Sediment Characteristics of North Carolina Streams, 1970–79

United States Geological Survey Water-Supply Paper 2364

Prepared in cooperation with the North Carolina Department of Environment, Health, and Natural Resources

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Sediment Characteristics of North Carolina Streams, 1970–79

By CLYDE E. SIMMONS

Prepared in cooperation with the North Carolina Department
of Environment, Health, and Natural Resources

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply inch-pound unit	By	To obtain metric units
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
acre-foot (acre-ft)	1,233.5	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3/s)	28.317	liter per second (L/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
gallon per day (gal/d)	0.0038	cubic meter per day (m^3/d)
	Flow per area	
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]
	Temperature	
degree Farenheit (°F)	5/9(F°−32)	degree Celsius (°C)
	Mass	
ton (short, 2,000 pounds)	0.9072	megagram (Mg), or metric ton (t)
pound (lb)	453.59	gram (g)

SEA LEVEL

In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level net of both the United States and Canada, formerly called "Sea Level Datum of 1929."

Sediment Characteristics of North Carolina Streams, 1970–79

By Clyde E. Simmons

ABSTRACT

Data collected at 152 sampling sites during 1970–79 were used to characterize fluvial sediment in North Carolina streams. On the basis of predominant land use in individual basins, sites were categorized into one of five groups: forested (7 sites), forested and affected by minor development (7 sites), rural affected by agriculture (83 sites), rural affected by nonagricultural activities (38 sites), and urban (17 sites). Results of more than 13,000 suspended-sediment samples collected during the study were used to determine sediment yield, sediment discharge, concentrations, and other site and basin characteristics.

Fluvial sediment characteristics, such as yields, are regionalized, with lower values occurring in the Coastal Plain Province. Statewide, when compared by predominant land use, minimum annual yields occur in forested basins and range from 5 to 58 tons per square mile; ratios of average annual yields for forested, rural-agricultural, and urban sites in the Piedmont Province are approximately 1:6:14, respectively. During high flow (0.1 percent flow duration) in Piedmont basins, the mean suspended-sediment concentration for large urban streams is about 1,600 milligrams per liter as compared with 870 milligrams per liter for rural-agricultural sites and 100 milligrams per liter for forested sites. Maximum sediment yields of rural-agricultural basins occur in predominantly clay soil areas of the western Piedmont, with annual values of as much as 470 tons per square mile, whereas minimum yields as small as 7 tons per square mile occur in the sandy soil of the Coastal Plain Province. Considerable amounts of fluvial sediment are deposited on flood plains and streambeds as major rivers flow from the rolling Piedmont Province into the flat Coastal Plain Province. For example, more than 130,000 tons are deposited annually in an 85-mile stretch of the Neuse River between stations at Smithfield and Kinston.

Mathematical relations were developed for estimating suspended-sediment transport characteristics at unmeasured rural-agricultural sites and urban sites in the Piedmont. Correlation coefficients for the relations range from 0.75 to 0.98, and standard errors of estimate range from 25 to 74 percent. The best single-variable equation used log-transformed values of drainage area.

INTRODUCTION

Recognized in the early 1900's as one of North Carolina's most urgent problems, fluvial sediment due to erosion is still considered to be the most widespread water-quality problem in the State (North Carolina Department of Natural Resources and Community Development, 1979a). Streamborne sediment not only reduces the esthetic quality of our streams and lakes but also causes other environmental and economic problems. For example, sediment deposition in stream channels reduces the flow-carrying capacities of the streams and, as a result, increases overbank flooding. Sedimentation also reduces storage capacities of lakes and reservoirs. Sediment-laden waters have large effects on stream biology, ranging from burial of fish eggs to the destruction of the entire aquatic food chain. Relatively moderate levels of sediment in an otherwise healthy stream commonly reduce the variety and abundance of aquatic life. Although these diverse effects on the environment have been well documented by studies across the Nation, little effort has been devoted to the definition of sediment characteristics of streams in this State, especially on a statewide basis.

Purpose and Scope

This report presents an analysis of sediment data collected in North Carolina streams as part of a comprehensive statewide study that began almost 20 years ago in cooperation with the North Carolina Department of Natural Resources and Community Development (currently known as the North Carolina Department of Environment, Health, and Natural Resources). To help resolve the need for characterizing fluvial sediment, the U.S. Geological Survey established a network of 28 sampling sites in eastern North Carolina in 1969. Other sites were steadily added to the network, and by 1975 the network included about 152 sites located on major and minor streams throughout the State. All sampling sites were located at stream-gaging stations to assure continuous discharge data required for sediment-transport computations. Although the collection of data for this study actually spanned a 13-year period, activities were most concentrated from 1970 to 1979; therefore, all computations of sediment transport and related values have been adjusted to this 10-year base period. Information provided by the study resides in a comprehensive, detailed data base that was used to satisfy the following primary study objectives: (1) to define the effect of land use on characteristics of suspended-sediment transport, (2) to compare suspended-sediment transport characteristics with selected basin characteristics, and (3) to develop relations for estimating suspended-sediment yield for unmeasured basins.

This report is the first attempt to characterize sediment transport on a statewide basis in North Carolina by using sample data. During the investigation, more than 13,000 samples that represent a wide range of flow conditions were collected at the 152 stations comprising the sampling network (fig. 1; table 19, located at the back of this report).

Previous Studies

One of the first efforts to quantify suspended sediment in North Carolina streams began in 1906 as part of a nationwide network operated by the U.S. Geological Survey to investigate the quality of the Nation's major streams (Dole, 1909). Daily sampling stations were operated from 1906 to 1907 at Cape Fear River at Wilmington, at Neuse River near Raleigh, and at Pee Dee River near Pee Dee. Dole and Stabler (1909) used data from this network to discuss chemical and physical erosion, including total suspended-sediment loads carried by the major rivers; however, only general conclusions could be drawn from this study because of the few stations and the short sampling period. In 1943, after a lapse in North Carolina of almost 35 years, the U.S. Geological Survey resumed limited sampling on several major streams.

Numerous watershed-type investigations have been conducted in North Carolina by various organizations and agencies since the early 1900's. Most of these early studies were reservoir siltation surveys conducted in the 1920's and 1930's by the North Carolina Department of Conservation and Development and by the U.S. Department of Agriculture's Soil Conservation Service (Eakin, 1936; Eargle, 1937; Connaughton and Hough, 1938; and many others). By the late 1930's, a few studies whose objectives were more reflective of research or interpretive aspects of fluvial transport, such as the Soil Conservation Service High Point (North Carolina) Demonstration Project (Potter and Love, 1942), were underway. With the establishment of the U.S. Forest Service's Coweeta Hydrologic Laboratory near Franklin in 1933, extensive studies were undertaken to determine the effects of human use of forest land on streamflow, including erosion from clear-cut and construction areas.

In 1934, the Tennessee Valley Authority began sampling for suspended sediment at seven stream sites in the Blue Ridge Province. The Tennessee Valley Authority also conducted several siltation surveys of western North Carolina reservoirs during the 1940's, and during 1953–62 it conducted a detailed study of erosion and sediment transport in the 1,060-acre Parker Branch watershed located near Asheville (Tennessee Valley Authority, 1963).

The U.S. Geological Survey selected the Yadkin River near Yadkin College as one of the long-term Federal Index-Sediment Stations and began collecting daily samples in 1951 for suspended-sediment concentrations and particle-size distribution; the station is still in operation (1993). Daily samples also were collected by the U.S. Geological Survey for several years in the late 1950's and early 1960's at sites on the South Yadkin and Tar Rivers; however, no interpretive report was prepared on these data.

Since the 1960's, an increasingly large number of reports dealing with various aspects of sediment transport and erosion have been prepared by university groups, consultants, State and Federal agencies, and others. As with previous studies, however, virtually all of these efforts were directed at relatively small, scattered watersheds having short-term data bases. Also, in most instances, the studies included coverage of various other constituents and parameters, and sediment received only cursory treatment.

Several relatively large-scale reports were released in the late 1970's. In 1976, the U.S. Geological Survey published results of a 5-year study (1969–73) of sediment characteristics of streams in a 6,000-mi^2 (square mile) area of the eastern Piedmont and western Coastal Plain region of North Carolina (Simmons, 1976). In late 1977, the Soil Conservation Service released a report that included estimates of erosion and stream-sediment transport values for the entire State (U.S. Department of Agriculture, 1977). The transport values were estimated from gross-surface erosion values computed by the Universal Soil Loss Equation. The report, however, provided the first overview of stream-transport characteristics on a statewide basis. In 1979, the U.S. Geological Survey released a report on water-quality characteristics of streams in forested basins of the State, which summarized efforts to define natural or background conditions, including fluvial sediment (Simmons and Heath, 1979).

Acknowledgments

This investigation was conducted in cooperation with the North Carolina Department of Environment, Health, and Natural Resources; however, sediment-transport data for approximately a third of the sampling stations were collected as part of cooperative programs with other agencies, including the U.S. Army Corps of Engineers; the U.S. Department of Agriculture, Soil Conservation Service; the Tennessee Valley Authority; the city of Charlotte; and Mecklenburg County. Funding support was also provided by the U.S. Geological Survey's Federal Research Program. Values of gross erosion for approximately 30 basins were provided by

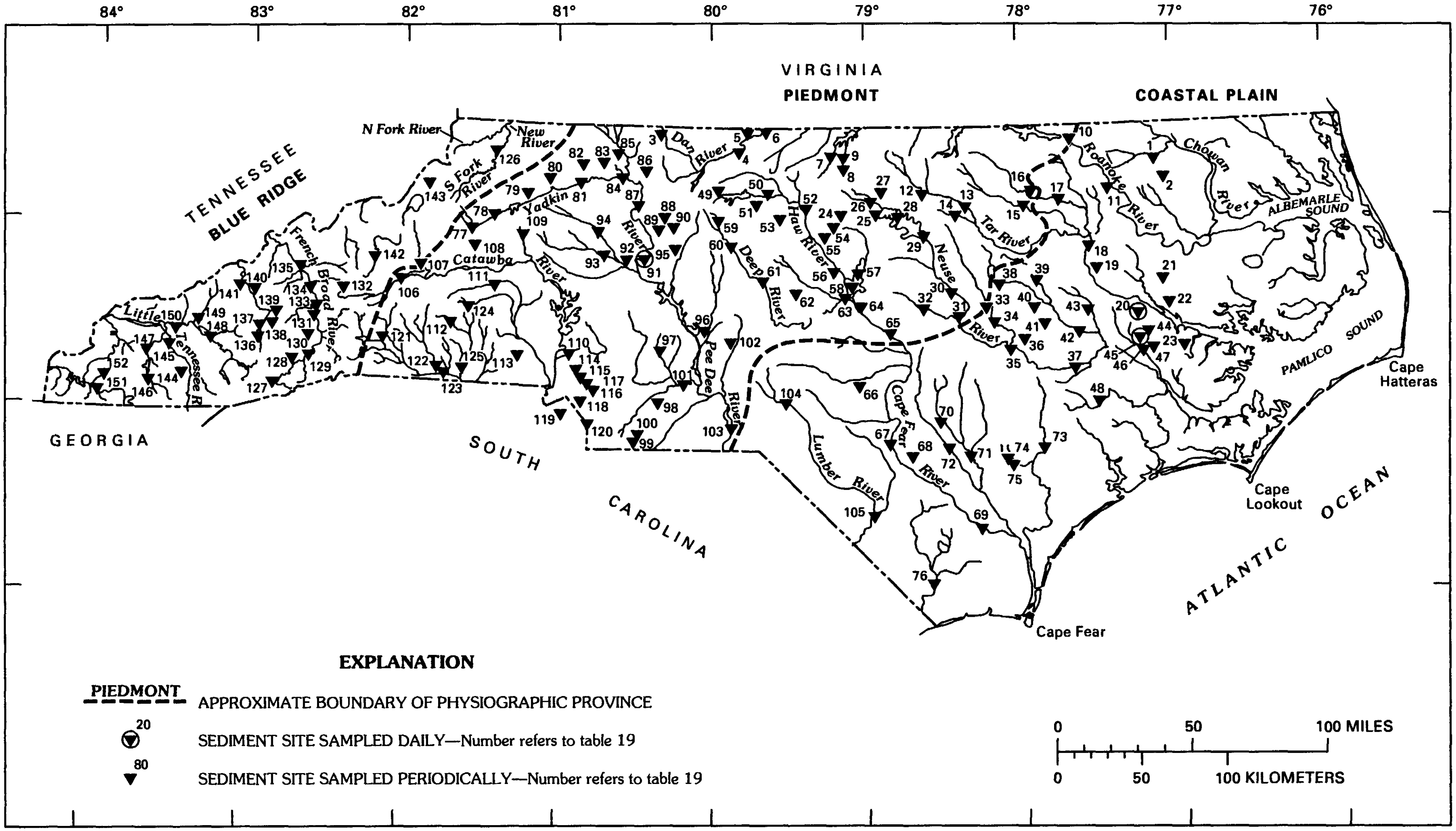


Figure 1. Locations of sediment-sampling sites in North Carolina.

Mr. Emmett Waller of the Raleigh State Office, Soil Conservation Service, U.S. Department of Agriculture.

Several private citizens deserve special recognition for their devoted efforts in collecting suspended-sediment samples at daily stations: Mr. J.C. Galloway (deceased, 1985), Greenville; Mr. Ervin Shoaf, Lexington; Messrs. Wayne and George Norman, Advance; and Ms. Vicki Cox, Vanceboro.

PHYSICAL FEATURES OF NORTH CAROLINA SIGNIFICANTLY RELATED TO EROSION AND SEDIMENT TRANSPORT

North Carolina, with almost 53,000 mi^2 of surface area, is the third largest Atlantic Coast State and ranks tenth in the Nation in population. One hundred counties lie within its boundaries, which span almost 500 mi (miles) from the Atlantic Ocean westward to Tennessee (fig. 2). Although the State is primarily rural, it contains 31 towns and cities having populations exceeding 15,000, according to the 1980 census. Numerous factors, both natural and human-induced, affect sediment characteristics of the State's numerous streams; however, it is not within the scope of this report to discuss all factors. Rather, the following sections deal only with those factors having a significant effect on erosion and sediment transport, such as slope, physiography, drainage, climate, and land use.

Slope

Surface runoff is the primary mover of waterborne sediments, although stream viscosity, depth, and other variables affect fluvial transport. Runoff velocity and associated turbulence often determine the quantity and size of materials transported. High runoff velocity associated with steep slopes is the most dynamic factor affecting erosion and subsequent sediment transport. In studying erosion from croplands, Wischmeier and others (1958) determined that both the steepness and the length of a surface slope are key factors in soil loss. Wischmeier and Smith (1965) used field data to show that soil loss from silty loams usually varies with the square root of the slope length for a given slope. Erosion generally increases as the length and steepness of a slope increases; consequently, if in two hypothetical basins all variables are identical except slope or topography, sediment transport will be greater from the basin having greater surface slopes.

Physiographic Provinces and Drainage

North Carolina extends across three distinctly different physiographic provinces: Blue Ridge, Piedmont, and Coastal Plain (figs. 1, 2). They are different not only in geologic age, soils, and rocks but also in relief and altitude above sea level. The State also lies in parts of three drainage regions: the Ohio River, the Tennessee River, and the South Atlantic region (which drains to the Atlantic Ocean). These regions, in turn, are drained by numerous major and tributary streams (fig. 3). As shown in figure 3, most drainage systems have formed classic dendritic patterns, with all possible directions of flow, but flows of major streams are generally in an eastward or southeastward direction.

Blue Ridge Province

The Blue Ridge Province is described by Stuckey (1965, p. 19) as a highly dissected mountain plateau bounded by two mountain chains: the Unaka and Great Smoky Mountains form the western bounds, and the Blue Ridge escarpment rising 1,500 to 4,000 ft (feet) above the Piedmont Province lies along its eastern boundary. Accounting for only about 10 percent of North Carolina's area, the Blue Ridge Province is the most rugged part of the State, with over 40 peaks exceeding an altitude of 6,000 ft above sea level. Mount Mitchell, about centrally located in the province, has an altitude of 6,684 ft and is the highest peak east of the Mississippi River. The crest of the Blue Ridge Mountains is the Eastern Continental Divide, with streams west of the divide draining into the Gulf of Mexico and streams east of the divide draining into the Atlantic Ocean.

Most of the province's major rivers, such as the French Broad and Tuckasegee, flow northward or northwestward to join the Tennessee and Ohio Rivers in other States; however, smaller tributary and headwater streams are found flowing in various directions. Valleys of major streams may vary from a few hundred feet to several miles in width, whereas valleys of most small streams are relatively narrow and often steep sided. Stream channels are always well defined. Streams that originate along the eastern slopes of the Eastern Continental Divide generally flow in an eastward or southeastward direction across the western Piedmont Province, forming major rivers such as the Yadkin, Catawba, and Broad (fig. 3).

Gradients of streams in this mountainous terrain are steep, and surface runoff is rapid. Many streams during floods are capable of transporting pebbles and large cobbles. Typical stream gradients range from 30 to 100 ft/mi (feet per mile), but those of smaller headwater streams often exceed 500 ft/mi. Excluding areas such as rapids and waterfalls, midstream flow velocities in many mountain streams often exceed 10 ft/s (feet per second) during floods and may be as high as 2 to 3 ft/s during base flow. Even on the larger streams, most floods peak sharply and pass quickly, usually within 24 hours. These fast-flowing streams are capable of transporting tremendous quantities of sediment; however, the amount of sediment supplied to these streams is considerably less than their

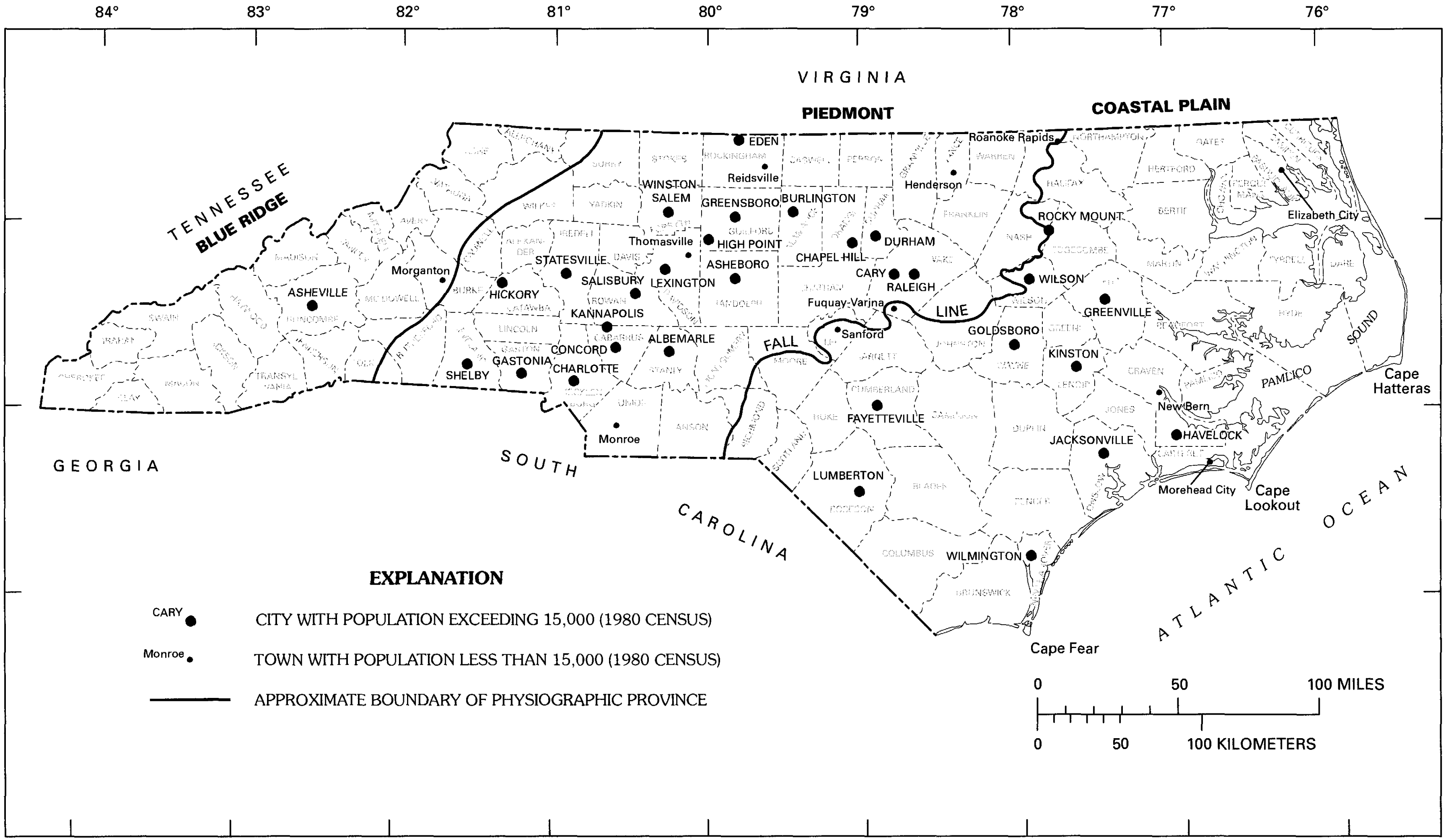


Figure 2. Counties and major population centers of North Carolina.

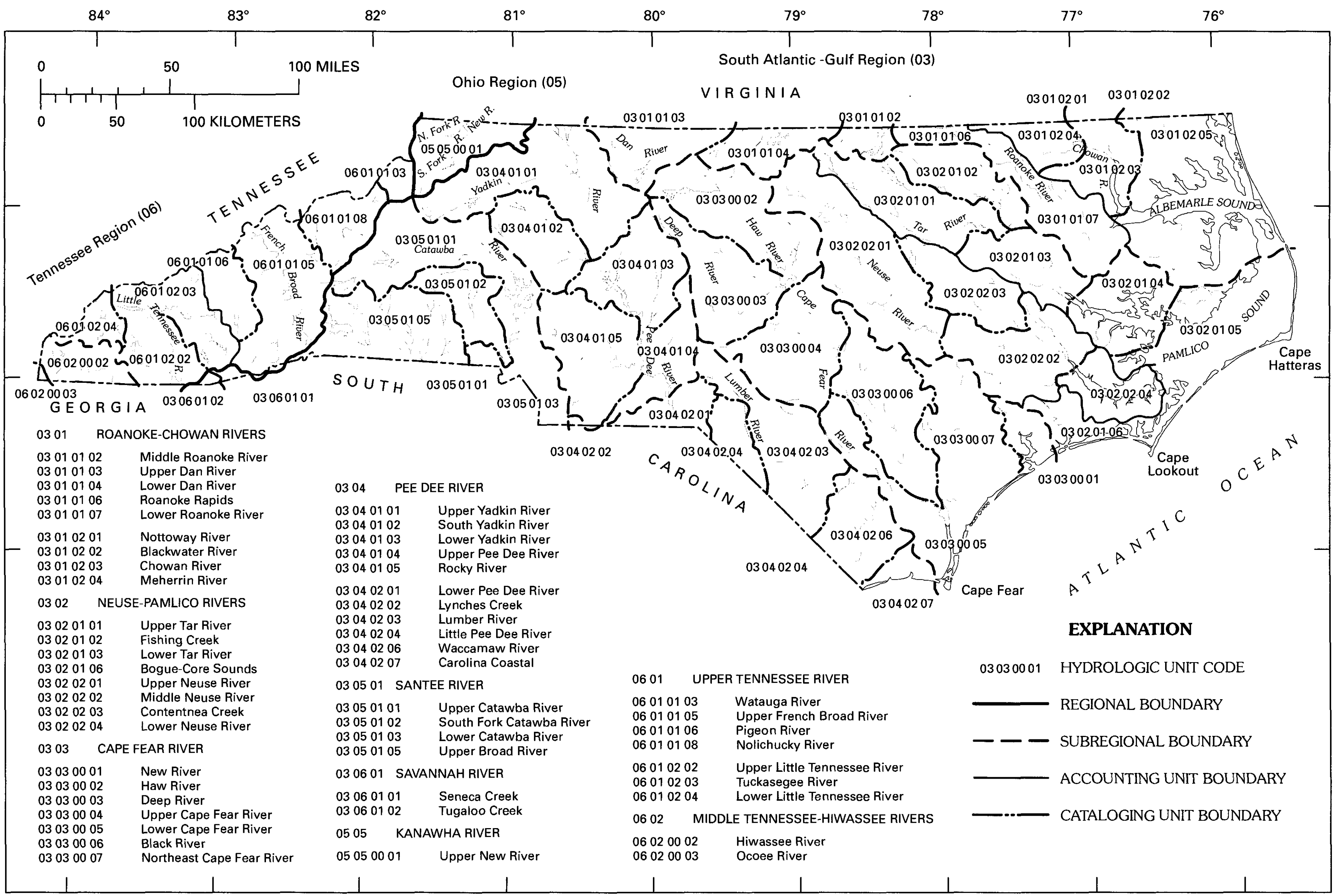


Figure 3. Hydrologic units and major streams in North Carolina.

carrying capacity. Because of the province's steep topography, freshly exposed materials ranging in size from clay to fine sand are quickly transported away by storm runoff unless erosion-preventive measures are applied. Fortunately, channel degradation and migration are prevented in most mountain streams by natural rock outcrops and streambed armoring, thereby minimizing sediment contribution from the channel itself.

Piedmont Province

The Piedmont Province occupies about 45 percent of North Carolina's area and extends eastward from the foot of the Blue Ridge Mountains to the Fall Line (fig. 2). The Fall Line is actually not a line but rather is an area ranging from several miles to about 40 mi wide that drops rather abruptly, like a step or series of steps, down to the low-lying Coastal Plain Province (Stuckey, 1965, p. 7–8). Altitudes in the Piedmont range from over 1,500 ft above sea level at many points along the western boundary to 300 to 600 ft along the Fall Line. The topography of the western Piedmont is characterized by steep prominent hills and low mountains, whereas gentle, well-rounded hills and long rolling ridges are characteristic of the eastern Piedmont.

Most of the streams that flow across the Piedmont also originate there (fig. 3). The Yadkin, Catawba, and Broad Rivers, whose headwaters begin on the slopes of the Blue Ridge Mountains, flow east and southeastward and drain the southwestern half of the province. The Tar, Neuse, and Cape Fear Rivers drain most of the central and eastern part of the province; the northern part is drained by the Dan River, whose headwaters are in Virginia. Most major streams in the province flow either eastward or southeastward; however, tributary streams most often follow the lay of the land and are found flowing in all directions. Typical stream gradients range from 10 to 20 ft/mi, but extreme examples may range from 2 to 3 ft/mi to over 300 ft/mi.

Although the topography of the Piedmont is not as rugged as that of the Blue Ridge, surface and stream gradients are sufficient to produce flood-flow velocities of 5 to 10 ft/s on many streams. The effects of intense rains combined with the province's steep gradients and highly erodible clayey soils produced some of the State's highest concentrations of fluvial sediment observed during this study. Depending on storm intensity and size of basin, streams might remain at flood stage from a few hours to several days.

Coastal Plain Province

The Coastal Plain Province extends from the Fall Line to the Atlantic Ocean. Occupying almost 45 percent of North Carolina's area, this province is characterized by gently rolling topography throughout most of its western boundary to relatively flat topography near the coast. Excluding the area immediately adjacent to the Fall Line, land surfaces decline eastward rather uniformly from altitudes of 300 to 400 ft along the western bounds to sea level along the Atlantic Coast and shores of major estuaries. Abnormally high areas occur in the Sand Hills area of Moore, Montgomery, and Richmond Counties, where altitudes vary from 500 to over 700 ft. Compared with the remainder of the State, however, the Coastal Plain Province is relatively flat, with altitudes averaging less than 20 ft over most of the province within 50 mi of the coast.

The major rivers flowing across the Coastal Plain, such as the Tar, Neuse, Cape Fear, and Roanoke, have their origins in other provinces; however, most of the smaller rivers, such as the Northeast Cape Fear, Waccamaw, Black, and Lumber, originate in the Coastal Plain Province (fig. 3). Flow of these larger streams is generally in an eastward or southeastward direction. Unlike the well-defined channels of the Piedmont and Blue Ridge Provinces, streams in the Coastal Plain often flow through swamps and marshes, where channels are indiscernible and flows are impeded. To increase drainage of low-lying lands, extensive networks of canals and cross-ditches have been constructed, which may alter "natural" runoff characteristics of entire watersheds. Many stream channels have been cleared of blockages or excavated. Vast areas along stream courses are susceptible to flooding, and frequently streams that may be a few tens of feet wide during low flow are several thousand feet wide during floods of low magnitude. With stream gradients often less than 5 ft/mi, flow velocities are sluggish and rarely sufficient to transport (in suspension) sand-size particles greater than 0.125 mm (millimeter) diameter. Even during floods, main-channel velocities at network stations seldom exceeded 6 ft/s and generally ranged from 2 to 5 ft/s. Primarily because of this flat topography, streams originating in the Coastal Plain Province have the lowest concentrations of suspended sediment in the State.

Soil Characteristics

Most fluvial sediment in North Carolina streams is derived from the surface soil horizon, except in special cases such as landslides, large-scale construction or excavation, and various industrial-waste activities. Usually, the erodibility of these soils depends primarily on sizes of the soil particles and, if present, the nature of the material binding the particles. Other important soil characteristics influencing erodibility include shape and specific gravity of particles, organic content, mineralogy, porosity, and water-storage capacity of the soil.

Generally, silty soils having low-clay content are the most erodible (Young, 1976), and soils having a low-silt content are less erodible regardless of whether the major component is sand or clay. Soils having high clay content are often less erodible because of increased cohesiveness attributed to the clay. The erodibility of silty soils may also be reduced by an increase in organic content, but in soils with high clay content, the volume of organic matter has little effect on erodibility. Many factors influence erodibility; the relative clay, silt, and sand composition of a soil must be considered along with other variables in studying erodibility. For example, a loose, sandy soil is usually considered highly erodible. However, because of high infiltration capacity, this type of soil might be less erodible than a "nonerodible" clay soil on the same slope if the slope is not steep and the rainfall intensity is not much greater than the infiltration capacity of the sandy soil. On steep slopes, a surface cover of coarse pebbles or larger rock fragments will protect underlying fine material from erosion; lacking this cover protection, however, all soil particle sizes are subject to detachment and eventual transport.

Although often not considered a part of the soil profile, the banks and beds of streams are frequently major sources of fluvial sediment. This is especially true in forested basins of the State, where trees, brush, and forest litter provide total ground cover, thereby minimizing surface erosion, and stream channels are essentially the only sediment source. Head cutting, bank failure, and channel degradation are the primary contributors of channel-derived sediments. In various processes, such as bank failure, boulders or other large materials that are too heavy for transport are deposited in channels. These materials may slowly contribute sediment through the process of disintegration by physical and chemical means.

Soils comprise most of the eroded material in fluvial processes; therefore, it may be argued that geology is of limited concern in studies of erosion and sediment transport. This is especially true in North Carolina, where soil coverage is extensive and exposed rock accounts for well below 1 percent of the State's surface area (H.E. LeGrand, consultant, oral commun., 1984). Because soils are derived primarily through the weathering and ultimate disintegration of rocks, the mineral composition of the rock largely controls the physical and chemical characteristics of resulting soils. Large differences exist between the more than 200 different soil types that have been identified in North Carolina (Clay and others, 1975). These differences are noticeable on a regional basis and range from light sands with little humus in the Sand Hills area of the Coastal Plain to the heavy plasticlike clays of the Piedmont, and from the black organic soils of the Coastal Plain to the brown loams of the Blue Ridge.

A generalized soils map of North Carolina is shown in figure 4. Major differences correspond to major changes in rock type. Considerable variation also exists within each region, and major changes in texture, color, or composition may occur within a few feet in many areas, especially throughout the Piedmont and Blue Ridge Provinces. Soils in these latter two regions are derived primarily from the disintegration and chemical weathering of the underlying rock, which largely controls the physical and chemical characteristics of the soil. It is the complexity of the geology in these regions, mentioned previously, that is responsible for the wide diversity of soil characteristics. For instance, soils derived from granites and gneisses are generally sandy-clay loams, metamorphosed volcanic rocks produce silty soils, and rocks composed mostly of mica schists generally produce silty-clay loams (Lee, 1955).

In contrast, soils in most of the Coastal Plain region are formed from sediments deposited in former sounds, lagoons, rivers, and beaches. Topography or relief is one of the most important factors causing differences in Coastal Plain soils. Low-lying swampy areas, such as pocosins, have soils that are gray, contain large amounts of organic matter, and are often plastic; whereas soils located in well-drained, higher areas are lighter in color, have relatively lower contents of organic matter, and are sandier in texture (Clay and others, 1975, p. 135).

Various properties of soils cause some to erode faster than others, although surface slope, rainfall, vegetative cover, and other factors might be identical. Wischmeier and others (1958) developed a soil erodibility factor *K*, which is a measure of the rate at which specific soils erode when all other factors are constant. *K* values for North Carolina soils range from about 0.10 to 0.49 tons/acre for standardized conditions (U.S. Department of Agriculture, 1976). Permeability and composition of surface soils are critical factors in determining erodibility and are directly related to erodibility. For instance, coarse, highly permeable sands generally have a *K* factor of 0.10 to 0.15, whereas silty loams, loams, and very fine sandy loams of low permeability are more erodible with factors of 0.43 to 0.49. Estimates of erodibility, determined by the Soil Conservation Service (U.S. Department of Agriculture, 1976), for surface soils commonly found throughout the State are presented in table 1.

Land Use

The most important land use or environmental factor affecting erosion in North Carolina is the amount of exposed soil, or, conversely, the amount of surface cover. Vegetative cover impedes erosion in many ways: (1) rainfall interception, which reduces splash erosion; (2) rainfall retention, which increases evaporation and biological uptake potential and reduces runoff potential; (3) soil retention through enhanced root systems and reduced velocity and energy components of flowing water; and (4) increased infiltration afforded by decaying vegetative litter deposited throughout the plants' seasonal and life cycles. According to Dissmeyer and Foster (1980) and others, there is generally little or no surface erosion from totally

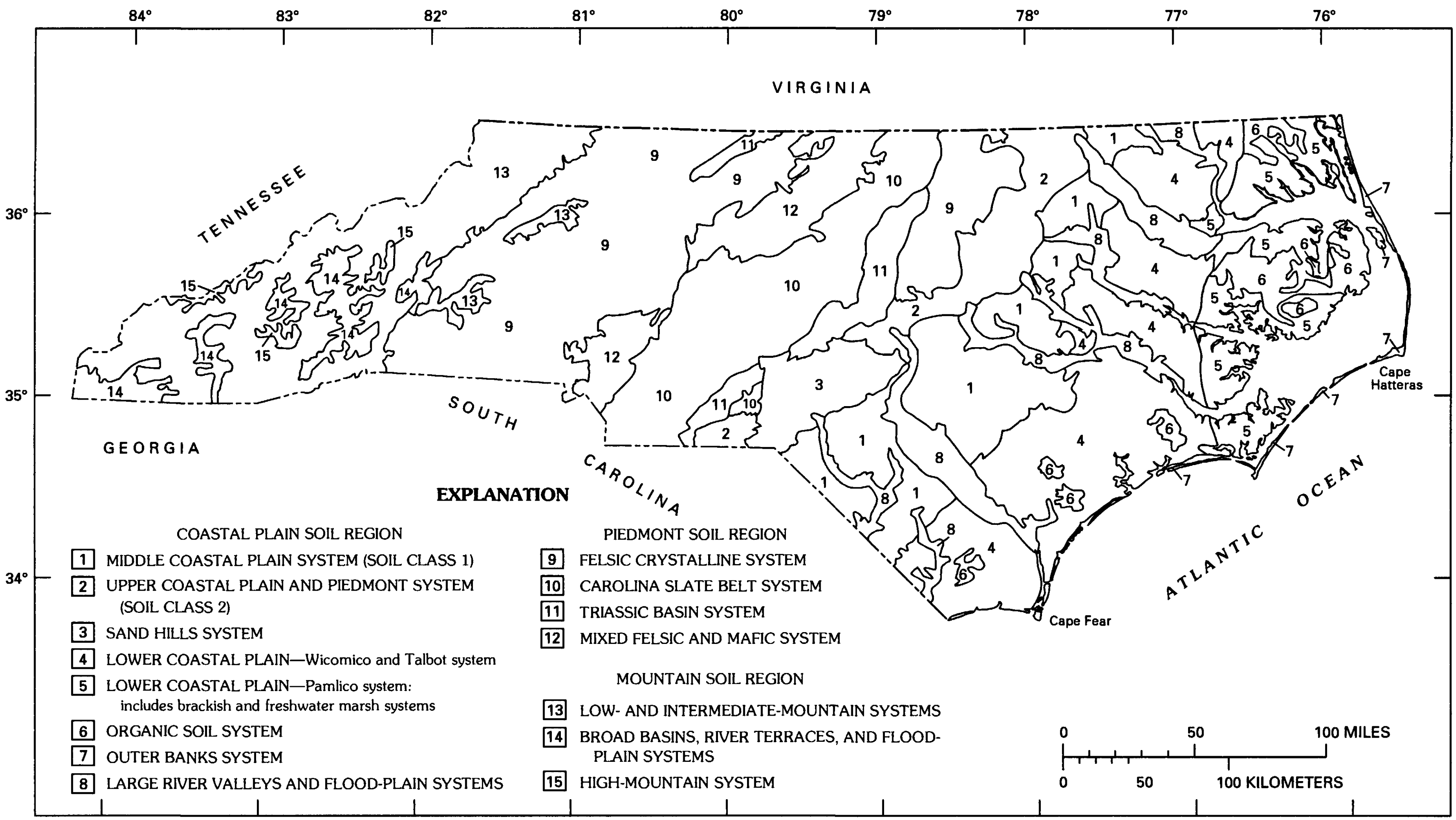


Figure 4. Generalized soils of North Carolina (adapted from Daniels and others, 1984).

Table 1. Guide for estimating erodibility *K* factors for soils in North Carolina

[Modified from U.S. Department of Agriculture, 1976]

Surface soil composition	Erodibility, in tons per acre: Very low →	Relative permeability within soil type		→ Very high
Clay, silty clay, sandy clay	0.37	0.32	0.28	0.24
Sandy clay loam, silty clay loam, clay loam	.43	.37	.32	.28
Silty loam, loam, very fine silty loam	.49	.43	.37	.32
Fine sandy loam, silty loam	.37	.32	.24	.20
Loamy sand, sand, loamy clay sand	.28	.24	.20	.15

forested basins. Erosion often increases proportionately to increases in the amount of exposed soil in a basin.

Statewide erosion data by the U.S. Department of Agriculture (1977) show considerable differences in average annual rates of erosion for various rural conditions, including 0.1 ton/acre from forests, 1.3 tons/acre from grassland pastures, and 7.5 tons/acre from croplands. Obviously, these are average values for the State and should not be used to define conditions at specific locations; however, they illustrate the dramatic effects of vegetative cover.

Little research has been done in this State regarding historical changes in land use and the effects on erosion and fluvial sediment. Prior to the arrival of European settlers in the 1700's, North Carolina was almost totally forested and erosion was certainly minimal. Accounts by early explorers, historians, and geologists attest to the purity and clarity of the State's streams, even during storm runoff. Many references to these early observations are presented in two reports by Trimble (1969, 1974), which document land-use changes in the southern Atlantic Piedmont Province. As pristine forests fell to the settlers' axes, these once-clear streams ran muddy. Erosion during the first 150 years of settlement was related almost entirely to agricultural activities. Dramatic changes in socioeconomic patterns in the State during the early 1900's, continuing up to today, have produced other major sources of sediment, such as urban and municipal developments, highway and bridge construction, aggregate and other mining operations, and large-scale silvicultural operations.

Although North Carolina is one of the South's most industrialized states, it also has the Nation's largest rural farm population (Clay and others, 1975, p. 3). Approximately 48 percent of the State's 5.9 million residents (1980 census) live in urban areas. Regionally, slightly over half of the population lives in the Piedmont, and about 15 percent lives in the Blue Ridge Province. Of the State's 31.3 million acres, approximate uses of land are as follows: urban, 5 percent; cropland, 23 percent; pasture, 5 percent; lakes and rivers, 1 percent; and, forests, 66 percent (U.S. Department of Agriculture, 1971). Although the physiographic provinces are often categorized as Blue Ridge and forests, Piedmont and industry, and Coastal Plain and agriculture, all classes of land use currently exist in each province. Primarily because of the State's rapid population increase—almost 16 percent from 1970 to 1980 (North Carolina Office of State Budget and Management, 1982)—significant changes in land use are underway. The greatest change is the conversion of forest and agricultural lands to urban and industrial developments. However, primarily in the Coastal Plain area, hundreds of thousands of acres of forest land were cleared during the project period for agricultural use (Sharitz and Gibbons, 1982).

Effects of Reservoirs

The sediment-trapping characteristics of lakes and reservoirs have been studied for many years and were the basis for some of the earliest sediment studies conducted in North Carolina. One or more dams are located on most major rivers, and there are countless farm ponds, lakes, and reservoirs on smaller headwater streams and tributaries. An inventory of dams conducted in 1969 lists over 900 dams of significant size and over 33,000 impoundments classified as farm ponds or irrigation storage reservoirs (North Carolina Board of Water and Air Resources, 1969). According to an unpublished survey conducted in 1977 by the Soil Conservation Service, U.S. Department of Agriculture, there are approximately 80,000 water bodies in the State less than 40 acres in size (James Canterberry, Soil Conservation Service, written commun., 1984). In August 1984, the North Carolina Department of Environment, Health, and Natural Resources (DEHNR) indicated that approximately 3,850 unlicensed, privately owned dams are located in the State that are at least 15 ft in height and have storage capacities exceeding 10 acre/ft (Steven M. McEvoy, DEHNR, oral commun., 1984). The reduction in sediment transport caused by this multitude of impoundments is unknown. According to Brune (1953), large reservoirs having storage capacities equal to or greater than the annual inflow volume of water often trap 95 to 100 percent of incoming sediment.

The U.S. Geological Survey is conducting studies related to the trapping characteristics of two in-stream sediment traps on Juniper Branch near Simpson, a small tributary to Chicod Creek, Pitt County (site 20, fig. 1). Drainage areas at the two traps are approximately 2 mi^2 and 4 mi^2. Although the Juniper Branch traps have ratios of storage capacity to annual inflow volume less than 0.02, they trap 20 to 60 percent of the suspended sediment, with the lesser trapping rates occurring during storm runoff (U.S. Geological Survey, 1979, unpublished data).

HYDROLOGIC CONDITIONS DURING STUDY PERIOD

Generally, streamflows in North Carolina are greater during winter than in summer, although severe flooding might occur at any time during the year. Meteorological and streamflow conditions often differ considerably from day to day and year to year, a factor that greatly complicates definition of trends and other hydrologic comparisons. Numerous reports are available describing the State's hydrologic characteristics, and the reader is referred to these for detailed background information. Several of the most informative reports are by Forrest and Speer (1961), Goddard (1963), Speer and Gamble (1964a, b), and Yonts (1971).

Precipitation

The long-term average annual (calendar-year) precipitation for North Carolina is about 49 in. (inches), although a large spatial variability exists across the State. The greatest variation occurs in the Blue Ridge, where abrupt changes in topography drastically affect rainfall amounts in the space of a few miles. For instance, annual precipitation at Highlands (Macon County), at an altitude of 3,350 ft above sea level, is over 82 in., the greatest amount east of the Rocky Mountains. In contrast, the city of Asheville (fig. 2), which is located in a sheltered valley 50 mi away and at an altitude of 2,200 ft, averages only 38 in. per year (Elder and others, 1983, p. 30). Variations in annual precipitation across the Piedmont and Coastal Plain Provinces are more subtle and range from about 44 to 54 in., with the greater amounts occurring along the coast.

North Carolina has no pronounced rainy or dry seasons. Based on long-term records, July and August receive the most rainfall, while the least amount falls in October and November. Although intense rainfall can occur in North Carolina during any month, historically the most intense rain occurs during the late summer months and results from violent local thunderstorms or from hurricanes of tropical origin. The State's most destructive storm, Hurricane Hazel, occurred in October 1954 and produced record 24-hour rainfall amounts at 10 weather stations, ranging from 6.5 in. at Burlington to 9.7 in. at Carthage (Hardy and Carney, 1962). One of the most severe storms recorded nationally occurred during August 1969 immediately north in central Virginia, when rains from Hurricane Camille exceeded 28 in. in 8 hours (Williams and Guy, 1973). Essentially, every long-term station in the State reports one or more summertime thunderstorms exceeding 4 in. in 24 hours during its history. According to records of the National Weather Service, rainfall for the 1970–79 study period was slightly above the long-term average for the State. Comparisons of annual totals to long-term mean values for selected cities are shown in figure 5. Although annual totals varied from −32 to +45 percent of long-term mean precipitation, means for the 10-year study period were within about 9 percent of long-term values (fig. 5).

The erosional processes begin when raindrops strike the exposed land surface, causing disintegration of soil aggregates. Rain splash moves soil particles in all directions, but the net movement is downslope. Except in coarse, sandy soils, the impact from raindrops also causes consolidation of surface particles and a subsequent reduction in infiltration potential. Sheet flow begins when the amount of precipitation exceeds the infiltration capacity of the soil. The erosive power of the sheet flow dislodges soil particles and transports them in addition to materials put into suspension by splash effect.

In North Carolina, the most important precipitation factors controlling sedimentation processes are the magnitude and intensity of rainfall. For example, a gentle, 3-in. rainfall spread over several days will not produce the same amount of erosion or sediment transport as an intense 3-in. rain that occurs over several hours. Larger raindrops associated with intense rainfall produce greater splash erosion; the soil's infiltration rate is quickly exceeded, and surface runoff is maximal; and the erosive energy of the surface runoff is increased by turbulence caused by impacting raindrops. Surface runoff, the transport medium, will not occur until the rate of rainfall exceeds the rate of infiltration.

Antecedent precipitation conditions also affect the sedimentation transport process. Rainfall following a lengthy dry period usually will produce more fluvial sediment than a similar event that immediately follows a flood, although the latter generally produces considerably more surface runoff. During dry weather, erodible material accumulates on the land surface through various processes such as wind erosion, chemical and physical weathering, atmospheric deposition, and disintegration of larger materials by animals and humans. Lower stream velocities associated with decreasing flows cause deposition of suspended materials on the streambed. These processes increase the supply of materials available for transport during floods.

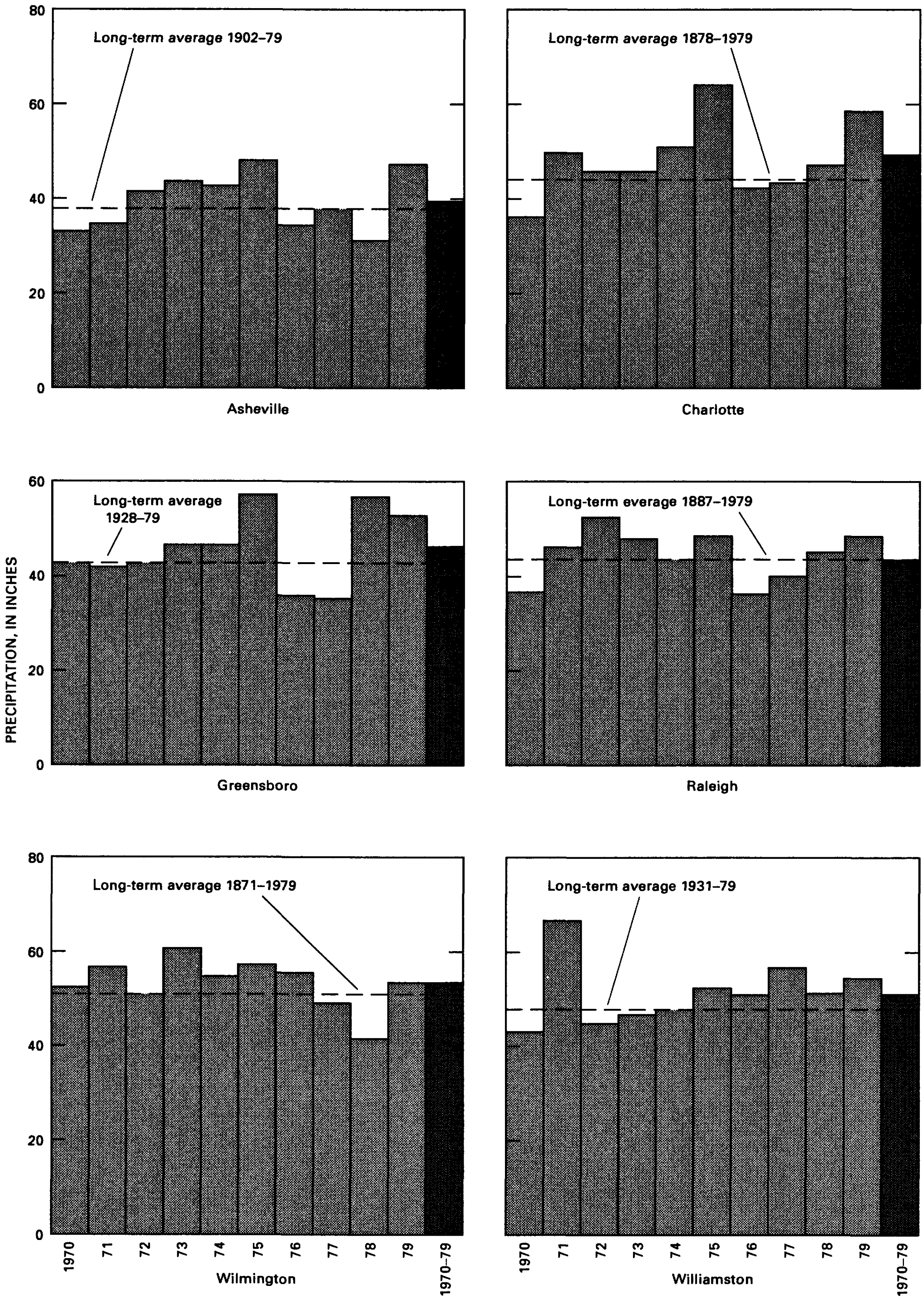


Figure 5. Comparison of annual precipitation during study period with long-term averages (dashed lines) at selected points.

Table 2. Average discharge for selected index gaging stations for period of record and 1970–79 reference period

Site number[1]	Name	Drainage area (square miles)	Period of record[2]		1970–79[2]
			Period	Average discharge (cubic feet per second)	Average discharge (cubic feet per second)
42	Contentnea Creek at Hookerton	729	1930–1984	772	788
63	Deep River at Moncure	1,434	1930–1984	1,479	1,650
93	South Yadkin River near Mocksville	306	1939–1984	345	408
134	French Broad River at Asheville	945	1896–1984	2,100	2,400

[1]Refers to figure 1 and table 19.
[2]Based on water year (October 1–September 30).

The hydrologic response to rainfall is often variable among different soil types. A clay-rich soil may be essentially impermeable and produce high surface runoff during heavy rains, whereas the same storm may produce little or no runoff from a sandy soil having large storage capacity and an infiltration rate of several inches per hour. Essentially all erosive characteristics of a soil are altered during freezing. Although North Carolina has a moderate climate, winter temperatures are often low enough in the Piedmont and Blue Ridge Provinces to freeze soils to depths of 2 ft or more. Infiltration, storage capacity, and porosity are reduced, whereas surface runoff and particle cohesiveness increase, when a soil is frozen. Immediately following a thaw, soils tend to expand and become less cohesive and more permeable. Surface runoff from recently thawed soils generally produces greater-than-normal amounts of sediment transport.

Streamflow

Comparisons of data from long-term gaging stations indicate that flows during the 1970–79 water-year base period were generally greater than long-term averages. A convenient method of showing this is by use of flow-duration curves, which are cumulative-frequency curves that show the percent of time-specific discharge values were equaled or exceeded in a selected period. Curves for four long-term index gaging stations are shown in figure 6. Only stations that have unregulated flows and that are representative of relatively rural basin conditions are selected for index purposes. As noted, except for extreme flood flows, discharge values statewide are slightly greater during 1970–79 (fig. 6). Because relatively little sediment is transported during low flow (≥80 percent duration), a large spread between curves at low flow represents only a minor difference in annual sediment load.

Comparisons of average discharge data for these index stations are shown in table 2. These comparisons indicate that while mean flows in the Coastal Plain's Contentnea Creek during 1970–79 were generally only a few percent above normal, flows in the Piedmont's South Yadkin River were 18 percent above normal (fig. 6). However, historically significant flooding occurred in only a few minor basins during the 10-year study period. In August 1970, heavy flooding in the upper headwaters of the Yadkin, Catawba, and Broad Rivers produced crests near, but not exceeding, the historic floods of 1916 and 1940. Recurrence intervals for the August 1970 peaks were about 20 years. In June 1972, tropical storm Agnes caused near-record floods in the upper basins of the Dan, Smith, and Yadkin basins with recurrence intervals on tributary streams approaching 50 years. Near-record floods occurred in the Blue Ridge Province along headwater tributaries of the French Broad and Pigeon Rivers in May 1973. The most severe flooding during 1970–79 occurred in the northern Blue Ridge Province during November 1977 in parts of the lower French Broad, Nolichucky, and New River basins. Flood crests on several streams during this storm exceeded those expected to occur once in 100 years; however, the most severe flooding occurred in basins not covered by sampling stations.

In addition to flow-duration data, information on the number and intensity of floods is significant in comparing flow similarities for different periods of time, especially as the analysis is related to sediment transport. Based on flood information from the U.S. Geological Survey WATSTORE peak-flow file and flood-frequency data from H.C. Gunter (U.S. Geological Survey, written commun., 1987), a comparison of numbers of floods occurring at 28 long-term gaging stations is shown in table 3. Although numerous localized exceptions probably occurred during the two periods, these data indicate that, compared with a 30-year reference period, the number and intensity

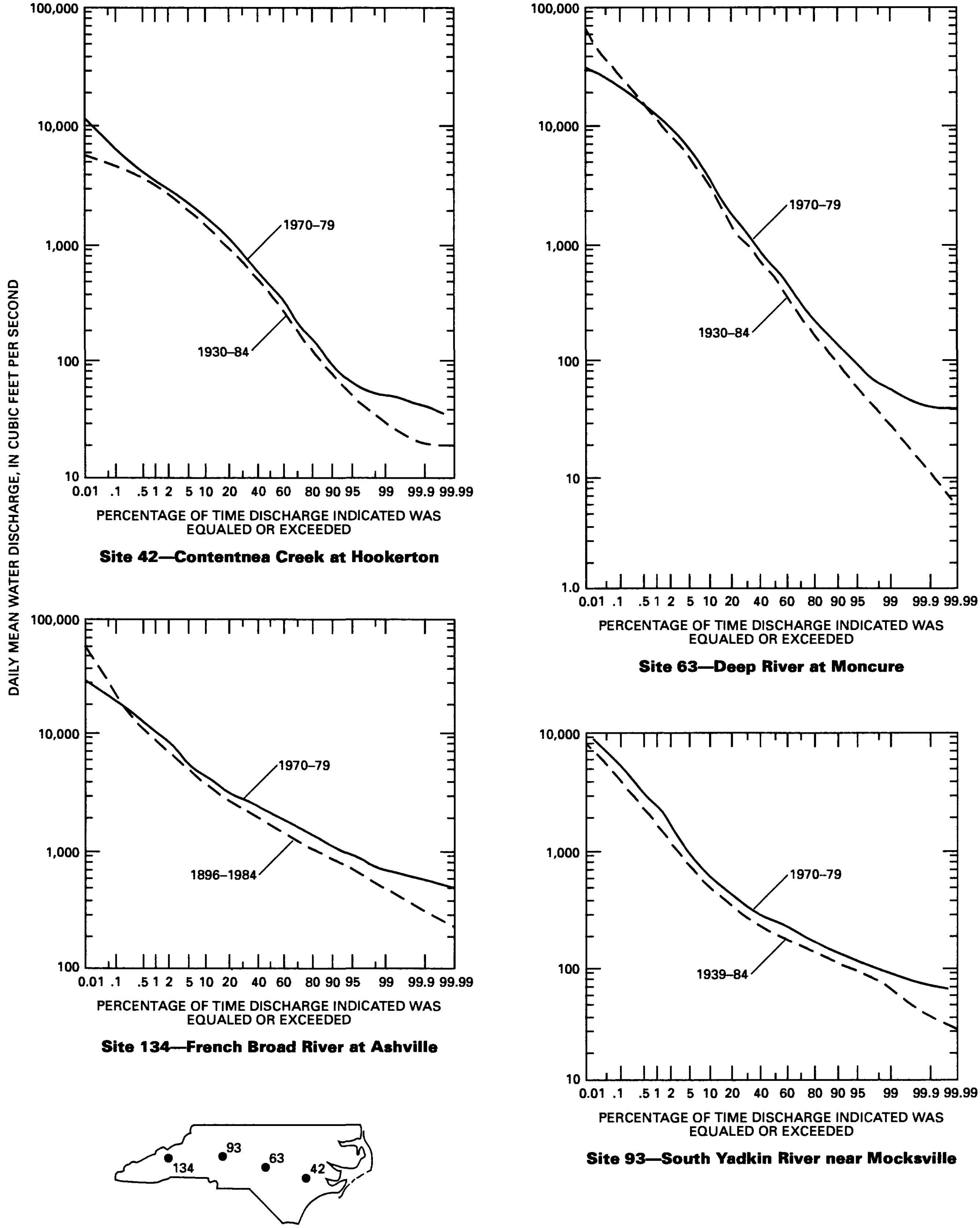


Figure 6. Comparisons of flow-duration curves for period of record and 1970–79 reference period at selected long-term index gaging stations.

Table 3. Numbers of floods at selected stations exceeding various intensities for long-term and study (1970–79) conditions

[—, no data]

Site number (fig. 1)	Station number (table 19)	Province	Flood base discharge (cubic feet per second)	Number of floods during reference period, 1950–79, exceeding stated criteria: 5-year recurrence interval	10-year recurrence interval	Flood base discharge	Number of floods during study period, 1970–79, exceeding stated criteria: 5-year recurrence interval	10-year recurrence interval	Flood base discharge
126	03161000	Blue Ridge	2,600	7	1	68	4	1	33
128	03441000	Blue Ridge	1,000	8	2	129	2	1	56
130	03446000	Blue Ridge	1,000	7	2	100	4	1	44
134	03451500	Blue Ridge	9,000	5	3	74	3	2	36
141	03460000	Blue Ridge	1,000	6	4	54	2	2	30
143	03479000	Blue Ridge	2,000	8	4	94	6	2	40
146	03504000	Blue Ridge	1,500	6	5	77	3	2	34
149	03512000	Blue Ridge	4,000	9	4	106	3	2	41
152	03550000	Blue Ridge	1,700	8	1	105	3	0	37
Mean number per station year				0.24	0.10	2.99	0.33	0.14	3.9
3	02068500	Piedmont	2,000	4	1	87	4	1	37
12	02081500	Piedmont	2,000	5	3	137	3	2	43
27	02085500	Piedmont	4,500	8	3	62	6	2	28
30	02087500	Piedmont	7,100	8	2	68	6	2	23
51	02095500	Piedmont	920	9	5	[1]159	7	3	[1]78
60	02099500	Piedmont	2,600	6	2	75	4	2	35
63	02102000	Piedmont	15,000	7	2	72	3	0	28
79	02111500	Piedmont	2,000	5	1	53	4	1	22
83	02113000	Piedmont	2,200	4	2	100	2	1	49
111	02143000	Piedmont	2,800	5	1	54	4	1	20
Mean number per station year				0.20	0.07	2.62	0.43	0.15	3.16
17	02083000	Coastal Plain	—	4	2	—	3	1	—
22	02084500	Coastal Plain	120	10	3	104	4	1	31
34	02088500	Coastal Plain	1,200	5	3	110	6	2	28
42	02091500	Coastal Plain	—	4	2	—	0	0	—
70	02106000	Coastal Plain	—	6	2	—	3	1	—
73	02108000	Coastal Plain	—	8	4	—	2	0	—
76	02109500	Coastal Plain	—	7	2	—	3	0	—
104	02133500	Coastal Plain	850	4	3	81	1	1	31
105	02134500	Coastal Plain	—	6	3	—	4	2	—
Mean number per station year				0.20	0.08	3.27	0.28	0.08	3.00

[1]Excluded from computations of mean values.

of floods occurring in 1970–79 was near normal in the Coastal Plain Province. In the Piedmont and Blue Ridge Provinces, however, the number of floods was often twice that expected to occur during an average 10-year period (table 3).

In summary, analyzing the representativeness of a short-term hydrologic record (1970–79) to long-term conditions requires more than a mere review of flow-duration data. In general, however, because of the often close relationship between water discharge and sediment transport, comparative data indicate that values of fluvial sediment in this report, based on 10 years of record, might be slightly greater than values representative of a longer period of record. This is especially true of values for streams in the Blue Ridge and Piedmont Provinces. One of the primary objectives of this report is to define sediment-related characteristics that occurred during 1970–79, but a general indication of the error one might incur by using these values to represent longer periods of record is discussed in a following section under "Stream Discharge."

SEDIMENT-SAMPLING NETWORK AND METHODS OF COMPUTATION

Computations of average annual sediment discharge require the availability of continuous water-discharge data for the period under investigation. Fortunately, a large network of continuous stream-gaging stations was already in operation across North Carolina in support of projects for various local, State, and Federal agencies. Most of these gaging stations were operated for defining long-term hydrologic characteristics, thereby assuring continuous-flow records needed for reliable transport computations. Streamflow records for 30 stations did not include all 10 years of the base period (1970–79). Records for these short-term stations were adjusted by methods suggested by Searcy (1959) so that flow-duration and related sediment-transport data for all network stations were based on the complete 10-year base period. Because of the widespread nature of the gaging network and the fact that flows were available for basins, large and small, representative of various land-use effects, sediment sampling was conducted at 152, or approximately 90 percent, of the existing gaging stations. The locations of stations in the sediment program are shown in figure 1, and site-descriptive information is provided in table 19 at the back of this report.

The large number of stations in the sampling network provided data covering a wide variety of basin and flow conditions. The sizes of drainage basins sampled ranged from 0.64 to more than 8,000 mi^2 (table 19). At least one sampling station was located on every major river in the State. A large variety of different basin land uses were included, ranging from totally forested to 97 percent urban (table 19). Sediment discharge (and yield) at some stations was influenced by other factors, such as upstream reservoirs, runoff from construction activities, channelization, and unpaved roads. The effect of these factors is discussed later in this report. Being statewide, the network was also designed to show regional variations in sediment caused by soils, topography, and other factors (to be discussed in following sections). The network included three stations sampled on a daily basis (fig. 1); however, most stations were sampled only periodically, depending primarily on flow conditions and data requirements for defining transport characteristics.

Except for an in-house computer program, SEDQ, used to compute values of sediment discharge and yield at selected stations, values of flow, suspended sediment, and related statistics were computed using standard U.S. Geological Survey or SAS (SAS Institute, Inc., 1985) programs. Because these methods are discussed in considerable detail in other reports, only brief explanations are included herein; however, pertinent references are provided should more information be desired.

Daily Sampling Stations

At daily stations, samples of suspended sediment are collected on a daily or more frequent basis. The network's daily stations were Creeping Swamp near Vanceboro (site 45, fig. 1), Chicod Creek near Simpson (site 20), and Yadkin River at Yadkin College (site 91). The computational procedures for daily stations differ from those for periodic stations in that a sediment discharge value is computed for each day of record. These procedures, outlined by Porterfield (1972), require the development of a temporal concentration graph from which values of daily mean concentrations are determined. The mean concentration (in milligrams per liter) is then multiplied by the mean water discharge (in cubic feet per second) and the conversion factor 0.0027 to obtain the suspended-sediment discharge (in tons) for the day. During floods or other periods of rapidly changing flow or concentration, however, suspended-sediment discharge is determined by subdividing the day into specific time increments (Porterfield, 1972, p. 47–52) and summing the incremental products of discharge and suspended-sediment concentration to obtain an integrated value for each day. Annual values are then obtained by simply summing the daily values. Records for the Chicod Creek and Creeping Swamp stations did not cover the entire 10-year base period and were adjusted to the base period using methods described by Anttila and Tobin (1978, p. 24–27).

Transport values, such as annual suspended-sediment discharge, computed using daily sediment data are generally considered to be more reliable than values computed from periodic data. Computations from daily stations are often used as the standard for comparisons of accuracy of other methods.

Periodic Sampling Stations

Periodic stations are those that were sampled on an intermittent basis ranging from once every 6 to 8 weeks to two or more samples during the same day for defining transport during floods. Of the 152 stations in the statewide sediment network, 149 stations were sampled periodically (fig. 1). A good relation generally exists between values of instantaneous water discharge and suspended-sediment discharge; the average curve obtained from plotting simultaneous values of each on a logarithmic graph is expressed as a sediment-transport curve. Tables presented later in this report (tables 5–8, 11) include the following information for each station transport curve: the number of actual samples used to define the curve, the range in values of these samples, and an indication of the degree of fit (correlation coefficient) of these values to the curve. Miller (1951) and Colby (1956) discuss in detail how data values from sediment-transport and flow-duration curves can be used to compute suspended-sediment discharge for a periodic station. Minor modifications of this method are discussed by Jones and others (1972), Simmons (1976), Anttila and Tobin (1978), and others. Compared with these methods, the computations in this study used a larger number of subdivisions of percentage time at high flows on streams that rise and fall quickly, thereby improving the accuracy of the method (J.M. Knott and G.D. Glysson, U.S. Geological Survey, oral commun., 1981). The method is briefly described as follows, using the Eno River near Durham (site 25, fig. 1) as an example for each step.

At each periodic-sampling station, sediment samples are collected at low, medium, and high flows. It is desirable that sufficient data values be available to define all ranges of flow that occurred during the 10-year base period. Additional samples are obtained on the rising and falling limbs of the storm hydrograph because a disproportionately large part of sediment is transported during high flows. The suspended-sediment concentration of each sample is converted to suspended-sediment discharge using the following equation:

$$Q_s = 0.0027\, CQ \qquad (1)$$

where

Q_s = instantaneous suspended-sediment discharge, in tons per day;
0.0027 = conversion factor;
C = concentration of sediment, in milligrams per liter; and
Q = instantaneous water discharge, in cubic feet per second.

Values of suspended-sediment discharge of the Eno River near Durham were calculated by the above equation and plotted on a logarithmic graph versus the corresponding water discharge to develop a sediment-transport curve (fig. 7). Cumulative frequency distributions of daily discharges are determined for the sampling station. These distributions show the percentage of time for which discharges are equaled or exceeded and are calculated using standard statistical programs of the U.S. Geological Survey. The line connecting the data points is referred to as a flow-duration curve. Cumulative-frequency data for the Eno River near Durham are plotted on a logarithmic probability graph in figure 8.

The computation of average annual suspended-sediment discharge is illustrated by the example shown in table 4. The process, using the Eno River near Durham, is as follows:

1. Incremental percentage limits (column 1) are selected by the user and may vary between stations. It is desirable to minimize the percentage range of each increment (column 2) at high flows and gradually increase the range (columns 1 and 2) as values of discharge decrease.

2. The midpoint of each increment (column 1) is shown in column 3.

3. Using the flow-duration curve (fig. 8), values of water discharge (column 4) were determined for the corresponding time increment shown in column 3.

4. Suspended-sediment discharges determined from corresponding values of water discharge on the sediment-transport curve (fig. 7) are shown in column 5.

5. Each suspended-sediment discharge (column 5) is multiplied by the corresponding incremental flow-duration percentage increment (column 2) to attain incremental sediment discharge (column 7); and

6. The sum of incremental sediment discharges in column 7 is the daily average suspended-sediment discharge, in tons per day, for the 10-year base period. The product of the daily average suspended-sediment discharge and the number of days in a year (365) is the average annual suspended-sediment discharge in tons per year. The average annual suspended-sediment yield, in tons per square mile per year, is determined by dividing the average annual suspended-sediment discharge by the area of the drainage basin (in square miles).

Suspended-sediment discharge and yield computations for periodic stations were performed by an in-house computer program, SEDQ, which did not round numerical values (table 4). Because these computer-generated values are considered as estimates, values of yield and sediment discharge are rounded to two significant figures if greater than 10 and to one significant figure if less than 10. For instance, the computed suspended-sediment discharge value of 22,941 tons (table 4) is rounded to 23,000 tons.

Methods of Sampling and Laboratory Analysis

Suspended-sediment samples were collected using the methods outlined by Guy and Norman (1970). A hand-held sampler (DH-48) is used for streams that can be waded; larger samplers (DH-59, 22 lb (pounds); and D-49, 62 lb) are used for streams that are too deep or swift to wade. The latter two samplers may be suspended by a hand-held rope or by cable-and-reel equipment. Basically, the Equal Width Increment method (Guy and Norman, 1970, p. 32–37) for sampling suspended sediment was used throughout the study. Depending on stream depth and velocity, the method utilizes the selection of a specific transit rate for raising and lowering the sampler at equally spaced verticals in the stream's cross section. The Equal Width Increment method, formerly called the Equal Transit Rate method, is discussed in considerable detail by Guy and Norman (1970, p. 32–37). It should be noted that the entire water column is not sampled. Depending on the type of samplers, the intake nozzle is located from about 0.2–0.4 ft above the sampler's bottom; therefore, each vertical

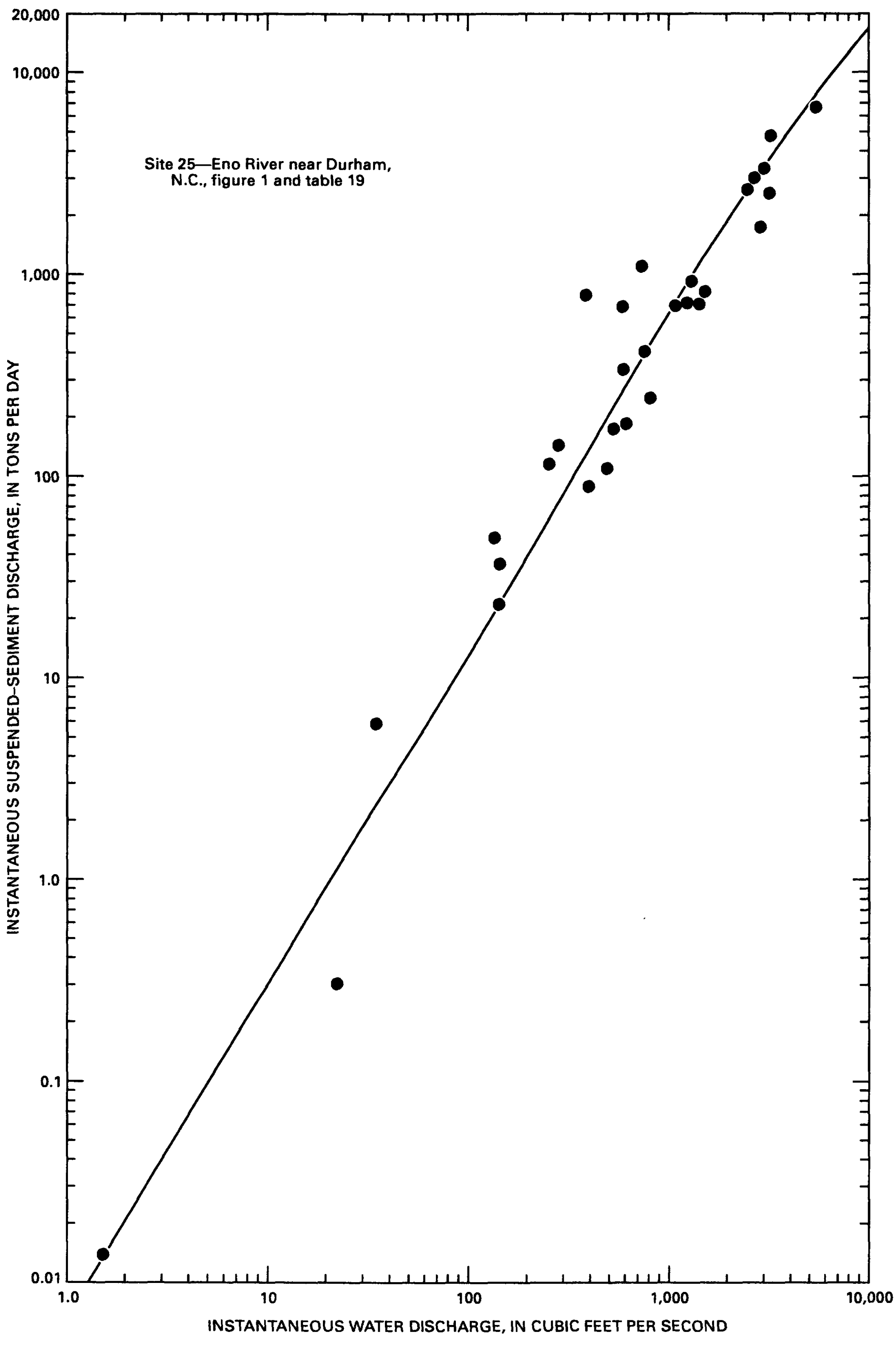


Figure 7. Sediment-transport curve for site 25, Eno River near Durham, 1970–79. Site location shown in figure 1.

sampling transit has an unmeasured zone of this distance (0.2–0.4 ft) above the streambed.

The unmeasured part constitutes primarily the bedload discharge and a percentage of the suspended-sediment discharge. Because standard samplers now in use cannot accurately measure sediment closer than 2–4 in. above the streambed, values must be estimated using mathematical or predictive techniques. The perplexities of selecting a "workable" method from the numerous techniques available are discussed by Shulits and Hill (1968). Primarily because of the lack of detailed particle-size data and of an acceptable sampler for verifying results, values of unmeasured discharge are not included in this report.

Concentrations of suspended sediment were determined in the U.S. Geological Survey sediment laboratory in Raleigh, North Carolina, using methods outlined by Guy (1969). Briefly, determinations were made by the filtration method, which involves weighing the sample and filtering, drying, and weighing the sediment. Filtration is accomplished by a 25-mL (milliliter) Gooch crucible and glass-fiber filter disks utilizing an electrical vacuum system. Analyses of particle sizes of suspended and bed materials were performed jointly by laboratories in Raleigh and in Baton Rouge, Louisiana. Size analyses were determined with sieves for material larger than 0.062 mm; the bottom-withdrawal tube method (Guy, 1969) was used for material finer than 0.062 mm.

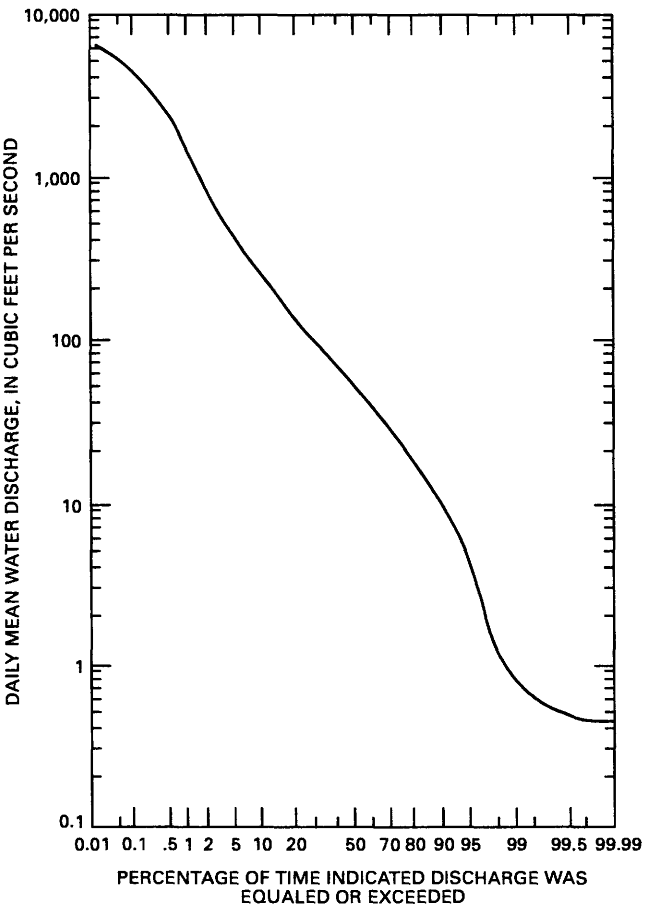


Figure 8. Flow-duration curve for site 25, Eno River near Durham, 1970–79. Site location shown in figure 1.

Comparisons of data in this report with historical data or with data collected by other organizations should not be performed unless similarity in both field and laboratory techniques can be established. For instance, values of suspended-sediment concentrations collected by the U.S. Geological Survey prior to about 1951 in North Carolina did not employ currently recommended depth-integrating methods.

EFFECTS OF LAND USE ON CHARACTERISTICS OF SEDIMENT TRANSPORT

Comparative analyses of various sediment characteristics are more meaningful when site basins are categorized by major factors that influence sediment, such as land use and development activities. Kennedy (1964), Vice and others (1969), Hindall (1976), Vanoni (1977), and others discuss the effects of various surface covers and land uses on sediment transport. For comparative purposes, each station in the sampling network was categorized into one of five classes:

1. forested basins representing background (pristine) conditions,
2. forested basins having minor developments,
3. rural basins affected by agriculture,
4. rural basins heavily affected by nonagricultural activities, and
5. urban basins (table 19).

This categorization reflects the most influential land-use factors affecting erosion and sediment transport in North Carolina. Because of a fairly balanced distribution of population, industry, and farming interests across the State, it is difficult to find basins exceeding several square miles in size that contain a single land-use activity. Information obtained from field inspection, aerial photographs, land-use maps, and topographic maps prepared since 1970 were used to determine land-use characteristics for study basins. The percentage of land use by major category is presented in table 19 for each sampling station.

Forested Basins Representing Background Conditions

The forested-basin land-use category is intended to characterize sediment transport from forested areas for the purpose of defining background (pristine) conditions. Only seven basins (table 5), ranging in size from 0.64 to 51.9

Table 4. Computation of average annual suspended-sediment discharge and yield of the Eno River near Durham, 1970–79[1]

(1) Limits of time increment (percent)	(2) Interval between time increments (percent)	(3) Midpoint of limits in column (1) (percent)	(4) Water discharge equaled or exceeded[2] (cubic feet per second)	(5) Suspended-sediment discharge[3] (tons per day)	(6) Water discharge multiplied by time interval (cubic feet per second)	(7) Sediment discharge multiplied by time interval (tons)
0.00 – 0.02	0.02	0.01	6,210.00	8,512.60	1.24	1.703
0.02 – .04	.02	.03	5,610.00	7,425.38	1.12	1.485
0.04 – .06	.02	.05	4,690.00	5,835.90	.93	1.167
0.06 – .10	.04	.08	4,570.00	5,635.98	1.82	2.254
0.10 – .15	.05	.12	4,470.00	5,470.77	2.23	2.735
0.15 – .30	.15	.22	3,680.00	4,211.80	5.52	6.318
0.30 – .50	.20	.40	2,560.00	2,547.82	5.12	5.096
0.50 – 1.0	.50	.75	1,910.00	1,672.54	9.55	8.363
1 – 2	1.00	1.50	1,170.00	827.03	11.70	8.270
2 – 4	2.00	3.00	695.00	359.47	13.90	7.189
4 – 7	3.00	5.50	464.00	183.08	13.92	5.492
7 – 11	4.00	9.00	304.00	90.35	12.16	3.614
11 – 15	4.00	13.00	231.00	57.12	9.24	2.285
15 – 20	5.00	17.50	178.00	36.96	8.90	1.848
20 – 25	5.00	22.50	142.00	25.34	7.10	1.267
25 – 35	10.00	30.00	106.00	15.55	10.60	1.556
35 – 45	10.00	40.00	79.00	9.52	7.90	.952
45 – 55	10.00	50.00	59.00	5.84	5.90	.585
55 – 65	10.00	60.00	44.00	3.58	4.40	.358
65 – 75	10.00	70.00	31.00	1.99	3.10	.200
75 – 85	10.00	80.00	19.00	.88	1.90	.088
85 – 95	10.00	90.00	9.40	.27	.94	.027
95 – 98.5	3.50	96.80	2.90	.03	.10	.001
98.5 – 99.9	1.40	99.20	.58	.00	.00	.000
					Total tons (per day)	62.853

[1]Average annual suspended-sediment discharge = 365 x 62.853 = 22,941 tons (rounded to 23,000). Drainage area of basin = 141 square miles. Average annual sediment yield = 22,941 ÷ 141 = 162.70 tons per square mile (rounded to 160).

[2]Determined from figure 8.

[3]Determined from figure 7.

mi^2, met the criteria of this category. Field reconnaissances indicated that 94 to 100 percent of the land surface in the seven basins was forested and that, although a few basins contained roads and isolated houses, minimal erosional effects were contributed by these sources because activities were at considerable distances from watercourses. Except for natural pools along the stream reaches, the basins contained no lakes or other manmade detention structures.

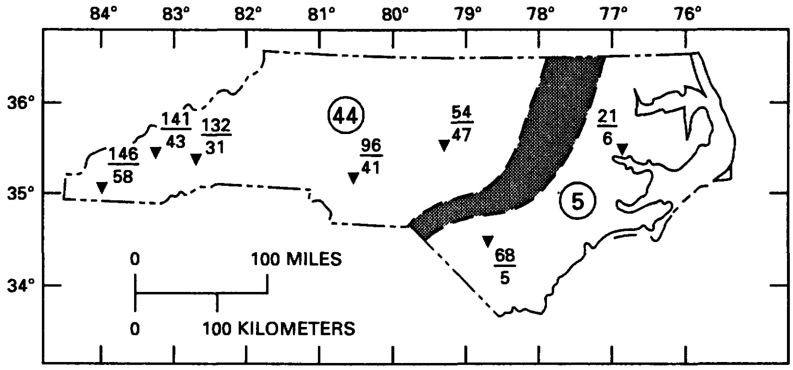
Although 64 percent of North Carolina's land area is forested, this coverage is highly fragmented by farms, urban developments, and other land-disturbing activities. Totally forested basins exceeding a few square miles in size are increasingly scarce and generally are found in government-owned (or controlled) parks, forests, and gamelands. Sizable forested areas are owned by paper companies and by industrial and commercial interests, but activities such as controlled burning of underbrush and timber harvesting generally preclude their use in defining background conditions.

The primary sources of fluvial sediment in the seven forested basins are related to bank caving, channel scour, and other more subtle changes in morphology of mainstream and tributary channels. Lesser amounts of fine materials (mostly clays and organics) are derived from the shallow root zone and surface during heavy rains. Many researchers (for example, Johnson and Swank, 1973; Dunne, 1978; Mosley, 1979) argue that most storms cause little or no actual surface runoff in well-drained forested areas having normal litter accumulation; however, small streamlets capable of transporting fine sediments often occur along

Table 5. Suspended-sediment characteristics for forested basins representing background (pristine) conditions, 1970–79

[Physiographic provinces: C, Coastal Plain; P, Piedmont; B, Blue Ridge. *r*, correlation coefficient for site sediment-transport curve defined by observed data]

Site number (fig. 1)	Name	Physiographic province	Drainage area (square miles)	Estimated mean annual suspended-sediment discharge (tons)	Estimated mean annual suspended-sediment yield (tons per square mile)	Mean daily discharge (cubic feet per second)	Estimated percentage of time indicated suspended-sediment concentration was equaled or exceeded (milligrams per liter)					Number of samples, correlation coefficient, and range in observed (measured) concentration (milligrams per liter)			
							0.1	1.0	10	50	90	Number	*r*	Maximum	Minimum
21	Black Swamp near Batts Crossroads	C	1.02	6	6	>1	17	16	13	8	6	17	0.88	35	2
54	Cane Creek near Buckhorn	P	0.64	30	47	>1	160	86	8	5	5	49	.76	120	2
68	Ellis Creek tributary near White Oak	C	1.81	9	5	>1	32	24	11	5	4	21	.80	50	4
96	Dutchmans Creek near Uwharrie	P	3.44	140	41	4	40	27	9	6	5	23	.80	108	4
132	Beetree Creek near Swannanoa	B	5.46	170	31	12	100	33	4	3	2	51	.83	88	1
141	Cataloochee Creek near Cataloochee	B	49.2	2,100	43	122	220	34	8	3	1	110	.87	383	0
146	Nantahala River near Rainbow Springs	B	51.9	3,000	58	232	58	40	16	5	1	34	.88	111	0

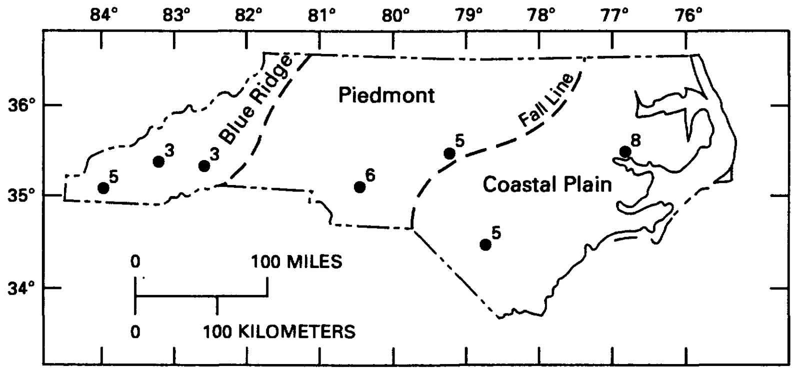


EXPLANATION

TRANSITION ZONE BETWEEN PIEDMONT AND COASTAL PLAIN PROVINCES

132 / 31 — ESTIMATED ANNUAL SUSPENDED-SEDIMENT YIELD, IN TONS PER SQUARE MILE:
Upper number is site number
Lower number is yield at site

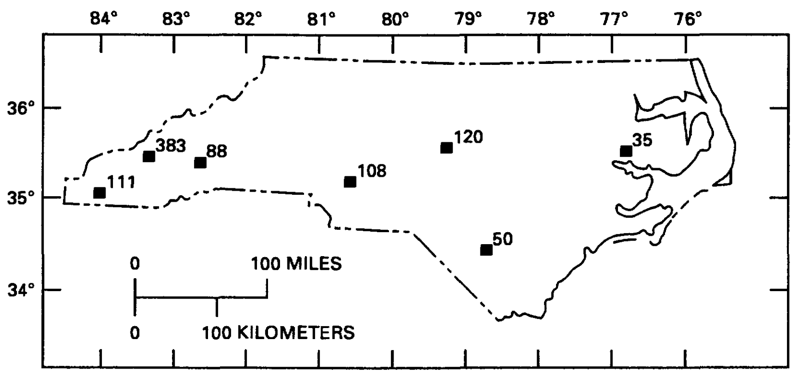
(44) AVERAGE YIELD FOR AREA



EXPLANATION

●3 ESTIMATED MEDIAN SUSPENDED-SEDIMENT CONCENTRATION, IN MILLIGRAMS PER LITER

— — APPROXIMATE BOUNDARY OF PHYSIOGRAPHIC PROVINCE



EXPLANATION

■88 MAXIMUM MEASURED SUSPENDED-SEDIMENT CONCENTRATION, IN MILLIGRAMS PER LITER

Figure 9. Estimated annual suspended-sediment yields and median and maximum suspended-sediment concentrations for streams draining forested basins (see table 5). Values represent background (pristine) conditions.

animal trails, streambanks, and areas partially devoid of litter cover. Burrowing-type animals, such as muskrats, were observed along most stream channels and, in large numbers, could accelerate bank erosion and subsequent fluvial sediment. Considerable sediment load may be generated in mountainous forested areas by debris avalanches, such as those that occurred in central Virginia as a result of Hurricane Camille (Williams and Guy, 1973); however, no hillside failures were noted during this investigation. Sediment characteristics presented herein, therefore, should be representative of long-term conditions in natural forested basins, excluding the effects of rare flood events and landslides.

The seven forested basins are well distributed across the State, with three stations located in the Blue Ridge Province, two in the Piedmont, and two in the Coastal Plain (fig. 9). Mean annual suspended-sediment yields at these sites range from 58 tons/mi^2 at Nantahala River near Rainbow Springs (site 146, fig. 1), located in Nantahala National Forest of the Blue Ridge Province, to only 5 tons/mi^2 at Ellis Creek tributary near White Oak (site 68), located in the southern Coastal Plain (fig. 9). Data from these basins indicate mean annual yields of approximately 44 tons/mi^2 for streams in the Blue Ridge and Piedmont Provinces and 5 tons/mi^2 in the Coastal Plain. A transition zone probably occurs in the vicinity of the Fall Line; values of yield probably decrease in an eastward direction within this zone (fig. 9).

The North Carolina Department of Natural Resources and Community Development (1979b) estimates that about 10 million acres of forest lands are in the Blue Ridge and Piedmont Provinces and that about 9.5 million acres are in the Coastal Plain Province. On the basis of these land-use statistics and the mean annual suspended-sediment yields from figure 9, the annual suspended-sediment contribution to the State's stream systems from forested lands, excluding any human-induced effects, is approximately 0.9 million tons.

Because of variability, comparisons of suspended-sediment concentration data between stations are most logically made during similar flow conditions. Concentrations of suspended sediment ranged from 1 to 8 mg/L (milligrams per liter) across the State (table 5) during low-flow periods when discharge was 50 to 90 percent duration. Large variations in suspended-sediment concentrations occur during high-flow periods (0.1 percent discharge duration); estimated concentrations range from 17 mg/L at Black Swamp (site 21, fig. 1) in the Coastal Plain Province to 220 mg/L at Cataloochee Creek (site 141, fig. 1) in the Blue Ridge Province. Maximum instantaneous concentrations observed during floods ranged from 35 mg/L at Black Swamp to 383 mg/L at Cataloochee Creek (table 5). Simmons and Heath (1979), in a less comprehensive study, reported suspended-sediment concentrations in flood samples for 39 forested basins varying from 5 mg/L at a Coastal Plain site to 235 mg/L at a Piedmont site. They also reported (p. 30) an average suspended-sediment concentration for the State during base runoff of about 6 mg/L, which compares favorably with the median values shown in figure 9.

Suspended sediment transported by streams includes both mineral (rock) and organic matter. Selected in-stream samples for four forested sampling sites were analyzed for organic content (fig. 10). Organic matter is relatively abundant in forested areas, and it is readily waterborne. North Carolina streams transport varying amounts of natural organic materials, ranging in size from microscopic algae to tree trunks; however, because of sediment-sampler characteristics, the size of materials discussed herein is restricted to the diameter of the sampler's intake nozzle. As shown in figure 10, the percentage of organic material in suspended sediments generally decreases as suspended-sediment concentrations and flow increase. Using

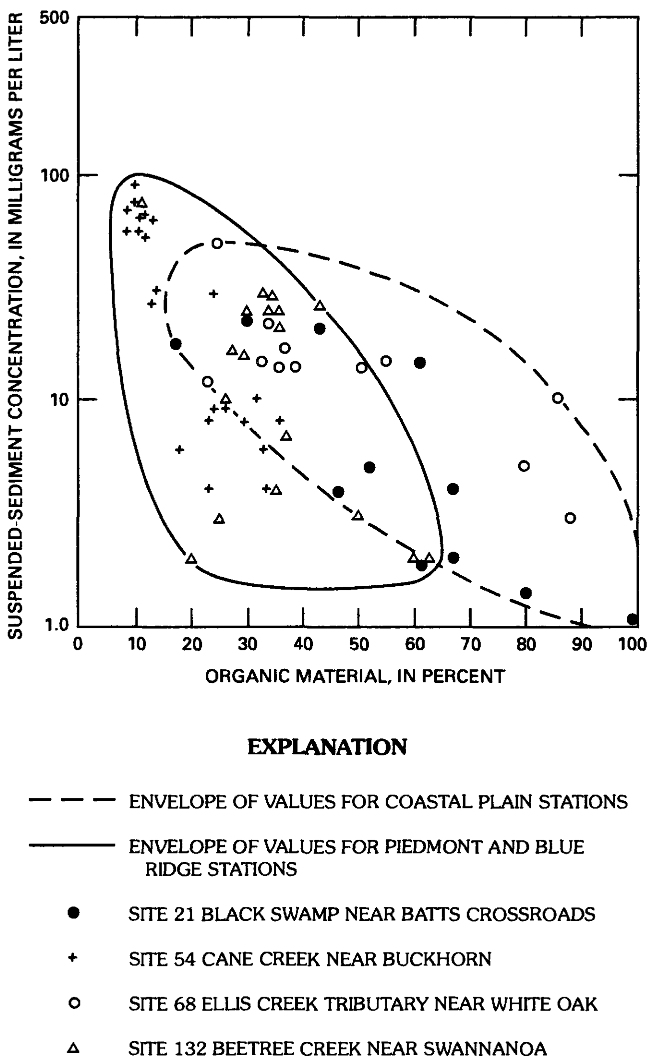


Figure 10. Relation of content of organic material in suspended sediment to concentration of suspended sediment for streams in selected forested basins.

discharge-weighted mean concentrations of suspended sediment from Black Swamp (14 mg/L), Ellis Creek (14 mg/L), Cane Creek (45 mg/L), and Beetree Creek (14 mg/L), estimates of organic material average 30 to 50 percent of suspended-sediment transport in the Coastal Plain Province and 10 to 30 percent in the Piedmont and Blue Ridge Provinces.

Forested Basins With Minor Development

Seven additional sites had essentially forested basins; however, reconnaissances through the basins indicated that each contained various land-use activities that would possibly increase fluvial transport over natural conditions (table 6). For example, the drainage basin for Flat Creek near Inverness (site 66, fig. 1) is 99 percent forested and located on the Fort Bragg Military Reservation; however, part of the basin was used periodically for military operations. The periodic fording of streams by trucks and various tracked vehicles may have accelerated bank erosion. Mean annual suspended-sediment yield of 60 tons/mi^2 for Flat Creek is significantly greater than yields of forested Piedmont sites shown in figure 9.

Forested area in the remaining six basins ranged from 88 to 98 percent but included paved and unpaved roads in close proximity to stream channels upstream of the sampling points. In addition to effects from roads, agricultural activities in the basins above Buckhorn Creek, Linville River, Jacob Fork, and South Toe River (sites 64, 107, 112, and 142, fig. 1) accounted for 6 to 12 percent of each basin's land area. Beginning in 1974, construction of summer resort homes and new roads in the Jacob Fork basin combined with existing land-use activities to produce a mean annual suspended-sediment yield of 280 tons/mi^2, the greatest yield sampled for basins exceeding 88 percent forested area. Even when forests cover over 90 percent of a basin, the presence of unpaved roads and farmlands may increase sediment considerably above background (pristine) levels if surface runoff from development activities access waterways (fig. 11).

Rural Basins Affected by Agriculture

North Carolina can be classified as a rural State. Agriculture is the State's largest industry; 115,000 farms cover 42 percent of its land area (North Carolina Soil and Water Conservation Section, 1979). Recent studies indicate that as much as 64 percent of gross erosion occurring in the State might be attributed to cropland (U.S. Department of Agriculture, 1977). Gross erosion is the total amount of soil moved from one place to another, whereas fluvial sediment, the subject of this report, is eroded soils that enter and are transported by and (or) deposited in streams. Other recent estimates indicate that agricultural lands of all types may be the source of 80 percent of the erosion in the State (North Carolina Department of Natural Resources and Community Development, 1979a). About 45 percent of the State's croplands are classified as lands having a water-erosion hazard. The significance, therefore, of agricultural lands as a major source of sediment throughout the State is well documented. In rural basins affected by agriculture, fluvial sediment is characterized with regard to general land use, not by quantified transport from site-specific land uses.

In this report, rural basins are defined as those in which agricultural activities are the primary sources of fluvial sediments above background levels. Eighty-three sampling stations are in this category, the largest category in the sampling network (table 7). Most of these basins contain residential areas, farm ponds, roads, forests, various land-clearing operations, and other human activities. Field inspections indicate, however, that agricultural-type activities are the primary source of increased sediment. The denuding and tillage of croplands increase erosion potential, but applied land-management practices and various physical factors such as soil type are controlling factors. Farm animals, such as cattle and swine, contribute to the erosional problem by destroying or altering ground cover, creating trails, and damaging streambanks. Logging trails and timber-harvesting activities related to silvicultural practices in most instances also increase sediment production (Harris, 1977).

The proximity of the erosional sources to streams causes significant variations in sediment yields from one basin to another. The proximity of tilled land to streams was not evaluated in this report; however, most farmlands in the Blue Ridge and western Piedmont Provinces are located in valleys and, as a rule, are in closer proximity to streams than in other areas of the State.

Basins in an otherwise rural environment, but having the following conditions, are excluded from this category: channelized main reach or major tributary reaches, upstream lakes and reservoirs that significantly affect flows and sediment transport at the sampling sites, major construction activities in close proximity to watercourses, land use exceeding 15 percent as urban development, and basins nearly or totally forested included in the preceding forested categories.

Sampling stations for monitoring rural basins affected by agriculture were quite uniformly located across the State, with 8 sites in the Blue Ridge, 52 sites in the Piedmont, and 23 sites in the Coastal Plain (fig. 1). This large network of sites permitted coverage of extreme ranges in rural-basin characteristics. For instance, the size of project basins ranges from 1.05 to 5,255 mi^2 (table 7), and the percentage of land used for row crops ranges from 5 to 63 percent (table 19). Data coverage of rural sites is also sufficient in some instances to show the effects of soil

Table 6. Suspended-sediment characteristics for forested basins with minor development, 1970–79

[Physiographic provinces: C, Coastal Plain; P, Piedmont; B, Blue Ridge. *r*, correlation coefficient for site sediment-transport curve defined by observed data]

Site number (fig. 1)	Name	Physiographic province	Drainage area (square miles)	Estimated mean annual suspended-sediment discharge (tons)	Estimated mean annual suspended-sediment yield (tons per square mile)	Mean daily discharge (cubic feet per second)	Estimated percentage of time indicated suspended-sediment concentration was equaled or exceeded (milligrams per liter)					Number of samples, correlation coefficient, and range in observed (measured) concentration (milligrams per liter)			
							0.1	1.0	10	50	90	Number	*r*	Maximum	Minimum
64	Buckhorn Creek near Corinth	P	76.3	5,800	76	81	190	120	51	23	9	26	0.98	329	5
66	Flat Creek nea Inverness	C	7.63	460	60	15	100	85	35	7	3	32	.83	145	1
107	Linville River near Nebo	B	66.7	7,600	110	189	260	86	14	5	2	24	.74	277	1
112	Jacob Fork at Ramsey	P	25.7	7,200	280	54	710	140	19	7	3	28	.82	2,600	2
128	Davidson River near Brevard	B	40.4	2,400	60	148	160	59	10	3	2	29	.90	555	1
136	West Fork Pigeon River above Lake Logan near Hazelwood	B	27.6	5,900	210	113	770	24	4	2	1	31	.98	721	0
142	South Toe River near Celo	B	43.3	5,500	130	169	300	180	5	2	1	44	.98	75	0

type, topography, land use, and other basin characteristics on sediment transport. Unless stated otherwise, however, the computation of mean values by physiographic province is generally restricted to data for sites of less than 400 mi^2 throughout the remainder of this report. The primary reasons for this restriction are (1) the complexities associated with the categorization increase with basin size, and proper categorization is often unsure for basins greater than several hundred square miles; and (2) most of the larger streams that originate in one province and flow into another generally tend to retain transport characteristics of the headwaters province.

The suspended-sediment concentration data listed in table 7 illustrate the variability of sediment in predominantly rural basins across the State. Concentrations during low base-flow periods (90 percent flow duration in streams having drainage areas less than 400 mi^2) are fairly consistent and range from 1 to 19 mg/L except for New Hope River near Pittsboro (31 mg/L) and South Yadkin River near Mocksville (33 mg/L), sites 57 and 93, respectively.

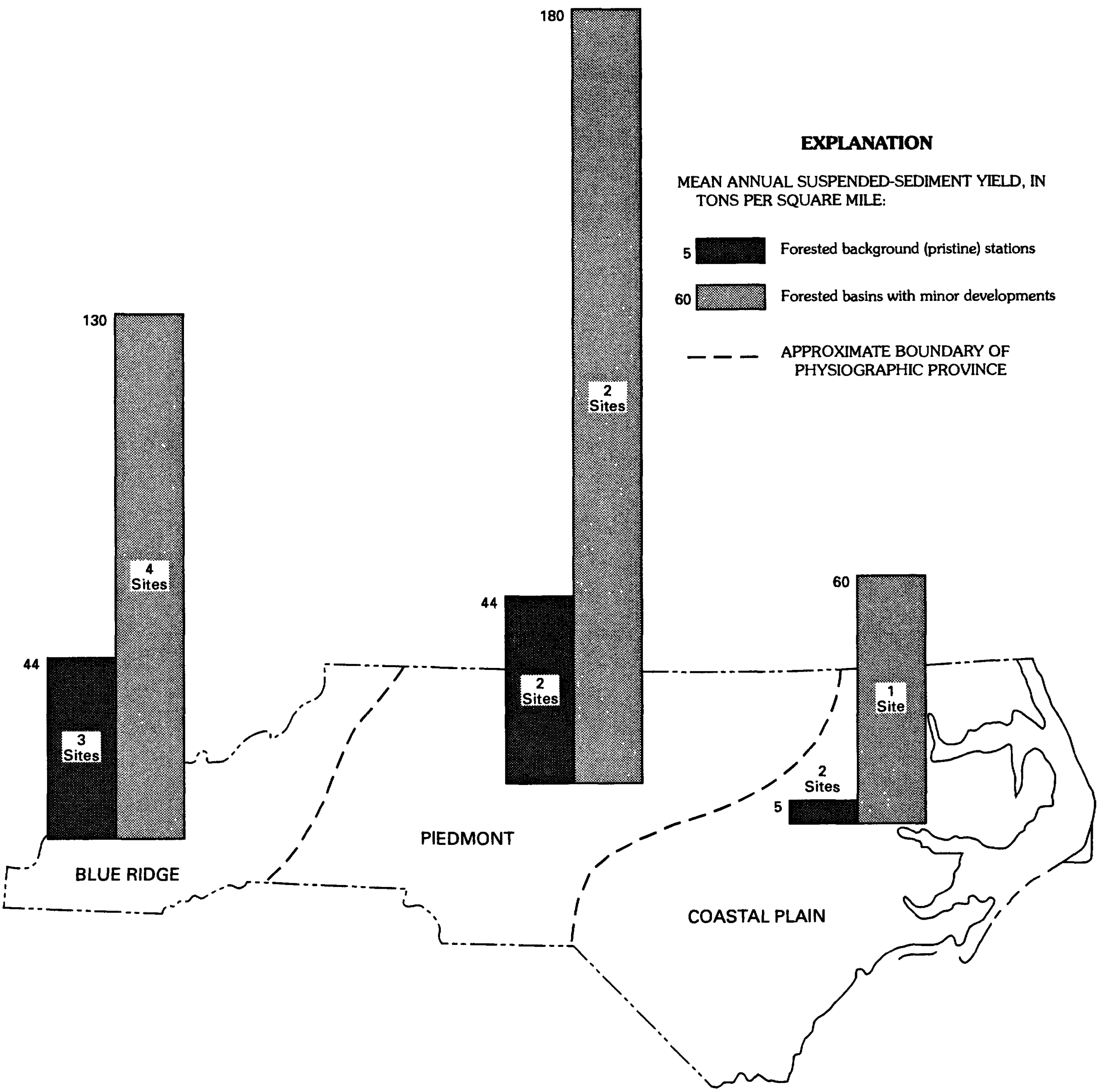


Figure 11. Comparisons of mean annual suspended-sediment yields for forested basins with and without minor development.

Table 7. Suspended-sediment characteristics for predominantly rural basins affected by agriculture, 1970–79

[Physiographic provinces: C, Coastal Plain; P, Piedmont; B, Blue Ridge. *r*, correlation coefficient for site sediment-transport curve defined by observed data]

Site number (fig. 1)	Name	Physiographic province	Drainage area (square miles)	Estimated mean annual suspended-sediment discharge (tons)	Estimated mean annual suspended-sediment yield (tons per square mile)	Mean daily discharge (cubic feet per second)	Estimated percentage of time indicated suspended-sediment concentration was equaled or exceeded (milligrams per liter)					Number of samples, correlation coefficient, and range in observed (measured) concentration (milligrams per liter)			
							0.1	1.0	10	50	90	Number	*r*	Maximum	Minimum
3	Dan River near Francisco	P	129.0	35,000	270	224	1,400	360	98	33	12	20	0.97	1,040	2
4	Dan River near Wentworth	P	1,053	460,000	440	1,450	1,400	840	240	98	47	28	.92	1,520	19
7	Hyco Creek near Leasburg	P	45.9	7,600	170	54	380	230	78	26	6	26	.86	379	3
8	Double Creek near Roseville	P	7.47	3,100	410	9	1,100	280	33	5	1	36	.99	1,780	1
9	South Hyco Creek near Roseville	P	56.5	10,000	180	66	450	270	93	39	14	21	.90	709	3
12	Tar River near Tar River	P	167	31,000	180	180	310	250	140	59	19	24	.87	463	7
13	Tar River at Louisburg	P	427	30,000	70	465	120	110	46	25	23	36	.89	243	4
14	Cedar Creek near Louisburg	P	48.2	4,800	100	49	260	160	72	40	15	22	.98	446	2
15	Swift Creek at Hilliardston	P	166	14,000	84	170	290	200	64	23	8	26	.76	278	2
16	Little Fishing Creek near White Oak	P	177	17,000	96	183	220	150	79	38	12	26	.90	207	4
17	Fishing Creek near Enfield	C	526	22,000	42	522	120	80	40	18	8	33	.71	166	4
18	Tar River at Tarboro	C	2,183	93,000	43	2,370	67	59	45	26	12	115	.74	454	5
20	Chicod Creek near Simpson	C	45.0	2,000	44	59	130	51	20	11	9	1,568	—	254	1
23	Durham Creek at Edward	C	26.0	300	12	44	14	7	7	7	6	38	.82	43	1
24	Eno River at Hillsborough	P	66.0	11,000	170	67	600	310	97	35	10	25	78	1,160	2
25	Eno River near Durham	P	141	23,000	160	141	450	290	110	37	11	33	.81	1,050	2
26	Little River near Orange Factory	P	80.4	11,000	140	81	440	230	56	22	7	29	.96	686	5
27	Flat River at Bahama	P	149	28,000	190	167	480	280	94	37	12	22	.67	104	8

Table 7. Suspended-sediment characteristics for predominantly rural basins affected by agriculture, 1970–79—Continued

[Physiographic provinces: C, Coastal Plain; P, Piedmont; B, Blue Ridge. *r*, correlation coefficient for site sediment-transport curve defined by observed data]

Site number (fig. 1)	Name	Physiographic province	Drainage area (square miles)	Estimated mean annual suspended-sediment discharge (tons)	Estimated mean annual suspended-sediment yield (tons per square mile)	Mean daily discharge (cubic feet per second)	Estimated percentage of time indicated suspended-sediment concentration was equaled or exceeded (milligrams per liter)					Number of samples, correlation coefficient, and range in observed (measured) concentration (milligrams per liter)			
							0.1	1.0	10	50	90	Number	*r*	Maximum	Minimum
28	Neuse River near Northside	P	535.0	73,000	140	548	240	210	130	47	10	32	0.83	687	5
32	Middle Creek near Clayton	P	83.5	4,500	54	89	97	78	55	27	12	32	.98	326	5
33	Little River near Kenly	C	191	7,900	42	198	83	66	41	23	10	26	.85	379	7
34	Little River near Princeton	C	232	10,000	43	255	68	64	43	22	10	27	.90	266	4
36	Bear Creek near Parkstown	C	4.27	100	23	4	60	47	19	13	7	120	.88	88	8
40	Turner Swamp near Eureka	C	2.10	94	45	3	150	46	20	9	6	31	.72	484	4
42	Contentnea Creek at Hookerton	C	729	20,000	27	788	31	30	28	23	19	55	.89	76	6
43	Little Contentnea Creek near Farmville	C	93.3	3,300	35	121	52	42	27	14	8	39	.97	362	3
44	Creeping Swamp near Calico	C	9.80	280	29	17	30	22	16	10	7	48	.86	97	1
45	Creeping Swamp near Vanceboro	C	27	920	34	44	49	29	17	11	7	1,543	—	110	3
47	Palmetto Swamp near Vanceboro	C	24.2	1,000	41	39	70	39	21	12	7	56	.92	159	4
48	Trent River near Trenton	C	168	1,900	11	210	17	17	10	5	2	48	.91	84	1
49	Reedy Fork near Oak Ridge	P	20.6	5,200	250	26	1,100	390	75	45	14	35	.86	3,800	11
53	Big Alamance Creek near Elon College	P	116	23,000	200	124	550	340	110	38	12	34	.80	975	6
55	Cane Creek near Teer	P	33.7	4,900	150	32	320	230	120	66	15	19	.90	578	3
56	Haw River near Bynum	P	1,277	180,000	140	1,400	460	310	66	19	8	33	.80	922	3
57	New Hope River near Pittsboro	P	288	23,000	80	327	110	96	81	67	31	29	.71	352	26
60	Deep River near Randleman	P	125	26,000	210	154	580	360	75	30	17	26	.89	508	7

Table 7. Suspended-sediment characteristics for predominantly rural basins affected by agriculture, 1970–79—Continued

[Physiographic provinces: C, Coastal Plain; P, Piedmont; B, Blue Ridge. *r*, correlation coefficient for site sediment-transport curve defined by observed data]

Site number (fig. 1)	Name	Physiographic province	Drainage area (square miles)	Estimated mean annual suspended-sediment discharge (tons)	Estimated mean annual suspended-sediment yield (tons per square mile)	Mean daily discharge (cubic feet per second)	Estimated percentage of time indicated suspended-sediment concentration was equaled or exceeded (milligrams per liter)					Number of samples, correlation coefficient, and range in observed (measured) concentration (milligrams per liter)			
							0.1	1.0	10	50	90	Number	*r*	Maximum	Minimum
61	Deep River at Ramseur	P	349.0	62,000	180	414	650	290	60	28	15	24	0.91	941	9
62	Tick Creek near Mount Vernon Springs	P	15.5	4,200	270	17	1,200	260	41	22	11	30	.94	319	5
63	Deep River at Moncure	P	1,434	190,000	130	1,650	180	180	120	38	8	34	.95	690	2
65	Cape Fear River at Lillington	P	3,464	420,000	120	3,840	350	270	96	20	5	49	.82	618	2
67	Cape Fear River near Tar Heel	C	4,852	330,000	68	5,410	210	160	66	26	8	29	.83	334	6
69	Cape Fear River near Kelly	C	5,255	290,000	55	6,100	100	83	55	27	15	114	.86	186	4
70	Little Coharie Creek near Roseboro	C	92.8	1,200	13	128	13	11	10	8	6	35	.81	50	2
71	Black River near Tomahawk	C	676	8,400	12	868	16	13	11	8	5	32	.82	26	1
72	South River near Parkersburg	C	379	2,500	7	445	8	7	6	5	5	31	.88	30	1
73	Northeast Cape Fear River near Chinquapin	C	599	9,000	15	822	16	15	12	9	4	31	.74	226	1
76	Waccamaw River at Freeland	C	680	5,500	8	812	8	7	7	7	6	34	.57	47	1
77	Yadkin River at Patterson	P	28.8	11,000	380	60	2,500	630	50	10	5	32	.81	2,050	1
78	Elk Creek at Elkville	P	48.1	21,000	440	119	1,200	480	81	14	4	27	.97	1,520	1
80	Roaring River at Roaring River	P	128	42,000	330	219	1,700	870	55	19	4	25	.99	2,180	3
81	Yadkin River at Elkin	P	869	300,000	350	1,630	1,100	710	160	37	19	25	.97	1,210	8
82	Mitchell River near State Road	P	78.8	17,000	220	143	1,500	300	40	15	7	31	.94	2,190	3
83	Fisher River near Copeland	P	128	45,000	350	211	1,600	650	69	18	7	25	.92	3,730	2
84	Yadkin River at Siloam	P	1,226	480,000	390	2,180	1,200	710	240	46	19	26	.97	2,240	13

Table 7. Suspended-sediment characteristics for predominantly rural basins affected by agriculture, 1970–79—Continued

[Physiographic provinces: C, Coastal Plain; P, Piedmont; B, Blue Ridge. *r*, correlation coefficient for site sediment-transport curve defined by observed data]

Site number (fig. 1)	Name	Physiographic province	Drainage area (square miles)	Estimated mean annual suspended-sediment discharge (tons)	Estimated mean annual suspended-sediment yield (tons per square mile)	Mean daily discharge (cubic feet per second)	Estimated percentage of time indicated suspended-sediment concentration was equaled or exceeded (milligrams per liter)					Number of samples, correlation coefficient, and range in observed (measured) concentration (milligrams per liter)			
							0.1	1.0	10	50	90	Number	*r*	Maximum	Minimum
85	Ararat River at Ararat	P	231.0	99,000	430	351	2,600	720	81	23	8	29	0.96	2,400	5
87	Yadkin River at Enon	P	1,694	800,000	470	2,930	906	750	390	66	30	21	.99	1,140	17
92	Humpy Creek near Fork	P	1.05	200	190	1	740	310	31	18	13	25	.98	746	8
93	South Yadkin River near Mocksville	P	306	90,000	290	408	640	510	210	97	33	33	.94	1,310	12
94	Hunting Creek near Harmony	P	155	68,000	440	247	1,200	830	160	42	19	43	.92	1,860	11
95	Leonard Creek near Bethesda	P	5.16	2,000	390	5	1,300	850	90	27	7	131	.96	1,750	12
97	Big Bear Creek near Richfield	P	55.6	11,000	200	61	860	210	22	6	3	28	.97	982	1
98	Gourdvine Creek near Olive Branch	P	8.75	2,500	290	9	690	210	21	18	10	146	.95	730	2
99	Lanes Creek near Trinity	P	4.92	1,100	220	5	450	210	41	25	12	124	.94	1,040	4
100	Wicker Branch near Trinity	P	5.83	880	150	6	210	130	24	8	6	135	.96	761	4
101	Rocky River near Norwood	P	1,372	270,000	200	1,570	420	340	100	20	10	33	.90	538	3
102	Little River near Star	P	106	15,000	140	128	570	260	26	14	9	29	.86	971	5
104	Drowning Creek near Hoffman	C	183	2,000	11	275	11	10	8	7	5	30	.93	31	1
105	Lumber River at Boardman	C	1,228	15,000	12	1,500	11	11	10	9	9	39	.73	24	2
106	Catawba River near Marion	P	172	61,000	360	413	1,200	540	100	21	6	32	.98	1,760	3
111	Henry Fork near Henry River	P	83.2	13,000	160	157	630	180	29	8	3	26	.81	1,120	1
113	Long Creek near Bessemer City	P	31.8	11,000	340	42	1,100	540	100	39	14	28	.87	1,820	9
120	Twelve Mile Creek near Waxhaw	P	76.5	18,000	240	76	550	430	100	22	9	25	.92	904	3

Table 7. Suspended-sediment characteristics for predominantly rural basins affected by agriculture, 1970–79—Continued

[Physiographic provinces: C, Coastal Plain; P, Piedmont; B, Blue Ridge. *r*, correlation coefficient for site sediment-transport curve defined by observed data]

Site number (fig. 1)	Name	Physiographic province	Drainage area (square miles)	Estimated mean annual suspended-sediment discharge (tons)	Estimated mean annual suspended-sediment yield (tons per square mile)	Mean daily discharge (cubic feet per second)	Estimated percentage of time indicated suspended-sediment concentration was equaled or exceeded (milligrams per liter)					Number of samples, correlation coefficient, and range in observed (measured) concentration (milligrams per liter)			
							0.1	1.0	10	50	90	Number	*r*	Maximum	Minimum
121	Cove Creek near Lake Lure	P	79.0	30,000	380	166	1,400	680	110	28	8	25	0.96	2,270	4
122	Second Broad River at Cliffside	P	220	50,000	230	374	1,100	420	56	23	12	36	.98	1,080	7
124	First Broad River near Casar	P	60.5	15,000	250	102	1,700	280	27	7	2	29	.94	1,290	1
127	French Broad River at Rosman	B	67.9	13,000	190	274	380	160	29	11	4	31	.87	2,080	2
129	French Broad River at Blantyre	B	296	78,000	260	1,210	400	190	65	31	15	33	.60	643	3
130	Mills River near Mills River	B	66.7	6,700	100	200	200	130	33	9	2	29	.89	471	1
131	French Broad River at Bent Creek	B	676	160,000	240	1,950	710	300	77	24	9	32	.87	820	4
138	East Fork Pigeon River near Canton	B	51.5	4,600	89	163	210	75	16	5	2	35	.87	1,230	1
143	Watauga River near Sugar Grove	B	92.1	13,000	140	221	190	96	54	31	9	32	.84	1,200	2
144	Cartoogechaye Creek near Franklin	B	57.1	11,000	190	155	620	210	57	19	8	28	.75	826	4
149	Oconaluftee River near Birdtown	B	184	23,000	130	560	430	170	31	7	2	37	.83	474	1

Minimum observed concentrations (in streams with less than 400 mi^2 of drainage area) range from 1 to 12 mg/L during extreme low-flow periods, except for New Hope River near Pittsboro (26 mg/L), and are generally lower than those for 90-percent flow duration. Comparisons of mean concentrations by physiographic province (fig. 12) indicate little difference in values during low flow (90-percent flow duration). Variations are more pronounced for median- and high-flow conditions (50- and 0.1-percent flow duration, respectively).

The effects of basin characteristics, such as soil types, topography, and land use, on sediment transport are markedly evident during intense storm runoff. For sites less than 400 mi^2, concentrations of suspended sediment in rural basins affected by agriculture for high-flow conditions (0.1-percent flow duration) ranged from 8 mg/L at South River near Parkersburg (site 72, fig. 1) and at Waccamaw River at Freeland (site 76, fig. 1) in the Coastal Plain Province to 2,600 mg/L at Ararat River at Ararat (site 85) in the western Piedmont Province. Variation of mean concentration of suspended sediment for rural stations during high-flow conditions is shown in figure 13; isopleths closely reflect boundaries of major soil groups discussed previously (fig. 4). Concentrations are also somewhat regionalized, with maximum values occurring primarily in the western Piedmont and minimum values in the Coastal Plain. For sites less than 400 mi^2 in size, maximum observed instantaneous concentrations for storms range from 30 mg/L at South River near Parkersburg (site 72) in the southern Coastal Plain to 3,800 mg/L at Reedy Fork near Oak Ridge (site 49) in the central Piedmont (table 7).

Concentrations of sediment at subject network stations are not representative of conditions at small-acreage, site-specific locations. For example, suspended-sediment samples collected in 1985 during storms at two agricultural sites in the Reedy Fork basin, 6 mi northeast of Greensboro (fig. 2), had maximum concentrations greater than 50,000 mg/L (U.S. Geological Survey, unpublished data, 1985). These values contrast sharply with the maximum sampled concentration of 3,800 mg/L for site 49 on Reedy Fork near Oak Ridge, only a few miles away, which occurred during a much more intense storm than for the preceding event. The drainage area of the Reedy Fork near Oak Ridge site is 20.6 mi^2, or 13,200 acres, as compared with 6 acres each for the two agricultural sites. In 1982, Blake (1984) measured suspended-sediment concentrations during storm runoff from a 10-acre soybean field located in the upper Neuse River basin about 12 mi northeast of Raleigh (fig. 2). Maximum concentrations reported by Blake for two storms exceeded 20,000 mg/L, or more than 10 times greater than maximum values observed at nearby sites with larger basins in the statewide network. The ability of small-acreage watersheds to produce greater unit concentrations of fluvial sediment than much larger watersheds is not unique to North Carolina. Maner (1962), Roehl (1962), Guy (1970a), and others discuss similar findings throughout much of the Nation. High concentrations produced by small-acreage sources diminish rapidly in a downstream direction as suspended materials are entrapped by vegetation or redeposited at toes of slopes, on flood plains, and in channels. This point is raised to again emphasize that the sediment characteristics discussed herein are representative of the State's perennial streams and reflect conditions at sampling sites exceeding 1 mi^2 in size.

Except during prolonged periods of low flow, sediment concentrations in rural Coastal Plain streams that are affected by agriculture and originate in the Piedmont are often greater than simultaneous concentrations in those streams originating in the Coastal Plain. As shown in figure 14, concentrations in the Cape Fear River during high-flow conditions (0.1-percent flow duration) are 2 to 30 times greater than those of Coastal Plain tributary streams. The addition of lower concentration waters from Coastal Plain tributaries has a diluting effect on sediment characteristics of the Cape Fear River, but concentrations of the most downstream station, Cape Fear River near Kelly (site 69, fig. 1), are still not representative of streams originating in the Coastal Plain. Similar differences occur in the Neuse and Tar Rivers and probably in other large Piedmont streams that cross the Coastal Plain. The abundance of clayey soils in the Piedmont Province is a major contributing factor. Stream velocities decrease considerably as Piedmont streams, such as the Cape Fear River, flow across the broad Coastal Plain; however, velocities are usually sufficient to keep clay-sized materials from the Piedmont in suspension well into the coastal estuaries.

A statewide plot of suspended-sediment yield values from table 7 is shown in figure 15 for rural sites affected by agriculture and having drainage areas less than 400 mi^2 in size. As with suspended-sediment concentration data shown previously in figure 13, values of mean annual suspended-sediment yield are greatest in the northwestern Piedmont and least in the southern and extreme eastern Coastal Plain. The maximum difference between site values ranges from 7 tons/mi^2 at South River near Parkersburg (site 72, fig. 1) to 440 tons/mi^2 at Elk Creek at Elkville (site 78) and Hunting Creek near Harmony (site 94). The range in yield values is further highlighted by the isopleths shown in figure 15, which indicate a dramatic twelvefold increase in yields from the Coastal Plain to the western Piedmont. Locations of these isopleths are also in close agreement with boundaries of major soil units (fig. 4). Most likely an even greater range in yield values would exist if small-acreage sites had been included in the network; however, the minimum basin size (site 92, table 7) was 1.05 mi^2 (670 acres).

Differences in sediment characteristics between major river basins are dramatically shown in figure 16. These data reflect conditions in rural, unregulated basins affected by agriculture of less than 400 mi^2 in size.

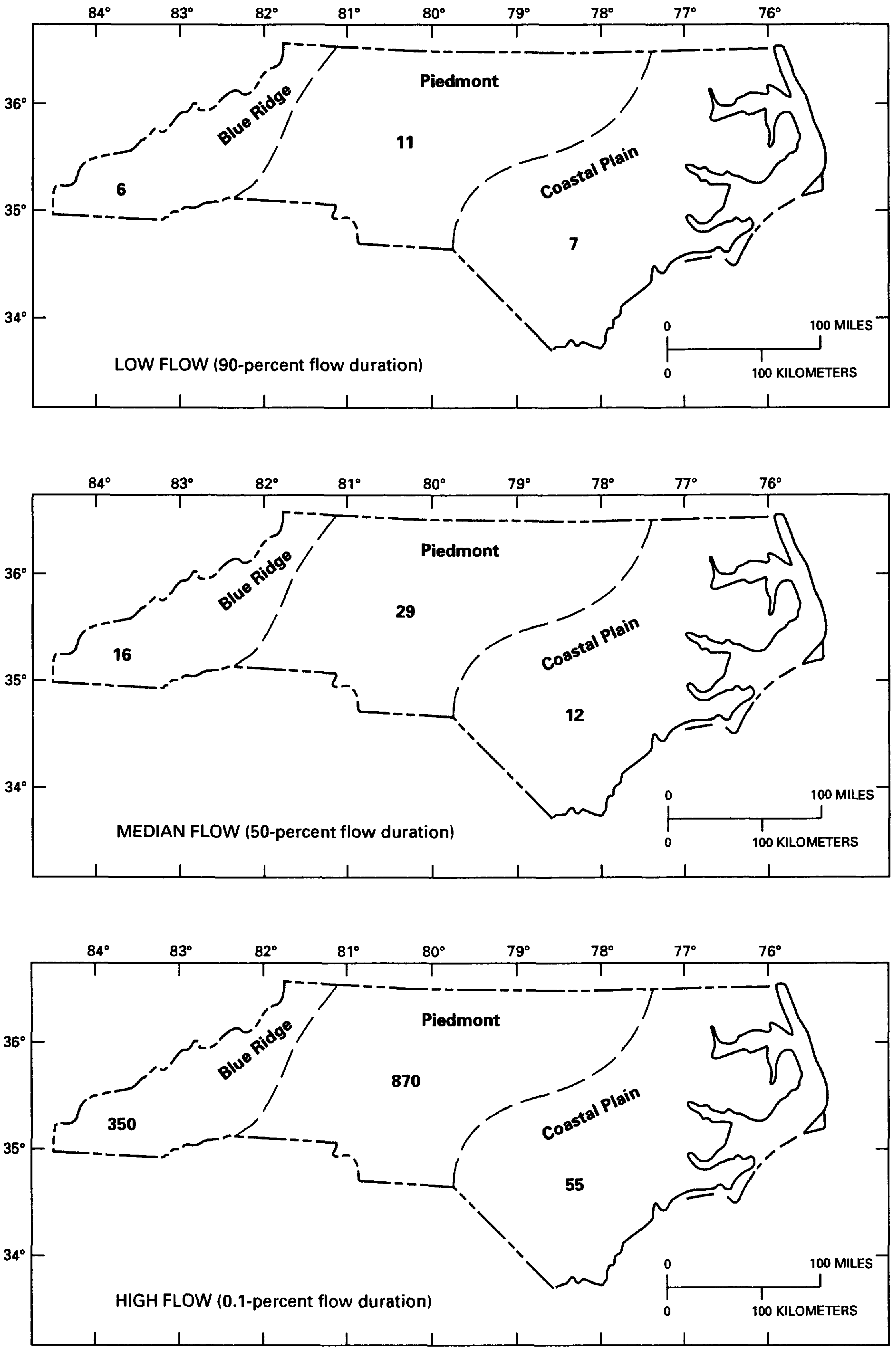


Figure 12. Mean concentrations of suspended-sediment (in milligrams per liter) by province for selected flow conditions in predominantly rural basins affected by agriculture. Mean concentrations calculated for basins less than 400 mi^2 in area.

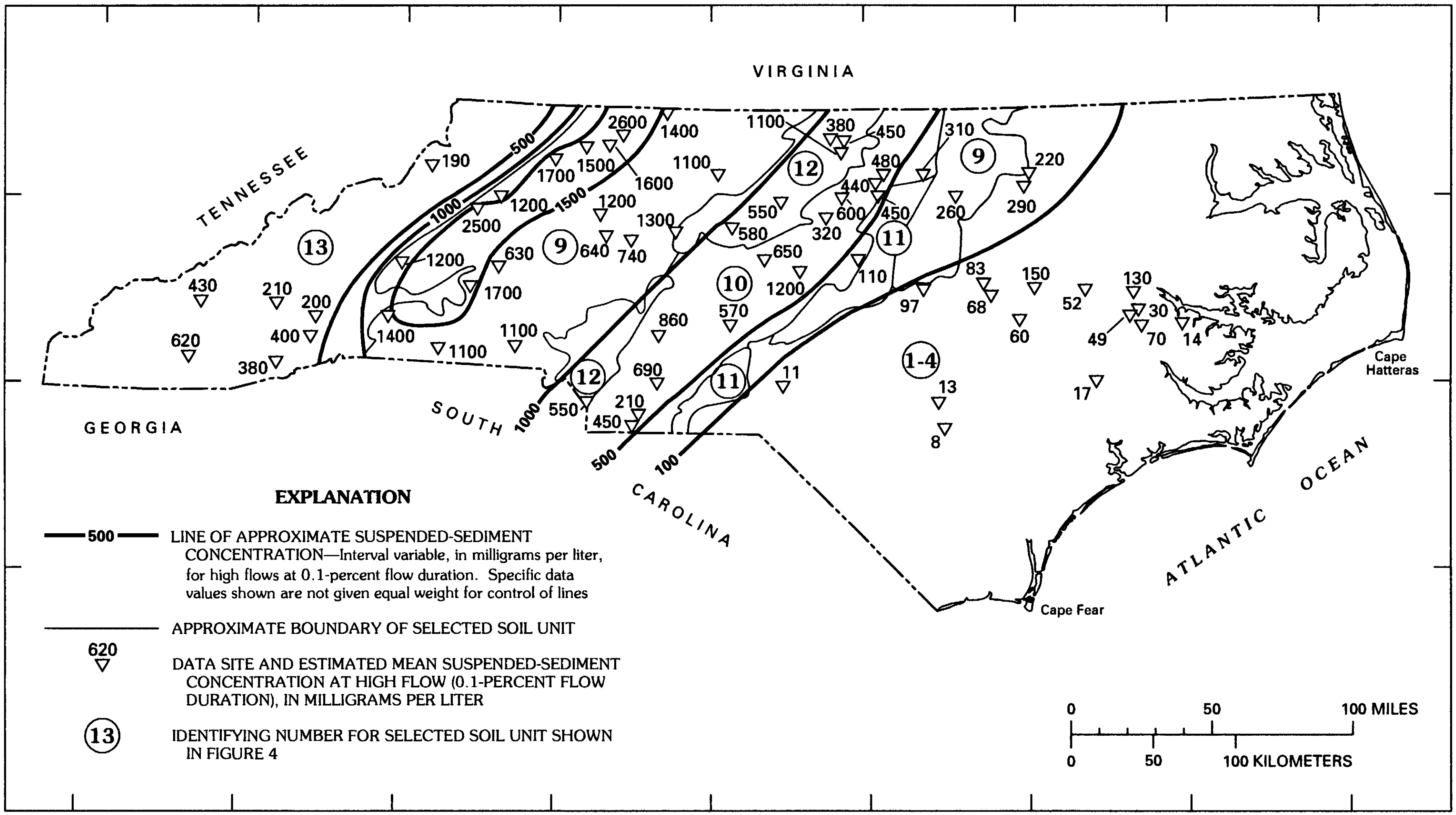


Figure 13. Major soil units and approximate mean concentration of suspended sediment during high flow (0.1-percent flow duration) for predominantly rural basins affected by agriculture. Mean concentrations calculated for basins less than 400 mi² in area.

Rural Basins Affected by Nonagricultural Activities

In addition to being affected by row-cropping and related agricultural operations, sediment characteristics at 38 predominantly rural study basins were also significantly affected by nonagricultural activities, such as channelization and highway construction (table 8). Quantification of sediment by specific activity was not possible, as nearly all sites were affected by more than

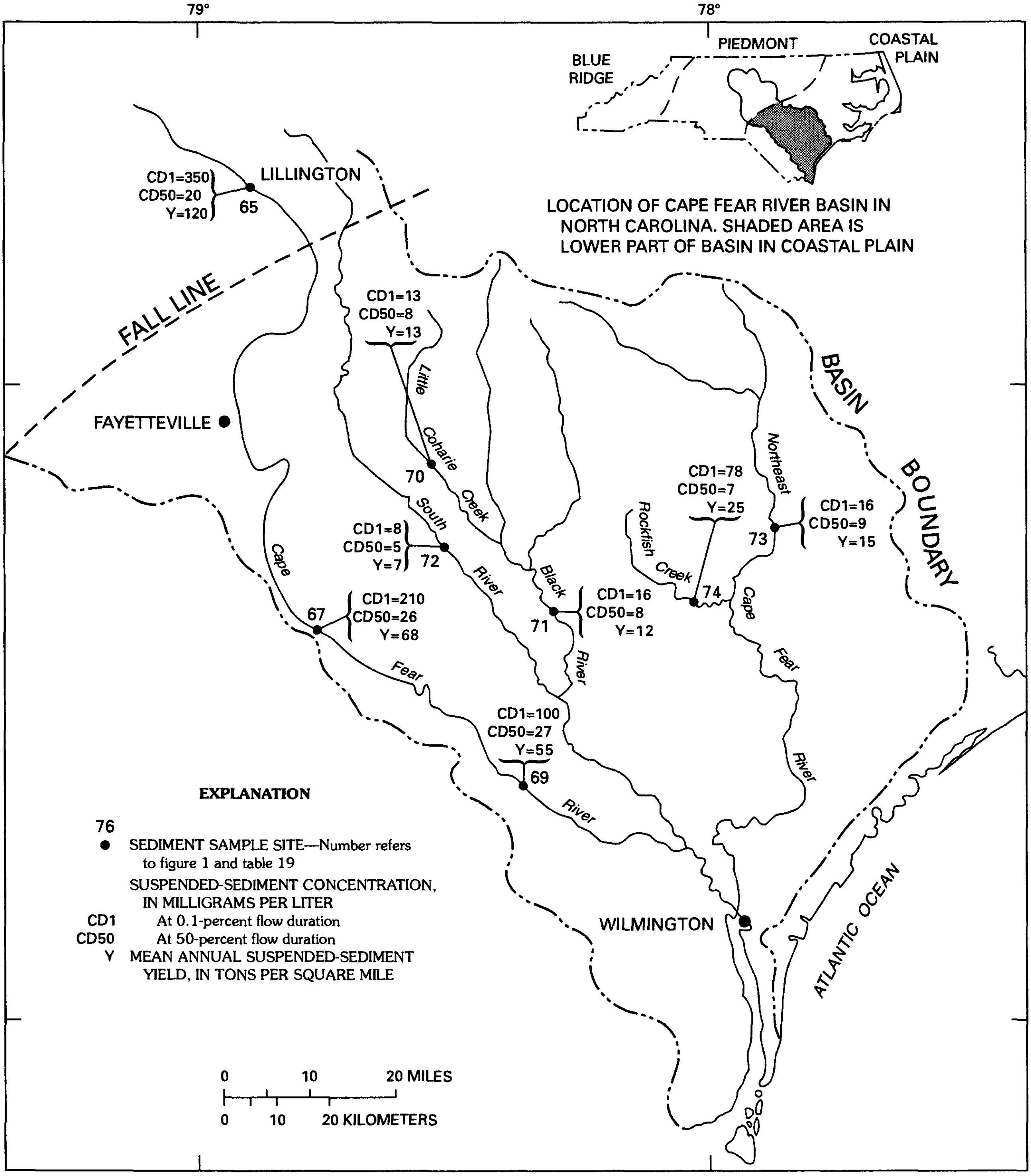


Figure 14. Suspended-sediment characteristics in lower Cape Fear River basin.

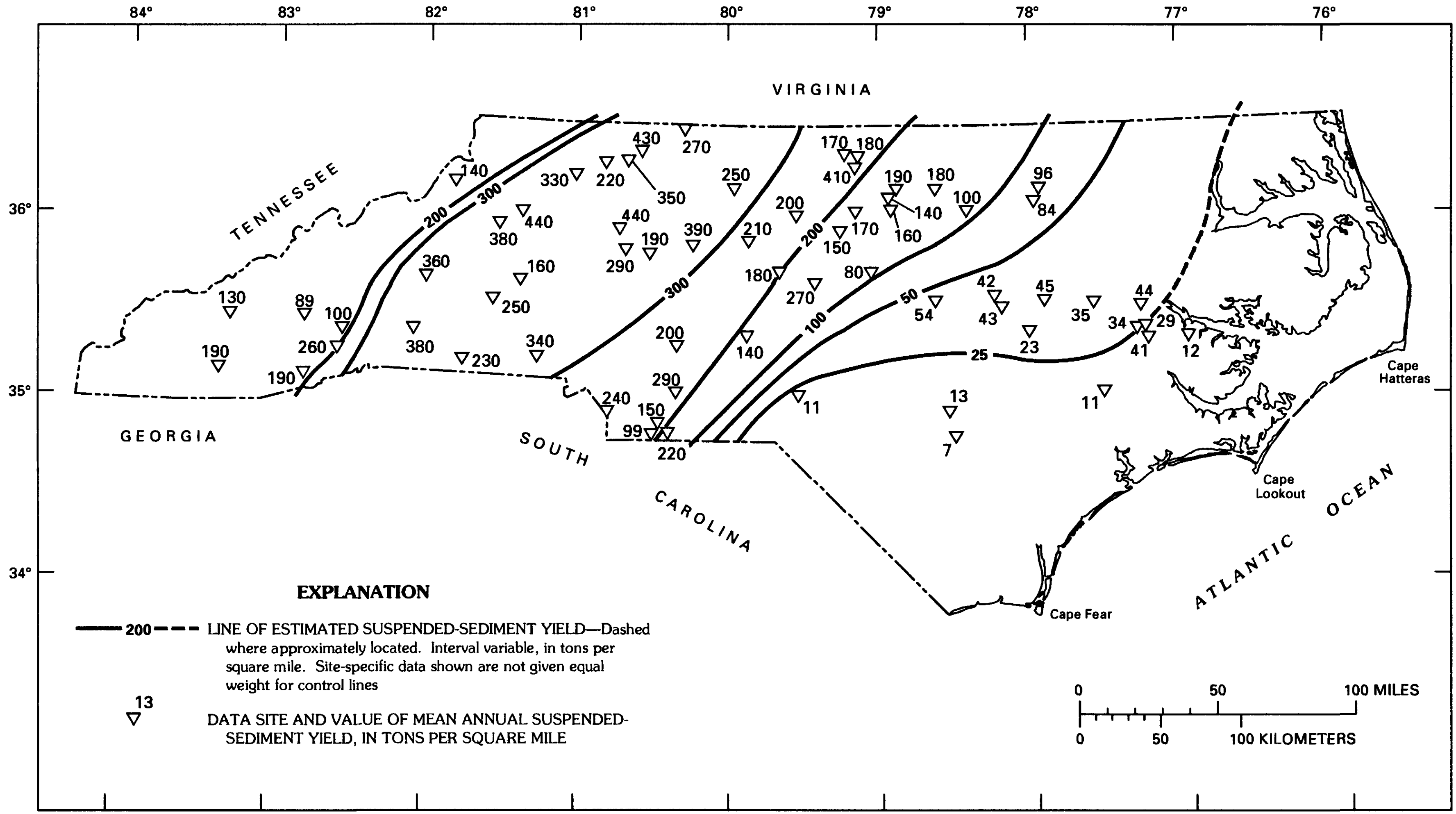


Figure 15. Mean annual suspended-sediment yield for predominantly rural basins affected by agriculture.

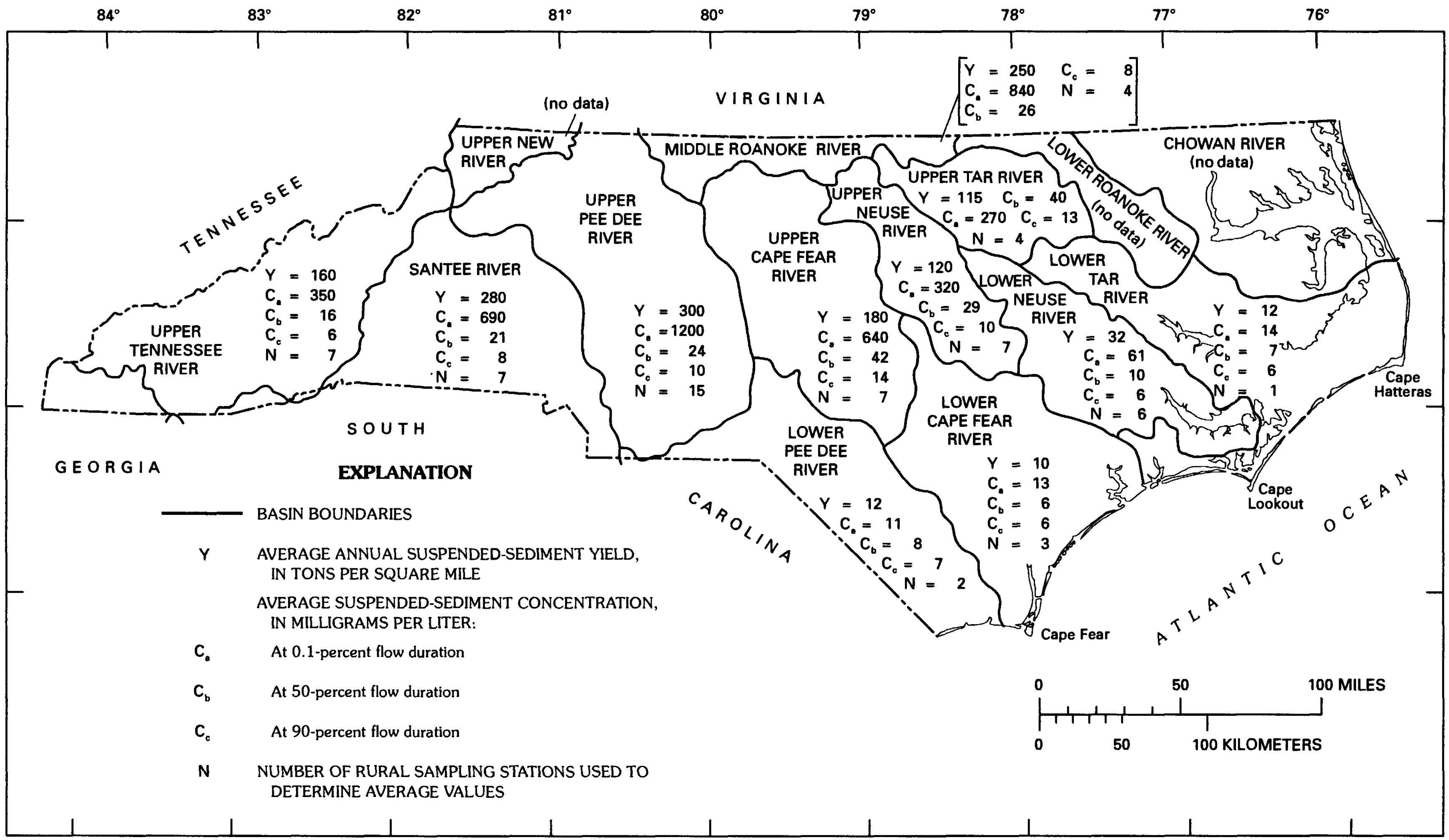


Figure 16. Selected suspended-sediment characteristics, by major river basin, for predominantly rural basins affected by agriculture.

Table 8. Suspended-sediment yields and related characteristics of rural basins affected by nonagricultural activities in addition to agricultural operations, 1970–79

[Physiographic provinces: C, Coastal Plain; P, Piedmont; B, Blue Ridge. *r*, correlation coefficient for site sediment-transport curve defined by observed data. Letter(s) following site name indicate(s) primary source of nonagricultural activity affecting sediment characteristics: c, channelization; h, highway or other large-scale construction; r, reservoir trapping effect; u, urban and municipal construction]

Site number (fig. 1)	Name	Physiographic province	Drainage area (square miles)	Estimated mean annual suspended-sediment discharge (tons)	Estimated mean annual suspended-sediment yield (tons per square mile)	Mean daily discharge (cubic feet per second)	Estimated percentage of time indicated suspended-sediment concentration was equaled or exceeded (milligrams per liter)					Number of samples, correlation coefficient, and range in observed (measured) concentration (milligrams per liter)			
							0.1	1.0	10	50	90	Number	*r*	Maximum	Minimum
1	Potecasi Creek near Union (c)	C	225.0	10,000	44	264	62	54	41	24	11	26	0.87	255	8
2	Ahoskie Creek at Ahoskie (c,u)	C	63.3	4,500	71	70	130	110	55	21	11	41	.79	404	4
5	Smith River at Eden (u,h)	P	538	130,000	240	741	2,000	760	71	25	11	26	.84	1,600	2
6	Dan River near Mayfield (h,u)	P	1,778	630,000	350	2,380	1,500	930	180	55	19	48	.86	2,290	5
10	Roanoke River at Roanoke Rapids (r)	P	8,384	100,000	12	9,270	16	16	13	9	6	91	.84	41	1
11	Roanoke River near Scotland Neck (r)	C	8,671	160,000	18	9,550	19	19	18	17	15	38	.89	31	8
19	Conetoe Creek near Bethel (c)	C	78.1	5,600	72	88	200	210	30	10	3	26	.76	579	1
22	Herring Run near Washington (c,u)	C	15.1	2,900	190	11	1,500	480	100	17	5	33	.85	2,340	3
29	Neuse River near Falls (u,h)	P	772	140,000	180	831	400	320	150	31	8	74	.68	926	4
30	Neuse River near Clayton (u,h)	P	1,150	220,000	190	1,170	570	460	160	20	5	95	.90	1,770	3
31	Neuse River at Smithfield (u,h)	P	1,206	220,000	180	1,340	400	330	170	39	11	38	.84	544	10
35	Neuse River near Goldsboro (u,h)	C	2,399	150,000	63	2,660	69	69	63	44	19	30	.58	386	19
37	Neuse River at Kinston (u,h)	C	2,690	84,000	31	3,010	28	28	26	25	25	123	.82	78	8
38	Contentnea Creek near Lucama (r)	C	161	7,600	47	162	68	67	50	28	12	19	.88	74	7
41	Nahunta Swamp near Shine (c)	C	80.4	5,100	63	92	160	110	51	25	12	27	.87	375	4
46	Swift Creek near Vanceboro (c)	C	182	12,000	66	234	110	81	51	32	19	29	.76	303	5

Table 8. Suspended-sediment yields and related characteristics of rural basins affected by nonagricultural activities in addition to agricultural operations, 1970–79—Continued

[Physiographic provinces: C, Coastal Plain; P, Piedmont; B, Blue Ridge. *r*, correlation coefficient for site sediment-transport curve defined by observed data. Letter(s) following site name indicate(s) primary source of nonagricultural activity affecting sediment characteristics: c, channelization; h, highway or other large-scale construction; r, reservoir trapping effect; u, urban and municipal construction]

Site number (fig. 1)	Name	Physiographic province	Drainage area (square miles)	Estimated mean annual suspended-sediment discharge (tons)	Estimated mean annual suspended-sediment yield (tons per square mile)	Mean daily discharge (cubic feet per second)	Estimated percentage of time indicated suspended-sediment concentration was equaled or exceeded (milligrams per liter)					Number of samples, correlation coefficient, and range in observed (measured) concentration (milligrams per liter)			
							0.1	1.0	10	50	90	Number	*r*	Maximum	Minimum
50	Reedy Fork near Gibsonville (r)	P	131.0	13,000	99	102	500	290	28	19	16	35	0.97	611	7
52	Haw River at Haw River (u,h)	P	606	160,000	260	647	750	560	170	36	12	33	.73	1,620	8
58	Haw River near Haywood (u,h)	P	1,689	280,000	170	1,840	400	320	160	45	16	37	.88	959	8
74	Rockfish Creek near Wallace (c)	C	69.3	1,700	25	102	78	30	9	7	7	30	.56	91	1
79	Reddies River at North Wilkesboro (h,u)	P	89.2	44,000	490	181	2,900	1,000	31	9	5	28	.99	3,970	3
86	Little Yadkin River at Dalton (h)	P	42.8	26,000	610	54	2,400	1,200	55	16	8	27	.94	3,020	6
91	Yadkin River at Yadkin College (u,h)	P	2,280	1,200,000	530	3,550	1,500	1,000	380	110	28	3,821	—	1,670	5
103	Pee Dee River near Rockingham (r)	P	6,860	380,000	55	9,640	70	70	48	25	17	97	.90	147	5
109	Lower Little River near All Healing Springs (h,u)	P	28.2	22,000	790	45	2,400	670	81	25	9	31	.74	5,600	8
123	Broad River near Boiling Springs (h,u)	P	875	340,000	390	1,850	780	710	210	48	11	32	.96	1,710	8
126	South Fork New River near Jefferson (h)	B	205	75,000	370	527	1,700	320	44	17	8	27	.82	1,840	1
134	French Broad River at Asheville (u,h)	B	945	390,000	410	2,400	1,100	640	160	43	12	28	.96	1,510	6
135	French Broad River at Marshall (u,h)	B	1,332	670,000	500	2,820	3,000	950	170	44	13	85	.72	10,800	3
137	West Fork Pigeon River below Lake Logan near Waynesville (r)	B	55.3	1,500	27	179	77	26	6	3	1	30	.99	331	1
139	Pigeon River at Canton (r,h)	B	133	7,200	54	372	150	55	13	4	2	30	.94	851	1
140	Pigeon River near Hepco (u,h)	B	350	65,000	190	772	610	260	68	31	18	59	.86	1,500	6

Table 8. Suspended-sediment yields and related characteristics of rural basins affected by nonagricultural activities in addition to agricultural operations, 1970–79—Continued

[Physiographic provinces: C, Coastal Plain; P, Piedmont; B, Blue Ridge. *r*, correlation coefficient for site sediment-transport curve defined by observed data. Letter(s) following site name indicate(s) primary source of nonagricultural activity affecting sediment characteristics: c, channelization; h, highway or other large-scale construction; r, reservoir trapping effect; u, urban and municipal construction]

Site number (fig. 1)	Name	Physiographic province	Drainage area (square miles)	Estimated mean annual suspended-sediment discharge (tons)	Estimated mean annual suspended-sediment yield (tons per square mile)	Mean daily discharge (cubic feet per second)	Estimated percentage of time indicated suspended-sediment concentration was equaled or exceeded (milligrams per liter)					Number of samples, correlation coefficient, and range in observed (measured) concentration (milligrams per liter)			
							0.1	1.0	10	50	90	Number	*r*	Maximum	Minimum
145	Little Tennessee at Needmore (h)	B	436.0	110,000	250	1,190	670	350	83	22	7	31	0.81	705	3
147	Nantahala River at Nantahala (r)	B	144	5,900	41	546	150	46	9	5	2	23	.99	251	1
148	Tuckasegee River at Dillsboro (r,h)	B	347	100,000	290	909	1,600	440	110	22	5	25	.67	1,590	1
150	Tuckasegee River at Bryson City (h,u)	B	655	150,000	230	1,810	840	270	90	32	12	32	.94	1,650	4
151	Hiwassee River above Murphy (r)	B	406	28,000	69	1,026	140	87	34	13	6	23	.92	397	3
152	Valley River at Tomotla (h,u)	B	104	27,000	260	280	520	270	88	31	10	26	.84	1,420	5

one activity. In some instances, the effects of upstream reservoirs were pronounced, and the effects of urban activities were noticeable at several sites.

The categorization of rural sites was often difficult because of the diverse land-use activities underway in many of the larger basins. For example, the Yadkin River at Patterson (site 77, fig. 1) was relatively simple to classify as rural, because land use in this 28.8-mi^2 basin was 16 percent agricultural and 5 percent urban; no major construction or other development occurred during the study period. However, the Yadkin River at Yadkin College basin (site 91) is 2,280 mi^2 in size and includes runoff from many small towns and part of a major city, Winston-Salem (population 132,000 in 1980). Land use upstream of Yadkin College is approximately 30 percent agricultural and 7 percent urban. Although only a relatively small part of the basin is urbanized, many large-scale developments occur along or near watercourses and may increase fluvial sediment considerably more than the small urban land-use percentage implies. Therefore, data from the Yadkin College site and similar sites shown in table 8 were not used to categorize rural-agricultural conditions, but rather to show the effects on suspended sediment of nonagricultural activities in an otherwise rural environment. A brief discussion of rural basins affected by nonagricultural activities follows.

Channelization

Seven sampling sites (Nos. 1, 2, 19, 22, 41, 46, and 74, fig. 1), located in the Coastal Plain Province, were affected by channelization of main stream and tributary channels (table 8, symbol c). No large-scale channel excavation occurred during 1970–79; therefore, data for these sites reflect post-channel-construction conditions. A study of the Black River in Harnett County (Simmons and Watkins, 1982) showed that levels of suspended sediment increased more than tenfold during the excavation phase, but that within a year following excavation, levels had decreased to about 5 times those of preexcavation levels. Although channel excavations at the subject sites generally occurred in the 1950's and early 1960's, mean concentrations and yields of suspended sediment during the 1970–79 study period were generally several times greater than for nearby unchannelized rural streams. Factors associated with channel excavations in the Coastal Plain that tend to increase sediment transport include alteration of the natural pool and ripple characteristics, washoff from spoil piles, failure of excavated channel banks, and increased flow velocities; these are discussed in detail by Simmons and Watkins (1982) and Watkins and Simmons (1984).

Using the preceding data, we can approximate the long-term effects of channelization on sediment transport. For this example, the Swift Creek near Vanceboro (site 46, table 8), which is a rural site affected primarily by agricultural operations and channelization, was used. Swift Creek is located in the eastern Coastal Plain region in the lower Neuse River basin. The main reach and major tributaries of Swift Creek were channelized in 1964. Using information from figure 9, we find that the mean annual suspended-sediment yield for background conditions in the vicinity of Swift Creek is about 5 tons/mi^2. From figure 16, the estimated average yield for rural sites affected primarily by agriculture is about 32 tons/mi^2 for sites in the lower Neuse River basin. Thus, using the estimated yield of 66 tons/mi^2 for the Swift Creek station (table 8), we see that the effects of channelization have about doubled the yield at the site as compared with other rural-agricultural sites in the same basin.

Highway and Large-Scale Construction

Basin reconnaissances indicated that erosion from large-scale construction for highways, reservoir sites, heavy industry, and related land-clearing operations most likely affected transport at 23 sites ranging in size from 28.2 to 2,690 mi^2 (table 8, symbol h). Sediment contributed by these activities to fluvial sediment derived from rural-agricultural sources is undefinable. Fluvial sediment was increased at a number of sites, such as sites 5 and 6 (table 8, fig. 1), by urban developments in addition to the previously mentioned activities. Mean annual yield at the 23 affected stations was generally 1.5 to 4 times greater than yields of nearby rural sites affected only by agriculture.

Urbanization

In this report, urban activities are not restricted entirely to the housing industry but also include municipal streets and highways, shopping centers, and other land uses associated with a populated area. Twenty of the 38 sampling sites listed as "rural affected by nonagricultural activities" (table 8) are affected by urban development, but not to the extent that would warrant categorization as urban. As noted in table 8, sediment characteristics at the 20 sites also are affected by other activities, such as highway construction. Comparison of data from rural sites affected by agriculture (table 7) with data from rural sites affected by nonagricultural activities (table 8) shows that sediment yields generally are greater for the latter sites having some urban development. Urbanization, even when minimal, has a major effect on sediment yield, especially during the construction phase if in close proximity to watercourses.

Reservoirs

Sediment characteristics at 10 sampling stations are affected by the trapping effects upstream of main-stream reservoirs (table 8, symbol r). As discussed by Brune

Table 9. Estimated trap efficiencies and related information for major reservoirs affecting suspended-sediment sampling sites, 1970–79

Site number (fig. 1)	Name	Reservoir inflow and storage characteristics: Reservoir name	Distance upstream from sampling site (miles)	Normal capacity[1] (cubic feet)	Estimated average annual water inflow (cubic feet)	Estimated trap efficiency[2] (percent)
10	Roanoke River at Roanoke Rapids	Roanoke Rapids Lake	3	3×10^9	210×10^9	52
10	Roanoke River at Roanoke Rapids	Lake Gaston	12	22×10^9	210×10^9	86
11	Roanoke River near Scotland Neck	Lake Gaston	34	22×10^9	210×10^9	86
38	Contentnea Creek near Lucama	Buckhorn Reservoir	1	69×10^6	5×10^9	53
50	Reedy Fork near Gibsonville	Lake Brandt	14	290×10^6	2×10^9	90
103	Pee Dee River near Rockingham	Blewett Falls Reservoir	3	4×10^9	255×10^9	60
137	West Fork Pigeon River below Lake Logan near Waynesville	Lake Logan	3	90×10^6	5×10^9	58
139	Pigeon River at Canton	Lake Logan	11	90×10^6	5×10^9	58
147	Nantahala River at Nantahala	Nantahala Lake	12	6×10^9	16×10^9	95
148	Tuckasegee River at Dillsboro	Dillsboro Powerplant	1	Unknown	25×10^9	Unknown
151	Hiwassee River above Murphy	Chatuge Lake	22	10×10^9	14×10^9	97

[1]Capacity at usable storage.
[2]Estimated from Brune (1953, fig. 6).

(1953), the trapping ability of a reservoir is affected by many factors; generally, however, the trap efficiency increases as the ratio of reservoir capacity to annual inflow increases. Estimated values of trap efficiency for major reservoirs in the 10 subject basins are given in table 9. The two Roanoke River sites (10 and 11) are further affected by John H. Kerr Reservoir (capacity 120×10^9 ft^3) (cubic feet) that lies primarily in Virginia, immediately upstream of Lake Gaston (fig. 17). The impoundments listed in table 9 are not necessarily the only ones in the subject basins, but they are believed to be the most significant regarding sediment transport at the subject sampling sites. Approximate locations of reservoirs and lakes discussed herein are shown in figure 17.

The effect of an upstream reservoir on fluvial sediment is largely dependent on the trap efficiency of the reservoir and its distance upstream from the sampling point. Reservoir effects often appear to diminish rapidly downstream. For example, the mean annual sediment discharge increases by approximately 60,000 tons on the Roanoke River from Roanoke Rapids (site 10, fig. 1) to Scotland Neck (site 11), a distance of about 31 river miles. The sediment contribution from rural streams in the intervening area (approximately 287 mi^2) is approximately 14,000 tons (fig. 16); the remaining 46,000 tons is attributed primarily to degradation of the Roanoke River channel.

Of all sites listed in table 9, the Roanoke River at Roanoke Rapids (site 10, fig. 1) shows the greatest reservoir effect. Based on data from figure 16 for the middle Roanoke River basin, the average annual yield should be a minimum of about 250 tons/mi^2 without the effect of reservoirs. The combined trapping effects of John H. Kerr Reservoir, Lake Gaston, and Roanoke Rapids Lake, however, reduce the yield at Roanoke Rapids (site 10) to only 12 tons/mi^2 (table 8), which is equivalent to a combined trap efficiency of suspended sediment of about 95 percent. Materials deposited in these impoundments generally are retained.

Sampling stations located immediately upstream and downstream of Lake Logan, Haywood County (fig. 17), permitted determination of trapping characteristics during storm runoff. Lake Logan, located on a high-gradient mountain stream subject to flash floods, has a capacity of 2,060 acre-ft (acre-feet) and a capacity to annual inflow

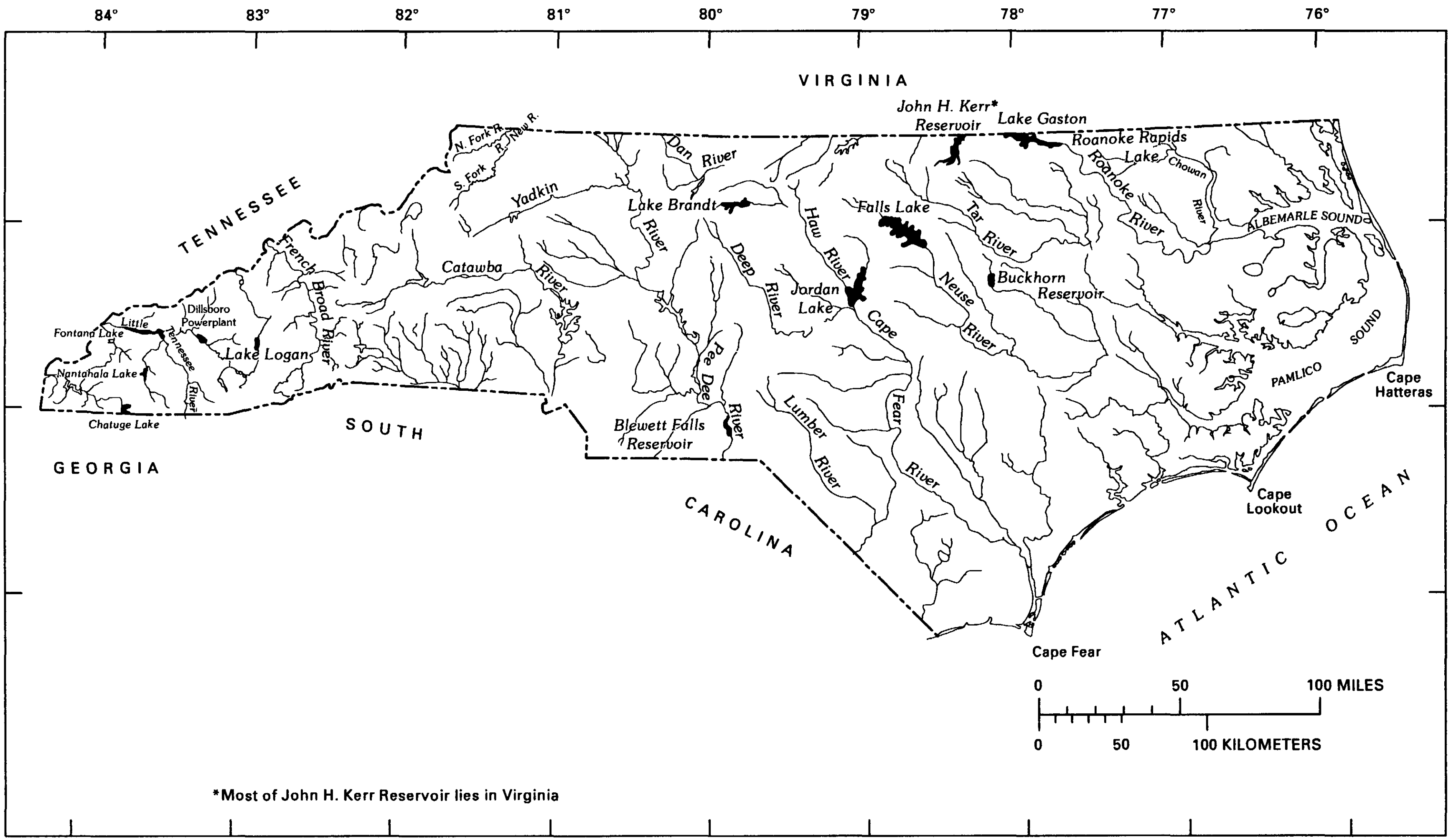


Figure 17. Locations of reservoirs that affect reported stream-sediment data.

volume ratio of 0.02. As shown in figure 18, the storm of August 7, 1978, produced a maximum inflow suspended-sediment concentration greater than 600 mg/L. Maximum outflow suspended-sediment concentration was about 160 mg/L. Preliminary loading estimates indicate that more than 550 tons of suspended sediment entered the lake on August 7, and 375 tons were trapped, resulting in a trap efficiency of about 70 percent for this storm. This relatively low trap efficiency is related to a small ratio of storage capacity to annual inflow, which permits greater flow velocities through the reservoir and thus more suspended sediment to be carried away as discharge from the reservoir. Ratios of storage capacity to annual inflow volume for major reservoirs such as Fontana Lake and John H. Kerr Reservoir (fig. 17) are greater, and trap efficiencies might exceed 95 percent; however, computations for these two lakes are not included in this report.

Sediment data downstream from two recently completed reservoirs provide a unique comparison of transport characteristics at two sampling sites before and after construction. The 12,500-acre Falls Lake (fig. 17), about 0.5 mi upstream of the Neuse River near Falls sampling station (site 29, fig. 1), was filled in June 1983. The Haw River near Moncure sampling station (site 58) is 300 ft downstream from the dam of 13,900-acre Jordan Lake, which was filled in February 1982. Sediment data were collected during 1984–85 at both sites as part of a cooperative study with the U.S. Army Corps of Engineers, and sediment-transport curves for both periods, 1970–79 (before reservoir construction) and 1984–85 (after reservoir construction), are shown in figure 19. Using the sediment-transport/flow-duration method discussed previously, the curves for 1984–85 were applied to water discharge data for the 1970–79 base period. By applying pre- and post-"reservoir" curves to the same water-discharge period, an estimate of the sediment-trapping ability of each reservoir can be made. As shown in table 10, had the reservoirs been in place during 1970–79, the average annual deposition of suspended sediment in Falls and Jordan Lakes would have been approximately 126,000 and 240,000 tons, respectively.

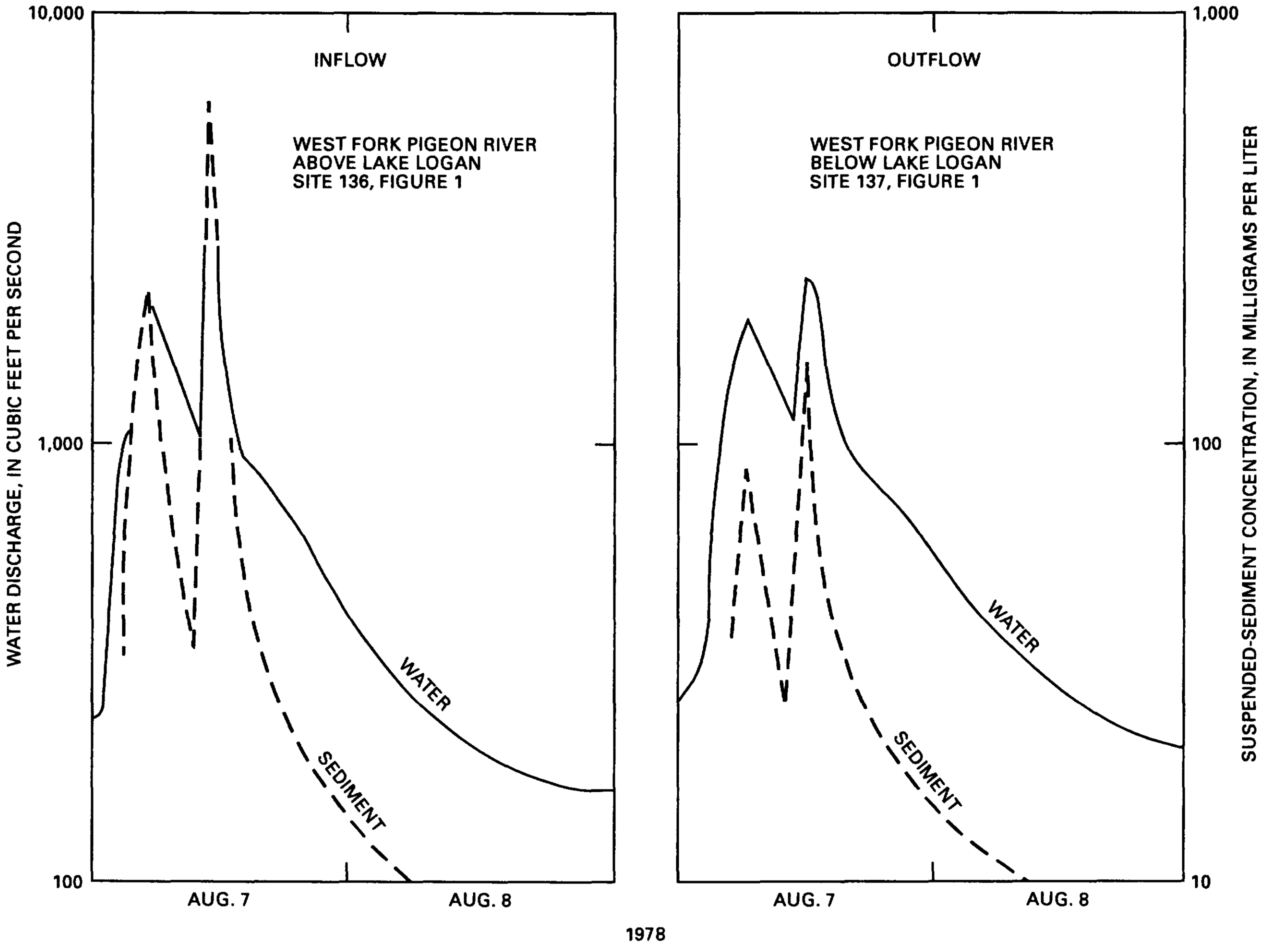


Figure 18. Flow and suspended sediment for inflow and outflow of Lake Logan, West Fork Pigeon River, during the storm of August 7–8, 1978.

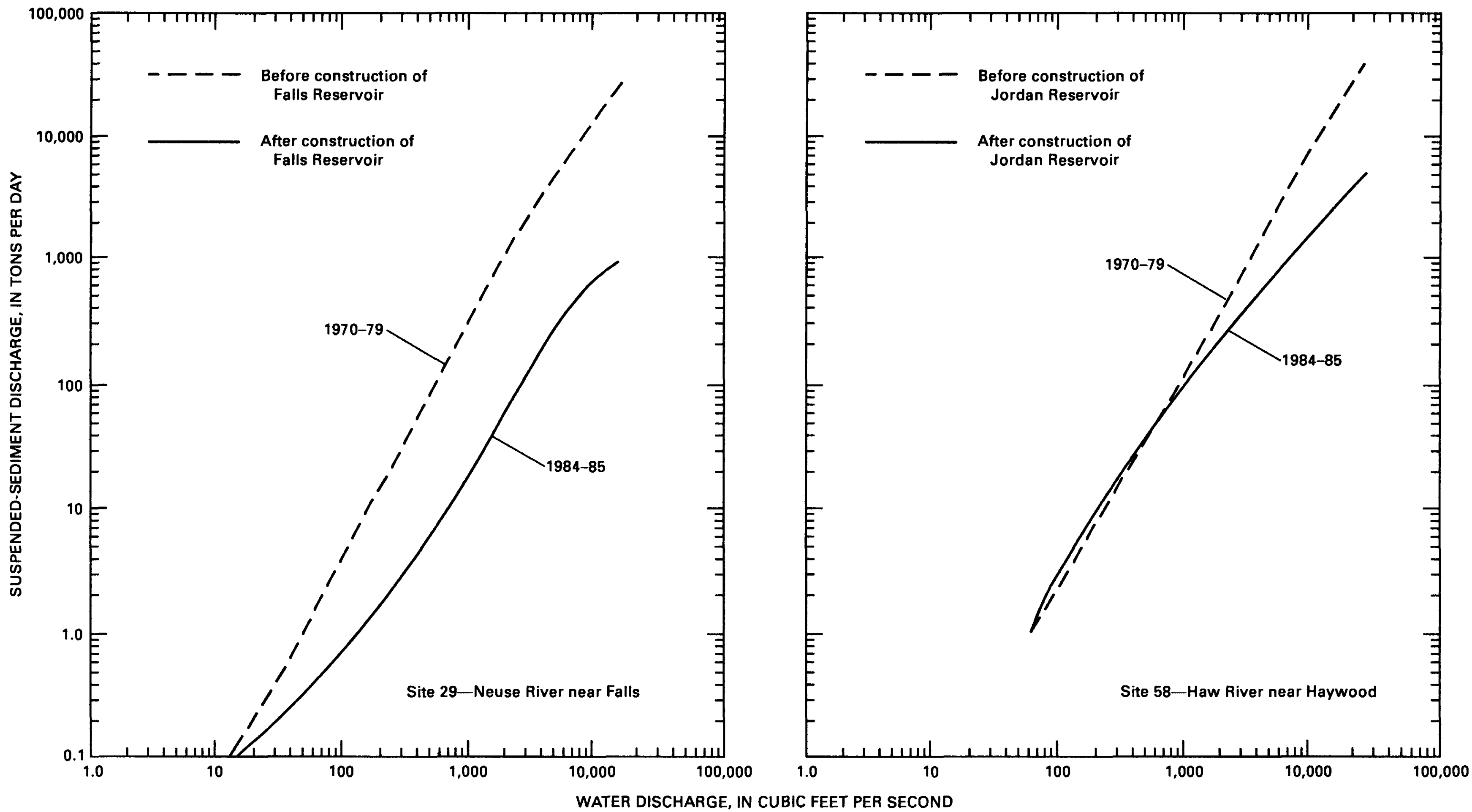


Figure 19. Sediment-transport curves for sampling stations on Neuse and Haw Rivers, demonstrating changes in sediment discharge after construction of major reservoirs immediately upstream from stations.

Table 10. Estimated trap-efficiency characteristics of Falls and Jordan Lakes, based on sampling data at downstream stations

Sampling station (fig. 1, table 19)	Reservoir upstream from station (fig. 17)	Estimated average annual sediment discharge at station: Based on 1970–79 curve (figure 19) (tons)	Estimated average annual sediment discharge at station: Based on 1984–85 curve (figure 19) (tons)	Estimated amount of suspended sediment trapped by reservoir annually (tons)	Estimated trap efficiency of reservoir (percent)
Neuse River near Falls (site 29)	Falls Lake	140,000	14,000	126,000	90
Haw River near Haywood (site 58)	Jordan Lake	280,000	40,000	240,000	86

Recent studies that discuss trapping effects of other reservoirs in North Carolina include Simmons (1976), Dendy and Champion (1978), U.S. Army Corps of Engineers (1980), and Harned and Meyer (1983).

Urban Basins

Seventeen stations in the sampling network are classified as urban (table 11). One station is located in the Blue Ridge Province and two in the Coastal Plain; the remaining 14 stations are scattered across the central and western Piedmont (fig. 20). Land-use activities directly related to urban and municipal development probably are the primary sources of fluvial sediment in these basins, although several basins (sites 89, 119, 133, fig. 20) have drainage areas greater than 100 mi^2, with substantial percentages as farmlands and forested lands (tables 11, 19). Urban study basins ranged in size from 1.42 to 262 mi^2, averaging about 60 mi^2.

The effects of urbanization on suspended-sediment yield are documented in numerous reports. Wolman and Schick (1967), Guy (1970b), Yorke and Davis (1972), and others report annual yields exceeding 100,000 tons/mi^2 in small-acreage urban basins in Virginia and Maryland. Wolman and Schick (1967) reported that urban areas in the Piedmont of Maryland commonly produced up to 200 times more sediment than comparable rural or forested areas. Yorke and Herb (1978) reported average annual sediment loads of 33 tons/acre (21,000 tons/mi^2) from small-acreage urban construction sites as compared with 0.03 tons/acre (19 tons/mi^2) from nearby small forested sites.

Numerous factors affect sediment delivery from urban areas. For instance, Wolman and Schick (1967) have demonstrated that a new, developing urban area produces far more sediment than an older, established area of the same size. They and others have shown that sediment yield from a newly developed area rapidly decreases as development is completed and the land stabilizes. Yields from construction areas increase with proximity to streams, especially in steep topographic terrains. Independent studies conducted in North Carolina (Putnam, 1972) and Virginia (Anderson, 1970) show that urbanization also causes an increase in flood peaks. These increased flows not only transport considerably more sediment, but they also erode and widen formerly stable stream channels; this turns the channel into an additional sediment source. Yorke and Herb (1978, p. 69) estimated that erosion of stream channels in one urban project area in Maryland contributed one ton of sediment per foot of channel length to the total sediment yield of the basin between 1967 and 1974. The trend to develop lands adjacent to streams and lakes will increase the sediment-yield potential of a basin.

Field reconnaissances of urban basins in this study showed that, while all of the urban basins were undergoing various degrees of development, the extent of new construction and land-use activities varied between basins. Transport data for these basins reflect effects from various land uses, including industrial, residential, municipal, roads and highways, recreational, and agricultural. Numerous sources of sediment were found throughout most basins, and no basin contained an apparent dominant source of sediment.

Suspended-sediment concentrations and related data are shown in table 11 for urban sites. Maximum observed suspended-sediment concentrations during the study occurred in streams in and around Charlotte, including 7,500 mg/L in McMullen Creek (site 117, fig. 20) and 5,280 mg/L in Irwin Creek (site 114). Urbanization is significant in the McMullen Creek and Irwin Creek basins, accounting for 93 and 85 percent, respectively, of land use. Minimum concentrations at sites, obtained by samples during prolonged low-flow periods, ranged from 1 to 16 mg/L and agree closely with values reported previously for rural basins across the State. It should be noted that 4 of the 17 urban sites are located in or near Charlotte, and 3 other urban sites are within a radius of 10 miles of Charlotte (table 11, fig. 20). This uneven distribution of sites, most of which are in the Piedmont, precludes the development of statewide urban sediment-transport relations.

As shown in figure 20, concentrations of suspended sediment for storms at the Piedmont urban sites commonly are 10 to 60 times greater than for urban sites in the

Table 11. Suspended-sediment characteristics for predominantly urban basins, 1970–79

[Physiographic provinces: C, Coastal Plain; P, Piedmont; B, Blue Ridge. *r*, correlation coefficient for site sediment-transport curve defined by observed data]

Site number (fig. 1)	Name	Physiographic province	Drainage area (square miles)	Estimated mean annual suspended-sediment discharge (tons)	Estimated mean annual suspended-sediment yield (tons per square mile)	Mean daily discharge (cubic feet per second)	Estimated percentage of time indicated suspended-sediment concentration was equaled or exceeded (milligrams per liter)					Number of samples, correlation coefficient, and range in observed (measured) concentration (milligrams per liter)			
							0.1	1.0	10	50	90	Number	*r*	Maximum	Minimum
39	Hominy Swamp at Wilson	C	7.90	880	110	7	300	120	42	25	12	33	0.81	779	9
51	North Buffalo Creek near Greensboro	P	37.1	7,000	190	75	300	210	62	21	15	32	.88	691	8
59	East Fork Deep River near High Point	P	14.8	7,000	470	22	1,000	530	61	24	15	25	.71	1,040	7
75	Little Rockfish Creek near Wallace	C	7.83	340	43	12	120	56	17	7	5	31	.62	122	2
88	Salem Creek near Atwood	P	65.6	27,000	410	78	1,200	800	250	24	8	26	.73	2,520	8
89	Muddy Creek near Muddy Creek	P	186	76,000	410	261	1,300	810	140	46	26	27	.83	1,430	16
90	South Fork Muddy Creek near Clemmons	P	42.9	20,000	470	52	1,600	1,100	140	40	21	28	.78	2,490	11
108	Lower Creek at Lenoir	P	28.1	18,000	640	47	1,800	1,700	110	28	20	23	.83	2,320	15
110	Long Creek near Paw Creek	P	16.4	7,200	440	20	1,400	500	110	38	15	31	.90	1,320	8
114	Irwin Creek near Charlotte	P	30.7	46,000	1,500	50	5,000	1,800	140	17	5	25	.90	5,280	3
115	Little Sugar Creek at Archdale Road at Charlotte	P	42.6	27,000	630	65	1,800	860	66	10	3	26	.94	2,480	10
116	McAlpine Creek at Sardis Road near Charlotte	P	39.6	19,000	480	47	1,400	680	110	26	12	21	.86	1,420	6
117	McMullen Creek near Charlotte	P	6.95	4,400	630	9	2,100	530	74	24	23	33	.80	7,500	6
118	McAlpine Creek near Pineville	P	92.4	32,000	350	122	420	420	230	32	11	27	.97	2,220	5
119	Sugar Creek near Fort Mill, South Carolina	P	262	100,000	380	285	1,200	710	95	15	10	42	.90	2,240	9
125	Sugar Branch near Boiling Springs	P	1.42	780	550	2	1,400	370	25	9	4	29	.97	3,100	1
133	Swannanoa River at Biltmore	B	130	45,000	350	187	1,300	610	210	54	10	32	.92	2,880	3

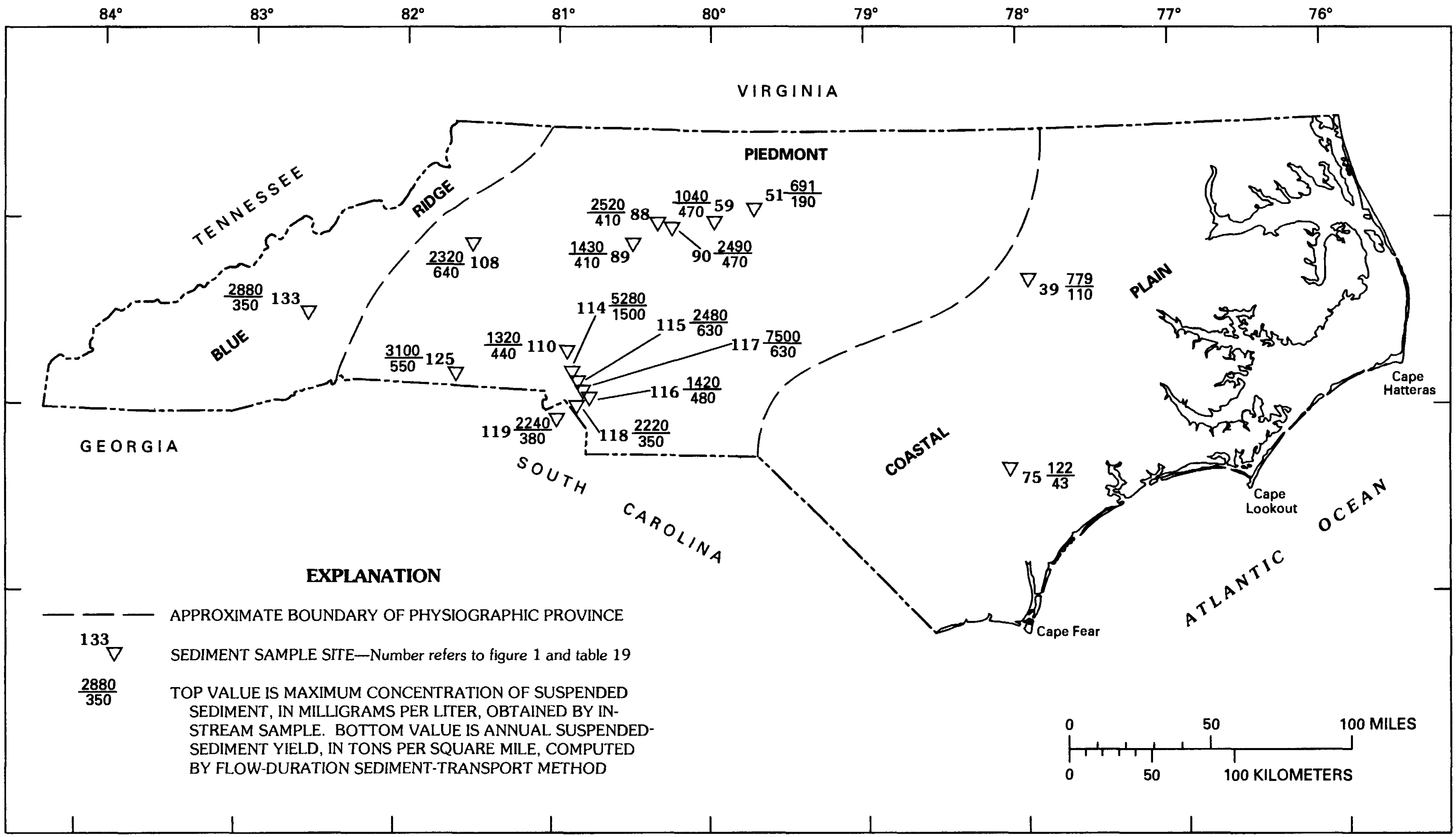


Figure 20. Maximum observed concentration of suspended sediment and mean annual yield at urban sampling sites.

Coastal Plain. Concentrations at network sites, however, are considerably less than those for small-acreage urban construction sites. For example, Wolman and Schick (1967) reported concentrations that ranged from 3,000 to 150,000 mg/L in storm runoff from urban sites under development in the eastern Piedmont Province of Maryland. Undoubtedly, similar concentrations are probably derived from urban construction areas of several acres or less in size in North Carolina's western Piedmont and possibly other parts of the State; however, comparative data are not available. Guy (1970a) and other researchers note that large quantities of eroded materials are redeposited on or near these small-acreage sources, on flood plains, and in channels; this dramatically reduces concentrations that might occur in the larger streams.

Mean annual suspended-sediment yield also is highly variable across the State (table 11), ranging from 43 tons/mi^2 at Little Rockfish Creek near Wallace (site 75, fig. 20) in the Coastal Plain Province to 1,500 tons/mi^2 at Irwin Creek (site 114) in the Piedmont Province.

The most detailed urban sediment data are available as part of the stream-quality program (Eddins and Crawford, 1984) in the city of Charlotte and Mecklenburg County. As shown in table 11 and figure 20, annual suspended-sediment yields at seven sites in and around Charlotte range from 350 to 1,500 tons/mi^2 for basins having drainage areas of 6.95 to 262 mi^2. The three sites in the Charlotte area having the greatest yields (sites 114, 115, and 117) also had the greatest percentage of urban land use (85, 97, and 93 percent, respectively).

COMPARISONS OF SUSPENDED-SEDIMENT TRANSPORT CHARACTERISTICS WITH SELECTED BASIN CHARACTERISTICS

The abundance of data covering almost all of North Carolina permits a comparison of various transport characteristics that until now has not been possible on a statewide basis. The information in this section is not a summary of, but rather is a supplement to, the information and findings from the data of the preceding sections.

Stream Discharge

Concentration of suspended sediment in North Carolina streams generally varies with stream discharge, as shown in figure 21 by the daily hydrographs for the Yadkin River at Yadkin College (site 91, fig. 1). The hydrographs are similar, and highs and lows occur almost simultaneously; at several points, the graphs seem to coincide. Even subtle changes in discharge during low-flow periods are often followed by similar changes in sediment. Most streams throughout the State exhibit a similar relation, but many low-gradient coastal streams and main-channel streams immediately downstream of reservoirs do not. Low velocities, flat terrain, and permeable (sandy) soils along much of the State's coastal area produce consistently low concentrations of suspended sediment regardless of flow conditions. Conversely, the input to streams of sediment by construction and other earth-moving activities, in or immediately adjacent to the stream channel, can cause increased levels even during low-flow periods.

Variation of suspended sediment with stream discharge is most pronounced during flood periods. According to Colby (1963), the maximum suspended-sediment concentration will occur (1) simultaneously with the maximum flow, (2) in advance of the maximum flow, or (3) following the maximum flow. Samples collected during this study show that maximum suspended-sediment concentration occurred prior to maximum flow for approximately 80 percent of the network stations; the remaining stations, most of which are high-gradient mountain streams in the Blue Ridge Province, respond simultaneously. Generally, the response characteristics of a specific stream are consistent; however, concentrations may peak in advance of maximum flow during one storm and simultaneously during the next storm because of unusual rainfall patterns or variations in source and amount of available sediment. Some Coastal Plain streams, such as the Waccamaw River at Freeland (site 76) and Lumber River at Boardman (site 105), are exceptions to the above, wherein concentrations are minimal and only minor fluctuations in concentrations occur even during severe floods (table 7).

In the stream cross section, concentrations of suspended sediment vary laterally and vertically with time and flow conditions. Variations exist in all streams throughout North Carolina. The most pronounced variations occur in Piedmont and Blue Ridge Province streams where concentrations are greatest. Concentrations may vary greatly under constant-flow conditions at a fixed point in the cross section because sediment often moves in so-called clouds or waves. Except for the large rivers and estuaries of the coastal counties, suspended-sediment concentrations are generally greatest near midstream, where flow velocities and turbulence are usually greatest, and decrease laterally toward the streambanks (fig. 22). Lateral variations in sediment concentration are markedly pronounced at higher flows because concentrations increase proportionately with velocity and stream discharge as the upward component of increasing turbulent flow maintains sediment in a suspended state (fig. 22).

A major proportion of sediment discharge occurs during storm runoff. As discussed previously, transport computations prepared for each sampling station include quantities of suspended sediment and water discharge representative of various time intervals (columns 1–3, table 4) that specific quantities are exceeded. Estimates of the percentage of time required for selected quantities of transport

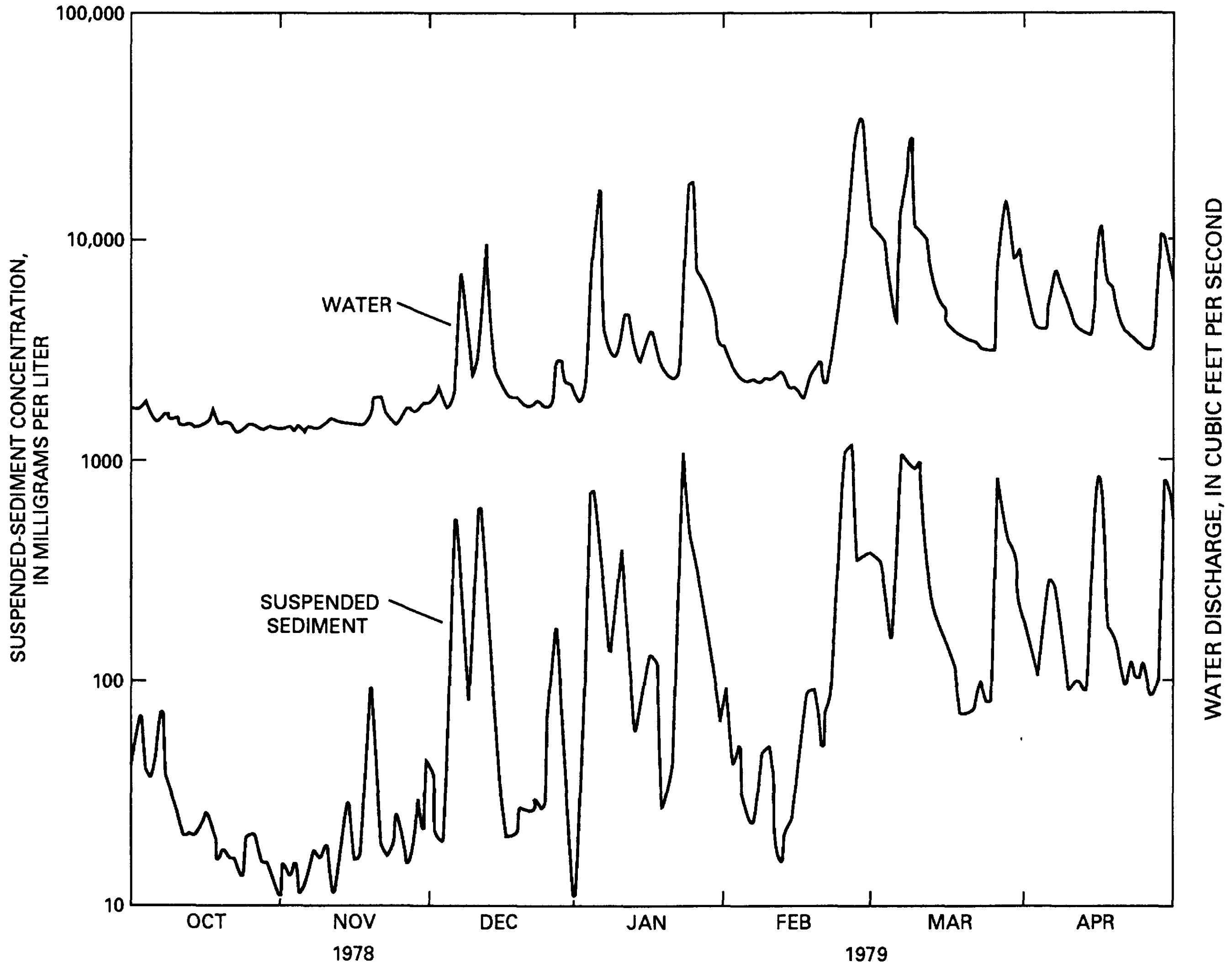


Figure 21. Streamflow and suspended-sediment concentration for Yadkin River at Yadkin College, October 1978–April 1979.

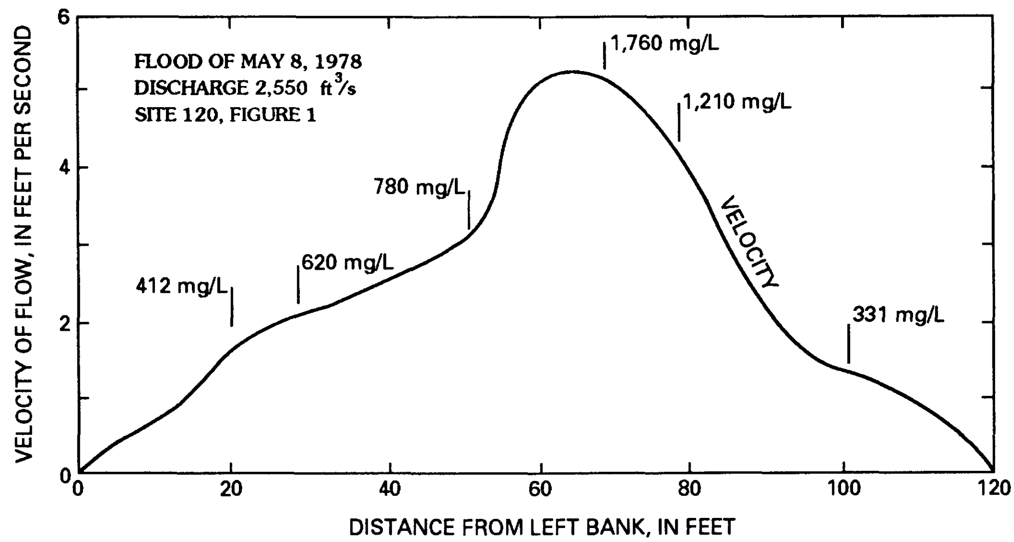


Figure 22. Velocity profile and mean concentration of suspended sediment in selected verticals during flood of May 8, 1978, at Twelve Mile Creek near Waxhaw.

Table 12. Estimated percentage of time required for higher flows at selected stations to transport 25 and 50 percent of sediment and water during 1970–79

Site number (fig. 1)	Name	Drainage area (square miles)	Percentage of time required for higher flows to transport 25 and 50 percent of suspended sediment and water discharge during 1970–79			
			25 percent of total transport		50 percent of total transport	
			Sediment	Water	Sediment	Water
	Blue Ridge Province					
127	French Broad River at Rosman	67.9	0.2	9	0.7	30
130	Mills River near Mills River	66.7	.2	9	2.0	24
131	French Broad River at Bent Creek	676	.5	7	3.9	22
138	East Fork Pigeon River near Canton	51.5	.2	7	.6	20
143	Watauga River near Sugar Grove	92.1	.4	3	3.0	17
149	Oconaluftee River at Birdtown	184	.2	6	1.5	22
	Piedmont Province					
4	Dan River near Wentworth	1,053	0.3	4	0.9	17
7	Hyco Creek near Leasburg	45.9	.2	1	.8	6
12	Tar River near Tar River	167	.4	1	1.6	4
25	Eno River near Durham	141	.2	1	.8	6
32	Middle Creek near Clayton	83.5	.8	2	4.5	10
49	Reedy Fork near Oak Ridge	20.6	.1	2	.4	13
55	Cane Creek near Teer	33.7	.4	1	1.5	5
56	Haw River near Bynum	1,277	.3	2	.9	9
61	Deep River at Ramseur	349	.2	1	.7	6
65	Cape Fear River at Lillington	3,464	.7	3	2.2	10
78	Elk River at Elkville	48.1	.1	3	.4	19
81	Yadkin River at Elkin	869	.5	6	2.4	24
93	South Yadkin River near Mocksville	306	.7	3	2.6	17
97	Big Bear Creek near Richfield	55.6	.1	1	.6	4
111	Henry Fork near Henry River	83.2	.1	4	.4	17
122	Second Broad River at Cliffside	220	.1	5	.4	22
	Coastal Plain Province					
17	Fishing Creek near Enfield	526	0.8	3	3.0	11
18	Tar River at Tarboro	2,183	2.3	4	7.2	13
23	Durham Creek at Edward	26.0	1.5	2	8.1	9
43	Little Contentnea Creek near Farmville	93.3	1.1	3	4.6	8
45	Creeping Swamp near Vanceboro	27.0	.4	2	2.4	4
71	Black River near Tomahawk	676	3.9	6	13	18
72	South River near Parkersburg	379	3.4	5	13	16
76	Waccamaw River at Freeland	680	4.2	4	14	15
105	Lumber River at Boardman	1,228	5.5	6	17	20

can be determined by summing incremental quantities (columns 6 and 7, table 4) to obtain the selected percentage of the total quantity. Using data for selected streams, the percentages of time are presented in table 12 that are required for the higher flow regimes to transport 25 and 50 percent of the total water and sediment discharged during the period 1970–79. For instance, in only 0.2 percent of the entire 10-year period (about 7 days), the French Broad River at Rosman (site 127, fig. 1) transported approximately 25 percent of the suspended sediment discharged during 1970–79 (table 12); approximately 50 percent was transported in 0.7 percent of the 10-year period. As shown in table 12, high flows in Piedmont and Blue Ridge streams generally transported 25 percent or more of the total sediment in less than 1 percent of the period. Of the nine Coastal Plain stations shown in table 12, an average of approximately 2.6 percent (95 days) of the 10-year period was required to transport 25 percent of the sediment.

Table 13. Comparison of estimated mean annual suspended-sediment yield for long-term and 1970–79 periods

[tons/mi², tons per square mile]

Site number (fig.1)	Name	Long-term: Period of record	Long-term: Estimated[1] mean annual yield (tons/mi²)	1970–79: Estimated mean annual yield (tons/mi²)	1970–79: Percentage of long-term yield
	Blue Ridge Province				
[2]134	French Broad River at Asheville	1897–1979	350	410	117
150	Tuckasegee River at Bryson City	1899–1979	220	230	105
	Piedmont Province				
30	Neuse River near Clayton	1928–1979	180	190	106
52	Haw River at Haw River	1929–1979	210	260	124
[2]63	Deep River at Moncure	1931–1979	110	130	118
[2]93	South Yadkin River near Mocksville	1940–1979	230	290	126
	Coastal Plain Province				
18	Tar River at Tarboro	1931–1979	40	43	108
[2]42	Contentnea Creek at Hookerton	1928–1979	26	27	104
105	Lumber River at Boardman	1930–1979	11	12	109

[1]Computed from long-term flow-duration data and sediment-transport curve for 1970–79.
[2]Long-term index gaging station (see fig. 6).

Information in table 12 is useful in showing that floods and high flows of relatively short duration generally transport the bulk of fluvial sediments.

In addition to variations caused by discharge, numerous other natural and human-induced factors often cause variations in suspended-sediment distribution in a stream reach, including abrupt changes in streambed cross section, sharp meanders, braided channels, and deep natural pools. On large streams, eroded materials from landslides or bank failures often cause short-term elevated concentrations for considerable distances downstream. Human-induced variations are caused by a variety of factors, varying from engineering structures to influxes from point and nonpoint sources. Runoff, especially during heavy rains, from construction projects, municipal storm sewers, unpaved road ditches, and lands cleared of vegetation almost always has greater concentrations of sediment than receiving waters and thereby elevates downstream levels.

In a previous section of this report, comparisons of mean flow for long-term stations indicated above-normal conditions for much of North Carolina during the study. Because sediment sampling did not begin at most sites until after 1970, similar comparisons of sediment transport using actual sediment data are not possible. By assuming, however, that sediment-transport curve data for 1970–79 are also representative of long-term conditions, estimates of suspended-sediment yield can be computed for purposes of comparing the effects of short- and long-term flow conditions. Computations for selected sites having 40 or more years of flow record indicate that mean values for the study period might range from about 4 to 26 percent greater than long-term values (table 13). Because of increased inaccuracies and unknowns associated with extending records, transport and flow values herein are not adjusted to long-term conditions and reflect characteristics representative of the study period only.

Particle Size of Suspended Sediment

Samples for determination of particle size of suspended materials were collected randomly during high-flow periods at approximately a third of the sites. Detailed size analyses of these samples were published in annual reports of the U.S. Geological Survey for the year during which specific samples were collected (U.S. Geological Survey, 1970–79). Although collected on an infrequent, limited basis, particle-size data are sufficient to show that significant differences exist across the State (table 14). For example, during high flow, silts and sands generally com-

Table 14. Average particle-size distribution for suspended-sediment samples collected in North Carolina streams during high flow

[mm, millimeter]

Physiographic province	Number of stations sampled	Number of samples used in mean	Percentage of suspended-sediment particles finer than indicated size										
			Clay		Silt				Sand				
			0.002 mm	0.004 mm	0.008 mm	0.016 mm	0.031 mm	0.062 mm	0.125 mm	0.250 mm	0.500 mm	1.00 mm	2.00 mm
Blue Ridge	9	12	12	16	22	32	40	52	67	86	98	99	100
Piedmont	40	74	30	41	52	62	70	77	86	94	98	99	100
Coastal Plain	11	9	39	53	64	70	75	82	90	96	99	100	100

prise about 84 percent of suspended materials in Blue Ridge streams but only about 47 percent in Coastal Plain streams (table 14). Surprisingly, the percentage of silt in suspended sediments in Blue Ridge and Piedmont streams is about the same (36 percent); however, clay accounts for more than 40 percent of suspended material in Piedmont streams but only about 16 percent in the Blue Ridge.

Land Use

Comparisons of yields between predominant land-use categories—forested (pristine), rural-agricultural, and urban—must give consideration to various regional and basin factors to improve the validity of findings. For instance, mean values of yield and other variables for characterizing rural basins were computed by using data only from sites that are unregulated, unchannelized, less than 400 mi^2 in drainage area, and in which agriculture is believed to be the major source of fluvial sediment. Consideration of these basin variables, as well as others mentioned in the report, then permits comparisons of fluvial-sediment characteristics, such as those shown in figure 23 for yields by land-use category. Assuming that the sediment derived from forested sources is the natural or background contribution, the additional amount is that part derived from human activities. It should be noted that values presented in figure 23 reflect characteristics in the Piedmont Province, which is the only province having sufficient data to make such a comparison. As shown, mean suspended-sediment yields for rural-agricultural and urban Piedmont basins are approximately 6 and 14 times, respectively, greater than yields from forested basins. In contrast, Wolman and Schick (1967) reported that yields from urban areas of Maryland's Piedmont are up to 200 times greater than yields for comparable rural-agricultural or forested areas. Guy (1970b), Yorke and Davis (1972), and others report similar findings in the Piedmont of Virginia and Maryland; however, these astronomical values are derived from small study basins generally ranging in size from less than 10 to about 50 acres that are undergoing intense construction activity related to the housing industry. Similar detailed studies of small-acreage sites are lacking in North Carolina, but it is logical that equally large values of transport occur in this State's developing Piedmont region. Based on the findings of this study, however, although large yields are probably produced from these small development sites, most of the eroded material is apparently redeposited near its source because these exaggerated values are not reflected in yields computed from actual data collected at this project's sampling sites.

Suspended-sediment data for Piedmont stations indicate that during the highest flows (0.1-percent duration), the mean concentration for large urban streams is approximately 1,600 mg/L as compared with 870 mg/L for rural sites

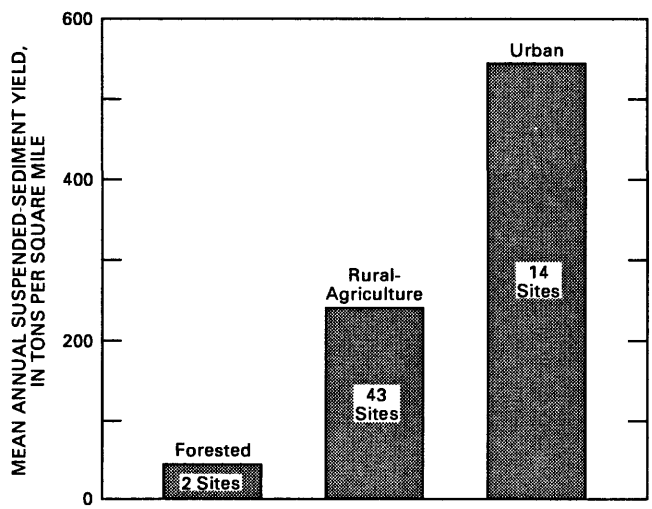


Figure 23. Mean annual suspended-sediment yield for selected forested (pristine), rural-agricultural, and urban sites in Piedmont Province.

and 100 mg/L for forested sites (fig. 24). Levels during low flows are substantially reduced at all Piedmont sites, with mean concentrations near 14 mg/L at urban sites, 11 mg/L at rural-agricultural sites, and 5 mg/L at forested sites.

Effects of Stream-Slope Change Across Fall Line

Comparisons of suspended-sediment discharge, mean concentrations, and related data along a stream reach often indicate locations of major sources of sediment, the trapping effects of reservoirs, evidence of natural aggradation or degradation, and other phenomena. Data collected during this study show that a significant decrease in suspended-sediment discharge occurs as large streams draining the Piedmont region flow across the Fall Line into the Coastal Plain region. The most dramatic examples are the Haw–Cape Fear and Neuse Rivers, both of which were relatively free of large-scale impoundments during the study period. Six sampling stations were located on each river. Three of the six stations shown on the Cape Fear River are actually located on the Haw River, a major headwaters tributary (fig. 25).

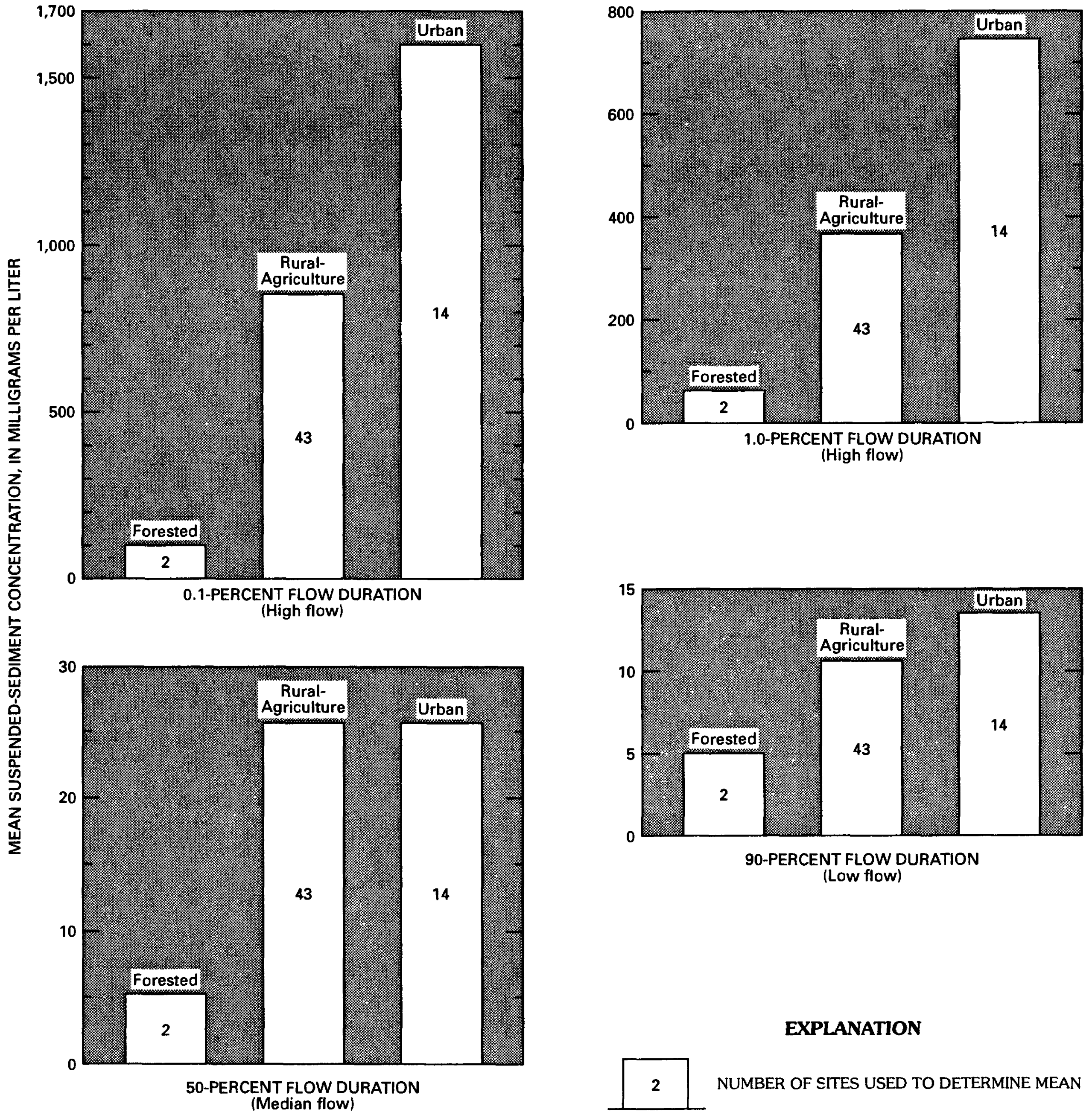
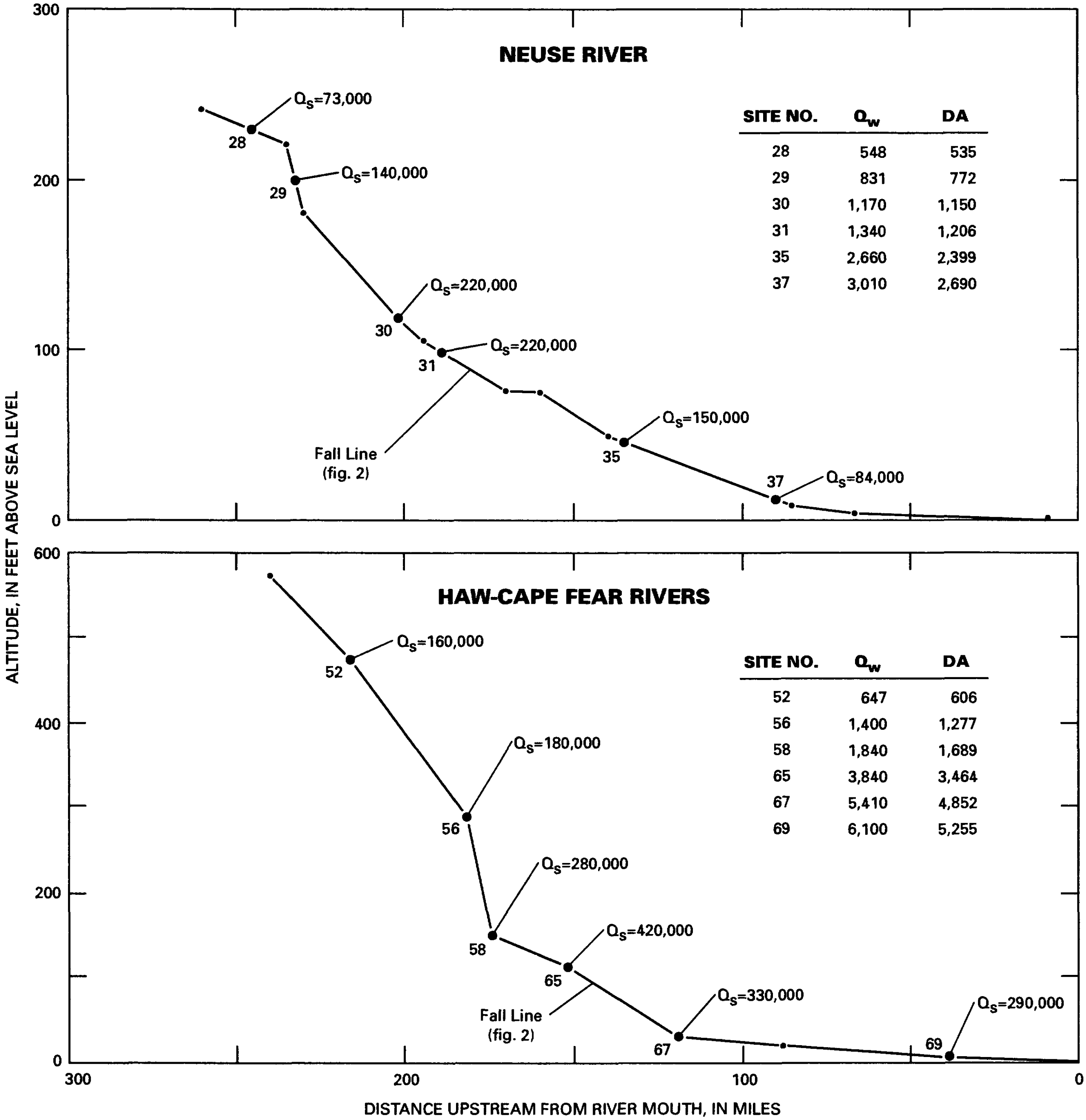


Figure 24. Mean suspended-sediment concentration, by percent flow duration, for forested (pristine), rural-agricultural, and urban sites in Piedmont Province.



EXPLANATION

—•— CHANNEL PROFILE BETWEEN SITES AND ALTITUDE AT NON-SAMPLING SITE

● 52 SEDIMENT SAMPLE—Number refers to figure 1 and table 19

DA DRAINAGE AREA, IN SQUARE MILES

Q_s MEAN ANNUAL SUSPENDED-SEDIMENT DISCHARGE FOR 1970–79, IN TONS PER YEAR

Q_w MEAN DAILY DISCHARGE DURING 1970–79, IN CUBIC FEET PER SECOND

Figure 25. Effects of low channel slope on suspended-sediment discharge of Neuse and Cape Fear Rivers when they reach the Coastal Plain.

The Neuse and Haw–Cape Fear Rivers originate in the eastern Piedmont Province. As shown in figure 25, the suspended-sediment discharge and water discharge of both rivers increase downstream as they cross the Piedmont. A dramatic decrease in sediment discharge occurs, however, as these streams flow into the low, flat Coastal Plain Province, although water discharge continues to increase with drainage area. For example, during the study period, an average of about 90,000 tons of suspended sediment were deposited annually in the Cape Fear River between Lillington and Tar Heel (sites 65 and 67, fig. 25). An additional 40,000 tons/yr were deposited between Tar Heel and Kelly (sites 67 and 69, fig. 25). On the Neuse River, more than 130,000 tons were deposited annually between Smithfield and Kinston (sites 31 and 37, fig. 25). Deposited amounts do not include unknown quantities of material deposited by smaller tributary streams entering the main-stream channels between sampling points. Other investigators (Meade and Trimble, 1974; Trimble, 1974; Meade, 1982) have reported decreasing sediment discharges from the Piedmont to the Coastal Plain Province; most, however, attribute at least part of the decrease to the trapping effects of dams and reservoirs.

The decreases in suspended-sediment discharge along the Neuse and Cape Fear Rivers are apparently directly related to natural basin factors. No significant dams existed along the Neuse River study reach, and only a few small dams and navigational locks were on the Cape Fear River. As the Neuse and Cape Fear Rivers enter the Coastal Plain Province, several significant changes in hydrologic characteristics occur: stream gradients and flow velocities decrease, flood plains become broader, and highly vegetated swamps and lowlands adjacent to the rivers are more prevalent. For example, discharge measurements at gaging stations show that main-channel velocities of both streams in the Piedmont average 6 to 7 ft/s during flows equal to the mean annual flood but decrease to 3 to 4 ft/s in the Coastal Plain. Velocities on broad flood plains are considerably less and often are near zero. Because the quantity of suspended material carried by a stream is largely dependent on the flow velocity (Guy, 1970a, p. 15), a reduction in velocity of the magnitude mentioned above is sufficient to cause a settling out of at least the larger particles.

Although the amount of sediment being deposited is large, deposition apparently occurs over a relatively large area, in which case the short-term accumulation, except that of a major flood, would not be noticeable. As on other North Carolina streams, material transported during floods in the Neuse and Cape Fear River basins accounts for well over half the average annual suspended-sediment load (table 12). In the Coastal Plain, overbank flooding is common along the Neuse and Cape Fear Rivers and on the average occurs 1 to 2 times per year. It is during overbank flooding that heavy underbrush and trees on these broad, flat flood plains further reduce the velocities of the sediment-laden waters, thereby causing part of the material to settle out on the flood plains. Using approximate widths of flood plains, the distances between stations, and estimates of annual storage, rough estimates of the depth of the material deposited on the flood plains were determined (table 15). These estimates assume uniform deposition across the flood plains and a mean specific weight of 52 lbs/ft^3 (pounds per cubic foot) for dry sediment (Dendy and Champion, 1978). A more accurate estimate of the rate of flood plain deposition would have to account for loss of material by decomposition and chemical weathering, erosion of material from flood plains during non-flood-producing rains, and quantification of materials eroded and deposited during historical and extreme floods.

Sediment transport and depositional characteristics in the State's sounds and estuaries are relatively unknown. The preceding estimates, however, indicate that most of the fluvial sediment derived from sources in the Piedmont and upper Coastal Plain is deposited on flood plains and along watercourses and probably never reaches the sounds and estuaries.

Gross Erosion and Sediment-Delivery Ratio

For many years, the U.S. Soil Conservation Service and others have used various techniques for estimating soil losses. Most of these techniques, such as the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965), are intended to predict quantities of soil moved by sheet and rill erosion on a particular area having known physical properties; however, users of erosion data quite often misunderstand the true definition and applicability of these data. According to Wischmeier (1976, p. 371), the USLE does not account for the eroded material deposited in depressions within a field or at the toe of slopes, along field boundaries, and in terrace channels. Consequently, the USLE predicts the total amount of material, called gross erosion, displaced in an area, regardless of whether the individual soil particles move only a few inches or feet or are transported to a stream channel by overland-flow processes. Predicted gross-erosion values, while representing the quantity of material eroded in a specific area, are considerably greater than the amount of material actually transported from the area.

The ratio of annual total sediment discharge to gross erosion is the sediment-delivery ratio. For example, a sediment-delivery ratio of 0.1 means that one-tenth (or 10 percent) of the material eroded in an area is actually transported as sediment from the area. Some researchers indicate that if approximate sediment-delivery ratios are available for an area, estimates of sediment discharge or gross erosion may be determined if either quantity is known; however, they generally agree that considerable

Table 15. Estimated sediment deposition in flood plains and channels of the lower Neuse and Cape Fear Rivers

[mi, mile; ft, foot; ft², square foot]

Site and number[1]	Distance between sites (mi)	Average channel width (ft)	Surface area of channel (ft²)	Average flood plain width (ft)	Surface area of flood plain (ft²)	Annual sediment storage (tons)	Annual deposition in channel (ft)	Annual deposition on flood plain (ft)
Neuse River								
At Smithfield (31)	43	175	4.0×10^7	800	14.2×10^7	70,000	0.067	0.019
At Goldsboro (35)								
At Kinston (37)	45	225	5.3×10^7	1,000	18.5×10^7	66,000	.048	.014
Cape Fear River								
At Lillington (65)	55	300	8.7×10^7	1,000	20.3×10^7	90,000	0.040	0.017
Near Tar Heel (67)								
Near Kelly (69)	56	325	9.6×10^7	1,000	20.0×10^7	40,000	.016	.008

[1]Refers to figure 25 and table 19.

judgment and knowledge of land use and other basinwide variables are required if reliable estimates are to be made using this method.

As a special contribution to this report, quantities of gross erosion for 30 network basins ranging in size from 4.92 mi² (site 99, fig. 1) to 5,255 mi² (site 69) were computed by the Soil Conservation Service (Emmett R. Waller, Jr., Soil Conservation Service, written commun., 1984) (table 16). These values are used with corresponding values of suspended-sediment discharge (values of total sediment discharge are unavailable, as discussed previously) to compute the sediment-delivery ratios presented in table 16, which show that these ratios apparently vary statewide. On the average, minimum delivery ratios occur in the Coastal Plain. As indicated by the ratios for sites 18, 43, and 69 (values of 0.02, 0.03, and 0.04, respectively; see table 16), only a small fraction of the soils eroded in the Coastal Plain is actually transported out as suspended sediment. Conversely, because of steeper slopes, greater surface runoff, and more erodible soils, larger delivery ratios (generally exceeding 0.10) occur in the Piedmont and Blue Ridge watersheds.

For comparative purposes, a statewide mean value of suspended-sediment yield was computed using data presented herein for each major land-use category. Because of a well-balanced distribution of sites across the State, mean values for rural-agricultural and forested (pristine) basins should be fairly representative of a statewide average. The statewide mean urban value was computed from yield values for the one Blue Ridge site (No. 133), the two Coastal Plain sites (Nos. 39, 75), and the two Piedmont sites having the second highest and lowest yield values (Nos. 108, 118). With 14 of the 17 urban sites located in the Piedmont Province, the statewide mean value would have been unfavorably biased had all sites been used. Average values of gross erosion were recently computed for North Carolina (U.S. Department of Agriculture, 1977). The U.S. Department of Agriculture (1977) did not provide a gross-erosion value for rural-agricultural basins; instead, erosion values were provided for specific land uses, such as forests, row crops, and pasture lands. Using average values of 62-percent forest, 34-percent row crop and pasture lands, and 4-percent urban for the 63 rural-agricultural study basins used in this analysis, a weighted statewide mean value for gross erosion of about 1,700 tons/mi² is computed (fig. 26). Comparisons of statewide mean values are shown in figure 26, which indicates that for forested (pristine) basins suspended-sediment yield was about 40 percent of gross erosion; however, this value is only about 20 percent for urban areas and 10 percent for rural-agricultural areas with less than 400 mi² drainage basins. It is logical that a relatively greater percentage of material eroded in a forested basin would become streamborne, since most erosion in forested basins occurs along stream channels. While the reader should consider these values as estimates, the main conclusion here is that only a small percentage of eroded material is actually delivered to the State's larger streams. The major bulk of the material is stored on flood plains, in stream channels, on upland slopes, and in countless other temporary resting places.

Table 16. Gross erosion and sediment-delivery ratio values for selected basins

[mi², square mile; tons/yr, tons per year. Predominant land-use symbols: R, rural-agricultural; N, rural affected by nonagricultural development; D, forested with minor development; U, urban; F, forested (pristine)]

Site number (fig. 1)	Name	Physiographic province	Drainage area (mi²)	Suspended-sediment discharge (tons/yr)	Gross erosion[1] (tons/yr)	Sediment delivery ratio[2]	Predominant land use
8	Double Creek near Roseville	Piedmont	7.47	3,100	22,400	0.14	R
13	Tar River at Louisburg	Piedmont	427	30,000	774,000	.03	R
18	Tar River at Tarboro	Coastal Plain	2,183	93,000	4,520,000	.02	R
26	Little River near Orange Factory	Piedmont	80.4	11,000	144,000	.08	R
27	Flat River at Bahama	Piedmont	149	28,000	262,000	.11	R
29	Neuse River near Falls	Piedmont	772	140,000	990,000	.14	N
43	Little Contentnea Creek near Farmville	Coastal Plain	93.3	3,300	130,000	.03	R
49	Reedy Fork near Oak Ridge	Piedmont	20.6	5,200	66,300	.08	R
58	Haw River near Haywood	Piedmont	1,689	280,000	1,060,000	.26	N
61	Deep River at Ramseur	Piedmont	349	62,000	603,000	.10	R
62	Tick Creek near Mount Vernon Springs	Piedmont	15.5	4,200	47,200	.09	R
63	Deep River at Moncure	Piedmont	1,434	190,000	2,080,000	.09	R
64	Buckhorn Creek near Corinth	Piedmont	76.3	5,800	41,000	.14	D
65	Cape Fear River near Lillington	Piedmont	3,464	420,000	5,710,000	.07	R
66	Flat Creek near Inverness	Coastal Plain	7.63	460	1,600	.29	D
69	Cape Fear River near Kelly	Coastal Plain	5,255	290,000	7,040,000	.04	R
77	Yadkin River at Patterson	Piedmont	28.8	11,000	30,000	.37	R
81	Yadkin River at Elkin	Piedmont	869	300,000	1,440,000	.21	R
95	Leonard Creek near Bethesda	Piedmont	5.16	2,000	13,500	.15	R
99	Lanes Creek near Trinity	Piedmont	4.92	1,100	22,400	.05	R
101	Rocky River near Norwood	Piedmont	1,372	270,000	4,030,000	.07	R
108	Lower Creek at Lenoir	Piedmont	28.1	18,000	28,400	.63	U
110	Long Creek near Paw Creek	Piedmont	16.4	7,200	13,900	.52	U
113	Long Creek near Bessemer City	Piedmont	31.8	11,000	76,600	.14	R
123	Broad River near Boiling Springs	Piedmont	875	340,000	1,070,000	.32	N
124	First Broad River near Casar	Piedmont	60.5	15,000	167,000	.09	R
129	French Broad River at Blantyre	Blue Ridge	296	78,000	254,000	.31	R
135	French Broad River at Marshall	Blue Ridge	1,332	670,000	1,860,000	.36	N
145	Little Tennessee River at Needmore	Blue Ridge	436	110,000	1,120,000	.10	N
146	Nantahala River near Rainbow Springs	Blue Ridge	51.9	3,000	46,300	.06	F

[1]Waller, E.R., Jr., U.S. Department of Agriculture, Soil Conservation Service, Raleigh, N.C., written commun., 1984.
[2]Ratio of suspended-sediment discharge to gross erosion.

ESTIMATING SEDIMENT TRANSPORT FROM BASINS

Since about 1950, many techniques have been developed for estimating suspended-sediment yield and discharge from various basins across the Nation. Most of these techniques, however, were developed for specific locations and have little transfer value to streams in North Carolina. Hindall (1976) developed predictive equations for streams in Wisconsin, but vast differences in physiography, land use, and soils negate their use for estimating suspended-sediment transport in North Carolina. Flaxman (1972) developed an equation for estimating yields from small watersheds in western states, but it is applicable primarily to deserts and to grass- and brush-covered rangelands. As with numerous other studies, these equations contained five or more variables that were difficult to measure accurately. One study derived a regression equation with 34 independent variables, including functions of watershed topography, roads, soils, forest fires, landslides, and geologic faults (Anderson, 1976). A few investigators, however, such as Kircher and Von Guerard (1982) and Lambing (1984), reported reliable predictive results using only one or two variables; however, the work was conducted in arid western states. An objective of this project was to develop methods for estimating sediment-transport values applicable to North Carolina streams using a minimum number of basin variables that are either available or easily determined.

A progression of steps was required in selecting and organizing data and information pertinent to the development of predictive equations. Preliminary analysis already discussed in this report indicates that predictive equations should consider several dimensionless-type basin variables, including the type and extent of land use, soil type, and geography. Although no numerical value can be assigned to these variables, various techniques, such as grouping, can be used to account for nonnumeric characteristics. Other variables considered to be related to sediment transport could be quantified by measurement and include the following:

drainage area (DA)
channel slope (SLOPE)
U.S. Soil Conservation Service soil-infiltration ratio (SIR)
average water discharge (AVGQ)
percentage in forests (FOR)
percentage in urban developments (URB)
average percentage surface slope in basin (PSS)
annual suspended-sediment discharge (SEDQ)
annual suspended-sediment yield (YIELD)
maximum observed stream velocity (VMAX)
U.S. Soil Conservation Service rainfall factor (SCS-R)
percentage of basin's land area in row crops (ROW) and
water discharge for the 2-year (Q2YR), 10-year (Q10YR), and 25-year (Q25YR) floods

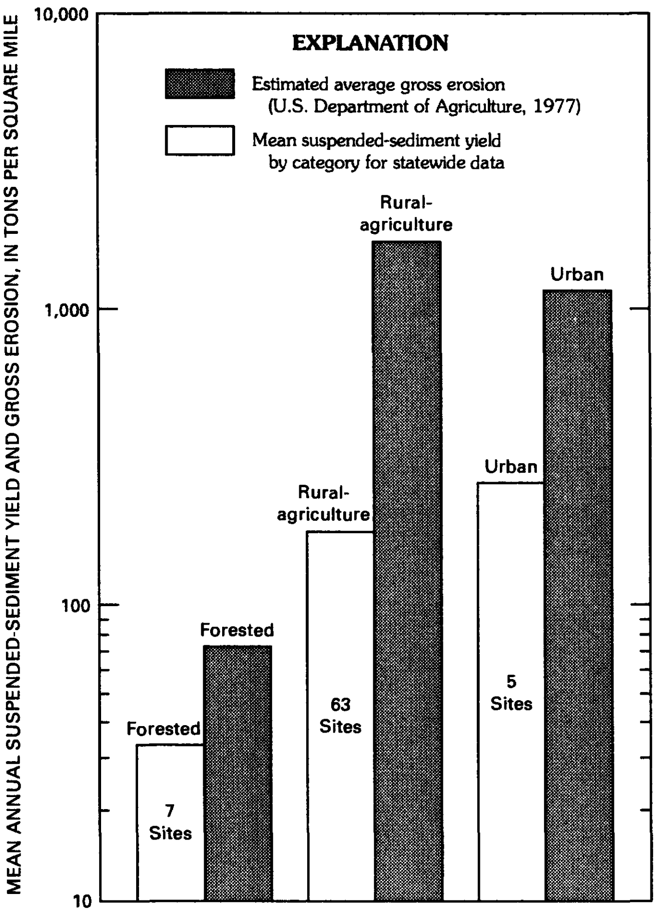


Figure 26. Comparison of mean annual suspended-sediment yield, by land-use category and for drainage areas of less than 400 mi², with values of gross erosion computed on statewide basis.

These data and selected basin information were assembled into a computerized data base along with other supplementary data, such as estimated mean concentrations and loads of suspended sediment for various percentages of time, periods of record, average precipitation, and codes for sources of various information. As previously discussed, all flow- and sediment-related data are drawn from the 10-year reference period, 1970–79.

The Statistical Analysis System, SAS, was used to evaluate the data and to determine the significance of different variables in predictive processes (SAS Institute, Inc., 1985). As demonstrated previously in this report, visual examination of suspended-sediment yields and other data on map plots of the State indicates close similarity of sediment characteristics within certain areas when consideration is given to soil class, basin size, land use, and several additional characteristics. Possible combinations of data and basin characteristics were evaluated for all sites using the multiple regression analysis computer program PROC STEPWISE/MAXR (SAS Institute, Inc., 1985). This determined the most significant variables from all independent variables examined. One-variable and multiple-variable models producing the greatest coefficient of determination (R^2) values were selected. Arithmetic and log-transformed operations also were performed. The dependent variables were suspended-sediment yield and suspended-sediment discharge. Results of this analysis indicated that the most reliable sediment relation could be developed by using the following guidelines:

1. Drainage area should not exceed 400 mi²;
2. Individual analyses should be grouped by predominant land-use category and soil class;
3. Basins containing major reservoirs and large-scale channelization should be omitted from analysis;
4. The independent variables that provide the greatest R^2 and smallest standard error of estimate were drainage area, average water discharge, 2-year flood, and 10-year flood (in decreasing order of significance);
5. Reliable predictive equations were possible for determining values of suspended-sediment discharge for specific land-use categories; and
6. Data in logarithmic format provided the best statistical results.

Another SAS program, PROC CORR (SAS Institute, Inc., 1985), was used to compute correlation coefficients and other statistics between independent variables. Correlation is a measure of goodness of fit of a linear relation between two variables, where a value of ±1 indicates a perfect fit. A value of zero indicates that there is no linear relation (variables are independent). Correlation coefficients computed by soil class (seven classes combined into four groups) for rural-agricultural basins less than 400 mi^2 in size are shown in table 17. Coefficients greater than about 0.8 indicate a high probability that a relation between variables exists. As shown in table 17, drainage area (DA) is the most significant single variable, and average water discharge (AVGQ) is second most significant. While correlation coefficients are good indicators of the significance of variables, other statistical tests along with an understanding of sediment hydrology are required to fully interpret results.

Although various methods exist for substantiating multiple-group similarities and boundaries, the SAS program CANDISC (SAS Institute, Inc., 1985) provides a visual display of discriminant analysis. Given a classification variable (soil class) and several quantitative variables (yield, slope, and suspended-sediment concentration at 0.1-percent flow duration) for each study basin, CANDISC produces a plot of these data that shows optimal separation of similar groups. Such a plot is shown in figure 27 and was derived using the preceding variables for sites having drainage areas less than 400 mi^2 that are affected by rural-agricultural land use. Each letter on the plot represents the plotting position for data from an individual data site. Its position was determined by statistical evaluation of the variables with regard to the various soil classes. As shown in figure 27, the close grouping of sites that lie in the same soil class indicates a similarity of sediment characteristics within each class; this interpretation of basin and sediment data by soil class is logical.

Final analysis and development of equations were performed with program PROC GLM (SAS Institute, Inc., 1985), which uses the method of least squares to fit general linear models. PROC GLM not only produces an equation but also gives statistical information for determining the predicted reliability of the equation. On the basis of data availability, the range in parametric values, and evaluation of statistical results, reliable predictive equations were developed for estimating sediment discharge from rural basins affected by agriculture and urban basins by soil classes of the State. The equations and corresponding statistics are shown in table 18. Equations developed for rural basins affected by agriculture using the best single variable, drainage area, show little or no statistical improvement when additional independent variables are included in the analysis (table 18). In keeping with the objectives of this study, estimated values of suspended-sediment discharge were computed using the single-variable equations. Estimates for soil classes 10, 11, and 13 are quite reliable (standard error of estimate ranging from 25 to 46 percent); however, estimates for the other soil groups are less reliable.

Table 17. Relation of sediment discharge to selected stream-basin parameters by soil groups for rural-agricultural basins

[SEDQ, annual suspended-sediment discharge; DA, drainage area; AVGQ, average water discharge; VMAX, maximum observed stream velocity; Q2YR, water discharge for the 2-year flood; Q10YR, water discharge for the 10-year flood; SCS-R, U.S. Soil Conservation Service rainfall factor; ROW, percentage of basin's land area in row crops; URB, percentage in urban developments; FOR, percentage in forests; PSS, average percentage surface slope in basin; SIR, U.S. Soil Conservation Service soil-infiltration ratio; *N*, number of sampling stations used in analysis]

Parameter	Correlation coefficients			
	Soil class (fig. 4)			
	1, 3, 4	10, 13	11	14
SEDQ	1.0000	1.0000	1.0000	1.0000
DA	.8811	.9750	.9782	.7456
AVGQ	.8616	.9731	.9759	.6390
VMAX	.0869	.5686	.3525	-.6151
Q2YR	.9142	.9336	.9585	.4555
Q10YR	.8607	.9293	.9572	.4135
SCS-R	-.5659	-.1239	-.8084	-.0169
ROW	.2298	.2226	.8017	.5241
URB	.1700	.3246	.0722	-.0710
FOR	.3141	.3684	.7695	.3079
PSS	.3533	.3859	-.0080	-.5679
SIR	.1190	.0077	-.3624	.3641
N	16	20	15	12

The relation of mean annual suspended-sediment discharge to drainage area for specific soil classes, shown in figure 28, was developed from the best-single-variable equations (table 18). Differences in transport characteristics, such as the approximate two-log-cycle spread between curves for the Coastal Plain group (soil classes 1, 3, and 4) and the Piedmont urban group (soil classes 10 and 13), are highlighted in figure 28. The fact that most of the curves are near a 1:1 slope indicates that sediment yields for study basins within specific soil classes are relatively uniform. For reasons discussed previously, the relations discussed in this section are not applicable to small-acreage basins of less than 1 mi^2 in size.

Efforts to develop transport equations for other categories of network stations were unsuccessful, generally because of insufficient numbers of sites per category. The uniqueness of some basins, such as those that were channelized or regulated by reservoirs, also precluded their use in developing areal or regional equations.

Table 18. Relations for estimating suspended-sediment discharge from rural-agricultural and urban basins by soil class (unchannelized basins ranging in size from 1 to 400 square miles)

[SEDQ, annual suspended-sediment discharge; DA, drainage area; AVGQ, average water discharge; ROW, percentage of basin's land area in row crops]

Condition	Soil class (fig. 4)	Regression equation	R^2	Standard error of estimate (percent)
Rural basins				
Best single variable	1, 3, 4	$SEDQ = 52.9\ DA^{0.801}$	0.776	74
	10, 13	$SEDQ = 204\ DA^{1.00}$	.951	35
	11	$SEDQ = 279\ DA^{0.893}$	.957	25
	14	$SEDQ = 258\ DA^{0.952}$	.560	66
Best three variables	1, 3, 4	$SEDQ = 88.4\ DA^{2.84}\ AVGQ^{-2.20}\ ROW^{0.252}$	0.823	72
	10, 13	$SEDQ = 203\ DA^{0.689}\ AVGQ^{0.335}\ ROW^{0.0035}$	.952	35
	11	$SEDQ = 31.0\ DA^{2.23}\ AVGQ^{1.18}\ ROW^{0.459}$	.966	25
	14	$SEDQ = 1{,}980\ DA^{2.43}\ AVGQ^{-1.37}\ ROW^{-0.543}$	.661	65
Urban basins				
Best single variable	10, 13	$SEDQ = 671\ DA^{0.909}$	0.885	46

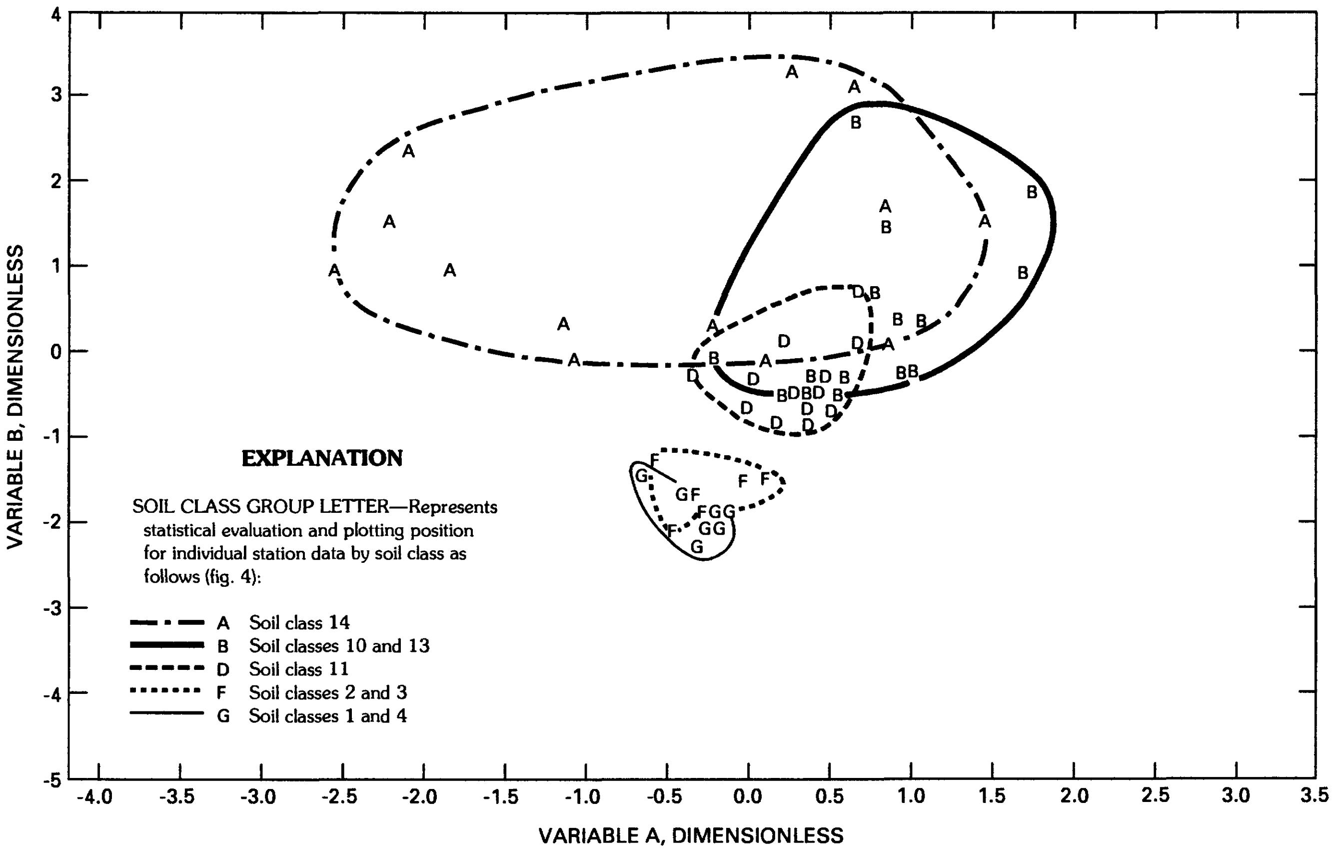


Figure 27. Multiple-group clustering of rural-agricultural sediment sites obtained from a comparison of selected basin and sediment characteristics by representative soil class.

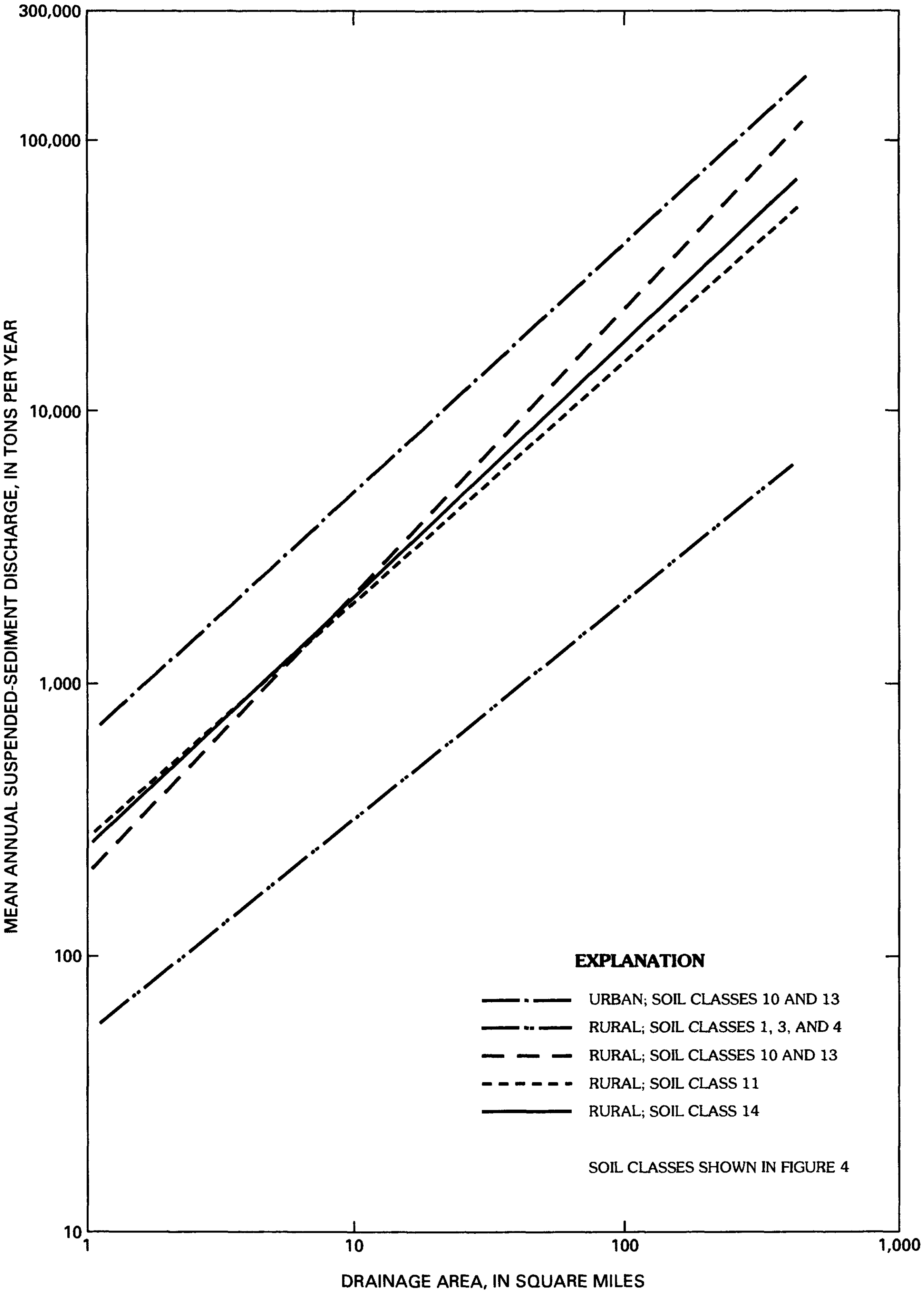


Figure 28. Relation of mean annual suspended-sediment discharge to drainage area by soil class for urban and rural-agricultural basins.

ADDITIONAL STUDIES

Although the findings in this report provide new information and answer many questions, further study is needed to resolve the following additional issues:

1. No sampling stations were located in North Carolina's sounds and estuaries; therefore, fluvial sediment transport into and through these coastal systems is unquantified and relatively unknown.

2. The millions of tons of sediment transported annually by the State's streams serve as a transport mechanism for various chemical constituents, many of which are toxic. Although legislative or other actions may help improve quality of flow in a stream, toxic-laden sediments may remain in the stream for decades. More information is needed regarding the quantity, quality, resuspension potential, and ultimate fate of these constituents.

3. During the erosion processes, only a small percentage of eroded materials reaches the stream system. This conclusion is based primarily on estimates of gross erosion generated from the Universal Soil Loss Equation and from site-specific projects conducted in other states. How representative are these erosion values to actual conditions in North Carolina?

4. As shown in this study, hundreds of thousands of tons of sediment are deposited annually along the lower reaches of major coastal streams. Many questions remain unanswered regarding where and how these sediments are deposited.

5. More data are needed from additional forested basins; seven sites were insufficient for making statistically sound generalizations regarding background (pristine) characteristics.

6. Quantities of bed-load discharge in the State's streams are unknown. In-stream measurements of bed-load discharge, using the Helly-Smith or other types of samplers, are needed in order to provide estimates of total suspended-sediment discharge.

7. The effect of the State's 80,000 small farm ponds and impoundments on sediment yields in rural areas needs to be studied.

8. The lack of long-term sediment data prevented evaluation of historical trends. Presently, it cannot be shown with any certainty that sediment conditions in North Carolina streams have improved or deteriorated with respect to time. Data obtained in conjunction with this study can serve as a base for future trend analyses.

9. More data are needed from small-drainage-area sites (0.1–1.0 mi^2) affected primarily by a single land-use category in order to better define characteristics of small headwater streams and to improve reliability of predictive equations.

SUMMARY

Data collected at 152 sampling sites during 1970–79 were used to characterize fluvial sediment in North Carolina. The study indicated that suspended-sediment characteristics across the State during 1970–79 were extremely variable. Variations were largely influenced by differences in the soils, topography, and land-use patterns. Data for the 152 sites were grouped according to predominant land use in the basin, including 7 sites categorized as forested (pristine), 83 sites as rural-agricultural, and 17 sites as urban. In addition, the network included 7 forested basins affected by runoff from interbasin roads and minor development, and 38 predominantly rural basins affected by nonagricultural activities. Suspended-sediment discharge, yield, mean concentrations by flow periods, and other characteristics were determined from more than 13,000 samples of suspended sediment collected during the 10-year study.

Comparisons of stream-discharge data for the 1970–79 study period with long-term data indicate that mean flows generally were 10 to 20 percent greater than the long-term average in the Blue Ridge and Piedmont Provinces and near long-term average in the Coastal Plain Province. The absence of widespread record floods during the 10-year study, however, probably makes the sediment values in this report more representative of long-term averages than indicated by flow comparisons.

Data from the network's seven forested basins were used to characterize pristine, or background, conditions. Comparisons of these data with those from developed basins indicate the degree of changes over background levels caused by human activities. Fluvial sediment in forested basins is extremely sensitive to even minor development in relatively close proximity to watercourses. Annual suspended-sediment yields for five forested sites in the Piedmont and Blue Ridge Provinces were comparable, ranging from 31 to 58 tons/mi^2 and having a mean value of 44 tons/mi^2; however, yields for two Coastal Plain sites were considerably lower, with a mean value of 5 tons/mi^2. Forested basins were relatively small in drainage area, ranging from 0.64 to 51.9 mi^2, and were generally representative of a single province and a single major soil class.

Comparisons of yields between predominant land-use categories—forested (pristine), rural-agricultural, and urban—were made for sites with drainage areas of less than 400 mi^2. Mean suspended-sediment yields for rural-agricultural and urban Piedmont basins are about 6 and 14 times greater, respectively, than yields from forested basins. In contrast, studies conducted in the Piedmont of Maryland and Virginia in small basins that range from about 10 to 50 acres reported yields from urban areas as much as 200 times greater than yields from comparable forested or rural-agricultural areas; however, these ex-

tremely high values were derived from areas undergoing intense construction activities related to the housing industry. Similar detailed studies of small-acreage sites are lacking in North Carolina, but it is logical that equally large values of transport probably occur in this State's developing area of the Piedmont Province. Although large yields are produced from small development sites, most of the eroded material is apparently redeposited near the source and is not reflected in yields computed for sampling sites in this study.

During high flow (0.1-percent flow duration) in Piedmont basins, the mean suspended-sediment concentration for large urban streams is about 1,600 mg/L as compared with 870 mg/L for rural-agricultural sites and 100 mg/L for forested sites. Concentrations during low-flow periods are minimal at Piedmont sites, with mean concentrations near 14 mg/L at urban sites, 11 mg/L at rural sites, and 5 mg/L at forested sites.

Results of this study indicate a relation between major soil types and sediment transport. Maximum sediment yields of rural-agricultural basins occur in predominantly clayey soil areas of the western Piedmont, with annual values of as much as 470 tons/mi^2, whereas minimum yields as small as 7 tons/mi^2 occur in the sandy soil of the Coastal Plain Province. Particle-size data collected during floods indicate that silts and sands comprise an average of about 84 percent of suspended materials in Blue Ridge streams and about 47 percent of materials in the Coastal Plain. Clay-sized material comprises more than 40 percent of suspended sediments in Piedmont streams during high flows but only about 16 percent in streams of the Blue Ridge Province.

Large main streams, such as the Neuse and Cape Fear Rivers, which originate in the Piedmont and flow across the Coastal Plain, maintain greater concentrations of sediment than tributary streams that originate in the Coastal Plain. However, vast quantities of sediment are deposited in the Coastal Plain along their routes to the sea. For example, on the average, more than 130,000 tons/yr of sediment is deposited along an 85-mi reach of the Neuse River between Smithfield and Kinston, and about 90,000 tons/yr is deposited by the Cape Fear River between Lillington and Tar Heel. This phenomenon probably is caused by a reduction in gradients and stream velocities as the streams flow from the Piedmont across the Coastal Plain. On other major rivers, such as the Pee Dee and Roanoke, dramatic reductions in transport are caused by the trapping effects of reservoirs. Together, John H. Kerr Reservoir, Lake Gaston, and Ronaoke Rapids Lake on the Roanoke River are estimated to trap about 95 percent of the river's suspended sediment and all of the bed-material discharge. These estimates indicate that the 80,000 farm ponds, reservoirs, and lakes in North Carolina probably trap millions of tons of sediment annually.

Only a small percentage of eroded material becomes suspended sediment in larger streams. Comparison of statewide yields by the three major land-use categories indicates that about 40 percent of gross erosion from forested basins, 20 percent of gross erosion from urban basins, and 10 percent of gross erosion from rural-agricultural basins were actually transported past the sampling station as suspended sediment. The overwhelming bulk of eroded material is stored on flood plains, in stream channels, on upland slopes, and in countless other temporary resting places. Compared with mean annual values of suspended-sediment discharge, less than 5 percent of materials eroded in the rural-agricultural basins of the Coastal Plain and about 16 percent of materials eroded in the rural-agricultural basins of the Piedmont and Blue Ridge Provinces become streamborne.

Regional relations were developed for estimating suspended-sediment discharge in rural-agricultural and urban basins with drainage areas that range from 1 to 400 mi^2. The best-single-variable equation used log-transformed values of drainage area. Standard errors of estimate for these equations, limited to specific major soil units, ranged from 25 to 74 percent. The addition of other seemingly important variables, such as percentage of basin's land area in row crops and average water-discharge values, to these equations showed little or no statistical improvement.

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TABLE 19

Table 19. Name, location, and physical characteristics of sediment-sampling stations

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area				Categor-ization
						Row crop	Pasture	Forest	Urban	
1	02053200	Potecasi Creek near Union	Lat 36°22'14", long 77°01'86", Hertford County, on right bank at downstream side of bridge on State Highway 11, and 2.8 mi N. of Union.	03010204	225	28	4	67	1	N
2	02053500	Ahoskie Creek at Ahoskie	Lat 36°16'50", long 77°00'00", Hertford County, on right bank 10 ft downstream from bridge on State Highway 350, and 0.8 mi SW. of Ahoskie.	03010203	63.3	27	6	51	16	N
3	02068500	Dan River near Francisco	Lat 36°30'53", long 80°18'11", Stokes County, on left bank 200 ft upstream from bridge on State Highway 704, and 3.0 mi E. of Francisco.	03010103	129	24	7	63	6	R
4	02071000	Dan River near Wentworth	Lat 36°24'47", long 79°49'45", Rockingham County, on right bank 600 ft downstream from Settles Bridge on Secondary Rd. 2150, and 3.5 mi NW. of Wentworth.	03010103	1,053	17	6	76	1	R
5	02074000	Smith River at Eden	Lat 36°31'31", long 79°45'57", Rockingham County, on right bank at Eden, and 0.3 mi downstream from bridge on State Highway 14.	03010103	538	19	5	75	1	N
6	02074218	Dan River near Mayfield	Lat 36°32'29", long 79°36'21", Rockingham County, near right bank on downstream end of bridge pier on Secondary Rd. 1761, and 3.0 mi NW. of Mayfield.	03010103	1,778	24	6	65	5	N
7	02077200	Hyco Creek near Leasburg	Lat 36°24'07", long 79°12'13", Caswell County, on right bank 10 ft upstream from bridge on U.S. Highway 158, and 2.5 mi W. of Leasburg.	03010104	45.9	25	6	66	3	R
8	02077240	Double Creek near Roseville	Lat 36°21'44", long 79°05'48", Person County, on left bank 21 ft downstream from culvert on Secondary Rd. 1166, and 3.0 mi NW. of Roseville.	03010104	7.47	27	7	65	1	R
9	02077250	South Hyco Creek near Roseville	Lat 36°23'12", long 79°06'22", Person County, on right bank at downstream side of bridge on U.S. Highway 158, and 4.2 mi NW. of Roseville.	03010104	56.5	35	7	57	1	R
10	02080500	Roanoke River at Roanoke Rapids	Lat 36°28'04", long 77°37'18", Halifax County, on right bank 2.8 mi downstream from Roanoke Rapids Dam.	03010107	8,384	24	6	66	4	N

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number	Station name	Location	Hydrologic unit	Drainage area (mi²)	Land use, in percent of total drainage area: Row crop	Pasture	Forest	Urban	Categor-ization
11	02081000	Roanoke River near Scotland Neck	Lat 36°12', long 77°23', Halifax County, on right bank 5.0 ft upstream from Highway 258, and 5.75 mi N. of Scotland Neck.	03010107	8,671	25	5	66	4	N
12	02081500	Tar River near Tar River	Lat 36°11'41", long 78°35'00", Granville County, on right bank 90 ft upstream from bridge on State Highway 96, and 2.5 mi E. of town of Tar River.	03020101	167	18	8	72	2	R
13	02081747	Tar River at Louisburg	Lat 36°05'34", long 78°17'48", Franklin County, on left bank 0.1 mi downstream from bridge on U.S. Highway 401 (Bickett Blvd.) at Louisburg.	03020101	427	20	8	66	6	R
14	020801800	Cedar Creek near Louisburg	Lat 36°03', long 78°20', Franklin County, on downstream end of center pier of bridge on U.S. Highway 401, and 3.7 mi SW. of Louisburg.	03020101	48.2	30	7	62	1	R
15	02082770	Swift Creek at Hilliardston	Lat 36°06'42", long 77°55'16", Nash County, near left bank at downstream side of bridge on Secondary Rd. 1310, and 0.7 mi NE. of Hilliardston.	03020101	166	30	5	64	1	R
16	02082950	Little Fishing Creek near White Oak	Lat 36°11'08", long 77°52'34", Halifax County, on right bank 8.0 ft downstream from bridge on Secondary Rd. 1338, and 1.1 mi W. of White Oak.	03020101	177	25	4	70	1	R
17	02083000	Fishing Creek near Enfield	Lat 36°09'03", long 77°41'35", Edgecombe County, on right bank 15 ft downstream from bridge on U.S. Highway 301, and 2.0 mi SW. of Enfield.	03020102	526	28	5	63	4	R
18	02083500	Tar River at Tarboro	Lat 35°53'38", long 77°32'00", Edgecombe County, near right bank on downstream end of pier of bridge on U.S. Highway 64 in Tarboro.	03020103	2,183	29	5	58	8	R
19	02083800	Conetoe Creek near Bethel	Lat 36°46'33", long 77°27'45", Pitt County, on right bank 5.0 ft downstream from bridge on Secondary Rd. 1409, and 5.5 mi W. of Bethel.	03020103	78.1	31	8	59	2	N
20	02084160	Chicod Creek near Simpson	Lat 35°33'47", long 77°13'43", Pitt County, on left bank at downstream side of bridge on Secondary Rd. 1760, and 2.8 mi ESE. of Simpson.	03020103	45	46	6	46	2	R

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area				Categor-ization
						Row crop	Pasture	Forest	Urban	
21	02084317	Black Swamp near Batts Crossroads	Lat 35°42'32", long 77°05'53", Beaufort County, on left bank at upstream side of culvert on Secondary Rd. 1420, and 1.8 mi NW. of Batts Crossroads.	03020104	1.02	0	0	100	0	F
22	02084500	Herring Run near Washington	Lat 35°34'03", long 77°01'09", Beaufort County, on left bank 10 ft downstream from bridge on Secondary Rd. 1506, and 2.8 mi NE. of Washington.	03020104	15.1	17	4	78	1	N
23	02084540	Durham Creek at Edward	Lat 35°19'25", long 76°52'26", Beaufort County, on left bank 5.0 ft downstream from bridge on Secondary Rd. 1949 at Edward.	03020104	26	34	5	60	1	R
24	02085000	Eno River at Hillsborough	Lat 36°04'20", long 79°06'30", Orange County, 1,000 ft downstream from U.S. Highway 70 at Hillsborough.	03020201	66.0	35	8	49	8	R
25	02085070	Eno River near Durham	Lat 36°04'21", long 78°54'24", Durham County, on right bank 275 ft downstream from bridge on U.S. Highway 501, and 5.0 mi N. of Durham.	03020201	141	29	7	60	4	R
26	02085220	Little River near Orange Factory	Lat 36°08'20", long 78°54'24", Durham County, on right bank 125 ft upstream from bridge on U.S. Highway 501, and 1.2 mi NW. of Orange Factory.	03020201	80.4	20	13	64	3	R
27	02085500	Flat River at Bahama	Lat 36°10'57", long 78°52'44", Durham County, on right bank 0.5 mi upstream from Lake Michie, and 1.2 mi N. of Bahama.	03020201	149	24	7	65	4	R
28	02087000	Neuse River near Northside	Lat 36°02'54", long 78°44'59", Durham County, on right bank 25 ft upstream from Fish Dam Bridge on Secondary Rd. 1801, and 2.5 mi S. of Northside.	03020201	535	15	6	72	7	R
29	02087183	Neuse River near Falls	Lat 35°56'24", long 78°34'32", Wake County, on left bank 0.3 mi downstream from bridge on Secondary Rd. 2000, and 0.4 mi NE. of Falls.	03020201	772	14	7	67	12	N
30	02087500	Neuse River near Clayton	Lat 35°38'50", long 78°24'21", Johnston County, on left bank at downstream side of bridge on State Highway 42, and 3.0 mi E. of Clayton.	03020201	1,150	23	7	60	10	N

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area: Row crop	Pasture	Forest	Urban	Categorization
31	02087570	Neuse River at Smithfield	Lat 35°30'46", long 78°21'00", Johnston County, on left bank 10 ft downstream from bridge on U.S. Hwy. 70 at Smithfield.	03020201	1,206	23	6	61	10	N
32	02088000	Middle Creek near Clayton	Lat 35°34'12", long 78°35'30", Johnston County, on right bank 300 ft downstream from bridge on State Highway 50, and 9.5 mi SW. of Clayton.	03020201	83.5	41	8	49	2	R
33	02088470	Little River near Kenly	Lat 35°35'18", long 78°11'12", Johnston County, near left bank on downstream side of bridge on Secondary Rd. 1934, and 3.7 mi W. of Kenly.	03020201	191	43	8	47	2	R
34	02088500	Little River near Princeton	Lat 35°30'40", long 78°09'36", Johnston County, on left bank 600 ft downstream from bridge on Secondary Rd. 2320, and 3.0 mi N. of Princeton.	03020201	232	38	7	50	5	R
35	02089000	Neuse River near Goldsboro	Lat 35°20'14", long 77°59'51", Wayne County, on left bank at downstream side of bridge on Secondary Rd. 1915, 0.2 mi upstream from Stony Creek, and 3.2 mi S. of Wayne County Courthouse in Goldsboro.	03020202	2,399	27	4	62	7	N
36	02089222	Bear Creek near Parkstown	Lat 35°22'22", long 77°48'10", Greene County, on left bank at upstream side of culvert on Secondary Rd. 1136, and 0.9 mi E. of Parkstown.	03020203	4.27	63	4	33	0	R
37	02089500	Neuse River at Kinston	Lat 35°15'29", long 77°35'09", Lenoir County. on left bank at Kinston, and 600 ft downstream from bridge on State Highway 11.	03020202	2,690	30	4	60	6	N
38	02090380	Contentnea Creek near Lucama	Lat 35°41'29", long 78°06'29", Wilson County, on right bank 250 ft upstream from bridge on State Highway 581, and 6.5 mi NW. of Lucama.	03020203	161	32	5	62	1	N
39	02090512	Hominy Swamp at Wilson	Lat 35°42'29", long 77°55'00", Wilson County, on left bank 17 ft upstream from culvert on Phillips St. in Wilson.	03020203	7.90	17	8	13	62	U
40	02090625	Turner Swamp near Eureka	Lat 35°34'10", long 77°52'40", Wayne County, on right bank at downstream side of bridge on Secondary Rd. 1505, and 2.0 mi N. of Eureka.	03020203	2.1	26	5	68	1	R

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi²)	Land use, in percent of total drainage area: Row crop	Pasture	Forest	Urban	Categorization
41	02091000	Nahunta Swamp near Shine	Lat 35°29'20", long 77°48'22", Greene County, on right bank 10 ft downstream from bridge on Secondary Rd. 1058, and 3.5 mi N. of Shine.	03020203	80.4	54	4	41	1	N
42	02091500	Contentnea Creek at Hookerton	Lat 35°25'38", long 77°35'09", Greene County, on right bank at Hookerton, and 0.3 mi upstream from bridge on State Highway 123.	03020203	729	42	3	51	4	R
43	02091700	Little Contentnea Creek near Farmville	Lat 35°32'08", long 77°30'41", Pitt County, near center of span on downstream side of bridge on U.S. Highway 264, and 5.5 mi SE. of Farmville.	03020203	93.3	43	2	50	5	R
44	02091960	Creeping Swamp near Calico	Lat 35°25'42", long 77°11'12", Beaufort County, on left bank at downstream side of bridge on State Highway 102, and 4.2 mi NE. of Calico.	03020202	9.8	20	4	71	5	R
45	02091970	Creeping Swamp near Vanceboro	Lat 35°23'30", long 77°13'46", Craven County, on left bank at downstream side of bridge on State Highway 43, and 7.9 mi NW. of Vanceboro.	03020202	27	29	3	66	2	R
46	02092000	Swift Creek near Vanceboro	Lat 35°20'42", long 77°11'45", Craven County, on left bank at downstream side of bridge on Secondary Rd. 1478, and 3.5 mi NW. of Vanceboro.	03020202	182	31	4	63	2	N
47	02092020	Palmetto Swamp near Vanceboro	Lat 35°20'18", long 77°10'16", Craven County, on left bank at upstream side of bridge on State Highway 43, and 2.5 mi NW. of Vanceboro.	03020202	24.2	27	3	64	6	R
48	02092500	Trent River near Trenton	Lat 35°03'55", long 77°27'25", Jones County, on left bank 50 ft downstream from Free Bridge on Secondary Rd. 1129, and 6.0 mi W. of Trenton.	03020204	168	20	2	77	1	R
49	02093800	Reedy Fork near Oak Ridge	Lat 36°10'24", long 79°57'15", Guilford County, on left bank at downstream side of bridge on Secondary Rd. 2128, and 2.0 mi E. of Oak Ridge.	03030002	20.6	37	12	45	6	R
50	02094500	Reedy Fork near Gibsonville	Lat 36°10'31", long 79°36'57", Guilford County, on right bank 0.2 mi downstream from Huffines Mill on Secondary Rd. 2719, and 6.0 mi NW. of Gibsonville.	03030002	131	27	12	53	8	N

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number	Station name	Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area: Row crop	Pasture	Forest	Urban	Categorization
51	02095500	North Buffalo Creek near Greensboro	Lat 36°07'13", long 79°42'30", Guilford County, on left bank 5.0 ft downstream from bridge on Secondary Rd. 2832, and 5.8 mi NE. of Post Office, Greensboro.	03030002	37.1	3	0	9	88	U
52	02096500	Haw River at Haw River	Lat 36°05'13", long 79°22'02", Alamance County, on left bank at Town of Haw River, 600 ft downstream from bridge on U.S. Highway 70 and State Highway 49.	03030002	606	24	9	56	11	N
53	02096700	Big Alamance Creek near Elon College	Lat 36°02'21", long 79°31'45", Alamance County, on right bank at downstream side of bridge on Secondary Rd. 1149, and 4.5 mi S. of Elon College.	03030002	116	25	10	52	13	R
54	02096842	Cane Creek near Buckhorn	Lat 36°01'33", long 79°10'30", Orange County, on right bank 0.1 mi upstream from culvert on Secondary Rd. 1126, and 2.5 mi SE. of Buckhorn.	03030002	0.64	0	5	95	0	F
55	02096850	Cane Creek near Teer	Lat 35°56'34", long 79°14'46", Orange County, on left bank at downstream side of bridge on State Highway 54, and 1.5 mi SW. of Teer.	03030002	33.7	19	9	71	1	R
56	02096960	Haw River near Bynum	Lat 35°45'48", long 79°08'02", Chatham County, on right bank 500 ft upstream from Pokeberry Creek, 0.9 mi SSE. of Bynum, and 1.1 mi downstream from U.S. Highway 15 and 501.	03030002	1,277	27	9	61	3	R
57	02098000	New Hope River near Pittsboro	Lat 35°44'12", long 79°01'36", Chatham County, on right bank at downstream side of bridge on U.S. Highway 64, and 8.8 mi E. of Pittsboro.	03030002	288	15	6	72	7	R
58	02098198	Haw River near Moncure	Lat 35°39'11", long 79°04'03", Chatham County, on right bank 300 ft downstream from B. Everett Jordan Dam, and 2.5 mi N. of Moncure.	03030002	1,689	22	9	56	13	N
59	02099000	East Fork Deep River near High Point	Lat 36°02'15", long 79°56'46", Guilford County, on left bank 5.0 ft upstream from bridge on Secondary Rd. 1541, and 5.2 mi NE. of High Point College, High Point.	03030003	14.8	43	16	26	15	U
60	02099500	Deep River near Randleman	Lat 35°54'06", long 79°51'05", Randolph County, on left bank 500 ft downstream from bridge on Secondary Rd. 1929, and 7.0 mi N. of Randleman.	03030003	125	24	6	55	15	R

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area				Categorization
						Row crop	Pasture	Forest	Urban	
61	02100500	Deep River at Ramseur	Lat 34°43'40", long 79°39'10", Randolph County, on right bank 0.2 mi downstream from Main St. Bridge in Ramseur.	03030003	349	22	5	56	17	R
62	02101800	Tick Creek near Mount Vernon Springs	Lat 35°39'37", long 79°20'08", Chatham County, on right bank 200 ft upstream from bridge on U.S. Highway 421, and 1.5 mi E. of Mount Vernon Springs.	03030003	15.5	36	20	41	3	R
63	02102000	Deep River at Moncure	Lat 35°37'41", long 79°06'48", Lee County, on right bank, 1.2 mi upstream from bridge on U.S. Highway 1, and 1.5 mi NW. of Moncure.	03030003	1,434	17	5	65	13	R
64	02102192	Buckhorn Creek near Corinth	Lat 35°34'28", long 78°58'09", Chatham County, on left bank at upstream side of bridge on State Highway 42, and 2.0 mi E. of Corinth.	03030004	76.3	5	1	93	1	D
65	02102500	Cape Fear River at Lillington	Lat 35°24'30", long 78°48'48", Harnett County, on right bank 60 ft downstream from downstream bridge on U.S. Highway 401, and 0.5 mi N. of Lillington.	03030004	3,464	21	7	61	11	R
66	02102908	Flat Creek near Inverness	Lat 35°10'54", long 79°10'40", Hoke County, Fort Bragg Military Reservation, on left bank 15 ft downstream from culvert on Manchester Rd., and 3.6 mi E. of Inverness.	03030004	7.63	0	0	99	1	D
67	02105500	Cape Fear River near TarHeel	Lat 34°50'05", long 78°49'27", Bladen County, on right bank 100 ft upstream from William O. Huske Lock, and 7.0 mi N. of TarHeel.	03030005	4,852	27	5	61	7	R
68	02105524	Ellis Creek tributary near White Oak	Lat 34°46'02", long 78°41'24", Bladen County, on right bank 15 ft upstream from culvert on Secondary Rd. 1325, and 3.0 mi NE. of White Oak.	03030005	1.81	0	0	100	0	F
69	02105769	Cape Fear River near Kelly	Lat 34°24'15", long 78°17'38", Bladen County on right bank near upstream end of Lock No. 1, and 4.6 mi SE. of Kelly.	03030005	5,255	29	5	61	5	R
70	02106000	Little Coharie Creek near Roseboro	Lat 34 57'13", long 78 29'17", Sampson County, on downstream end of center pier of bridge on State Highway 24, and 1.2 mi E. of Roseboro.	03030006	92.8	44	5	50	1	R

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number	Station name	Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area: Row crop	Pasture	Forest	Urban	Categorization
71	02106500	Black River near Tomahawk	Lat 34°45'17", long 78°17'21", Sampson County, on left bank 30 ft upstream from bridge on State Highway 411, and 3.8 mi NE. of Tomahawk.	03030006	676	40	4	55	1	R
72	02107000	South River near Parkersburg	Lat 34°48'45", long 78°27'26", Bladen County, near center of span on downstream side of bridge on Secondary Rd. 1503, and 1.9 mi SW. of Parkersburg.	03030006	379	35	6	58	1	R
73	02108000	Northeast Cape Fear River near Chinquapin	Lat 34°49'45", long 77°49'57", Duplin County, on right bank 540 ft downstream from bridge on State Highway 41, and 1.2 mi W. of Chinquapin.	03030007	599	38	6	54	2	R
74	02108500	Rockfish Creek near Wallace	Lat 34°44'32", long 78°02'22", Duplin County, on right bank at downstream side of bridge on State Highway 41, and 2.5 mi W. of Wallace.	03030007	69.3	41	3	55	1	N
75	02108548	Little Rockfish Creek near Wallace	Lat 34°44'02", long 77°59'03", Duplin County, on right bank 0.4 mi downstream from bridge on State Highway 41, and 0.6 mi ESE. of Wallace.	03030007	7.83	37	5	34	24	U
76	02109500	Waccamaw River at Freeland	Lat 34°05'43", long 78°32'56", Brunswick County, on left bank 150 ft downstream from New Britton Bridge on State Highway 130, and 1.0 mi SW. of Freeland.	03040206	680	20	2	77	1	R
77	02111000	Yadkin River near Patterson	Lat 35°59'29", long 81°33'30", Caldwell County, on left bank 200 ft upstream from bridge on State Highway 268, and 0.5 mi S. of Patterson.	03040101	28.8	8	8	79	5	R
78	02111180	Elk Creek at Elkville	Lat 36°04'16", long 81°24'13", Wilkes County, on left bank 700 ft upstream from bridge on State Highway 268 in community of Elkville.	03040101	48.1	8	5	86	1	R
79	02111500	Reddies River at North Wilkesboro	Lat 36°10'29", long 81°10'09", Wilkes County, on left bank 400 ft upstream from bridge on Secondary Rd. 1517, and 1.2 mi NW. of North Wilkesboro.	03040101	89.2	11	7	81	1	N
80	02112120	Roaring River at Roaring River	Lat 36°14'59", long 81°02'41", Wilkes County, 800 ft upstream from bridge on Secondary Rd. 1990, and 3.8 mi NW. of village of Roaring River.	03040101	128	9	6	84	1	R

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area				Categorization
						Row crop	Pasture	Forest	Urban	
81	02112250	Yadkin River at Elkin	Lat 36°14'28", long 80°50'49", Yadkin County, on right bank at downstream side of bridge on U.S. Highway 21 at Elkin.	03040101	869	9	9	72	10	R
82	02112360	Mitchell River near State Road	Lat 36°18'58", long 80°48'36", Surry County, on right bank 18 ft upstream from bridge on Secondary Rd. 1001, and 3.3 mi E. of State Road.	03040101	78.8	13	9	77	1	R
83	02113000	Fisher River near Copeland	Lat 36°20'27", long 80°41'10", Surry County, on left bank 500 ft upstream from bridge on State Highway 268, and 2.0 mi NW. of Copeland.	03040101	128	9	6	84	1	R
84	02113500	Yadkin River at Siloam	Lat 35°16'42", long 80°33'18", Yadkin County, on right bank at upstream side of bridge on Secondary Rd. 1003 at Siloam.	03040101	1,226	9	6	82	3	R
85	02113850	Ararat River at Ararat	Lat 36°24'16", long 80°33'43", Surry County, on right bank at upstream side of bridge pier on Secondary Rd. 2019 at Ararat.	03040101	231	24	12	59	5	R
86	02114450	Little Yadkin River at	Lat 36°17'56", long 80°24'53", Stokes County, on Dalton left bank 1,200 ft downstream from bridge on U.S. Highway 52, and 1.0 mi SW. of Dalton.	03040101	42.8	30	23	46	1	N
87	02115360	Yadkin River at Enon	Lat 36°07'55", long 80°26'39", Forsyth County, on left bank 100 ft upstream from bridge on Secondary Rd. 1525, and 1.5 mi E. of Enon.	03040101	1,694	13	8	76	3	R
88	02115856	Salem Creek near Atwood	Lat 36°02'16", long 80°18'18", Forsyth County, on left bank 5.0 ft upstream from bridge at Winston-Salem Elledge Wastewater Treatment Plant, and 1.4 mi SE. of Atwood.	03040101	65.6	8	12	26	54	U
89	02115860	Muddy Creek near Muddy Creek	Lat 36°00'01", long 80°20'25", Forsyth County, on right bank 100 ft upstream from bridge on Secondary Rd. 2995, and 1.8 mi E. of community of Muddy Creek.	03040101	186	7	10	37	46	U
90	02115900	South Fork Muddy Creek near Clemmons	Lat 36°00'22", long 80°18'07", Forsyth County, on right bank 5.0 ft upstream from bridge on Secondary Rd. 2902, and 4.2 mi SE. of Clemmons.	03040101	42.9	27	20	26	27	U

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area: Row crop	Pasture	Forest	Urban	Categorization
91	02116500	Yadkin River at Yadkin College	Lat 35°51'24", long 80°23'10", Davidson County, near left bank on downstream side of pier of bridge on U.S. Highway 64, and 1.5 mi S. of Yadkin College.	03040101	2,280	20	10	63	7	N
92	02117030	Humpy Creek near Fork	Lat 35°51'17", long 60°26'24", Davie County, on left bank 9.0 ft upstream from culvert on Secondary Rd. 1813, and 1.9 mi S. of Fork.	03040101	1.05	20	30	49	1	R
93	02118000	South Yadkin River near Mocksville	Lat 35°50'39", long 80°39'38", Rowan County, on right bank at downstream side of bridge on Secondary Rd. 1972, and 6.5 mi SW. of Mocksville.	03040102	306	27	14	53	6	R
94	02118500	Hunting Creek near Harmony	Lat 36°00'01", long 80°44'45", Iredell County, on right bank at downstream side of bridge on Secondary Rd. 2115, and 3.5 mi NE. of Harmony.	03040102	155	23	12	62	3	R
95	02121493	Leonard Creek near Bethesda	Lat 35°53'14", long 80°12'30", Davidson County, on left downstream wingwall of bridge on Secondary Rd. 1837, and 2.2 mi E. of Bethesda.	03040103	5.16	50	11	37	2	R
96	02123567	Dutchmans Creek near Uwharrie	Lat 35°22'05", long 80°01'49", Montgomery County, near midstream at upstream end of two 6-ft corrugated metal-pipe culverts on Secondary Rd. 1150, and 3.0 mi SW. of Uwharrie.	03040103	3.44	0	2	98	0	F
97	02125000	Big Bear Creek near Richfield	Lat 35°20'02", long 80°20'09", Stanly County, on left bank 400 ft upstream from bridge on Secondary Rd. 1134, and 10 mi SW. of Richfield.	03040105	55.6	38	26	34	2	R
98	02125557	Gourdvine Creek near Olive Branch	Lat 35°06'02", long 80°20'11", Union County, on right bank 3.0 ft downstream from bridge on Secondary Rd. 1715, 0.8 mi downstream from Secondary Rd. 1006, and 0.9 mi SW. of Olive Branch.	03040105	8.75	49	13	35	3	R
99	02125696	Lanes Creek near Trinity	Lat 34°50'39", long 80°28'49", Union County, on left bank downstream of culvert on Secondary Rd. 2115, and 3.0 mi SE. of Trinity.	03040105	4.92	59	7	31	3	R
100	02125699	Wicker Branch near Trinity	Lat 34°52'53", long 80°26'24", Union County, on left bank at upstream side of bridge on Secondary Rd. 1940, and 4.0 mi NE. of Trinity.	03040105	5.83	43	15	36	6	R

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area: Row crop	Pasture	Forest	Urban	Categorization
101	02126000	Rocky River near Norwood	Lat 35°08'54", long 80°10'33", Stanly County, on left bank 1.5 mi upstream from bridge on Secondary Rd. 1935, and 6.0 mi SW. of Norwood.	03040104	1,372	29	12	57	2	R
102	02128000	Little River near Star	Lat 35°23'11", long 79°49'56", Montgomery County, on left bank 9.0 ft downstream from bridge on Secondary Rd. 1340, and 3.0 mi W. of Star.	03040104	106	18	10	71	1	R
103	02129000	Pee Dee River near Rockingham	Lat 34°56'46", long 79°52'11", Richmond County, on left bank at bridge on U.S. Highway 74, 3.3 mi downstream from Blewett Falls Hydroelectric Plant, 6.0 mi W. of Rockingham.	03040201	6,860	20	10	68	2	N
104	02133500	Drowning Creek near Hoffman	Lat 35°03'38", long 79°29'39", Richmond County, on right bank 10 ft downstream from bridge on U.S. Highway 1, and 4.0 mi NE. of Hoffman.	03040203	183	14	3	79	4	R
105	02134500	Lumber River at Boardman	Lat 34°26'32", long 78°57'38", Robeson County, on right bank 50 ft downstream from bridge on U.S. Highway 74 at Boardman.	03040203	1,228	17	2	79	2	R
106	02138000	Catawba River near Marion	Lat 35°42'26", long 82°02'00", McDowell County, on right bank 15 ft downstream from bridge on U.S. Highway 221, and 2.2 mi NW. of Marion.	03050101	172	7	4	86	3	R
107	02138500	Linville River near Nebo	Lat 35°°47'43", long 81°53'27", Burke County, in Pisgah National Forest, on right bank 370 ft upstream from bridge on State Highway 126, and 6.0 mi NE. of Nebo.	03050101	66.7	6	3	90	1	D
108	02141150	Lower Creek at Lenoir	Lat 35°54'20", long 81°31'59", Caldwell County, on left bank at upstream side of bridge on Mulberry St., and 0.8 mi SE. of Courthouse, Lenoir.	03050101	28.1	5	8	67	20	U
109	02142000	Lower Little River near Healing Springs	Lat 35°56'44", long 81°14'13", Alexander County, on left bank at upstream side of bridge on Secondary Rd. 1313, and 2.2 mi NE. of All Healing Springs.	03050101	28.2	15	8	75	2	N
110	02142900	Long Creek near Paw Creek	Lat 35°19'42", long 80°54'35", Mecklenburg County, on left bank at upstream side of bridge on Secondary Rd. 2042, and 3.6 mi N. of community of Paw Creek.	03050101	16.4	3	9	65	23	U

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area: Row crop	Pasture	Forest	Urban	Categor-ization
111	02143000	Henry Fork near Henry River	Lat 35°41'06", long 81°24'03", Catawba County, on left bank 325 ft downstream from bridge on Secondary Rd. 1124, and 2.0 mi SE. of village of Henry River.	03050102	83.2	14	8	77	1	R
112	02143040	Jacob Fork at	Lat 35°35'26", long 81°34'02", Burke County, on left bank 16 ft downstream from bridge on Secondary Rd. 1924, and 0.67 mi N. of Ramsey.	03050102	25.7	6	4	88	2	D
113	02144000	Long Creek near Bessemer City	Lat 35°18'23", long 81°14'03", Gaston County, on right bank 700 ft upstream from bridge on Secondary Rd. 1456, and 2.0 mi NE. of Bessemer City limits.	03050102	31.8	29	21	43	7	R
114	02146300	Irwin Creek near Charlotte	Lat 35°11'51", long 80°54'10", Mecklenburg County, on left bank at city of Charlotte's sewage disposal plant, and 4.2 mi SW. of City Hall, Charlotte.	03050103	30.7	4	5	6	85	U
115	02146507	Little Sugar Creek at Archdale Road at Charlotte	Lat 35°08'52", long 80°51'29", Mecklenburg County, on left bank at downstream side of bridge on Secondary Rd. 3657 (Archdale Dr.) in Charlotte, and 5.3 mi S. of City Hall, Charlotte.	03050103	42.6	0	1	2	97	U
116	02146600	McAlpine Creek at Sardis Road near Charlotte	Lat 35°08'13", long 80°46'06", Mecklenburg County, near left bank on downstream end of bridge pier at Secondary Rd. 3356 (Sardis Rd.), and 7.0 mi SE. of City Hall, Charlotte.	03050103	39.6	2	6	41	51	U
117	02146700	McMullen Creek near Charlotte	Lat 35°08'26", long 80°49'12", Mecklenburg County, on left downstream side of culvert wingwall at Secondary Rd. 3673 (Sharon View Rd.), Charlotte.	03050103	6.95	1	1	5	93	U
118	02146750	McAlpine Creek near Pineville	Lat 35°03'59", long 80°52'12", Mecklenburg County, on right bank at city of Charlotte's waste treatment plant, and 2.1 mi S. of Pineville.	03050103	92.4	4	7	38	51	U
119	02146800	Sugar Creek near Fort Mill, South Carolina	Lat 35°00'21", long 80°54'09", York County, on right bank at downstream side of bridge on State Highway 160, and 2.6 mi E. of Fort Mill, S.C.	03050103	262	5	10	33	52	U
120	02146900	Twelve Mile Creek near Waxhaw	Lat 34°57'06", long 80°45'23", Union County, on left bank 90 ft upstream from bridge on State Highway 16, and 2.5 mi N. of Waxhaw.	03050103	76.5	20	16	60	4	R

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area				Categor-ization
						Row crop	Pasture	Forest	Urban	
121	02149000	Cove Creek near Lake Lure	Lat 35°25'24", long 82°06'42", Rutherford County, on left bank 40 ft upstream from bridge on U.S. Highways 64 and 74, and 5.0 mi E. of town of Lake Lure.	03050105	79	8	5	86	1	R
122	02151000	Second Broad River at Cliffside	Lat 35°14'08", long 81°45'57", Rutherford County, on left bank 0.2 mi downstream from dam at Cliffside Mills, and at Cliffside.	03050105	220	16	5	75	4	R
123	02151500	Broad River near Boiling Springs	Lat 35°12'39", long 81°41'52", Cleveland County, on right bank 0.5 mi upstream from bridge on Secondary Rd. 1186, and 3.5 mi SW. of Boiling Springs.	03050105	875	15	6	71	8	N
124	02152100	First Broad River near Casar	Lat 35°29'35", long 81°40'56", Cleveland County, on right bank 570 ft upstream from bridge on Secondary Rd. 1530, and 4.0 mi SW. of Casar.	03050105	60.5	30	10	53	7	R
125	02152610	Sugar Branch near Boiling Springs	Lat 35°15'00", long 81°37'20", Cleveland County, on left downstream wingwall of culvert on State Highway 150, and 2.8 mi E. of Boiling Springs.	03050105	1.42	38	28	17	17	U
126	03161000	South Fork New River near Jefferson	Lat 36°23'40", long 81°24'27", Ashe County, on right bank 600 ft upstream from bridge on State Highways 16 and 88, and 4.0 mi SE. of Jefferson.	05050001	205	18	22	56	4	N
127	03439000	French Broad River at Rosman	Lat 35°08'32", long 82°49'28", Transylvania County, on left bank at upstream side of bridge on U.S. Highway 178 at Rosman.	06010105	67.9	9	12	78	1	R
128	03441000	Davidson River near Brevard	Lat 35°16'23", long 82°42'21", Transylvania County, on right bank 150 ft upstream from bridge on State Highway 280, and 3.3 mi NE. of Brevard.	06010105	40.4	0	4	96	0	D
129	03443000	French Broad River at Blantyre	Lat 35°17'56", long 82°37'27", Transylvania County, on left bank 40 ft upstream from bridge on Secondary Rd. 1503 at Blantyre.	06010105	296	5	4	86	5	R
130	03446000	Mills River near Mills River	Lat 35°23'56", long 82°35'46", Henderson County, on right bank 1.5 mi downstream from confluence of North and South Forks, and 1.8 mi NW. of Mills River.	06010105	66.7	8	6	83	3	R

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area: Row crop	Pasture	Forest	Urban	Categorization
131	03448000	French Broad River at Bent Creek	Lat 35°30'07", long 82°35'35", Buncombe County, on left bank 50 ft downstream from Bent Creek, and 6.7 mi S. of Asheville.	06010105	676	12	12	72	4	R
132	03450000	Beetree Creek near Swannanoa	Lat 35°39'11", long 82°24'20", Buncombe County, on left bank 0.8 mi upstream from Beetree Reservoir Dam, and 3.8 mi N. of Swannanoa.	06010105	5.46	0	0	100	0	F
133	03451000	Swannanoa River at Biltmore	Lat 35°34'06", long 82°32'42", Buncombe County, on left bank at Biltmore, and 100 ft downstream from Biltmore Ave. Bridge.	06010105	130	4	5	79	12	U
134	03451500	French Broad River at Asheville	Lat 35°36'32", long 82°34'41", Buncombe County, on right bank 27 ft upstream from Pearson Bridge (Secondary Rd. 1348) at Asheville.	06010105	945	9	9	76	6	N
135	03453500	French Broad River at Marshall	Lat 35°47'10", long 82°39'39", Madison County, on right bank upstream from Hayes Creek, and 1.5 mi SE. of Marshall.	06010105	1,332	9	9	73	9	N
136	03455500	West Fork Pigeon River above Lake Logan near Hazelwood	Lat 35°23'46", long 82°56'17", Haywood County, on right bank at upstream side of bridge on Secondary Rd. 1216, 600 ft upstream from Big Creek, and 6.7 mi SE. of Hazelwood.	06010106	27.6	1	1	98	0	D
137	03456000	West Fork Pigeon River below Lake Logan near Waynesville Rd.	Lat 35°26'38", long 82°54'46", Haywood County, on right bank at downstream side of bridge on Secondary 1111 at Riverside Church, 3.4 mi downstream from Lake Logan, and 5.3 mi SE. of Waynesville.	06010106	55.3	1	1	95	3	N
138	03456500	East Fork Pigeon River near Canton	Lat 35°27'42", long 82°52'12", Haywood County, on right bank 800 ft upstream from bridge on U.S. Highway 276, and 5.2 mi SW. of Canton.	06010106	51.5	7	4	86	3	R
139	03457000	Pigeon River at Canton	Lat 35°31'30", long 82°50'28", Haywood County, on left bank 200 ft downstream from Pigeon St. Bridge at Canton.	06010106	133	6	6	82	6	N

Table 19. Name, location, and physical characteristics of sediment-sampling stations—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area				Categorization
						Row crop	Pasture	Forest	Urban	
140	03459500	Pigeon River near Hepco	Lat 35°38'05", long 82°59'21", Haywood County, on left bank 95 ft E. of Interstate Highway 40, 0.8 mi downstream from Jonathan Creek, and 2.0 mi S. of Hepco.	06010106	350	8	7	80	5	N
141	03460000	Cataloochee Creek near Cataloochee	Lat 35°40'02", long 83°04'23", Haywood County, in Great Smoky Mountains National Park, on left bank 20 ft downstream from bridge on State Highway 284, and 2.0 mi N. of Cataloochee.	06010106	49.2	1	5	94	0	F
142	03463300	South Toe River near Celo	Lat 35°49'52", long 82°11'04", Yancey County, on right bank on Secondary Rd. 1168, 800 ft upstream from bridge on Secondary Rd. 1167, and 1.9 mi SE. of Celo.	06010108	43.3	5	7	88	0	D
143	03479000	Watauga River near Sugar Grove	Lat 36°14'18", long 81°49'22", Watauga County, on right bank 250 ft upstream from bridge on Secondary Rd. 1121, and 2.3 mi SW. of Sugar Grove.	06010103	92.1	9	18	70	3	R
144	03500240	Cartoogechaye Creek near Franklin	Lat 35°09'31", long 83°23'39", Macon County, on downstream side of center pier of bridge on Secondary Rd. 1152, and 1.8 mi S. of Franklin.	06010202	57.1	7	4	85	4	R
145	03503000	Little Tennessee at Needmore	Lat 35°20'11", long 83°31'39", Swain County, on left bank 0.8 mi downstream from Dehart Creek, and 0.8 mi N. of Needmore.	06010202	436	6	5	85	4	N
146	03504000	Nantahala River near Rainbow Springs	Lat 35°07'35", long 83°37'11", Macon County, on right bank on Nantahala Forest Service Rd. 437,300 ft upstream from Roaring Fork, and 5.0 mi downstream from town of Rainbow Springs.	06010202	51.9	2	3	95	0	F
147	03505500	Nantahala River at Nantahala	Lat 35°17'55", long 83°39'22", Swain County, on left bank on U.S. Highway 19, 1.0 mi NE. of Nantahala, and 2.8 mi downstream from Nantahala Dam powerhouse.	06010202	144	6	5	80	9	N
148	03510500	Tuckasegee River at Dillsboro	Lat 35°21'59", long 83°15'38", Jackson County, on left bank on Secondary Rd. 1377, 0.5 mi downstream from bridge on U.S. Highway 23 at Dillsboro.	06010203	347	9	8	80	3	N

Table 19.—Continued

[Categorization symbols: F, forested (pristine); D, forested with minor development; R, rural affected by agriculture; N, rural affected by nonagricultural activities; U, urban]

Site number (fig. 1)	Station number and name		Location	Hydrologic unit	Drainage area (mi^2)	Land use, in percent of total drainage area				Categor-ization
						Row crop	Pasture	Forest	Urban	
149	03512000	Oconaluftee River at Birdtown	Lat 35°27'42", long 83°21'13", Swain County, in Cherokee Indian Reservation, on left bank 200 ft upstream from bridge on Secondary Rd. 1359, and 0.5 mi S. of Birdtown.	06010203	184	6	7	86	1	R
150	03513000	Tuckasegee River at Bryson City	Lat 35°25'40", long 83°26'50", Swain County, on left bank 400 ft downstream from bridge on Secondary Rd. 1364, Everett St., in Bryson City.	06010203	655	5	4	89	2	N
151	03548500	Hiwassee River above Murphy	Lat 36°04'49", long 84°00'10", Cherokee County, on right bank of U.S. Highway 64, and 2.0 mi SE. of Murphy.	06020002	406	7	7	85	1	N
152	03550000	Valley River at Tomotla	Lat 35°08'20", long 83°58'50", Cherokee County, on right bank 15 ft downstream from bridge on Secondary Rd. 1373 at Tomotla.	06020002	104	6	5	87	2	N

GLOSSARY

Because many of the terms related to fluvial sediment are not completely standardized, the following definitions are included as a guide to the terminology used in this report:

Bed material. The sediment mixture of which the bed is composed.

Bed load or sediment discharged as bed load. Includes both the sediment that moves in continuous contact with the streambed and the material that bounces along the bed in short skips or leaps.

Drainage area of a stream at a specified location. That area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into the stream above the specified point. Figures of drainage area given herein include all closed basins, or noncontributing areas, within the area.

Erosion. The wearing away of the land surface by detachment and movement of soil and rock fragments through the action of moving water, wind, and other natural means.

Flood-base discharge. A value of high flow usually computed during the first 5 years of station operation that, on the average, is exceeded about three times per year.

Gross erosion. The total of all sheet, gully, and channel erosion in a drainage basin, usually expressed in units of mass.

Particle size. The diameter (usually the intermediate diameter), in millimeters, of suspended sediment or bed material determined by either sieve or other sedimentation methods.

Particle-size classification. Agrees with recommendations made by the American Geophysical Union Subcommittee on Sediment Terminology. The classification is as follows:

Classification	*Particle size (millimeters)*
Clay	0.00024 – 0.004
Silt	.004 – .062
Sand	.062 – 2.0
Gravel	2.0 – 64.0

Sediment. Solid material that originates mostly from disintegrated rocks and is transported by, suspended in, or deposited from water; it includes chemical and biochemical precipitates and decomposed organic material such as humus.

Sediment-delivery ratio. The ratio of sediment yield to gross erosion, expressed in percent.

Sediment-transport curve. Usually the relation between water discharge and suspended-sediment discharge, but it can be between water discharge and bed-load discharge, unmeasured sediment discharge, or total sediment discharge.

Suspended sediment. The sediment that at any given time is maintained in suspension by the upward components of turbulent currents or that exists in suspension as a colloid.

Suspended-sediment concentration. The ratio of the mass of dry sediment in a water-sediment mixture to the mass of the water-sediment mixture. In this report, it is that sediment in the sampled zone (from the water surface to a point approximately 0.1 meter (0.3 foot) above the bed), expressed as milligrams of dry sediment per liter of water-sediment mixture.

Suspended-sediment discharge. The quantity of suspended sediment passing a transect in a unit of time. When expressed in tons per day, it is computed by multiplying water discharge (in cubic feet per second) by the suspended-sediment concentration (in milligrams per liter) and by the factor 0.0027.

Total sediment discharge. The total quantity of sediment passing a section in a unit of time.

Unmeasured sediment discharge. The difference between total sediment discharge and measured suspended-sediment discharge.

Water discharge. The amount of water and sediment flowing in a channel, expressed as volume per unit of time. The water contains both dissolved solids and suspended sediment.

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