QUALITY OF SURFACE AND GROUND WATER IN THE WHITE CREEK AND MOSSY CREEK WATERSHEDS,

WHITE COUNTY, GEORGIA, 1992-93

U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the

CHESTATEE-CHATTAHOOCHEE RESOURCE CONSERVATION AND DEVELOPMENT COUNCIL

OPEN-FILE REPORT 94-540

Cover Photograph*: *Mossy Creek at Rogers Mill, White County, Georgia

Photograph couresty of Diane C. Burgoon

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Atlanta, Georgia
1994

U. S DEPARTMENT OF THE INTERIOR

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U. S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

Length

Multiply	by	to obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
feet per mile (ft/mi)	0.189	meters per kilometer

Area

acre	0.4047	hectare
square mile (mi^2)	2.590	square kilometer

Volume

gallon (gal)	3.785	liter

Flow

cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	0.06309	liter per second

Yield

pound per day per square mile ($lbs/d/mi^2$)	116.4	kilogram per day per hectare

Temperature

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

$$° F = 1.8 (° C) + 32$$

ACRONYMS

CCRCDC	Chestatee-Chattahoochee Resource Conservation and Development Council
EPD	Georgia Department of Natural Resources, Environmental Protection Division
GIS	Geographic Information Systems
GWSI	Ground-Water Site Inventory System
NAWQA	National Water Quality Assessment
SCS	U.S. Department of Agriculture, Soil Conservation Service
TVA	Tennessee Valley Authority
USGS	U.S. Geological Survey

VERTICAL DATUM

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called “Sea Level Datum of 1929.”

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ABSTRACT

Surface- and ground-water quality data were collected and evaluated from streams and wells in the White Creek and Mossy Creek watersheds in White County, Georgia, during three sampling periods in 1992 and 1993, to identify stream reaches and wells affected by nonpoint-source contaminants. Livestock operations in these watersheds account for approximately 9.8 million tons of manure per year, which is spread over about 5,000 acres of pasture and cropland in the watersheds. White Creek and Mossy Creek are tributaries of the Chattahoochee River which flows into Lake Sidney Lanier. Lake Sidney Lanier and the Chattahoochee River downstream from the lake are the primary sources of drinking water for the Atlanta Metropolitan area and numerous smaller communities downstream of Atlanta.

Water samples were collected from 31 stream sites during baseflow and stormwater-runoff conditions and from 8 shallow wells completed in the regolith and 16 deeper wells completed in the crystalline bedrock. All water samples were analyzed for the nutrients ammonia, nitrite plus nitrate, and orthophosphate. None of the surface-water samples from either sampling period had concentrations of these constituents that exceed the Georgia Department of Natural Resources, Environmental Protection Division (EPD), drinking-water standards. Generally, in both watersheds, the streamwater temperature was cool, specific conductance low, dissolved oxygen high, and pH near neutral. Ground-water samples collected from 8 shallow regolith wells and the 16 deep bedrock wells had nutrient concentrations below EPD drinking-water standards, except for two of the deep bedrock wells with nitrite plus nitrate concentrations slightly above the 10 mg/L drinking-water standard of EPD.

INTRODUCTION

Poultry and cattle production are common land uses in northeastern Georgia, and there are concerns about nonpoint-source contaminants from these livestock operations degrading surface- and ground-water quality in this area of the State. The White Creek and Mossy Creek watersheds in White County, Ga. (fig. 1), were selected as study basins to evaluate the effect of livestock operations on the quality of water in streams and wells.

Manure from livestock operations is believed to be a major source of contaminants in the watersheds. Manure is spread over about 5,000 acres of pasture and cropland at a rate of approximately 9.8 million tons per year (Jerry L. Boling, Chestatee-Chattahoochee Resource Conservation and Development Council, written commun., 1987). Other potential sources of contaminants are livestock feeding and loafing areas located near streams, erosion of streambanks where livestock have access directly to streams, poultry carcass-disposal pits, and septic-tank effluent. The Georgia Department of Natural Resources, Environmental Protection Division (EPD), previously identified White Creek as having water-quality problems that exceeded drinking-water standards for fecal coliform, turbidity, and concentrations of suspended solids, nitrogen, and phosphorus (Georgia Department of Natural Resources, 1985). Similar agricultural practices in the Mossy Creek watershed also might be adversely affecting water-quality conditions of streams and wells. White Creek and Mossy Creek are tributaries of the Chattahoochee River which flow into Lake Sidney Lanier. Lake Sidney Lanier and the Chattahoochee River downstream of the lake are the primary sources of drinking water for the Atlanta Metropolitan area and numerous smaller communities downstream from Atlanta.

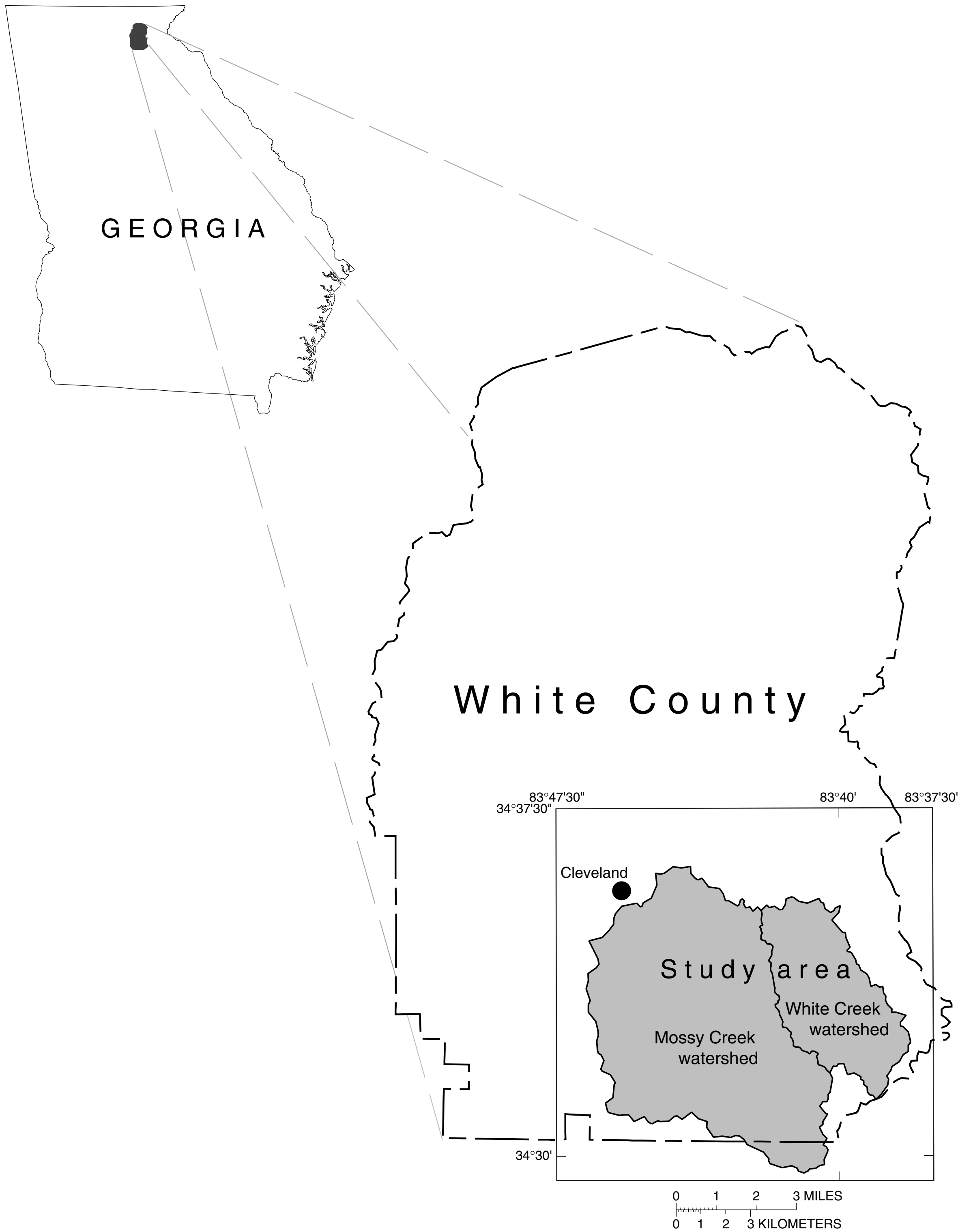

Figure 1. Location of study area.

Purpose and Scope

The purpose of this report is to characterize water-quality conditions of streams and wells in the White Creek and Mossy Creek watersheds and to identify stream reaches and wells that have been affected by contributions from nonpoint sources of contamination. Analytical determinations of surface-water samples collected from 31 sites during September 30 and October 1, 1992, and January 12, 1993, and ground-water samples collected from eight shallow regolith wells and 16 deeper bedrock wells during March 23–30 and May 5, 1993, are presented in tables and graphs. Nitrogen and phosphorous concentrations and determinations of turbidity in water from streams during baseflow and stormwater-runoff conditions and from wells after a period of possible winter recharge from precipitation were used as indicators of the overall quality of water in the watersheds.

This study was conducted by the U.S. Geological Survey (USGS) in cooperation with the Chestatee-Chattahoochee Resource Conservation and Development Council (CCRCDC). These water-quality data also were collected in conjunction with the USGS National Water Quality Assessment (NAWQA) program. The NAWQA program, conducted in the Apalachicola-Chattahoochee-Flint River basin, encompasses the White Creek and Mossy Creek watersheds.

Previous Studies

Previous water-quality studies in the White Creek and Mossy Creek watersheds are limited to a reconnaissance of stream quality conditions in the White Creek watershed conducted in 1985 by EPD (Georgia Department of Natural Resources, 1985), and a land-use assessment of both watersheds completed in 1990 by the Tennessee Valley Authority (TVA) (Carroll and Sagona, 1992). One well in the White Creek watershed was sampled in 1962 by the USGS for the determination of pH, temperature, specific conductance, and major ions (Grantham and Stokes, 1976).

The study by EPD determined the extent of possible nonpoint-source pollution in the surface-water resources of Georgia. During the EPD study, water samples were collected from 21 streams in Georgia, including White Creek from April 1981 to September 1983. White Creek was identified as having water-quality problems of fecal coliform bacteria, high turbidity, and high concentration of suspended solids, nitrogen, and phosphorous (Georgia Department of Natural Resources, 1985). Of the 21 streams sampled, White Creek had the highest turbidity (41 nephelometric turbidity units (NTU)) and suspended solids (84 milligrams per liter (mg/L)) and the second highest mean concentration of nitrite plus nitrate (1.14 mg/L) and ammonia (0.18 mg/L).

The study conducted by the TVA for the CCRCDC delineated land uses and potential nonpoint sources of pollution in the White Creek and Mossy Creek watersheds. These data were compiled from low-altitude, color, infrared, aerial photographs taken in February 1990, plotted on 7 1/2-minute USGS topographic maps, digitized by the U.S. Department of Agriculture, Soil Conservation Service (SCS), and incorporated into an SCS geographic information systems (GIS) data base.

Site-Numbering System

Surface-water stations are identified by a numbering system used for all USGS reports and publications since October 1, 1950. The station-identification number is assigned according to downstream order, and gaps are left in the series of numbers to allow for new stations that may be established; hence, the numbers are not consecutive. The complete number of each station, such as 02331655, includes the two-digit part number “02” plus the downstream-order number “331655,” which can be from 6 to 12 digits (Stokes and McFarlane, 1994, p. 10). In this report, surface-water sampling sites were assigned site numbers from 1 to 31 (fig. 2, table 1). Numbers 1 to 7 were assigned to sites in the White Creek watershed and numbers 8 to 31 in the Mossy Creek watershed. Each site number has a corresponding USGS downstream order number (table 1). Main-stem and tributary sites in each watershed were numbered sequentially in upstream order. Numbering began in the White Creek watershed with the most downstream site on the main stem. After main-stem sites were assigned numbers, sites on tributaries to the main stem were assigned numbers in upstream order beginning with the most downstream site on the tributary nearest the mouth of the main stem. All sites in the tributary watershed were numbered before advancing to the next tributary. Sites on the next tributary on the main stem were then numbered. Numbering continued in this manner until all sites in the White Creek and Mossy Creek watersheds were assigned numbers. This method of site numbering allows sites to be easily located on maps and figures in this report (fig. 2).

Wells inventoried during this study (fig. 3, table 2) are numbered according to a system based on the USGS index of topographic maps of Georgia. Each 7 1/2-minute topographic map in the State has been assigned a six-digit number and letter designation beginning at the southwestern corner of the State. Numbers increase sequentially eastward and letters advance alphabetically northward. Quadrangles in the northern part of the State are designated by double letters; AA follows Z, and so forth. The letters “I,” “O,” “II,” and “OO” are not used. Wells inventoried in each quadrangle are numbered consecutively, beginning with 01. Thus, the fourth well scheduled in the 16LL quadrangle is designated 16LL04.

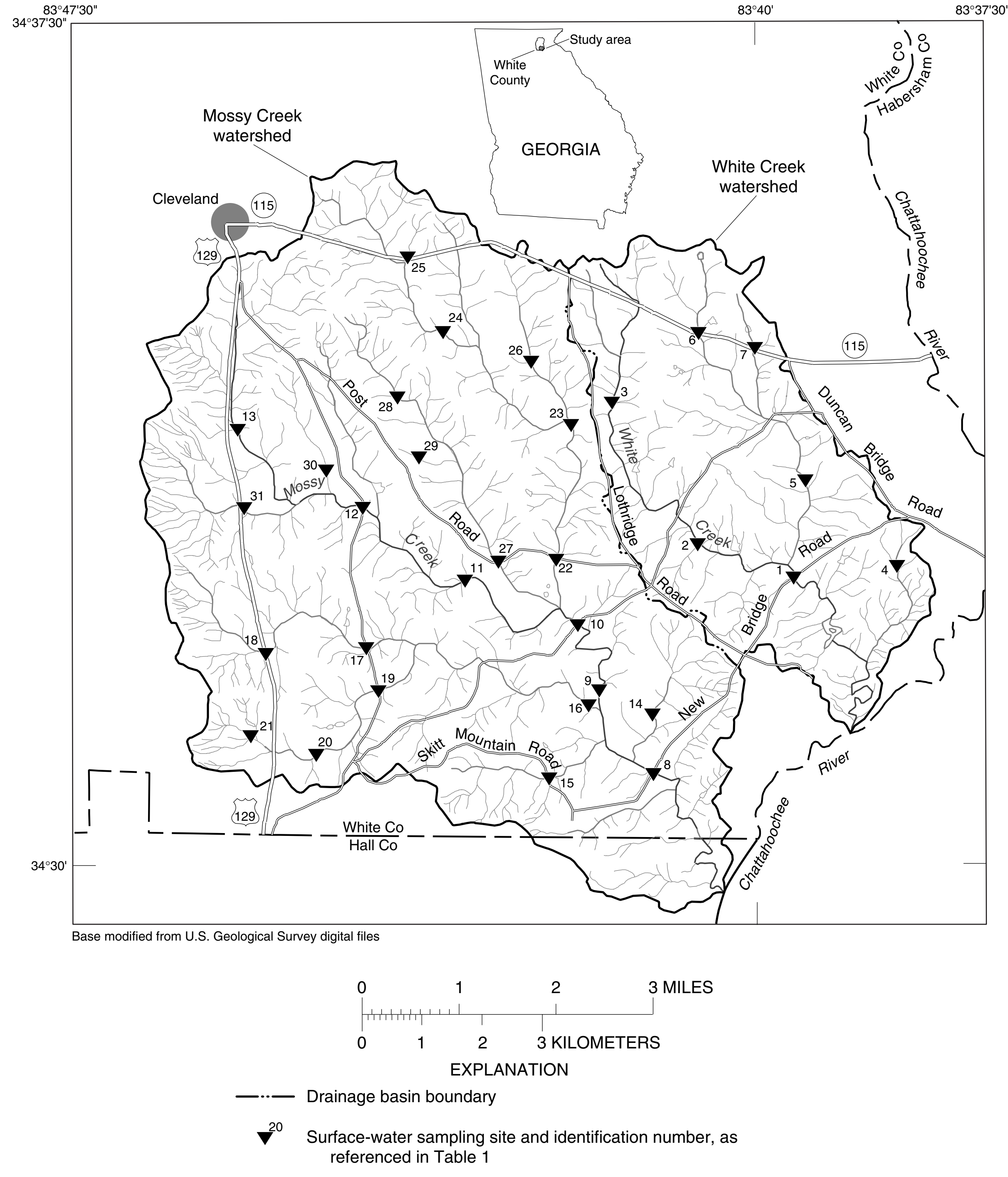

Figure 2. Major streams and tributaries in the White Creek and Mossy Creek watersheds and locations of surface-water sampling sites.

Table 1. Surface-water sampling sites in the White Creek and Mossy Creek watersheds

[mi^2, square miles; *site type*: M, main-stem; T, tributary site]

Site number	Site type	Downstream order number	Station name	Drainage area (mi^2)	Number of livestock operations upstream
1	M	02331650	White Creek at New Bridge Road	8.37	55
2	M	02331620	White Creek at Sam Craven Road	2.78	12
3	M	02331615	White Creek at Mary Davidson Road	1.15	4
4	T	02331655	White Creek tributary at Ronnie London Road	.17	3
5	T	02331640	Flat Creek at Barrett Mill Road	2.85	25
6	T	02331630	Flat Creek at SR 115	.57	4
7	T	02331635	Flat Creek tributary at SR 115	.21	2
8	M	02331790	Mossy Creek at New Bridge Road	27.5	127
9	M	02331772	Mossy Creek at Bill Prestley Road	21.7	63
10	M	02331768	Mossy Creek at SR 254	16.8	55
11	M	02331730	Mossy Creek at Tom Teague Road	7.45	16
12	M	02331720	Mossy Creek at SR 75	5.30	8
13	M	02331700	Mossy Creek at True Love Road	2.08	2
14	T	02331789	Mossy Creek tributary no. 6	.85	11
15	T	02331788	Mossy Creek tributary no. 5 at Cold Spring Road	0.76	5
16	T	02331786	Dean Creek at Hulsey Mill Road	6.92	39
17	T	02331780	Dean Creek at SR 75	2.30	12
18	T	02331775	Dean Creek at US 129	.90	2
19	T	02331784	Dean Creek tributary at SR 75	1.87	9
20	T	02331783	Dean Creek tributary at Joe Turner Road	.89	5
21	T	02331781	Dean Creek tributary at Webb Road	.18	0
22	T	02331765	Mossy Creek tributary at Post Road	5.92	22
23	T	02331760	Mossy Creek tributary at Airport Road	4.73	15
24	T	02331752	Mossy Creek tributary at Cooley Wood Road	1.78	6
25	T	02331750	Tributary of Mossy Creek tributary at SR 115	.09	2
26	T	02331758	Tributary no. 2 of Mossy Creek tributary	.70	5
27	T	02331740	Mossy Creek tributary no. 2 at Post Road	2.24	10
28	T	02331733	Mossy Creek tributary no. 2 at Cooley Wood Road	.56	0
29	T	02331735	Tributary of Mossy Creek tributary no. 2	.08	2
30	T	02331715	Mossy Creek tributary no. 3	.48	1
31	T	02331710	Mossy Creek no. 4 at Totherow Road	.82	2

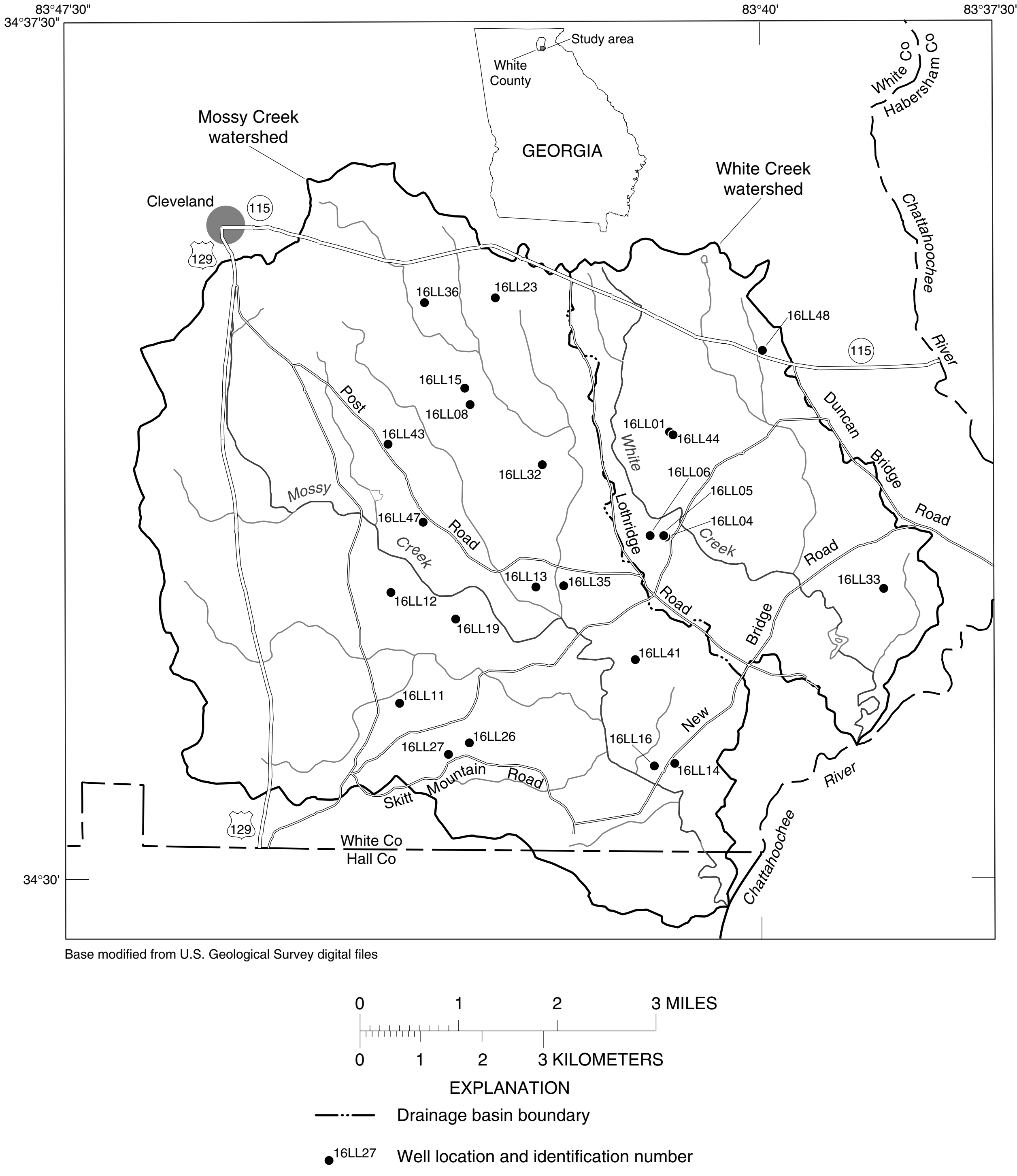

Figure 3. Locations of wells where ground-water samples were collected in the White Creek and Mossy Creek watersheds.

Table 2. Summary of well data in the White Creek and Mossy Creek watersheds

[*Well type*: R, regolith; B, crystalline bedrock; *use of water*: H, domestic; L, livestock; F, fire; I, irrigation; gal/min, gallons per minute; —, data not available]

Grid number	Station name	Latitude	Longitude	Land-surface altitude (feet)	Well depth (feet)	Casing depth (feet)	Casing diameter (inches)	Well type	Use of water	Discharge (gal/min)
16LL01	Congregationalist No. 2	34°33'52"	83°40'58"	1,413	343	67	6	B	H	15
16LL04	Leonard Craven	34°32'57"	83°41'00"	1,347	27	27	28	R	H	—
16LL05	Aubrey Craven	34°32'58"	83°41'02"	1,355	37	37	28	R	H	—
16LL06	Rev. Asa Dorsey	34°32'58"	83°41'10"	1,410	160	32	6	B	H	5
16LL08	Mike Fitzpatrick	34°34'08"	83°43'06"	1,470	560	100	6	B	L	27
16LL11	Old Oak Farm	34°31'31"	83°43'52"	1,443	260	73	6	B	H	3.5
16LL12	Mossy Creek Fire Dept.	34°32'28"	83°43'58"	1,420	425	95	6	B	F	20
16LL13	A & C Dairy	34°32'32"	83°42'24"	1,371	265	121	6	B	L	100
16LL14	Stanley McDougald	34°31'00"	83°40'59"	1,362	240	80	6	B	H	100
16LL15	Mike Fitzpatrick	34°34'17"	83°43'17"	1,430	145	41	6	B	L	10
16LL16	Sills Dairy Farm	34°30'57"	83°41'08"	1,308	230	82	6	B	H,L	100
16LL19	Rondal Barnes No. 2	34°32'15"	83°43'17"	1,419	30	30	30	R	I	—
16LL23	Joe Kittner	34°35'03"	83°42'50"	1,497	400	105	6	B	H	3
16LL26	Ken Dorsey	34°31'09"	83°43'07"	1,422	55	55	28	R	H,L	—
16LL27	Ken Dorsey	34°31'03"	83°43'21"	1,479	250	—	6	B	H,L	—
16LL32	Roy Ash, Jr. (R & R Farms)	34°33'36"	83°42'21"	1,444	450	70	6	B	L	18
16LL33	Ronnie Johnson	34°32'30"	83°38'40"	1,403	225	62	6	B	H,L	15
16LL35	Cecil Crumley	34°32'32"	83°42'07"	1,345	55	55	28	R	H	—
16LL36	Leroy Black	34°35'01"	83°43'36"	1,485	67	67	28	R	H	—
16LL41	H & S Farms	34°31'53"	83°41'21"	1,342	42	42	28	R	L	—
16LL43	Ray Meaders	34°33'47"	83°43'59"	1,460	162	—	6	B	H,L	20
16LL44	Congregationalist No. 3	34°33'51"	83°40'55"	1,420	464	—	6	B	H	—
16LL47	Mossy Creek UM Church	34°33'05"	83°43'30"	1,470	250	108	6	B	H	55
16LL48	A. Martin	34°34'35"	83°39'59"	1,390	15	15	28	R	H	—

Description of the Study Area

The White Creek and Mossy Creek study area lies in the Piedmont physiographic province of northeastern Georgia in White County, southeast of the city of Cleveland (fig. 1). The area consists mostly of low rolling hills and is bordered by mountains on the north, west, and southwest that range in elevation from 1,725 to 2,249 feet (ft) above sea level. The White Creek and Mossy Creek watersheds are tributaries to the upper reach of the Chattahoochee River. The White Creek watershed covers an area of about 6,635 acres, about 10 square miles (mi^2). Land use in the watershed consists of about 3,265 acres in forest land; 2,518 acres in pasture land; 397 acres in urban areas; and 455 acres in other minor land uses (Carroll and Sagona, 1992). There are 69 livestock operations in the watershed, 33 poultry, 32 cattle, 3 horse, and 1 swine operation (Carroll and Sagona, 1992). The Mossy Creek watershed covers an area of about 19,013 acres, about 30 mi^2. Land use in the watershed consists of about 11,304 acres in forest land; 5,331 acres in pasture land; 2,038 acres in urban areas; 188 acres in crop land; and 152 acres in other minor land uses (Carroll and Sagona, 1992). There are 139 livestock operations in the watershed, 68 cattle, 63 poultry, 3 swine, 3 dairy, and 2 horse operations (Carroll and Sagona, 1992).

This area of northeastern Georgia receives an average of about 60 inches (in.) of precipitation annually (Carter and Stiles, 1983); average for the State is 54 in. (Cressler and others, 1983). Precipitation occurs primarily during the winter and early spring. The average annual temperature is about 13.8 ° C (57 ° F) and ranges from an average of 3.8 ° C (39 ° F) during the winter to 24.4 ° C (76 ° F) during the summer (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 1992).

The study area generally is well drained by streams having gradients that average about 54 feet per mile (ft/mi) in the White Creek watershed and 43 ft/mi in the Mossy Creek watershed. The White Creek watershed has about 30 mi of streams and the Mossy Creek watershed about 77 mi of streams (Carroll and Sagona, 1992). Baseflow in the main tributaries is fairly consistent throughout the year; most smaller streams are perennial. Runoff from storms is rapid and may last only a few hours after rainfall has ceased.

Ground water in the study area is transmitted through the regolith and secondary openings in the crystalline bedrock such as fractures, foliation, joints, lithologic contacts, veins, or other geologic features that have been enhanced by weathering (Cressler and others, 1983; Radtke and others, 1986) (fig. 4). In most areas, a transition zone between the regolith and the crystalline bedrock is present and is composed of partially weathered bedrock (Daniel, 1990). The regolith is composed of semi-consolidated to unconsolidated saprolite (weathered bedrock), soil, and other surficial deposits that overlie the crystalline bedrock (Clarke and Peck, 1991). The crystalline bedrock is composed of complex, structurally deformed metamorphic and igneous rocks. The crystalline-rock aquifers are not thought to be laterally extensive. The aquifers vary in yield, water level, and water quality over small areas (Chapman and others, 1993). Precipitation recharges both the regolith and crystalline-rock aquifers. Most wells in the study area are either shallow, large-diameter, bored wells completed in the regolith or deeper, 6-in. diameter drilled wells completed in the crystalline bedrock (fig. 4).

Methods of Data Collection

Water samples were taken from streams and wells in the White Creek and Mossy Creek watersheds and analyzed for concentrations of ammonia, nitrite plus nitrate nitrogen, and orthophosphate phosphorus (nutrients) and determinations of turbidity (stream sites only). Nutrient data commonly are used to assess the effects of nonpoint-source contributions from agricultural areas on water quality. These data were used to identify stream reaches and wells affected by nonpoint-source contributions from livestock operations. Turbidity, a key indicator of stream-quality degradation, was used to identify areas contributing substantial nonpoint-source contributions of suspended material to the streams. Nutrient and turbidity data, in conjunction with field determinations of water temperature, dissolved oxygen, pH, and specific conductance, were used to describe surface-water and ground-water quality conditions in the watersheds.

To evaluate the relative nonpoint-source contributions from storm runoff, nutrient and turbidity data from surface-water samples collected at baseflow when the major component of flow is from ground-water discharge were compared to data during storm runoff when flow is predominantly from overland runoff. To evaluate the affects of nonpoint-source contributions on ground-water quality, wells were sampled in early Spring, after a period of possible recharge from winter precipitation.

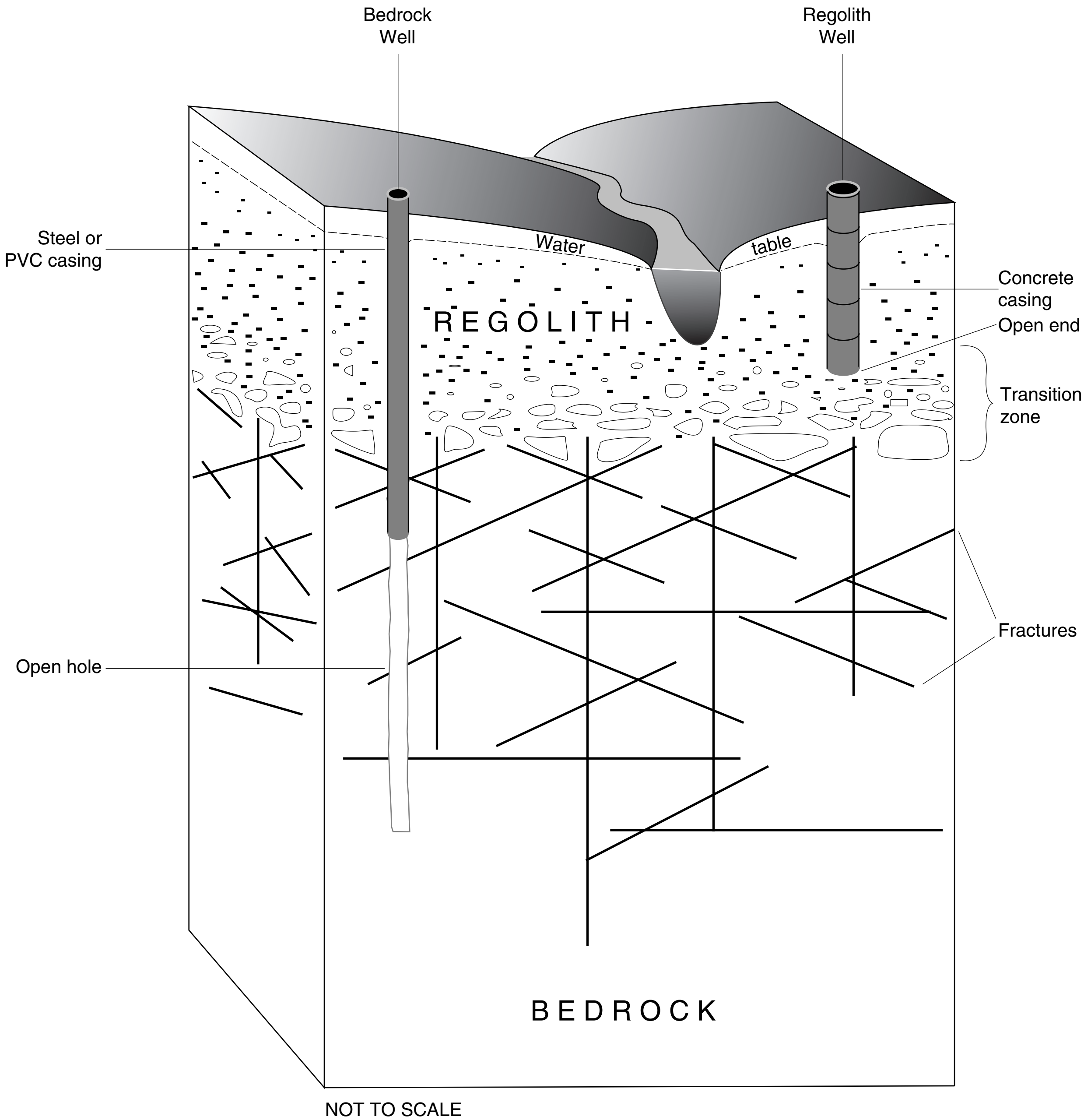

Figure 4. Principal components of the hydrogeologic system in the Piedmont physiographic province and typical regolith and bedrock well construction.

Surface-water samples

Surface-water samples were collected at 31 sites established by the USGS in the White Creek and Mossy Creek watersheds (fig. 2, table 1). Site selection was based on land-use data compiled by the TVA for the CCRCDC (Carroll and Sagona, 1992) and accessibility of stream crossings at bridges and culverts during baseflow and stormwater-runoff conditions. The sampling sites in each watershed are divided into two categories: (1) main-stem sites located along the main stream channel and (2) tributary sites. Land-use data were used to determine the number of livestock operations upstream from each sampling point (table 1). The size of each drainage area associated with each sampling point was determined by digitizing each basin and using GIS to calculate the square miles of each (fig. 5, table 1).

Water samples were collected during baseflow conditions on September 30 and October 1, 1992, and during stormwater-runoff conditions on January 12, 1993. Samples were analyzed for turbidity and concentrations of ammonia, nitrite plus nitrate, and orthophosphate. Field measurements of streamflow and determinations of water temperature, dissolved oxygen, specific conductance, and pH were made at each site. Water samples were collected using depth-integrating isokenetic samplers at multiple depths where stream width and depth allowed, otherwise, single samples or surface-grab samples were collected. Depth-integrating samplers minimize sampling errors by collecting a combined water-sediment sample from a stream so that the water entering the sampler is at or near the same velocity as that of the stream where the sample is being collected (Guy and Norman, 1982). Water samples collected at each site were composited into a 3.7-gallon churn splitter and subsamples were withdrawn into appropriate containers. Water samples collected during stormwater-runoff conditions were chilled and transported to the USGS, Georgia District Laboratory, Atlanta, Ga., where they were filtered through a 0.45-micron filter. Baseflow samples were not filtered. All nutrient samples were preserved using a 0.5 mL mercuric chloride solution, chilled to 4 °C, and shipped for analyses within 24 hours of collection to the USGS, Water Quality Laboratory, Ocala, Fla.

Ground-water samples

Availability and suitability of wells for ground-water sampling in the White Creek and Mossy Creek watersheds were determined using information obtained from local well drillers, the White County Health Department, individual well owners, the files of the USGS, and from site visits to the wells (fig. 3, table 2). Information consisted of well construction, well yield, frequency of well pumping, and water-quality problems, if known. Each site was assessed to determine if a water sample could be collected at or near the well head before the water entered a pressure tank or filtration system. Of the 51 wells inventoried, 24 were suitable for sampling (fig. 3; table 2)—8 shallow wells completed in the regolith and 16 deeper wells completed in the crystalline-bedrock aquifers. Most of the 24 wells were pumped for many hours on a daily basis. The location of the wells were plotted on 7 1/2-minute topographic maps, assigned a well-identification number, and entered into the USGS Ground-Water Site Inventory (GWSI) data base.

Water samples were collected from the 24 wells during March 23-30, 1993. This period was selected because ground-water levels in the regolith, and possibly the crystalline-bedrock aquifers, were expected to be at their annual high as a result of winter recharge from precipitation. Three wells were resampled on May 5, 1993, to verify the initial results.

Prior to sample collection, each well was pumped for about one hour or until readings of specific conductance, pH, dissolved oxygen, and temperature taken at 10-minute intervals were consistent. All samples were filtered through a 0.45-micron filter at the site, preserved using a 0.5 mL mercuric chloride solution, chilled to 4 °C, and shipped within 24 hours of collection to the USGS, National Water-Quality Laboratory, Arvada, Co., and subsequently analyzed for concentrations of ammonia, nitrite plus nitrate, and orthophosphate.

Quality-control samples

Quality-control samples were used to provide information on potential contamination of samples and variability of analyses resulting from collection, processing, and analysis procedures. These samples were used to identify steps, such as filtering, preserving, storing, and transporting; or to identify analyses that may have been improperly performed.

Replicate quality-control samples were collected sequentially at five surface-water sites within a few minutes of the regular sample during the baseflow-sampling period and identically processed. Duplicate samples, which were split off of the regular sample, were collected at five sites during the stormwater-runoff sampling period. Duplicate samples were used in place of sequentially collected replicate samples because of the potential for changing concentrations associated with the variable streamflow in sequential samples. Both types of samples provide a check of sample collection and processing techniques and reproducibility of constituent concentrations.

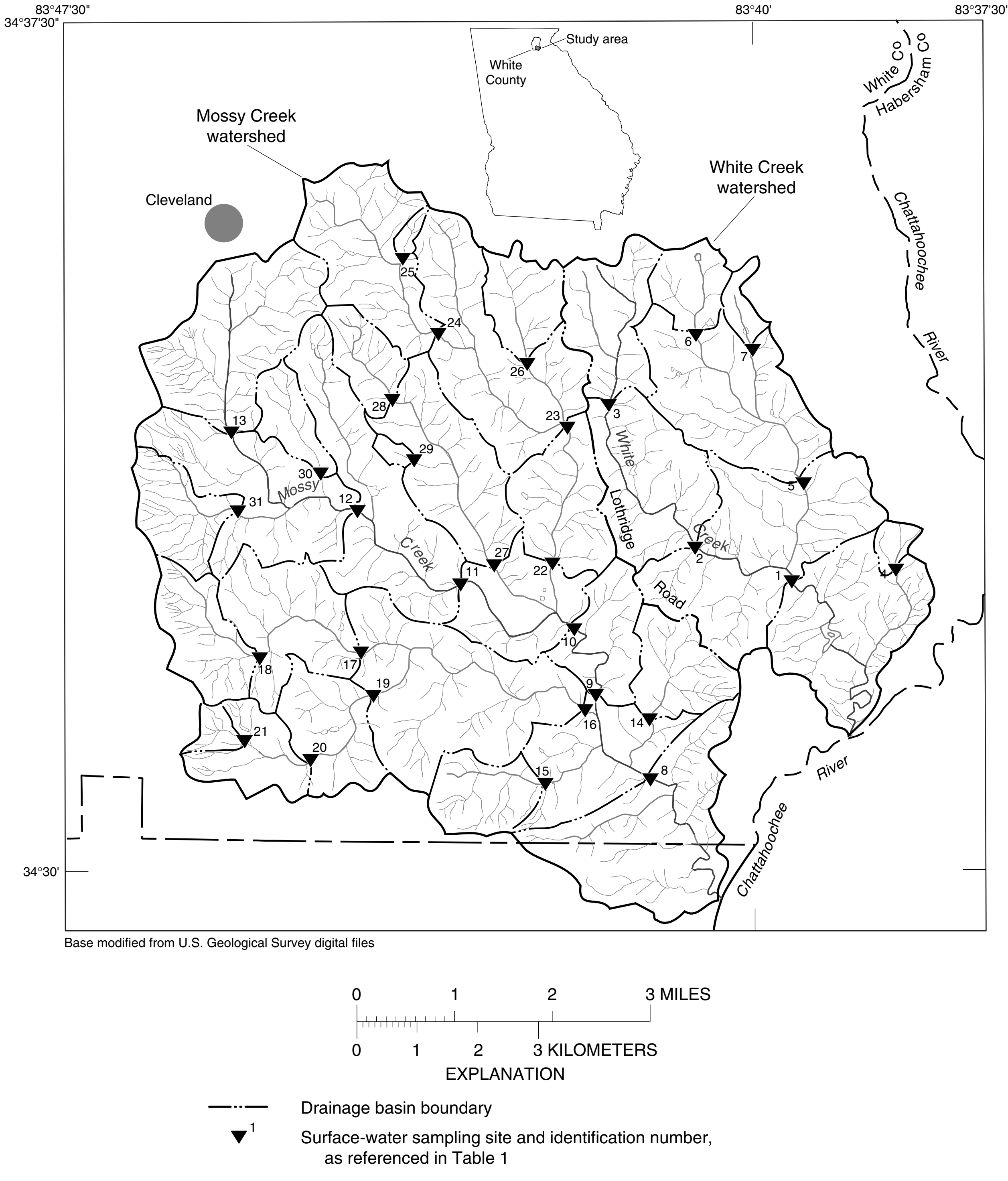

Figure 5. Drainage areas and surface-water sampling sites.

Field-blank samples were collected at seven well sites subsequent to the collection of ground-water samples. A field-blank sample is chemically pure water that is subjected to all aspects of sample collection, field processing, preservation, transportation, and laboratory handling as the environmental sample. Field blanks demonstrate whether the sampling equipment-cleaning procedure has adequately removed contaminants introduced by previous use.

Acknowledgments

The authors extend their appreciation to the many landowners, local well drillers, and employees of the White County Tax Office who furnished well information. In addition, the authors wish to thank Stanley McDougald of M & R Well Drilling, Cleveland, Ga.; Prime Pump & Well, Dahlonega, Ga.; and Cash & Thomas Contractors, Toccoa, Ga.; for providing construction information for many wells in the study area.

The authors also appreciate the background information on the quality of ground water in White County provided by Mitchell S. Biggers, White County Health Department, and Michael Harris, White County Extension Service. William E. White and Kathy Burroughs, SCS, Athens, Ga., provided digitized land-use data from the SCS GIS data base. Appreciation also is extended to those landowners who permitted the sampling of wells and streams on their property.

SURFACE-WATER QUALITY

Water-quality conditions in streams in the White Creek and Mossy Creek watersheds are described in terms of field measurements of water temperature, pH, dissolved oxygen and specific conductance, nutrient concentrations, and turbidity. Baseflow and stormwater-runoff data from the main-stem and tributary sites in each watershed are compared to one another and to each watershed. Stream discharge measured at the time of baseflow sampling ranged from 0.12 cubic ft per second (ft^3/s) at site 29 to 52 ft^3/s at site 8. Discharge measured during storm runoff ranged from 1.0 ft^3/s at site 25 to 586 ft^3/s at site 8. Streamflow measured during stormwater-runoff conditions was at least an order of magnitude greater than streamflow measured during baseflow conditions at all surface-water sites.

White Creek Watershed

Seven streamflow sites were sampled in the White Creek watershed during the study period. Three streamflow sites were located on the main-stem (sites 1 through 3) and four streamflow sites were located on tributaries (sites 4 through 7) (fig. 2). Water temperature averaged 16.9 ° C during baseflow conditions and 9.1 ° C during stormwater-runoff conditions. Dissolved oxygen concentrations in the White Creek watershed were measured only during stormwater-runoff conditions and ranged from 10.1 to 11.3 mg/L. Specific conductance measured during baseflow ranged from 29 to 61 microsiemens per centimeter (µS/cm), and ranged from 25 to 62 µS/cm during stormwater-runoff conditions. The pH remained comparatively constant during both sampling periods at each site. Overall, the pH ranged from 6.0 to 6.8 at baseflow and 5.8 to 7.0 during stormwater-runoff conditions.

Ammonia concentrations were the same during baseflow and stormwater-runoff sampling at two of the three main-stem sites. Concentrations were 0.02 mg/L at sites 2 and 3 during both sampling periods but increased from 0.05 mg/L during baseflow to 0.14 mg/L during stormwater runoff at site 1 (table 3). Nitrite plus nitrate concentrations were higher during baseflow than at stormwater-runoff conditions at all main-stem sites (fig. 6, table 3). Concentrations of nitrite plus nitrate ranged from 0.92 to 1.8 mg/L at baseflow and 0.55 to 0.89 mg/L during runoff conditions. Lower nitrite plus nitrate concentration for stormwater-runoff conditions are the result of dilution of the ground-water component of the streamflow by surface runoff (Hallberg and Keeney, 1993). Concentrations of orthophosphate were higher during runoff than during baseflow conditions. Orthophosphate concentrations ranged from 0.01 to 0.04 mg/L at baseflow and 0.09 to 0.56 mg/L during stormwater-runoff conditions (fig. 6, table 3). Higher orthophosphate concentrations may result from increased runoff of soluble material from the land surface. Turbidity ranged from 3.8 to 9.6 NTU at baseflow and from 93 to 680 NTU during stormwater-runoff conditions (fig. 7, table 3).

Ammonia concentrations at the tributary sites were slightly higher at all sites during stormwater-runoff conditions than at baseflow conditions. Concentrations ranged from 0.03 to 0.07 mg/L at baseflow to 0.07 to 0.10 during runoff conditions (table 4). Nitrite plus nitrate concentrations were higher during baseflow than at stormwater-runoff conditions at all of the tributary sites. Concentrations of nitrite plus nitrate ranged from 1.2 to 2.7 mg/L during baseflow to 0.51 to 1.1 mg/L during stormwater-runoff conditions (fig. 6, table 4). Again, the decrease in concentration from baseflow to runoff conditions is due to the dilution of the streamflow by surface runoff. Orthophosphate concentrations at all of the sites were higher during stormwater-runoff conditions than during baseflow conditions, again, due to the increase in runoff of phosphate from the land surface. Concentrations ranged from 0.03 to 0.04 mg/L at baseflow to 0.27 to 0.61 mg/L during runoff conditions (fig. 6, table 4). Turbidity was also higher during stormwater runoff than during baseflow conditions and ranged from 9.6 to 14 at baseflow to 92 to 440 during runoff conditions (fig. 7, table 4).

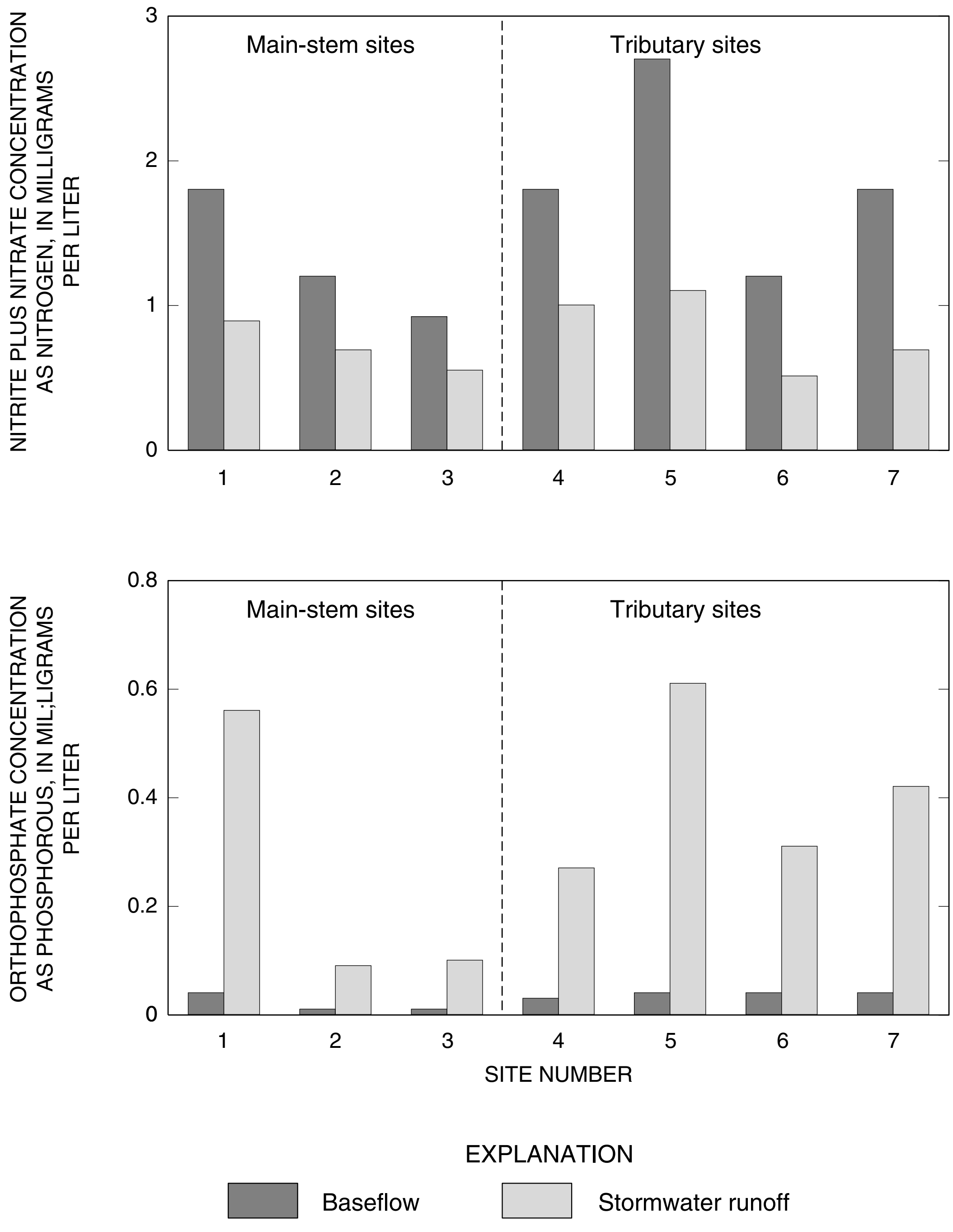

Figure 6. Concentration of nitrite plus nitrate and orthophosphate in the White Creek watershed during baseflow (September 30, 1992) and stormwater-runoff (January 12, 1993) conditions.

Table 3. Water-quality data at main-stem sites in the White Creek watershed during baseflow, September 30, 1992, and stormwater-runoff conditions, January 12, 1993

[ft^3/s, cubic feet per second; ° C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 ° C; mg/L, milligrams per liter; NTU, nephelometric turbidity units; —, data not available]

Site number	Date sampled	Discharge (ft^3/s)	Water temperature (° C)	pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Ammonia nitrogen, as N (mg/L)	Nitrite plus nitrate, as N (mg/L)	Orthophosphate phosphorus, as P (mg/L)	Turbidity (NTU)
1	09-30-92	14	16.9	6.5	36	—	0.05	1.8	0.04	9.6
	01-12-93	—	9.0	6.2	44	10.5	.14	.89	.56	680
2	09-30-92	4.7	15.8	6.7	29	—	.02	1.2	.01	6.5
	01-12-93	—	9.5	6.9	33	10.1	.02	.69	.09	110
3	09-30-92	1.7	15.7	6.4	31	—	.02	.92	.01	3.8
	01-12-93	27	9.6	5.8	25	10.4	.02	.55	.10	93
Baseflow conditions	Range	1.7-14	15.7-16.9	6.4-6.7	29-36	—	0.02-0.05	0.92-1.8	0.01-0.04	3.8-9.6
	Mean	6.8	16.1	6.5	32	—	0.03	1.31	0.02	6.6
Stormwater-runoff conditions	Range	—	9.0-9.6	5.8-6.9	25-44	10.1-10.5	0.02-0.14	0.55-0.89	0.09-0.56	93-680
	Mean	—	9.4	6.3	34	10.3	0.06	0.71	0.25	294

Table 4. Water-quality data at tributary sites in the White Creek watershed during baseflow, September 30, 1992, and stormwater-runoff conditions, January 12, 1993

[ft^3/s, cubic feet per second; ° C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 ° C; mg/L, milligrams per liter; NTU, nephelometric turbidity units; —, data not available]

Site number	Date sampled	Discharge (ft^3/s)	Water temperature (° C)	pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Ammonia nitrogen, as N (mg/L)	Nitrite plus nitrate, as N (mg/L)	Orthophosphate phosphorus, as P (mg/L)	Turbidity (NTU)
4	09-30-92	0.14	16.8	6.0	46	—	0.07	1.8	0.03	9.6
	01-12-93	6.0	9.0	6.2	32	11.3	.10	1.0	.27	92
5	09-30-92	4.1	18.1	6.8	61	—	.03	2.7	.04	14
	01-12-93	56	9.0	7.0	62	10.4	.10	1.1	.61	200
6	09-30-92	1.0	17.4	6.4	41	—	.03	1.2	.04	—
	01-12-93	22	9.1	6.2	50	10.9	.08	.51	.31	140
7	09-30-92	0.56	17.6	6.2	53	—	.05	1.8	.04	11
	01-12-93	11	8.5	6.5	39	10.9	.07	.69	.42	440
Baseflow conditions	Range	0.14-4.1	16.8-18.1	6.0-6.8	41-61	—	0.03-0.07	1.2-2.7	0.03-0.04	9.6-14
	Mean	1.45	17.5	6.3	50	—	0.04	1.9	0.04	11.5
Stormwater-runoff conditions	Range	6.0-56	8.5-9.1	6.2-7.0	32-62	10.4-11.3	0.07-0.10	0.51-1.1	0.27-0.61	92-440
	Mean	23.7	8.9	6.5	46	10.9	0.09	0.8	0.40	218

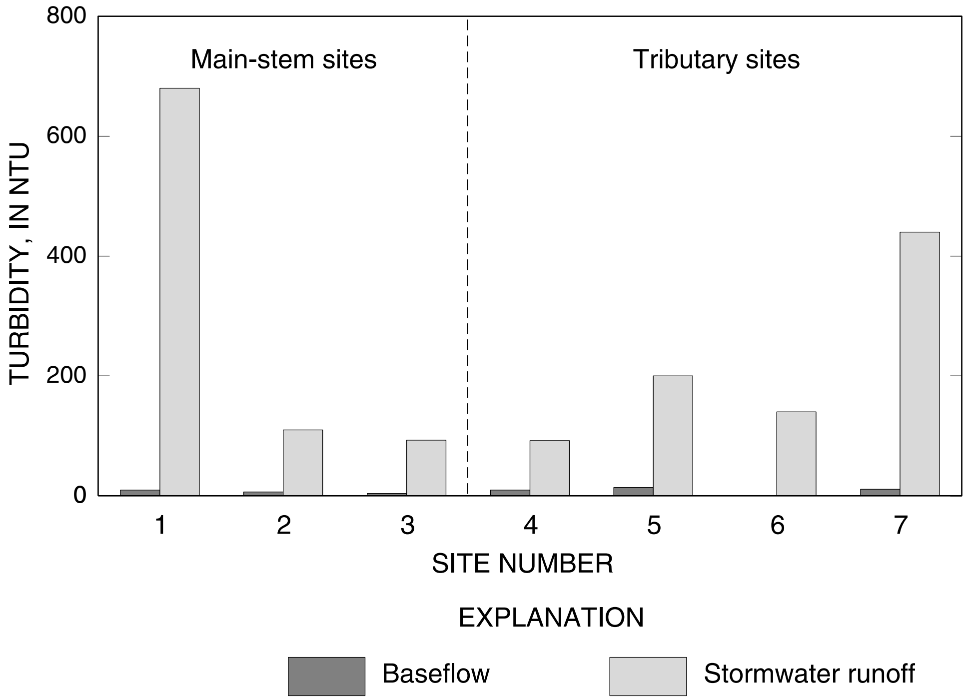

Figure 7. Turbidity in the White Creek watershed during baseflow (September 30, 1992) and stormwater-runoff (January 12, 1993) conditions.

Mossy Creek Watershed

Twenty-four streamflow sites were sampled in the Mossy Creek watershed during the study period. Six sites were located on the main stem (sites 8-13) and 18 were located on tributaries (sites 14-31) (fig. 2). Water temperature averaged 15.3 °C during baseflow conditions and 9.5 °C during stormwater-runoff conditions. Dissolved oxygen concentrations measured during baseflow ranged from 7.8 to 10.1 mg/L and 8.6 to 11 mg/L during stormwater runoff. Specific conductance ranged from 20 to 62 µS/cm at baseflow and 8 to 72 µS/cm during stormwater runoff. The pH remained comparatively constant, except at sites 10 and 19, where it was a unit or more lower during stormwater-runoff conditions. The pH ranged from 6.4 to 7.5 at baseflow and 5.7 and 7.0 during stormwater runoff.

Ammonia concentrations at the main-stem sites ranged from 0.01 to 0.2 mg/L during baseflow conditions and 0.02 to 0.26 mg/L during stormwater-runoff conditions (table 5). Concentrations of nitrite plus nitrate were higher during stormwater runoff than during baseflow conditions. Concentrations ranged from 0.2 to 0.86 mg/L during baseflow and 0.01 to 0.64 mg/L during stormwater-runoff conditions (fig. 8, table 5). Orthophosphate concentrations ranged from 0.01 to 0.05 mg/L during baseflow and 0.02 to 0.24 mg/L during stormwater-runoff conditions (fig. 8, table 5). Again, the higher concentration during stormwater-runoff conditions may result from increased runoff of soluble material from the land surface. Turbidity ranged from 6.6 to 13 NTU during baseflow and 110 to 640 NTU during stormwater-runoff conditions (fig. 9, table 5).

Ammonia concentrations at the tributary sites ranged from 0.01 to 0.04 mg/L during baseflow and from less than the minimum reporting level (0.01 mg/L) to 0.56 mg/L during stormwater-runoff conditions (table 6). Concentrations of nitrite plus nitrate at all of the sites decreased from baseflow to stormwater-runoff conditions, except at sites 25 and 28 (fig. 1). There are two livestock operations upstream of sampling site 25, but there are no livestock operations upstream of site 28. Nitrite plus nitrate concentrations at site 25 increased from 1.0 to 1.4 mg/L and increased at site 28 from less than the reporting level of 0.02 mg/L to 1.2 mg/L. Overall, concentrations of nitrite plus nitrate ranged from less than the reporting level (0.02 mg/L) to 3.4 mg/L during baseflow to 0.06 to 1.4 during stormwater-runoff conditions (fig. 8, table 6). Orthophosphate concentrations ranged from less than the reporting level (0.01 mg/L) to 0.04 during baseflow to 0.02 to 0.50 mg/L during stormwater-runoff conditions (fig. 8, table 6). Turbidity ranged from 2.2 to 14 NTU during baseflow, and 23 to 520 NTU during stormwater-runoff conditions (fig. 9, table 6).

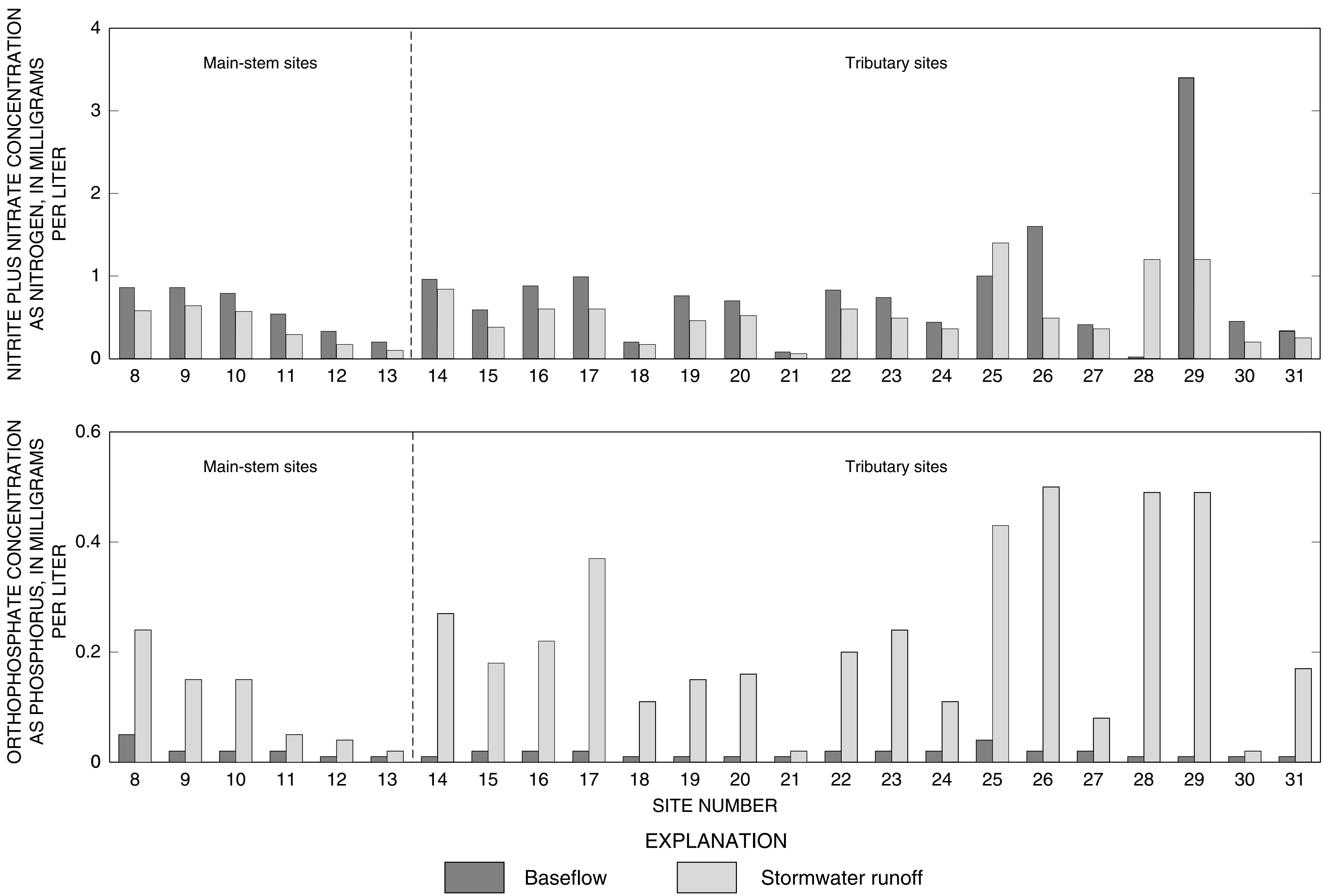

Figure 8. Concentration of nitrite plus nitrate and orthophosphate in the Mossy Creek watershed during baseflow (September 30 and October 1, 1992) and stormwater-runoff (January 12, 1993) conditions.

Table 5. Water-quality data at main-stem sites in the Mossy Creek watershed during baseflow, September 30 and October 1, 1992, and stormwater-runoff conditions, January 12, 1993

[ft^3/s, cubic feet per second; ° C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 ° C; mg/L, milligrams per liter; NTU, nephelometric turbidity units]

Site number	Date sampled	Discharge (ft^3/s)	Water temperature (° C)	pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Ammonia nitrogen, as N (mg/L)	Nitrite plus nitrate, as N (mg/L)	Orthophosphate phosphorus, as P (mg/L)	Turbidity (NTU)
8	09-30-92	52	16.4	6.9	40	9.6	0.20	0.86	0.05	11
	01-12-93	586	9.6	6.1	31	10.8	.21	.58	.24	200
9	09-30-92	32	16.1	7.1	38	10.0	.01	.86	.02	12
	01-12-93	370	9.7	6.3	34	10.1	.26	.64	.15	150
10	09-30-92	30	15.7	7.0	38	9.8	.02	.79	.02	12
	01-12-93	319	9.8	5.9	30	10.7	.22	.57	.15	160
11	10-01-92	13	13.5	7.5	33	10.1	.01	.54	.02	13
	01-12-93	203	9.5	6.0	25	10.2	.02	.29	.05	170
12	10-01-92	9.2	13.9	7.1	30	9.8	.01	.33	.01	6.6
	01-12-93	188	9.5	6.9	25	10.1	.02	.17	.04	640
13	09-30-92	4.4	14.5	6.8	33	8.7	.04	.20	.01	7.5
	01-12-93	55	9.5	6.6	18	9.6	.02	.10	.02	110
Baseflow conditions	Range	4.4-52	13.5-16.4	6.8-7.5	30-40	8.7-10.1	0.01-0.20	0.20-0.86	0.01-0.05	6.6-13
	Mean	23.4	15.0	7.1	35	9.7	0.05	0.60	0.02	10.4
Stormwater-runoff conditions	Range	55-586	9.5-9.8	5.9-6.9	18-34	9.6-10.8	0.02-0.26	0.10-0.64	0.02-0.24	110-640
	Mean	287	9.6	6.3	27	10.2	0.12	0.39	0.11	238

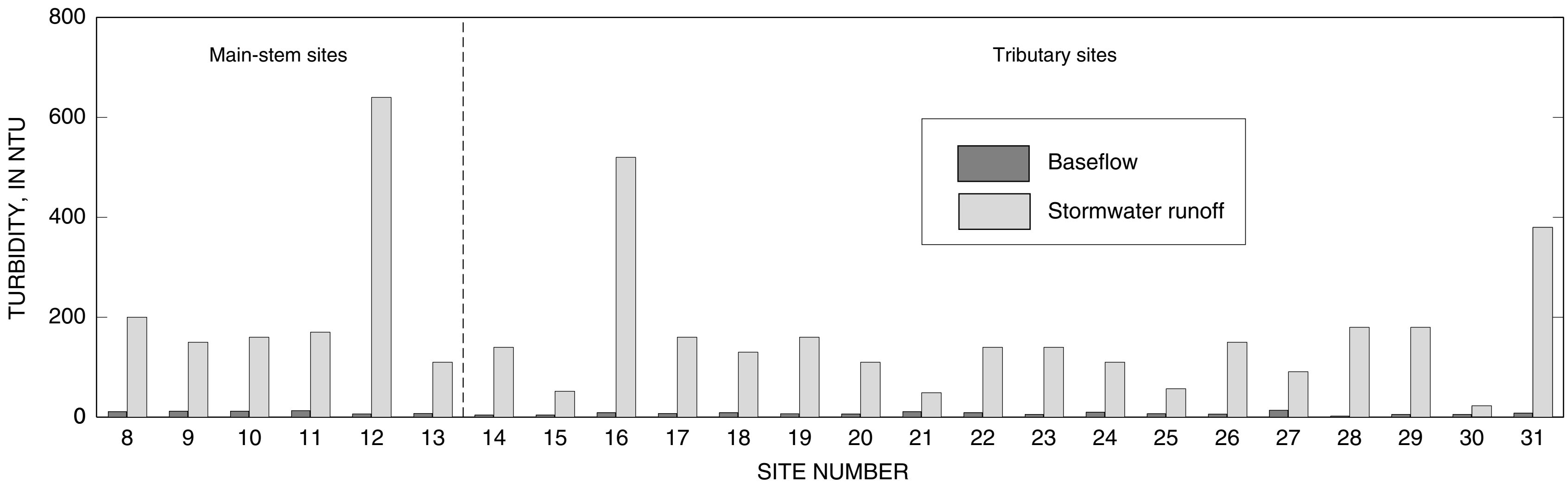

Figure 9. Turbidity in the Mossy Creek watershed during baseflow (September 30 and October 1, 1992) and stormwater-runoff (January 12, 1993) conditions.

Table 6. Water quality at tributary sites in the Mossy Creek watershed during baseflow, September 30 and October 1, 1992, and stormwater-runoff conditions, January 12, 1993

[ft^3/s, cubic feet per second; ° C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 ° C; mg/L, milligrams per liter; NTU, nephelometric turbidity units; —, data not available; <, less than]

Site number	Date sampled	Discharge (ft^3/s)	Water temperature (° C)	pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Ammonia nitrogen, as N (mg/L)	Nitrite plus nitrate, as N (mg/L)	Orthophosphate phosphorus, as P (mg/L)	Turbidity (NTU)
14	09-30-92	1.1	16.1	6.6	32	9.6	0.01	0.96	0.01	4.1
	01-12-93	35	8.8	6.0	27	11.0	.06	.84	.27	140
15	10-01-92	0.95	17.0	6.6	38	8.8	.03	.59	.02	4.2
	01-12-93	21	9.1	6.0	28	11.0	.09	.38	.18	52
16	10-01-92	14	16.0	7.2	42	9.9	.01	.88	.02	8.9
	01-12-93	207	8.9	6.5	27	10.3	.14	.60	.22	520
17	09-30-92	4.6	17.5	6.6	39	8.6	.02	.99	.02	7.0
	01-12-93	71	8.8	6.5	19	8.9	.36	.60	.37	160
18	09-30-92	1.5	15.1	6.9	24	9.4	.03	.20	.01	8.9
	01-12-93	32	8.9	6.7	9	10.9	.07	.17	.11	130
19	09-30-92	3.3	15.6	7.0	43	9.6	.01	.76	.01	6.8
	01-12-93	40	9.0	6.0	9	8.6	.05	.46	.15	160
20	09-30-92	1.5	14.8	6.9	42	9.0	.02	.70	.01	6.3
	01-12-93	17	9.4	6.1	32	10.7	.04	.52	.16	110
21	09-30-92	0.28	15.0	7.0	39	9.3	.01	0.08	.01	11
	01-12-93	2.1	10.6	6.6	23	9.5	.01	.06	.02	49
22	09-30-92	12	16.0	6.8	37	9.3	.02	.83	.02	8.8
	01-12-93	97	9.6	6.8	39	9.2	.56	.60	.20	140
23	09-30-92	12	14.8	6.7	35	—	.01	.74	.02	5.5
	01-12-93	132	9.5	7.0	37	10.4	.25	.49	.24	140
24	09-30-92	2.8	14.3	6.8	36	8.6	.03	.44	.02	9.9
	01-12-93	30	9.6	6.7	28	10.5	.03	.36	.11	110

Table 6. Water quality at tributary sites in the Mossy Creek watershed during baseflow, September 30 and October 1, 1992, and stormwater-runoff conditions, January 12, 1993—Continued

[ft³/s, cubic feet per second; ° C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 ° C; mg/L, milligrams per liter; NTU, nephelometric turbidity units; —, data not available; <, less than]

Site number	Date sampled	Discharge (ft^3/s)	Water temperature (° C)	pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Ammonia nitrogen, as N (mg/L)	Nitrite plus nitrate, as N (mg/L)	Orthophosphate phosphorus, as P (mg/L)	Turbidity (NTU)
25	09-30-92	.17	15.1	6.9	62	—	.04	1.0	.04	6.8
	01-12-93	1.0	10.4	6.8	72	9.2	.05	1.4	.43	57
26	09-30-92	1.7	15.0	6.4	46	—	.04	1.6	.02	5.9
	01-12-93	19	9.3	6.3	41	10.1	.16	.49	.50	150
27	09-30-92	4.6	14.5	6.5	25	8.0	.04	.41	.02	14
	01-12-93	49	9.8	5.7	18	10.5	.03	.36	.08	91
28	09-30-92	1.0	16.0	6.5	20	8.8	.01	<.02	<.01	2.2
	01-12-93	10	10.1	6.2	8	9.6	.08	1.2	.49	180
29	09-30-92	.12	16.0	6.4	50	7.8	.02	3.4	.01	5.3
	01-12-93	3.2	8.9	6.1	39	10.7	.08	1.2	.49	180
30	09-30-92	.94	14.4	6.7	23	9.6	.01	.45	.01	5.4
	01-12-93	6.6	10.8	6.4	14	9.2	<.01	.20	.02	23
31	09-30-92	1.7	14.0	6.6	31	9.6	.02	.33	.01	8.1
	01-12-93	30	9.1	6.7	25	10.5	.06	.25	.17	380
Baseflow conditions	Range	0.12-14	14.0-17.5	6.4-7.2	20-62	7.8-9.9	0.01-0.04	<0.02-3.4	<0.01-0.04	2.2-14
	Mean	3.57	15.4	6.7	37	9.1	0.02	0.84	0.02	7.2
Stormwater-runoff conditions	Range	1.0-207	8.8-10.8	5.7-7.0	8-72	8.6-11.0	<0.01-0.56	0.06-1.4	0.02-0.50	23-520
	Mean	44.6	9.5	6.4	27	10.0	0.12	0.56	0.23	154

Baseflow Yields in the White Creek and Mossy Creek Watersheds

Nitrite plus nitrate and orthophosphate yields at sampling sites in the White Creek and Mossy Creek watersheds were computed using concentrations and discharge determined during baseflow sampling which are reported in pounds per day per square mile (lbs/d/mi^2). Baseflow yields provide estimates of nonpoint-source inputs for a watershed and can be used to identify land areas that are contributing relatively high amounts of nutrients to streams. Yields were not determined for stormwater-runoff conditions because a single sample and discharge measurement do not provide data that are representative of the storm period.

Nitrite plus nitrate and orthophosphate yields for samples collected during baseflow were determined by the following equation:

$$Y = \frac{C x Q}{A} x 5.39 \qquad (1)$$

where

- Y = yield in lbs/d/mi^2;
- C = constituent concentration in mg/L;
- Q = discharge in ft^3/s;
- A = drainage area in mi^2; and
- 5.39 = conversion factor.

In the White Creek watershed, the highest base-flow yields of nitrite plus nitrate and orthophosphate were at the tributary sites (fig. 10, table 7). The highest nitrite plus nitrate yields were at tributary sites 5 (21.0 lbs/d/mi^2) and 7 (25.8 lbs/d/mi^2). Nitrite plus nitrate yields at sites 5 and 7 are similar; however, the size of the drainage areas and the number of livestock operations in the watershed varies greatly. Site 7 has a drainage area of 0.21 mi^2 and has two livestock operations; site 5 has a drainage area of 2.85 mi^2 and has 25 livestock operations (table 1). Nitrite plus nitrate yield at site 1, the farthest downstream site in the watershed, was 16.2 lbs/d/mi^2. Highest orthophosphate yields were at tributary sites 7 (0.6 lbs/d/mi^2) and 6 (0.4 lbs/d/mi^2) (table 7). Orthophosphate yield at site 1 was 0.4 lbs/d/mi^2.

In the Mossy Creek watershed, the highest baseflow yields of nitrite plus nitrate were at the tributary sites (fig. 11, table 8). Sites 26 and 29 (fig. 2) had the highest yields of 20.9 and 27.4 lbs/d/mi^2, respectively. Site 29 has a drainage area of 0.08 mi^2 and has two livestock operations; site 26 has a drainage area of 0.7 mi^2 and has five livestock operations (table 1). The nitrite plus nitrate yield at site 8, the farthest downstream site in the watershed, was 8.8 lbs/d/mi^2. Orthophosphate yields at the main-stem sites ranged from 0.1 to 0.5 lbs/d/mi^2. The highest orthophosphate yields were at sites 8 (0.5 lbs/d/mi^2) and 25 (0.4 lbs/d/mi^2) (table 8).

Table 7. Baseflow yields of nitrite plus nitrate and orthophosphate at surface-water sampling sites in the White Creek watershed, September 30, 1992

[M, main-stem site; T, tributary site; lbs/d/mi^2, pounds per day per square mile]

Station number	Site type	Nitrite plus nitrate, as N (lbs/d/mi^2)	Orthophosphate phosphorus, as P (lbs/d/mi^2)
01	M	16.2	0.4
02	M	10.9	.1
03	M	7.3	.1
04	T	8.0	.1
05	T	21.0	.3
06	T	11.3	.4
07	T	25.8	.6

Table 8. Baseflow yields of nitrite plus nitrate and orthophosphate at selected surface-water sampling sites in the Mossy Creek watershed, September 30 and October 1, 1992

[M, main-stem site; T, tributary site; lbs/d/mi^2, pounds per day per square mile]

Station number	Site type	Nitrite plus nitrate as N, (lbs/d/mi^2)	Orthophosphate phosphorus, as P (lbs/d/mi^2)
8	M	8.8	0.5
9	M	6.8	.2
10	M	7.6	.2
11	M	5.1	.2
12	M	3.1	.1
13	M	2.3	.1
14	T	6.7	.1
15	T	4.0	.1
16	T	9.6	.2
17	T	10.6	.2
18	T	1.8	.1
19	T	7.2	.1
20	T	6.4	.1
21	T	0.7	.1
22	T	9.0	.2
23	T	10.1	.3
24	T	3.7	.2
25	T	10.2	.4
26	T	20.9	.3
27	T	4.5	.2
28	T	0.2	.1
29	T	27.4	.1
30	T	4.7	.1
31	T	3.7	.1

Baseflow yields at main-stem and tributary sites in both watersheds were not directly correlated to upstream land use. However, relatively high yields upstream of some sites indicate land-use activities are affecting water-quality conditions in the stream reach.

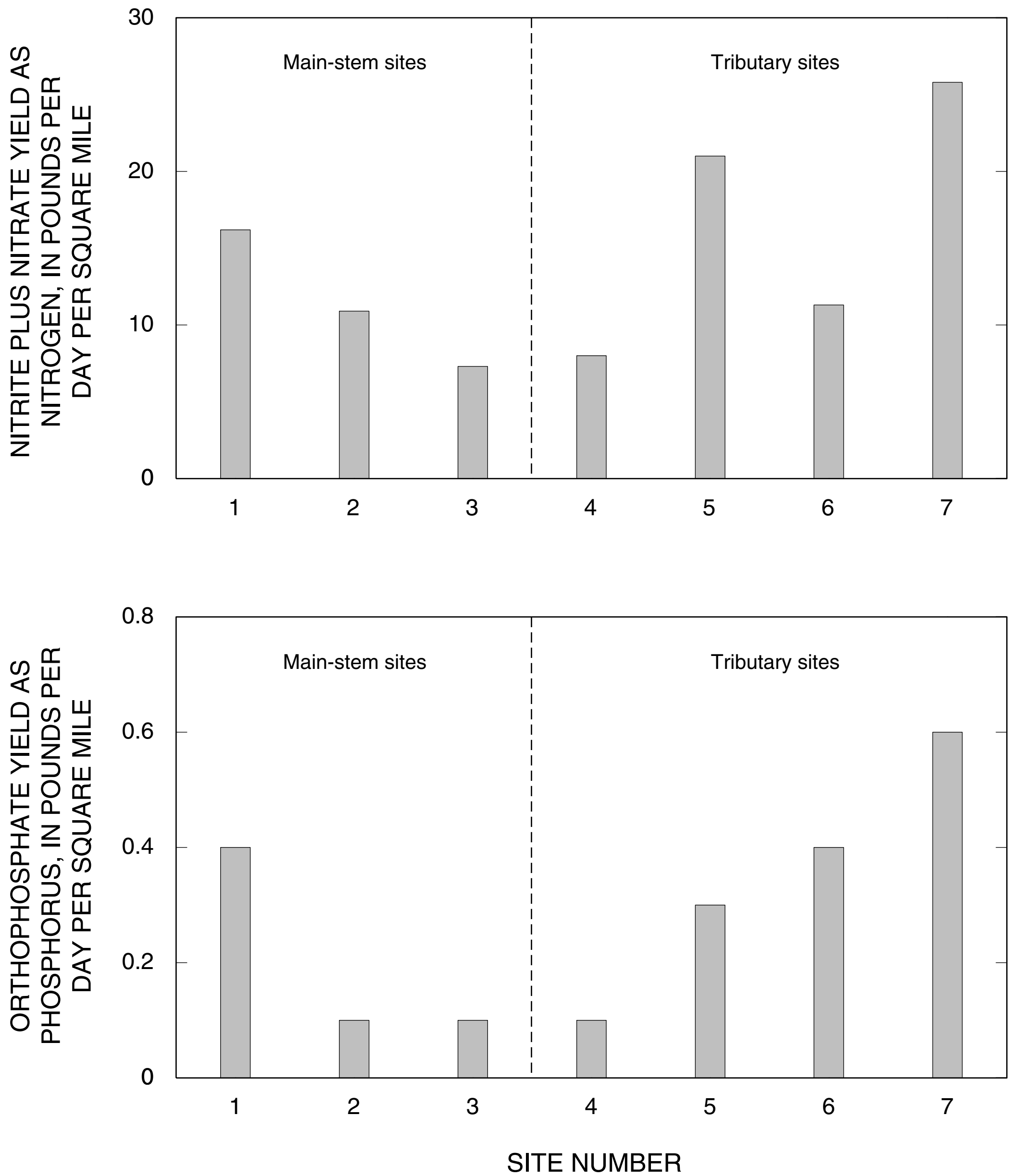

Figure 10. Baseflow yields of nitrite plus nitrate and orthophosphate at sampling sites in the White Creek watershed (September 30, 1992).

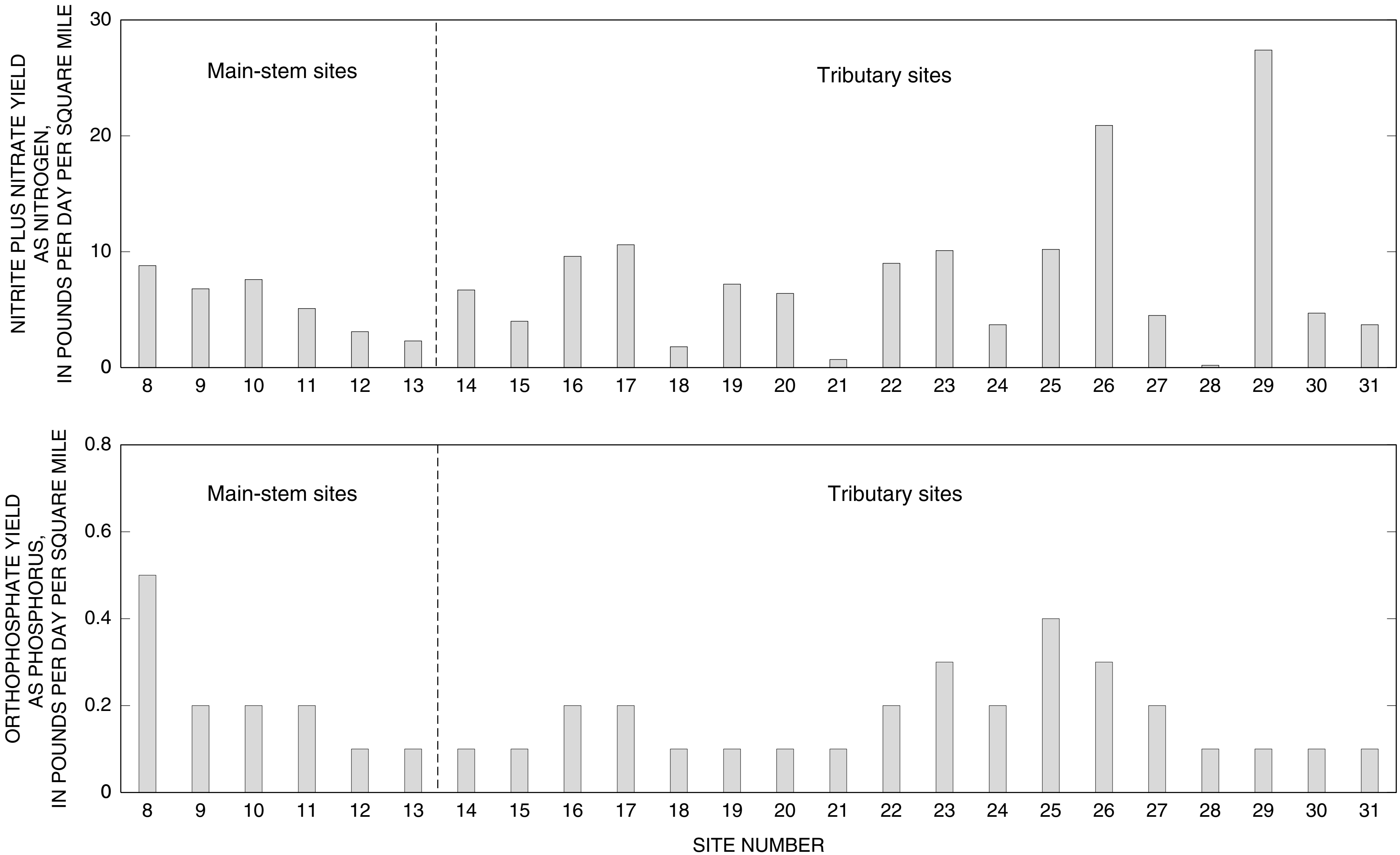

Figure 11. Yields of nitrite plus nitrite and orthophosphate at sampling sites in Mossy Creek watershed during baseflow conditions (September 30 and October 1, 1992).

GROUND-WATER QUALITY

Water samples were collected from regolith and bedrock wells throughout the study area. The regolith wells receive water from a shallow zone composed of semi-consolidated to unconsolidated saprolite, soil, and other surficial deposits; bedrock wells receive water from fractures and other secondary openings in the crystalline bedrock, and also, from the regolith.

Regolith Wells

Eight regolith wells sampled in the White Creek and Mossy Creek watersheds (fig. 3, table 2) ranged in depth from 15 to 67 ft. Most of these wells are used for a combination of domestic- and livestock-water supply. Water samples from the eight regolith wells were analyzed for concentrations of ammonia, nitrite plus nitrate, and orthophosphate. Field measurements were made for water temperature, dissolved oxygen, specific conductance, and pH (table 9). Water temperature ranged from 12.4 to 16.0 °C, dissolved oxygen ranged from 4.4 to 9.2 mg/L, specific conductance ranged from 20 to 94 µS/cm, and pH ranged from 5.3 to 5.9.

Concentrations of ammonia in all water samples collected from the regolith wells were either at or below the minimum reporting level of 0.01 mg/L. Nitrite plus nitrate ranged from 0.53 mg/L at well 16LL05 to 7.4 mg/L at well 16LL26; none of the samples had nitrate concentrations that exceeded the EPD drinking-water standard of 10 mg/L (table 9) (Georgia Department of Natural Resources, Environmental Protection Division, 1993). Concentration of orthophosphate was either at or below the minimum reporting level of 0.01 mg/L in water from all wells, except well 16LL26 (fig. 3), which had a concentration of 0.02 mg/L. During May 1993, well 16LL26 was resampled to verify the elevated concentration of nitrite plus nitrate detected in the initial sample. Concentration in the second sample was slightly lower, 5.4 mg/L nitrite plus nitrate, and the orthophosphate concentration was at or below the reporting level of 0.01 mg/L (table 9).

Wells completed in the regolith may be more susceptible to contamination directly from the land surface (Todd, 1980). Runoff from feed lots, waste impoundments, or areas where manure is spread on cropland or pastures are possible sources of nitrite plus nitrate. Another potential source of nitrite plus nitrate is from septic-tank effluent which may leach into the regolith. Indicators of contamination from surface sources are bacteria and turbid well water. Throughout White County, many bored wells have been abandoned because of bacterial contamination (Mitchell S. Biggers, White County Health Department, oral commun., 1992). During the well inventory for this study, some well owners reported that they had abandoned their regolith wells because of contamination from bacteria and replaced them with bedrock wells. Some well owners also reported that after heavy rains, their regolith wells become very muddy.

Bedrock Wells

The 16 bedrock wells sampled in the White Creek and Mossy Creek watersheds ranged in depth from 145 to 560 ft and had casing depths from 32 to 121 ft (fig. 3, table 2). Most of these wells are used for a combination of domestic and livestock water supply. Water samples were analyzed for ammonia, nitrite plus nitrate, and orthophosphate. Field measurements were made for water temperature, dissolved oxygen, specific conductance, and pH (table 10). Water temperature ranged from 15.2 to 17.2 °C, dissolved oxygen ranged from 0.15 to 10.91 mg/L, specific conductance ranged from 51 to 226 µS/cm, and pH ranged from 4.9 to 7.6 (table 10).

Concentrations of ammonia were at or below the minimum reporting level of 0.01 mg/L for all wells sampled during March 1993 (table 10). Orthophosphate concentrations ranged from the minimum reporting level of 0.01 to 0.09 mg/L; nitrite plus nitrate concentrations ranged from the minimum reporting level of 0.02 to 16.0 mg/L (table 10). Concentrations of nitrite plus nitrate exceeded the EPD drinking-water standard of 10 mg/L in water from wells 16LL27 and 16LL43 (fig. 3). Both of these wells were resampled in May 1993, to verify the initial elevated concentration of nitrite plus nitrate. Nitrite plus nitrate concentration in well 16LL27 was 14.0 mg/L in March, and 12.0 mg/L when resampled in May (table 10). The nitrite plus nitrate concentration in well 16LL43 was 16.0 mg/L in March and 14.0 mg/L when resampled in May. Possible sources of nitrite plus nitrate may be attributed to animal wastes in the area. Well 16LL27 is located in the Mossy Creek watershed along the top of a small drainage divide near large-scale poultry operations. Well 16LL43 is located in a low area within a few hundred feet of a large-scale poultry operation and is within one of the smaller drainage areas (fig. 5) near surface-water sampling site 18 on Mossy Creek. Site 18 had a nitrite plus nitrate concentration of 3.4 mg/L during the baseflow-sampling period, and 1.2 mg/L during the stormwater-runoff sampling period. These were some of the highest concentrations of nitrite plus nitrate detected. It was assumed at the beginning of this study that the highest concentrations of nitrite plus nitrate would be found in the shallower regolith wells because recharge to these wells is at or near the well head. However, the highest nitrite plus nitrate concentrations were detected in two of the deep bedrock wells. Recharge to the bedrock wells is not well understood and it is difficult to identify the source of the contaminants. If the well casing leaks or the well is not constructed properly, contaminants may enter the well directly at or near the well head.

Table 9. Quality of water from selected regolith wells in the White Creek and Mossy Creek watersheds, March 23–25, and May 5, 1993

[° C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 ° C; mg/L, milligrams per liter; <, less than]

Site number	Date sampled	Well depth (feet)	Water temperature (° C)	pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Ammonia nitrogen, as N (mg/L)	Nitrite plus nitrate, as N (mg/L)	Orthophosphate phosphorus, as P (mg/L)
16LL04	03-25-93	27	14.3	5.6	23	7.7	<0.01	0.58	<0.01
16LL05	03-25-93	37	15.3	5.9	38	7.3	<.01	.53	<.01
16LL19	03-24-93	30	16.0	5.3	62	7.1	<.01	4.5	.01
16LL26	03-23-93	55	14.3	5.6	94	9.2	.01	7.4	.02
	05-05-93	55	14.8	5.6	85	8.0	.01	5.4	<.01
16LL35	03-25-93	55	16.0	5.7	39	7.8	<.01	1.8	<.01
16LL36	03-24-93	67	15.2	5.7	85	7.2	<.01	6.1	<.01
16LL41	03-25-93	42	15.8	5.7	20	8.7	<.01	.77	<.01
16LL48	03-25-93	15	12.4	5.4	68	4.4	<.01	2.2	<.01

Table 10. Quality of water from selected bedrock wells in the White Creek and Mossy Creek watersheds, March 23–30, and May 5, 1993

[° C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 ° C; mg/L, milligrams per liter; <, less than; —. data not available]

Site number	Date sampled	Well depth (feet)	Casing depth (feet)	Water temperature (° C)	pH	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Ammonia nitrogen, as N (mg/L)	Nitrite plus nitrate, as N (mg/L)	Orthophosphate phosphorus, as P (mg/L)
16LL01	03-25-93	343	67	16.3	6.5	54	10.91	<0.01	0.41	0.03
16LL06	03-25-93	160	32	15.3	5.8	62	8.70	<.01	3.4	<.01
16LL08	03-24-93	560	100	16.6	6.2	201	0.15	<.01	<.02	.04
16LL11	03-23-93	260	73	15.2	6.9	93	8.20	<.01	.21	.04
16LL12	03-23-93	425	95	16.5	7.4	135	.67	<.01	.02	.02
16LL13	03-26-93	265	121	16.2	7.5	226	3.10	<.01	.02	.06
16LL14	03-30-93	240	80	16.0	6.9	107	3.46	<.01	.04	<.01
16LL15	03-24-93	145	41	15.9	7.0	96	1.70	<.01	<.02	.04
16LL16	03-26-93	230	82	16.4	7.6	151	.18	<.01	.73	<.01
16LL23	03-26-93	400	105	15.6	6.3	51	7.90	<.01	.05	.02
16LL27	03-23-93	250	—	16.6	4.9	142	2.90	<.01	14	.01
	05-05-93	250	—	16.6	4.9	145	1.40	<.01	12	<.01
16LL32	03-30-93	450	70	17.0	7.0	71	7.07	<.01	.29	.06
16LL33	03-24-93	225	62	17.2	6.9	131	.20	<.01	.04	.04
16LL43	03-24-93	162	—	16.6	6.2	185	7.08	<.01	16	.03
	05-05-93	162	—	16.5	6.0	178	7.50	.02	14	.03
16LL44	03-30-93	464	—	17.0	7.2	91	4.28	<.01	.14	.09
16LL47	03-23-93	250	108	15.7	6.6	75	2.30	<.01	.40	.02

QUALITY-CONTROL DATA

Quality-control samples were collected at surface-water sampling sites in the White Creek and Mossy Creek watersheds during baseflow and stormwater-runoff sampling periods (table 11). Differences in concentration of ammonia, nitrite plus nitrate, and orthophosphate between environmental samples and quality-control samples were at or below the minimum reporting levels for each constituent. Therefore, neither sampling nor sample processing resulted in sample contamination in the field, and further sample handling and transportation to USGS laboratories did not introduce sample contamination.

Field-blank samples were collected at five wells during the March sampling period and at two wells during resampling in May, and analyzed for the same constituents as the ground-water samples (table 12). Nutrient concentrations in the blank samples were at or below minimum reporting levels, indicating that the sample collection, handling, and processing were carried out without sample contamination (table 12).

Table 11. Analyses of quality-control samples collected at surface-water sampling sites in the White Creek and Mossy Creek watersheds during baseflow, September 30, 1992, and stormwater-runoff conditions, January 12, 1993, and difference in concentration between sampling pairs

[mg/L, milligrams per liter; <, less than]

Site number	Date sampled	Ammonia nitrogen, as N (mg/L)			Nitrite plus nitrate nitrogen, as N (mg/L)			Orthophosphate phosphorus, as P (mg/L)		
		Regular sample	Quality-control sample	Difference	Regular sample	Quality-control sample	Difference	Regular sample	Quality-control sample	Difference
Baseflow conditions (replicate samples)										
05	09-30-92	0.03	0.03	0	2.7	2.6	0.1	0.04	0.03	0.01
07	09-30-92	.05	.05	0	1.8	1.7	.1	.04	.04	0
18	09-30-92	.03	.02	0.01	0.20	0.21	.01	.01	.02	.01
22	09-30-92	.02	.02	0	.83	.84	.01	.02	.02	0
28	09-30-92	.01	.01	0	<.02	<.02	0	<.01	<.01	0
Stormwater-runoff conditions (duplicate samples)										
02	01-12-93	.02	.02	0	.69	.68	.01	.09	.08	0.01
07	01-12-93	.07	.07	0	.69	.72	.03	.42	.43	.01
10	01-12-93	.22	.22	0	.57	.57	0	.15	.15	0
21	01-12-93	.01	.01	0	.06	.06	0	.02	.02	0
22	01-12-93	.56	.54	0.02	.60	.59	0.01	.20	.19	0.01
Range of difference				0–0.02			0–0.03			0–0.01

Table 12. Analyses of quality-control samples of water from selected regolith and bedrock wells in the White Creek and Mossy Creek watersheds, March 23–30 and May 5, 1993

[mg/L, milligrams per liter; type of well, R, regolith; B, crystalline bedrock; <, less than]

Site number	Date sampled	Type of well	Ammonia nitrogen, as N (mg/L)	Nitrite plus nitrate, as N (mg/L)
16LL12	03-23-93	B	<0.01	<0.02
16LL14	03-30-93	B	.01	<.02
16LL15	03-24-93	B	<.01	<.02
16LL27	05-05-93	B	.01	<.05
16LL35	03-25-93	R	<.01	<.02
16LL36	03-24-93	R	<.01	<.02
16LL43	05-05-93	B	.02	<.05

SUMMARY

The White Creek and Mossy Creek watersheds are located in the Piedmont physiographic province in northeastern Georgia. Poultry and cattle production are common land uses in most of this area, and there are concerns about nonpoint-source contaminants from these livestock operations degrading surface- and ground-water quality. Manure production from livestock operations in the watersheds is approximately 9.8 million tons per year, which is spread over about 5,000 acres of pasture and cropland. White Creek and Mossy Creek are tributaries of the Chattahoochee River, which flows into Lake Sidney Lanier. Lake Sidney Lanier and the Chattahoochee River downstream of the lake are the primary sources of drinking water for the Atlanta Metropolitan area and numerous small communities downstream of Atlanta.

Water samples were taken from streams and wells in the White Creek and Mossy Creek watersheds and analyzed for concentrations of ammonia, nitrite plus nitrate nitrogen, and orthophosphate phosphorus (nutrients) and determinations of turbidity (stream sites only). Stream-sampling sites in each watershed are divided into two categories (1) main-stem sites located along the main stream channel and (2) tributary sites. Ground-water samples were collected from eight shallow wells completed in the regolith and from 16 deeper wells completed in the crystalline bedrock.

Thirty-one stream sites were sampled in the White Creek and Mossy Creek watersheds during baseflow (September 30 and October 1, 1992) and during stormwater-runoff (January 12, 1993) conditions. During both sampling periods, field measurements were made for temperature, pH, specific conductance, and dissolved oxygen. Streamflow measured during baseflow conditions ranged from 0.12 to 52 cubic feet per second (ft^3/s), and the streamflow measured during stormwater runoff ranged from 1.0 to 586 ft^3/s. Concentrations of nitrite plus nitrate in both watersheds decreased from baseflow to stormwater-runoff conditions as a result of the dilution of the ground-water component of streamflow by surface runoff. Concentrations of orthophosphate increased in both watersheds from baseflow to stormwater-runoff conditions and may result from increased runoff of soluble material from the land surface. Water temperatures in the streams ranged from an average of 15.5 degrees Celsius (° C), during baseflow to an average of 9.2 ° C during stormwater runoff. Dissolved oxygen concentrations ranged from 7.8 to 10.1 milligrams per liter (mg/L) during baseflow and 8.6 to 11.3 mg/L during stormwater-runoff conditions. Specific conductance ranged from 20 to 62 microsiemens per centimeter (µS/cm) during baseflow and 8 to 72 µS/cm during runoff; and pH ranged from 6.0 to 7.5 during baseflow and 5.7 to 7.0 during stormwater-runoff conditions. Generally, water temperature was cool, specific conductance low, dissolved oxygen is high, and pH is near neutral throughout both watersheds.

In the White Creek watershed, ammonia concentrations in water collected from the main-stem sites were the same during baseflow and stormwater-runoff sampling at two of the three main-stem sites. Concentrations were 0.02 mg/L at sites 2 and 3 during both sampling periods but at site 1 concentrations increased from 0.05 mg/L during baseflow to 0.14 mg/L during stormwater runoff. Nitrite plus nitrate concentrations were higher during baseflow than at stormwater-runoff conditions at all main-stem sites. Concentrations of nitrite plus nitrate ranged from 0.92 to 1.8 mg/L at baseflow and 0.55 to 0.89 mg/L during runoff conditions. Concentrations of orthophosphate were higher during runoff than during baseflow conditions. Orthophosphate concentrations ranged from 0.01 to 0.04 mg/L at baseflow and 0.09 to 0.56 mg/L during stormwater-runoff conditions. Turbidity was 6.5 to 14 NTU at baseflow and 110 to 680 NTU during stormwater-runoff conditions.

Ammonia concentrations in water samples collected from the White Creek tributary sites were slightly higher than at the main-stem sites during both sampling periods and ranged from 0.03 to 0.07 mg/L at baseflow and 0.07 to 0.10 mg/L during stormwater-runoff conditions. Concentrations of nitrite plus nitrate ranged from 1.2 to 2.7 mg/L at baseflow and 0.51 to 1.1 mg/L during stormwater-runoff conditions. Orthophosphate concentrations at the tributary sites ranged from 0.03 to 0.04 mg/L at baseflow to 0.27 and 0.61 mg/L during runoff conditions. Turbidity ranged from 9.6 to 14 NTU at baseflow and 92 to 440 NTU during stormwater-runoff conditions.

In the Mossy Creek watershed, ammonia concentrations in water samples collected from the main-stem sites ranged from 0.01 to 0.2 mg/L during baseflow conditions and 0.02 to 0.26 mg/L during stormwater-runoff conditions. Concentrations of nitrite plus nitrate ranged from 0.2 to 0.86 mg/L during baseflow and 0.01 to 0.64 mg/L during stormwater-runoff conditions. Orthophosphate concentrations ranged from 0.01 to 0.05 mg/L during baseflow and 0.02 to 0.24 mg/L during stormwater-runoff conditions. Turbidity was 6.6 to 13 NTU during baseflow and 110 to 640 NTU during stormwater-runoff conditions.

Ammonia concentrations at the Mossy Creek tributary sites ranged from 0.01 to 0.04 mg/L during baseflow and from less than the minimum reporting level (0.01 mg/L) to 0.56 mg/L during stormwater-runoff conditions. Nitrite plus nitrate concentrations ranged from less than the minimum reporting level (0.02 mg/L) to 3.4 mg/L during baseflow and 0.06 to 1.4 mg/L during stormwater-runoff conditions.

Orthophosphate concentrations ranged from less than the minimum reporting level (0.01 mg/L) to 0.04 mg/L and were slightly higher during stormwater runoff, ranging from 0.11 to 0.5 mg/L. Turbidity ranged from 2.2 and 14 NTU during baseflow and 23 to 520 NTU during stormwater-runoff conditions.

Yields for nitrite plus nitrate and orthophosphate were calculated for samples collected during baseflow conditions. Yields were not determined for stormwater-runoff conditions because a single sample and discharge measurement does not provide data that are representative of the storm period. In the White Creek watershed, the nitrite plus nitrate yield at the farthest downstream site was 16.2 pounds per day per square mile (lbs/d/mi^2); and in the Mossy Creek watershed, nitrite plus nitrate yield at the farthest downstream site was 8.8 lbs/d/mi^2. Orthophosphate yields were slightly higher in the White Creek watershed and ranged from 0.1 to 0.6 lbs/d/mi^2; and in the Mossy Creek watershed, ranged from 0.1 to 0.5 lbs/d/mi^2. Baseflow yields at the main-stem and tributary sites in both watersheds were not directly correlated to upstream land use. However, relatively high yields of nitrite plus nitrate and orthophosphate upstream of some sites indicate land-use activities are affecting water-quality conditions within the stream reach.

Ground-water samples were collected from eight shallow wells completed in the regolith, and 16 deeper wells completed in crystalline bedrock in both watersheds during March 1993. Field measurements obtained during sampling indicate that the shallow regolith wells had lower water temperature, specific conductance, and pH; and higher dissolved oxygen content than the deeper bedrock wells. Measurements of water temperature ranged from 12.4 to 16.0 ° C in the regolith wells and from 15.2 to 17.2 ° C in the bedrock wells. Dissolved oxygen concentrations ranged from 4.4 to 9.2 mg/L in the regolith wells and from 0.15 to 10.91 mg/L in the bedrock wells. Specific conductance ranged from 20 to 94 μS/cm in the regolith wells and from 51 to 226 μS/cm in the bedrock wells. The pH ranged from 5.3 to 5.9 in the regolith wells and from 4.9 to 7.6 in the bedrock wells. Concentrations of ammonia were at or below the minimum reporting level of 0.01 mg/L in the regolith wells and ranged from the minimum reporting level 0.01 mg/L to 0.02 mg/L in the bedrock wells. Orthophosphate concentration ranged from the minimum reporting level of 0.01 mg/L to 0.02 mg/L in water sampled from regolith wells and ranged from less than the minimum reporting level 0.01 mg/L to 0.09 mg/L in bedrock wells. Nitrite plus nitrate concentration ranged from 0.53 to 7.4 mg/L in water sampled from regolith wells and ranged from less than the minimum reporting level of 0.02 mg/L to 16 mg/L in bedrock wells. When sampled in March 1993, water in two bedrock wells had concentrations of 14 and 16 mg/L nitrite plus nitrate, which exceeded the Georgia Department of Natural Resources, Environmental Protection Division, maximum contaminant level of 10 mg/L for drinking water. Both wells were resampled in May 1993, and had nitrite plus nitrate concentrations of 12 mg/L and 14 mg/L. Sources of contaminants detected in two bedrock wells could not be determined because of the complex nature of the crystalline-rock aquifers and lack of data pertaining to the recharge and movement of water through crystalline-rock aquifers.

Quality-control samples were collected at surface-water sampling sites in both watersheds during baseflow and stormwater runoff conditions and from two regolith wells and five bedrock wells. Results from the analyses of these samples indicated that neither sampling nor sample processing resulted in sample contamination in the field; and further sample handling and transportation to USGS laboratories did not introduce sample contamination.

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