tissue (in µg/G except where noted)[14/]** | | | | | |
| Aluminum | 1 | Cobalt | .1 | Selenium | .1 |
| Antimony | .1 | Copper | .5 | Silver | .1 |
| Arsenic | .1 | Iron | 1 | Strontium | .1 |
| Barium | .1 | Lead | .1 | Thorium | .1 |
| Beryllium | .1 | Manganese | .1 | Uranium | .1 |
| Boron | .2 | Mercury | .1 | Vanadium | .1 |
| Cadmium | .1 | Molybdenum | .1 | Zinc | .5 |
| Chromium | .5 | Nickel | .1 | Moisture (percent) | .1 |

[1/]Analytical methods described in Fishman and Friedman (1989).

[2/]Analytical methods described in Guy (1973).

[3/]Analytical methods described in Sandstrom and others (1992).

[4/]Analytical methods described in Rose and Schroeder (1995).

[5/]Analytical methods described in Thatcher and others (1977).

[6/]Analytical methods described in Furlong and others (1996).

[7/]Analytical methods described in Foreman and others (1995).

[8/]Analytical methods described in Wershaw and others (1983).

[9/]Analytical methods described in Arbogast (1990).

[10/]Analyte included in analysis of bed sediments and subsamples of reservoir cores.

[11/]Analyte included in analysis of bed sediments only.

[12/]Analyte included in analysis of subsamples of reservoir cores only.

[13/]Analytical methods described in Leiker and others (1995).

[14/]Analytical methods described in Hoffman 1996.