ANALYSES OF WATER QUALITY, SEDIMENTATION, AND IMPACTS OF LAND USE ON THE CONECUH AND BLACKWATER RIVER WATERSHEDS

Photograph by Marlon R. Cook

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ANALYSES OF WATER QUALITY, SEDIMENTATION, AND IMPACTS OF LAND USE ON THE CONECUH AND BLACKWATER RIVER WATERSHEDS

OPEN FILE REPORT 0805

By

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EXECUTIVE SUMMARY

The Conecuh and Blackwater River watersheds cover much of south Alabama (fig. 1, plate 1), but relatively little water data are available to determine the current status of water quality- conditions, effects of land use, and a course of action to protect these waters. The purpose of the project is to generate data that can be used by the Conecuh-Sepulga Clean Water Partnership (CSCWP) in cooperation with local, state, and federal agencies and citizens to develop, manage, and protect the surface-water resources of the Conecuh and Blackwater River Watersheds.

Monitoring-site selections were based on hydrogeologic characteristics, geographic distribution (plate 1) and land uses (plate 2) associated with particular stream reaches. The Sepulga (site 3) and Blackwater (site 6) Rivers were suspected to have minimal water-quality impacts from primarily forested lands. Sites on Big Escambia (site 4), Buck (site 7), Big (site 8), and Little Patsaliga (site 12) Creeks, and Robertson Branch (site 10) are on reaches that drain areas dominated by agricultural land use. Tanyard Branch (site 1) is an urban drainage, flowing through the city of Greenville. Rocky Creek (site 2) is on a stream listed by the Alabama Department of Environmental Management (ADEM) as impaired by a possible industrial pollutant source, and three sites are on downstream (site 5), midstream (site 9), and upstream (site 11) reaches of the Conecuh River, respectively.

The primary constituents that affect water quality in streams in Alabama have nonpoint sources and consist of sediment, nutrients, bacteria, and metals. Evaluations of these constituents provide a good indication of overall water quality and stream health. Geochemical characterization of water quality, when combined with evaluations of land-use, provides indications of pollutant sources as well as magnitudes of impact.

Sedimentation is a primary cause of nonpoint source pollution. Erosion rates, which are related to sedimentation, are accelerated by human activity such as agriculture, construction, timber harvesting, unimproved roadways, or any activity where soils or geologic units are exposed or disturbed. Sediment loads are composed of suspended and bed sediment. Buck Creek had the largest loads and Big Escambia Creek had the lowest.

A typical aquatic ecosystem includes plants and animals that are composed of carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur. These substances decompose upon the death of the plants and animals and serve as nutrients for development and growth of new organisms. However, excessive nutrient enrichment is a major cause of water-quality impairment. Evaluations of normalized nitrate loads and average phosphorus concentrations indicate that Buck Creek (site 7) and Robertson Branch (site 10) had the largest nutrient loads and concentrations and Little Patsaliga Creek (site 12) had the lowest.

Microorganisms are present in all surface waters and include viruses, bacteria, fungi, algae, and protozoa. Analyses of bacteria levels may be used to assess the quality of water and to indicate the presence of human and animal waste in surface and ground water. Fecal coliform and fecal streptococcus groups of bacteria are frequently used as indicator organisms for this type of water pollution. Robertson Branch (site 10), Tanyard Branch (site 1), and Little Patsaliga Creek (site 12) had the highest average fecal coliform bacteria counts. Big Escambia Creek (site 4) and Blackwater River (site 6) had the lowest.

Numerous metals are naturally present in streams in small concentrations. However, toxic metals in streams are usually a result of man's activities. Recently, lead and mercury have received much attention. Detectable concentrations of lead are commonly found in streams and may originate from local sources or through atmospheric deposition from sources that may be long distances from the site of deposition. Lead was the only metal from anthropogenic sources with excessive concentrations measured during the project period. Average lead concentrations were highest in Blackwater River (site 6) and lowest in Little Patsaliga Creek (site 12).

Alabama's 2006 303(d) list includes segments of four streams in the Conecuh watershed and a segment of Blackwater River. Stream segments removed from the 2006 list include the Conecuh River in Pike County (siltation, organic enrichment, and dissolved oxygen (DO)), Conecuh River in Covington and Crenshaw Counties (siltation), and the Conecuh River in Covington County (siltation) (plate 3). These segments were removed due to establishment of approved TMDLs (total maximum daily loads).

When all primary constituents (sediment, nutrients, bacteria, and metals) are considered, Buck Creek (site 8), Robertson Branch (site 10), and Tanyard Branch (site 1) were the most impacted of the monitored streams in the Conecuh River watershed and

Big Escambia Creek (site 4), Little Patsaliga Creek (site 12), and Sepulga River (site 3) were the least impacted. The highly impacted sites correlate well with pollutant sources and land uses in the respective watersheds, as theorized prior to monitoring. However, data from Little Patsaliga and Big Escambia Creeks showed less impact from agricultural practices in the watersheds than was expected.

INTRODUCTION

The investigation of water quality, sedimentation, and impacts of land use in the Conecuh and Blackwater River watersheds was commissioned by the Conecuh-Sepulga Clean Water Partnership (CSCWP). Partners for the project include the Solon and Martha Dixon Foundation, PowerSouth (formerly the Alabama Electric Cooperative), Greenville Water Works and Sewer Board, Covington Electric Cooperative, the Thelma Dixon Foundation, First South Farm Credit, Wiregrass Resource Conservation and Development (RC&D) Council, Ala-Tom RC&D Council, Conecuh/Sepulga Watershed Alliance, Covington County Soil and Water Conservation District, the Geological Survey of Alabama (GSA), and CSCWP.

The Conecuh and Blackwater River watersheds cover much of south Alabama (fig. 1), but relatively little water data are available to determine the current status of water-quality conditions, effects of land use, and a course of action to protect these waters. The purpose of the project is to generate data that may be used by the CSCWP in cooperation with local, state, and federal agencies and by citizens to develop, manage, and protect the surface-water resources of the Conecuh and Blackwater River Watersheds.

Twelve sites on nine streams were selected for evaluation by the local project cooperating agencies (plate 1). The streams are Conecuh River (one monitoring site in the upstream part of the reach in Pike County (site 11), one site in mid-reach in Crenshaw County (site 9), and one site in the downstream reach near the Alabama-Florida state line (site 5)), Tanyard Branch at Greenville (site 1), Rocky Creek at Butler County Road 16 (site 2), Sepulga River at Conecuh County Road 29 (site 3), Big Escambia Creek at Escambia County Road 30 (site 4), Blackwater River at Chesser Bridge in Okaloosa County Florida (site 6), Buck Creek at Covington County Road 23 (site 7), Big Creek at

Figure 1.--Index map showing the Conecuh and Blackwater Rivers project area.

data presented in this report characterize water quality, stream discharge, and nutrient and sediment loads. The water quality and stream discharge datasets are composed of samples collected by the GSA from July 2006 to February 2008. These data can be utilized to determine the quantity and quality of water in the selected streams and to evaluate the effects of land-use practices in each assessed watershed so that watershed management practices can be developed to protect and improve water quality and habitat conditions.

ACKNOWLEDGMENTS

The Geological Survey of Alabama would like to acknowledge those individuals and entities whose participation and cooperation have made this assessment possible. In particular, Ms. Janet Wofford, Facilitator for the CSCWP; Mr. Bruce Branham, Chairman of the CSCWP; Mr. Bill Godwin, Covington County Soil and Water Conservation District and former Chairman of the CSCWP; Ms. Doris Tyler, President, Solon and Martha Dixon Foundation; and Ms. Sandra Owens, Covington County Soil and Water Conservation District.

GEOGRAPHIC CHARACTERIZATION OF ASSESSED WATERSHEDS

The Conecuh River (three monitoring sites) and nine tributaries in south-central and southwest Alabama were selected for this investigation (plate 1). The water from these streams eventually leaves Alabama and flows across northwest Florida where it enters the Gulf of Mexico through Pensacola Bay. Assessed watersheds were selected due to land use that creates unique assemblages of physical and geochemical characteristics. Monitored streams and watershed areas are shown in table 1.

The Conecuh River Watershed is contained in portions of nine counties in south-central and southwest Alabama and covers approximately 3,800 square miles (mi^2) (plate 1).

HYDROGEOLOGY AND GEOMORPHOLOGY

The study area is underlain by unconsolidated sediments of Alabama's coastal plain. These sediments consist largely of sand, clay, and thinly bedded limestone. Also, alluvial deposits of sand, gravel, and clay are present in the flood plains of rivers and major streams.

Table 1—Monitoring sites and watershed areas.

Stream monitoring site	Site no.	Watershed areas (mi^2)
Tanyard Branch at Greenville	1	2.5
Rocky Creek at Butler Co. Road 16	2	49.4
Sepulga River at Conecuh Co. Road 29	3	59.7
Big Escambia Creek at Escambia Co. Road 30	4	140.0
Conecuh River at Escambia Co. Florida Road 4	5	1,318.0
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	92.0
Buck Creek at Covington Co. Road 23	7	13.5
Big Creek at Ala. Hwy. 29	8	8.3
Conecuh River at Dozier	9	587.0
Robertson Branch at Pike Co. Road 28	10	3.2
Conecuh River at Pike Co. Road 28	11	382.0
Little Patsaliga Creek at Crenshaw Co. Road 35	12	114.0

Ground water moving through these geologic units issues from seeps and springs in the stream valleys and is the major source of stream discharge during drought conditions. The topographic and geomorphologic characteristics of these streams cause flashy storm runoff. Stream water levels are highly variable, especially during winter and spring. The stream channels are characterized by steep banks and stream beds composed of silt and sand. Most tributaries in the watershed are classified as youthful to mature with narrow floodplains, V-shaped valleys, and narrow meander belts. The Conecuh River is classified as mature to old age with a wide flood plain, meanders, ox bow lakes, meander scars, and relatively low gradient. The stream gradient of the Conecuh River varies from about 6 feet per mile (ft/mi) near the headwaters in Bullock County to less than 1 ft/mi in southern Escambia County.

LAND-USE IMPACTS ON WATER QUALITY

Land use is an important factor that influences water quality, but may be difficult to determine on a regional scale. However, classifications of land use are discernible using the Multi-Resolution Land Characteristics Consortium's (MRLC) National Land Cover Data (NLCD). This dataset was compiled from Landsat Thematic Mapper satellite imagery (circa 2001) with a spatial resolution of 30 meters and supplemented by various ancillary data, where available. From this dataset, 15 land-use/land-cover classifications were identified within the state, with each classification displayed in a specific color. Four shades of red symbolize developed (open space), developed (low intensity), developed (medium intensity), and developed (high intensity). These areas include residential, commercial, and industrial development and transportation corridors. Green areas correspond to forest, with dark green representing evergreen forest; medium green, the deciduous forest; and light green, mixed evergreen and deciduous forest. Yellow indicates pasture or hay and brown indicates cultivated crops. Three areas of intense agriculture were observed in the Conecuh River watershed. The boundaries of these areas, designated A, B, and C (plate 2), were derived by assessing the geology, soils, physiography, topography, and land-use patterns. Clayton, Porters Creek, and Nanafalia Formations, all of which are composed of sand, clay, and limestone, dominate the geology of area A. Area B is underlain primarily by the Gosport Sand, Lisbon Formation, Tallahatta Formation, Jackson Group undifferentiated, and residuum that contains sand, clay, claystone, chert, and limestone. The geology of Area C is composed mostly of the Citronelle Formation, which contains gravel, sand, and clay.

As the geologic materials weather, they create a base for the soils. In addition, the underlying sands, clays, and limestones provide a good foundation for soils. Soils in the designated areas are classified as the Ultisols and Entisols order. Ultisols are soils that occur in humid areas and have clay-enriched subsoil that is low in nutrients. With soil amendments, they are productive for row crops. The Entisols are soils that have little or slight development and are characterized by properties of their parent material. They include soils on steep slopes, flood plains, and sand dunes. Both Ultisols and Entisols have a strong reliance on the base material or geology. These soils are particularly valuable for agricultural production.

The geology, soils, physiography, and topography collectively create an environment favorable for agricultural land uses observed in areas A, B, and C, which, in large part, are pasture, hay, and row crops. These land-use activities cause excessive sedimentation, bacteria, and nutrients in the watershed. Runoff from fertilizers and waste from animals create excessive amounts of phosphorus, nitrate, and bacterial activity that cause deterioration of water quality. Big Escambia Creek (site 4), Buck Creek (site 7), Big Creek (site 8), Robertson Branch (site 10), and Little Patsiliga Creek (site 12) were selected to evaluate the impact of these areas of intensive agriculture on the water quality of streams that drain them. Refer to these areas in constituent sections

CLEAN WATER ACT SECTION 303(d) LISTED STREAMS

Section 303(d) of the Clean Water Act requires that states identify waters that do not support their designated uses, to determine the pollutants that cause degradation of water quality, and to establish a total maximum daily load (TMDL) for the pollutants of concern to allow implementation of applicable water quality standards (Alabama Department of Environmental Management (ADEM), 2008). Alabama's 2006 303(d) list includes segments of four streams in the Conecuh River watershed and a segment of Blackwater River (plate 2). Blackwater River from the Alabama-Florida state line to Blackwater Creek was listed for metals (mercury). Rocky Creek from Persimmon Creek to a county road north of Chapman was listed for unknown toxicity. The Conecuh River from the Alabama-Florida state line to Mantle Branch was listed for metals (mercury). Little Escambia Creek from the Alabama-Florida state line to Wild Fork Creek was listed for metals (mercury). Big Escambia Creek from the Alabama-Florida state line to Big Spring Creek was listed for metals (mercury).

Stream segments included on the 2004 list and removed from the 2006 list include the Conecuh River in Pike County (siltation, organic enrichment, and DO), Conecuh River in Covington and Crenshaw Counties (siltation), and the Conecuh River in Covington County (siltation) (plates1, 2). These segments were removed due to establishment of approved TMDLs.

CHEMICAL AND PHYSICAL PARAMETERS

STREAM DISCHARGE

Discharge is a primary physical parameter that influences or affects surface-water quality. Ionic concentrations, specific conductance, dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS), bed sediment, and bacterial concentrations are all influenced by the volume of stream discharge. Discharge is an essential component of constituent loading calculations and interwatershed comparisons of ionic concentrations and normalization of water-quality data.

The evaluated streams generally attain low flow conditions during July or August. Except for occasional runoff from isolated cyclonic storms, most of the discharge from the watersheds during August, September, and October of each year can be attributed to ground-water discharge. Field observations indicate that storm-water runoff is flashy and is characterized by rapid rise and fall of stream water levels. Flooding occurs periodically and is caused by cyclonic storms associated with spring weather fronts or by summer and fall tropical storms or hurricanes that move through south Alabama. Monitored discharge events were selected to establish a data set distributed from low to high flows (fig. 2).

Discharge data were collected using a Price AA flow meter attached to a top set wading rod or a bridgeboard. The data were collected according to United States Geological Survey (USGS) flow measurement guidelines. Continuously collected discharge data were available from five USGS stream monitoring stations in the Conecuh River watershed. Mean daily discharge values collected at the USGS sites were used to normalize discharge values measured at all 12 project streams. This was accomplished by establishing ratios of watershed drainage area between each project watershed and the nearest USGS monitoring site. Measured discharge and mean stream flow velocities are shown in table 2.

STREAM TEMPERATURE

Water temperature is an important catalyst that affects the physical and geochemical characteristics of a stream. Dissolved oxygen, biological activity and equilibrium reactions are significantly influenced by water temperature. The standard for

Figure 2.--Measured discharge in monitored streams in the Conecuh and Blackwater River watersheds.

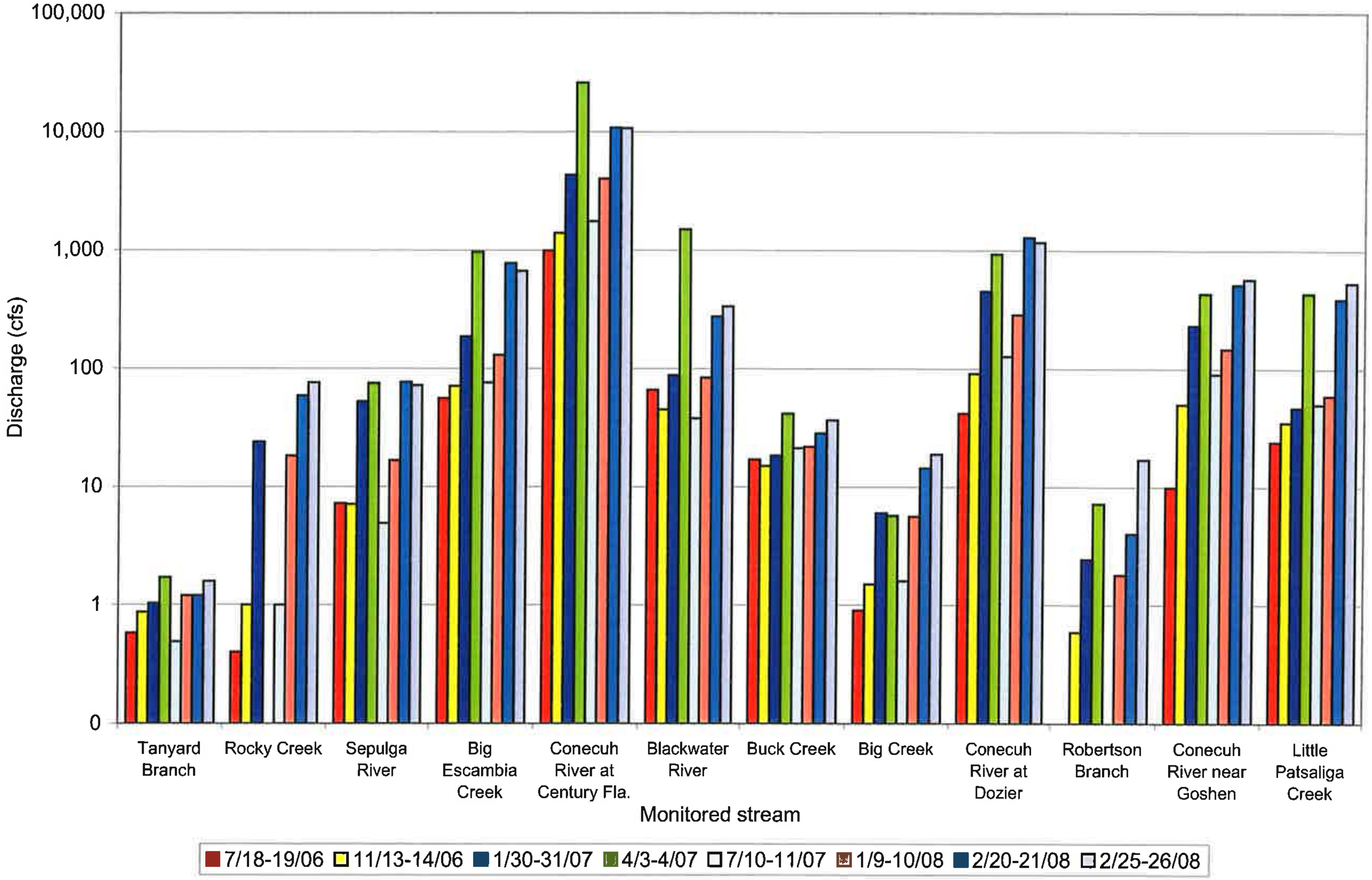


Table 2— Discharge measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream Monitoring site	Site no.	Discharge (cfs)			Average mean stream flow velocity (fps)
		Max.	Min.	Avg.	
Tanyard Branch at Greenville	1	1.6	0.5	1.1	0.7
Rocky Creek at Butler Co. Road 16	2	76	.4	26	.7
Sepulga River at Conecuh Co. Road 29	3	77	4.9	39	.9
Big Escambia Creek at Escambia Co. Road 30	4	963	56	366	2.1
Conecuh River at Escambia Co. Florida Road 4	5	26,000	989	7,498	n/a
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	1,500	45	304	1.1
Buck Creek at Covington Co. Road 23	7	37	15	24	1.1
Big Creek at Ala. Hwy. 29	8	19	.9	7	.8
Conecuh River at Dozier	9	1,283	42	60	1
Robertson Branch at Pike Co. Road 28	10	17	0	4.1	.6
Conecuh River at Pike Co. Road 28	11	570	9.9	256	.7
Little Patsaliga Creek at Crenshaw Co. Road 35	12	531	24	200	.6

maximum temperature established by the Alabama Department of Environmental Management (ADEM, 1992) for surface water classified as Fish and Wildlife is 32.2°C. The maximum temperature standard was not exceeded in any monitored stream during the project period (table 3).

CONDUCTANCE

Surface water in each project watershed is characterized by a unique conductance (microseimens/centimeter (μS/cm)) profile based on physical and chemical properties. The variability of conductivity is influenced by differences in stream temperature, discharge, total dissolved solids, local geology and soil conditions, and possible ionic influxes from nonpoint sources of pollution. The trend of discharge and conductance is an inverse relationship in streams with no significant source of contamination.

Typically, low conductance values were measured during large discharge events, indicating that rainfall made up the majority of stream discharge during these measurement periods. Low conductance may also indicate that the concentration of nonpoint source pollutants commonly flushed into streams during high discharge events was negligible. However, this trend was reversed in Tanyard Branch (site 1) where the highest conductance values were measured during periods of high discharge, indicating significant sources of contaminants in runoff. These contaminants probably originate from urban areas in the monitored stream watershed. The highest conductance values were measured in Rocky Creek (site 2) (table 4). However, these anomalously high values were measured during low flow, indicating significant contamination that is diluted during higher discharge.

Table 3— Temperature values measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream Monitoring site	Site no.	Temperature (°C)		
		Max.	Min.	Avg.
Tanyard Branch at Greenville	1	25.0	7.0	15.5
Rocky Creek at Butler Co. Road 16	2	27.4	7.3	16.1
Sepulga River at Conecuh Co. Road 29	3	27.2	7.5	16.3
Big Escambia Creek at Escambia Co. Road 30	4	26.6	8.0	16.6
Conecuh River at Escambia Co. Florida Road 4	5	29.5	9.0	18.4
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	27.0	8.9	16.7
Buck Creek at Covington Co. Road 23	7	23.4	6.7	15.6
Big Creek at Ala. Hwy. 29	8	26.5	8.7	16.8
Conecuh River at Dozier	9	29.6	7.8	17.4
Robertson Branch at Pike Co. Road 28	10	21.0	6.6	13.4
Conecuh River at Pike Co. Road 28	11	27.3	6.8	17.8
Little Patsaliga Creek at Crenshaw Co. Road 35	12	27.0	6.4	16.2

Table 4— Conductance values measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream Monitoring site	Site no.	Conductance (µS/cm)		
		Max.	Min.	Avg.
Tanyard Branch at Greenville	1	240	44	112
Rocky Creek at Butler Co. Road 16	2	625	21	195
Sepulga River at Conecuh Co. Road 29	3	64	43	50
Big Escambia Creek at Escambia Co. Road 30	4	44	24	31
Conecuh River at Escambia Co. Florida Road 4	5	173	50	100
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	37	21	29
Buck Creek at Covington Co. Road 23	7	44	32	39
Big Creek at Ala. Hwy. 29	8	37	25	32
Conecuh River at Dozier	9	182	51	85
Robertson Branch at Pike Co. Road 28	10	82	31	58
Conecuh River at Pike Co. Road 28	11	173	44	70
Little Patsaliga Creek at Crenshaw Co. Road 35	12	103	59	73

HYDROGEN ION CONCENTRATION (pH)

The concentration of hydrogen ions (H^+) is a critical water-quality parameter in natural and treated waters. Concentrations of hydrogen ions control speciation of other constituents, influence dissolution and precipitation of chemical elements, and determine whether the water will support aquatic life. Aquatic organisms are sensitive to pH changes, as such, the ADEM standard for pH in surface waters is 6 to 9. Water treatment (including disinfection) with specific types of chemicals requires stringent pH control.

Hydrogen ion activity is controlled by interrelated chemical reactions that produce or consume hydrogen ions (Hem, 1985). Therefore, pH is an important indicator of the status of equilibrium reactions that determine the ionic composition of water that flows through the project watersheds. Maximum values of pH in project streams varied from 4.9 to 7.8, while minimum pH varied from 4.1 to 6.1 (table 5, fig. 3).

The lowest pH values measured in each stream during the project period were measured during large discharge events. Low pH may indicate the acidity of rainfall that made up the majority of water in the streams during periods of high discharge. The overall lowest pH values were measured in Blackwater River (site 6). These low values (table 5) indicate the presence of tannic acid, a result of high organic content in the watershed. Elevated pH was measured during periods of low water temperatures and is indicative of the inverse relationship between water temperature and pH.

DISSOLVED OXYGEN

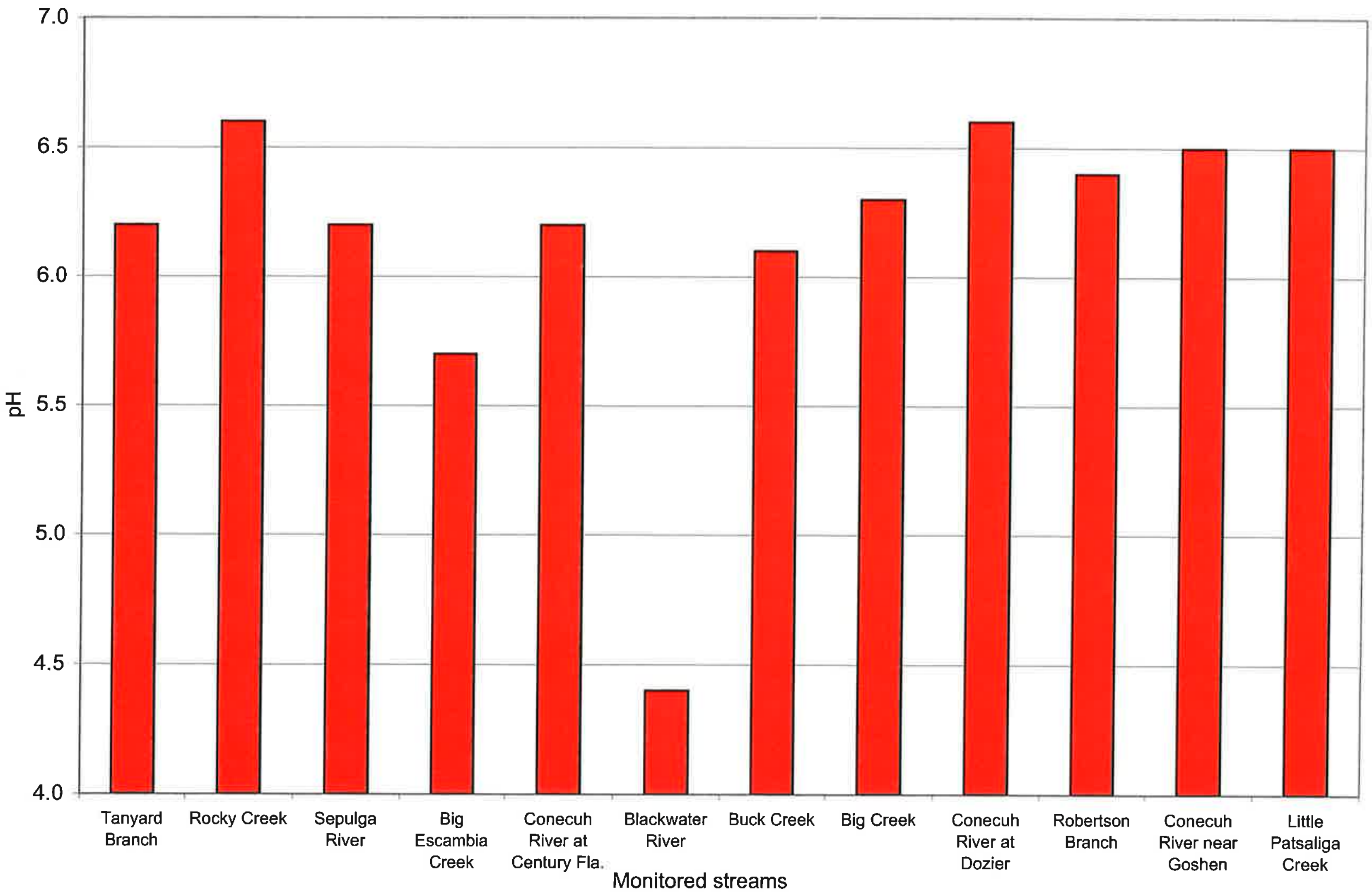
Dissolved oxygen (DO) concentration is an essential constituent that affects the biological health and the chemical composition of surface waters. Biological processes, oxidation, and sediment loads all contribute to depletion of DO in surface water. The ADEM standard for DO in surface water classified as Fish and Wildlife is 5.0 mg/L except under extreme conditions where it may be as low as 4.0 mg/L. The effects of an impoundment on DO in the impounded waters and in the downstream release from the impoundment must be carefully considered in the planning and design stage of a reservoir project.

The equilibrium concentration of DO in water that is in contact with air is primarily related to water temperature and barometric pressure and secondarily related to

Table 5— Hydrogen ion concentration measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream monitoring sites	Site no.	Hydrogen ion concentration		
		Max.	Min.	Avg.
Tanyard Branch at Greenville	1	6.6	5.8	6.2
Rocky Creek at Butler Co. Road 16	2	7.3	5.9	6.6
Sepulga River at Conecuh Co. Road 29	3	6.4	5.9	6.2
Big Escambia Creek at Escambia Co. Road 30	4	6.1	5.0	5.7
Conecuh River at Escambia Co. Florida Road 4	5	6.7	5.6	6.2
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	4.9	4.1	4.4
Buck Creek at Covington Co. Road 23	7	6.6	5.9	6.1
Big Creek at Ala. Hwy. 29	8	7.0	5.6	6.3
Conecuh River at Dozier	9	7.1	6.1	6.6
Robertson Branch at Pike Co. Road 28	10	7.4	5.3	6.4
Conecuh River at Pike Co. Road 28	11	7.8	5.0	6.4
Little Patsaliga Creek at Crenshaw Co. Road 35	12	7.0	6.0	6.5

Figure 3.--Measured average pH in monitored streams in the Conecuh and Blackwater River watersheds.



concentrations of other solutes (Hem, 1985). Equilibrium DO in water at 10°C and 25°C is 11.27 mg/L and 8.24 mg/L, respectively. DO concentrations in the project watersheds are significantly affected by water temperature, stream discharge and concentrations of organic material in the water. These factors are represented in table 6 where observed DO is compared to the 100 percent dissolved oxygen saturation for the observed stream temperature for each of the monitoring periods. The highest average observed DO as a percentage of atmospheric saturation for the monitoring period was 93 percent for Buck Creek and the lowest was 66 percent for Rocky Creek. The relatively low DO at Rocky Creek is probably caused by contaminants that led to placement of the stream on the Section 303(d) list of impaired waters.

Dissolved oxygen concentrations were lowest during the sampling period at Rocky Creek (1.6 mg/L) and the Tanyard Branch (2.0 mg/L) (table 6). These were the only dissolved oxygen concentrations measured during the project period that were below the 5 mg/L ADEM minimum standard (fig. 4).

BIOCHEMICAL OXYGEN DEMAND

Biochemical oxygen demand (BOD) is an empirical measure of the amount of oxygen used for the biochemical oxidation of organic matter by the microbial population of a water body. This parameter may be used to indicate the presence and magnitude of organic pollutants. It is often used to determine the effect of waste discharges on the oxygen resources of receiving waters. BOD effluent limitations established by the USEPA for biologically treated municipal wastewater is 30 mg/L. Standards established by some states for water-quality sensitive surface-water bodies may be as low as 5 mg/L (Mays, 1996).

Average BOD was 1.0 or less for all but three monitored streams (table 7). Water samples collected from the Tanyard Branch (site 1) had the highest average BOD levels measured during the monitoring period (3.3 mg/L) (fig. 5). Average BOD values in Rocky Creek (site 2) and Robertson Branch (site 10) were both 1.7 mg/L.

Table 6— Dissolved oxygen measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream Monitoring sites	Site no.	Dissolved oxygen (mg/L)			Average DO saturation (percentage of atmospheric saturation)
		Max.	Min.	Avg.	
Tanyard Branch at Greenville	1	9.7	2.0	6.9	71
Rocky Creek at Butler Co. Road 16	2	9.8	1.6	6.9	66
Sepulga River at Conecuh Co. Road 29	3	10.1	6.6	8.3	82
Big Escambia Creek at Escambia Co. Road 30	4	8.9	6.3	7.8	80
Conecuh River at Escambia Co. Florida Highway 4	5	8.9	6.3	7.8	77
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	9.3	6.7	8.4	87
Buck Creek at Covington Co. Road 23	7	10.8	7.7	9.6	93
Big Creek at Ala. Hwy. 29	8	9.7	7.3	8.7	87
Conecuh River at Dozier	9	10.4	7.4	8.5	88
Robertson Branch at Pike Co. Road 28	10	8.9	6.9	7.6	74
Conecuh River at Pike Co. Road 28	11	8.7	6.8	7.3	81
Little Patsaliga Creek at Crenshaw Co. Road 35	12	9.7	6.7	8.3	85

Figure 4.--Measured dissolved oxygen in monitored streams in the Conecuh and Blackwater River watersheds.

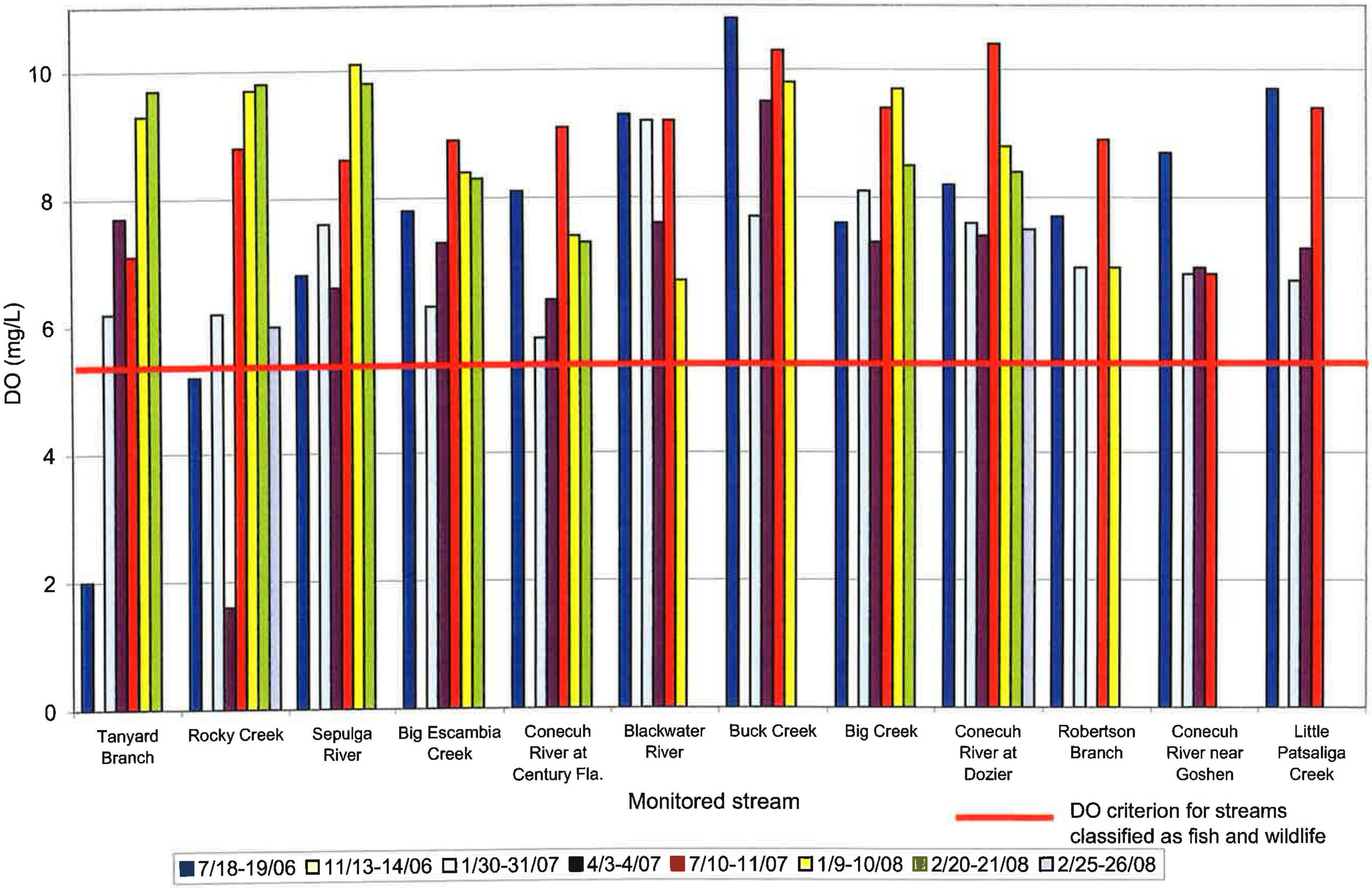
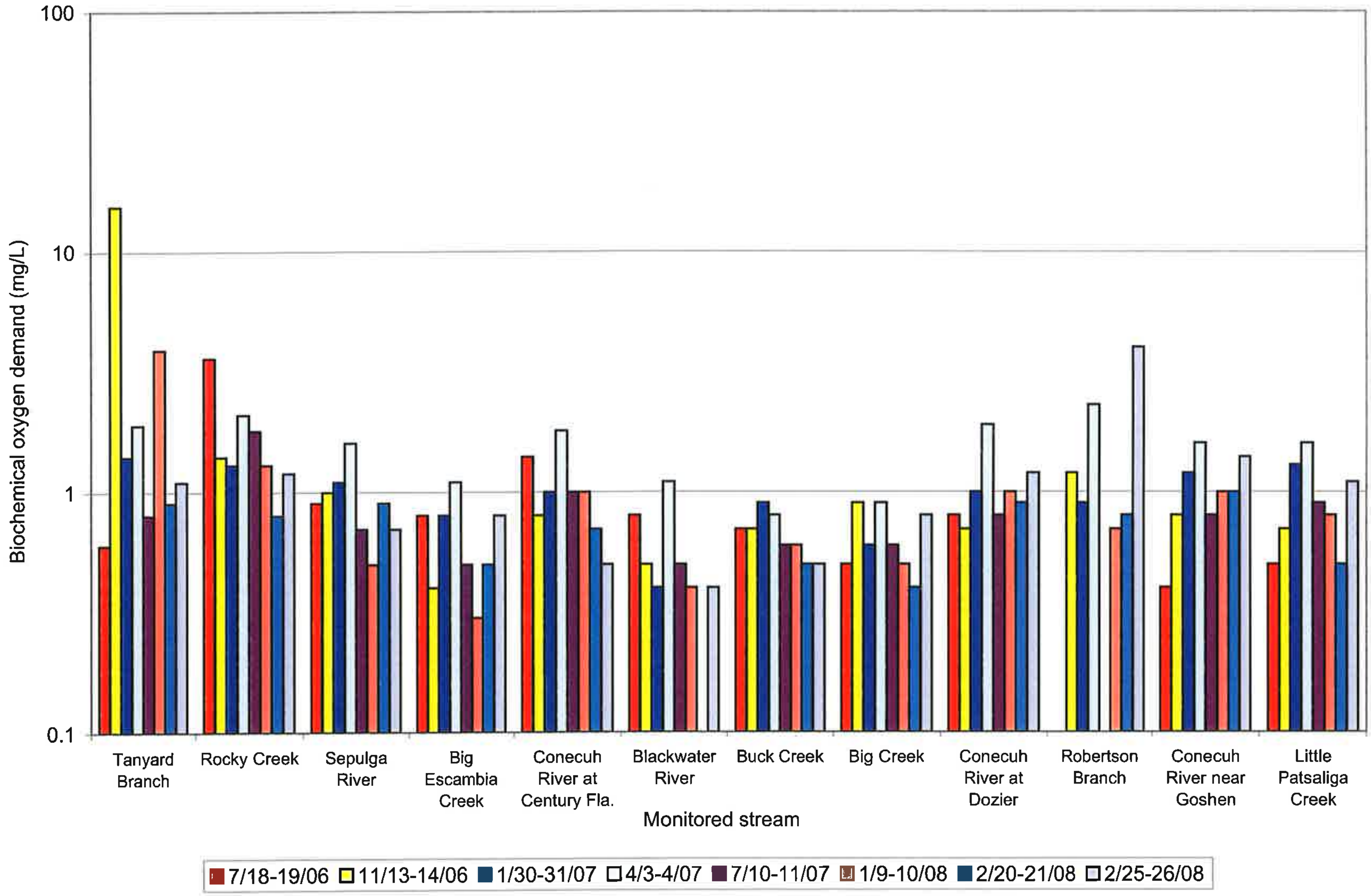


Table 7— Biochemical oxygen demand measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream Monitoring site	Site no.	Biochemical oxygen demand (mg/L)		
		Max.	Min.	Avg.
Tanyard Branch at Greenville	1	15.4	0.6	3.3
Rocky Creek at Butler Co. Road 16	2	3.6	0.8	1.7
Sepulga River at Conecuh Co. Road 29	3	1.6	0.5	0.9
Big Escambia Creek at Escambia Co. Road 30	4	1.1	0.3	0.7
Conecuh River at Escambia Co. Florida Road 4	5	1.4	0.5	1.0
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	1.1	0.4	0.5
Buck Creek at Covington Co. Road 23	7	0.9	0.5	0.7
Big Creek at Ala. Hwy. 29	8	0.9	0.5	0.7
Conecuh River at Dozier	9	1.9	0.7	1.0
Robertson Branch at Pike Co. Road 28	10	4.0	0.7	1.7
Conecuh River at Pike Co. Road 28	11	1.6	0.4	1.0
Little Patsaliga Creek at Crenshaw Co. Road 35	12	1.6	0.5	0.9

Figure 5.--Measured biochemical oxygen demand in monitored streams in the Conecuh and Blackwater River watersheds.



TURBIDITY

Turbidity values measured from water samples may be utilized to formulate an estimate of long-term trends of total suspended solids (TSS). Turbidity data may also be used to evaluate the type of treatment necessary to remove sediment from water utilized for public water supply. Turbidity is reported in Nephelometric Turbidity Units (NTU). Values measured for the project streams are shown in table 8.

CONSTITUENT LOADING IN PROJECT STREAMS

The basic concept of constituent loads in a river or stream is simple. However, the mathematics of determining a constituent load may be quite complex. The constituent load is the mass or weight of a constituent that passes a cross section of a stream in a specific amount of time. Loads are expressed in mass units (e.g., tons, kilograms) and are considered for time intervals that are relative to the type of pollutant and the watershed area for which the loads are calculated. Loads are calculated from concentrations of constituents obtained from analytical analyses of water samples and stream discharge, which is the volume of water that passes a cross section of the river in a specific amount of time.

The computer model Regr_Cntr.xls (*Regression with Centering*) was selected to calculate constituent loads for this project. The program is an Excel implementation of the USGS seven-parameter regression model for load estimation (Cohn and others, 1992). It estimates loads in a manner very similar to that used most often by the Estimatr.exe (*USGS Estimator*) program. The Regr_Cntr.xls program was adapted by R. Peter Richards at the Water Quality Laboratory at Heidelberg College (Richards, 1999). The program establishes a regression model using a calibration set of data composed of concentrations of the constituent of interest and discharge values measured at the time of water sampling. Constituent loads can be estimated for any year for which mean daily discharge data are provided.

Table 8— Turbidity measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream monitoring sites	Site no.	Turbidity (NTU)		
		Max.	Min.	Avg.
Tanyard Branch at Greenville	1	28	7	17
Rocky Creek at Butler Co. Road 16	2	28	4	16
Sepulga River at Conecuh Co. Road 29	3	48	5	25
Big Escambia Creek at Escambia Co. Road 30	4	11	1	3
Conecuh River at Escambia Co. Florida Road 4	5	58	3	26
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	17	1	6
Buck Creek at Covington Co. Road 23	7	53	2	22
Big Creek at Ala. Hwy. 29	8	25	1	11
Conecuh River at Dozier	9	70	9	27
Robertson Branch at Pike Co. Road 28	10	80	3	23
Conecuh River at Pike Co. Road 28	11	46	4	20
Little Patsaliga Creek at Crenshaw Co. Road 35	12	25	1	10

SEDIMENTATION

Sedimentation is a process by which eroded particles of rock are transported primarily by moving water from areas of relatively high elevation to areas of relatively low elevation, where the particles are deposited. Upland sediment transport is primarily accomplished by overland flow and rill and gully development. Lowland or flood plain transport occurs in streams of varying order, where upland sediment joins sediment eroded from flood plains, stream banks, and stream beds. Erosion rates are accelerated by human activity related to agriculture, construction, timber harvesting, unimproved roadways, or any activity where soils or geologic units are exposed or disturbed. Excessive sedimentation is detrimental to water quality, destroys biological habitat, reduces storage volume of water impoundments, impedes the usability of aquatic recreational areas, and causes damage to structures. Sediment loads in streams are primarily composed of relatively small particles suspended in the water column (suspended solids) and larger particles that move on or periodically near the stream bed (bed load).

SUSPENDED SEDIMENT

Suspended solids are defined as that portion of a water sample that is separated from the water by filtering. This solid material may be composed of organic and inorganic material that includes algae, industrial and municipal wastes, urban and agricultural runoff, and eroded material from geologic formations. These materials are transported to stream channels by overland flow related to storm-water runoff. For the purposes of this investigation, total suspended solids (TSS) is synonymous with suspended sediment transported by the project streams.

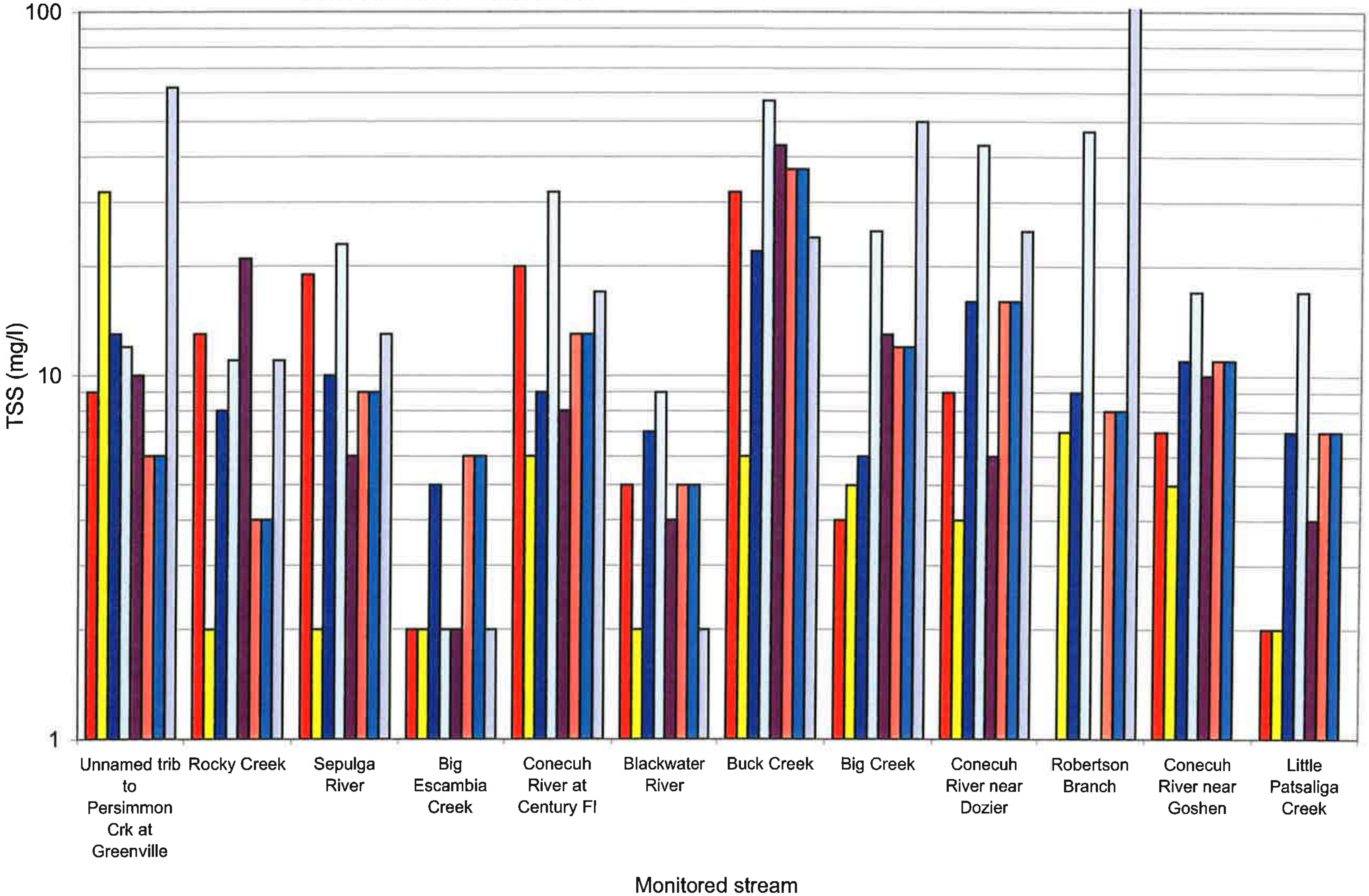
Concentrations of TSS in mg/L were determined by laboratory analysis of water samples. Samples were collected during a range of discharge events from low to high flow. Results of analyses indicate that TSS in high flow samples is from 5 to 20 times greater than samples collected during low flow, except in Big Escambia Creek (site 4) and Blackwater River (site 6) (table 9, figure 6).

Table 9— Total suspended solids and TSS loads measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream monitoring site	Site no.	Total suspended solids (mg/L)			TSS load	
		Max.	Min.	Avg.	Tons/yr	Tons/mi^2/yr
Tanyard Branch at Greenville	1	32	6	19	36	15
Rocky Creek at Butler Co. Road 16	2	21	BDL[1]	11	539	11
Sepulga River at Conecuh Co. Road 29	3	23	BDL	11	487	8
Big Escambia Creek at Escambia Co. Road 30	4	6	BDL	4	767	6
Conecuh River at Escambia Co. Florida Road 4	5	32	6	16	60,069	21
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	9	BDL	5	932	10
Buck Creek at Covington Co. Road 23	7	57	6	29	827	61
Big Creek at Ala. Hwy. 29	8	50	4	17	242	29
Conecuh River at Dozier	9	43	4	18	5,675	10
Robertson Branch at Pike Co. Road 28	10	110	5	31	94	29
Conecuh River at Pike Co. Road 28	11	50	5	16	7,253	19
Little Patsaliga Creek at Crenshaw Co. Road 35	12	51	BDL	12	1,193	11

[1] BDL-Below detection limit – 4 mg/L.

Figure 6.--Measured total suspended solids in monitored streams in the Conecuh River watershed.



TSS loads for each monitored stream were estimated using measured TSS concentrations and estimated mean daily discharge values and the regression with centering model, discussed previously in this report. Estimated annual suspended sediment loads are shown in figures 7 and 8. As expected, the most downstream site and the site with the largest drainage area, Conecuh River (site 5), had the largest suspended sediment load (60,069 tons/yr). However, when the loads were normalized with respect to unit watershed area, Buck Creek (site 7) had the largest suspended sediment load (61 tons/mi^2/yr).

STREAM BED SEDIMENT

Transport of stream bed material is controlled by a number of factors including stream discharge and flow velocity, erosion and sediment supply, stream base level, and physical properties of the stream bed material. Most stream beds are in a state of constant flux in order to maintain a stable base level elevation. The energy of flowing water in a stream is constantly changing to supply the required power for erosion or deposition of bed load to maintain equilibrium with the local water table and regional or global sea level. Stream base level may be affected by regional or global events including fluctuations of sea level or tectonic movement. Local factors affecting base level include fluctuations in the water table elevation, changes in the supply of sediment to the stream caused by changing precipitation rates and land use practices that promote excessive erosion in the floodplain or upland areas of the watershed.

Bed load sediment is composed of particles that are too large or too dense to be carried in suspension by stream flow. These particles roll, tumble, or are periodically suspended as they move downstream. Traditionally, bed load sediment has been difficult to quantify due to deficiencies in monitoring methodology or inaccuracies of estimating volumes of sediment being transported along the stream bed. This is particularly true in streams that flow at high velocity or in streams with excessive sediment loads.

Figure 7.--Estimated annual suspended sediment loads for in the Conecuh and Blackwater River watersheds.

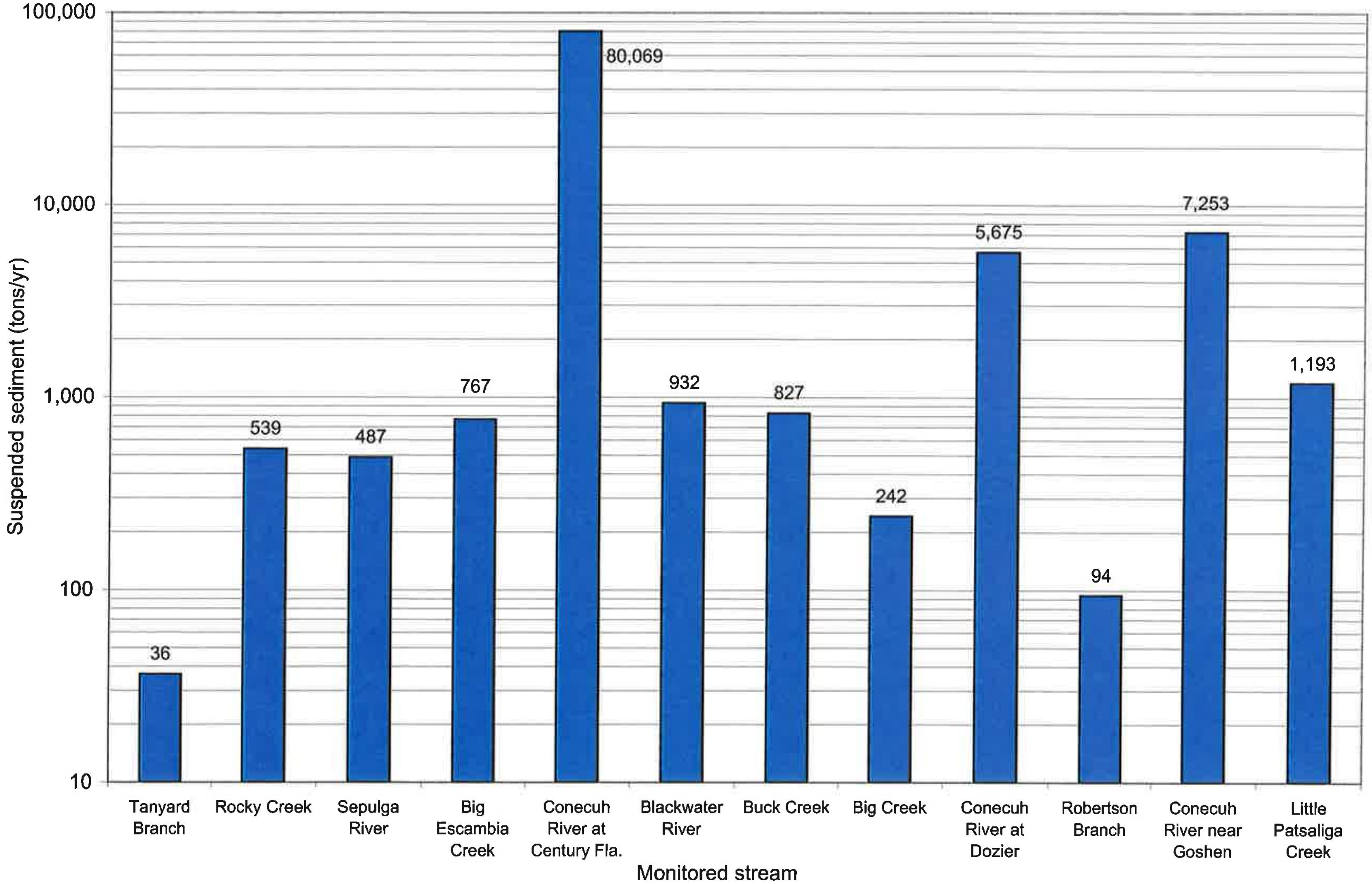
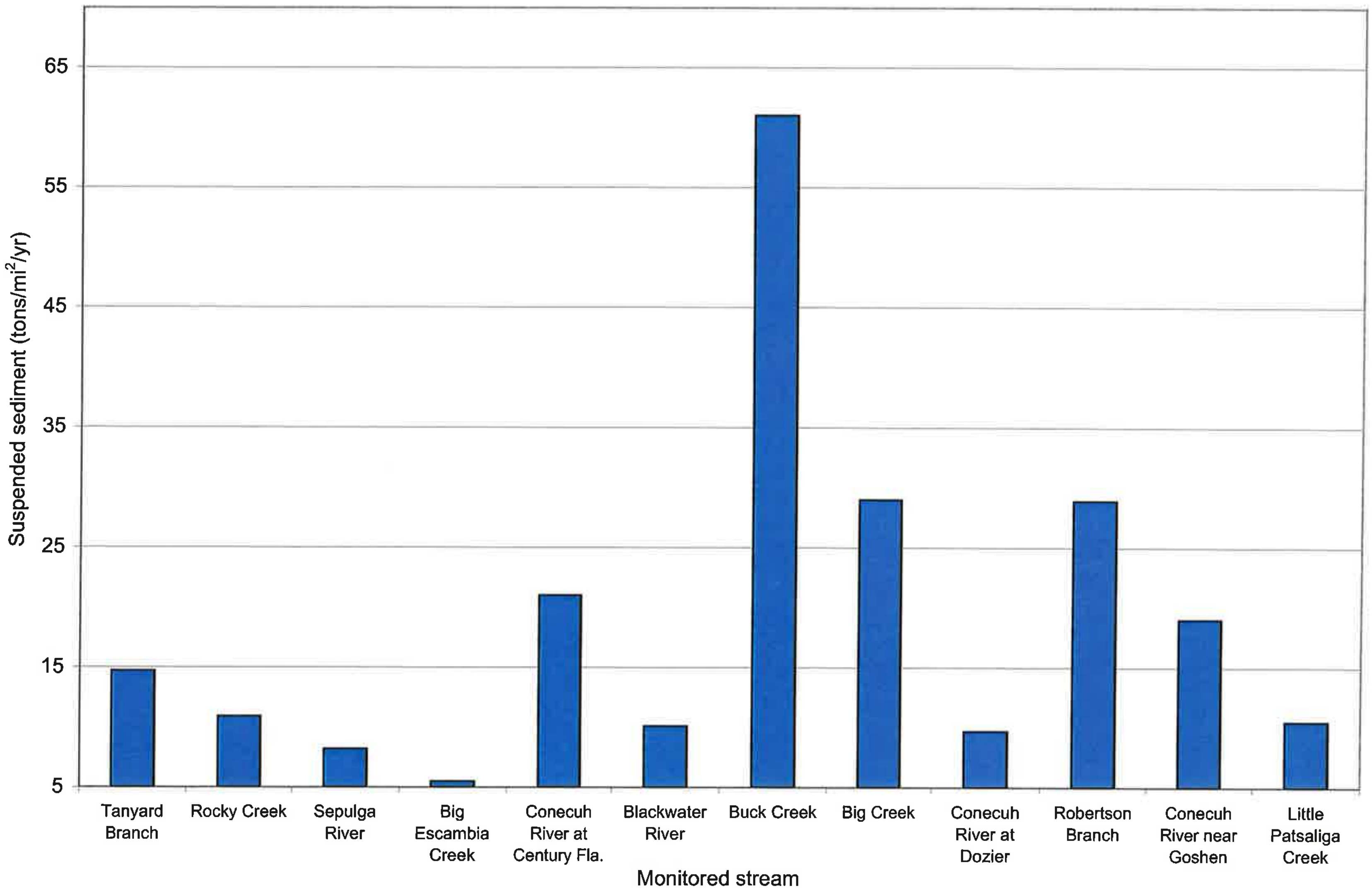


Figure 8.--Estimated normalized annual suspended sediment loads in the Conecuh and Blackwater River watersheds.



The Geological Survey of Alabama developed a portable bed load sedimentation rate-monitoring device to accurately measure bed sediment in shallow sand or gravel bed streams (Cook and Puckett, 1998). The device was utilized during this project to periodically measure bed load over a range of discharge events to calculate daily bed load sedimentation rates. Figure 9 shows measured bed sediment loads for monitoring sites in selected streams in the project area. Bed sediment was not measured at sites 1, 2, and 5. The stream channel in Tanyard Branch at site 1 is lined with concrete so all sediment is assumed to be suspended. A beaver dam in Rocky Creek, upstream from site 2 prevented the downstream transport of bed sediment. The Conecuh River at site 5 was too deep for bed sediment measurement. Figures 10 and 11 show measured stream discharge and bed sediment at Sepulga River (site 3) and Buck Creek (site 7). Note the excellent correlation between measured discharge and corresponding bed sediment transport rates. As with suspended sediment, it is possible to use discharge/sediment relationships to develop regression models to determine mean daily bed load volumes and annual bed sediment loads. Figure 12 shows estimated annual bed sediment loads for monitoring sites in selected streams in the project area. Figure 13 shows estimated annual bed sediment loads normalized with respect to watershed drainage area. Table 10 gives annual bed sediment loads and normalized annual bed sediment loads for monitoring sites in selected streams in the project area. Frequently, due to downstream accumulation of sediment, watershed drainage area and sediment loads are well correlated. The Conecuh River (site 9) had the largest bed sediment load and the largest drainage area for sites that were monitored for bed sediment (fig. 12, tables 1, 10). Robertson Branch (site 10) had the smallest bed sediment load and the smallest drainage area (fig. 12, tables 1, 10). However, in order to compare relative impacts of erosion and resulting sedimentation, watersheds must be evaluated with respect to unit drainage area, a method called normalization. After normalization of bed sediment loads, the Conecuh River at Dozier (site 9) had the largest load. Buck Creek (site 7) also had a significant bed sediment load (fig. 13, table 10).

Figure 9.--Measured bed sediment in monitored streams in the Conecuh and Blackwater River watersheds.

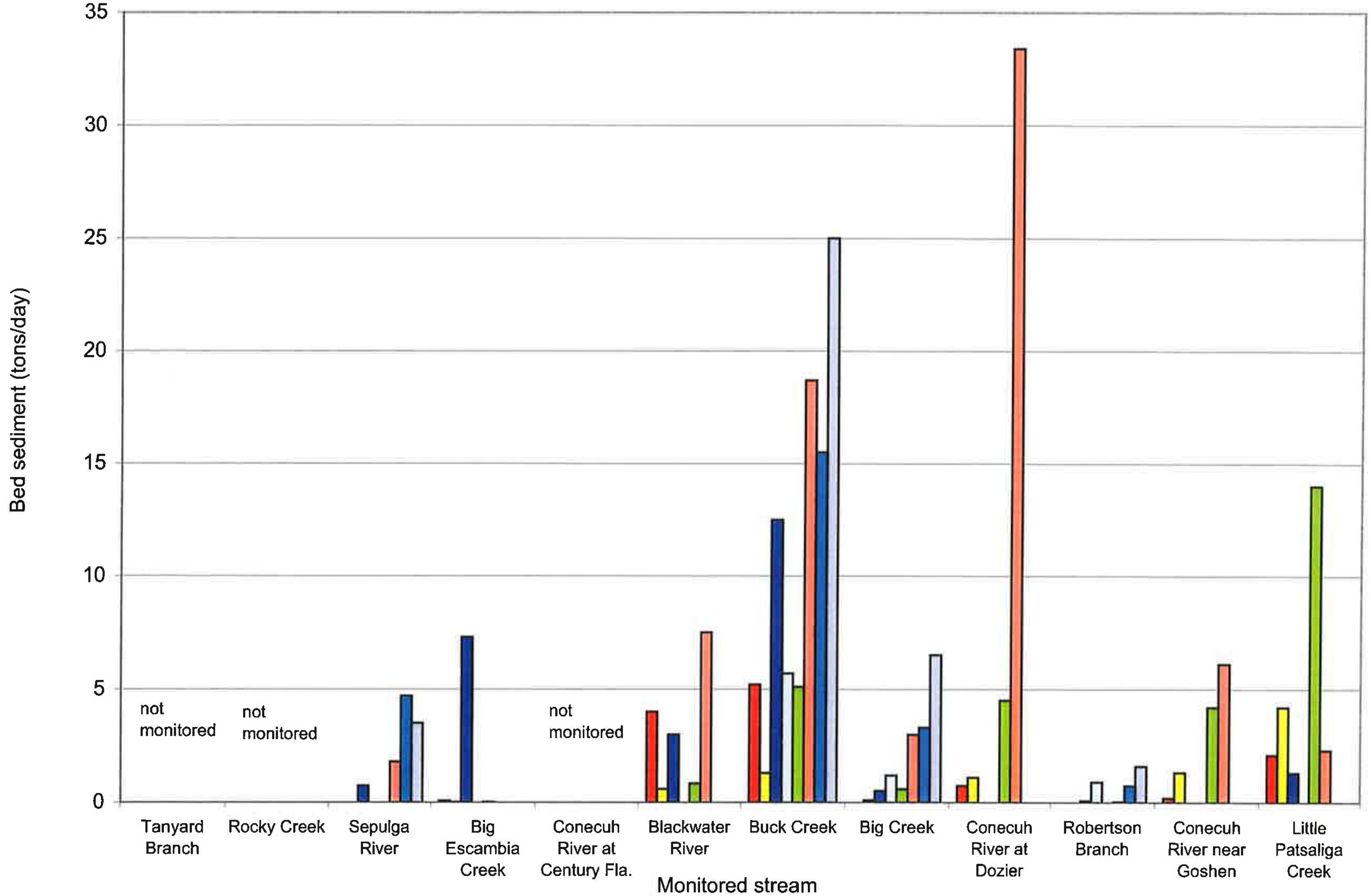


Figure 10.--Measured bed sediment and discharge at Sepulga River site 3 of the Conecuh River watershed.

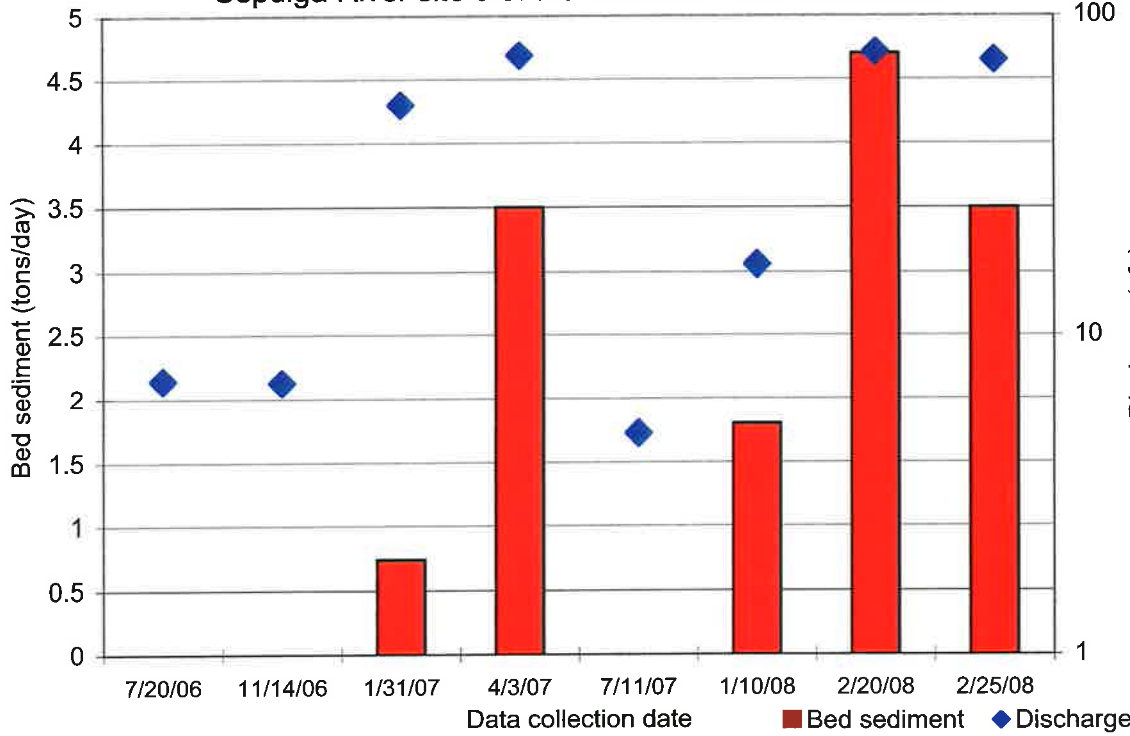


Figure 11.--Measured bed sediment and discharge at Buck Creek site 7 of the Conecuh River watershed.

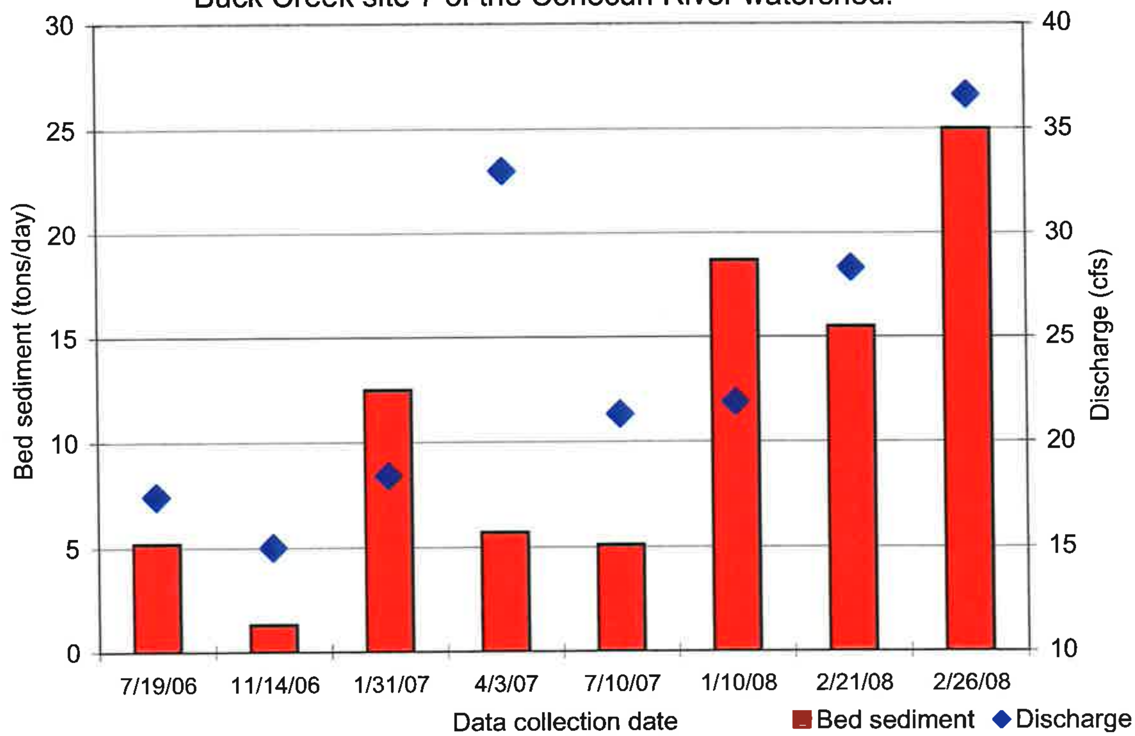


Figure 12.--Estimated annual bed sediment loads for monitored streams in the Conecuh and Blackwater River watersheds.

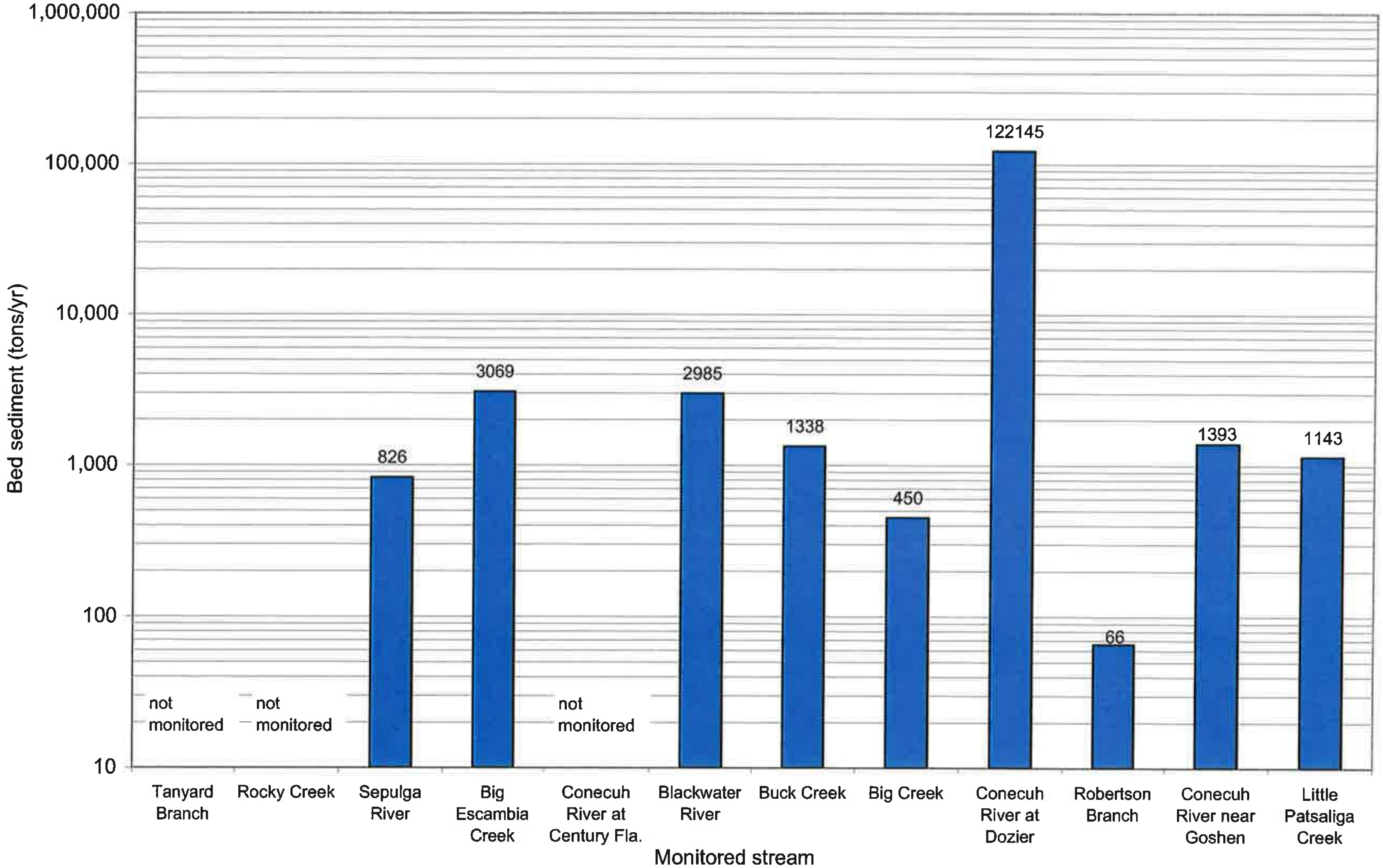


Figure 13.--Estimated normalized annual bed sediment loads for monitored streams in the Conecuh and Blackwater River watersheds.

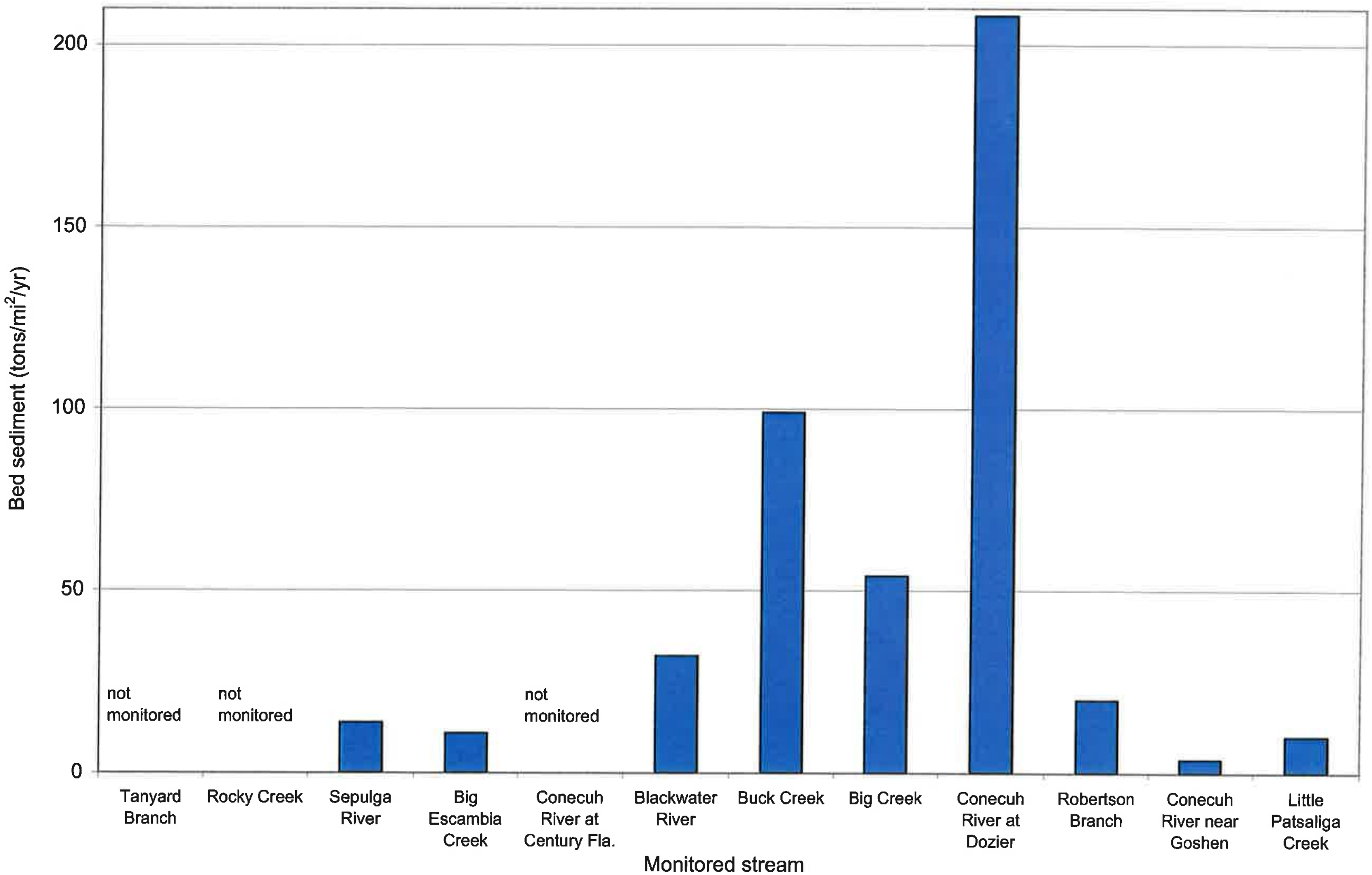


Table 10— Bedload sediment measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream monitoring site	Site no.	Bed sediment loads			
		tons/yr	$tons/mi^2/yr$	ft^3/yr	acre-ft/yr
Tanyard Branch at Greenville	1	No measureable bedload			
Rocky Creek at Butler Co. Road 16	2	Beaver activity prevented measurement			
Sepulga River at Conecuh Co. Road 29	3	826	14	13,765	0.32
Big Escambia Creek at Escambia Co. Road 30	4	3,069	11	51,150	1.20
Conecuh River at Escambia Co. Florida Road 4	5	Bed sediment not measureable			
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	2,985	32	49,750	1.10
Buck Creek at Covington Co. Road 23	7	1,338	99	22,300	0.50
Big Creek at Ala. Hwy. 29	8	450	54	7,493	0.17
Conecuh River at Dozier	9	122,145	208	1,097	46.70
Robertson Branch at Pike Co. Road 28	10	66	20	1,097	0.03
Conecuh River at Pike Co. Road 28	11	1,393	4	22,217	3.70
Little Patsaliga Creek at Crenshaw Co. Road 35	12	1,143	10	19,033	0.40

TOTAL SEDIMENT LOADS

Total sediment loads are composed of suspended and bed sediment. Without human impact, the geologic erosion rate is about 64 tons/mi^2/yr (Maidment, 1993). The largest total annual sediment load (about 128,000 tons/yr) was estimated for the Conecuh River at Dozier (table 11 and fig. 14). This is about 3.5 times the geologic erosion rate. When total sediment loads are normalized with respect to watershed area, the largest loads were estimated for Conecuh River (site 9) (218 tons/mi^2/yr), Buck Creek (site 7) (160 tons/mi^2/yr), and Big Creek (site 8) (83 tons/mi^2/yr) (fig. 15).

The sediment load estimated by ADEM using the Universal Soil Loss Equation during the TMDL development process for the lower segment of the Conecuh River (drainage area 658 mi^2) was 518 tons/mi^2/yr (ADEM, 2008). The sediment load estimated from measured sediment during this project for the Conecuh River (site 9), drainage area 587 mi^2) was 218 tons/mi^2/yr. The sediment load estimated by ADEM for the upper segment of the Conecuh River upstream from site 11 (drainage area 401 mi^2) was 269 tons/mi^2/yr (ADEM, 2008). The sediment load estimated from measured sediment during this project for the Conecuh River at site 11 (drainage area 382 mi^2) was 23 tons/mi^2/yr.

Comparisons of sediment loads from other watersheds are helpful in determining the severity of erosion problems in a watershed of interest. Estimates of sediment loads from 25 streams throughout Alabama indicate that sediment loads estimated for selected sites in the Conecuh River watershed are comparable to sediment loads from watersheds with other types of anthropogenic erosional impacts and those with minimal impacts. Figure 16 shows similar sediment loads in streams in the Choctawhatchee River watershed in southeast Alabama and the Bear Creek watershed in northwest Alabama (erosion primarily from row crop agriculture and timber harvesting), tributaries to the Gantt and Point A reservoirs in south-central Alabama (erosion primarily from unpaved roads), and sites 7 and 9 in the Conecuh River watershed. The Sepulga River (site 3) has similar loads to Bear Creek and Yellow River sites, which have minimal erosional impacts.

Table 11.— Total estimated sediment loads in selected monitored streams in the Conecuh and Blackwater River watersheds.

Stream monitoring site	Site no.	Estimated geologic erosion rate total sediment load (tons/yr)	Estimated total annual sediment load (tons/yr)	Estimated normalized total annual sediment load (tons/mi ^{2}/yr)
Tanyard Branch at Greenville	1	159	36*	15*
Rocky Creek at Butler Co. Road 16	2	3,162	539*	11*
Sepulga River at Conecuh Co. Road 29	3	3,821	1,313	21
Big Escambia Creek at Escambia Co. Road 30	4	8,960	3,836	17
Conecuh River at Escambia Co. Florida Road 4	5	244,288	60,069*	21*
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	5,888	3,917	42
Buck Creek at Covington Co. Road 23	7	864	2,165	160
Big Creek at Ala. Hwy. 29	8	531	692	83
Conecuh River at Dozier	9	37,568	127,820	218
Robertson Branch at Pike Co. Road 28	10	207	160	49
Conecuh River at Pike Co. Road 28	11	24,448	8,646	23
Little Patsaliga Creek at Crenshaw Co. Road 35	12	7,296	2,336	21

*Sediment loads composed of suspended sediment only.

Figure 14.--Total annual sediment loads estimated for monitored streams in the Conecuh and Blackwater River watersheds.

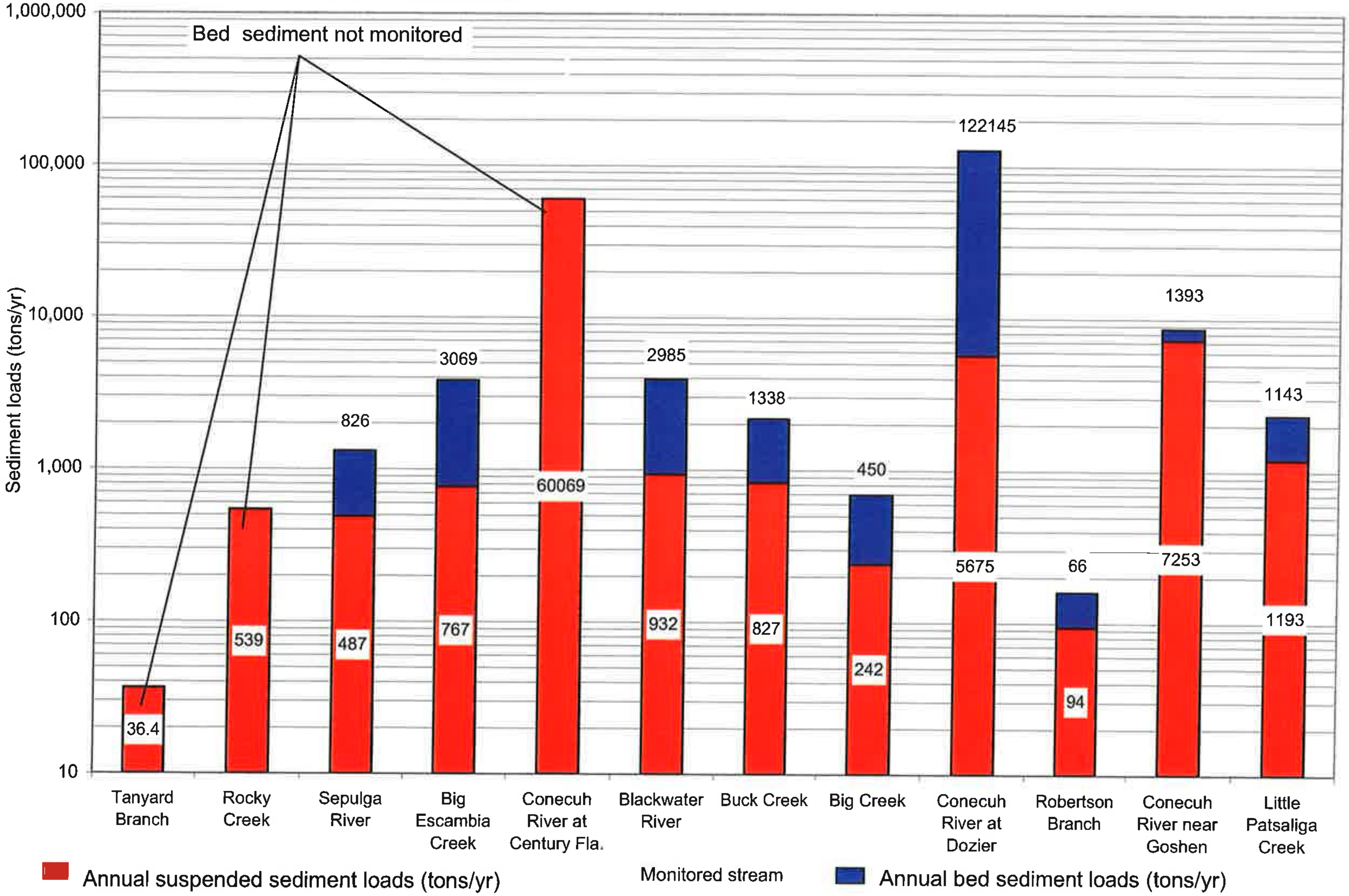


Figure 15.--Normalized total sediment loads estimated for monitored streams in the Conecuh and Blackwater River watersheds.

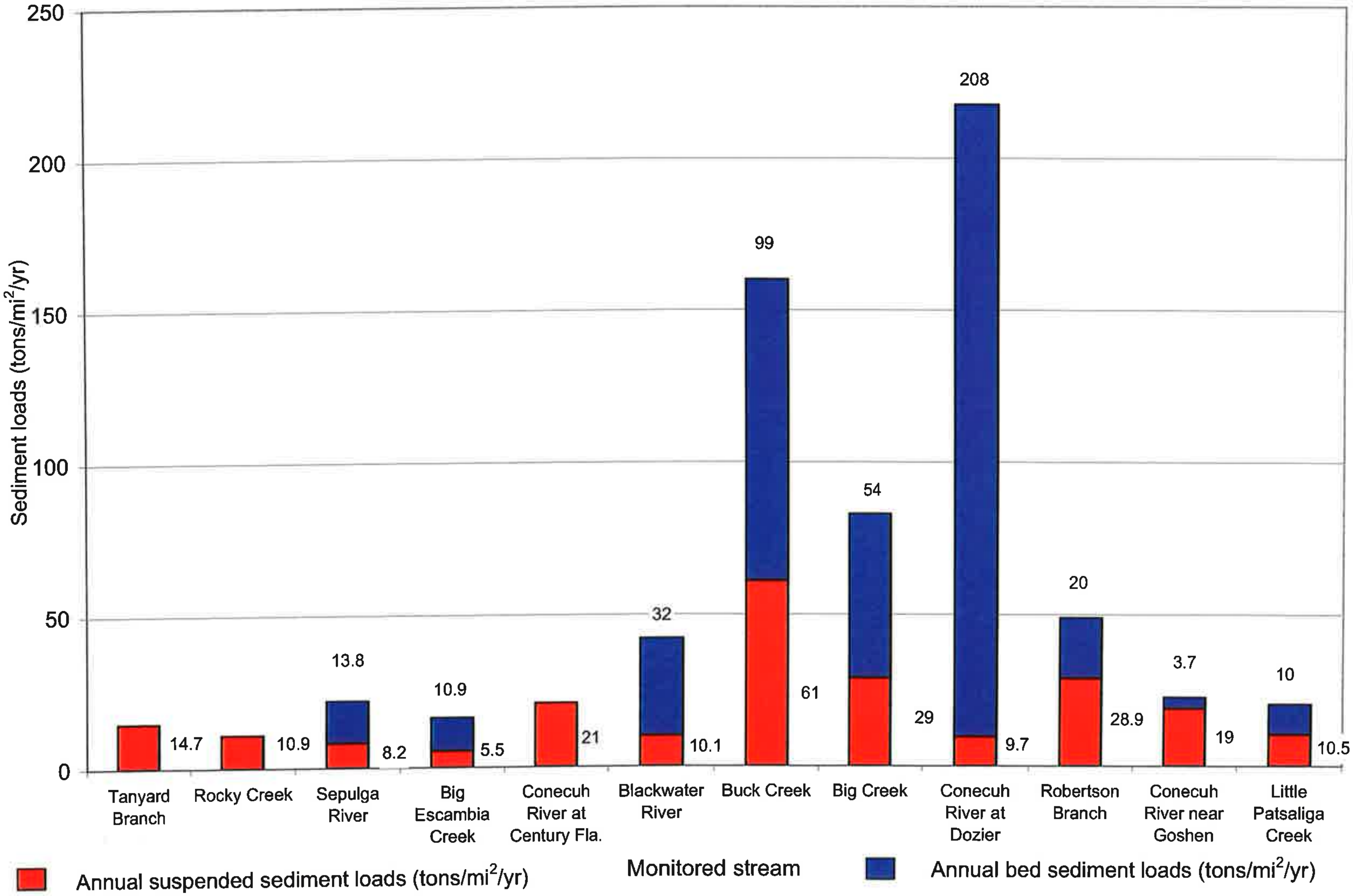
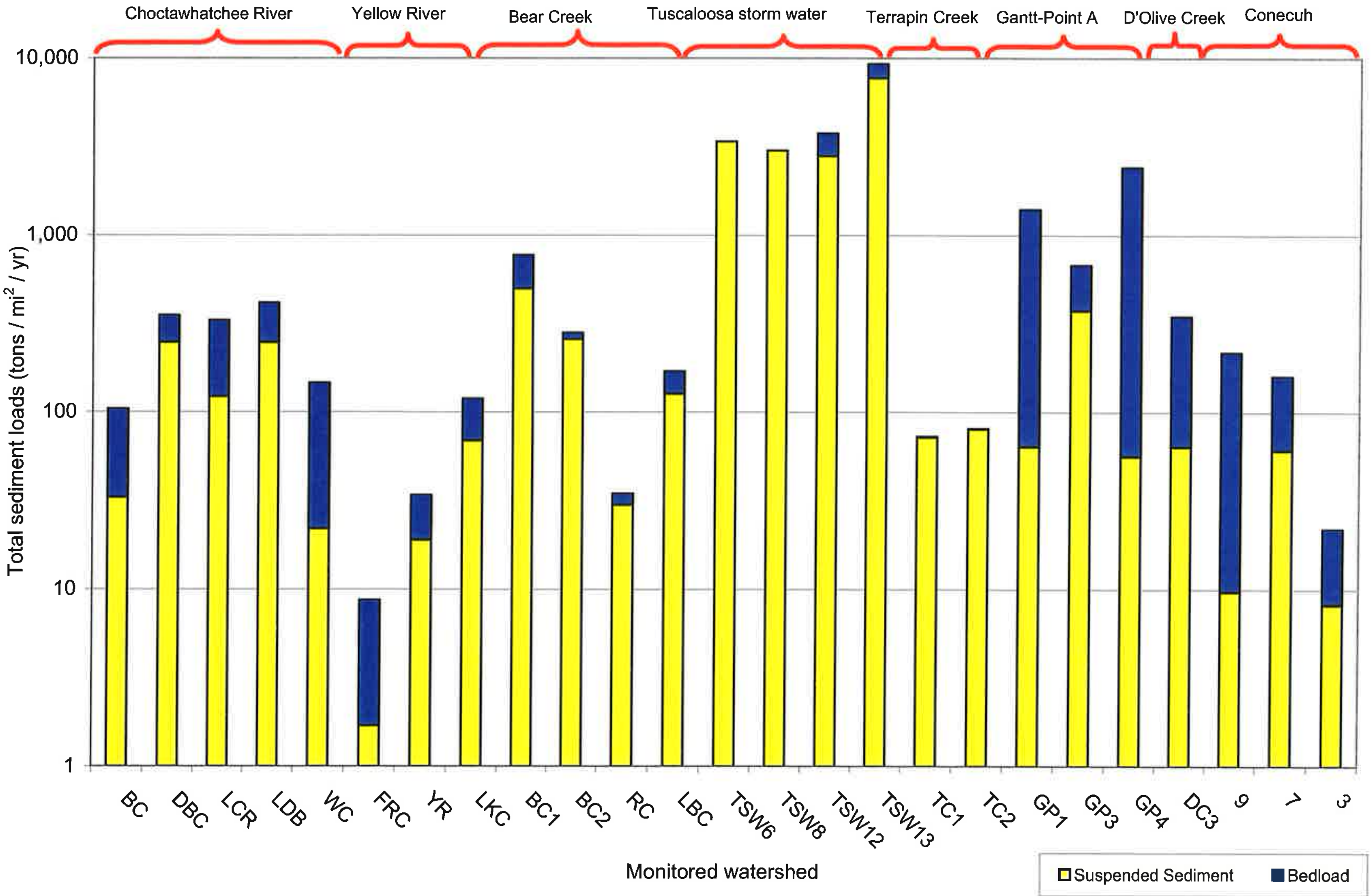


Figure 16.--Estimated normalized total annual sediment loads for selected watersheds in Alabama.



NUTRIENTS IN PROJECT STREAMS

A typical aquatic ecosystem includes plants and animals that are composed of carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur. These substances decompose upon the death of the plants and animals and serve as nutrients for development of new organisms. However, excessive nutrient enrichment is a major cause of water-quality impairment. Excessive concentrations of nutrients, primarily nitrogen and phosphorus, in the aquatic environment may lead to increased biological activity, decreased dissolved oxygen concentrations, and decreased numbers of species (Mays, 1996). This process is called eutrophication.

Nutrient impaired waters are characterized by numerous problems related to growth of algae, other aquatic vegetation, and associated bacterial strains. Blooms of algae and associated bacteria can cause taste and odor problems in drinking water. Toxins also can be produced during blooms of particular algal species. Nutrient impaired water can dramatically increase treatment costs required for drinking water.

AMMONIA

Concentrations of ammonia (NH_3 as N) in uncontaminated streams may be as low as 0.01 mg/L. Concentrations of ammonia in contaminated streams and in streams downstream from wastewater discharges are generally from 0.5 to 3.0 mg/L. Concentrations higher than 0.5 mg/L may cause significant ammonia toxicity to fish and other organisms (Maidment, 1993). The toxicity limit (0.5 mg/L) was exceeded in 13 percent of samples collected at Tanyard Branch (site 1) and Rocky Creek (site 2) (table 12).

Table 12— Ammonia measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream monitoring site	Site no.	Ammonia (NH_3 as N mg/L)		
		Max.	Min.	Avg.
Tanyard Branch at Greenville	1	1.84	0.14	0.40
Rocky Creek at Butler Co. Road 16	2	0.72	BDL[1]	0.15
Sepulga River at Conecuh Co. Road 29	3	0.08	0.02	0.04
Big Escambia Creek at Escambia Co. Road 30	4	0.04	BDL	0.03
Conecuh River at Escambia Co. Florida Road 4	5	0.17	0.04	0.08
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	0.05	BDL	0.02
Buck Creek at Covington Co. Road 23	7	0.08	0.03	0.05
Big Creek at Ala. Hwy. 29	8	0.05	BDL	0.04
Conecuh River at Dozier	9	0.08	0.03	0.05
Robertson Branch at Pike Co. Road 28	10	0.14	0.04	0.06
Conecuh River at Pike Co. Road 28	11	0.07	0.03	0.04
Little Patsaliga Creek at Crenshaw Co. Road 35	12	0.07	0.02	0.05

[1] BDL- Below Detection Limit mg/L.

NITRATE

The EPA maximum contaminant level (MCL) for nitrate in drinking water is 10 mg/L. Concentrations of nitrate in streams without significant nonpoint sources of pollution generally vary from 0.1 to 0.5 mg/L and rarely exceed the higher figure. Streams fed by runoff or shallow ground water draining agricultural areas may approach 10 mg/L although concentrations exceeding 0.5 mg/L can cause excessive algae growth (Maidment, 1993). Fifty percent of samples collected at Buck Creek (site 7), 33 percent of samples collected at Robertson Branch (site 10), and 13 percent of samples collected at Tanyard Branch (site 1), and Conecuh River sites 9 and 11 exceeded 0.5 mg/L (fig. 17).

Total nitrate loads were determined by application of the regression with centering computer program to nitrate concentrations and mean daily discharge obtained for each monitored stream during the project period (table 13). Figure 18 and table 13 show that the Conecuh River transports about 800 tons of nitrate per year at site 5 at the Florida state line. The largest nitrate loads transported by tributaries to the Conecuh River include Big Escambia Creek (site 4) (18.2 tons/yr), Buck Creek (site 7) (13.1 tons/yr), and Little Patsaliga Creek (site 12) (11.6 tons/yr). When nitrate loads were normalized, Buck Creek (site 7) and Robertson Branch (site 10) transported the largest loads per unit watershed area (fig. 19, table 13).

Figure 17.--Measured nitrate (NO_3 as N) in monitored streams in the Conecuh and Blackwater River watersheds.

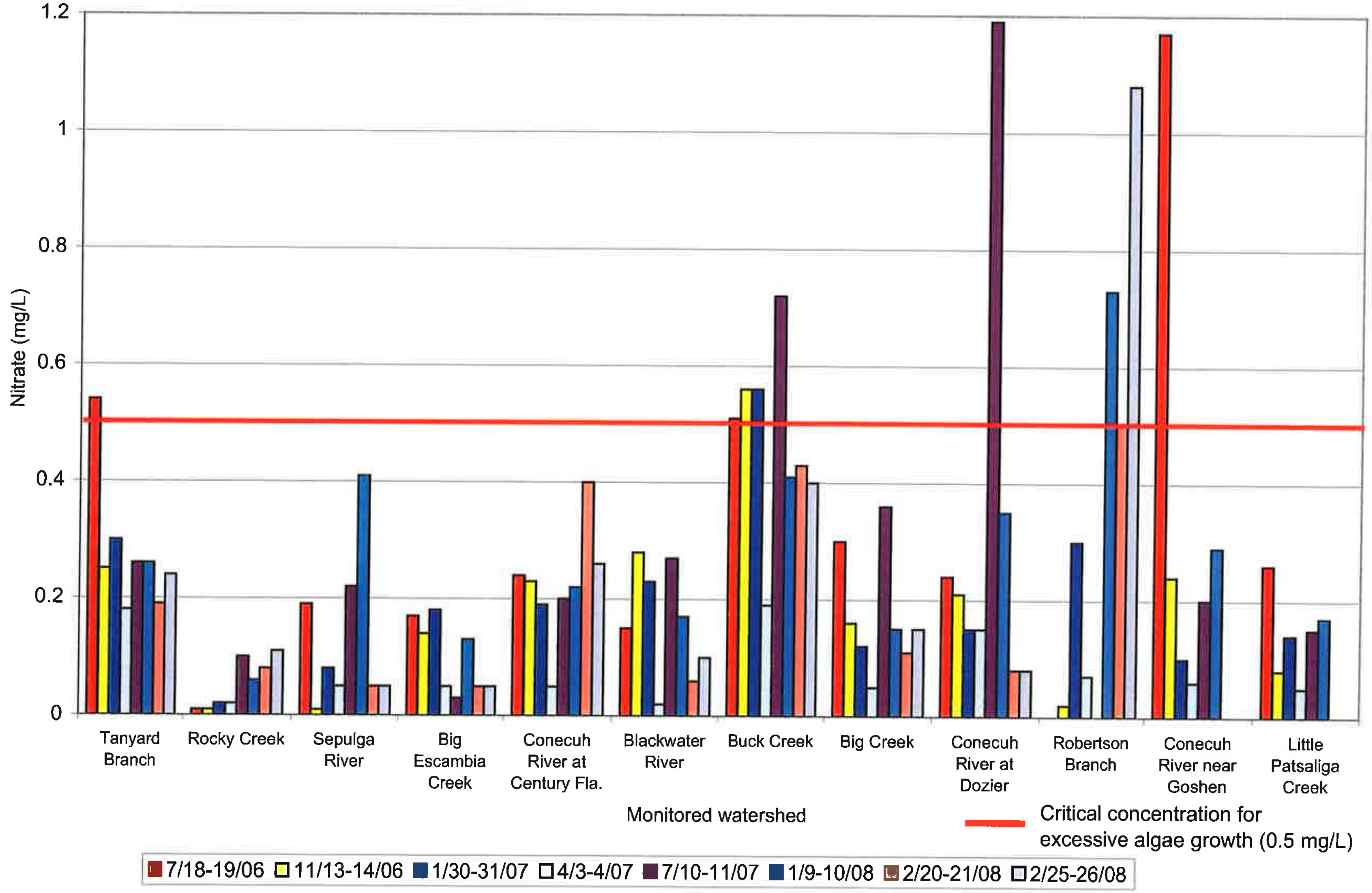


Table 13— Measured nitrate and estimated annual nitrate loads in monitored streams in the Conecuh and Blackwater River watersheds.

Stream monitoring site	Site no.	Nitrate (NO_3 as N) mg/L			Nitrate load tons/year (lbs/yr)	Nitrate load tons/ mi^2/yr (lbs/ mi^2/yr)
		Max.	Min.	Avg.		
Tanyard Branch at Greenville	1	0.54	0.18	0.28	0.27 (529)	0.11 (213)
Rocky Creek at Butler Co. Road 16	2	0.11	BDL[1]	0.05	4.1 (8,181)	0.08 (166)
Sepulga River at Conecuh Co. Road 29	3	0.22	BDL	0.09	3.2 (6,439)	0.05 (108)
Big Escambia Creek at Escambia Co. Road 30	4	0.18	BDL	0.11	18.2 (36,383)	0.12 (260)
Conecuh River at Escambia Co. Florida Road 4	5	0.40	0.05	0.22	808 (1,616,265)	0.21 (423)
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	0.28	BDL	0.16	18.7 (37,485)	0.2 (408)
Buck Creek at Covington Co. Road 23	7	0.72	0.19	0.47	13.1 (26,240)	0.97 (1,944)
Big Creek at Ala. Hwy. 29	8	0.36	0.11	0.18	0.7 (1,389)	0.08 (167)
Conecuh River at Dozier	9	1.19	0.08	0.31	60 (119,070)	0.1 (203)
Robertson Branch at Pike Co. Road 28	10	1.08	0.04	0.06	2.1 (4,190)	0.65 (1,293)
Conecuh River at Pike Co. Road 28	11	1.17	0.03	0.27	19.5 (39,029)	0.05 (102)
Little Patsaliga Creek at Crenshaw Co. Road 35	12	0.26	0.05	0.13	11.6 (23,153)	0.1 (203)

[1] BDL- Below Detection Limit 0.006 mg/L

Figure 18.--Estimated annual nitrate (NO_3 as N) loads for monitored streams in the Conecuh and Blackwater River watersheds.

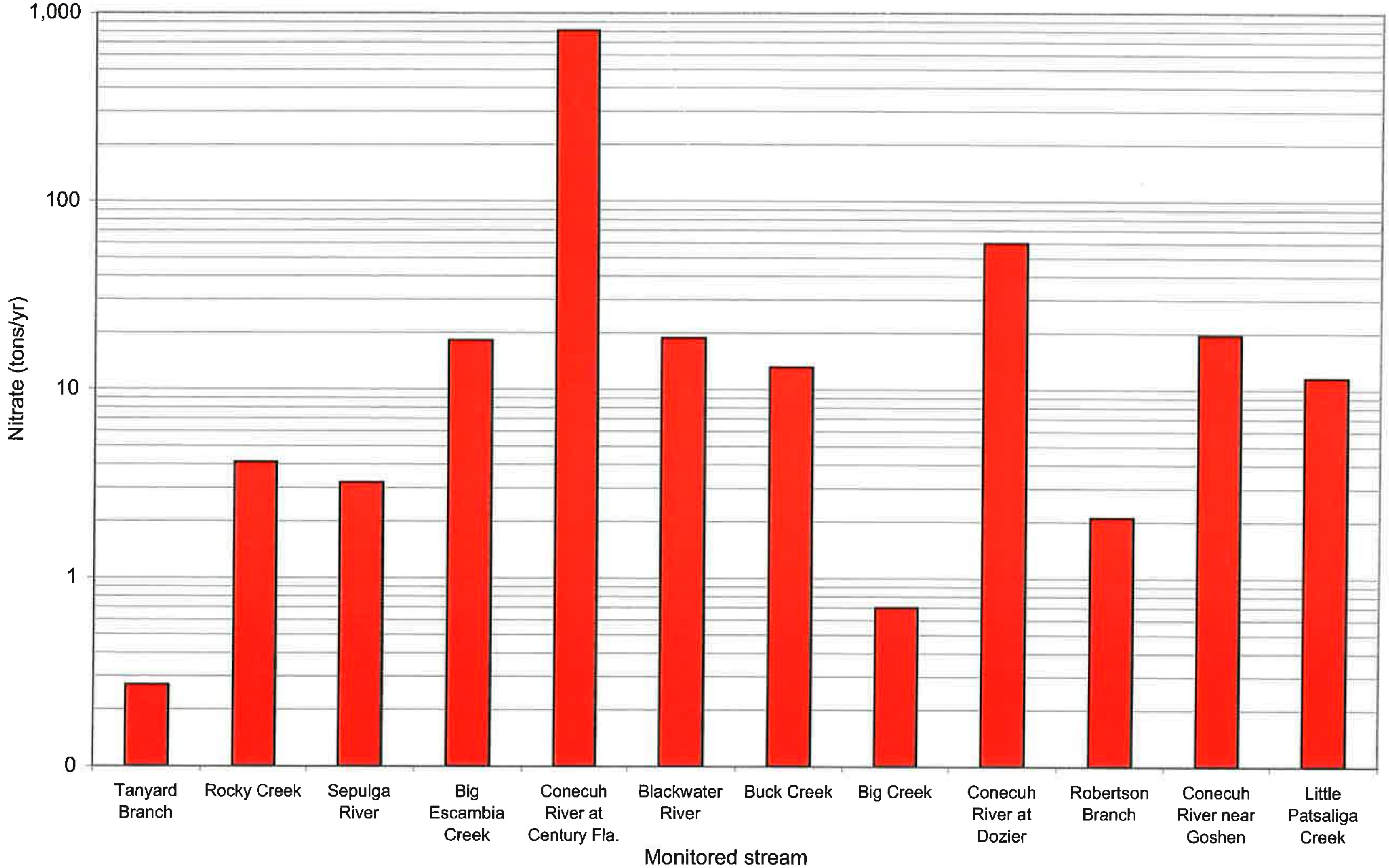
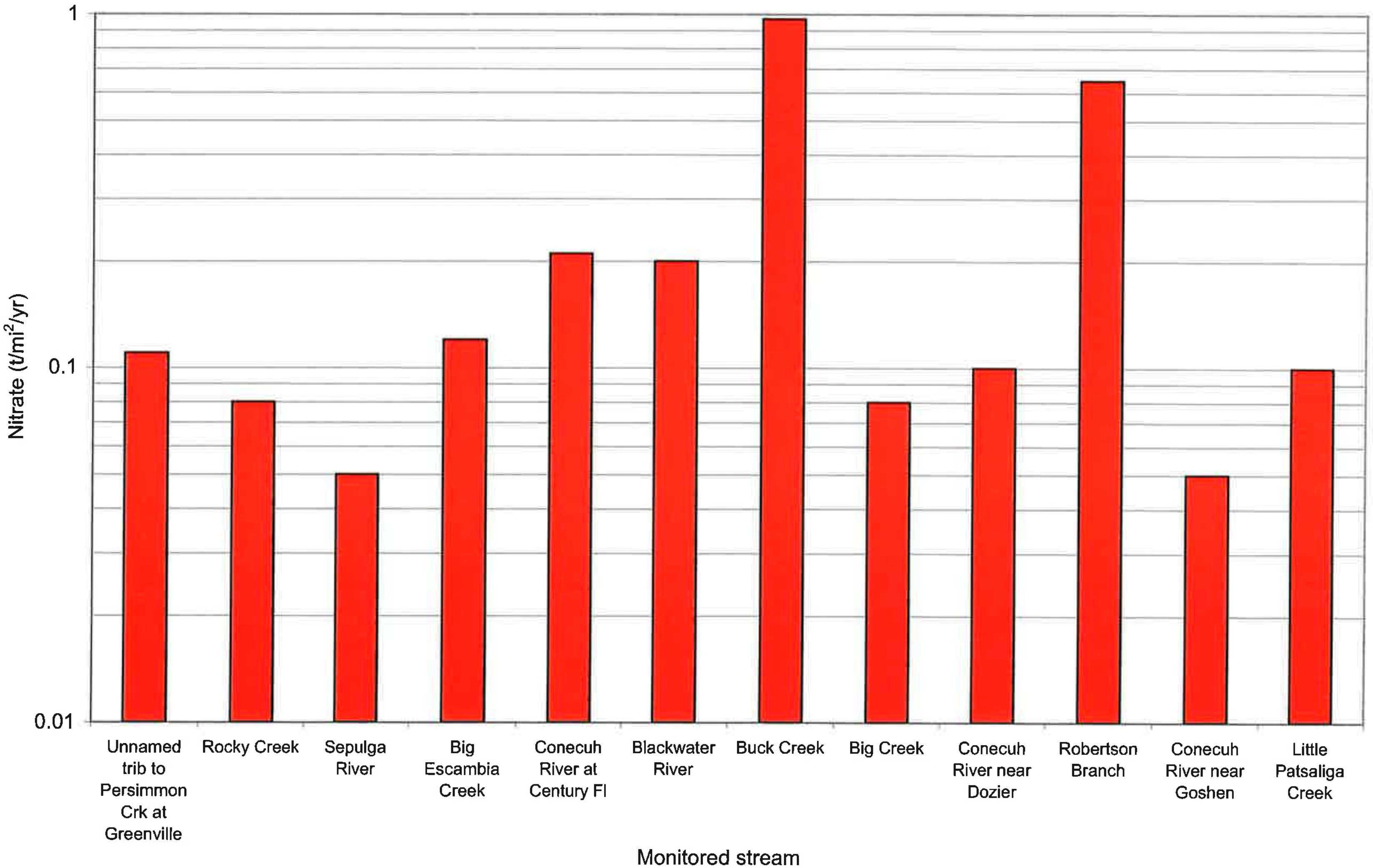


Figure 19.--Estimated normalized annual nitrate (NO_3 as N) loads for monitored streams in the Conecuh River watershed.



PHOSPHORUS

The origin of phosphorus in streams is the leaching of mineralized phosphates from soil and rocks or drainage containing fertilizer or other industrial products. The principal components of the phosphorus cycle include organic phosphorus and inorganic phosphorus in the form of orthophosphate (PO_4) (Maidment, 1993). Orthophosphate is soluble and is the only biologically available form of phosphorus. The natural background concentration of total dissolved phosphorus is approximately 0.025 mg/L. Phosphorus concentrations as low as 0.01 to 0.005 mg/L may cause excessive algae growth, but the critical level of phosphorus necessary for excessive algae is around 0.05 mg/L. Although no official water-quality criterion for phosphorus has been established in the United States, total phosphorus should not exceed 0.05 mg/L in streams or 0.025 mg/L within a lake or reservoir to prevent the development of biological nuisances (Maidment, 1993). In many streams phosphorus is the primary nutrient that influences excessive biological activity. These streams are termed "phosphorus limited." Of the eight samples collected in monitored streams, the critical concentration of phosphorus (0.05 mg/L-total P) was exceeded in 25 percent of samples collected from Conecuh River (site 11), and Patsiliga Creek (site 12); 38 percent of samples from Tanyard Branch (site 1), Big Escambia Creek (site 4), Conecuh River (sites 5 and 9), Blackwater River (site 6), Buck Creek (site 7), and Robertson Branch (site 10); 50 percent of samples from Sepulga River (site 3), and Big Creek (site 8); and 63 percent of samples from Rocky Creek (site 2) (fig. 20). The highest concentration was measured at Tanyard Branch (site 1) and the highest average concentration was observed at Rocky Creek (site 2) (table 14).

BACTERIA

Microorganisms are present in all surface waters and include viruses, bacteria, fungi, algae, and protozoa. Analyses of bacteria levels may be used to assess the quality of water and to indicate the presence of human and animal waste in surface and ground water. Fecal coliform and fecal streptococcus groups of bacteria are frequently used as indicator organisms of this type of water pollution. The membrane filter procedure as described in the 19th edition of standard methods (Eaton and others, 1995) is used for

Figure 20.--Measured total phosphorus in monitored streams in the Conecuh and Blackwater River watersheds.

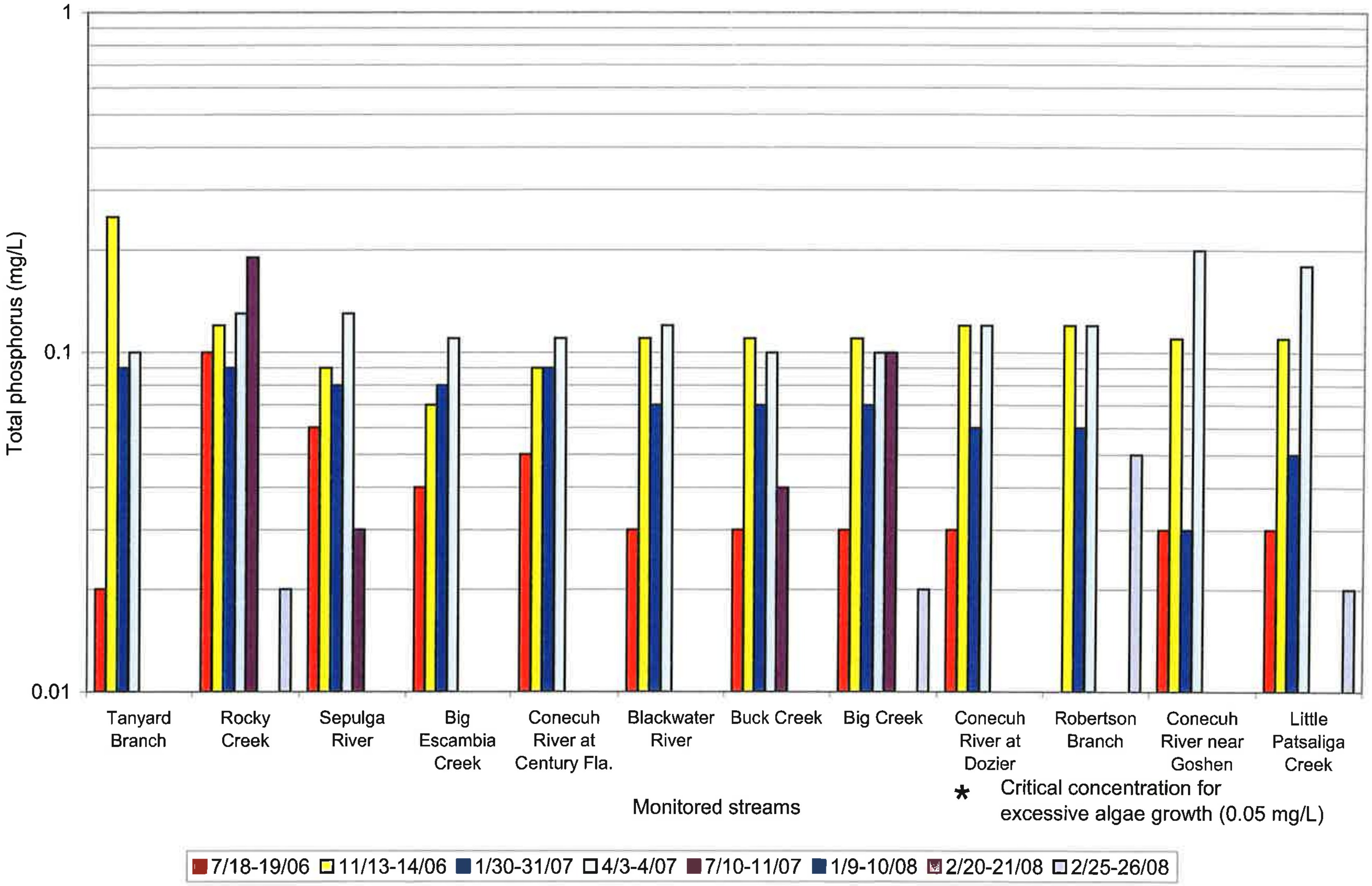


Table 14— Phosphorus measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream monitoring site	Site no.	Total Phosphorus (mg/L)		
		Max.	Min.	Avg.
Tanyard Branch at Greenville	1	0.25	BDL	0.06
Rocky Creek at Butler Co. Road 16	2	0.19	BDL	0.08
Sepulga River at Conecuh Co. Road 29	3	0.13	BDL	0.05
Big Escambia Creek at Escambia Co. Road 30	4	0.08	BDL	0.04
Conecuh River at Escambia Co. Florida Road 4	5	0.09	BDL	0.05
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	0.12	BDL	0.05
Buck Creek at Covington Co. Road 23	7	0.11	BDL	0.05
Big Creek at Ala. Hwy. 29	8	0.11	BDL	0.06
Conecuh River at Dozier	9	0.12	BDL	0.05
Robertson Branch at Pike Co. Road 28	10	0.12	BDL	0.06
Conecuh River at Pike Co. Road 28	11	0.20	BDL	0.06
Little Patsaliga Creek at Crenshaw Co. Road 35	12	0.18	BDL	0.05

[1]BDL- Below Detection Limit mg/L.

determining fecal coliform and fecal streptococcus bacteria counts for water samples collected from streams at project sampling sites.

For many years the ratio of fecal coliform to fecal streptococcus colonies has been used to differentiate human fecal contamination from that of other warm-blooded animals (table 15). A ratio of 4 was considered indicative of human fecal contamination, whereas a ratio of less than 0.7 was considered to be contamination by nonhuman sources.

The 19th Edition of Standard Methods (Eaton and others, 1995) reports that the value of this ratio has been questioned because of variable survival rates of fecal streptococcus group species in water and the methods for enumerating fecal streptococci. However, a large body of literature is available that documents the differences in bacteria concentrations between humans and animals and the utility of the ratio method as a means to differentiate human and animal contamination of water.

Fecal coliform bacteria were more prevalent than fecal streptococcus bacteria during the sampling period. This was unexpected, due to the land-use characteristics of the project watersheds (table 16). Average ratios of fecal coliform to fecal streptococci bacteria for the sampling period are shown in table 16. These ratios suggest that bacterial contamination in streams in the project watersheds have varying human impacts with the exception of Buck Creek, which had no indication of human influence.

The limit for fecal coliform bacteria, established for surface waters classified as Fish and Wildlife, is 2,000 colonies per 100 milliliter sample for single samples (ADEM, 1992). Sampling results indicate that the single sample limit was exceeded in 1 sample collected from Tanyard Branch (site 1) and Robertson Branch (site 10). All other sites did not exceed the limit (fig. 21).

Table 15.--Estimated per capita contribution of indicator microorganisms from humans and selected animals (Tchobanoglous and Schroeder, 1985).

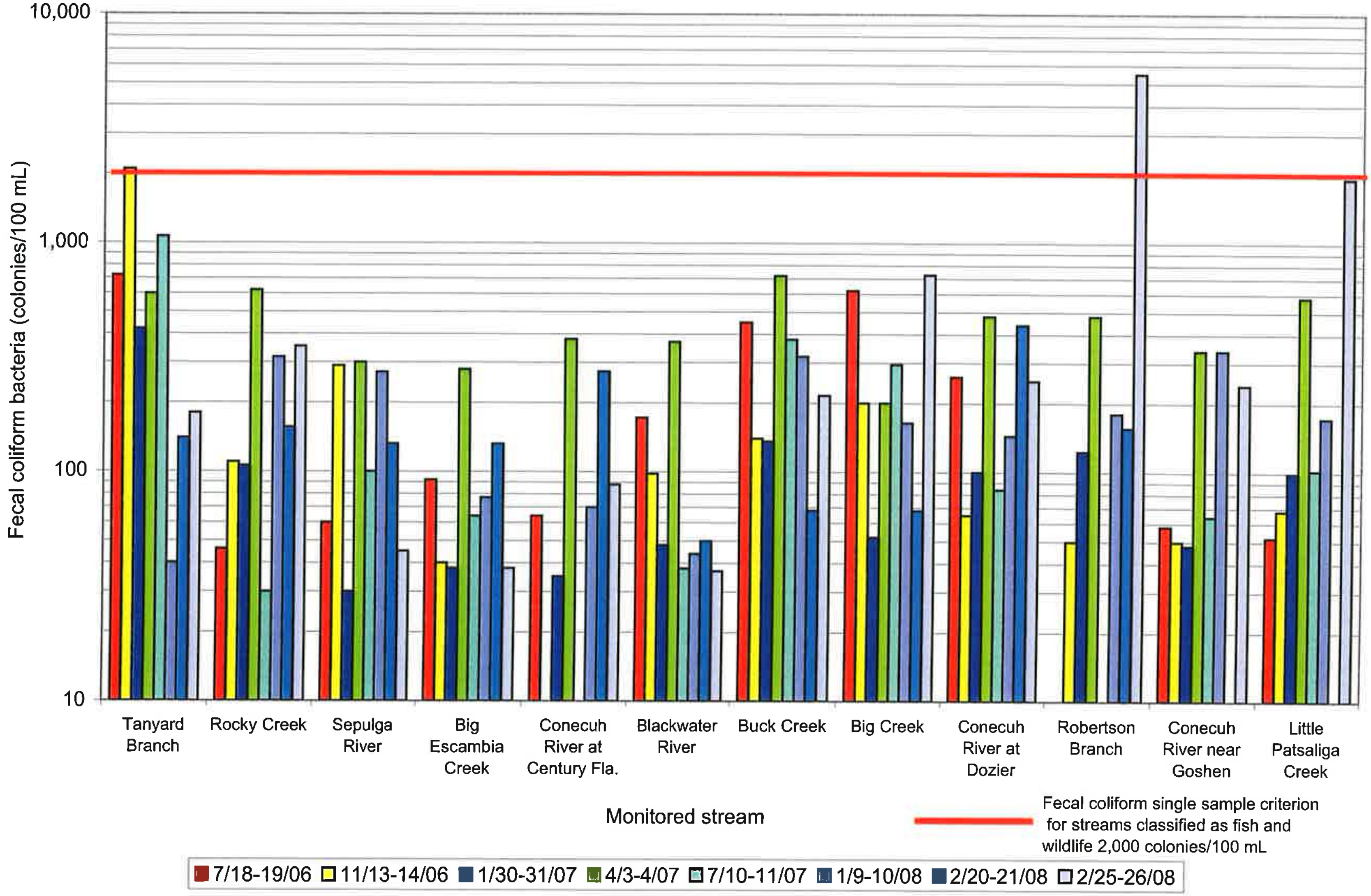
	Average Indicator Organisms (number/grams feces)		
Animal	Fecal Coliform (FC) 10^6	Fecal Streptococci (FS) 10^6	Ratio FC/FS
Human	13.0	3.0	4.4
Chicken	1.3	3.4	0.4
Cow	0.23	1.3	0.2
Duck	33.0	54.0	0.6
Pig	3.3	84.0	0.04
Sheep	16.0	38.0	0.4
Turkey	0.29	2.8	0.1

Table 16.-- Fecal coliform and fecal streptococci bacteria measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream monitoring site	Site no.	Max FC[1] (col/100ml)	Max FS[2] (col/100ml)	Average FC (col/100ml)	Average FS (col/100ml)	Ratio FC/FS (average)
Tanyard Branch at Greenville	1	2,100	3,200	658	733	0.9
Rocky Creek at Butler Co. Road 16	2	620	700	217	333	0.7
Sepulga River at Conecuh Co. Road 29	3	300	328	154	121	1.3
Big Escambia Creek at Escambia Co. Road 30	4	280	430	95	119	0.8
Conecuh River at Escambia Co. Florida Road 4	5	380	480	116	154	0.8
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	370	220	107	57	1.9
Buck Creek at Covington Co. Road 23	7	720	2,700	304	699	0.4
Big Creek at Ala. Hwy. 29	8	728	950	291	299	1.0
Conecuh River at Dozier	9	480	440	228	130	1.8
Robertson Branch at Pike Co. Road 28	10	5,500	6,200	1,082	1,399	0.8
Conecuh River at Pike Co. Road 28	11	340	276	163	127	1.3
Little Patsaliga Creek at Crenshaw Co. Road 35	12	1,920	736	428	235	1.8

[1] Max FC (col/100 mL) = Maximum fecal coliform (colonies per 100 mL of sample)
[2] Max FS (col/100 mL) = Maximum fecal streptococci (colonies per 100 mL of sample)

Figure 21.--Measured fecal coliform bacteria in monitored streams in the Conecuh and Blackwater River watersheds.



METALLIC CONSTITUENTS

Numerous metals are naturally present in streams in small concentrations. However, toxic metals in streams are usually a result of man's activities. Recently, lead and mercury have received much attention. Detectable concentrations of lead are commonly found in streams. Lead may originate from local sources or through atmospheric deposition from distant sources. Other toxic metals may also be found in relatively large concentrations and may be associated with point sources of pollution.

Water samples collected from the project streams were analyzed for selected metallic constituents. Table 17 shows average concentrations for detected metallic constituents (concentrations in red are above drinking water standards). Naturally occurring small concentrations of aluminum, barium, iron, manganese, and zinc commonly occur in Coastal Plain streams. Lead is pervasive in streams in the Conecuh River watershed. Lead occurred in 38 percent of samples from Tanyard Branch (site 1), Buck Creek (site 7), and Patsaliga Creek (site 12); 50 percent of samples from Big Escambia Creek (site 4), Big Creek (site 8), Conecuh River (site 9), and Conecuh River (site 11); 63 percent of samples from Rocky Creek (site 2), Sepulga River (site 3), and Blackwater River (site 6); 67 percent of samples from Robertson Branch (site 10); and 88 percent of samples from Conecuh River (site 5). The highest concentrations were measured at Blackwater River (site 6) (85.6, 47.4, and 44.3 μg/l) (fig. 22). These anomalously high concentrations are related to the consistently low pH of Blackwater River that keeps available lead in solution.

Table 17.--Average concentrations of metallic constituents measured in monitored streams in the Conecuh and Blackwater river watersheds.

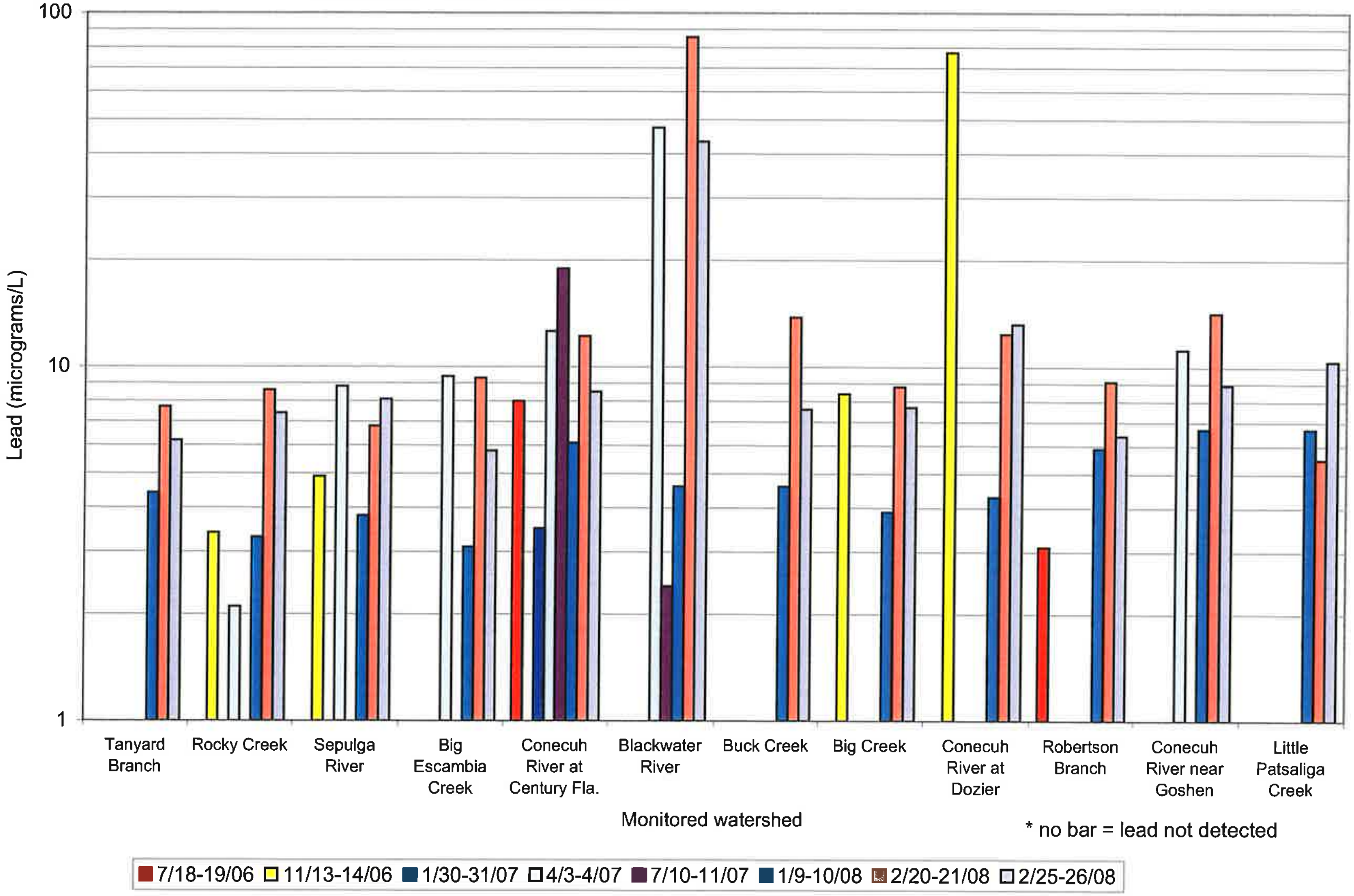
Metallic Constituent	USEPA Primary/ secondary drinking water standards (mg/L)	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
Aluminum	0.05-.2	.08	.21	.1	.13	.13	.25	.08	.07	.1	.14	.11	.08
Arsenic	0.010	BDL[1]	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Barium	0.06	0.06	.06	.05	.05	.04	.03	.03	.04	.05	.10	.05	.04
Beryllium	0.004	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cadmium	0.005	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Chromium	0.1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Copper	1.3/1.0	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Iron	0.3	2.60	1.40	.84	.39	.40	.24	.45	.47	.66	.59	.77	.81
Lead	0.015	.004	.004	.005	.005	.009	.02	.005	.005	.01	.005	.006	.004
Manganese	0.05	.44	.10	.06	.05	.05	.04	.05	.04	.06	.24	.13	.09
Mercury	0.002	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Selenium	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Thallium	0.002	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zinc	5.0	.02	.02	.02	.02	.02	.02	.02	.02	.02	.03	.02	.01

[1] BDL- Below Detection Limit.

ORGANIC CONSTITUENTS

Organic compounds are commonly used in our society today. Frequently, these compounds appear in streams and ground-water aquifers. Many of these compounds have been found to be harmful to human health and the health of the aquatic environment. A limited group of organic constituents were analyzed in water samples collected from the Conecuh River watershed monitoring sites. They include total organic carbon (TOC), phenol, and oil and grease. TOC analysis is a well-defined and commonly used methodology that measures the carbon content of dissolved and particulate organic matter present in water. Many water utilities monitor TOC to determine raw water quality or to evaluate the effectiveness of processes designed to remove organic carbon. Some wastewater utilities also employ TOC analysis to monitor the efficiency of the treatment process. In addition to these uses for TOC monitoring, measuring changes in TOC concentrations can be an effective "surrogate" for detecting contamination from organic

Figure 22.--Measured lead in monitored streams in the Conecuh and Blackwater River watersheds.



compounds (e.g., petrochemicals, solvents, pesticides). Thus, while TOC analysis does not give specific information about the nature of the threat, identifying changes in TOC can be a good indicator of potential threats to a system (USEPA, 2005). Typical TOC values for natural waters vary from 1 to 10 mg/L (Mays, 1996). Average TOC values for monitoring sites are shown in table 18.

Phenols are used in the production of phenolic resins, germicides, herbicides, fungicides, pharmaceuticals, dyes, plastics, and explosives (USGS, 1992-96). They may occur in domestic and industrial wastewaters, natural waters, and potable water supplies. Generally they are traceable to industrial effluents or landfills (Eaton and others, 1995). The EPA states that phenols should be limited to 0.3 mg/L in lakes and streams to protect human health from the possible harmful effects of exposure. Phenols cause acute and chronic toxicity to freshwater aquatic life. Phenols or oil and grease were not detected in any samples collected during the project period.

SUMMARY OF FINDINGS

The Conecuh and Blackwater River watersheds cover much of south Alabama, but relatively little water-quality data are available to determine the current status of water-quality conditions, effects of land use, and a course of action to protect these waters. The purpose of the project is to generate data that can be used by the CSCWP in cooperation with local, state, and federal agencies, and citizens to develop, manage, and protect the surface-water resources of the Conecuh River and Blackwater River watersheds.

Land use is one of the most important factors influencing water quality. The project area was divided into two major land-use categories, those areas dominated by agriculture and those dominated by forests (plate 3). Monitoring-site selections were based on stream locations and land uses associated with particular stream reaches. Sites 3 and 6 were suspected to be low-impact sites on streams that drain primarily forested lands. Sites 4, 7, 8, 10, and 12 are on stream reaches that drain areas dominated by agricultural land use. Tanyard Brnach (site 1) is an urban drainage, flowing through the city of Greenville. Site 2 is on Rocky Creek, a stream on the 303(d) list with a possible industrial impact, and sites 5, 9, and 11 are on downstream, midstream, and upstream reaches of the Conecuh River, respectively.

Table 18.— Average concentrations of total organic carbon measured in monitored streams in the Conecuh and Blackwater River watersheds.

Stream monitoring site	Site no.	Average total organic carbon (mg/L)
Tanyard Branch at Greenville	1	2.8
Rocky Creek at Butler Co. Road 16	2	12.4
Sepulga River at Conecuh Co. Road 29	3	5.0
Big Escambia Creek at Escambia Co. Road 30	4	7.2
Conecuh River at Escambia Co. Florida Road 4	5	6.0
Blackwater River at Okaloosa Co. Florida Chesser Bridge	6	10.1
Buck Creek at Covington Co. Road 23	7	2.1
Big Creek at Ala. Hwy. 29	8	3.6
Conecuh River at Dozier	9	5.3
Robertson Branch at Pike Co. Road 28	10	6.9
Conecuh River at Pike Co. Road 28	11	6.2
Little Patsaliga Creek at Crenshaw Co. Road 35	12	4.6

The primary constituents that affect water quality in Alabama streams have nonpoint sources and consist of sediment, nutrients, bacteria, and metals. Evaluations of these constituents provide a good indication of overall water quality and stream health. Geochemical characterization of water quality, when combined with evaluations of land-use, provides indications of pollutant sources as well as magnitudes of impact.

An effective method of comparing water quality at respective monitoring sites is to rank each site as to the magnitude of particular water-quality constituents. Tables 19, 20, and 21 show rankings of project sites from highest (1) to lowest (12) magnitude of priority constituents. Table 19 shows rankings of normalized suspended and bed sediment loads. Buck Creek (site 7) had the largest loads and Big Escambia Creek (site 4) had the lowest. Table 20 shows rankings of normalized nitrate loads and average phosphorus concentrations. Buck Creek (site 7) and Robertson Branch (site 10) had the largest loads and concentrations and Little Patsaliga Creek (site 12) had the lowest.

Table 19— Ranking of streams with respect to sediment loads in the Conecuh and Blackwater River watersheds.

Site no.	Suspended sediment load tons/square mile/year	Bed sediment load tons/square mile/year	Rank
1	5	5	4
2	6	6	6
3	11	6	9
4	12	7	10
5	4	not measureable	
6	9	4	7
7	1	2	1
8	2	3	2
9	10	1	5
10	3	5	3
11	8	9	9
12	7	8	8

Analyses of bacteria levels may be used to assess the quality of water and to indicate the presence of human and animal waste in surface and ground water. Fecal coliform groups of bacteria are frequently used as indicator organisms of this type of water pollution. Table 21 indicates that Robertson Branch (site 10), the unnamed tributary to Pigeon Creek (site 1), and Little Patsaliga Creek (site 12) had the highest average fecal coliform bacteria counts. Big Escambia Creek (site 4) and Blackwater River (site 6) had the lowest. Lead was the only non-naturally occurring metal with excessive concentrations.

Table 21 shows that average lead concentrations were highest in Blackwater River (site 6) and lowest in Little Patsaliga Creek (site 12). BOD may be used to indicate

Table 20— Ranking of streams with respect to nutrient loads and concentrations in the Conecuh and Blackwater River watersheds.

Site	Nitrate Load tons/square mile/year	Average total phosphorus	Rank
1	5	2	3
2	6	1	3
3	9	3	7
4	4	4	4
5	3	3	2
6	10	3	8
7	1	3	1
8	7	2	5
9	11	3	9
10	2	2	1
11	8	2	6
12	12	3	10

the presence and magnitude of organic pollutants. Table 21 shows that Tanyard Branch (site 1), Rocky Creek (site 2), and Robertson Branch (site 10) had the highest average BOD concentrations, respectively. This is not surprising since Tanyard Branch is an urban drainage, site 2 (Rocky Creek) is downstream from a likely industrial pollutant source, and site 3 (Sepulga River) is downstream from intensive agricultural activity (row crop and poultry production). Also, as expected from a watershed that is dominated by forest and pasture, Blackwater River (site 6) had the lowest BOD.

When all priority constituents were considered (table 21; also shown on plate 3), Buck Creek (site 7), Robertson Branch (site 10), and Tanyard Branch (site 1) had the highest magnitude of impacted water quality, respectively, and Big Escambia Creek (site 4), Little Patsaliga Creek (site 12), and Sepulga River (site 3) had the lowest magnitude of impacted water quality, respectively. This correlates well with pollutant sources and land uses in the respective watersheds, as theorized prior to monitoring.

Table 21— Ranking of key constituents in streams in the Conecuh and Blackwater River watersheds.

Site no.	BOD	Suspended sediment load	Bed sediment load	Nitrate Load	Average total phosphorus	Average fecal coliform	Average lead	Rank
1	1	5	5	5	2	2	10	3
2	2	6	6	6	1	7	11	7
3	5	11	6	9	3	9	5	10
4	6	12	7	4	4	12	6	12
5	4	4	4	3	3	10	3	4
6	7	9	4	10	3	11	1	9
7	6	1	2	1	3	4	7	1
8	6	2	3	7	2	5	8	5
9	4	10	1	11	3	6	2	6
10	3	3	5	2	2	1	9	2
11	4	8	9	8	2	8	4	8
12	5	7	8	12	3	3	12	11

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