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Research and Development

Camp Branch and Cross Creek Experimental Watershed Projects

Objectives, Facilities, and Ecological Characteristics

Interagency Energy/Environment R&D Program Report

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ERRATA SHEET FOR
"CAMP BRANCH AND CROSS CREEK EXPERIMENTAL WATERSHED PROJECTS:
OBJECTIVES, FACILITIES, AND ECOLOGICAL CHARACTERISTICS"
(EPA-600/7-79-053; TVA/ONR-79/04)

p. 34 - Table 14 heading "Biomass (mg/g)" changed to "Concentration (mg/g)".

p. 101 - Disregard "F" preceding persimmon percent cover value.

p. 102 - Table D.2. Title "the upland oak mixed hardwood cover type on Camp Branch Watershed" changed to "the mesophytic hardwood cover type on Cross Creek".

p. 102 - Table D.2. Title "values for the upland oak-mixed hardwood cover type on Camp Branch Watershed" changed to "values for the pine cover type on Cross Creek".

p. 103 - Table D.4. Title "Camp Branch" changed to "Cross Creek".

p. 104 - Table D.5. Title "the upland oak mixed hardwood" changed to "the mesophytic hardware".

p. 104 - Table D.6. Title "the upland oak-mixed hardwood cover" changed to "the pine cover".

p. 151 - Table H.2. Title "weight of nitrogen" changed to "weight of sulfur".

p. 152 - Table H.3. Title "weight of nitrogen" changed to "weight of phosphorus".

p. 152 - Table H.4. Title "weight of nitrogen" changed to "weight of potassium".

p. 153 - Table H.4. Title "weight of nitrogen" changed to "weight of magnesium".

p. 153 - Table H.6. Title "weight of nitrogen" changed to "weight of calcium".

p. 154 - Title and Subtitle "Camp Branch and Camp Cross" changed to "Camp Branch and Cross Creek".

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CAMP BRANCH AND CROSS CREEK EXPERIMENTAL WATERSHED PROJECTS: OBJECTIVES, FACILITIES, AND ECOLOGICAL CHARACTERISTICS

by

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DISCLAIMER

ABSTRACT

One of the most serious environmental problems facing the eastern United States is the degradation of air quality and its subsequent impact on terrestrial and aquatic ecosystems. Small experimental watersheds, which define practical ecosystems, are used to study and evaluate (1) the impact of anthropogenic emissions on individual ecosystem processes and (2) the integrated response of the total system.

The watershed approach to evaluating biogeochemical processes integrates several long- and short-term studies. This study is directed toward an evaluation of chronic rather than acute effects. Therefore, two study areas were prepared so that an impacted area could be compared with a background area. The Cross Creek watershed has been subjected to about 30 years of sulfur and nitrogen input from the Widows Creek coal-fired power plant. The Camp Branch watershed, located in a relatively remote area, away from the influence of any major anthropogenic sulfur or nitrogen source, is being used to represent background conditions. A comparative study of these two sites will serve two purposes: (1) It will contribute needed information on the cycling of chemical elements in natural systems; and (2) it will enable construction of empirical models with which to predict the ecological effects of man's activities. This information can then be used to guide the legislative process in determining and promulgating atmospheric emission standards.

This report outlines the objectives of the project, describes the facilities that have been developed, and summarizes the ecological characteristics of each watershed. Detailed comparisons of these and other data will be the subject of subsequent reports.

This report was submitted by the Tennessee Valley Authority, Division of Environmental Planning, in partial fulfillment of Energy Accomplishment Plan 80 BDO under terms of Interagency Agreement EPA-IAG-D5-721 with the Environmental Protection Agency. Work was completed as of July 31, 1978.

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ACKNOWLEDGMENT

This work was conducted as part of the Federal Interagency Energy/Environment Research and Development Program with funds administered through the Environmental Protection Agency (EPA Contract No. EPA-IAG-D6-0721, TVA Contract No. TV-41967A).

The EPA Project Officer for this research project is S. R. Reznek, 401 M Street, SW, Washington, D.C. His contribution to the direction of the research and constructive review of the reported results are gratefully acknowledged. The TVA Project Director is Herbert C. Jones, E and D Building, Muscle Shoals, Alabama.

SECTION 1

OBJECTIVES

The overall objective of this study is to characterize and quantify the transfer, fate, and effects of sulfur and nitrogen oxides and acid precipitation on deciduous forest ecosystems representative of the Tennessee Valley region.

From an ecological standpoint, emission standards should be keyed to the loading factor acceptable to the most sensitive component of the system. Little has been done to characterize the fate of air pollutants, such as sulfur and nitrogen oxides, in forest ecosystems. Research conducted as part of this program will provide information on

1. The elemental composition of wet and dry atmospheric deposition.

2. The ability of forest canopies to scavenge airborne pollutants and the fate of these pollutants after they have been scavenged.

3. The influence of air pollutants on the general fertility level of the soil and the ability of the soil to act as a long-term sink for air pollutants.

4. The determination of allowable changes in system processes and transfers as a function of air quality.

With this information, meaningful input on system response and tolerance to atmospheric loading could be used in the legislative process to determine and set realistic standards for emission levels. Also, greater understanding of system characteristics, processes, and transfers will be valuable in assessing the impact of other environmental disturbances (e.g., surface mining, biomass utilization for fuel, whole tree harvest, and clear cutting).

SECTION 2

INTRODUCTION

The term ecosystem, as defined by Tansley (1935), emphasized the inseparable nature of organisms and their environment, which together form a physical system. The ecosystem concept itself is somewhat artificial because it tends to segregate overlapping and interacting systems into isolates for convenient study. The definition places little restriction on area or spatial volume to be included in delineating an ecosystem; nevertheless, to carry this definition to extremes in either direction runs the risk of over-generalization or disconnected finiteness. The problem, then, is to choose a realistic experimental unit whose systematic response has practical importance to the solution of ecological problems. A watershed defines a practical ecosystem that reacts to the inputs from the atmosphere above, depends largely on the regolith below for nutrition, and is subject to irreversible loss through surface streamflow and deep seepage, but which resists such loss by constant recycling and biosynthesis.

Experimental watersheds have been used to study biogeochemical processes within landscapes and to evaluate the response of those processes to manipulations by man (Likens et al. 1970, Frederiksen 1972, Johnson and Swank 1973, Henderson and Harris 1974). The chemical composition of the atmosphere is a principal consideration in such studies because it contributes large quantities of materials to the land surface (Whitehead and Feth 1964, Gambell and Fisher 1966, Fisher et al. 1968, Swank and Henderson 1976).

Chemical solutes and particulate matter in the surface water or in deep seepage water represent an irreversible loss to the terrestrial ecosystem. At the same time, dynamic processes of weathering, biological uptake, fixation, decomposition, and atmospheric input tend to replenish the supply and to cycle the elements within the system. Water received as precipitation contains chemical elements and also acts as solvent and carrier for nutrients; thus, chemical makeup, rate, and volume of precipitation are major factors in determining the chemical flux of terrestrial ecosystems. The climatic and microclimatic regime is therefore an integral part of the total system, which establishes, to a great degree, the rate of biotic production, decomposition, energy input, and nutrient loss.

The flux of nutrients in both biotic and abiotic compartments must be examined to quantitatively describe and account for the biogeochemical behavior of various system processes, transfers, and pools. Figure 1 presents a conceptual model of a mineral nutrient cycle in a deciduous forest watershed. Quantification of this cycle requires breaking the cycle into several source and sink compartments, transfers, and transfer processes. Factors that influence a particular parameter and the variables that must be quantified should be considered.

The watershed approach to the evaluation of biogeochemical processes represents an integration of several long- and short-term studies. Many variables, owing either to seasonal or annual variability, require several months to years of observation before representative values can be derived,

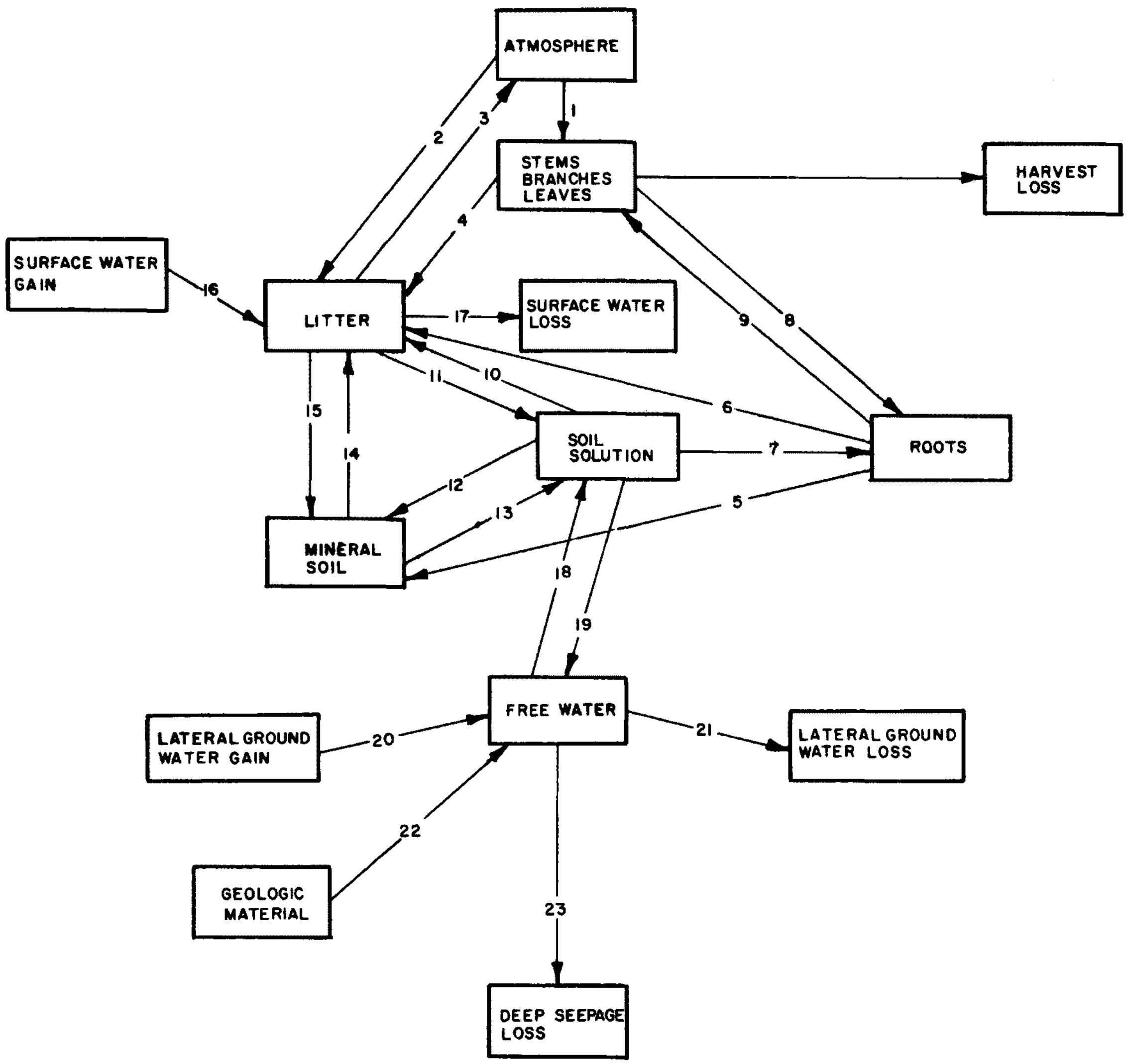

Figure 1. Conceptual model of a mineral nutrient cycle in a deciduous forest watershed.

whereas others can be quantified in a single growing season. It would not be reasonable to assume that significant changes in all parameters could be detected with current-time restraints. In order that anticipated effects might be detected within current-time and budget restraints, two similar forested watersheds typical of those found on the Cumberland Plateau were prepared as study sites. The two sites are located about 19 and 95 km, respectively, from the Widows Creek coal-fired power plant, a 1958-megawatt installation (Figure 2). The site nearest to the plant has been subjected to sulfur and nitrogen input at fairly heavy levels for about 30 years. The second site, located in a relatively remote area away from the influence of any major anthropogenic sulfur or nitrogen source, is being used to represent background conditions on the Plateau. The soils and vegetation complex on the Plateau are ideally suited to this type of study, because when compared with other possible sites within the Valley, any positive or negative impact should be easier to detect because of the thin, relatively infertile and unbuffered nature of the soil.

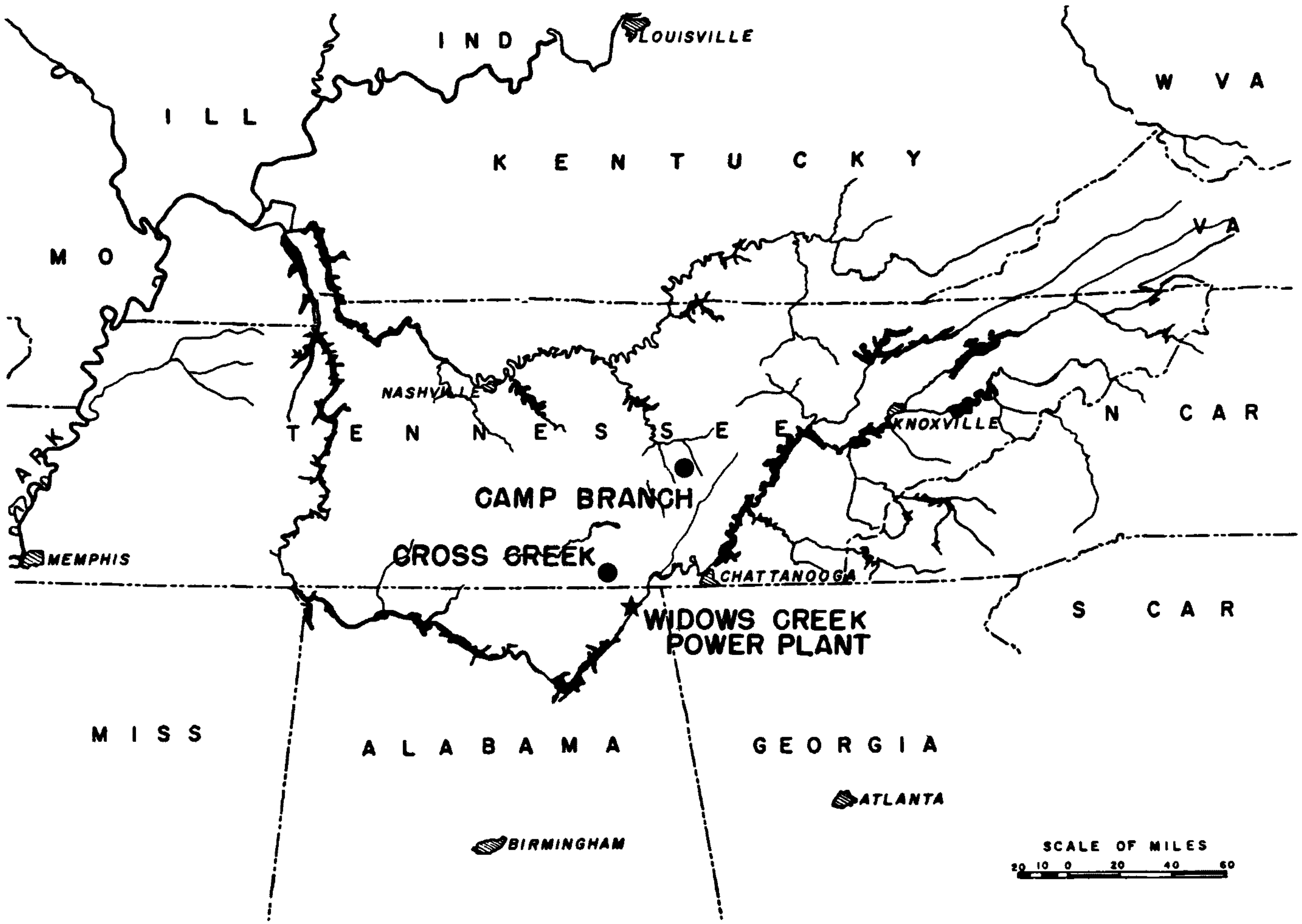

Figure 2. Location of Camp Branch and Cross Creek watersheds.

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

The watershed approach to the evaluation of biogeochemical processes represents a holistic approach to perturbation analysis. Because of the inherent variability of these systems, meaningful studies require as a minimum a 5-year commitment to input and output data collection, supplemented by short-term, intensive studies on various system components and processes. Two comparable watersheds have been identified and prepared for extended study. This report documents the biotic and edaphic characteristics of each study site and will serve as the base for future comparative studies.

Longevity of operation is the key recommendation for acquisition of the meaningful data needed to address the complex questions associated with an expanding, coal-based energy system. Many short-term evaluations conducted over the course of an extended study can provide timely input to current interests, while the final integration of the total study will provide the necessary holistic insight for predicting and evaluating integrated system response.

A second recommendation is that a watershed study network be developed to use existing sites such as Coweeta, Walker Branch, Fernow, Hubbard Brook, and others. Comparable work carried out at all these sites would provide an enhanced picture of landscape response in the eastern United States to anthropogenic perturbations. TVA, because of its past experience in integrative studies and close cooperation with Oak Ridge National Laboratory, could assume the role as lead agency for such a program.

SECTION 4

EXPERIMENTAL AREA

LOCATION

The Camp Branch Experimental Watershed is located on the Cumberland Plateau within the boundaries of Fall Creek Falls State Park in Bledsoe County, Tennessee (35°38' N; 85°18' W) (Figure 2). The study area encompasses the major portion of the area drained by the south fork of Camp Branch; the weir is located about 175 m upstream from the confluence of the north and south forks. Camp Branch is a tributary of Cane Creek, which is a tributary of Caney Fork River, which forms the main body of the U.S. Corps of Engineers Center Hill Reservoir.

The Camp Branch watershed occupies a total of 94 ha (233 acres) and ranges in elevation from 597.5 m at its highest point to 518.3 m at the weir (Figure 3). Access to the watershed is provided by a tertiary road located along the western crest of the watershed.

The Cross Creek Experimental Watershed is located within the boundaries of the Marion-Franklin State Forest in Marion County, Tennessee (35°4' N; 85°51' W) (Figure 2). The study area encompasses the major portion of the area drained by a tributary of the east fork of Cross Creek. Cross Creek is a tributary of Crow Creek, which is a tributary to that part of the Tennessee River that forms the body of the Tennessee Valley Authority's (TVA's) Guntersville Reservoir.

The Cross Creek watershed occupies a total of 36 ha (89 acres) and ranges in elevation from 573.5 m at its highest point to 495.4 m at the weir (Figure 4). Access to the watershed is provided by a tertiary road located along the eastern crest of the watershed.

CLIMATE

The climate of the Cumberland Plateau is temperate and continental. The winters are moderate, with short cold periods, and the summers are mild to hot. Precipitation is well distributed over the year. The average annual precipitation for the Camp Branch watershed is about 144.3 cm, whereas the long-term mean for the Cross Creek watershed is about 10 cm greater (154.8 cm). Comparison of climographs (Figure 5) developed for each site on the basis of data from National Oceanic and Atmospheric Administration observation stations at Crossville, Tennessee (30 km north of Camp Branch) and Monteagle, Tennessee (6 km north of Cross Creek), respectively, illustrates the basic similarity of climatic trends for the two study sites. The most striking difference between the two sites is the distinctly lower level of precipitation at Camp Branch during the month of November. Monthly temperature means for the Camp Branch site are also slightly lower when compared with the Cross Creek site (Figure 5).

Figure 6 is a generalized representation of the water balance for each site according to the Thornthwaite (1957) climatic classification. The most striking feature of the Plateau climate, as far as plant growth

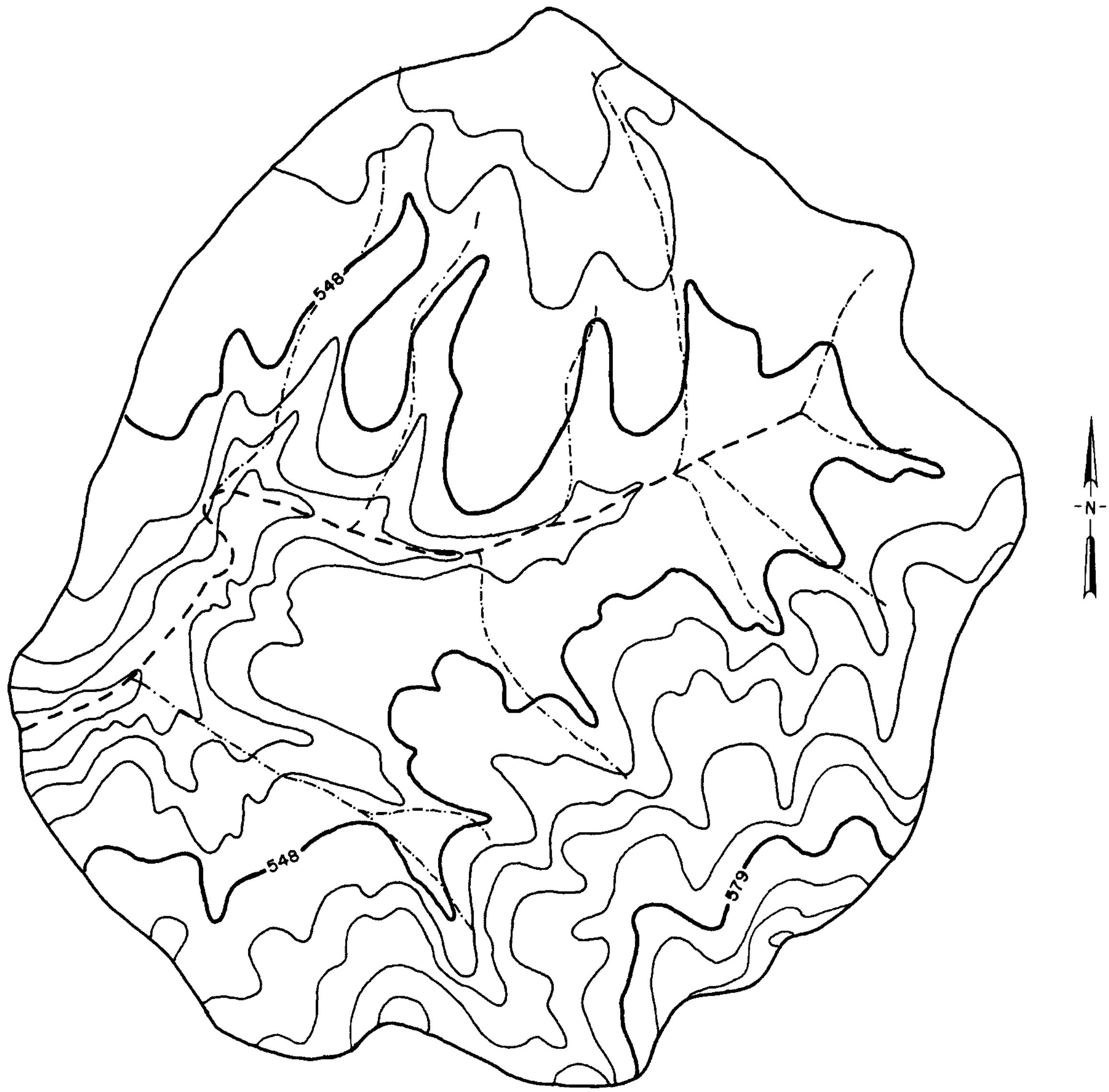

Figure 3. Topographic map for Camp Branch watershed.
Contour interval is 3.07 m (10.0 ft).

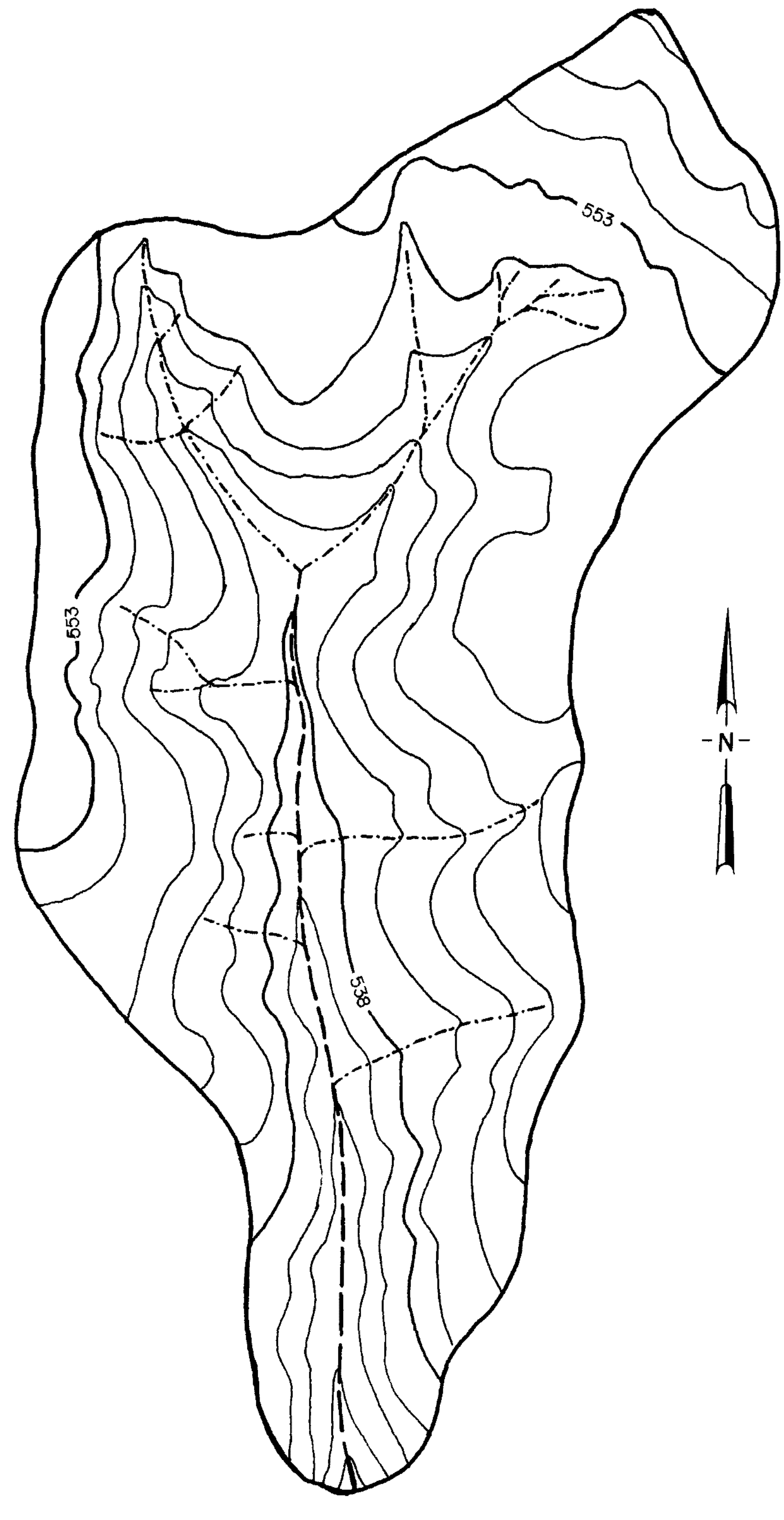

Figure 4. Topographic map for Cross Creek watershed. Contour interval is 3.07 m (10.0 ft).

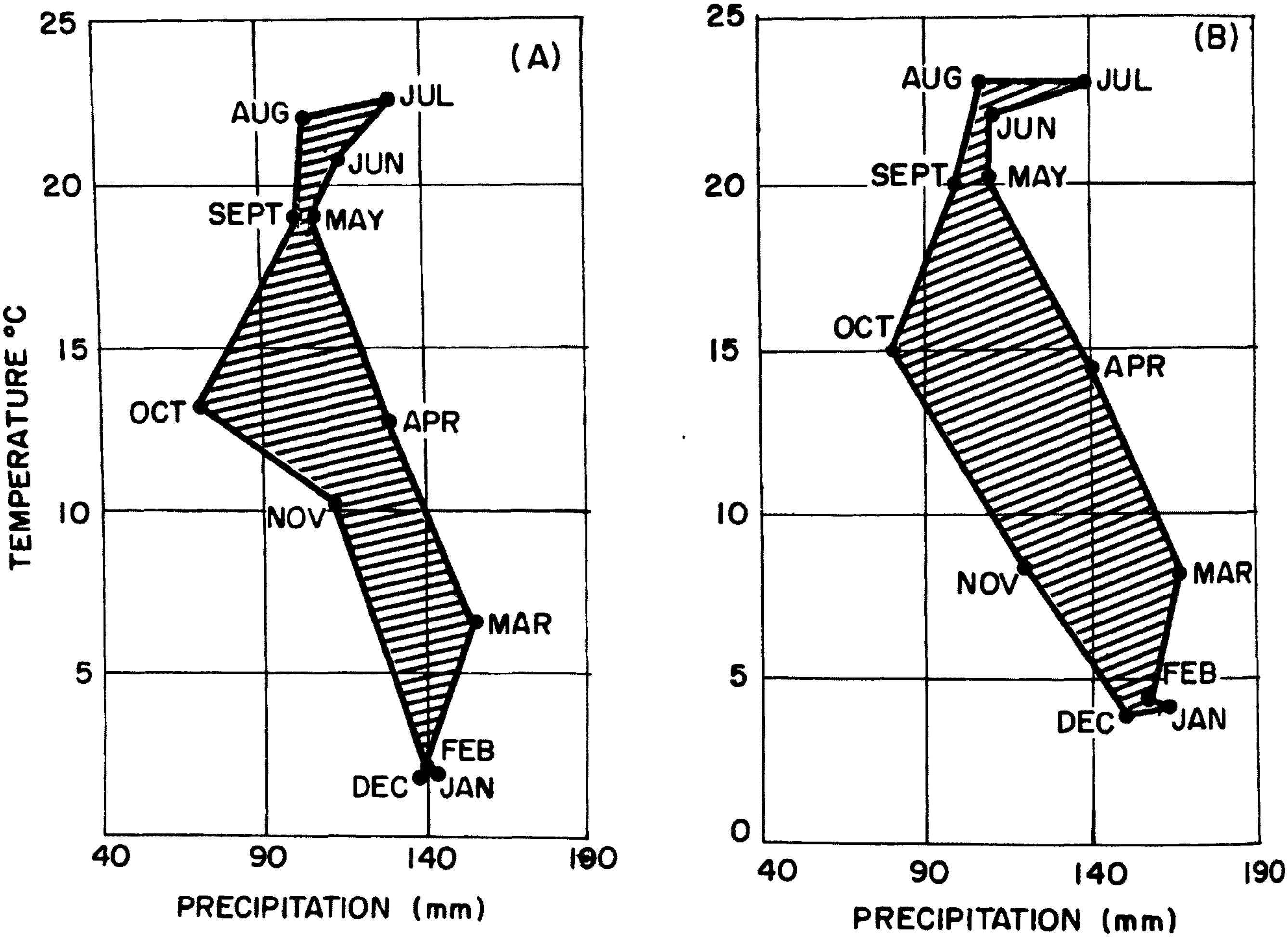

Figure 5. Climographs for the Camp Branch (A) and Cross Creek (B) watersheds.

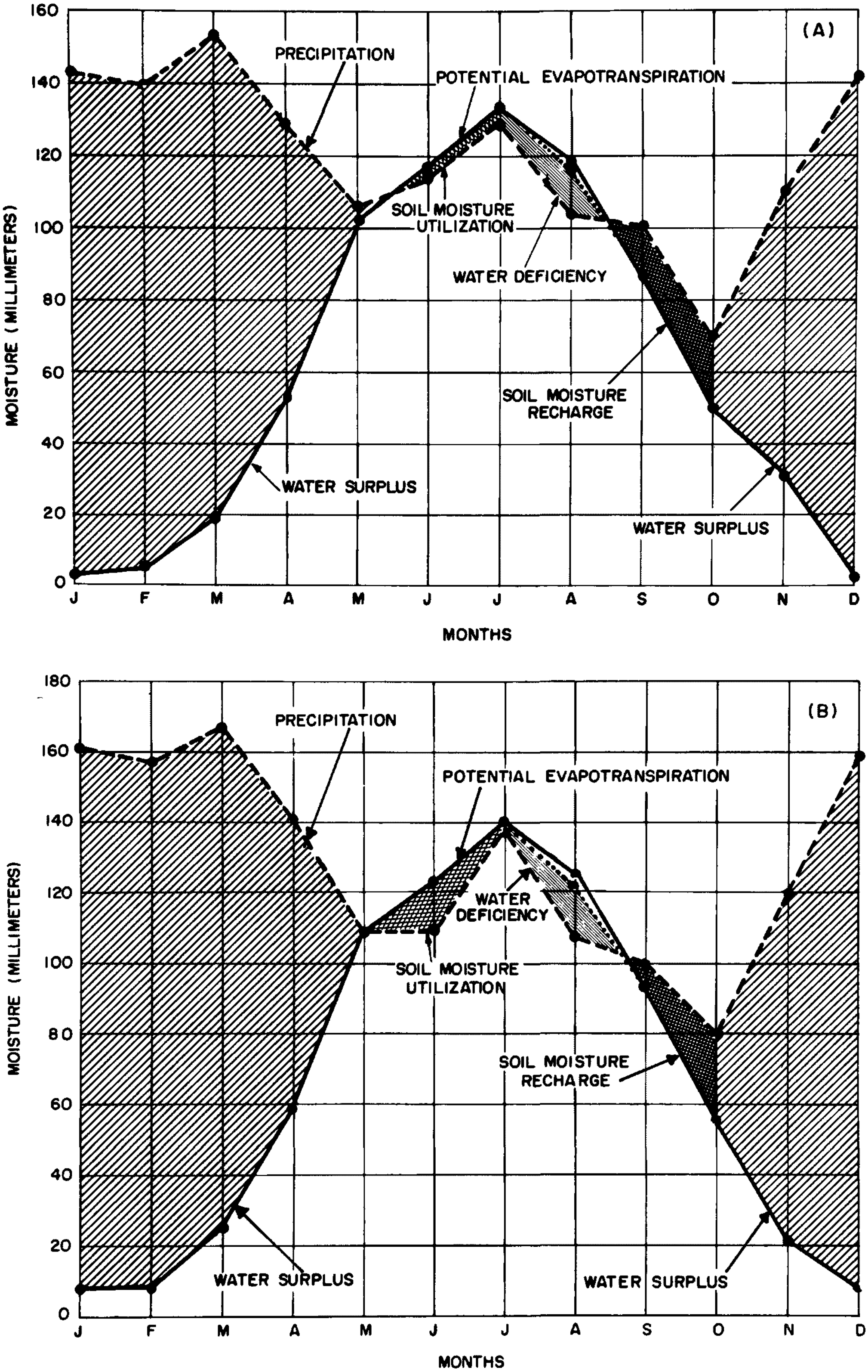

Figure 6. Annual water balance of the Camp Branch (A) and Cross Creek (B) watersheds, assuming 150 mm of storage at each site.

is concerned, is that the period of minimum precipitation generally occurs near or after the end of the growing season. Consequently, only a relatively small water deficiency develops during the growing season. In fact, precipitation input exceeds evapotranspiration during 9 months out of the year.

Local variations in temperature and precipitation do occur. These variations are caused primarily by the lay of the land, including direction of slope and the effect of relief on air drainage. Local variations in rainfall may result, in part, from the fact that much of the rain in late spring and summer comes in the form of thundershowers. The prevailing winds blow from the south and southwest (Hubbard 1950).

PHYSIOGRAPHY AND GEOLOGY

Physiographically, both study areas are located on the Cumberland Plateau, which is part of the Appalachian Plateau Province (Elder et al. 1958). In its more typical part, the Cumberland Plateau has an undulating surface, submaturely dissected by young valleys whose steepness and depth increase toward the edges. Its foremost characteristic is seen in broad remnants of a surface in which only shallow valleys of an older generation are found. This part of the surface is underlain by the Walden and Lookout sandstone and conglomerate. Weaker beds at the surface are negligible topographically, but enough of them remain to show by their bending that the surface is a true peneplain. The immaturity of the topography in the current cycle results partly from the hardness of the sandstone, and partly from its great thickness, 185 to 215 m; consequently, sapping occurs only along the edges (Fenneman 1938).

The west-facing escarpment is conspicuous everywhere until it is gradually lost in Alabama due to diminishing height. At places the slope is almost uninterrupted; at others it is terraced by formations of Chester age. Everywhere its steepness is due to sapping. The escarpment rises from about 500 m at the northern border of Tennessee to 615 m at the southern border.

The boundary on the east, known as the Cumberland Front, is also an escarpment, which grows in clarity and height toward the north. The straightness of the east face contrasts sharply with the frayed character of the scarp on the other side of the province. The weak Bangor limestone at the base of the eastern face is responsible for the large-scale sapping on this face (Fenneman 1938).

The Cumberland Plateau is underlain largely by rocks of Pottsville age (Fenneman 1938). The formations consist of massive, cross-bedded sandstone containing numerous quartz pebbles (Elder et al. 1958). These strata are stronger than most of the rocks of the Allegheny Plateau, but the interbedding of shales has favored the stripping of the sandstone (Fenneman 1938). The Walden and Lookout sandstones of the Pennsylvanian cap the Plateau at both study areas (Elder et al. 1958).

REFERENCE GRID SYSTEM

A high-density grid system (Figures 7 and 8) was superimposed on each watershed area at a grid interval of 100 m. The north-south and east-west grid lines were cleared and marked with flagging. Metal posts were driven into the ground at the intersection of grid lines, and a tag identifying the north-south and east-west coordinates was attached to each post. Posts were also erected and tagged at either end of each north-south and east-west grid line to mark the watershed boundary. These points were identified by the coordinates of the previous grid point plus the distance in meters from that point. This grid system provides the reference base for all maps and surveys on each watershed.

SOILS

Most of the soils of the Cumberland Plateau are well drained. The poorly drained soils occupy small areas; somewhat poorly drained and moderately well drained soils are more common, but not extensive. The degree of erosion varies greatly; many of the soils are uneroded and others are severely eroded. Some of the soils contain loose fragments of chert or cobblestones (Elder 1958).

Many soils of the uplands and high stream terraces have been severely leached. Consequently, they are acid and rather low in fertility and organic matter (Elder 1958). Nearly all the soils of the Plateau uplands have formed from weathered products of interstratified sandstone and shale, mainly sandstone (Hubbard 1950). Thus, the properties of the soils are generally closely related to the kind of underlying rock from which the parent materials originated (Elder 1958).

Soil Survey

A medium-intensity soil survey was conducted on both watersheds by personnel of the Soil Conservation Service. As a result of that survey six soil mapping units representing five established series were delineated on the Camp Branch watershed (Figure 9), and seven mapping units representing five established series were delineated on the Cross Creek watershed (Figure 10). Tables 1 and 2 list the soil series observed at each site and the total area occupied by each series, its classification according to the Comprehensive System of Soil Classification, and other descriptive data. Detailed descriptions of the established series profiles are given in Appendix A.

The soils on both watersheds represent three orders according to the Comprehensive System of Soil Classification: Alfisol, Inceptisol, and Ultisol. Ultisols (Cotaco, Gilpin, Hartsells, Jefferson, and Linker) are highly weathered mature soils with well-developed profiles, whereas Inceptisols (Muskingum, Philo, and Ramsey) are soils formed from recently deposited materials, which are not so highly weathered or developed as Ultisols. Alfisols (Wellston) represent a somewhat intermediate position between Ultisols and Inceptisols.

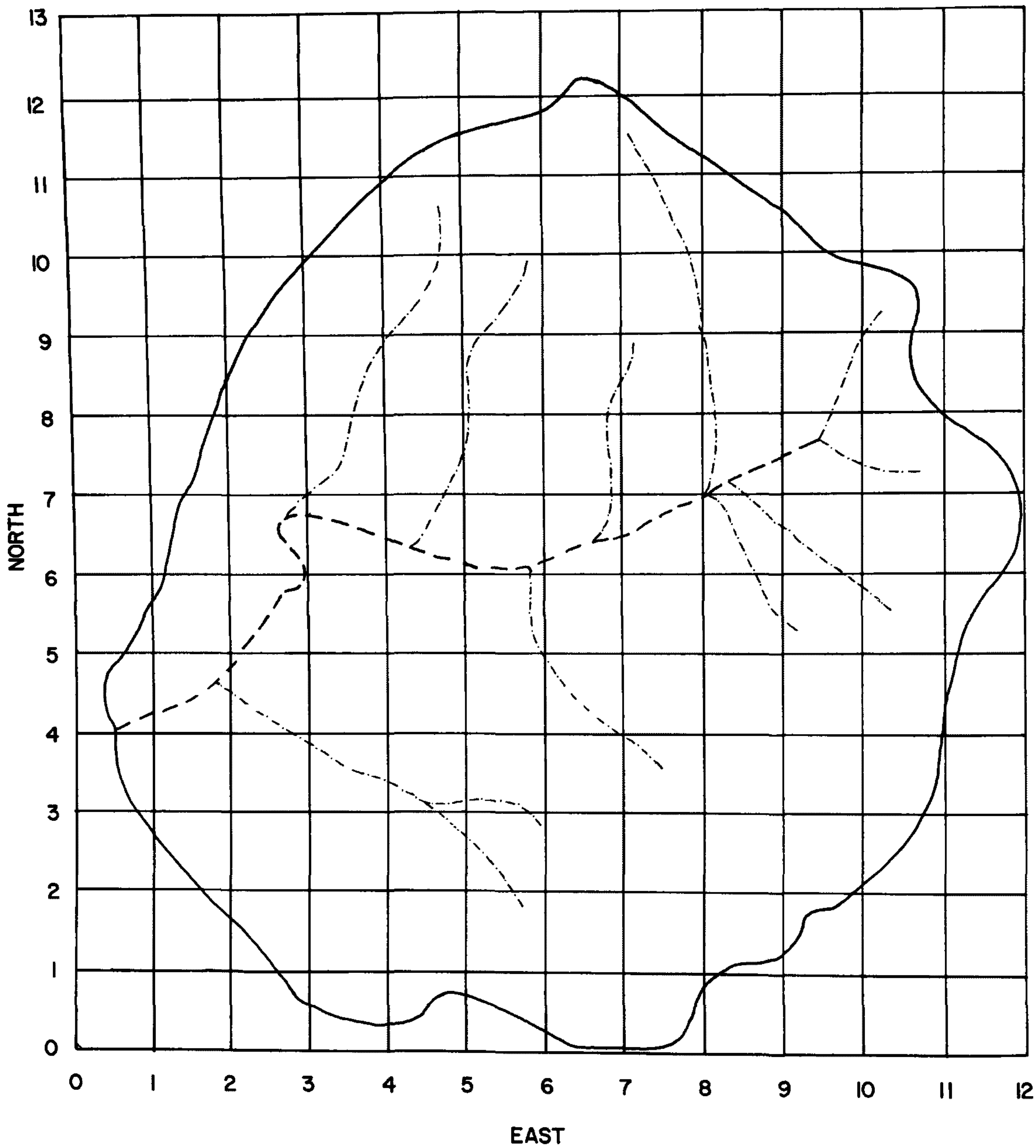

Figure 7. Reference grid system, Camp Branch watershed.

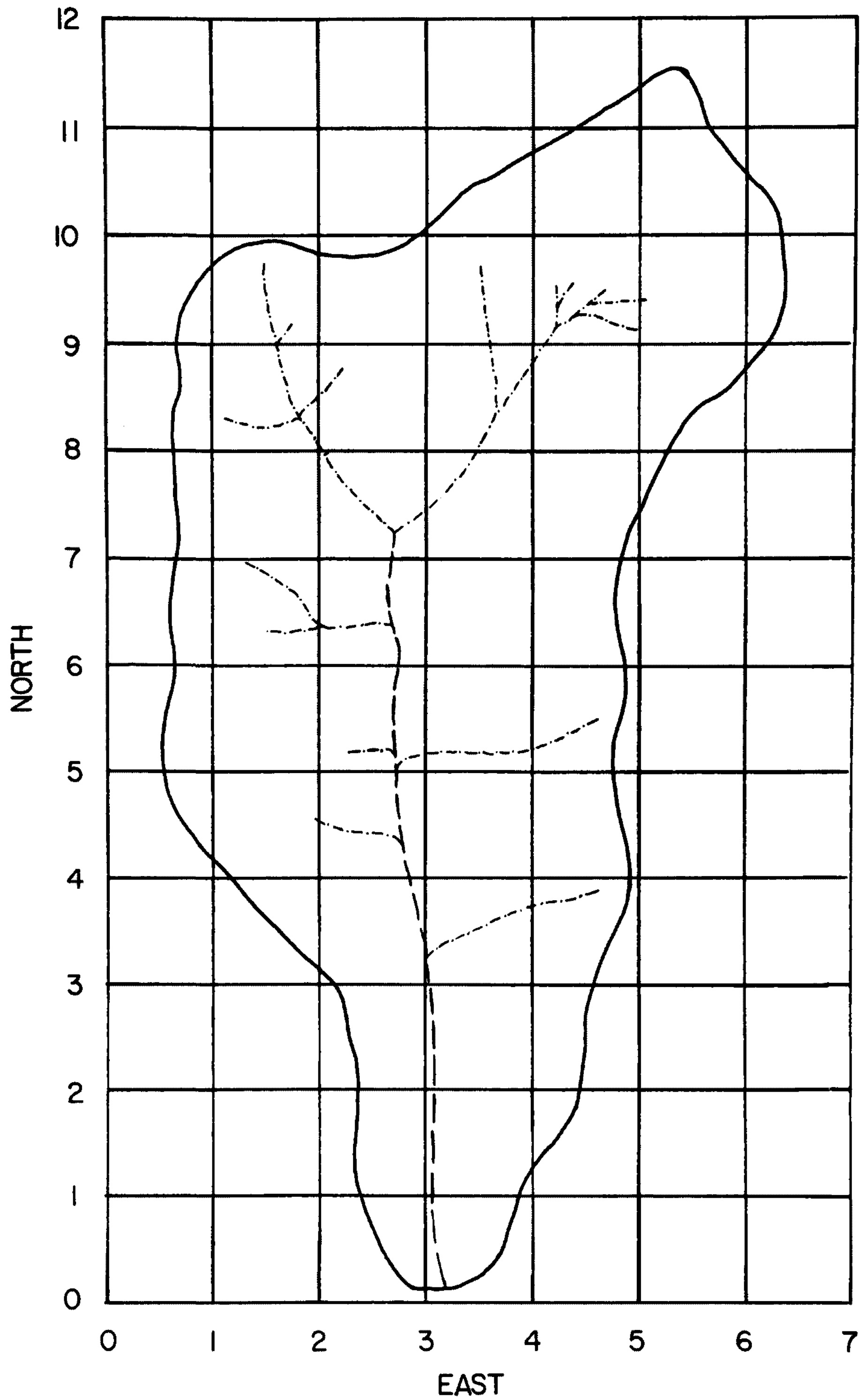

Figure 8. Reference grid system, Cross Creek watershed.

Figure 9. Soil survey map, Camp Branch watershed.

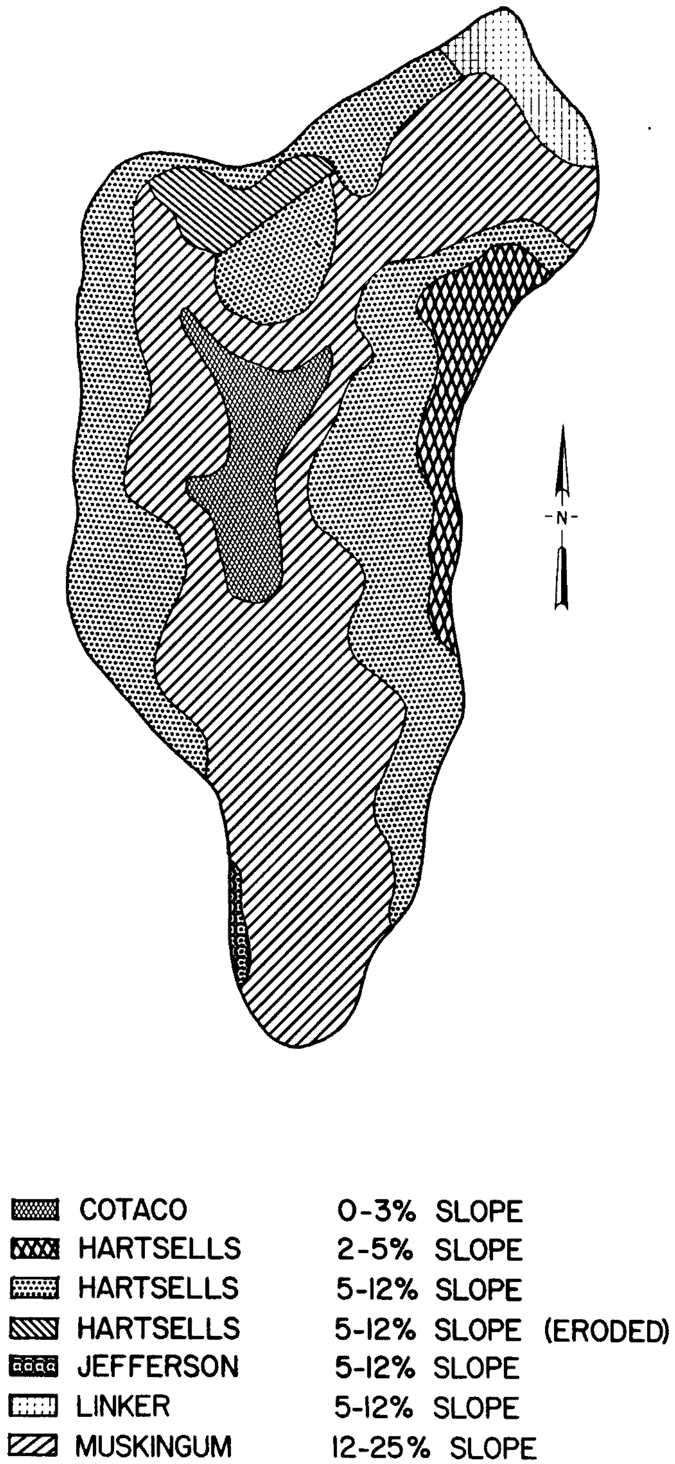

Figure 10. Soil survey map, Cross Creek watershed.

Soils of the Cotaco series are deep, moderately well drained, moderately permeable soils formed in loamy sediments of acid sandstone, siltstone, and shale. The Cotaco unit occurs only on the Cross Creek site and occupies 2.2 ha, or 6.0 percent of the study area. Slope ranges from 0 to 3 percent, and depth to bedrock is generally greater than 100 cm. Fragments of sandstone or siltstone range from 2 to 35 percent in any horizon. Reaction ranges from strongly acid through extremely acid. Seep spots are common on this type of soil.

Soils of the Gilpin series are moderately deep, well-drained soils that are found on gently sloping to steep, convex, dissected uplands with slope gradients of 2 to 70 percent. The two Gilpin mapping units account for about 45 percent (42.2 ha) of the area at the Camp Branch site. Solum thickness ranges from 50 to 100 cm. Thin flat coarse fragments of shale, siltstone, and sandstone comprise 5 to 40 percent of individual horizons of the solum and 30 to 90 percent of the C horizon. Reaction ranges from strongly to extremely acid. The clay mineralogy is mixed with illite predominantly and with kaolinite and vermiculite in lesser quantities.

Soils in the Hartsells unit occur on broad, smooth plateau areas and on hilltops. Slopes between 3 and 8 percent are dominant, but the extreme range of slopes for the units mapped was 2 to 12 percent. This soil is formed in moderately coarse to medium textured materials. This soil is derived from acid, hard sandstone containing thin strata of shale or siltstone in some places. Depth to bedrock and solum thickness range from 50 to 100 cm. The amount of coarse fragments, chiefly sandstone, ranges from 0 to 15 percent in any horizon, except B3 and C horizons, which range up to 35 percent. The soil is extremely to strongly acid throughout the profile. This series accounts for 5.6 percent of the total area on the Camp Branch site, but contributes 41.2 percent on the Cross Creek site (Tables 1 and 2).

The Jefferson series is typically found on steep mountainsides and footslopes, often below sandstone escarpments. These soils have formed in colluvium from soils formed in residuum of acid sandstone and siltstone. These are well-drained soils with medium permeability. Thickness of the solum ranges from 100 to 150 cm with a sandstone fragment content of 10 to 25 percent. The soil ranges from strongly to very strongly acid throughout. The Jefferson series on the Cross Creek watershed contributes less than 1 percent of the total area; this series does not occur on the Camp Branch site.

Linker soils occur on broad plateaus, mountain- and hilltops, and benches. Most slopes range between 2 and 8 percent. This soil formed in loamy residuum weathered from sandstone or interbedded sandstone, siltstone, and shale; is well drained; and has moderate permeability. The soil is extremely acid through strongly acid, and solum thickness and depth to bedrock range from 50 to 100 cm. The Linker series occurs only on the Cross Creek watershed and accounts for 3 percent of the total area.

Thickness of the solum and depth to bedrock for the Muskingum series are 50 to 100 cm. The B and C horizons are strongly or very strongly acid. Coarse fragments of shale, siltstone, or sandstone range from 10 to 30

TABLE 1. SOIL SERIES OBSERVED ON CAMP BRANCH WATERSHED

Soil series	Texture	Total area (ha)	Total area (%)	Slope range (%)	Permeability range (cm/h)	Available water capacity (cm/cm)	pH	Comprehensive classification
Gilpin	Silt loam	42.2	44.7	5-25	1.6-5.0	0.15-0.50	4.0-5.5	Typic Hapludults, Fine loamy, mixed, mesic
Rolling phase		(37.0)	(39.3)	5-12				
Hilly phase		(5.2)	(5.4)	12-25				
Hartsells	Fine sandy loam	5.3	5.6	5-12	1.5-15.2	0.25-0.45	3.6-5.5	Typic Hapludults, Fine loamy, siliceous, thermic
Philo	Silt loam	6.5	6.9	0-3	0.5-50.8	0.15-0.50	4.5-6.0	Fluvaquentic Dystrochrepts, Coarse loamy, mixed, mesic
Ramsey	Loam	4.7	4.9	25-70	15.2-50.8	0.10-0.30	4.5-5.5	Lithic Dystrochrepts, Loamy, siliceous, mesic
Wellston	Silt loam	35.5	37.6	2-5	1.5-5.0	0.30-0.55	4.5-6.5	Ultic Hapludalfs, Fine silt, mixed, mesic

TABLE 2. SOIL SERIES OBSERVED ON CROSS CREEK WATERSHED

Soil series	Texture	Total area (ha)	Total area (%)	Slope range (%)	Permeability range (cm/h)	Available water capacity (cm/cm)	pH	Comprehensive classification
Cotaco	Silt loam	2.2	6.0	0-3	1.5-15.2	0.17-0.50	3.6-5.5	Aquic Hapludults, Fine loamy, mixed, mesic
Hartsells	Fine sandy loam	15.0	41.2	2-12	1.5-15.2	0.25-0.45	3.6-5.5	Typic Hapludults, Fine loamy, siliceous, thermic
Undulating phase		(1.6)	(4.5)	2-5				
Rolling phase		(12.3)	(33.9)	5-12				
Eroded rolling phase		(1.1)	(2.8)	5-12				
Jefferson	Fine sandy loam	0.2	0.5	5-12	5.0-15.2	0.20-0.40	4.5-5.5	Typic Hapludults, Fine loamy, siliceous, mesic
Linker	Loam	1.0	3.0	5-12	1.5-5.0	0.20-0.50	3.6-5.5	Typic Hapludults, Fine loamy, siliceous, thermic
Muskingum	Stoney fine sandy loam	17.9	49.3	12-25	1.5-15.2	0.05-0.45	4.5-6.0	Typic Dystrochrepts, Fine loamy, mixed, mesic

percent by volume in all parts of the B horizon and are more than 35 percent in the C horizon. Slope gradients range from 12 to 25 percent. The soil is formed in residuum weathered from interbedded siltstone, sandstone, and shale. Muskingum is the dominant soil series on the Cross Creek site, contributing 17.9 ha (49.3%) of the total area. This series does not occur on the Camp Branch site.

Nearly level floodplains are the setting for soils in the Philo unit. Slopes range from 0 to 3 percent. These soils have developed in recent alluvium washed mainly from sandstone- and shale-derived soils. Thickness of the solum ranges from 50 to 100 cm. Depth to bedrock ranges from 100 to more than 350 cm depending on location. The weighted average content of coarse fragments in the textural control section ranges from 0 to 20 percent. The seasonally fluctuating water table rises to a higher point 40 to 60 cm below the soil surface. Reaction ranges from very strongly to medium acid. The Philo unit, found only on the Camp Branch site, accounts for 6.9 percent of the total area.

Soils of the Ramsey series are found on hill- and mountainsides. Slope gradients range from 10 to 70 percent. The soils are generally formed in residuum and in some places contain local alluvium from sandstone or quartzite. Outcrops of bedrock are common. Solum thickness and depth to sandstone bedrock ranges from 18 to 50 cm. Each horizon contains a few percent to 35 percent by volume of fragments of quartzite. Reaction in each horizon is strongly acid or very strongly acid. About 5 percent (4.7 ha) of the Camp Branch watershed study area has been classified as belonging to this series. The Ramsey series does not occur on the Cross Creek site.

Wellston soils are found on gently sloping to steep uplands in areas of acid sandstone, siltstone, or shale bedrock. The soil is very silty, drained from loess or siltstone, or a combination of these materials to depths of up to 100 cm. The underlying bedrock is acid sandstone. Slopes range from 2 to 5 percent, with a solum thickness of 80 to 125 cm. The reaction is medium acid to extremely acid through the solum. Content of coarse fragments ranges from 0 percent in the upper part of the B horizon to 60 percent in the lower few centimeters. About 38 percent (35.5 ha) of the study area has been classified as belonging to the Wellston series.

As a group, the soils from both study sites can be classified as ranging in textural classification from fine sandy loam to silt loam with the dominant class at Camp Branch being silt loams (82.3%) and at Cross Creek being fine sandy loams (90.5%). Soils from similar topographic positions, although differing in series designation, do compare favorably in terms of permeability, available water, and pH values (Tables 1 and 2). The differences in soil types between the two sites result primarily from small differences in parent material and relative age, with the Camp Branch soils tending to be more mature.

Nutrient Levels--Litter

Samples of 01 and 02 litter were collected at each reference grid sampling point in conjunction with the mineral soil samples. Samples were collected from a 0.25-m^2 area so that weight per unit area could be estimated. Estimates of branch and bole litter were obtained by collecting and weighing all branch and bole material on plots with an area of 0.02 ha. These values were combined to provide estimates of total litter weight on each watershed (Tables 3 and 4). The entire 01 and 02 samples were processed for chemical analysis, while subsamples were taken for nutrient determination on the branch and bole collections.

TABLE 3. WEIGHT OF LITTER ON THE FOREST FLOOR BY SOIL MAPPING UNIT ON THE CAMP BRANCH WATERSHED

Soil type	Litter weight (kg/ha)			
	01 litter	02 litter	Branch and bole	Total
Gilpin, 5-12% slope	2,407	6,684	3,153	12,245
Hartsells, 5-12% slope	2,874	5,858	2,885	11,618
Philo, 0-3% slope	1,945	3,120	9,095	14,160
Ramsey, 25-70% slope	2,388	7,550	2,689	12,628
Wellston, 2-5% slope	3,089	8,402	2,818	14,310
Mean, all soil types	2,541	6,323	4,128	12,992

TABLE 4. WEIGHT OF LITTER ON THE FOREST FLOOR BY SOIL MAPPING UNIT ON THE CROSS CREEK WATERSHED

Soil type	Litter weight (kg/ha)			
	01 litter	02 litter	Branch and bole	Total
Cotaco, 0-3% slope	4,709	8,184	11,223	24,118
Hartsells, 2-5% slope	4,992	5,609	4,143	14,744
Hartsells, 5-12% slope	6,409	7,270	6,779	20,458
Hartsells, 5-12% slope (eroded)	1,332	5,390	5,461[a]	12,183
Jefferson, 5-12% slope	4,895	5,134	9,117	19,147
Linker, 5-12% slope	1,473	8,334	7,799[b]	17,607
Muskingum, 12-25% slope	5,040	5,269	7,736	18,046
Mean, all soil types	4,121	6,456	7,465	18,043

[a]Estimated value based on mean of other two Hartsells units.
[b]Estimated value based on mean of all branch and bole values.

Comparison of the total litter weights in Tables 3 and 4 indicates that differences occur within watersheds as well as between watersheds. The Cross Creek site has a greater standing mass of litter, with a mean for all soil types of about 18,000 kg/ha of total litter compared with about 13,000 kg/ha for the Camp Branch site.

Nutrient concentration values for 01 and 02 litter do not exhibit consistent trends with respect to watershed. Mean nitrogen and phosphorus levels across all soil types were higher on the Camp Branch watershed, whereas calcium, magnesium, and potassium levels were generally lower than those observed at Cross Creek (Tables 5 and 6). Sulfur values were equivalent in the 01 litter, whereas Cross Creek 02 samples exhibited a higher sulfur level than Camp Branch 02.

TABLE 5. NUTRIENT CONCENTRATIONS FOR 01 AND 02 LITTER BY SOIL MAPPING UNIT ON THE CAMP BRANCH WATERSHED

		Nutrient concentration (μg/g)					
Soil type	Layer	N	K	P	Ca	Mg	S
Gilpin,	01	11,568.0	622.0	580.8	9,268.0	529.3	1,149.5
5-12% slope	02	14,448.0	708.4	785.2	8,384.0	497.8	1,467.5
Gilpin,	01	9,500.0	490.0	500.0	8,000.0	560.0	1,040.0
12-25% slope	02	15,900.0	740.0	670.0	12,500.0	500.0	-
Hartsells,	01	11,157.1	860.0	808.6	9,085.7	598.3	1,075.7
5-12% slope	02	13,166.7	701.7	925.0	9,833.3	555.3	1,373.3
Philo,	01	10,566.7	716.7	603.3	8,300.0	652.7	1,143.3
0-3% slope	02	11,266.7	583.3	596.7	6,033.3	528.0	1,283.3
Ramsey,	01	12,300.0	745.0	680.0	10,575.0	552.3	1,170.0
25-70% slope	02	13,840.0	602.0	764.0	10,080.0	544.6	1,400.0
Wellston,	01	11,263.6	663.3	591.5	8,500.0	549.4	1,134.6
2-5% slope	02	14,151.5	640.9	765.2	7,204.2	440.8	1,480.4
Mean, all	01	11,059.0	682.7	627.0	8,954.7	573.3	1,118.5
soil types	02	13,795.2	662.3	750.8	9,005.6	510.6	1,167.2

TABLE 6. NUTRIENT CONCENTRATIONS FOR 01 AND 02 LITTER BY SOIL MAPPING UNIT ON THE CROSS CREEK WATERSHED

Soil type	Layer	Nutrient concentration (μg/g)					
		N	K	P	Ca	Mg	S
Cotaco, 0-3% slope	01	12,100.0	833.3	630.0	19,500.0	1,003.3	1,190.0
	02	11,966.7	940.0	603.3	22,233.3	970.0	1,266.7
Hartsells, 2-5% slope	01	9,680.0	546.0	448.0	14,920.0	550.0	968.0
	02	12,020.0	804.0	512.0	15,260.0	712.0	1,254.0
Hartsells, 5-12% slope	01	10,807.4	610.7	514.8	14,992.6	750.0	1,108.9
	02	12,375.0	882.1	493.6	15,807.1	793.2	1,325.0
Jefferson, 5-12% slope	01	10,900.0	535.0	440.0	9,000.0	535.0	1,195.0
	02	13,950.0	965.0	610.0	7,200.0	395.0	1,500.0
Linker, 5-12% slope	01	10,000.0	560.0	820.0	14,200.0	690.0	1,050.0
	02	9,500.0	660.0	200.0	15,900.0	790.0	1,240.0
Muskingum, 12-25% slope	01	10,186.7	616.1	596.1	14,233.3	755.0	1,104.4
	02	12,411.1	860.0	523.3	14,061.1	724.4	1,318.1
Mean, all soil types	01	10,612.2	616.9	574.7	14,462.5	713.8	1,102.5
	02	12,037.0	851.8	490.2	15,076.8	730.7	1,317.2

Nutrient Levels--Mineral Soil

Mineral soil samples were collected in conjunction with the 01 and 02 litter samples at each reference grid sampling point. Samples were taken to a depth of 100 cm or bedrock, whichever came first, in five increments: 0 to 10, 10 to 30, 30 to 50, 50 to 70, and 70 to 100 cm. In preparation for chemical analysis the samples were oven-dried at 80°C and ground to pass through a 2-mm sieve. The results of the chemical analysis are presented in Appendix B and are summarized by soil mapping unit in Tables 7 and 8. Except for total potassium and exchangeable sulfur, lower concentration values were found for all elements in the soils on the Cross Creek site than for those on the Camp Branch site. Cation exchange capacity values for the Cross Creek soils ranged from 5.0 to 7.4, while Camp Branch values exhibited a slightly higher range at 9.5 to 12.3. Mean pH values tended to be slightly higher for Cross Creek soils (Table 8). The organic matter content of the soil exhibited some variability among the various soil types on each watershed, whereas the mean value for all soils were essentially equivalent at 1.30 and 1.36 percent for Cross Creek and Camp Branch respectively.

TABLE 7. SUMMARY MEANS FOR CAMP BRANCH WATERSHED SOIL CHEMICAL ANALYSIS[a]

Mapping unit	Depth range (cm)	Nutrient concentration (μg/g)									Cation exchange capacity	pH	Organic matter (%)
		Total				Exchangeable							
		N	P	K	S	Ca	Mg	K	S	P			
Gilpin, 5-12% slope	0-100	597.6	207.1	928.8	130.2	110.6	35.4	53.4	33.7	5.6	10.6	4.6	1.21
Gilpin, 12-25% slope	0-100	582.2	185.2	1444.0	125.4	99.8	39.8	51.5	35.2	6.1	10.8	4.6	0.94
Hartsells, 5-12% slope	0-100	606.8	242.7	1252.9	130.8	176.5	41.8	66.7	47.9	5.7	10.6	5.0	0.99
Philo, 0-3% slope	0-100	703.8	218.0	843.6	141.1	120.2	43.1	55.5	32.0	5.1	10.4	4.6	1.58
Ramsey, 25-70% slope	0-50	1043.3	246.0	1003.3	139.1	120.4	22.0	58.1	48.8	9.1	12.3	4.5	2.20
Wellston, 2-5% slope	0-100	581.6	226.3	908.9	140.3	106.9	33.8	52.4	36.9	4.9	9.5	4.6	1.27
Mean, all soil types		685.3	220.8	1063.1	134.5	122.4	35.9	56.3	39.0	6.1	10.7	-	1.36

[a]Values presented are the means for samples taken at all depths and locations within a mapping area.

TABLE 8. SUMMARY MEANS FOR CROSS CREEK WATERSHED SOIL CHEMICAL ANALYSIS[a]

Mapping unit	Depth range (cm)	Nutrient concentration (μg/g)									Cation exchange capacity	pH	Organic matter (%)
		Total				Exchangeable							
		N	P	K	S	Ca	Mg	K	S	P			
Cotaco, 0-3% slope	0-100	696.6	216.7	5956.7	193.9	115.6	34.9	55.1	81.2	4.5	7.4	4.9	1.42
Hartsells, 2-5% slope	0-100	485.6	156.4	4001.0	182.9	80.8	28.1	47.3	65.6	2.9	6.7	4.8	1.23
Hartsells, 5-12% slope	0-100	500.5	165.2	4526.3	217.3	103.2	41.8	49.6	67.1	3.7	6.9	4.8	1.29
Hartsells, 5-12% slope (eroded)	0-100	422.0	160.0	4000.0	190.0	98.0	20.0	37.0	46.4	3.6	5.9	4.9	1.00
Jefferson, 5-12% slope	0-100	441.0	166.0	5800.0	186.0	70.5	23.4	43.9	96.4	3.1	8.9	4.7	1.12
Linker, 5-12% slope	0-30	705.0	210.0	2700.0	165.0	113.5	55.0	33.0	24.5	4.5	5.0	4.9	1.60
Muskingum, 12-25% slope	0-100	605.2	212.1	6250.2	191.2	116.2	31.1	52.6	70.4	3.8	7.0	5.2	1.48
Mean, all soil types	0-100	550.6	183.2	4747.6	189.1	99.3	33.5	45.5	64.5	3.7	6.8	-	1.30

[a]Values presented are the means for samples taken at all depths and locations within a mapping unit.

VEGETATION

The vegetation on the surface of the Cumberland Plateau is very different from that of the steep slopes and gorges described by Caplenor (1965). Today, little of the original upland vegetation remains, and the poor secondary growth gives little indication of the former forest (Braun 1950). The poorly drained spots are swampy, and red maple (Acer rubrum) now prevails. These areas were formally occupied by pin oak (Quercus palustris) and sweet gum (Liquidambar styraciflua) with lesser amounts of sourwood (Oxydendrum arboreum), swamp white oak (Quercus bicolor), and shingle oak (Quercus imbricaria). Communities of post oak (Quercus stellata) and blackjack oak (Quercus marilandica) occupy very shallow, dry soil areas of the plateau where the sandstone is close to the surface (Braun 1950). Over the greater part of the area, one sees mixed oak, oak-hickory, and oak-pine communities. A semi-virgin plateau surface forest described by Braun (1950) was comprised primarily of white oak (Quercus alba), with some black oak (Quercus velutina), hickory (Carya sp.), sourwood, and an occasional basswood (Tilia americana). Virginia pine (Pinus virginiana) and shortleaf pine (Pinus echinata) are the most common pine species (Braun 1950). According to Braun (1950), the oak-dominated forest that covers much of the plateau represents a physiographic climax, maintained by topography and soil, rather than a true climatic climax. Fingers of mixed mesophytic forest creep up into the oak-dominated forests along stream courses and in drainage ways, where soil moisture relations are more mesic (Caplenor 1965). Yellow poplar (Liriodendron tulipifera), red maple, and sourwood are commonly found mixed with the more mesophytic oaks and hickories (Caplenor 1965).

Forest Cover Types

The initial step in characterizing the vegetation of each watershed was mapping the forest overstory on the basis of species composition. Mapping was done from the ground using the grid system as a reference. Each grid square, or portion thereof, was classified according to dominant species and delineated on the map. From the individual grid square classification data, a composite forest cover map was created for each watershed (Figures 11 and 12). The cover maps were used as a base for distributing 1-ha study plots over the watershed to obtain representative data on species composition within each forest cover type. On the Camp Branch watershed, two sample plots were located in areas classified as upland oak-mixed hardwood, two were located in the mixed mesophytic type, two were located in the transition areas between these two cover types, and one was located in the pine cover type. Likewise, on the Cross Creek site, two sample plots were located in the upland oak-mixed hardwood type, two were located in the mixed mesophytic, one was located in the transition between these two types, and one was located in the pine cover type. Appendix Tables D.1 through D.6 present these data.

Selected data from the individual hectare plots have been summarized for each cover type on both watersheds and are presented in Tables 9, 10, and 11. Based on the total sample data, the watershed vegetation at Camp Branch is clearly an oak forest, with seven species of oak accounting for about 60 percent of the cover and 40 percent of the number. This forest

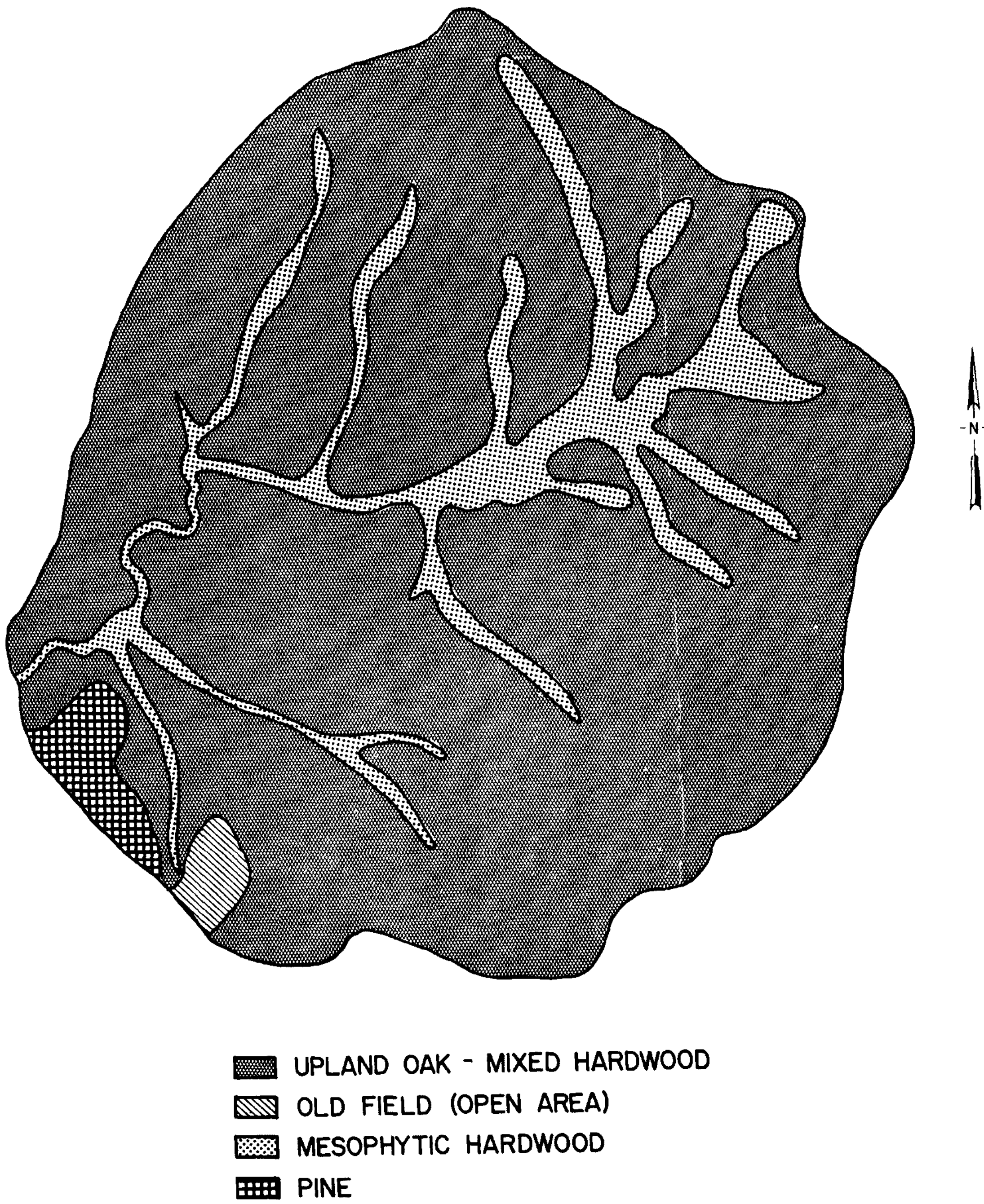

Figure 11. Forest cover map, Camp Branch watershed.

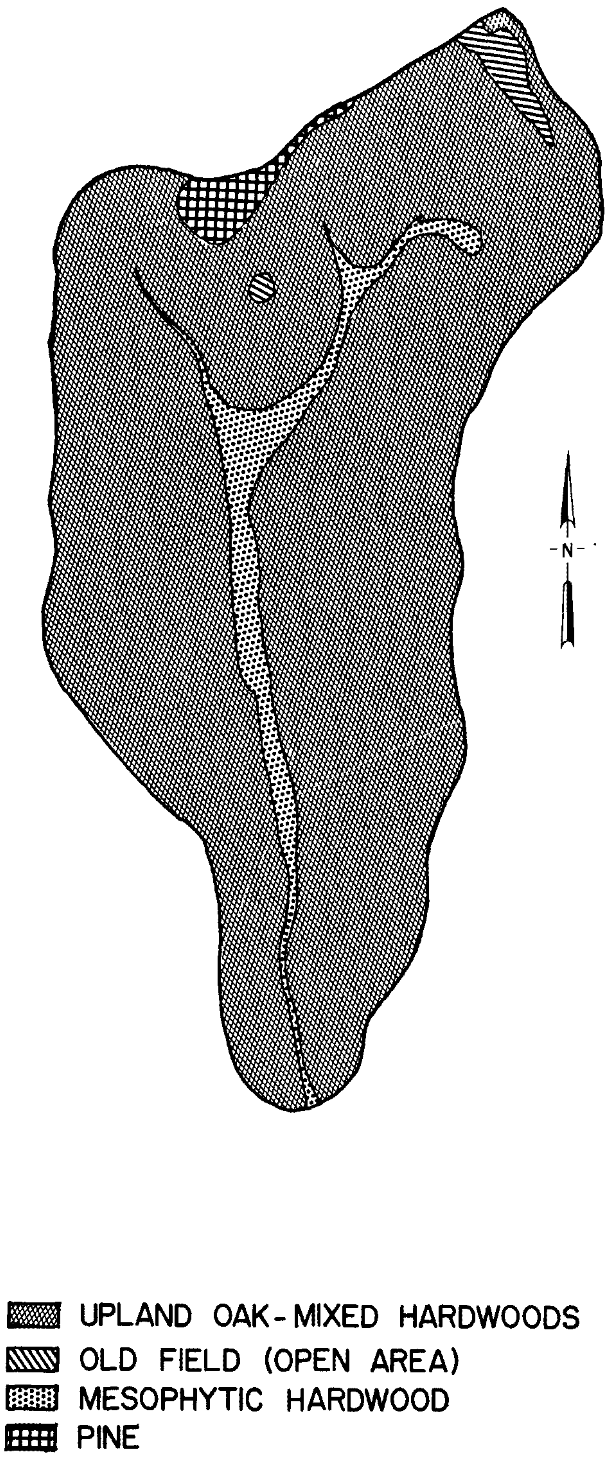

Figure 12. Forest cover map, Cross Creek watershed.

TABLE 9. SUMMARY COVER AND DENSITY VALUES FOR MAJOR[a] OVERSTORY SPECIES IN THE UPLAND OAK-MIXED HARDWOOD FOREST COVER TYPE ON THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

Species	Camp Branch			Cross Creek		
	Cover (cm/ha)	Percent cover	Density	Cover (cm/ha)	Percent cover	Density
Scarlet oak	27,769.6	12.6	0.005	43,784.4	22.2	0.016
Post oak	b			40,833.0	20.7	0.012
White oak	41,721.9	18.9	0.024	16,006.9	8.1	0.020
Hickory	35,317.0	16.0	0.014	12,602.8	6.4	0.004
Black oak	28,383.7	12.9	0.010	29,710.1	15.0	0.032
Chestnut oak	31,544.1	14.3	0.015	b		
Sourwood	13,981.8	6.4	0.031	15,763.4	8.0	0.021
Red maple	13,751.0	6.2	0.043	b		

[a]Contributing greater than 5% cover.
[b]Contributing less than 5% to total cover on a particular watershed.

TABLE 10. SUMMARY COVER AND DENSITY VALUES FOR MAJOR[a] OVERSTORY SPECIES IN THE MIXED MESOPHYTIC HARDWOOD FOREST COVER TYPE ON THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

Species	Camp Branch			Cross Creek		
	Cover (cm/ha)	Percent cover	Density	Cover (cm/ha)	Percent cover	Density
Red maple	47,889.3	44.7	0.038	11,665.8	5.3	0.025
White oak	23,937.9	22.4	0.020	79,335.0	36.2	0.031
Hickory	b			52,665.4	24.1	0.012
Black gum	17,837.3	16.7	0.027	15,163.8	6.9	0.015
Black oak	b			24,358.8	11.1	0.006
Dogwood	b			17,317.3	7.9	0.036
Yellow poplar	5,378.4	5.0	0.012	b		

[a]Contributing greater than 5% cover.
[b]Contributing less than 5% to total cover on a particular watershed.

TABLE 11. SUMMARY COVER AND DENSITY VALUES FOR MAJOR[a] OVERSTORY SPECIES IN THE PINE FOREST COVER TYPE ON THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

	Camp Branch			Cross Creek		
Species	Cover (cm/ha)	Percent cover	Density	Cover (cm/ha)	Percent cover	Density
Loblolly pine	b			1,078,080.0	88.7	0.100
Virginia pine	327,535.0	78.3	0.122	b		
Dogwood	38,870.0	9.3	0.077	b		
Sassafras	b			110,310.0	9.0	0.130
Red maple	23,733.0	5.7	0.068	b		

[a]Contributing greater than 5% cover.
[b]Contributing less than 5% to total cover on a particular watershed.

appears much as the oak-hickory forest typical of much of the southeastern United States except that hickory is scarce--accounting for only about 4 percent of the total cover and number. The Cross Creek watershed is more typical of the southeastern oak-hickory forest, with hickory and five species of oak accounting for about 78 percent of the total cover and 34 percent of the number.

Within individual cover types, oak species contribute 59 percent of the cover in the upland oak-mixed hardwood type on the Camp Branch watershed, whereas oak species contribute 66 percent of the cover on the Cross Creek site (Table 9). Oaks strongly dominate the cover values in the mixed mesophytic type also, contributing 22 and 47 percent, respectively, at the Camp Branch and Cross Creek sites (Table 10).

Red maple (45 percent) and tulip poplar (5.0 percent) are also important cover contributors in the mixed mesophytic type on Camp Branch, but contribute only 5.3 and 1.2 percent, respectively, at the Cross Creek site. These differences can probably be attributed to differences in topography between the two sites. On the Camp Branch site, the mesic areas are broad, relatively level areas at the head of the watershed, whereas the mesic sites on Cross Creek are narrow strips confined largely to the stream course and upper source areas. The fact that the mesic habitat is of much greater extent on Camp Branch provides a greater opportunity for development of a more distinct vegetation type.

Stands of both planted and naturally occurring pine are found on the watersheds (Table 11). On the Camp Branch site, a small area dominated by a dense growth of Virginia pine occurs. This site has all the typical features of old field succession. Core samples indicated that the field has been abandoned at least 40 years. The large number of small hardwoods under the dominant pine cover are early invaders of the climax forest. On the Cross Creek site, a small segment of a loblolly pine plantation occurs on the northern edge of the watershed (Figure 12). This plantation, established in 1957, has an average cover value for the dominant species of about 1 x 10^6 cm/ha, compared with about one third that amount in the Camp Branch pine type (Table 11). This difference can be attributed primarily to the high stocking rate in the loblolly plantation. Compared with the Camp Branch site, there is a definite lack of invading species in the Cross Creek plantation.

Biomass Estimates--Above Ground

Measurements of diameter at breast height (DBH) taken to determine cover values for each forest type were used to determine biomass values for each cover type through the use of whole tree harvest regression techniques (Attiwill and Ovington 1968, Baskerville 1972). The data presented in Table 12 summarize the above-ground biomass estimates by component in each forest type for both watersheds. Total biomass estimates for the upland oak-mixed hardwood forest cover types for both sites are reasonably comparable at 135,131 and 116,120 kg/ha. The data from the pine type exhibits a similar comparability at 155,120 and 165,869 kg/ha. The major difference between the two sites in terms of above-ground biomass is in the mesophytic hardwood forest type. As discussed previously, the mesophytic hardwood forest type is of limited extent on the Cross Creek site, but has attained a high degree of development on the Camp Branch site. Biomass values for this forest type on the Camp Branch watershed are slightly more than three times the Cross Creek estimates (Table 12). These differences may be partly explained by previously discussed differences in topography, which creates a trend toward selection for taller tree species. This trend limits the amount of light available to subdominant species such as red maple and black gum and thus limits their growth. Both species contribute heavily to the total value on the Camp Branch site.

TABLE 12. SUMMARY ABOVE-GROUND BIOMASS BY COMPONENT AND COVER TYPE FOR THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

	Biomass (kg/ha)					
	Upland oak - mixed hardwoods		Mesophytic hardwoods		Pine	
Component	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek
Heart	33,075.8	37,194.5	68,479.7	24,392.9	32,012.7	26,528.2
Sap	50,504.5	58,427.9	139,243.6	40,734.6	91,770.7	88,957.6
Bark	8,605.7	9,625.8	17,248.9	6,581.8	8,971.0	7,404.0
Branches	23,934.6	29,883.2	61,241.9	19,522.8	33,115.4	32,230.9
Total	116,120.6	135,131.4	286,214.1	91,232.1	165,869.8	155,120.7

Biomass Estimates--Below Ground

Estimates of root biomass were obtained by combining two techniques; core samples were combined with DBH regressions to estimate root crown weights. The below-ground biomass data are summarized by forest type for both watersheds in Table 13. Below-ground biomass values from the Cross Creek watershed were 16 to 48 percent higher than values from the same forest cover type on the Camp Branch watershed. Fibrous roots generally account for about 95 percent of the below-ground biomass at both sites.

TABLE 13. SUMMARY BELOW-GROUND BIOMASS BY COVER TYPE FOR THE CROSS CREEK AND CAMP BRANCH WATERSHEDS

	Biomass (kg/ha)					
	Upland oak - mixed hardwoods		Mesophytic hardwoods		Pine	
Component	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek
Fibrous roots	43,857.8	64,253.6	38,261.6	51,189.6	28,281.1	62,493.0
Root crown	2,840.1	2,574.9	7,200.2	2,094.5	6,201.4	3,016.1
Total	46,697.9	66,828.5	45,461.8	53,284.1	34,482.5	65,509.1

Nutrient Content Above and Below Ground

Mean nutrient concentration values for the various components of above- and below-ground biomass are presented in Table 14. Mean concentration values for the above-ground components are quite similar for both watersheds. Root nitrogen, phosphorus, and calcium values from the Cross Creek site tend to be slightly higher; potassium values are lower, and sulfur values are equivalent (Table 17).

Comparison of the nutrient weight values for above-ground biomass in each watershed presented in Tables 15 and 16 indicates differences within and between watersheds. Nitrogen loading for the upland oak-mixed hardwoods and pine cover types is quite similar for both watersheds, but nitrogen weights for the mesophytic hardwoods are almost three times as high on Camp Branch (Table 15) as on Cross Creek (Table 16). This large difference results from the much higher biomass values in this forest type at Camp Branch. Similar relationships exist for sulfur at both sites (Tables 15 and 16).

TABLE 14. MEAN NUTRIENT CONCENTRATIONS FOR ABOVE- AND BELOW-GROUND BIOMASS BY COMPONENT FOR THE CROSS CREEK AND CAMP BRANCH WATERSHEDS

	Biomass (μg/g)											
	N		S		P		K		Mg		Ca	
Component	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek
Heart	1,321.4	1,255.2	90.4	107.9	33.6	45.5	789.6	696.9	262.5	317.3	1,925.0	1,510.3
Sap	1,853.3	1,703.2	184.0	247.1	110.3	132.9	802.7	810.6	227.7	238.1	2,140.0	2,109.7
Bark	4,643.3	4,490.3	417.0	399.0	246.7	247.7	1,093.0	1,111.3	518.7	503.2	19,383.3	22,441.9
Branches	5,016.7	4,625.8	365.7	419.4	370.0	364.8	1,891.0	1,314.8	664.0	607.7	8,036.7	9,338.7
Roots	10,713.6	12,234.8	1,465.0	1,442.9	1,645.1	1,998.6	2,388.7	1,719.6	1,383.3	1,411.9	5,104.1	13,603.3

TABLE 15. SUMMARY ABOVE-GROUND NUTRIENT WEIGHTS BY COVER TYPE AND COMPONENT FOR THE CAMP BRANCH WATERSHED

Cover type	Component	Nutrient weight (kg/ha)					
		N	K	P	Ca	Mg	S
Upland oak - mixed hardwoods	Heart	44.9	25.7	0.9	54.8	5.4	3.5
	Sap	99.2	42.0	5.7	105.8	10.9	10.1
	Bark	40.8	8.1	1.8	174.5	3.9	4.3
	Branches	125.7	41.8	8.9	168.0	14.9	9.8
	Total	310.6	117.6	17.3	503.1	35.1	37.7
Mesophytic hardwoods	Heart	87.7	43.0	2.5	125.2	11.0	6.1
	Sap	232.9	75.6	17.6	310.3	26.9	22.7
	Bark	84.3	22.7	5.0	428.9	10.1	7.6
	Branches	315.8	154.8	24.9	411.0	36.0	22.5
	Total	720.7	296.1	50.0	1275.4	84.0	58.9
Pine	Heart	41.5	21.1	1.3	69.6	10.3	2.4
	Sap	143.8	49.8	10.0	189.7	21.8	14.5
	Bark	42.7	12.6	2.6	169.9	6.1	3.4
	Branches	153.9	67.2	12.4	259.3	23.3	10.4
	Total	381.9	150.7	26.3	688.5	61.5	30.7

TABLE 16. SUMMARY ABOVE-GROUND NUTRIENT WEIGHTS BY COVER TYPE AND COMPONENT FOR CROSS CREEK WATERSHED

Cover type	Component	Nutrient weight (kg/ha)					
		N	K	P	Ca	Mg	S
Upland oak - mixed hardwoods	Heart	47.4	23.9	1.0	49.4	9.5	3.7
	Sap	102.1	48.4	7.3	137.6	14.8	15.8
	Bark	42.2	10.7	2.2	259.1	4.5	3.5
	Branches	140.0	39.5	10.3	301.0	19.3	13.1
	Total	331.7	122.5	20.8	747.1	48.1	36.1
Mesophytic hardwoods	Heart	31.5	15.1	0.6	31.8	6.8	2.4
	Sap	70.4	33.0	4.7	100.1	10.7	11.2
	Bark	29.3	7.4	1.5	184.8	3.1	2.4
	Branches	90.1	25.9	6.4	197.5	12.4	8.5
	Total	221.3	81.4	13.2	514.2	33.0	24.5
Pine	Heart	33.4	20.4	1.8	45.3	11.7	3.2
	Sap	137.9	64.4	10.6	165.4	24.1	19.2
	Bark	34.3	8.3	2.0	129.0	4.2	3.3
	Branches	140.6	43.2	11.5	282.5	17.9	12.8
	Total	346.2	136.3	25.9	622.2	57.9	38.5

TABLE 17. NUTRIENT WEIGHTS IN BELOW-GROUND BIOMASS AS A FUNCTION OF COVER TYPE FOR THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

	Nutrient weight (kg/ha)					
	Upland oak - mixed hardwoods		Mesophytic hardwoods		Pine	
Nutrient	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek
N	217.5	355.8	227.6	333.5	160.1	332.0
K	43.9	54.0	34.4	52.6	42.4	57.3
P	28.9	51.7	35.2	47.3	28.3	52.6
Ca	108.8	227.7	100.3	200.2	71.5	292.7
Mg	23.5	42.8	29.1	37.4	21.1	44.6
S	27.9	42.1	30.3	36.6	21.9	39.0

Nutrient weights in below-ground biomass (Table 17) generally reflect the higher concentration values (Table 14) observed at the Cross Creek site and the higher below-ground biomass values. Cross Creek sulfur weight values were 20 to 60 percent higher than the values observed for Camp Branch. Other elements exhibited similar trends (Table 17).

SECTION 5

MATERIALS AND METHODS

SCOPE

The watershed approach to the evaluation of biogeochemical processes represents an integration of several long- and short-term studies. Quantification of these processes requires breaking the system down into a number of source and sink compartments, transfers, and transfer processes. Factors that influence a particular parameter and the variables to be quantified must also be considered. Table 18 provides an outline for the overall research program, including transfer processes, sources, influencing factors, and critical measurement variables. Many variables, owing either to seasonal or annual variability, require several months to years of observation before representative values can be derived, whereas others can be quantified in a single growing season.

The first step in any watershed study is to establish the boundaries of the watershed and then describe quantitatively the vegetation, soils, hydrology, and nutrient status of the system (Table 19). Consequently, the first period of study at each watershed has been devoted to baseline quantification and the establishment of long-term sampling programs consistent with the needs of the overall program, as outlined in Figure 1 and Table 18.

When sufficient data have been collected on each compartment and transfer, the 19- and 95-km sites will be compared. The comparisons are expected to ultimately provide a good understanding of system response to anthropogenic sulfur and nitrogen input. Information collected in the baseline program will be used to develop detailed workplans for subsequent study years and to identify the need for special studies and the addition or deletion of certain parameters.

FACILITIES AND INSTRUMENTATION

The facilities and equipment discussed here are designed to provide comprehensive data, either directly or indirectly, on (1) the flow pattern and quantity of nutrients and water that enter and leave the study area and (2) the internal cycles of these elements while in the study area.

Hydrological Monitoring Equipment

The principal component in monitoring hydrological parameters is the weir and associated stage height recording system. The Camp Branch weir, illustrated in Figure 13, is capable of measuring maximum flows of 10.30 m^3/s (355.00 cfs). The V-notch section alone will measure flows up to 0.035 m^3/s (1.24 cfs). The first rectangular section in conjunction with the V-notch will measure flows up to 2.34 m^3/s (80.70 cfs). The Cross Creek weir (Figure 13) is basically the same design as the Camp Branch weir, except that the second rectangular section measures 22.9 cm in height rather than 53.3 cm. Flow values for the V-notch section and the V-notch section plus the first rectangular section would be the same for both weirs.

TABLE 18. TRANSFERS, TRANSFER PROCESSES, SOURCES, INFLUENCING FACTORS, AND CRITICAL MEASUREMENT VARIABLES FOR A MINERAL NUTRIENT CYCLE IN A DECIDUOUS FOREST WATERSHED

Transfer process	Transfer number (Figure 1)	Source	Influencing factors	Critical measurement variables
Atmospheric deposition	1 & 2	Elements scavenged from the atmosphere by wet or dry deposition, direct absorption, or impaction	Wind patterns; frequency, intensity and duration of precipitation; vegetation type and degree of canopy development	Aerosol and gaseous concentrations above, within, and below canopy, wet and dry deposition of particulate[a]
Volatilization	3	Litter and soil	Season of year, stage of plant growth, soil moisture content, temperature, soil reaction (pH), soil aeration, soil nutrient status, microbial population levels	Form, amount, and rate of loss; mechanism of loss; seasonal patterns (pertains primarily to nitrogen and sulfur)
Litterfall	4	Stems, branches, leaves	Season of year, stages of plant growth, plant species, climate, soil moisture content	Weight of litter; species and amount of nutrients; seasonal patterns
Throughfall leaching	4	Branches and leaves	Season of the year, stage of plant growth, plant species, precipitation characteristics, temperature, canopy structure, understory characteristics	Volume of leachate; species and amount of nutrients in leachate;[b] seasonal pattern

Table 18 (continued)

Transfer process	Transfer number (Figure 1)	Source	Influencing factors	Critical measurement variables
Stemflow leaching	4	Stems and branches	Season of year, stage of plant growth, plant species, precipitation characteristics, temperature, canopy structure, understory characteristics	Volume of stemflow; species and amount of nutrients in stemflow; seasonal patterns
Fixation	2, 4, 5	Atmosphere, litterfall, throughfall, stemflow; dead and sloughed root material	Season of year, stage of plant growth, plant species, soil moisture content, temperature, soil reaction (pH), soil aeration, soil nutrient status, microbial population levels	Kind and amount of fixing microorganisms; rate of fixation; form of fixation; form and amount of fixed nutrients; seasonal patterns
Root uptake	7	Soil solution	Season of year, stage of plant growth, plant species, climate, soil moisture content, soil reaction (pH), soil aeration, soil chemical properties, soil microflora and fauna populations, concentration and form of nutrients in soil solution, root configuration and distribution, mechanism of uptake	Mass or area of absorbing roots; total or rate of uptake; kind and form of nutrients absorbed; seasonal patterns

Table 18 (continued)

Transfer process	Transfer number (Figure 1)	Source	Influencing factors	Critical measurement variables
Root sloughing and root depth	5 & 6	Roots	Season of year, stage of plant growth, plant species, soil moisture content, temperature, soil aeration, soil microflora and fauna populations, root configuration and distribution, age of individual trees	Weight of sloughed or dead roots; kind, form and amount of nutrients in sloughed or dead roots; seasonal patterns
Translocation	8 & 9	Roots, stems, branches, leaves	Season of year, stage of plant growth, plant species, climate, soil moisture content, temperature, support tissue and structure	Kind, form, and amount of nutrients transferred; origin and end points for nutrient transfers; seasonal patterns
Decomposition	10, 11, 12, 13, 14 & 15	Litter, organic matter in the mineral soil	Season of year, soil and litter moisture content, temperature, soil reaction (pH), soil aeration, soil chemical properties, soil microflora and microfauna populations	Nutrient flux in litter, soil, and soil solution; microflora and microfauna populations
Surface water gain and loss	16 & 17	Input from upslope or loss to downslope positions	Season of year, precipitation characteristics, soil moisture content, temperature, topographic position, slope, soil physical properties, nutrient characteristics of source, canopy structure	Volume of inflowing and outflowing water and nutrients; loss and gain patterns

Table 18 (continued)

Transfer process	Transfer number (Figure 1)	Source	Influencing factors	Critical measurement variables
Free water-soil solution equilibrium	18 & 19	Free water, soil solution	Season of year, stage of plant growth, soil moisture content, soil physical properties, nutrient status of free and soil water, depth of free water, root distribution, precipitation characteristics	Volume of water moving up and down, kind and amount of nutrients in free water and soil solution; seasonal patterns
Lateral ground water gain and loss	20 & 21	Upslope ground water (gain), free water (loss)	Season of year, stage of plant growth, soil moisture content, soil physical properties, topographic position, slope, presence of free water, precipitation characteristics, nutrient status of source	Volume of inflowing and outflowing water; kind, form, and amount of incoming and outgoing nutrients; seasonal patterns
Geologic weathering	22	Geologic parent material	Climate, nature of geologic material, plant species, topographic position, depth to geologic material, rate of weathering microbial populations, root distribution	Kind, form, and amounts of nutrients released; movement of nutrients after release

Table 18 (continued)

Transfer process	Transfer number (Figure 1)	Source	Influencing factors	Critical measurement variables
Deep seepage loss	23	Free water	Bedrock characteristics, topographic position, slope, soil physical properties, precipitation characteristics, presence of free water, nutrient status of free water	Volume of water lost; kind, form, and amount of nutrients lost; seasonal patterns

[a]Must be compared with throughfall and stemflow nutrient content.
[b]Must be compared with wetfall-dryfall nutrient content.

TABLE 19. PARAMETERS TO BE EVALUATED, METHODS OF MEASUREMENT, AND FREQUENCY OF DETERMINATION FOR EACH EXPERIMENTAL WATERSHED

Parameters	Method of measurement	Frequency of determination
Gaseous sulfur	A TECO pulse fluorescence monitor is being used to determine the contribution of SO_2 sulfur to the study area. It is anticipated that a major portion of the incoming gaseous sulfur will be in the SO_2 form. Air samples will be drawn from above, within, and below the forest canopy by using a manifold-sequencer system.	Each position is sampled at a 60-s interval until sufficient data are accumulated for determination of an optimum sampling interval.
Gaseous nitrogen	Instrumentation to measure gaseous nitrogen inputs is still being evaluated. An instrument compatible with the three-level intake and manifold system has not been found; consequently, other methods will be evaluated and a satisfactory system developed in the near future.	
Suspended particulate	A millipore filter system has been developed whereby air samples can be drawn from above, within, and below the canopy. It is anticipated that particulate input may account for a large portion of the non-SO_2 sulfur entering the system. This sampling system will allow determination of total input as well as the amount stripped from the air due to deposition or impaction on the vegetation.	Filter pads are being changed weekly until an optimum sampling interval is determined.

Table 19 (continued)

Parameters	Method of measurement	Frequency of determination
Wet/dry fall	Two AEC-type wet/dry fall monitors are located on the watershed; one above the canopy, the other below. This device allows particulate deposition rates to be determined as well as partitioning atmospheric input into wet and dry components for chemical analysis. A volume and pH determination will be made on all wetfall samples before chemical analysis.	Samples are being collected biweekly initially, but may be composited and analyzed monthly after a period of evaluation.
Soil nutrient status	A soil survey was conducted to delineate soil boundaries, and a sampling program keyed to the reference grid system was used to collect soil samples for chemical and physical analysis. These data will be used to develop a detailed description of the physical and chemical status of the watershed soils.	The soil survey and intensive sampling program will be conducted only once at the start of the program.
Soil solution	Porous cup lysimeters installed at four depths (25, 50, 75, and 100 cm) at intervals along slope gradient transects.	Samples will be collected biweekly and composited into a monthly sample.
Stage height	An automatic stage height recorder is used to measure the level of water behind the weir so that nutrient concentrations can be converted to nutrient loss values.	Continuous record

Table 19 (continued)

Parameter	Method of measurement	Frequency of determination
Stream nutrient flux	An automatic discrete sampler is used to collect samples of water leaving the system by streamflow.	Water samples will be collected in proportion to the flow passing the weir.
Solar	A net radiometer placed above the canopy is used to determine the input of solar energy into the system.	15-s intervals
Wind	Wind speed and direction are monitored above the canopy. Data of this sort are needed to construct realistic deposition and impaction models and evapotranspiration models.	15-s intervals
Branch and bole	Fifty-six trees were harvested for biomass and chemical determinations. The sizes and species of the trees were determined by the results of the vegetation survey. Biomass estimates were made using standard regression techniques. Trees harvested for biomass determination were also divided into several components, and each component was analyzed for elemental content.	Biomass and elemental content of branch and bole components will require quantifications only once.
Leaves	A series of litter traps located at random within a cover type are being used to quantify the annual input of leaf litter to the forest floor as well as to provide estimates of standing leaf biomass. Weight determinations are made on all samples and	Litter traps are run monthly, except during the annual leaf fall period when biweekly collections will be made. Living leaves will be collected biweekly during the growing season.

Table 19 (continued)

Parameters	Method of measurement	Frequency of determination
	subsamples are taken for chemical analysis. To evaluate nutrient flux both on and in living leaves, samples will be collected biweekly and processed for chemical analysis.	
Roots	Below-ground biomass was determined through the use of periodic core samples for lateral roots and regression analysis for stump and major lateral roots. Samples collected for biomass determinations will also be used for chemical determinations.	Stumps and major laterals need to be extracted only once. Core samples will be collected monthly.
Litter decomposition	Nylon net bags containing known amounts of fresh mixed litter will be followed through time to determine weight and nutrient flux.	Bags will be collected monthly for a 36-month period.
Throughfall	Incoming precipitation which passes directly through the canopy can change in chemical composition as a consequence of contact with the canopy. Throughfall collectors have been distributed throughout the watershed with placement being random within a vegetation type. After collection, the samples are returned to the lab for volume and pH determinations and then prepared for chemical analysis.	Sample bottle exchanges will be keyed to precipitation with biweekly collections generally being used.

Table 19 (continued)

Parameters	Method of measurement	Frequency of determination
Stemflow	A portion of incoming precipitation, rather than passing directly through the canopy, is funneled to the soil surface by the branch and bole system of the tree. The chemical composition of precipitation can be altered significantly due to contact with the tree bark. Using data derived from the vegetation survey, trees of various size classes have been fitted with stemflow collectors. Volume of sample collected will be determined in the field, and a subsample taken for chemical analysis.	Sample collection will be keyed to precipitation just as throughfall.
Total precipitation	A standard recording rain gage will be located in an open area to measure total precipitation input to the watershed.	Precipitation input will be recorded continuously and reported hourly.
Vegetation survey	An intensive vegetation survey was conducted so that the boundaries of various vegetation types can be established and descriptive and quantitative data on stand characteristics collected.	The intensive vegetation survey will be conducted only once at the start of the program.

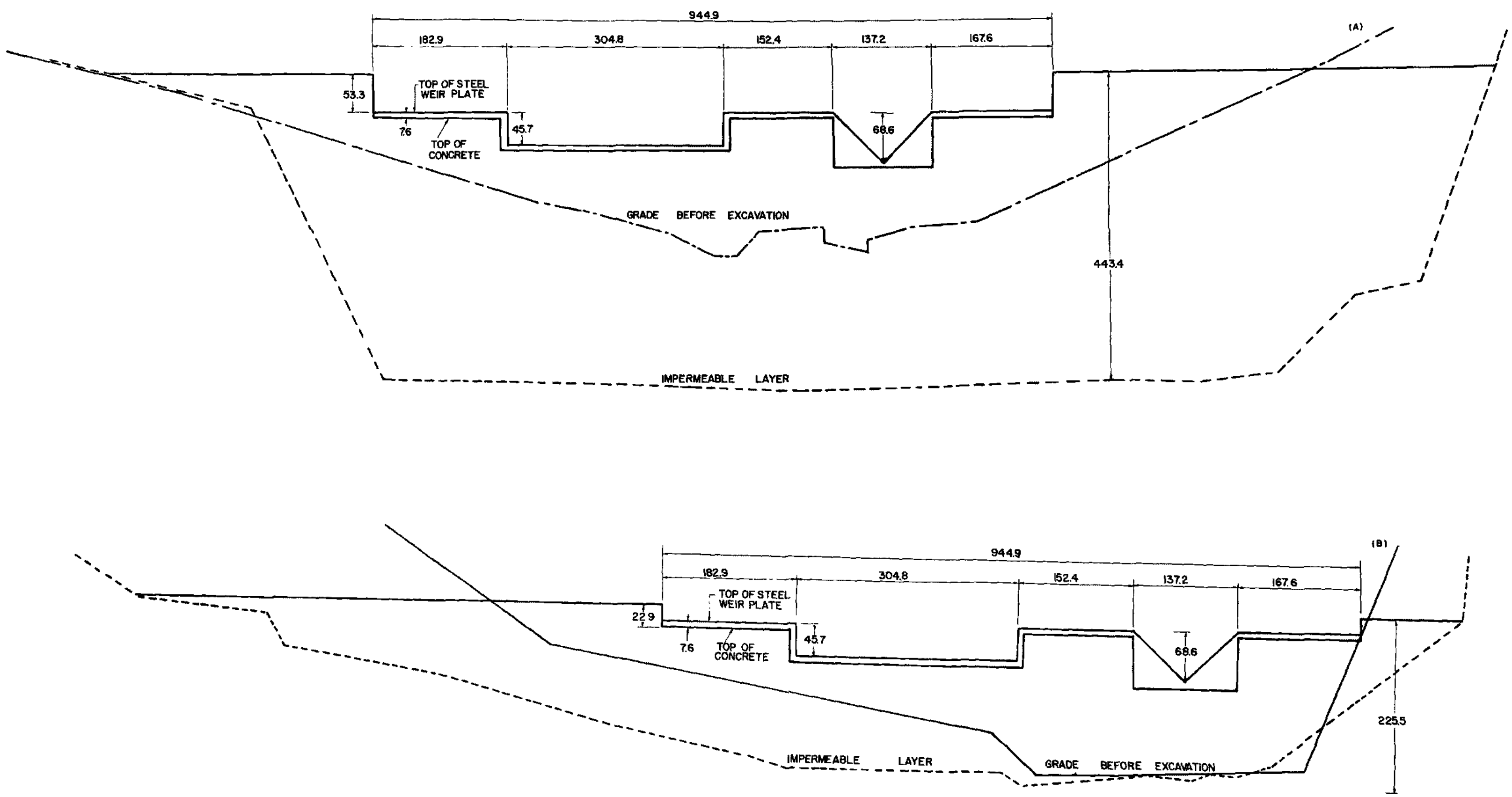

Figure 13. Schematic diagram of the Camp Branch (A) and Cross Creek (B) weirs. (All measurements are in centimeters.)

However, the maximum flow value of 4.81 m^3/s (170.00 cfs) is somewhat less for the Cross Creek weir due to the reduced height of the second rectangular section. Both weirs are constructed of steel-reinforced concrete and are protected from undercutting by a concrete apron which extends downstream from the weir. Bypass drains have been located in the base of the dam so that the weir pool may be drained if necessary.

Stage height is detected through the use of a float-mounted potentiometer. One-liter samples of water are collected for chemical analysis on a flow-proportional basis with a Manning S-6003 discrete sampler. Two of these units have been combined to provide the capability of collecting 48 individual samples before a bottle change is necessary. Samples are stored in a refrigerated unit in the base of the sampler. Samples may be collected on either a flow-proportional basis or on a unit-time basis.

A standard measurement of precipitation input to each watershed is being obtained through the use of a Belfort model 5915-12 spring weighing and potentiometric output type rain gage. The rain gage is mounted on a concrete pad located in a cleared area near the watershed crest at both locations. Data from the rain gage are recorded continuously by the data logging system and reported at 60-min intervals.

Environmental Monitoring Equipment

The information presented in Table 20 outlines the environmental parameters being evaluated, the place at which the measurement is being taken, and the type of instrument used to make the measurement. A 25-m, free-standing tower has been erected at each location to facilitate the measurement of certain parameters both above and below the forest canopy so that gradients or profiles can be developed. Sampling points for ambient air temperature, air turbulence, dew point, suspended particulates, solar radiation, sulfur dioxide, wet-dry precipitation, wind direction, and wind speed are located above the canopy at the 25-m level. Dew point, suspended particulates, and sulfur dioxide are also measured just below the canopy (7 m) and at ground level (1 m); additional measurements of ambient air temperature and wet-dry precipitation are made at ground level (1 m). A three-position intake system supplies a flow of ambient air to the sulfur dioxide monitor and dew point hygrometer through a manifold sequencer system (Figure 14). The frequency of determination for each environmental parameter and the appropriate scaling factor are presented in Table 21.

Data Collection, Processing, and Control

The basic component in the hydrologic and environmental monitoring system is a minicomputer-controlled data logger and control system, which automatically measures or controls the measurement of the parameters discussed previously. The system, as outlined in Table 22 and illustrated in Figure 14, consists of a minicomputer, a high-speed paper tape reader teletype printer and paper punch, a battery real-time clock, a scanner, and a digital multimeter. Sensor outputs are measured at selected rates (Table 21), and calculations are performed for a data output each hour. Outputs to the teletype printer and paper punch will be hourly averages

TABLE 20. ENVIRONMENTAL AND HYDROLOGIC PARAMETERS TO BE MEASURED, LOCATION OF SENSOR, AND DESCRIPTION OF INSTRUMENTATION USED TO MEASURE EACH PARAMETER LISTED

Parameter	Location	Description
Ambient air temperature	Tower (25 and 1 m)	Aerodet (ARI Industries, Inc.), Model R-22.3-E50 RTD (platinum wire Resistance Temperature Detector) mounted in motor-fan aspirated solar radiation shield. Climet Instruments, Inc., Model 016-1. Data recording range -9.9 to 99.9°F; RTD accuracy ±0.06°F; aspirated shield maximum radiation error, -0 to +0.2°F.
Atmospheric turbulence	Tower (25 m)	Same sensor as for wind direction. Sigma y, horizontal turbulence, via statistical formula in computer, data recording range 0-90° to a resolution of 1°.
Dew point	Tower (25, 7, and 1 m)	EG&G, Inc., Model 440 dew point hygrometer, computer-controlled level selection unit; data logger system operating range -30°F to +100°F; calibration range from -110°F to +140°F; hygrometer accuracy within ±0.7°F.
Liquid level transmitter-flow totalizer	Weir	Float mounted potentiometer.
Particulate sampler	Tower (25, 7, and 1 m)	One-micron Teflon filter 47-mm diameter, pump, rotameter; flow rate 500 cc/min.
Precipitation (standard measurement)	Open (1 m)	Belfont Instrument Co., Model 5915-12; spring weighing and potentiometer output type; calibrated range, 0 to 9.9", data recording range 0.00 to 9.99"; accuracy ±0.5% (±0.06"); sensitivity, 0.01".

Table 20 (continued)

Parameter	Location	Description
Solar radiation	Tower (25 m)	Epply Laboratories, 180° Pyranometer, Model 8-48 calibrated range 0 to 2 g-cal/cm^{2}min^1; data recording range, 0.00 to 3.00 g-cal; linearity ±1% from 0 to 2 g-cal; response time 4 s; cosine response ±2% from 10 to 90°; sensitivity, near 7.5 mv per g-cal/cm^{2}min^1; typical output 0-14 mv.
Sulfur dioxide	Tower (25, 7, and 1 m)	Thermo Electron Corp. Model 43 pulsed fluorescent SO_2 monitor, computer-controlled level selection unit; data logger system operating range 0-0.5, 0-1, 0-5 ppm (0-10V) precision 0.005 ppm; zero drift (12 and 24 h) ±0.005 ppm; span drift (24 h) ±1%; lag time 10 s; rise time 3 min; fall time 3 min.
Water sampler	Weir (head of minimum pool)	2 each Manning Model 6003, each with 24 1-L sample bottles. bottles. Sampling rate controlled by computer.
Wet-dry precipitation	Tower (25 and 1 m)	AEC design wet-dry precipitation collector; stainless steel sensor, top and support arms; 1/4" anodized aluminum base; linearized polyethylene buckets.
Wind direction	Tower (25 m)	Climet Instruments, Inc., Model 012-10; horizontal, calibrated range, electrical 0--537°, mechanical 0--360° continuous, data recording range 0-540° (0-4.8v), linearity ±0.5%, accuracy ±3°.
Wind speed	Tower (25 m)	Climet Instruments, Inc., Model 011-1; starting threshold, 0.6 mph; operating range, 0-110 mph; calibrated range 0.6-90 mph; data recording range 0-99.9 mph; accuracy within ±1 percent or 0-15 mph, whichever is greater from 0.6 to 90 mph.

TABLE 21. PERIOD BETWEEN SCANS AND SCALING CALCULATIONS FOR ENVIRONMENTAL AND HYDROLOGIC PARAMETERS LISTED

Parameter	Period between scans	Scaling calculations (x = value of measurement)
Ambient air temperature	60 s	$\frac{x \text{ ohms} - 46.46 \text{ ohms}}{\text{ohms}/^{\circ}\text{F}}$ $\frac{x - 46.46^{\circ}\text{F}}{11}$
Dew point	60 s	$\frac{xV - 56.80}{40V/^{\circ}\text{F}} + 32^{\circ}\text{F}_1 = \text{F}^{\circ a}$, if $\text{F}_1^{\circ} < 32^{\circ}\text{F}$, then: $\text{F}_2^{\circ} = \text{F}_1^{\circ} + 0.0005661(32^{\circ}\text{F} - \text{F}_1^{\circ})^2 - 0.1326(32^{\circ}\text{F} - \text{F}_1^{\circ})$
Stage height	5 min	$\frac{x \text{ ohms} - 1\text{k ohms}}{2\text{k ohms/ft}} = \text{ft}$
Particulate sampler	Continuous	
Precipitation	60 min	$\frac{x \text{ ohms}}{\text{ohms/in.}} = \frac{x}{1750} \text{ in.}$
Solar radiation	15 s	$\frac{x\text{mv}}{\text{mv/gm-cal/cm}^2\text{min}} = \frac{x}{7.14} \text{ gm-cal/cm}^2\text{min}$
Sulfur dioxide	60 s	10 V full scale (0.5, 1, or 5 ppm) $\frac{(x-z)}{(10)}$ (FS) = ppm z - zero offset
Water sampler	Variable	Sampling frequency proportional to streamflow
Wind direction	5 s	$\frac{x\text{mv}}{\text{mv/degree}} = \frac{x}{8.9}$ degrees
Wind speed	15 s	$\frac{x\text{mv}}{\text{mv/mph}} = \frac{x}{48}$ mph

[a] F_1° = Dew point unless value is less than 32°F; then it is the frost point.
F_2° = Dew point temperature calculated from the frost point.

TABLE 22. COMPONENT PARTS FOR DATA LOGGER--CONTROL SYSTEM

Component	Description
Battery real-time clock	(TVA) Battery run clock to reset time in case of power failure
Computer	Data General Corp., Nova 1200 jumbo 32K, auto-load and restart, real-time clock
Digital multimeter	Hewlett-Packard Co., Model 3450B, with remote control and digital output options
High-speed reader	Data General Corp., Model 6013, 400 cps
Printer-punch	Teletype Corp., Model ASR-33
Scanner	(TVA) 24-channel reed relay scanner with dew point control and 6-bit relay tree, computer interface and BRTC control

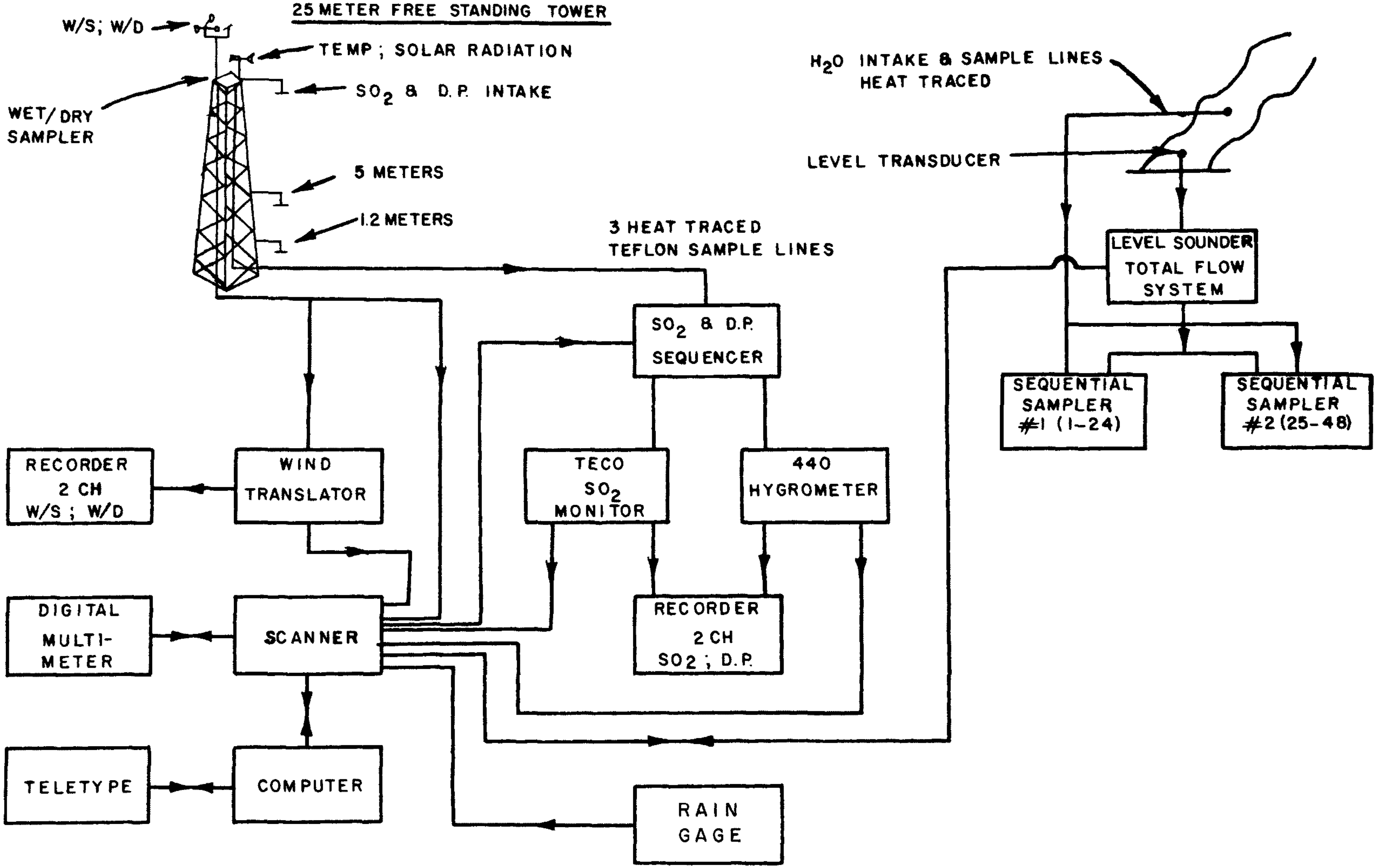

Figure 14. Block diagram of instrument package developed for Camp Branch and Cross Creek watersheds.

for temperature, dew point, wind speed, and wind direction. Sulfur dioxide values will be the hourly average plus the peak for that hour. Stream stage will be read on a 5-min basis, and stage height and flow calculations will be outputted hourly. There is also a signal from the proportional sampler to the computer to signify when a sample is taken, and this time will be printed out by the computer. A similar signal is sent to the computer each time the wet-dry precipitation collector is activated.

Passive Sampling Equipment

In addition to the more sophisticated equipment used to monitor various hydrologic and environmental parameters, other devices are located on each study area to collect other types of needed information. Leaf and litter fall is being collected in litter traps, which are wooden boxes, 1 x 1 m square and 25 cm tall. The boxes are open from the top and have fiberglass screen bottoms. Each box is supported by four legs so that it is held in a level position about 30 cm above the forest floor. Throughfall collectors were fabricated from brown 2-L polypropylene bottles connected to a polypropylene funnel 16 cm in diameter. Porous cup lysimeters inserted in the soil to depths of 25, 50, 75, and 100 cm are used to collect samples of the soil solution.

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APPENDIX A

ESTABLISHED SERIES DESCRIPTIONS FOR CAMP BRANCH AND CROSS CREEK SOILS

COTACO SERIES

The Cotaco series consists of deep, moderately well drained, moderately permeable soils formed in loamy sediments of acid sandstone, siltstone, and shale origin. These soils are on footslopes, colluvial fans, and low stream terraces. Slope gradients range from 0 to 8 percent.

Taxonomic Class: Fine-loamy, mixed, mesic Aquic Hapludults.

Typifying Pedon: Cotaco loam--cultivated. (Colors are moist soil unless otherwise stated.)

Ap -- 0 to 20 cm, dark grayish brown (10YR 4/2) loam; weak fine granular structure; very friable; many roots; 5 percent gravel; medium acid; clear smooth boundary. (18 to 30 cm thick)

B1 -- 20 to 43 cm, yellowish brown (10YR 5/4) loam; weak fine subangular blocky structure; friable; common roots; 5 percent gravel; strongly acid; gradual smooth boundary. (10 to 36 cm thick)

B2t -- 43 to 76 cm, yellowish brown (10YR 5/4) sandy clay loam; common medium distinct mottles of strong brown (7.5YR 5/6) and light brownish gray (10YR 6/2); moderate medium subangular blocky structure; friable; few clay films; few roots; few small black concretions; 5 percent gravel; strongly acid; gradual smooth boundary. (25 to 50 cm thick)

B3 -- 76 to 91 cm, mottled light yellowish brown (10YR 6/4), strong brown (7.5YR 5/6), and light gray (10YR 7/2) sandy clay loam; weak medium subangular blocky structure; firm; few clay films; common small black concretions; 10 percent gravel; strongly acid; gradual wavy boundary. (10 to 40 cm thick)

C -- 91 to 152 cm, light brownish gray (2.5Y 6/2) gravelly sandy clay loam with common medium distinct mottles of strong brown (7.5YR 5/6); massive; friable; few black concretions; 25 percent gravel; strongly acid. (30 to 185 or more cm thick)

Type Location: Perry County, Kentucky; 1.8 km west of junction of State Highways 15 to 80 at Darfort, 185 m northwest of State Highway 80.

Range in Characteristics: Depth to bedrock is more than 152 cm. Solum thickness ranges from 71 to 127 cm. Fragments of sandstone or siltstone range from 2 to 35 percent in any horizon. Unless limed, reaction ranges from strongly acid through extremely acid.

The Ap horizon is grayish brown (10YR 5/2), dark grayish brown (10YR 4/2), and brown (10YR 5/3) or (10YR 4/3). Texture is loam, silt loam, and fine sandy loam.

The B1 horizon ranges from brown (10YR 5/3) through dark yellowish brown (10YR 4/4). The B2t horizon ranges from reddish brown (5YR 4/3) through olive yellow (2.5Y 6/6) and has common or many brownish and grayish mottles. Some pedons lack a dominant color and are evenly mottled with the colors described. The matrix color of the B3 and C horizon ranges from dominantly light gray (2.5Y 7/1) through dominantly strong brown (7.5YR 5/6) with mottles in shades of gray, brown, or red. Textures of the B2, B3, and C horizons are heavy loam, sandy clay loam, and light clay loam, and consistence ranges from friable to firm. Some pedons have B3 horizons with weak platy structure.

Competing Series and Their Differentiae: These are the Adelphia, Blairton, Cana, Delanco, Holmdel, and Tuscarawas series of the same family. Competing series in other families are Altavista and Whitwell. Adelphia and Holmdel soils contain glauconite. Blairton soils contain more silt, less sand, and 30 to 70 percent shale fragments in the lower solum. Cana and Tuscarawas soils contain more silt and less sand and, in addition, Cana soils have an upper argillic horizon developed in loess. Delanco soils contain medium amounts of mica in the solum. Altavista and Whitwell soils are similar, but have average temperatures warmer than 59°C, and, in addition, Whitwell soils are siliceous.

Setting: Footslopes, colluvial fans and low stream terraces with slopes of 0 to 8 percent. The regolith is alluvium of acid sandstone, siltstone, and shale origin. Near the type location, the average annual precipitation is about 107 cm, and average annual air temperature is 12°C.

Principal Associated Soils: These are the Allegheny and Monongahela series on stream terraces, the Pope and Stendal series of the flood plains, and the Clymer, Dekalb, Jefferson, and Shelocta series of the surrounding uplands. Allegheny, Clymer, Jefferson, and Shelocta soils lack gray mottles in the upper 60 cm of the argillic horizon. Monongahela soils have fragipans. Dekalb, Pope, and Stendal soils lack an argillic horizon.

Drainage and Permeability: Moderately well drained; medium runoff; moderate permeability. Seep spots are common.

Distribution and Extent: The Cumberland-Allegheny Plateau in Kentucky, Tennessee, Virginia, West Virginia, and possibly Pennsylvania. Extent is moderate.

GILPIN SERIES

The Gilpin series is a member of the fine-loamy, mixed mesic family of Typic Hapludults. These soils have a dark grayish brown shaly silt loam Ap horizon, yellowish brown shaly silt loam B horizons of clay accumulation, and a yellowish brown very shaly loam C horizon underlain by acid shale and siltstone at depths of 50 to 100 cm.

Taxonomic Class: Fine-loamy, mixed Typic Hapludults

Typifying Pedon: Gilpin shaly silt loam--cultivated. (Colors are for moist soil.)

Ap -- 20 cm, dark grayish brown (10YR 4/2) shaly silt loam; weak fine granular structure; friable; slightly sticky, slightly plastic; 20 percent coarse fragments; medium acid; abrupt smooth boundary. (15 to 25 cm thick)

B21t -- 20 to 33 cm, yellowish brown (10YR 5/4) shaly silt loam; weak fine and medium subangular blocky structure; friable; slightly sticky, slightly plastic; thin discontinuous clay films on ped faces and in pores; 25 percent coarse fragments; medium acid; gradual wavy boundary. (10 to 30 cm thick)

B22t -- 33 to 60 cm, yellowish brown (10YR 5/6) shaly heavy silt loam; moderate medium subangular blocky structure; friable; slightly sticky, plastic; thin discontinuous clay films on ped faces and in pores; 30 percent coarse fragments; very strongly acid; clear irregular boundary. (15 to 36 cm thick)

C -- 60 to 76 cm, brown (10YR 5/3) very shaly loam; massive; friable; slightly sticky, slightly plastic; few clay coatings and common black iron and manganese coatings on fragments; 70 percent coarse fragments; very strongly acid; clear wavy boundary. (0 to 25 cm thick)

R -- 76 to 90+ cm, light olive brown (2.5Y 5/4) fractured shale and siltstone with silt and clay coatings in fissures; strongly acid.

Type Location: Indiana County, Pennsylvania; North Mahoning Township, about 1.4 km southeast of Marchand, on hilltop 150 m east of Township Road 660.

Range in Characteristics: Solum thickness ranges from 50 to 91 cm. Rippable bedrock is at depths of 50 to 102 cm. Thin, flat coarse fragments of shale, siltstone and sandstone comprise 5 to 40 percent of individual horizons of the solum and 30 to 90 percent of the C horizon. Reaction ranges from strongly to extremely acid throughout, unless limed. The clay mineralogy is mixed, with illite dominant and kaolinite and vermiculite in lesser quantities. Undisturbed pedons have thin dark A1 horizons underlain by a 5- to 13-cm-thick grayish brown A2 horizon with granular structure. The Ap horizon has a hue of 10YR with values of 3 through 5 and chromas of 2 through 4. Dry values are 6 or 7. The A horizon is silt loam or loam, including shaly or channery analogues, with fine and medium granular structure that is weak or moderate. The Bt horizons commonly are yellowish brown (10YR 5/4 through 5/8) or strong brown (7.5YR 5/6 through 5/8), but range to light olive brown (2.5Y 5/4). Colors tend to become more reddish with depth. Textures are heavy silt loam, heavy loam, or light silty clay loam on their shaly or channery analogues, with a weighted average silt content ranging from 40 to 60 percent. Structure is weak or moderate, fine or medium, subangular or angular blocky. Consistence is slightly sticky and slightly plastic or plastic. Clay films on ped faces, on coarse fragments, and in pores are thin, discontinuous or continuous. A B3 horizon is present in many pedons and in some places lies directly on bedrock. C horizons have colors ranging from dark brown to yellowish brown and olive brown to light olive brown. Texture is shaly, very shaly, channery, or very channery silt loam or loam, and structure is weak, fine, or medium subangular blocky or platy. Consistence is friable or firm, nonsticky or slightly sticky and nonplastic or slightly plastic. Many of the coarse fragments have few, patchy coatings of fine earth and clay films.

Competing Series and Their Differentiae: The Gilpin series is a member of a large family in which only Bedington, Clymer, and Rayne series are considered to be closely competing. Also competing are Berks, Cardiff, Dekalb, Manlius, Muskingum, Wellston, and Westmoreland series. Bedington, Clymer, and Rayne soils have thicker sola with depth to rock greater than 102 cm. Berks, Cardiff, Dekalb, Manlius, and Muskingum soils lack argillic horizons. Westmoreland soils have more than 35 percent base saturation, and Wellston soils, in addition, are more silty.

Setting: Gilpin soils are on gently sloping to steep, convex, dissected uplands with gradients of 2 to 70 percent. The regolith is weathered from interbedded gray and brown acid siltstone, shale, and sandstone. The climate is humid temperate with an average annual rainfall of 91 to 127 cm, average annual air temperatures of 8 to 14°C and a growing season of 120 to 180 days.

Principal Associated Soils: These include Blairton, Cavode, Ernest, Shelocta, Upshur, Weikert, and Wharton series and the competing Berks, Clymer, Dekalb, Muskingum, Rayne, Wellston, and Westmoreland series. Blairton, Cavode, Ernest, and Wharton soils have mottled subsoils. Shelocta soils are more than 102 cm to rock. Upshur soils have finer textures. Weikert soils have bedrock at 50 cm or less.

Drainage and Permeability: Well drained with medium to very rapid runoff and moderate permeability.

Distribution and Extent: Pennsylvania, West Virginia, Ohio, Kentucky, Tennessee, Virginia, and Indiana. The series is of large extent.

HARTSELLS SERIES

The Hartsells series is a member of the fine-loamy siliceous, thermic family of Typic Hapludults. These soils have dark grayish brown and brown fine sandy loam A horizons and yellowish brown sandy clay loam B2t horizons. Acid sandstone bedrock is at about 90 cm.

Taxonomic Class: Fine-loamy, siliceous, Thermic Typic Hapludults

Typifying Pedon: Hartsells fine sandy loam--pasture. (Colors are for moist conditions.)

Ap -- 0 to 13 cm, dark grayish brown (10YR 4/2) fine sandy loam; weak fine granular structure; very friable; many fine roots; 10 percent by volume 0.5- to 2.5-cm angular fragments of sandstone; strongly acid; clear smooth boundary. (10 to 20 cm thick)

A2 -- 13 to 23 cm, brown (10YR 5/3) fine sandy loam; weak fine granular structure; very friable; many fine roots; 10 percent by volume 0.5- to 8-cm angular fragments of sandstone; strongly acid; clear smooth boundary (10 to 20 cm thick)

B1 -- 23 to 33 cm, yellowish brown (10YR 5/4) loam; weak fine subangular blocky structure; friable; common fine roots; few fine fragments of sandstone; most sand grains coated with clay; very strongly acid; gradual smooth boundary (0 to 15 cm thick)

B21t -- 33 to 50 cm, yellowish brown (10YR 5/4) sandy clay loam; weak and moderate medium subangular blocky structure; friable; common fine roots; few fine fragments of sandstone; thin continuous clay films on faces of most peds; very strongly acid; gradual smooth boundary. (10 to 20 cm thick)

B22t -- 50 to 76 cm, yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; friable; few fine roots; thin patchy clay films on faces of most peds; 10 percent by volume 1.0- to 5.0-cm angular fragments of sandstone; very strongly acid; gradual smooth boundary. (10 to 25 cm thick)

B3 -- 76 to 91 cm, yellowish brown (10YR 5/6) channery sandy loam, texture coarsens with increasing depths; weak medium subangular blocky structure; very friable; 30 percent by volume; 1.0- to 5.0-cm angular fragments of sandstone; sand grains coated with clay; very strongly acid; abrupt boundary. (0 to 20 cm thick)

R -- 91 cm, acid sandstone.

Type Location: Marshall County, Alabama; Land Mountain NW Corner of NW1/4SE1/4sec. 24, T. 8 S., R. 3 E. Very near the center of the section.

Range in Characteristics: Depth to bedrock and solum thickness range from 50 to 100 cm. The amount of coarse fragments, chiefly sandstone, ranges from none to 15 percent in any horizon, except the B3 and C horizons, which range up to 35 percent. Where the soil has not been limed, it is extremely acid through strongly acid throughout.

The Ap horizon is dark grayish brown (10YR 4/2; 2.5Y 4/2), dark brown (10YR 4/3), dark yellowish brown (10YR 4/4), grayish brown (10YR 5/2; 2.5Y 5/2), brown (10YR 5/3), or yellowish brown (10 YR 5/4, 5/6, 5/8). Some pedons have a 2- to 10-cm A1 horizon that is very dark grayish brown (10YR 3/2), grayish brown (10YR 4/2; 2.5Y 4/2), or dark brown (10YR 4/3). The A2 horizon is dark yellowish brown (10YR 4/4), brown (10YR 5/3), yellowish brown (10YR 5/4, 5/6, 5/8), or pale brown (10YR 6/3). Texture of the A horizon is fine sandy loam or loam.

The B1 horizon is dark yellowish brown (10YR 4/4), yellowish brown (10YR 5/4, 5/6, 5/8), or brown (7.5YR 4/4). Texture is sandy loam or loam.

The B2t horizon is yellowish brown (10YR 5/4, 5/6, 5/8), strong brown (7.5YR 5/6, 5/8), or brown (7.5YR 4/4), and the lower part commonly is mottled in shades of red, brown, or yellow. Texture is sandy loam, loam, sandy clay loam, or clay loam. The average clay content of the upper 50 cm of the B2t horizon or to bedrock commonly is 18 to 24 percent, but ranges from 18 to 30 percent.

The B3 or C horizon is similar to the B2t horizon in color and texture.

Competing Series and Their Differentiae: These are the Albertville, Allen, Apison, Cahaba, Cheaha, Clymer, Durham, Enders, Granville, Holston, Kalmia, Linker, Maxton, Mountainburg, Nectar, Pirum, and Townley series. Albertville, Enders, and Townley soils average more than 35 percent clay in the upper 50 cm of the Bt horizon, and in addition Enders soils have Bt horizons of 5YR or 2.5YR hue. Allen and Holston soils have sola thicker than 150 cm, and Allen soils have Bt horizons of 5YR or 2.5YR hue. Aposon soils have appreciably more silt with silt loam or silty clay loam Bt horizons. Cahaba, Kalmia, and Maxton soils are deeper than 150 cm to bedrock and have sand or loamy sand C horizons. Chesha soils have more than 15 percent coarse fragments throughout the solum. Clymer soils have mean annual soil temperatures of less than 15°C. Durham soils are deeper than 150 cm to bedrock, but have C horizons of sandy loam saprolite at about 120 cm. Granville soils have loamy material extending below 130 cm. Linker soils have Bt horizons of 5YR or 2.5YR hue. Mountainburg soils have bedrock within 50 cm of the soil surface. Nectar soils have redder Bt horizons and depth to rock is more than 100 cm. Pirum soils have an irregular lower boundary at contact with bedrock.

Setting: The Hartsells soils occur on broad smooth plateaus, mountaintops, or hilltops. Slopes between 3 and 8 percent are dominant, but the extreme range of slope is 2 to 25 percent. The soil formed in moderately coarse to medium textured materials. The country rock consists of acid hard sandstone containing thin strata of shale or siltstone in some places. Near the type location the average annual air temperature is 16°C, and the average rainfall is 142 cm.

Principal Associated Soils: These include the competing Albertville, Enders, Linker, Nectar, and Townley series and the Crossville, Hector, and Wynnville series. Crossville and Hector soils lack argillic horizons, and in addition, Hector soils have bedrock within 50 cm of the soil surface. Wynnville soils have a fragipan.

Drainage and Permeability: Well drained; medium runoff; moderate permeability.

Distribution and Extent: Cumberland Plateau in Alabama, Georgia, Kentucky, and Tennessee; the Boston Mountains and adjoining ridges in Arkansas and possibly Oklahoma. The series is of large extent.

JEFFERSON SERIES

The Jefferson series is a member of the fine-loamy, siliceous, mesic family of Typic Hapludults. Jefferson soils have thin dark grayish brown or dark yellowish brown gravelly loam A horizons and thick yellowish brown gravelly loam or gravelly light clay loam, very strongly acid Bt horizons.

Taxonomic Class: Fine-loamy, siliceous, mesic Typic Hapludults.

Typifying Pedon: Jefferson gravelly loam-- wooded. (Colors are for moist conditions.)

A1 -- 0 to 8 cm, dark grayish brown (10YR 4/2) gravelly loam; moderate fine and medium granular structure; very friable; many small roots; 15 percent sandstone fragments; strongly acid; clear smooth boundary. (5 to 13 cm thick)

A2 -- 8 to 20 cm, dark yellowish brown (10YR 4/4) gravelly loam; weak fine and medium granular structure; very friable; many small roots; 15 percent sandstone fragments; strongly acid; gradual smooth boundary. (10 to 23 cm thick)

B1t -- 20 to 38 cm, yellowish brown (10YR 5/4) gravelly heavy loam; moderate fine and medium subangular blocky structure; friable; common roots; thin patchy clay films; 20 percent angular sandstone fragments; very strongly acid; gradual smooth boundary. (0 to 25 cm thick)

B21t -- 38 to 97 cm, yellowish brown (10YR 5/6) gravelly light clay loam; moderate medium subangular blocky structure; friable, slightly sticky; few roots; thin clay films on most ped surfaces; 25 percent sandstone fragments; very strongly acid; gradual smooth boundary. (43 to 76 cm thick)

B22t -- 97 to 132 cm, yellowish brown (10YR 5/6) gravelly heavy loam; few medium faint brown (10YR 5/3) mottles; moderate medium subangular blocky structure; friable; few roots; thin patchy clay films; 30 percent sandstone fragments; very strongly acid; gradual wavy boundary. (36 to 51 cm thick)

C -- 132 to 157 cm, yellowish brown (10YR 5/6) gravelly loam; common medium faint brown (10YR 5/3) and strong brown (7.5YR 5/6) mottles; massive; friable; 40 percent sandstone fragments; very strongly acid.

Type Location: Lee County, Kentucky; 138 m south of gravel road at a point 1.6 km west of Kentucky Highway 11; 4.8 km south of the Wolfe County line.

Range in Characteristics: Thickness of the solum ranges from 107 to 152 cm. Content of sandstone fragments 3 to 20 cm across ranges from 10 to 25 percent to a depth of about 91 cm. Below 91 cm the fragments may be longer and the content ranges from 20 to 45 percent. Unless limed, the soil ranges from strongly to very strongly acid throughout. The A1 horizon ranges from very dark gray (10YR 3/1) through grayish brown (10YR 5/2). The A2 horizon ranges from pale brown (10YR 6/3) through dark yellowish brown (10YR 4/4). The Ap horizon ranges from dark grayish brown (10YR 4/2) through yellowish brown (10YR 5/4). Texture of the A horizons ranges from loam to fine sandy loam and their gravelly analogs. The Bt horizons range from yellowish brown (10YR 5/4) through strong brown (7.5YR 5/8). Texture in these horizons is heavy loam, sandy clay loam, heavy sandy loam or clay loam and their gravelly analogs. Structure is fine and medium subangular blocky. The matrix colors of the C horizon range from yellowish brown (10YR 5/6) through strong brown (7.5YR 5/6). In some pedons the B22t and the C horizons have a few brown to grayish brown or light brownish gray mottles. The C horizons are gravelly and texture of the fines is loam, sandy clay loam, or light clay loam. A IIC horizon of clayey residuum from shales is at a depth of 1.5 to 2 m in some pedons.

Competing Series and Their Differentiae: The Marr, Sassafras, and Sunnyside series are currently listed in the same family. Other closely competing soils include the Apison, Brevard, Cahaba, Clymer, Granville, Hartsells, Holston, Linker, Meadowville, Murrill, Shelocta, Tate, and Thurmont series. The Marr soils have essentially no coarse fragments, and the sand fraction in the B horizon is nearly all in the fine or very fine sand classes. The Sassafras soils have a solum thickness of 76 to 101 cm and contain pebbles rather than sandstone fragments. Sunnyside soils have hue redder than 7.5YR and no coarse fragments in the Bt horizon. Apison and Hartsells soils have bedrock within a 100-cm depth. Brevard, Clymer, Meadowville, Murrill, Shelocta, Tate, and Thurmont soils have mixed mineralogy. In addition, Brevard soils have developed red colors in the B horizon, and Clymer soils have a solum less than 100 cm in thickness, Meadowville soils have more than 40 percent silt and 5 to 10 percent coarse fragments, Murrill soils have a buried argillic horizon of high clay content, Shelocta soils have more than 40 percent silt, and Thurmont soils are streaked or mottled with reddish and strong brown colors and contain quartz, quartzite, granitic gravel, cobbles, and stones. Cahaba and Linker soils have hues redder than 7.5YR. Granville soils are high in exchangeable aluminum. Holston soils have a solum more than 150 cm thick.

Setting: Steep mountainsides and footslopes, often below sandstone escarpments, with slopes ranging from 5 to 60 percent. These soils have formed in colluvium from soils formed in residuum of acid sandstone and siltstone. At the type location the average annual precipitation is about 117 cm, and the average annual air temperature is about 13.2°C.

Principal Associated Soils: These are in the Clymer, Dekalb, Gilpin, Muskingum, Ramsey, Shelocta, Wharton, and Whitley series. Dekalb, Muskingum, and Ramsey soils lack argillic horizons. Wharton soils have more clay and less sand and Whitley soils have more silt and less sand.

Drainage and Permeability: Well drained. Rapid or medium runoff, depending on slope. Permeability is moderately rapid.

LINKER SERIES

The Linker series is a member of the fine-loamy, siliceous, thermic family of Typic Hapludults. These soils have brown strongly acid fine sandy loam A horizons, yellowish red very strongly acid sandy clay loam B horizons, and sandstone bedrock is at depths of about 1 meter.

Taxonomic Class: Fine-loamy, siliceous, thermic Typic Hapludults.

Typifying Pedon: Linker fine sandy loam--pasture. (Colors are for moist soil.)

Ap -- 0 to 13 cm, brown (10YR 5/3) fine sandy loam; weak medium granular structures; very friable; common roots; few sandstone flags on surface and in soil; common fine pores; few worm casts; strongly acid; clear wavy boundary. (10 to 18 cm thick)

B1 -- 13 to 25 cm, yellowish red (5YR 4/6) heavy fine sandy loam; weak medium subangular blocky structure; friable; common fine roots; many medium pores; clay coats and bridging on sand grains and in some pores; few worm casts; few sandstone flags; very strongly acid; clear wavy boundary. (0 to 18 cm thick)

B2t -- 25 to 64 cm, yellowish red (5YR 4/8) sandy clay loam; moderate medium subangular blocky structure; friable; few roots; common fine pores; patchy thin clay films on peds and in pores; few sandstone flags; very strongly acid; clear wavy boundary. (30 to 50 cm thick)

B3 -- 64 to 89 cm, yellowish red (5YR 4/8) gravelly light sandy clay loam; common medium distinct red (2.5YR 4/6), strong brown 7.5YR 5/6) and prominent pale brown (10YR 6/3) mottles; weak medium subangular blocky structure; friable; common fine pores; few thin discontinuous clay films; about 20 percent pebbles and flagstones of sandstone; very strongly acid; abrupt wavy boundary. (0 to 38 cm thick)

R -- 89 cm, hard massive level-bedded acid sandstone.

Type Location: Pope County, Arkansas; 3.8 km north of Moreland on Buck Mountain, 92 m east and 15 m north of road turn, on crest of ridge, SW1/4SW1/4NW1/4 sec. 35, T. 9 N., R. 19 W.

Range of Characteristics: Solum thickness and depth to bedrock range from 50 to 100 cm. Base saturation in the horizon above bedrock is about 10 to 25 percent. If unlimed, the soil is extremely acid through strongly acid. The Ap horizon is brown (10YR 5/3, 4/3; 7.5YR 5/4, 4/4, 4/2), dark yellowish brown (10YR 4/4), or dark grayish brown (10YR 4/2). Some pedons have A1 horizons, 5 to 10 cm thick, that are dark grayish brown (10YR 4/2) or very dark grayish brown (10YR 3/2), and A2 horizons that are grayish brown (10YR 5/2), brown (10YR 5/3, 7.5YR 5/2 or that are grayish brown (10YR 5/2), brown (10YR 5/3, 7.5YR 5/2 or 7.5YR 5/4), or yellowish brown (10YR 5/4). The A horizon is fine sandy loam or loam.

Gravelly, flaggy, and stony phases are recognized. The B1 horizon is yellowish red (5YR 4/6, 4/8, 5/6 or 5/8) or strong brown (7.5YR 4/6 or 5/6). It is fine sandy loam, sandy clay loam, or loam. The B2t horizon is yellowish red (5YR 4/6, 4/8, 5/6 or 5/8) or red (2.5YR 4/6, 4/8, 5/6 or 5/8). It is sandy clay loam, clay loam, or loam. The B3 horizon has the same colors as the B2t horizon and is mottled with shades of brown. It is sandy loam or sandy clay loam. The upper 20 in. of the B horizon average between 18 and 28 percent clay and more than 20 percent fine and coarser sand. Pebble and flagstone content by volume in the B1 and B2t horizons is 0 to about 10 percent and in the B3 horizon is 0 to about 25 percent. Some pedons have C horizons, 2 to 15 cm thick, of red, brown, or gray soft weathered sandstone.

Competing Series and Their Differentiae: These are the Alamance, Albertville, Allen, Apison, Cahaba, Durham, Enders, Granville, Grover, Hartsells, Holston, Johns, Kalmia, Kempsville, Maxton, Mountainburg, Pirum, Saffell, Townley, Whitwell, and Wickham series. Alamance soils have less than 15 percent fine and coarser sand in the upper 50 cm of the B horizon. Albertville, Enders, and Townley soils average more than 35 percent clay in the upper 50 cm of the B horizon. Albertville soils, in addition, have 7.5YR or yellower hue. Allen and Holston soils have sola thicker than 150 cm. Holston soils, in addition, have 7.5YR or yellower hue. Apison soils have B horizons of 7.5YR or yellower hue of gravelly silty clay loam. Cahaba, Kalmia, Kempsville, and Maxton soils are deeper than 150 cm to bedrock and have sand or loamy sand C horizons. Durham, Granville, and Hartsells soils have B2 horizons of 7.5YR or yellower hue. Grover soils have micaceous mineralogy. Johns and Whitwell soils have colors of 2 or lower chroma in mottles in the matrix in the upper part of the B horizon. Mountainburg soils have bedrock at depths of less than 50 cm. Pirum soils have B horizons with irregular lower boundary and with strong brown or yellower colors. Saffell soils have more than 35 percent by volume of fragments larger than 2 mm in the B horizon. Wickham soils have mixed mineralogy and lack rock within depths of 2 m.

Setting: Linker soils are on broad plateaus, mountain- and hilltops, and benches. Much of the soil has slopes between 2 and 8 percent, and the full range is from 1 to 15 percent. The soil formed in loamy residuum weathered from sandstone or interbedded sandstone, siltstone, and shale. Near the type location, average annual temperature is about 15°C, and average annual precipitation is about 124 cm.

Principal Associated Soils: These are the competing Allen, Enders, Hartsells, Holston, and Mountainburg soils, and the Hector and Ramsey soils. The two last named soils are less than 50 cm deep to bedrock and contain more sand.

Drainage and Permeability: Well drained; slow to rapid runoff depending upon slope; moderate permeability.

Distribution and Extent: Boston Mountains, Arkansas Valley and Ouachita Highlands of Arkansas and Oklahoma; Cumberland Plateau and Mountains of Tennessee, Kentucky, and Georgia; Sand Mountain area of Alabama. The series is of large extent, probably in excess of 120,000 ha.

MUSKINGUM SERIES

The Muskingum series is a member of the fine-loamy, mixed, mesic family of Typic Dystrochrepts. These soils have brownish silt loam A horizons and yellowish brown silt loam B horizons. They contain coarse fragments throughout and bedrock is at 50 to 100 cm.

Taxonomic Class: Fine-loamy, mixed, mesic Typic Dystrochrepts.

Typifying Pedon: Muskingum silt loam--forested. (Colors are for moist soil.)

A1 -- 0 to 8 cm, very dark grayish brown (10YR 3/2) silt loam; moderate fine granular structure; very friable; many roots; 10 percent coarse fragments; medium acid; clear wavy boundary. (5 to 13 cm thick)

A2 -- 8 to 23 cm, brown (10YR 5/3) silt loam; weak fine granular and weak fine subangular blocky structure; very friable; common roots; 10 percent coarse fragments; strongly acid; clear wavy boundary. (5 to 20 cm thick)

B2 -- 28 to 60 cm, yellowish brown (10YR 5/6) channery silt loam; moderate fine and medium subangular blocky structure; friable; few roots; 20 percent coarse fragments; strongly acid; gradual wavy boundary. (20 to 46 cm thick)

B3 -- 60 to 82 cm, yellowish brown (10YR 5/6) channery silt loam; weak fine and medium subangular blocky structure; friable; 30 percent coarse fragments; strongly acid; gradual wavy boundary. (0 to 30 cm thick)

C -- 82 to 89 cm, fractured brown and gray horizontally bedded soft siltstone and fine grained sandstone and 10 to 15 percent fines like that in the B3 horizon. (0 to 25 cm thick)

R -- 89 cm, fractured siltstone and fine grained sandstone.

Type Location: Raleigh County, West Virginia; 5.6 km east of Arnett on W. Va. Route 3, then north 1.2 km on W. Va. Route (3/10); 46 m east of road.

Range in Characteristics: Thickness of the solum ranges from 40 to 91 cm. Depth to hard bedrock is 50 to 100 cm. The B and C horizons are strongly or very strongly acid except where the soil has been limed. Coarse fragments of shale, siltstone, or sandstone range from 10 to 30 percent by volume in all parts of the B horizon and are more than 35 percent in the C horizon. The control section averages less than 35 percent coarse fragments.

The Ap horizon ranges from dark brown (10YR 3/3) through strong brown (7.5YR 5/6). The A1 horizon is less than 15 cm thick and commonly is very dark grayish brown or dark brown. The A horizon is silt loam, loam, or fine sandy loam and may be channery. It is friable to very friable. The B2 horizon ranges from dark yellowish brown (10YR 4/4) to strong brown (7.5YR 5/6). It is silt loam or channery silt loam. It has weak or moderate, fine or medium, subangular blocky structure. A few discontinuous clay films are in some pedons. The C horizon is yellowish brown (10YR 5/4) or brown (10YR 5/3 or 7.5YR 5/4). It is channery or very channery loam or silt loam.

Competing Series and Their Differentiae: The Citico, Kitsap, and Sadie series are members of the same family. The Citico soils have thicker sola, bedrock is at depths of more than 100 cm, and they formed in residuum weathered from phyllite. Kitsap and Sadie soils lack bedrock within depths of 100 cm. Other related soils are in the Berks, Brandywine, Dekalb, Garmon, Gilpin, Lordstown, Parker, Steinsburg, and Westmoreland series. Berks, Brandywine, Dekalb, Parker, and Steinsburg soils average more than 35 percent coarse fragments within the control section. Garmon soils have higher base saturation. Gilpin and Westmoreland soils have argillic horizons. Lordstown soils average less than 18 percent clay within the control section.

Setting: Muskingum soils are mainly on rugged topography of dissected plateaus. Slope gradients range from 5 to 70 percent and are mostly more than 20 percent. The soil formed in residuum weathered from interbedded siltstone, sandstone, and shale. Mean annual precipitation ranges from 89 to 140 cm, and mean annual air temperatures range from 10 to 14°C.

Principal Associated Soils: These are the competing Dekalb, Gilpin, and Westmoreland soils and the Ernest, Ramsey, Rayne, Shelocta, and Upshur soils. All except the Ramsey soils have argillic horizons. The Ramsey soils have bedrock at less than 50 cm.

Drainage and Permeability: Runoff is medium to high. Permeability is moderate.

Distribution and Extent: West Virginia, Virginia, Pennsylvania, Ohio, Kentucky, Indiana, Illinois, and Tennessee. The series is of large extent.

PHILO SERIES

The Philo series is a member of the coarse-loamy, mixed, mesic family of Fluvaquentic Dystrochrepts. Philo soils have dark brown silt loam Ap horizons, dark yellowish brown silt loam upper B horizons and brown mottled silt loam lower B horizons, and gray silt loam and intermingled gray and strong brown loam C horizons underlain by stratified sand and gravel.

Taxonomic Class: Coarse-loamy, mixed, mesic Fluvaquentic Dystrochrepts

Typifying Pedon: Philo silt loam--cultivated. (Colors are for moist soils.)

Ap -- 0 to 15 cm, dark brown (10YR 4/3) silt loam; moderate fine granular structure; friable; strongly acid; abrupt smooth boundary. (13 to 25 cm thick)

B1 -- 15 to 40 cm, dark yellowish brown (10YR 4/4) silt loam; moderate fine granular structure; friable; strongly acid; gradual smooth boundary. (20 to 40 cm thick)

B2 -- 40 to 56 cm, brown (10YR 5/3) silt loam, few fine distinct mottles of dark brown to brown (7.5YR 4/4) and gray (10YR 5/1); weak very fine subangular blocky structure; friable to firm; strongly acid; clear smooth boundary. (13 to 38 cm thick)

C1 -- 56 to 81 cm, gray (10YR 5/1) silt loam, common distinct strong brown (7.5YR 5/8) mottles; massive; friable; common; iron concretions strongly acid; clear smooth boundary. (0 to 30 cm thick)

C2 -- 81 to 107 cm, variegated gray (10Y 5/1) and strong brown (7.5YR 5/8) loam; massive; firm; strongly acid; clear smooth boundary. (0 to 30 cm thick)

IIC3 -- 107 to 132 cm, stratified sand and gravel.

Type Location: Barbour County, West Virginia; north of Big Run on the south side of U.S. Highway 119 near the intersection with State Route 36.

Range in Characteristics: Solum thickness ranges from 50 to 100 cm. Depth to low chroma mottling ranges from 30 to 60 cm. In some pedons, stratified sand and gravel is at depths as shallow as 76 cm; however, the transition zone is 13 cm or more thick. In other pedons, medium textured materials extend to depths of 152 cm or more. Depth to hard rock ranges from 107 to 366 cm or more. The weighted average content of coarse fragments in the textural control section ranges from 0 to 20 percent. The seasonally fluctuating water table rises to a high point

40 to 60 cm below the soil surface. Reaction when unlimed ranges from very strongly acid to medium acid. Textures of all horizons above the II C horizon range from silt loam to sandy loam, and the II C horizon ranges from sand to silt loam including gravelly phases. The A horizon ranges from dark grayish brown (10YR 3/2) through brown (10YR 4/3). If moist values are 3, then either dry values are more than 5.5, or the A horizon is less than 1/3 the thickness from the soil surface to the base of the cambic horizon. The B horizons range from brown (7.5YR 4/3) through yellowish brown (10YR 5/6) and reddish yellow (7.5YR 6/6). Low chroma mottles range from dark grayish brown (10YR 4/2) through light gray (10YR 6/1). High chroma mottles range from dark brown (7.5YR 4/4) through strong brown (7.5YR 5/8). The C horizon ranges from light yellowish brown (10YR 6/4) through dark gray (N 4/) and dark grayish brown (2.5Y 4/2) and is mottled. Mottles are strong brown (7.5YR 5/6 or 7.5YR 5/8), yellowish red (5YR 4/6), or redder. If matrix chromas are greater than 2, mottles have chromas of 2 or less.

Competing Series and Their Differentiae: The Basher and Podunk series are in the same family. Other competing series are the Adler, Codorus, Lobdell, Pope, Rowland, Steff, Stendal, and Winooski series. Basher and Podunk soils have a sand fraction dominated by feldspars. Adler and Winooski soils have coarse-silty textural control sections. Codorus, Lobdell, and Rowland soils have fine-loamy textural control sections. Pope soils lack mottles with chromas of 2 or less within a depth of 60 cm. Steff and Stendal soils have fine-silty textural control sections.

Setting: Philo soils are on nearly level floodplains. Slopes range from 0 to 3 percent. The soils developed in recent alluvium washed mainly from sandstone- and shale-derived soils. Climate is humid temperate. Average annual precipitation ranges from 102 to 117 cm, and air temperature ranges from 8 to 14°C. The average number of days without killing frost is 155.

Principal Associated Soils: These are the well drained Pope, somewhat poorly drained Stendal, poorly drained Atkins, and poorly and very poorly drained Elkins soils on floodplains. The Buchanan, Cotaco, and Ernest soils are moderately well-drained soils on footslopes and colluvial fans. The Dekalb, Gilpin, and Muskingum soils are well-drained upland soils. Chenango and Alton soils are skeletal soils on adjacent terraces. The Holly and Papakating soils are more poorly drained alluvial soils.

Drainage and Permeability: Moderately well drained. Subject to stream overflow. Runoff is slow or very slow, and permeability is moderate or moderately slow.

Distribution and Extent: Alabama, Arkansas, Georgia, southern Indiana, Kentucky, Missouri, southern Ohio, Oklahoma, Pennsylvania, Tennessee, Virginia, and West Virginia. Extent is large.

RAMSEY SERIES

The Ramsey series is a member of the loamy, siliceous, mesic family of Lithic Dystrochrepts. These soils have brown loam A horizons and thin yellowish brown loam B horizons. Bedrock is at depths less than 50 cm.

Taxonomic Class: Loamy, siliceous, mesic Lithic Dystrochrepts.

Typifying Pedon: Ramsey loam--forested. (Colors are for moist soil.)

A1 -- 0 to 2.5 cm, very dark grayish brown (10YR 3/2) loam; weak medium granular structure; very friable; many fine and medium roots; strongly acid; abrupt smooth boundary. (0 to 5 cm thick)

A2 -- 2.5 to 13 cm, brown (10YR 4/3) loam; weak medium granular structure; very friable; many fine and medium roots and pores; about 10 percent by volume of fragments of sandstone; strongly acid; clear smooth boundary. (7 to 13 cm thick)

B2 -- 13 to 30 cm, yellowish brown (10YR 5/4) loam; weak fine subangular blocky structure; friable; common fine and medium roots and pores; 15 percent by volume of fragments of sandstone; strongly acid; clear smooth boundary. (10 to 20 cm thick)

B3 -- 30 to 46 cm, yellowish brown (10YR 5/4) loam; weak fine and medium subangular blocky structure; very friable; common fine and medium roots and pores; 25 percent by volume of fragments of sandstone; strongly acid. (0 to 13 cm thick)

R -- 46 cm, acid sandstone bedrock.

Type Location: White County, Tennessee; on Cumberland Plateau, 3.2 km south of Clarktown and 30 m northwest of junction of Big Lost Creek and Clarktown-Clifty Road.

Range in Characteristics: Solum thickness and depth to sandstone or quartzite bedrock range from 18 to 50 cm. Each horizon contains a few percent to 35 percent by volume of fragments of sandstone or quartzite. Fragments are mostly less than 8 cm in size in the upper part of the solum, but some in the lower part are as much as 15 cm in size. Average annual soil temperature at 50-cm depth ranges from 8 to 15°C. Reaction in each horizon is strongly acid or very strongly acid.

The A1 horizon is very dark grayish brown (10YR 3/2), dark brown (10YR 3/3, 4/3), or dark grayish brown (10YR 4/2). The A2 horizon is brown (10YR 4/3, 5/3), dark grayish brown (10YR 4/2), yellowish brown (10YR 5/4), or pale brown (10YR 6/3). Texture of the fine-earth in the A horizon is loam, sandy loam, or fine sandy loam.

The B horizon is yellowish brown (10YR 5/4, 5/6), brown (10YR 5/3; 7.5YR 4/4, 5/4), dark yellowish brown (10YR 4/4), light yellowish brown (10YR 6/4), strong brown (7.5YR 5/6), pale brown (10YR 6/3), or light brown (7.5YR 6/4). It is loam or sandy loam or stony equivalents containing 10 to 22 percent clay. Structure grade is weak or moderate, and consistence is very friable or friable. Some pedons have loam to loamy sand C horizons 7 to 15 cm thick rather than B3 horizons.

Competing Series and Their Differentiae: These are the Arnot, Ashe, Basehor, Catlett, Cleveland, Colyer, Crossville, Hector, Holyoke, Klinesville, Manteo, Muskingum, Nassau, Pickens, and Weikert series. Arnot, Catlett, Colyer, Cleveland, Klinesville, Manteo, Nassau, Pickens, and Weikert soils have mixed mineralogy and contain more than 35 percent coarse fragments. Manteo and Pickens soils, in addition, have mean annual temperature of more than 15°C. Ashe and Muskingum soils have mixed mineralogy and lack bedrock within depths of 100 cm. Basehor soils lack sandstone fragments in the solum. Crossville soils have umbric epipedons, and lack bedrock within depths of 100 cm. Hector soils have mean annual temperature of more than 15°C. Holyoke soils have mixed mineralogy.

Setting: Ramsey soils are on hills and mountains. Slope gradients range from 10 to 70 percent. The soils formed in residuum and in some places contain alluvium from sandstone or quartzite. Outcrops of bedrock are common. Near the type location, mean temperature is 13°C, and mean annual precipitation is 136 cm.

Principal Associated Soils: These are the competing Crossville and Muskingum series and the Berks, Dekalb, Hartsells, and Jefferson series. All these soils have sola thicker than 50 cm. In addition, Hartsells and Jefferson soils have argillic horizons.

Drainage and Permeability: Somewhat excessively drained; medium to rapid runoff; rapid permeability.

Distribution and Extent: The Cumberland Plateau and mountains of Georgia, Tennessee, Kentucky, and Virginia, and possibly West Virginia and Pennsylvania, and the Blue Ridge Mountains of Tennessee, North Carolina, and Virginia. The series is of large extent, probably more than 200,000 ha.

WELLSTON SERIES

The Wellston series is a member of the fine-silty, mixed, mesic family of Ultic Hapludalfs. Wellston soils have thin silt loam A horizons, well developed yellowish-brown, and brown silty B horizons, a major part of which formed in a mantle with a high silt content and has a low content of sands and coarse fragments. The lower B and C horizons are derived from siltstone, sandstone, or shale.

Taxonomic Class: Fine-silty, mixed, mesic Ultic Hapludalfs.

Typifying Pedon: Wellston silt loam--forested. (Colors are for moist soil.)

A1 -- 0 to 4 cm, very dark brown (10YR 2/2) silt loam; weak fine granular structure; friable; many fine roots; strongly acid; abrupt wavy boundary. (2 to 13 cm thick)

A2 -- 4 to 18 cm, pale brown (10YR 6/3) silt loam; weak coarse subangular blocky structure breaking to weak fine granular; friable; many fine roots; many fine to coarse pores; strongly acid; clear wavy boundary. (5 to 23 cm thick)

B1t -- 18 to 25 cm, yellowish-brown (10YR 5/6) silt loam; weak medium subangular blocky structure; friable; many fine roots; many fine to medium pores; thin very patchy dark yellowish-brown (10YR 4/4) clay films; brown (10YR 5/3) silty coatings of variable thickness, mostly less than 1 mm, on more than 50 percent of vertical surfaces; strongly acid; clear smooth boundary. (5 to 20 cm thick)

B21t -- 25 to 38 cm, brown (7.5YR 5/4) heavy silt loam; moderate films; fine and medium subangular blocky structure; firm; common fine roots; few coarse pores; thin continuous brown (7.5YR 4/4) clay films; very strongly acid; gradual wavy boundary. (10 to 25 cm thick)

B22t -- 38 to 53 cm, brown (7.5YR 5/4) light silty clay loam; moderate fine and medium subangular blocky structure; firm; common fine roots; few coarse pores; thin continuous brown (7.5YR 4/4) clay films; very strongly acid; abrupt wavy boundary. (10 to 25 cm thick)

B23t -- 53 to 64 cm, brown (7.5YR 5/4) silty clay loam; moderate fine and medium subangular blocky structure; firm; common fine roots; few fine pores; thin patchy brown (7.5YR 4/4) clay films 3 percent sandstone channers; very strongly acid; clear smooth boundary. (5 to 15 cm thick)

IIB3t-- 64 to 91 cm, strong brown (7.5YR 5/6) silt loam; weak medium subangular blocky structure; firm; sharp brittleness; few fine roots; few fine pores; thin very patchy pale brown (10YR 6/3) clay films and few thin gray (10YR 5/1) silty coatings in lower part; 20 percent sandstone and siltstone channers; strongly acid; abrupt wavy boundary. (13 to 38 cm thick)

IIC -- 91 to 115 cm, strong brown (7.5YR 5/6) loam; many medium light brownish-gray (10YR 6/2) mottles or variegations; massive; firm; occasional roots; few fine pores; 80 percent siltstone fragments increasing to 90 percent in the lower part; strongly acid; abrupt irregular boundary. (0 to 60 cm thick)

R -- 115 cm, light olive brown (2.5Y 5/6) acid fine-grained sandstone or siltstone; fractured; strong brown (7.5YR 5/6) soil in cracks 2 mm thick that extend to about 132 in.; rock layers grade to hard and compact below 132 in.

Type Location: Washington County, Ohio, SE10 SE40 SW160 Sec. 8, 1.1 km southeast of Watertown, 30 m north of junction of land with CO-2, Watertown Township.

Range in Characteristics: Solum thickness ranges from 81 to 127 cm. Depth to base of the argillic horizon is usually about 89 cm and ranges from 76 to 114 cm. Depth to bedrock ranges from 102 to 183 cm. Content of coarse fragments ranges from none in the upper part of the B horizon, to as many as 60 percent in the lower few centimeters. The weighted average content of coarse fragments in the B horizon is less than 10 percent. Base saturation at 127 cm below the top of the argillic horizon, or at the contact with rock, ranges from 35 to 60 percent. In unlimed soils, the reaction ranges from strongly to extremely acid throughout the solum. Ap horizons are dark grayish-brown (10YR 4/2), brown (10YR 5/3), or dark brown (10YR 4/3). A2 horizons are pale brown (10YR 6/3), brown (10YR 5/3), or yellowish-brown (10YR 5/4) in color. The B1 horizon is degraded, with silty surfaces differing from the ped interiors in being more porous and having less clay and lower chroma. Bt horizons are yellowish-brown (10YR 5/4, or 5/6), brown (7.5YR 4/4), or strong brown (7.5YR 5/6) in color, and 46 to 92 cm thick. Texture ranges from silt loam to light silty clay loam, with silt content more than 60 percent and clay content ranging 20 to 35 percent. Structure is mostly moderate or strong, fine or medium subangular blocky. Consistence is friable or firm. Clay films are evident, typically dark yellowish-brown (10YR 4/4), or brown (7.5YR 4/4) in color. The lower Bt horizon has 5 to 40 percent coarse fragments in most pedons, with silt loam texture in the fine earth fraction. The C horizon has 20 to 90 percent coarse fragments, with the fine fraction having silt loam, clay loam, or loam texture.

Competing Series and Their Differentiae: Elk, Elkinsville, Fogelsville, and Pike series are in the same family. Other competing series include

Alford, Allegheny, Gilpin, Rayne, Shelocta, Westmore, Westmoreland, and Whitley. Elk, Elkinsville, Pike, Alford, and Allegheny soils are very low in coarse fragments, greater depth to bedrock, and generally have thicker solums. Allegheny soils have base saturation below 35 percent 127 cm below the top of the argillic horizon. Fogelsville soils have thicker argillic horizons and overlie limestone bedrock. Gilpin soils have thinner argillic horizons and a shallower depth to skeletal material and bedrock. Gilpin, Shelocta, and Ramne soils have base saturation below 35 percent at the lithic contact, or 127 cm below the top of the argillic horizon, and are fine loamy. Westmore soils have more clay in their lower solums and higher base saturation. Westmoreland soils are higher in sand and coarse fragments in the upper solum and are fine loamy. Whitley soils have base saturation below 35 percent in the lower solum, just above the lithic contact.

Setting: Wellstone soils are on gently sloping to steep uplands in areas of acid sandstone, siltstone, or shale bedrock. The soil is very silty, derived from loess or siltstone, or a combination of these materials to depths of up to 102 cm. The underlying bedrock is acid siltstone, sandstone, or shale. Slopes range from 2 to 30 percent or more, and are dominantly 4 to 18 percent. Mean annual air temperature ranges from 9 to 32°C, and mean annual precipitation ranges from 86 to 112 cm.

Principal Associated Soils: These are Berks, Dekalb, Gilpin, Muskingum, Sadler, Shelocta, and Zanesville. Berks, Dekalb, and Muskingum soils lack argillic horizons and generally have thinner solums. They generally occur on the steeper slopes near Wellston soils. On nearby more level areas, Sadler and Zanesville soils occur. They have fragipans, and Sadler soils have low chroma mottles high in their solum.

Drainage and Permeability: Well drained. Runoff is medium to rapid. Permeability is moderate.

Distribution and Extent: Southern and eastern Ohio, southern Indiana, southern Illinois, western Kentucky, and parts of Pennsylvania and West Virginia. The soil is of large extent, with an area of about 100,000 ha.

APPENDIX B

SOIL CHEMICAL ANALYSIS FOR CAMP BRANCH MAPPING UNITS

TABLE B.1. SOIL CHEMICAL ANALYSIS, GILPIN, 5 TO 12% SLOPE UNIT, CAMP BRANCH WATERSHED[a]

Depth	Chemical content (μg/g) Total-N		Total-P		Total-K		Total-S		Percent organic matter	
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	1166.5	73.4	219.0	8.5	789.1	47.2	174.1	7.4	3.40	0.21
10-30	666.1	35.4	199.3	7.5	943.5	63.6	141.8	5.0	1.30	0.06
30-50	470.5	18.7	205.1	8.5	931.3	67.6	125.4	4.7	0.67	0.05
50-70	355.2	17.7	199.8	12.2	935.0	104.9	131.2	8.1	0.37	0.03
70-100	329.7	33.9	212.3	27.3	1045.0	179.4	78.5	3.8	0.31	0.03

Depth	Chemical content (μg/g) Exchangeable-Ca		Exchangeable-Mg		Exchangeable-K		Exchangeable-S		Exchangeable-P	
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	93.3	6.4	23.4	2.9	60.4	2.6	0.3	1.3	12.3	2.4
10-30	97.6	3.7	17.8	3.2	52.3	2.0	36.8	2.2	6.0	0.3
30-50	109.6	4.6	35.7	3.6	56.1	3.0	48.8	4.3	4.7	0.6
50-70	114.9	6.2	54.1	7.2	51.3	3.1	44.8	5.0	3.1	0.4
70-100	137.5	26.6	45.8	7.6	47.0	5.4	37.6	4.0	1.8	0.3

Depth	Cation exchange capacity		pH	Depth to bedrock (cm)	
(cm)	$\bar{X}$	SE	$\bar{X}$	$\bar{X}$	SE
0-10	13.50	1.20	4.3	76.5	5.9
10-30	9.74	0.45	4.5		
30-50	9.28	0.45	4.7		
50-70	9.27	0.91	4.8		
70-100	11.40	1.50	4.8		

[a]Values presented are means with one standard error.

TABLE B.2. SOIL CHEMICAL ANALYSIS, GILPIN, 12 TO 25% SLOPE UNIT, CAMP BRANCH WATERSHED[a]

Depth	Chemical content (μg/g)								Percent organic matter	
	Total-N		Total-P		Total-K		Total-S			
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	1006.0	140.0	198.0	6.0	1260.0	40.0	129.0	0.0	2.60	0.25
10-30	628.0	90.0	209.0	22.0	1720.0	250.0	136.5	21.5	0.94	0.05
30-50	621.0	83.0	176.0	4.0	1745.0	535.0	136.0	14.0	0.61	0.05
50-70	407.0	62.0	111.0	20.0	1475.0	445.0	124.5	3.5	0.33	0.05
70-100	249.0	-[b]	172.0	-	1020.0	-	101.0	-	0.22	-

Depth	Chemical content (μg/g)									
	Exchangeable-Ca		Exchangeable-Mg		Exchangeable-K		Exchangeable-S		Exchangeable-P	
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	93.5	1.5	15.5	0.5	58.0	1.0	34.3	4.5	14.6	-
10-30	105.5	10.5	17.0	7.0	48.5	6.5	32.9	1.0	6.2	1.3
30-50	96.0	7.0	50.0	28.0	51.0	8.0	32.2	7.5	4.9	2.4
50-70	101.0	0.0	73.5	22.5	57.0	11.0	51.0	4.8	2.5	0.1
70-100	103.0	-	43.0	-	43.0	-	25.6	-	2.2	-

Depth	Cation exchange capacity		pH	Depth to bedrock (cm)	
(cm)	$\bar{X}$	SE	$\bar{X}$	$\bar{X}$	SE
0-10	14.40	0.15	4.4	79.0	7.5
10-30	9.85	1.30	4.5		
30-50	11.30	0.80	4.6		
50-70	8.85	0.25	4.9		
70-100	9.70	-	4.8		

[a] Values presented are means with one standard error.
[b] Indicates only one sample collected.

TABLE B.3. SOIL CHEMICAL ANALYSIS, HARTSELLS, 5 TO 12% SLOPE UNIT, CAMP BRANCH WATERSHED[a]

Depth	Chemical content (μg/g)								Percent organic matter	
	Total-N		Total-P		Total-K		Total-S			
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	1110.3	121.8	240.3	29.8	1182.5	34.1	173.0	13.7	2.60	0.22
10-30	620.9	48.0	231.8	17.0	1261.3	76.2	120.5	11.1	1.00	0.10
30-50	471.3	31.9	242.4	13.2	1350.0	55.7	159.3	19.4	0.60	0.05
50-70	407.2	43.8	226.0	12.5	1238.3	106.0	121.3	14.0	0.42	0.05
70-100	424.5	45.4	272.8	23.9	1232.5	194.7	79.8	3.1	0.32	0.05

Depth	Chemical content (μg/g)									
	Exchangeable-Ca		Exchangeable-Mg		Exchangeable-K		Exchangeable-S		Exchangeable-P	
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	263.5	152.5	24.3	3.8	66.5	11.0	34.2	2.7	14.4	5.5
10-30	178.3	73.9	17.6	4.2	68.8	15.5	40.9	2.1	6.1	0.7
30-50	157.6	33.0	37.9	6.5	68.9	11.5	61.1	10.8	3.7	0.6
50-70	145.8	23.3	55.7	11.4	64.3	9.0	51.8	8.1	2.7	0.7
70-100	137.3	32.8	73.5	25.6	65.0	6.9	51.3	6.6	1.7	0.4

Depth	Cation exchange capacity		pH	Depth to bedrock (cm)	
(cm)	$\bar{X}$	SE	$\bar{X}$	$\bar{X}$	SE
0-10	10.7	1.1	5.8	87.2	18.6
10-30	9.0	0.8	4.7		
30-50	10.0	0.6	4.7		
50-70	10.2	1.2	4.8		
70-100	12.9	1.5	4.9		

[a]Values presented are means with one standard error.

TABLE B.4. SOIL CHEMICAL ANALYSIS, PHILO, 0 TO 3% SLOPE UNIT, CAMP BRANCH WATERSHED[a]

Depth (cm)	Chemical content (μg/g) Total-N X̄	Total-N SE	Total-P X̄	Total-P SE	Total-K X̄	Total-K SE	Total-S X̄	Total-S SE	Percent organic matter X̄	Percent organic matter SE
0-10	1488.2	227.8	233.8	21.0	818.0	152.0	177.9	3.7	4.40	0.45
10-30	745.4	86.5	210.4	27.0	830.0	65.4	150.8	5.0	1.60	0.18
30-50	499.6	62.0	224.6	17.7	890.0	67.6	149.9	5.4	0.87	0.10
50-70	413.0	21.3	215.0	30.9	900.0	127.0	138.0	5.2	0.57	0.09
70-100	373.0	83.0	206.5	51.5	780.0	390.0	88.7	3.6	0.45	0.05

Depth (cm)	Chemical content (μg/g) Exchangeable-Ca X̄	Exchangeable-Ca SE	Exchangeable-Mg X̄	Exchangeable-Mg SE	Exchangeable-K X̄	Exchangeable-K SE	Exchangeable-S X̄	Exchangeable-S SE	Exchangeable-P X̄	Exchangeable-P SE
0-10	123.0	11.4	33.6	8.1	61.6	10.4	28.8	2.2	9.9	1.1
10-30	110.2	11.2	20.8	5.1	49.0	8.4	35.9	7.4	6.6	1.0
30-50	163.8	52.4	51.2	15.2	59.4	12.0	33.8	8.2	4.3	0.8
50-70	105.3	5.8	50.3	15.0	52.0	10.4	37.2	9.8	3.1	0.7
70-100	98.5	7.5	59.5	20.5	55.5	22.5	24.2	4.1	1.7	0.2

Depth (cm)	Cation exchange capacity X̄	Cation exchange capacity SE	pH X̄	Depth to bedrock (cm) X̄	Depth to bedrock (cm) SE
0-10	12.7	1.9	4.2	106.5	18.3
10-30	10.2	1.4	4.5		
30-50	8.9	1.1	4.6		
50-70	9.6	1.3	4.8		
70-100	10.8	2.0	4.9		

[a]Values presented are means with one standard error.

TABLE B.5. SOIL CHEMICAL ANALYSIS, RAMSEY, 25 TO 70% SLOPE UNIT, CAMP BRANCH WATERSHED[a]

Depth	Chemical content (μg/g)								Percent organic matter	
	Total-N		Total-P		Total-K		Total-S			
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	1632.3	759.4	274.0	43.1	772.5	114.6	165.3	9.0	3.93	0.56
10-30	918.0	129.4	238.5	20.4	1012.5	150.1	126.0	13.7	1.80	0.10
30-50	579.5	83.5	225.5	25.5	1225.0	485.0	126.0	24.0	0.88	0.01

Depth	Chemical content (μg/g)									
	Exchangeable-Ca		Exchangeable-Mg		Exchangeable-K		Exchangeable-S		Exchangeable-P	
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	122.3	30.3	25.0	5.0	69.8	7.3	32.8	6.8	16.9	4.0
10-30	154.8	41.1	19.5	4.5	60.5	7.5	41.8	9.2	5.5	0.8
30-50	84.0	2.0	21.5	10.5	44.0	9.0	71.7	45.3	4.8	0.9

Depth	Cation exchange capacity		pH	Depth to bedrock (cm)	
(cm)	$\bar{X}$	SE	$\bar{X}$	$\bar{X}$	SE
0-10	13.9	2.5	4.4	41.7	9.0
10-30	12.3	2.2	4.6		
30-50	10.6	3.1	4.6		

[a]Values presented are means with one standard error.

TABLE B.6. SOIL CHEMICAL ANALYSIS, WELLSTON, 2 TO 5% SLOPE UNIT, CAMP BRANCH WATERSHED[a]

Depth	Chemical content (μg/g)								Percent organic matter	
	Total-N		Total-P		Total-K		Total-S			
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	1192.8	73.7	225.8	9.5	783.0	42.5	200.8	22.7	3.40	0.15
10-30	567.8	25.6	199.9	7.4	864.4	40.3	152.6	10.8	1.30	0.08
30-50	452.2	19.7	210.4	8.7	938.5	49.3	136.0	10.6	0.77	0.05
50-70	366.9	18.1	219.2	10.9	966.9	78.8	126.3	8.5	0.49	0.01
70-100	328.5	17.4	276.4	20.5	991.9	66.7	86.0	23.0	0.37	0.05

Depth	Chemical content (μg/g)									
	Exchangeable-Ca		Exchangeable-Mg		Exchangeable-K		Exchangeable-S		Exchangeable-P	
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	97.3	4.9	21.3	1.9	57.5	2.8	31.9	1.7	9.4	0.5
10-30	103.3	5.3	18.6	2.4	47.9	2.0	35.2	1.9	5.6	0.3
30-50	106.6	4.9	31.1	3.2	52.8	2.6	40.9	2.5	4.2	0.3
50-70	107.6	5.7	48.3	4.9	50.0	2.7	39.4	3.1	2.9	0.3
70-100	119.8	11.1	49.6	6.1	54.0	5.7	37.0	3.5	2.2	0.2

Depth	Cation exchange capacity		pH	Depth to bedrock (cm)	
(cm)	$\bar{X}$	SE	$\bar{X}$	$\bar{X}$	SE
0-10	11.6	0.5	4.3	102.9	3.8
10-30	8.8	0.4	4.5		
30-50	8.3	0.3	4.7		
50-70	8.7	0.4	4.8		
70-100	10.2	0.5	4.9		

[a]Values presented are means with one standard error.

APPENDIX C

SOIL CHEMICAL ANALYSIS FOR CROSS CREEK MAPPING UNITS

TABLE C.1. SOIL CHEMICAL ANALYSIS, COTACO, 0 TO 3% SLOPE UNIT, CROSS CREEK WATERSHED[a]

Depth	Chemical content (μg/g)								Percent organic matter	
	Total-N		Total-P		Total-K		Total-S			
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	1506.6	89.8	293.3	23.3	4500.0	360.5	193.3	12.0	3.16	0.14
10-30	706.6	18.5	240.0	5.7	5800.0	264.5	226.7	8.8	1.56	0.06
30-50	630.0	150.1	280.0	20.0	5033.3	959.7	190.0	11.6	1.10	0.40
50-70	360.0	10.0	145.0	5.0	7100.0	400.0	155.0	5.0	0.70	0.01
70-100	280.0	50.0	125.0	5.0	7350.0	650.0	205.0	5.0	0.60	0.01

Depth	Chemical content (μg/g)									
	Exchangeable-Ca		Exchangeable-Mg		Exchangeable-K		Exchangeable-S		Exchangeable-P	
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	230.6	66.2	23.3	4.3	66.3	7.6	16.4	1.2	11.3	1.4
10-30	75.3	19.6	13.0	2.0	41.6	2.6	22.7	6.1	5.0	1.5
30-50	77.3	7.3	19.3	5.8	47.3	3.7	26.5	6.0	4.3	2.8
50-70	119.5	0.5	58.5	5.5	60.5	2.5	35.3	0.4	1.0	0.1
70-100	75.5	13.5	60.5	2.5	60.0	0.1	34.3	3.2	1.0	0.1

Depth	Cation exchange capacity		pH	Depth to bedrock (cm)	
(cm)	$\bar{X}$	SE	$\bar{X}$	$\bar{X}$	SE
0-10	10.1	0.2	5.0	90.0	10.0
10-30	7.3	0.4	4.7		
30-50	7.0	0.5	4.8		
50-70	6.1	1.0	5.0		
70-100	6.7	0.3	4.9		

[a]Values presented are means with one standard error.

TABLE C.2. SOIL CHEMICAL ANALYSIS, HARTSELLS, 2 TO 5% SLOPE UNIT, CROSS CREEK WATERSHED[a]

Depth (cm)	Chemical content (μg/g) Total-N $\bar{X}$	Total-N SE	Total-P $\bar{X}$	Total-P SE	Total-K $\bar{X}$	Total-K SE	Total-S $\bar{X}$	Total-S SE	Percent organic matter $\bar{X}$	Percent organic matter SE
0-10	972.0	40.4	174.0	12.8	4120.0	677.7	142.0	13.6	2.78	0.14
10-30	486.0	26.7	138.0	3.7	3960.0	227.1	176.0	20.6	1.34	0.08
30-50	397.5	23.5	210.0	7.0	3750.0	409.2	205.0	35.2	0.77	0.06
50-70	315.0	15.5	122.5	13.1	4175.0	154.7	175.0	33.3	0.65	0.05
70-100	257.5	18.4	137.5	16.5	4000.0	270.8	217.5	48.7	0.65	0.02

Depth (cm)	Chemical content (μg/g) Exchangeable-Ca $\bar{X}$	Exchangeable-Ca SE	Exchangeable-Mg $\bar{X}$	Exchangeable-Mg SE	Exchangeable-K $\bar{X}$	Exchangeable-K SE	Exchangeable-S $\bar{X}$	Exchangeable-S SE	Exchangeable-P $\bar{X}$	Exchangeable-P SE
0-10	98.8	12.1	11.6	1.2	46.0	2.2	12.2	0.9	6.6	0.6
10-30	54.2	9.6	10.0	1.7	34.0	3.7	11.4	0.9	4.0	0.7
30-50	72.2	14.6	18.5	4.2	47.7	4.7	24.2	6.0	1.7	0.4
50-70	102.2	22.6	44.2	13.8	55.7	8.2	43.7	13.9	1.2	0.2
70-100	76.7	14.2	56.0	10.0	53.0	6.4	51.0	13.0	1.2	0.2

Depth (cm)	Cation exchange capacity $\bar{X}$	Cation exchange capacity SE	pH $\bar{X}$	Depth to bedrock (cm) $\bar{X}$	Depth to bedrock (cm) SE
0-10	7.4	0.2	4.6	67.8	12.5
10-30	5.4	0.3	4.8		
30-50	6.7	0.4	4.7		
50-70	5.6	0.8	4.8		
70-100	8.2	1.0	4.9		

[a]Values presented are means with one standard error.

TABLE C.3. SOIL CHEMICAL ANALYSIS, HARTSELLS, 5 TO 12% SLOPE UNIT, CROSS CREEK WATERSHED[a]

Depth	Chemical content (μg/g)								Percent organic matter	
	Total-N		Total-P		Total-K		Total-S			
(cm)	X̄	SE	X̄	SE	X̄	SE	X̄	SE	X̄	SE
0-10	1046.3	54.1	181.4	5.7	3907.4	116.8	373.0	103.2	2.82	0.11
10-30	502.5	16.4	159.6	5.9	4662.9	98.7	171.9	7.2	1.40	0.04
30-50	418.4	10.1	177.2	8.7	5076.0	185.9	203.2	9.2	0.76	0.04
50-70	290.4	12.3	164.3	12.0	4500.0	151.9	180.9	10.6	0.62	0.03
70-100	245.0	13.3	143.5	7.7	4485.0	187.2	158.0	8.6	0.87	0.27

Depth	Chemical content (μg/g)									
	Exchangeable-Ca		Exchangeable-Mg		Exchangeable-K		Exchangeable-S		Exchangeable-P	
(cm)	X̄	SE	X̄	SE	X̄	SE	X̄	SE	X̄	SE
0-10	130.1	13.9	14.2	1.1	48.1	2.1	12.7	0.6	8.7	0.5
10-30	80.4	11.9	13.3	1.9	35.8	1.7	12.3	0.7	4.8	0.6
30-50	111.6	13.0	38.3	8.3	46.3	2.7	21.8	3.0	2.0	0.3
50-70	113.8	8.9	75.0	10.4	69.3	8.5	32.6	4.3	1.3	0.1
70-100	80.3	6.6	68.0	8.5	48.5	2.5	32.3	2.0	1.5	0.1

Depth	Cation exchange capacity		pH	Depth to bedrock (cm)	
(cm)	X̄	SE	X̄	X̄	SE
0-10	8.0	0.3	4.6	84.9	3.1
10-30	5.6	0.2	4.8		
30-50	7.0	0.2	4.8		
50-70	6.9	0.4	4.9		
70-100	7.1	0.4	5.0		

[a]Values presented are means with one standard error.

TABLE C.4. SOIL CHEMICAL ANALYSIS, HARTSELLS, 5 TO 12% SLOPE ERODED UNIT, CROSS CREEK WATERSHED[a]

Depth (cm)	Chemical content (μg/g): Total-N		Total-P		Total-K		Total-S		Percent organic matter	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	800.0	-[b]	150.0	-	3500.0	-	200.0	-	2.50	-
10-30	440.0	-	190.0	-	3500.0	-	110.0	-	0.80	-
30-50	330.0	-	190.0	-	3800.0	-	270.0	-	0.40	-
50-70	310.0	-	140.0	-	3400.0	-	230.0	-	0.60	-
70-100	230.0	-	130.0	-	5800.0	-	140.0	-	0.70	-

Depth (cm)	Chemical content (μg/g): Exchangeable-Ca		Exchangeable-Mg		Exchangeable-K		Exchangeable-S		Exchangeable-P	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	70.0	-	7.0	-	38.0	-	9.9	-	7.0	-
10-30	51.0	-	9.0	-	21.0	-	7.4	-	4.0	-
30-50	116.0	-	13.0	-	39.0	-	2.9	-	3.0	-
50-70	92.0	-	47.0	-	57.0	-	53.0	-	1.0	-
70-100	161.0	-	24.0	-	30.0	-	4.0	-	3.0	-

Depth (cm)	Cation exchange capacity		pH	Depth to bedrock (cm)	
	$\bar{X}$	SE	$\bar{X}$	$\bar{X}$	SE
0-10	6.8	-	4.6	100.0	-
10-30	3.9	-	4.9		
30-50	6.1	-	5.3		
50-70	6.3	-	4.9		
70-100	6.6	-	4.9		

[a]Values presented are means with one standard error.
[b]Indicates only one sample collected.

TABLE C.5. SOIL CHEMICAL ANALYSIS, JEFFERSON, 5 TO 12% SLOPE UNIT, CROSS CREEK WATERSHED[a]

Depth	Chemical content (µg/g)								Percent organic matter	
	Total-N		Total-P		Total-K		Total-S			
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	900.0	90.0	210.0	50.0	4150.0	250.0	220.0	20.0	2.60	0.30
10-30	500.0	60.0	150.0	20.0	5700.0	200.0	205.0	55.0	1.20	0.10
30-50	265.0	145.0	220.0	50.0	7650.0	1850.0	215.0	5.0	0.80	0.10
50-70	280.0	-[b]	70.0	-	5000.0	-	120.0	-	0.50	-
70-100	260.0	-	180.0	-	6500.0	-	170.0	-	0.50	-

Depth	Chemical content (µg/g)									
	Exchangeable-Ca		Exchangeable-Mg		Exchangeable-K		Exchangeable-S		Exchangeable-P	
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	52.5	6.5	11.0	0.1	44.0	5.0	17.8	1.3	8.0	1.0
10-30	60.0	0.0	6.0	0.1	43.5	3.5	17.2	1.6	3.0	1.0
30-50	64.0	15.0	27.0	19.0	41.0	9.0	40.7	15.7	2.5	1.5
50-70	96.0	-	30.0	-	43.0	-	44.7	-	1.0	-
70-100	80.0	-	43.0	-	48.0	-	40.3	-	1.0	-

Depth	Cation exchange capacity		pH	Depth to bedrock (cm)	
(cm)	$\bar{X}$	SE	$\bar{X}$	$\bar{X}$	SE
0-10	8.5	1.5	4.7	70.0	20.0
10-30	8.2	0.1	4.5		
30-50	8.4	2.2	4.8		
50-70	6.7	-	4.6		
70-100	12.7	-	4.7		

[a]Values presented are means with one standard error.
[b]Indicates only one sample collected.

TABLE C.6. SOIL CHEMICAL ANALYSIS, LINKER, 5 TO 12% SLOPE UNIT, CROSS CREEK WATERSHED[a]

Depth	Chemical content (μg/g)								Percent organic matter	
	Total-N		Total-P		Total-K		Total-S			
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	1000.0	-[b]	150.0	-	2300.0	-	150.0	-	2.20	-
10-30	410.0	-	270.0	-	3100.0	-	180.0	-	1.00	-

Depth	Chemical content (μg/g)									
	Exchangeable-Ca		Exchangeable-Mg		Exchangeable-K		Exchangeable-S		Exchangeable-P	
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	141.0	-	100.0	-	31.0	-	9.9	-	7.0	-
10-30	86.0	-	10.0	-	35.0	-	6.4	-	2.0	-

Depth	Cation exchange capacity		pH	Depth to bedrock (cm)	
(cm)	$\bar{X}$	SE	$\bar{X}$	$\bar{X}$	SE
0-10	6.1	-	4.9	30.0	-
10-30	3.9	-	4.8		

[a]Values presented are means with one standard error.
[b]Indicates only one sample collected.

TABLE C.7. SOIL CHEMICAL ANALYSIS, MUSKINGUM, 12 TO 25% SLOPE UNIT, CROSS CREEK WATERSHED[a]

Depth	Chemical content (μg/g)								Percent organic matter	
	Total-N		Total-P		Total-K		Total-S			
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	1395.0	116.5	241.1	18.3	4527.8	238.6	211.7	12.7	3.61	0.30
10-30	673.9	59.8	202.8	15.2	5400.0	295.3	208.9	10.4	1.82	0.10
30-50	443.8	21.0	197.6	17.8	5607.6	339.7	186.9	10.4	0.79	0.01
50-70	286.0	25.7	185.0	17.8	7430.0	1448.8	160.0	14.8	0.60	0.02
70-100	227.1	34.2	234.2	65.3	8285.7	2261.4	188.6	32.6	0.58	0.04

Depth	Chemical content (μg/g)									
	Exchangeable-Ca		Exchangeable-Mg		Exchangeable-K		Exchangeable-S		Exchangeable-P	
(cm)	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
0-10	153.4	43.9	17.3	1.0	57.0	2.6	17.5	17.5	9.1	1.0
10-30	108.7	26.9	12.2	1.4	42.6	1.7	14.6	1.7	5.0	0.5
30-50	109.8	32.2	24.3	5.4	45.0	3.9	24.7	5.2	2.1	0.2
50-70	107.6	26.2	48.3	10.2	58.8	5.5	31.6	7.0	1.1	0.1
70-100	101.4	33.6	53.2	10.6	59.8	9.8	30.4	8.0	1.8	0.5

Depth	Cation exchange capacity		pH	Depth to bedrock (cm)	
(cm)	$\bar{X}$	SE	$\bar{X}$	$\bar{X}$	SE
0-10	10.3	0.7	5.2	69.8	7.7
10-30	6.2	0.3	5.2		
30-50	6.4	0.4	5.3		
50-70	5.7	0.1	5.2		
70-100	6.6	0.5	5.2		

[a]Values presented are means with one standard error.

APPENDIX D

COVER, NUMBER, AND DENSITY VALUES BY SPECIES FOR EACH COVER TYPE ON THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

TABLE D.1. MEAN COVER, PERCENT COVER, NUMBER, PERCENT NUMBER, DENSITY, AND FREQUENCY VALUES FOR THE UPLAND OAK-MIXED HARDWOOD COVER TYPE ON CAMP BRANCH WATERSHED

Species	Cover (cm^2/ha)	Percent cover	Number	Percent number	Density	Frequency
Scarlet oak	43,784.4	22.2	155	8.8	0.0155	68
Post oak	40,833.0	20.7	120	6.9	0.0120	68
Black oak	29,710.1	15.0	322	18.4	0.0322	86
White oak	16,006.9	8.1	199	12.3	0.0199	59
Sourwood	15,763.4	8.0	206	12.7	0.0206	59
Hickory	12,602.8	6.4	41	2.3	0.0041	58
Blackjack oak	8,168.6	4.1	41	2.3	0.0041	25
Virginia pine	7,053.0	3.5	26	1.4	0.0026	19
Chestnut oak	6,161.9	3.1	32	1.8	0.0032	13
Southern red oak	4,170.6	2.1	95	5.4	0.0095	41
Red maple	3,739.9	1.9	114	6.5	0.0114	40
Dogwood	3,137.0	1.6	121	6.9	0.0121	43
Black gum	3,052.1	1.5	106	6.0	0.0106	52
Sassafras	2,469.3	1.2	165	8.6	0.0165	61
Yellow poplar	198.9	0.1	2		0.0002	1
Hawthorn	69.1	0.03	2		0.0002	1
Blueberry	55.1	0.02	3	0.17	0.0003	2
Red cedar	34.0	0.01	1	0.05	0.00007	1
Persimmon	16.0	F0.01	1	0.05	0.0001	5
Total	197,026.1		1752			

TABLE D.2. MEAN COVER, PERCENT COVER, NUMBER, PERCENT NUMBER, DENSITY, AND FREQUENCY VALUES FOR THE UPLAND OAK-MIXED HARDWOOD COVER TYPE ON CAMP BRANCH WATERSHED

Species	Cover (cm^2/ha)	Percent cover	Number	Percent number	Density	Frequency
White oak	79,335.0	36.2	319	20.6	0.031	89
Hickory	52,665.4	24.1	120	7.7	0.012	62
Black oak	24,358.8	11.1	69	4.5	0.006	42
Dogwood	17,317.3	7.9	362	23.4	0.036	92
Black gum	15,163.8	6.9	150	9.7	0.015	65
Red maple	11,665.8	5.3	254	16.4	0.025	66
Sourwood	6,796.5	3.1	123	7.9	0.012	54
Scarlet oak	6,358.5	2.9	8	0.5	0.0008	8
Yellow poplar	2,655.0	1.2	69	4.5	0.007	27
Chestnut oak	2,038.5	0.9	23	1.5	0.002	23
Sassafras	924.2	0.4	38	2.5	0.004	31
Wild cherry	147.7	0.1	4	0.2	0.0004	4
Serviceberry	75.4	0.3	8	0.5	0.0008	4
Total	219,501.9		1547			

TABLE D.3. MEAN COVER, PERCENT COVER, NUMBER, PERCENT NUMBER, DENSITY, AND FREQUENCY VALUES FOR THE UPLAND OAK-MIXED HARDWOOD COVER TYPE ON CAMP BRANCH WATERSHED

Species	Cover (cm^2/ha)	Percent cover	Number	Percent number	Density	Frequency
Loblolly pine	1,078,080.0	88.7	1000	24	0.100	100
Sassafras	110,310.0	9.0	1300	31	0.130	100
Sourwood	7,535.0	0.6	100	2	0.010	100
Black gum	5,350.0	0.4	350	8	0.035	100
Persimmon	5,100.0	0.4	450	11	0.045	100
Dogwood	4,500.0	0.3	350	8	0.035	100
Tulip poplar	1,815.0	0.1	50	1	0.005	-
Hackberry	1,145.0	0.09	50	1	0.005	-
Chokecherry	980.0	0.08	50	1	0.005	-
Red maple	900.0	0.07	450	11	0.045	-
Cedar	76.5	0.006	50	1	0.005	-
Box elder	40.0	0.003	50	1	0.005	-
Total	1,215,831.5		4250			

TABLE D.4. MEAN COVER, PERCENT COVER, NUMBER, PERCENT NUMBER, DENSITY, AND FREQUENCY VALUES FOR THE UPLAND OAK-MIXED HARDWOOD COVER TYPE ON CAMP BRANCH WATERSHED

Species	Cover (cm^2/ha)	Percent cover	Number	Percent number	Density	Frequency
White oak	41,721.9	18.9	240	11.6	0.0240	78.2
Hickory	35,317.0	16.0	143	6.9	0.0143	66.2
Chestnut oak	31,544.1	14.3	150	7.3	0.0150	51.8
Black oak	28,383.7	12.9	104	5.0	0.0104	53.6
Scarlet oak	27,769.6	12.6	49	2.4	0.0049	32.4
Sourwood	13,981.8	6.4	310	15.0	0.0310	84.2
Red maple	13,751.0	6.2	434	21.0	0.0434	78.2
Black gum	8,622.9	3.9	149	7.2	0.0149	61.2
Dogwood	7,246.7	3.3	214	10.4	0.0214	61.4
Post oak	4,041.4	1.8	9	0.4	0.0009	6.8
Sassafras	2,494.0	1.1	120	5.8	0.0120	42.8
Yellow poplar	2,034.3	0.9	14	0.7	0.0014	8.2
Mountain laurel	775.7	0.4	77	3.7	0.0077	15.6
Shortleaf pine	748.7	0.3	3	0.2	0.0003	0.4
American holly	548.5	0.03	5	0.2	0.0005	2.2
Post x White oak	465.8	0.2	2	0.1	0.0002	1.6
Witch hazel	188.0	0.09	13	0.6	0.0013	3.2
Chestnut x White oak	150.4	0.07	1	0.05	0.00004	0.4
American beech	150.2	0.07	1	0.05	0.0001	0.4
Serviceberry	125.4	0.06	7	0.3	0.0007	5.0
Persimmon	118.8	0.05	7	0.3	0.0007	5.4
Black locust	39.9	0.02	2	0.1	0.0002	1.6
Wild cherry	21.6	0.01	1	0.05	0.0001	1.0
American chestnut	16.2	0.01	1	0.05	0.0001	0.6
Red cedar	14.6	0.01	2	0.1	0.0002	1.2
Virginia pine	13.5	0.01	1	0.05	0.00002	0.2
White pine	11.2	0.01	1	0.05	0.0001	0.6
Sparkleberry	10.3	0.005	1	0.05	0.0001	0.8
Stewartia	10.1	0.005	1	0.05	0.0001	1.4
Azalea	8.9	0.004	1	0.05	0.0001	0.6
Smooth sumac	8.2	0.003	1	0.05	0.0001	0.6
Loblolly pine	5.9	0.003	1	0.05	0.00002	0.2
Wild grape	2.7	0.001	1	0.05	0.00002	0.2
Total	220,343.0	2066				

TABLE D.5. MEAN COVER, PERCENT COVER, NUMBER, PERCENT NUMBER, DENSITY, AND FREQUENCY VALUES FOR THE UPLAND OAK-MIXED HARDWOOD COVER TYPE ON CAMP BRANCH WATERSHED

Species	Cover (cm^2/ha)	Percent cover	Number	Percent number	Density	Frequency
Red maple	47,889.3	44.7	376	31.5	0.038	95
White oak	23,937.9	22.4	199	16.7	0.020	69
Black gum	17,837.3	16.7	272	22.9	0.027	76
Yellow poplar	5,378.4	5.0	122	10.3	0.012	49
Southern red oak	3,898.9	3.6	21	1.8	0.002	13
Post oak	3,625.4	3.4	20	1.7	0.002	13
Sourwood	2,913.2	2.7	113	9.5	0.011	46
Sweet gum	1,140.4	1.1	36	3.0	0.004	12
Hemlock	180.3	0.02	1	0.08	0.0001	1
Dogwood	144.3	0.1	9	0.7	0.0009	9
Hickory	121.0	0.1	7	0.6	0.0007	5
Virginia pine	68.2	0.01	2	0.2	0.0002	1
Black oak	64.9	0.06	1	0.08	0.0001	1
Blueberry	28.9	0.02	4	0.3	0.0004	2
Scarlet oak	20.0	0.02	1	0.08	0.0001	1
Alder	14.4	0.01	2	0.20	0.0002	2
Azalea	7.2	0.006	1	0.08	0.0001	1
American holly	7.2	0.006	1	0.08	0.0001	1
Sassafras	7.2	0.006	1	0.08	0.0001	1
Total	107,104.1		1189			

TABLE D.6. MEAN COVER, PERCENT COVER, NUMBER, PERCENT NUMBER, DENSITY, AND FREQUENCY VALUES FOR THE UPLAND OAK-MIXED HARDWOOD COVER TYPE ON CAMP BRANCH WATERSHED

Species	Cover (cm^2/ha)	Percent cover	Number	Percent number	Density	Frequency
Virginia pine	327,535.0	78.3	1220	39.6	0.122	100
Dogwood	38,870.0	9.3	770	25.1	0.077	90
Red maple	23,733.0	5.7	680	22.2	0.068	100
Yellow poplar	18,034.0	4.3	80	2.6	0.008	40
Sourwood	7,736.0	1.8	280	9.1	0.028	30
Red cedar	2,270.0	0.5	20	0.5	0.002	10
Black gum	212.0	0.05	30	0.9	0.003	30
Total	418,390.0		3080			

APPENDIX E

BIOMASS AND ELEMENT CONCENTRATION BY SPECIES OF BRANCHES, BOLE, HEARTWOOD, SAPWOOD, AND BARK FOR OVERSTORY SPECIES FROM THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

TABLE E.1. BIOMASS AND ELEMENT CONCENTRATION BY SPECIES OF BRANCHES, BOLE, HEARTWOOD, SAPWOOD, AND BARK FOR OVERSTORY SPECIES FROM THE CAMP BRANCH WATERSHED AS DETERMINED BY WHOLE TREE HARVEST

Species	DBH[a] (cm)	Component	Weight (kg)	Concentration (μg/g)					
				N	S	P	K	Mg	Ca
Blackjack oak	6.8	Heart	3.9	1,400	160	30	600	231	2,000
		Sap	3.8	1,800	280	70	1,030	280	2,800
		Bark	0.9	4,700	560	180	1,190	360	14,900
		Limbs	1.2	3,800	420	130	210	400	6,000
	11.4	Heart	17.9	1,500	90	20	1,510	400	2,000
		Sap	17.0	2,500	220	130	2,000	510	1,600
		Bark	4.1	4,600	270	160	800	280	14,000
		Limbs	17.5	5,500	420	390	1,620	690	5,100
	20.9	Heart	49.0	1,700	140	50	3,000	280	2,400
		Sap	46.6	2,200	230	140	2,620	260	2,000
		Bark	11.2	3,800	270	140	1,030	250	20,500
		Limbs	51.4	5,000	320	360	1,490	480	10,100
Black oak	7.8	Heart	7.1	1,200	60	10	400	30	1,000
		Sap	6.8	1,800	160	100	410	130	1,600
		Bark	1.6	4,600	380	230	720	350	19,900
		Limbs	3.9	5,000	270	320	1,890	540	9,100
	14.8	Heart	42.4	1,000	80	10	300	20	1,000
		Sap	40.3	1,600	170	90	600	100	300
		Bark	9.7	3,900	230	170	530	290	13,300
		Limbs	15.3	5,200	300	420	1,810	800	6,000
	21.6	Heart	155.3	1,200	60	20	320	60	1,100
		Sap	147.6	1,300	130	50	400	80	500
		Bark	35.4	3,400	260	160	600	290	16,000
		Limbs	53.2	5,000	290	290	1,400	620	9,100

Table E.1 (continued)

Species	DBH[a] (cm)	Component	Weight (kg)	Concentration (μg/g) N	S	P	K	Mg	Ca
Chestnut oak	6.4	Heart	4.8	1,200	60	20	780	20	1,900
		Sap	4.6	1,900	180	120	500	160	3,800
		Bark	1.1	4,200	340	190	710	560	18,000
		Limbs	1.5	5,100	530	350	2,130	540	9,100
	14.3	Heart	33.5	1,100	50	10	680	30	1,000
		Sap	31.9	1,800	150	100	610	120	1,200
		Bark	7.7	3,800	320	480	1,110	390	15,300
		Limbs	18.3	5,300	430	400	1,920	890	10,900
	20.5	Heart	80.4	1,200	50	20	800	30	1,000
		Sap	76.4	2,000	150	140	1,270	170	1,200
		Bark	18.3	4,900	330	270	1,030	480	15,600
		Limbs	41.4	5,900	370	560	2,390	1,120	9,000
Hickory	6.6	Heart	2.3	1,700	160	80	1,400	1,500	8,000
		Sap	7.9	1,800	160	80	700	490	4,100
		Bark	0.6	4,600	490	240	1,300	950	36,000
		Limbs	1.6	4,100	250	270	1,310	910	18,300
	8.5	Heart	3.3	1,500	110	40	1,230	1,100	1,500
		Sap	11.2	1,700	110	80	800	390	4,300
		Bark	0.9	4,400	420	200	810	570	27,900
		Limbs	1.8	4,300	270	350	1,910	1,000	22,000
	10.9	Heart	7.0	1,300	60	30	500	1,090	3,200
		Sap	23.8	1,900	150	90	700	580	2,400
		Bark	1.8	4,900	380	290	1,410	1,800	25,800
		Limbs	8.4	5,700	340	390	2,500	1,090	12,700

Table E.1 (continued)

Species	DBH[a] (cm)	Component	Weight (kg)	Concentration (μg/g)					
				N	S	P	K	Mg	Ca
Post oak	6.8	Heart	4.3	1,600	200	10	400	180	1,900
		Sap	4.0	2,700	350	130	600	300	4,600
		Bark	1.0	5,600	810	160	820	580	16,000
		Limbs	1.6	5,400	630	280	1,090	620	4,900
	9.8	Heart	11.8	1,500	140	50	980	250	1,900
		Sap	11.2	2,300	170	130	810	270	1,300
		Bark	2.7	6,800	940	270	1,090	800	21,900
		Limbs	8.0	5,300	480	320	1,210	600	4,900
	24.5	Heart	76.7	1,300	120	20	390	140	1,300
		Sap	72.9	1,900	190	120	980	230	2,400
		Bark	17.5	4,500	770	130	900	690	34,000
		Limbs	47.6	6,900	570	500	1,700	900	6,100
Red maple	8.9	Heart	5.8	1,100	30	90	490	140	2,000
		Sap	19.8	1,500	70	150	500	140	2,100
		Bark	1.5	4,600	340	350	1,680	400	21,800
		Limbs	5.9	5,800	380	550	2,110	590	8,900
	13.2	Heart	10.9	1,200	60	90	1,490	220	1,800
		Sap	37.1	1,700	170	180	420	180	1,400
		Bark	2.9	5,400	270	370	910	300	8,100
		Limbs	11.0	7,000	480	620	2,300	520	4,000
	19.7	Heart	22.3	1,200	40	70	480	170	2,000
		Sap	76.1	1,400	150	100	310	130	900
		Bark	5.8	4,500	260	310	1,910	440	11,800
		Limbs	34.8	4,100	320	360	1,680	530	5,900

Table E.1 (continued)

Species	DBH[a] (cm)	Component	Weight (kg)	Concentration (μg/g)					
				N	S	P	K	Mg	Ca
Sourwood	5.1	Heart	-	-	-	-	-	-	-
		Sap	2.6	1,600	130	120	510	150	1,400
		Bark	0.2	5,600	520	270	790	410	13,700
		Limbs	1.4	3,200	170	240	690	970	4,200
	9.1	Heart	4.6	1,300	160	70	500	190	1,800
		Sap	15.8	1,500	150	100	490	110	800
		Bark	1.2	4,900	460	210	570	320	7,200
		Limbs	5.7	4,500	380	330	1,200	410	4,900
	20.9	Heart	26.5	1,500	50	70	570	230	1,200
		Sap	90.4	1,100	130	70	400	150	400
		Bark	7.0	4,600	460	170	430	330	6,300
		Limbs	27.6	4,000	350	300	1,000	460	6,900
Southern red oak	6.5	Heart	4.5	1,400	90	20	1,810	160	2,100
		Sap	4.3	3,400	320	140	1,300	240	2,400
		Bark	1.0	4,700	610	190	900	260	16,000
		Limbs	2.2	4,800	410	390	1,530	440	6,000
	9.5	Heart	12.7	1,300	80	10	350	120	1,700
		Sap	12.1	1,900	180	100	1,190	190	2,000
		Bark	2.9	4,500	330	220	1,300	330	15,100
		Limbs	3.9	5,800	320	440	6,800	630	8,000
	14.4	Heart	28.5	1,300	60	10	590	130	1,100
		Sap	27.1	1,800	320	133	90	1,060	230
		Bark	6.5	3,300	180	150	830	300	13,000
		Limbs	9.3	5,600	410	430	1,310	610	7,200

Table E.1 (continued)

Species	DBH[a] (cm)	Component	Weight (kg)	Concentration (μg/g)					
				N	S	P	K	Mg	Ca
Tulip poplar	6.4	Heart	-	-	-	-	-	-	-
		Sap	10.1	1,700	180	110	390	320	2,900
		Bark	1.4	5,300	340	440	390	320	15,200
		Limbs	1.7	4,400	300	350	2,430	900	6,000
	15.9	Heart	16.1	1,400	60	20	330	160	2,000
		Sap	54.8	1,100	180	100	510	190	1,700
		Bark	4.2	5,500	370	450	2,450	1,100	12,600
		Limbs	20.2	3,800	280	360	1,800	680	4,800
	24.2	Heart	51.2	1,000	30	20	330	160	2,000
		Sap	174.6	1,300	160	110	390	160	1,300
		Bark	13.4	3,900	290	280	1,900	1,100	11,700
		Limbs	36.5	4,500	240	390	2,310	800	5,000
White oak	7.8	Heart	7.1	1,200	80	20	590	100	2,000
		Sap	6.8	2,300	190	140	580	210	7,200
		Bark	1.6	4,600	610	230	710	330	48,000
		Limbs	3.8	5,200	290	360	800	420	10,000
	9.3	Heart	8.5	1,500	70	10	400	170	2,000
		Sap	8.1	1,900	160	120	910	190	3,500
		Bark	1.9	4,700	350	250	1,090	520	33,000
		Limbs	4.2	5,000	310	270	9,800	370	6,000
	21.4	Heart	67.7	1,200	80	30	990	80	1,100
		Sap	64.4	2,200	230	110	1,090	170	1,200
		Bark	15.4	4,500	350	240	920	280	38,900
		Limbs	41.4	5,300	440	380	1,510	390	10,000

[a]Diameter at breast height.

TABLE E.2. BIOMASS AND ELEMENT CONCENTRATION BY SPECIES OF BRANCHES, BOLE, HEARTWOOD, SAPWOOD, AND BARK FOR OVERSTORY SPECIES FROM THE CROSS CREEK WATERSHED AS DETERMINED BY WHOLE TREE HARVEST

Species	DBH[a] (cm)	Component	Weight (kg)	Concentration (mg/g)					
				N	S	P	K	Mg	Ca
Black gum	5.4	Heart	1.5	1,400	120	70	1,190	530	1,100
		Sap	5.2	1,700	240	150	670	400	3,100
		Bark	0.4	5,400	900	310	1,100	2,390	31,000
		Limbs	1.2	3,900	400	330	1,900	730	8,200
Black oak	5.7	Heart	3.0	1,400	70	50	810	300	1,900
		Sap	2.9	1,800	240	100	620	300	3,700
		Bark	0.7	4,500	360	190	1,000	360	23,000
		Limbs	0.6	4,000	410	260	1,060	540	11,900
	7.1	Heart	6.5	1,100	110	10	380	230	800
		Sap	6.2	1,700	380	120	1,130	160	1,000
		Bark	1.5	3,300	300	200	1,360	330	20,900
		Limbs	1.9	3,900	490	250	1,120	500	9,200
	9.5	Heart	15.5	1,300	100	10	770	200	1,000
		Sap	14.7	1,900	400	140	1,710	340	1,800
		Bark	3.5	3,800	230	190	930	450	30,100
		Limbs	18.5	4,400	340	290	1,500	610	9,100
	11.0	Heart	25.9	1,800	210	185	70	710	200
		Sap	24.6	1,700	200	110	620	110	1,200
		Bark	5.9	4,300	300	250	790	410	24,000
		Limbs	11.2	5,500	410	410	1,850	1,240	10,000
	13.2	Heart	26.9	1,000	100	10	320	220	800
		Sap	25.6	1,700	270	90	710	130	1,000
		Bark	6.1	4,400	260	200	1,500	470	29,100
		Limbs	10.9	5,000	360	300	1,210	470	10,000

Table E.2 (continued)

Species	DBH[a] (cm)	Component	Weight (kg)	Concentration (mg/g) N	S	P	K	Mg	Ca
Chestnut oak	4.0	Heart							
		Sap	3.5	1,800	230	110	700	200	2,800
		Bark	0.3	4,400	440	270	1,280	560	20,000
		Limbs	0.6	5,500	500	510	1,190	750	13,900
	7.2	Heart	5.5	1,400	90	20	540	56	2,000
		Sap	5.3	2,200	260	180	910	290	3,100
		Bark	1.3	4,200	420	180	800	570	24,100
		Limbs	2.8	5,300	450	530	1,300	720	14,000
	10.3	Heart	18.8	1,200	60	20	890	42	1,500
		Sap	17.9	2,000	270	170	780	250	3,000
		Bark	4.3	4,200	380	180	720	510	30,400
		Limbs	7.9	5,100	480	520	1,090	680	11,800
	16.9	Heart	54.5	900	60	20	670	20	1,500
		Sap	51.8	1,800	430	100	1,110	180	900
		Bark	12.4	3,700	210	190	1,190	570	18,000
		Limbs	21.7	4,900	450	390	1,330	780	900
	20.4	Heart	70.6	1,200	110	20	890	210	800
		Sap	67.1	2,000	210	450	1,290	180	1,000
		Bark	16.1	3,600	250	230	1,230	550	18,700
		Limbs	35.6	5,700	490	410	1,670	870	12,000
Hickory	2.9	Heart							
		Sap	1.8	1,600	220	90	800	360	4,000
		Bark	0.2	4,200	490	220	1,010	570	24,900
		Limbs	0.3	3,700	740	250	1,310	650	11,000

Table E.2 (continued)

Species	DBH[a] (cm)	Component	Weight (kg)	Concentration (mg/g)					
				N	S	P	K	Mg	Ca
	4.2	Heart	0.6	1,100	70	20	790	210	800
		Sap	2.1	1,700	200	110	890	160	2,100
		Bark	0.2	4,300	300	240	1,670	670	20,900
		Limbs	1.0	4,100	420	260	1,030	800	8,900
	6.0	Heart	2.1	1,400	140	70	780	1,000	2,000
		Sap	7.1	1,700	690	70	580	480	2,300
		Bark	0.6	4,800	530	250	1,050	610	32,200
		Limbs	1.5	5,700	510	400	1,960	840	17,200
	6.5	Heart	2.7	1,300	70	70	690	810	1,800
		Sap	9.1	1,800	240	80	470	560	4,000
		Bark	0.7	4,400	450	230	1,030	490	32,900
		Limbs	1.8	4,000	540	260	1,610	520	12,100
	15.0	Heart	16.2	1,700	100	30	1,530	850	2,900
		Sap	55.3	1,700	300	60	720	680	4,900
		Bark	4.3	4,000	380	220	1,000	820	34,800
		Limbs	7.8	4,300	390	280	1,400	860	17,000
Red maple	6.8	Heart	3.0	1,100	80	40	310	610	4,900
		Sap	10.2	1,400	220	120	500	150	1,300
		Bark	0.8	4,800	270	350	1,390	380	13,900
		Limbs	2.5	3,000	160	300	630	340	5,400
	9.3	Heart	5.7	1,300	70	90	880	400	1,000
		Sap	19.5	1,600	140	160	960	180	1,000
		Bark	1.5	4,800	320	330	1,500	300	10,900
		Limbs	8.6	4,400	360	320	1,200	320	6,900

Table E.2 (continued)

Species	DBH[a] (cm)	Component	Weight (kg)	Concentration (mg/g) N	S	P	K	Mg	Ca
	13.8	Heart	14.8	1,400	80	110	930	400	1,000
		Sap	50.5	1,400	260	140	1,180	190	1,000
		Bark	3.9	4,600	180	370	1,490	420	11,800
		Limbs	15.7	4,300	350	410	1,610	470	6,000
	17.1	Heart	17.6	1,000	50	30	490	153	2,100
		Sap	60.1	1,100	110	100	400	130	1,000
		Bark	4.6	4,100	270	349	1,790	380	12,300
		Limbs	23.4	5,200	330	550	1,700	410	8,300
	19.3	Heart	23.2	1,100	70	40	500	160	2,000
		Sap	79.0	1,400	110	130	520	120	1,000
		Bark	6.1	4,500	310	380	2,100	280	16,900
		Limbs	24.8	6,200	360	730	2,000	400	7,800
Sourwood	6.7	Heart	2.3	1,200	68	70	590	360	900
		Sap	8.0	1,400	120	120	900	160	800
		Bark	0.6	3,800	610	240	700	390	7,100
		Limbs	1.6	3,500	380	270	1,030	480	6,300
	10.1	Heart	5.0	1,400	70	130	900	430	1,000
		Sap	17.0	1,800	200	180	1,110	250	1,000
		Bark	1.3	5,700	700	240	530	290	9,200
		Limbs	4.2	4,200	290	380	1,110	610	8,100
	12.0	Heart	5.4	1,100	60	90	690	380	900
		Sap	18.4	1,600	200	160	510	230	900
		Bark	1.4	5, 30	550	210	500	310	6,000
		Limbs	8.2	5,000	450	340	1,060	540	6,000

Table E.2 (continued)

Species	DBH[a] (cm)	Component	Weight (kg)	Concentration (mg/g)					
				N	S	P	K	Mg	Ca
	14.0	Heart	13.4	1,200	100	70	700	120	1,600
		Sap	45.6	1,200	80	90	390	110	800
		Bark	3.5	4,700	500	210	610	360	7,400
		Limbs	10.4	4,600	350	360	1,030	490	7,900
	16.0	Heart	15.5	1,200	60	100	560	181	1,600
		Sap	52.8	1,700	130	150	590	170	600
		Bark	4.1	4,700	430	210	580	330	6,900
		Limbs	11.2	3,700	300	260	910	430	3,300
White oak	4.3	Heart	1.7	1,300	70	20	200	300	1,900
		Sap	1.6	1,800	160	100	510	220	6,000
		Bark	0.4	6,800	570	330	1,020	390	38,000
		Limbs	0.5	4,100	460	250	790	1,150	10,200
	7.4	Heart	5.1	1,200	80	10	300	200	1,200
		Sap	4.9	2,300	530	130	540	90	5,100
		Bark	1.2	5,000	490	280	1,100	200	36,200
		Limbs	1.9	5,000	360	330	1,330	230	12,300
	9.2	Heart	10.1	1,200	80	10	200	200	1,000
		Sap	9.6	1,600	220	110	800	140	1,300
		Bark	2.3	4,600	420	210	1,290	340	33,100
		Limbs	2.4	3,900	400	240	700	300	6,800
	14.4	Heart	22.0	1,300	100	10	680	370	800
		Sap	20.9	2,000	240	140	1,490	310	1,700
		Bark	5.0	4,100	250	210	1,090	560	40,000
		Limbs	9.0	5,000	530	360	1,600	550	8,900

Table E.2 (continued)

Species	DBH[a] (cm)	Component	Weight (kg)	Concentration (mg/g)					
				N	S	P	K	Mg	Ca
	21.9	Heart	7.0	1,200	70	10	1,320	59	2,000
		Sap	6.7	1,700	160	160	620	150	2,000
		Bark	1.6	4,200	300	220	1,100	340	31,000
		Limbs	32.7	6,300	540	560	1,500	560	8,100

[a]Diameter at breast height.

APPENDIX F

BELOW-GROUND BIOMASS VALUES BY COVER TYPE AND DEPTH FOR THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

TABLE F.1. BELOW-GROUND BIOMASS VALUES BY COVER TYPE AND DEPTH FOR THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

		Biomass (kg/ha)					
		Upland oak - mixed hardwoods		Mesophytic hardwoods		Pine	
Component	Depth (cm)	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek
Fibrous roots	0-10	15,464.1	18,445.2	19,328.9	19,790.0	9,878.8	19,950.8
	10-30	14,711.5	15,022.1	7,385.3	9,270.6	14,146.7	17,702.9
	30-50	6,253.8	10,646.3	6,392.9	13,494.5	2,775.4	11,913.0
	50-70	3,626.9	10,272.0	2,983.5	8,634.5	1,480.2	11,359.8
	70-100	3,801.5	9,868.0	2,171.0			1,566.5
Root crown		2,840.1	2,574.9	7,200.2	2,094.5	6,201.4	3,016.1
Total		46,697.9	66,828.5	45,461.8	53,284.1	34,482.5	65,509.1

APPENDIX G

NUTRIENT WEIGHT IN ABOVE-GROUND BIOMASS

TABLE G.1. WEIGHT OF CALCIUM IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Calcium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.40	2.41	1.68	2.69	7.18
Blackjack oak	1.18	1.35	2.20	2.32	7.05
Black oak	0.32	0.41	1.44	1.77	3.94
Chestnut oak	0.08	0.27	0.32	0.44	1.11
Dogwood	0.17	2.16	1.50	2.23	6.06
Laurel	0.00	0.17	0.12	0.14	0.43
Mockernut hickory	0.07	1.35	0.94	1.53	3.89
Pignut hickory	0.34	1.38	0.95	1.91	4.58
Post oak	12.81	22.00	42.47	24.73	102.01
Prunus	0.00	0.01	0.01	0.01	0.03
Red maple	1.38	4.45	3.51	6.08	15.42
Sassafras	0.04	1.32	0.92	1.24	3.52
Scarlet oak	24.52	38.37	78.79	77.44	219.12
Sourwood	2.41	5.99	5.21	11.17	24.78
Southern red oak	8.25	11.36	18.76	22.24	60.81
Tulip poplar	0.00	0.19	0.11	0.12	0.42
Virginia pine	1.18	2.98	2.07	4.66	10.89
White oak	1.61	9.64	13.48	7.25	31.98

TABLE G.2. WEIGHT OF MAGNESIUM IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Magnesium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.08	0.30	0.07	0.23	0.65
Blackjack oak	0.17	0.22	0.04	0.17	0.60
Black oak	0.01	0.05	0.03	0.14	0.23
Chestnut oak	<0.01	0.02	0.01	0.04	0.07
Dogwood	0.03	0.27	0.06	0.19	0.55
Laurel	0.00	0.02	0.01	0.01	0.04
Mockernut hickory	0.02	0.18	0.02	0.09	0.31
Pignut hickory	0.10	0.19	0.02	0.11	0.42
Post oak	1.43	2.12	1.22	3.30	8.02
Prunus	0.00	<0.01	<0.01	<0.01	<0.01
Red maple	0.13	0.46	0.10	0.53	1.22
Sassafras	0.01	0.17	0.04	0.11	0.33
Scarlet oak	2.10	3.63	1.51	6.22	13.46
Sourwood	0.34	0.95	0.20	1.28	2.77
Southern red oak	0.69	1.41	0.38	1.76	4.24
Tulip poplar	0.00	0.02	0.01	0.02	0.05
Virginia pine	0.23	0.38	0.09	0.40	1.10
White oak	0.11	0.46	0.13	0.33	1.03

TABLE G.3. WEIGHT OF NITROGEN IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Nitrogen (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.21	1.86	0.49	1.44	4.00
Blackjack oak	0.85	1.37	0.58	1.57	4.37
Black oak	0.35	0.80	0.35	1.11	2.61
Chestnut oak	0.07	0.24	0.08	0.25	0.64
Dogwood	0.09	1.67	0.44	1.19	3.39
Laurel	0.00	0.13	0.04	0.08	0.25
Mockernut hickory	0.03	0.68	0.15	0.41	1.27
Pignut hickory	0.12	0.69	0.15	0.51	1.47
Post oak	11.06	18.28	9.98	27.37	66.69
Prunus	0.00	0.01	<0.01	<0.01	0.01
Red maple	0.83	4.65	1.22	5.47	12.17
Sassafras	0.02	1.02	0.27	0.66	1.97
Scarlet oak	20.48	35.34	16.67	53.55	126.04
Sourwood	2.25	9.67	2.89	8.17	22.98
Southern red oak	6.74	15.22	5.32	17.00	44.28
Tulip poplar	0.00	0.13	0.04	0.09	0.26
Virginia pine	0.61	2.30	0.61	2.49	6.01
White oak	1.23	5.18	1.55	4.32	12.28

TABLE G.4. WEIGHT OF PHOSPHORUS IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Phosphorus (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.01	0.13	0.03	0.12	0.29
Blackjack oak	0.02	0.07	0.02	0.10	0.21
Black oak	<0.01	0.04	0.02	0.08	0.14
Chestnut oak	<0.01	0.02	0.01	0.02	0.05
Dogwood	<0.01	0.12	0.03	0.10	0.25
Laurel	0.00	0.01	<0.01	0.01	0.03
Mockernut hickory	<0.01	0.03	0.01	0.03	0.07
Pignut hickory	<0.01	0.03	0.01	0.04	0.08
Post oak	0.20	1.01	0.33	1.71	3.25
Prunus	0.00	<0.01	<0.01	<0.01	<0.01
Red maple	0.06	0.43	0.09	0.49	1.07
Sassafras	<0.01	0.07	0.02	0.05	0.14
Scarlet oak	0.33	1.91	0.78	3.71	6.73
Sourwood	0.11	0.67	0.12	0.61	1.51
Southern red oak	0.07	0.71	0.24	1.32	2.34
Tulip poplar	0.00	0.01	<0.01	0.01	0.02
Virginia pine	0.03	0.16	0.04	0.20	0.43
White oak	0.02	0.30	0.08	0.28	0.68

TABLE G.5. WEIGHT OF POTASSIUM IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Potassium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.11	0.62	0.14	0.55	1.42
Blackjack oak	0.94	1.19	0.13	0.36	2.62
Black oak	0.11	0.24	0.05	0.37	0.77
Chestnut oak	0.05	0.10	0.02	0.10	0.27
Dogwood	0.05	0.56	0.13	0.46	1.20
Laurel	0.00	0.04	0.01	0.03	0.08
Mockernut hickory	0.02	0.28	0.04	0.17	0.51
Pignut hickory	0.08	0.28	0.04	0.21	0.61
Post oak	4.45	6.34	1.66	6.22	18.67
Prunus	0.00	<0.01	<0.01	<0.01	<0.01
Red maple	0.50	1.24	0.38	1.97	4.09
Sassafras	0.01	0.34	0.08	0.25	0.68
Scarlet oak	12.81	17.02	3.34	19.99	53.16
Sourwood	0.86	3.22	0.34	2.02	6.44
Southern red oak	4.63	7.61	1.29	4.74	18.27
Tulip poplar	0.00	0.04	0.02	0.05	0.11
Virginia pine	0.33	0.77	0.17	0.96	2.23
White oak	0.63	2.09	0.31	3.38	6.41

TABLE G.6. WEIGHT OF SULFUR IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Sulfur (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.01	0.18	0.04	0.10	0.33
Blackjack oak	0.07	0.15	0.05	0.13	0.40
Black oak	0.10	0.08	0.03	0.06	0.27
Chestnut oak	<0.01	0.02	0.01	0.02	0.05
Dogwood	0.01	0.16	0.03	0.08	0.28
Laurel	0.00	0.01	<0.01	0.01	0.02
Mockernut hickory	<0.01	0.05	0.01	0.02	0.08
Pignut hickory	0.01	0.05	0.01	0.03	0.10
Post oak	1.15	1.88	1.49	2.61	7.13
Prunus	0.00	<0.01	<0.01	<0.01	<0.01
Red maple	0.03	0.39	0.07	0.38	0.87
Sassafras	<0.01	0.10	0.02	0.05	0.17
Scarlet oak	1.52	3.58	1.62	4.07	10.79
Sourwood	0.17	0.94	0.28	0.63	2.02
Southern red oak	0.39	1.76	0.48	1.20	3.83
Tulip poplar	0.00	0.02	<0.01	0.01	0.03
Virginia pine	0.04	0.22	0.05	0.17	0.48
White oak	0.10	0.47	0.15	0.29	1.01

TABLE G.7. WEIGHT OF SULFUR IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Sulfur (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	0.11	0.02	0.05	0.18
Black oak	0.14	0.25	0.13	0.25	0.77
Dogwood	0.12	1.77	0.39	0.99	3.27
Holly	0.00	<0.01	<0.01	<0.01	<0.01
Pignut hickory	0.00	0.12	0.03	0.06	0.21
Red cedar	0.04	0.26	0.06	0.19	0.55
Red maple	0.02	0.22	0.04	0.19	0.47
Sourwood	0.04	0.21	0.06	0.14	0.45
Southern red oak	0.29	1.05	0.33	0.83	2.50
Tulip poplar	0.24	2.93	0.47	1.81	5.45
Virginia pine	1.11	6.79	1.49	5.09	14.48
White oak	0.44	0.77	0.40	0.78	2.39

TABLE G.8. WEIGHT OF CALCIUM IN ABOVE-GROUND BIOMASS IN THE MESOPHYTIC HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Calcium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Ash	0.00	0.03	0.02	0.03	0.08
Azalea	0.00	0.61	0.47	0.49	1.57
Black gum	0.00	4.68	3.90	2.82	11.40
Black oak	12.93	21.35	70.01	77.94	182.23
Chestnut oak	1.14	2.73	4.88	5.60	14.35
Crataegus	0.00	0.02	0.01	0.01	0.04
Dogwood	0.00	4.75	3.71	5.01	13.47
Hickory	5.14	31.54	22.10	44.15	102.93
Red maple	0.00	3.04	3.15	4.53	10.72
Sassafras	0.00	<0.01	<0.01	<0.01	<0.01
Sourwood	0.00	1.17	0.87	2.14	4.18
Tulip poplar	0.00	0.02	0.02	0.02	0.06
White oak	12.57	30.15	75.67	54.81	173.20

TABLE G.9. WEIGHT OF MAGNESIUM IN ABOVE-GROUND BIOMASS IN THE MESOPHYTIC HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Magnesium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Ash	0.00	<0.01	<0.01	<0.01	<0.01
Azalea	0.00	0.09	0.02	0.03	0.14
Black gum	0.00	0.60	0.30	0.25	1.15
Black oak	2.70	2.55	1.11	5.22	11.58
Chestnut oak	0.06	0.28	0.12	0.40	0.86
Crataegus	0.00	<0.01	<0.01	<0.01	<0.01
Dogwood	0.00	0.69	0.12	0.32	1.13
Hickory	1.97	4.08	0.48	2.45	8.98
Red maple	0.00	0.44	0.08	0.26	0.78
Sassafras	0.00	<0.01	<0.01	<0.01	<0.01
Sourwood	0.00	0.26	0.04	0.17	0.47
Tulip poplar	0.00	<0.01	<0.01	<0.01	<0.01
White oak	2.06	1.70	0.78	3.30	7.84

TABLE G.10. WEIGHT OF NITROGEN IN ABOVE-GROUND BIOMASS IN THE MESOPHYTIC HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Nitrogen (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Ash	0.00	0.03	0.01	0.01	0.05
Azalea	0.00	0.50	0.13	0.25	0.88
Black gum	0.00	2.57	0.68	1.34	4.59
Black oak	15.52	21.60	11.18	35.40	83.70
Chestnut oak	0.92	2.48	0.88	2.82	7.10
Crataegus	0.00	0.01	<0.01	0.01	0.02
Dogwood	0.00	3.95	0.99	2.49	7.43
Hickory	3.77	15.49	3.29	14.54	37.09
Red maple	0.00	3.96	1.09	3.04	8.09
Sassafras	0.00	<0.01	<0.01	<0.01	<0.01
Sourwood	0.00	2.20	0.58	1.42	4.20
Tulip poplar	0.00	0.02	<0.01	0.01	0.03
White oak	11.29	17.60	10.48	28.76	68.13

TABLE G.11. WEIGHT OF PHOSPHORUS IN ABOVE-GROUND BIOMASS IN THE MESOPHYTIC HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Phosphorus (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Ash	0.00	<0.01	<0.01	<0.01	<0.01
Azalea	0.00	0.04	0.01	0.02	0.07
Black gum	0.00	0.23	0.04	0.11	0.38
Black oak	0.35	1.37	0.57	2.34	4.63
Chestnut oak	0.02	0.26	0.05	0.25	0.58
Crataegus	0.01	<0.01	<0.01	<0.01	<0.01
Dogwood	0.00	0.30	0.06	0.20	0.56
Hickory	0.13	0.75	0.18	0.97	2.03
Red maple	0.00	0.37	0.08	0.30	0.75
Sassafras	0.00	<0.01	<0.01	<0.01	<0.01
Sourwood	0.00	0.20	0.03	0.11	0.34
Tulip poplar	0.00	<0.01	<0.01	<0.01	<0.01
White oak	0.11	1.20	0.53	2.06	3.90

TABLE G.12. WEIGHT OF POTASSIUM IN ABOVE-GROUND BIOMASS IN THE MESOPHYTIC HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Potassium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Ash	0.00	0.01	<0.01	<0.01	0.02
Azalea	0.00	0.24	0.03	0.08	0.35
Black gum	0.00	1.01	0.14	0.65	1.80
Black oak	7.03	11.75	3.07	10.53	32.38
Chestnut oak	0.59	1.21	0.23	0.70	2.73
Crataegus	0.00	0.01	<0.01	<0.01	0.01
Dogwood	0.00	1.85	0.24	0.77	2.86
Hickory	2.60	6.31	0.87	4.88	14.66
Red maple	0.00	2.04	0.40	0.94	3.38
Sassafras	0.00	<0.01	<0.01	0.00	<0.01
Sourwood	0.00	1.11	0.07	0.35	1.53
Tulip poplar	0.00	0.01	<0.01	<0.01	0.01
White oak	4.92	7.42	2.38	7.01	21.73

TABLE G.13. WEIGHT OF SULFUR IN ABOVE-GROUND BIOMASS IN THE MESOPHYTIC HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Sulfur (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Ash	0.00	<0.01	<0.01	<0.01	<0.01
Azalea	0.00	0.07	0.01	0.02	0.10
Black gum	0.00	0.36	0.11	0.14	0.61
Black oak	1.39	3.66	0.80	3.12	8.97
Chestnut oak	0.06	0.35	0.07	0.25	0.73
Crataegus	0.00	<0.01	<0.01	<0.01	<0.01
Dogwood	0.00	0.55	0.10	0.23	0.88
Hickory	0.26	3.01	0.33	1.73	5.33
Red maple	0.00	0.48	0.06	0.21	0.75
Sassafras	0.00	<0.01	<0.01	<0.01	<0.01
Sourwood	0.00	0.21	0.07	0.12	0.40
Tulip poplar	0.00	<0.01	<0.01	<0.01	<0.01
White oak	0.73	2.45	0.86	2.71	6.75

TABLE G.14. WEIGHT OF CALCIUM IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Calcium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	0.73	0.61	0.36	1.70
Box elder	0.00	<0.01	<0.01	<0.01	<0.01
Cedar	0.00	0.01	<0.01	<0.01	0.02
Chokecherry	0.00	0.10	0.07	0.09	0.26
Dogwood	0.00	0.30	0.23	0.28	0.81
Hackberry	0.00	0.11	0.09	0.10	0.30
Persimmon	0.00	0.47	0.37	0.41	1.25
Red maple	0.00	0.04	0.04	0.04	0.12
Sassafras	1.33	10.63	8.30	13.81	34.07
Sourwood	0.00	0.43	0.32	0.79	1.54
Tulip poplar	0.00	0.19	0.15	0.19	0.53
Virginia pine	43.96	152.34	118.77	266.42	581.49

TABLE G.15. WEIGHT OF MAGNESIUM IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Magnesium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	0.09	0.05	0.03	0.17
Box elder	0.00	<0.01	<0.01	<0.01	<0.01
Cedar	0.00	<0.01	<0.01	<0.01	<0.01
Chokecherry	0.00	0.01	<0.01	0.01	0.02
Dogwood	0.00	0.04	0.01	0.02	0.07
Hackberry	0.00	0.02	<0.01	0.01	0.03
Persimmon	0.00	0.07	0.01	0.03	0.11
Red maple	0.00	0.01	<0.01	<0.01	0.01
Sassafras	0.34	1.55	0.27	0.87	3.03
Sourwood	0.00	0.10	0.01	0.06	0.17
Tulip poplar	0.00	0.03	<0.01	0.01	0.04
Virginia pine	11.33	22.17	3.83	16.88	54.21

TABLE G.16. WEIGHT OF NITROGEN IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Nitrogen (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	0.40	0.11	0.17	0.68
Box elder	0.00	<0.01	<0.01	<0.01	<0.01
Cedar	0.00	<0.01	<0.01	<0.01	0.01
Chokecherry	0.00	0.08	0.02	0.04	0.14
Dogwood	0.00	0.25	0.06	0.14	0.45
Hackberry	0.00	0.09	0.02	0.05	0.16
Persimmon	0.00	0.39	0.10	0.20	0.69
Red maple	0.00	0.05	0.01	0.03	0.09
Sassafras	0.98	8.85	2.20	6.86	18.89
Sourwood	0.00	0.81	0.21	0.53	1.55
Tulip poplar	0.00	0.16	0.04	0.09	0.29
Virginia pine	32.45	126.81	31.53	132.43	323.22

TABLE G.17. WEIGHT OF PHOSPHORUS IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Phosphorus (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	0.04	0.01	0.01	0.06
Box elder	0.00	<0.01	<0.01	<0.01	<0.01
Cedar	0.00	<0.01	<0.01	<0.01	<0.01
Chokecherry	0.00	0.01	<0.01	<0.01	0.01
Dogwood	0.00	0.02	<0.01	0.01	0.03
Hackberry	0.00	0.01	<0.01	<0.01	0.02
Persimmon	0.00	0.03	0.01	0.02	0.06
Red maple	0.00	<0.01	<0.01	<0.01	0.01
Sassafras	0.05	0.68	0.13	0.56	1.42
Sourwood	0.00	0.07	0.01	0.04	0.12
Tulip poplar	0.00	0.01	<0.01	0.01	0.02
Virginia pine	1.78	9.74	1.85	10.81	24.18

TABLE G.18. WEIGHT OF POTASSIUM IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Potassium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	0.16	0.02	0.08	0.26
Box elder	0.00	<0.01	<0.01	<0.01	<0.01
Cedar	0.00	<0.01	<0.01	<0.01	<0.01
Chokecherry	0.00	0.04	<0.01	0.01	0.06
Dogwood	0.00	0.12	0.02	0.04	0.18
Hackberry	0.00	0.04	0.01	0.02	0.07
Persimmon	0.00	0.18	0.02	0.06	0.26
Red maple	0.00	0.03	0.01	0.01	0.05
Sassafras	0.60	4.14	0.54	2.11	7.39
Sourwood	0.00	0.41	0.03	0.13	0.57
Tulip poplar	0.00	0.07	0.01	0.03	0.11
Virginia pine	19.80	59.23	7.68	40.74	127.45

TABLE G.19. WEIGHT OF SULFUR IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Sulfur (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	0.06	0.18	0.02	0.26
Box elder	0.00	<0.01	<0.01	<0.01	<0.01
Cedar	0.00	<0.01	<0.01	<0.01	<0.01
Chokecherry	0.00	0.01	<0.01	<0.01	0.02
Dogwood	0.00	0.04	0.01	0.01	0.06
Hackberry	0.00	0.01	<0.01	<0.01	0.02
Persimmon	0.00	0.05	0.01	0.02	0.08
Red maple	0.00	0.01	<0.01	<0.01	0.01
Sassafras	0.09	1.23	0.21	0.62	2.15
Sourwood	0.00	0.08	0.02	0.04	0.14
Tulip poplar	0.00	0.02	<0.01	0.01	0.03
Virginia pine	3.12	17.67	3.06	12.02	35.87

TABLE G.20. WEIGHT OF CALCIUM IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Calcium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
American chestnut	0.00	<0.01	<0.01	<0.01	<0.01
Ash	0.69	2.37	1.84	4.48	9.38
Azalea	0.00	0.23	0.18	0.18	0.59
Beech	0.00	<0.01	<0.01	<0.01	<0.01
Black gum	0.15	4.54	3.78	3.16	11.63
Black oak	16.95	29.13	93.08	106.04	245.20
Chestnut oak	8.78	14.93	32.59	44.41	100.71
Crab apple	0.00	<0.01	<0.01	<0.01	<0.01
Dogwood	0.18	2.75	2.15	3.30	8.38
Hickory	3.78	22.92	16.07	33.40	76.17
Laurel	0.00	0.02	0.02	0.02	0.06
Mockernut hickory	0.58	3.58	2.51	5.18	11.85
Persimmon	0.00	0.11	0.09	0.11	0.31
Pignut hickory	1.58	9.25	6.48	14.49	31.80
Post oak	0.34	0.63	1.68	1.59	4.24
Red cedar	0.00	<0.01	<0.01	0.00	<0.01
Red maple	0.46	3.24	3.35	5.24	12.29
Sassafras	0.00	0.43	0.34	0.43	1.20
Sourwood	0.30	2.44	1.81	4.99	9.54
Sumac	0.00	<0.01	0.00	0.00	<0.01
Tulip poplar	0.00	0.01	0.01	0.01	0.03
Viburnum	0.00	<0.01	<0.01	<0.01	<0.01
Virginia pine	0.00	<0.01	<0.01	<0.01	<0.01
White ash	0.97	3.34	2.60	6.47	13.38
White oak	14.67	37.72	90.56	67.47	210.42

TABLE G.21. WEIGHT OF MAGNESIUM IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Magnesium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
American chestnut	0.00	<0.01	<0.01	<0.01	<0.01
Ash	0.18	0.34	0.06	0.28	0.86
Azalea	0.00	0.03	0.01	0.01	0.05
Beech	0.00	<0.01	<0.01	<0.01	<0.01
Black gum	0.07	0.59	0.29	0.28	1.23
Black oak	3.54	3.48	1.48	7.10	15.60
Chestnut oak	0.50	1.52	0.81	3.21	6.04
Crab apple	0.00	<0.01	<0.01	<0.01	<0.01
Dogwood	0.05	0.40	0.07	0.21	0.73
Hickory	1.45	2.97	0.35	1.85	6.62
Laurel	0.00	<0.01	<0.01	<0.01	<0.01
Mockernut hickory	0.22	0.46	0.05	0.29	1.02
Persimmon	0.00	0.02	<0.01	0.01	0.03
Pignut hickory	0.60	1.20	0.14	0.80	2.74
Post oak	0.05	0.05	0.03	0.11	0.24
Red cedar	0.00	<0.01	<0.01	<0.01	<0.01
Red maple	0.07	0.47	0.09	0.30	0.93
Sassafras	0.00	0.06	0.01	0.03	0.10
Sourwood	0.07	0.55	0.08	0.40	1.10
Sumac	0.00	<0.01	0.00	0.00	<0.01
Tulip poplar	0.00	<0.01	<0.01	<0.01	<0.01
Viburnum	0.00	<0.01	<0.01	<0.01	<0.01
Virginia pine	0.00	<0.01	<0.01	<0.01	<0.01
White ash	0.25	0.49	0.08	0.41	1.28
White oak	2.40	2.13	0.93	4.07	9.53

TABLE G.22. WEIGHT OF NITROGEN IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Nitrogen (kg/ha)				
	Heart	Sap	Bark	Branches	Total
American chestnut	0.00	<0.01	<0.01	<0.01	<0.01
Ash	0.51	2.00	0.49	2.23	5.23
Azalea	0.00	0.19	0.05	0.09	0.33
Beech	0.00	<0.01	<0.01	<0.01	<0.01
Black gum	0.20	2.49	0.66	1.50	4.85
Black oak	20.34	29.47	14.87	48.16	112.84
Chestnut oak	7.11	13.54	5.89	22.37	48.91
Crab apple	0.00	<0.01	<0.01	<0.01	<0.01
Dogwood	0.13	2.29	0.57	1.64	4.63
Hickory	2.77	11.26	2.39	11.00	27.42
Laurel	0.00	0.02	<0.01	0.01	0.03
Mockernut hickory	0.42	1.76	0.37	1.71	4.26
Persimmon	0.00	0.09	0.02	0.06	0.17
Pignut hickory	1.16	4.54	0.97	4.77	11.44
Post oak	0.33	0.49	0.26	0.79	1.87
Red cedar	0.00	<0.01	<0.01	<0.01	<0.01
Red maple	0.25	4.22	1.16	3.52	9.15
Sassafras	0.00	0.36	0.09	0.21	0.66
Sourwood	0.30	4.57	1.20	3.31	9.38
Sumac	0.00	<0.01	0.00	0.00	<0.01
Tulip poplar	0.00	0.01	<0.01	<0.01	0.02
Viburnum	0.00	<0.01	<0.01	<0.01	<0.01
Virginia pine	0.00	<0 01	<0.01	<0.01	<0.01
White ash	0.72	2.78	0.69	3.22	7.41
White oak	13.18	22.02	12.55	35.4	83.15

TABLE G.23. WEIGHT OF PHOSPHORUS IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Phosphorus (kg/ha)				
	Heart	Sap	Bark	Branches	Total
American chestnut	0.00	<0.01	<0.01	<0.01	<0.01
Ash	0.03	0.15	0.03	0.18	0.39
Azalea	0.00	0.01	<0.01	0.01	0.02
Beech	0.00	<0.01	<0.01	<0.01	<0.01
Black gum	0.01	0.22	0.04	0.13	0.39
Black oak	0.46	1.88	0.75	3.19	6.28
Chestnut oak	0.12	1.40	0.31	1.99	3.82
Crab apple	0.00	<0.01	<0.01	<0.01	<0.01
Dogwood	0.01	0.18	0.03	0.13	0.35
Hickory	0.10	0.54	0.13	0.73	1.50
Laurel	0.00	<0.01	<0.01	<0.01	<0.01
Mockernut hickory	0.01	0.08	0.02	0.11	0.22
Persimmon	0.00	0.01	<0.01	<0.01	0.02
Pignut hickory	0.04	0.22	0.05	0.32	0.63
Post oak	0.01	0.04	0.01	0.06	0.12
Red cedar	0.00	<0.01	<0.01	<0.01	<0.01
Red maple	0.01	0.40	0.09	0.35	0.85
Sassafras	0.00	0.03	0.01	0.02	0.06
Sourwood	0.02	0.42	0.05	0.25	0.74
Sumac	0.00	0.00	<0.01	0.00	<0.01
Tulip poplar	0.00	<0.01	<0.01	<0.01	<0.01
Viburnum	0.00	<0.01	<0.01	<0.01	<0.01
Virginia pine	0.00	<0.01	<0.01	<0.01	<0.01
White ash	0.04	0.21	0.04	0.26	0.55
White oak	0.13	1.50	0.63	2.53	4.79

TABLE G.24. WEIGHT OF POTASSIUM IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Potassium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
American chestnut	0.00	<0.01	<0.01	<0.01	<0.01
Ash	0.31	0.92	0.12	0.68	2.03
Azalea	0.00	0.09	0.01	0.03	0.13
Beech	0.00	<0.01	<0.01	<0.01	<0.01
Black gum	0.17	0.98	0.13	0.73	2.01
Black oak	9.21	16.04	4.09	14.3	43.64
Chestnut oak	4.52	6.62	1.53	5.56	18.23
Crab apple	0.00	<0.01	<0.01	<0.01	<0.01
Dogwood	0.08	1.07	1.14	0.50	2.79
Hickory	1.91	4.58	0.68	3.69	10.82
Laurel	0.00	0.01	<0.01	<0.01	0.01
Mockernut hickory	0.29	0.72	0.10	0.57	1.68
Persimmon	0.00	0.04	0.01	0.02	0.07
Pignut hickory	0.80	1.85	0.26	1.60	4.51
Post oak	0.16	0.24	0.07	0.21	0.68
Red cedar	0.00	<0.01	<0.01	0.00	<0.01
Red maple	0.13	2.17	0.42	1.09	3.81
Sassafras	0.00	0.17	0.02	0.07	0.26
Sourwood	0.17	2.31	0.14	0.81	3.43
Sumac	0.00	0.00	0.00	0.00	0.00
Tulip poplar	0.00	<0.01	<0.01	<0.01	<0.01
Viburnum	0.00	<0.01	<0.01	<0.01	<0.01
Virginia pine	0.00	<0.01	<0.01	<0.01	<0.01
White ash	0.44	1.30	0.17	0.99	2.90
White oak	5.74	9.28	2.84	8.62	26.48

TABLE G.25. WEIGHT OF SULFUR IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CROSS CREEK WATERSHED

Species	Sulfur (kg/ha)				
	Heart	Sap	Bark	Branches	Total
American chestnut	0.00	<0.01	<0.01	<0.01	<0.01
Ash	0.03	0.27	0.05	0.20	0.57
Azalea	0.00	0.03	0.01	0.01	0.05
Beech	<0.01	<0.01	<0.01	<0.01	<0.01
Black gum	0.02	0.35	0.11	0.15	0.63
Black oak	1.82	4.99	1.06	4.25	12.12
Chestnut oak	0.48	1.93	0.50	2.00	4.91
Crab apple	0.00	<0.01	<0.01	<0.01	<0.01
Dogwood	0.01	0.32	0.06	0.15	0.54
Hickory	0.19	2.19	0.24	1.31	3.93
Laurel	0.00	<0.01	<0.01	<0.01	<0.01
Mockernut hickory	0.03	0.34	0.04	0.20	0.61
Persimmon	0.00	0.01	<0.01	0.01	0.02
Pignut hickory	0.08	0.88	0.10	0.57	1.63
Post oak	0.02	0.07	0.02	0.07	0.18
Red cedar	0.00	<0.01	<0.01	<0.01	<0.01
Red maple	0.01	0.51	0.07	0.24	0.83
Sassafras	0.00	0.05	0.01	0.02	0.08
Sourwood	0.05	0.43	0.14	0.28	0.90
Sumac	0.00	<0.01	0.00	0.00	<0.01
Tulip poplar	0.00	<0.01	<0.01	<0.01	<0.01
Viburnum	0.00	0.00	<0.01	<0.01	<0.01
Virginia pine	0.00	<0.01	<0.01	<0.01	<0.01
White ash	0.07	0.39	0.07	0.29	0.82
White oak	0.85	3.07	1.03	3.34	8.29

TABLE G.26. WEIGHT OF CALCIUM IN ABOVE-GROUND BIOMASS IN THE UPLAND OAK-MIXED HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Calcium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	5.94	17.56	12.22	24.93	60.65
Dogwood	0.47	1.33	0.93	1.75	4.48
Laurel	0.00	0.02	0.02	0.02	0.06
Post oak	19.74	32.50	64.47	35.70	152.41
Prunus	0.00	0.01	0.01	0.01	0.03
Red maple	31.83	81.00	63.88	128.06	304.77
Sourwood	0.00	0.09	0.08	0.10	0.27
Southern red oak	0.00	<0.01	<0.01	<0.01	<0.01
Tulip poplar	21.68	69.36	38.63	74.17	203.84
Virginia pine	0.00	0.01	0.01	0.01	0.03
White oak	45.51	108.41	248.67	146.24	548.83

TABLE G.27. WEIGHT OF MAGNESIUM IN ABOVE-GROUND BIOMASS IN THE MESOPHYTIC HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Magnesium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	1.15	2.21	0.51	2.13	6.00
Dogwood	0.09	0.17	0.04	0.15	0.45
Laurel	0.00	<0.01	<0.01	<0.01	<0.01
Post oak	2.21	3.14	1.86	4.76	11.97
Prunus	0.00	<0.01	<0.01	<0.01	<0.01
Red maple	2.90	8.28	1.75	11.16	24.09
Sourwood	0.00	0.01	<0.01	0.01	0.02
Southern red oak	0.00	<0.01	<0.01	<0.01	<0.01
Tulip poplar	1.55	7.86	3.62	11.17	24.20
Virginia pine	0.00	<0.01	<0.01	<0.01	<0.01
White oak	3.13	5.19	2.35	6.63	17.30

TABLE G.28. WEIGHT OF NITROGEN IN ABOVE-GROUND BIOMASS IN THE MESOPHYTIC HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Nitrogen (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	3.09	13.56	3.59	13.33	33.57
Dogwood	0.24	1.03	0.27	0.93	2.47
Laurel	0.00	0.02	<0.01	0.01	0.04
Post oak	17.04	27.02	15.15	39.52	98.73
Prunus	0.00	0.01	<0.01	0.01	0.02
Red maple	19.22	84.65	22.21	115.13	241.21
Sourwood	0.00	0.14	0.04	0.07	0.25
Southern red oak	0.00	<0.01	<0.01	<0.01	<0.01
Tulip poplar	13.32	48.20	14.38	59.61	135.51
Virginia pine	0.00	0.01	<0.01	<0.01	0.02
White oak	34.80	58.29	28.62	87.19	208.90

TABLE G.29. WEIGHT OF PHOSPHORUS IN ABOVE-GROUND BIOMASS IN THE MESOPHYTIC HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Phosphorus (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.01	0.96	0.22	0.11	1.30
Dogwood	0.01	0.07	0.02	0.08	0.18
Laurel	0.00	<0.01	<0.01	<0.01	<0.01
Post oak	0.31	1.49	0.50	2.47	4.77
Prunus	0.00	<0.01	<0.01	<0.01	<0.01
Red maple	0.14	7.90	1.58	10.42	20.04
Sourwood	0.00	0.01	<0.01	0.01	0.02
Southern red oak	0.00	<0.01	<0.01	<0.01	<0.01
Tulip poplar	0.17	3.78	1.14	5.17	10.26
Virginia pine	0.00	<0.01	<0.01	<0.01	<0.01
White oak	0.54	3.36	14.9	5.69	11.08

TABLE G.30. WEIGHT OF POTASSIUM IN ABOVE-GROUND BIOMASS IN THE MESOPHYTIC HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Potassium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	1.69	4.54	1.02	5.11	12.36
Dogwood	0.13	0.34	0.08	0.36	0.91
Laurel	0.00	0.01	<0.01	<0.01	0.01
Post oak	6.85	9.36	2.52	8.98	27.71
Prunus	0.00	<0.01	<0.01	<0.01	0.01
Red maple	13.50	22.64	6.89	41.49	72.52
Sourwood	0.00	0.05	0.01	0.02	0.08
Southern red oak	0.00	<0.01	<0.01	<0.01	<0.01
Tulip poplar	3.11	15.16	6.55	30.70	55.52
Virginia pine	0.00	<0.01	<0.01	<0.01	<0.01
White oak	17.67	23.50	5.64	68.10	114.91

TABLE G.31. WEIGHT OF SULFUR IN ABOVE-GROUND BIOMASS IN THE MESOPHYTIC HARDWOOD COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Sulfur (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.18	1.29	0.28	0.90	2.65
Dogwood	0.01	0.10	0.02	0.06	0.19
Laurel	0.00	<0.01	<0.01	<0.01	<0.01
Post oak	1.78	2.78	2.26	3.77	10.59
Prunus	0.00	<0.01	<0.01	<0.01	<0.01
Red maple	0.71	7.18	1.33	8.03	17.25
Sourwood	0.00	0.01	<0.01	0.01	0.02
Southern red oak	0.00	<0.01	<0.01	<0.01	<0.01
Tulip poplar	0.50	6.10	0.98	3.84	11.42
Virginia pine	0.00	<0.01	<0.01	<0.01	<0.01
White oak	2.95	5.27	2.72	5.86	16.80

TABLE G.32. WEIGHT OF CALCIUM IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON CAMP BRANCH WATERSHED

Species	Calcium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	1.50	1.04	1.45	3.99
Black oak	2.17	5.12	11.80	6.19	25.28
Dogwood	3.90	24.16	16.83	27.23	72.12
Holly	0.00	<0.01	<0.01	<0.01	<0.01
Pignut hickory	0.00	3.04	2.11	3.42	8.57
Red cedar	1.46	3.58	2.49	5.25	12.78
Red maple	0.76	2.44	1.92	3.07	8.19
Sourwood	0.64	1.35	1.18	2.59	5.76
Southern red oak	6.19	6.77	12.91	15.45	41.32
Tulip poplar	10.52	33.36	18.58	34.86	97.32
Virginia pine	37.25	92.43	64.30	140.26	334.24
White oak	6.74	15.91	36.72	19.52	78.89

TABLE G.33. WEIGHT OF MAGNESIUM IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Magnesium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	0.19	0.04	0.12	0.35
Black oak	0.15	0.25	0.11	0.28	0.79
Dogwood	0.76	3.05	0.70	2.33	6.84
Holly	0.00	<0.01	<0.01	<0.01	<0.01
Pignut hickory	0.00	0.41	0.05	0.19	0.65
Red cedar	0.28	0.45	0.10	0.45	1.28
Red maple	0.07	0.25	0.05	0.27	0.64
Sourwood	0.09	0.21	0.05	0.30	0.65
Southern red oak	0.52	0.84	0.26	1.22	2.84
Tulip poplar	0.75	3.78	1.74	5.25	11.52
Virginia pine	7.21	11.65	2.67	11.99	33.52
White oak	0.46	0.76	0.35	0.89	2.46

TABLE G.34. WEIGHT OF NITROGEN IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Nitrogen (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	1.16	0.31	0.77	2.24
Black oak	1.66	2.75	1.36	3.69	9.46
Dogwood	2.03	18.66	4.95	14.56	40.20
Holly	0.00	<0.01	<0.01	<0.01	0.01
Pignut hickory	0.00	1.52	0.33	0.91	2.76
Red cedar	0.76	2.76	0.73	2.81	7.06
Red maple	0.46	2.55	0.67	2.76	6.44
Sourwood	0.59	2.18	0.65	1.89	5.31
Southern red oak	5.05	9.08	3.66	11.81	29.60
Tulip poplar	6.46	23.19	6.92	28.01	64.58
Virginia pine	19.36	71.37	18.89	75.01	184.63
White oak	5.16	8.56	4.23	11.64	29.59

TABLE G.35. WEIGHT OF PHOSPHORUS IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Phosphorus (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	0.08	0.02	0.06	0.16
Black oak	0.03	0.16	0.07	0.24	0.50
Dogwood	0.09	1.32	0.30	1.19	2.90
Holly	0.00	<0.01	<0.01	<0.01	<0.01
Pignut hickory	0.00	0.07	0.12	0.07	0.26
Red cedar	0.03	0.20	0.04	0.23	0.50
Red maple	0.03	0.24	0.05	0.25	0.57
Sourwood	0.03	0.15	0.03	0.14	0.35
Southern red oak	0.05	0.42	0.16	0.92	1.55
Tulip poplar	0.08	1.81	0.55	2.43	4.87
Virginia pine	0.84	5.05	1.16	6.11	13.16
White oak	0.08	0.49	0.22	0.76	1.55

TABLE G.36. WEIGHT OF POTASSIUM IN ABOVE-GROUND BIOMASS IN THE PINE COVER TYPE AS A FUNCTION OF SPECIES AND PLANT COMPONENT ON THE CAMP BRANCH WATERSHED

Species	Potassium (kg/ha)				
	Heart	Sap	Bark	Branches	Total
Black gum	0.00	0.39	0.09	0.30	0.78
Black oak	0.84	1.11	0.27	2.89	5.11
Dogwood	1.11	6.24	1.40	5.58	14.33
Holly	0.00	<0.01	<0.01	<0.01	<0.01
Pignut hickory	0.00	0.62	0.08	0.37	1.07
Red cedar	0.42	0.92	0.21	1.08	2.63
Red maple	0.32	0.68	0.21	0.99	2.20
Sourwood	0.23	0.73	0.08	0.47	1.51
Southern red oak	3.48	4.54	0.89	3.29	12.20
Tulip poplar	1.51	7.29	3.15	14.43	26.38
Virginia pine	10.59	23.87	5.36	28.76	68.58
White oak	2.62	3.45	0.83	9.09	15.99

APPENDIX H

NUTRIENT WEIGHT IN BELOW-GROUND BIOMASS

TABLE H.1. WEIGHT OF NITROGEN IN BELOW-GROUND BIOMASS AS A FUNCTION OF DEPTH AND COVER TYPE FOR THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

		Nitrogen (kg/ha)					
		Upland oak - mixed hardwoods		Mesophytic hardwoods		Pine	
Component	Depth (cm)	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek
Fibrous roots	0-10	98.8	131.0	120.7	128.5	67.1	132.7
	10-30	66.1	66.9	40.5	53.9	68.7	70.4
	30-50	24.8	57.7	26.5	69.2	15.3	56.5
	50-70	12.4	52.1	19.4	81.2	7.3	62.3
	70-100	14.8	47.4	18.5			9.1
Root crown		0.68	0.71	2.04	0.65	1.73	1.0
Total		217.6	355.8	227.6	333.5	160.1	332.0

TABLE H.2. WEIGHT OF NITROGEN IN BELOW-GROUND BIOMASS AS A FUNCTION OF DEPTH AND COVER TYPE FOR THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

		Sulfur (kg/ha)					
		Upland oak - mixed hardwoods		Mesophytic hardwoods		Pine	
Component	Depth (cm)	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek
Fibrous roots	0-10	11.4	15.4	13.5	16.2	10.3	15.2
	10-30	9.4	9.1	5.7	6.3	8.9	9.5
	30-50	3.6	6.5	4.8	8.0	1.7	6.3
	50-70	1.6	5.3	3.4	6.0	0.8	7.2
	70-100	1.8	5.6	2.6			0.7
Root crown		0.09	0.08	0.31	0.07	0.23	0.12
Total		27.9	42.0	30.3	36.6	21.9	39.0

TABLE H.3. WEIGHT OF NITROGEN IN BELOW-GROUND BIOMASS AS A FUNCTION OF DEPTH AND COVER TYPE FOR THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

		Phosphorus (kg/ha)					
		Upland oak - mixed hardwoods		Mesophytic hardwoods		Pine	
Component	Depth (cm)	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek
Fibrous roots	0-10	13.0	16.9	19.6	16.6	11.8	18.0
	10-30	8.4	11.1	4.4	8.5	12.7	13.3
	30-50	3.4	9.0	6.1	9.4	2.4	9.1
	50-70	1.5	7.7	2.4	12.7	1.1	10.4
	70-100	1.7	6.9	2.4			1.6
Root crown		0.89	0.11	0.32	0.09	0.30	0.19
Total		28.9	51.7	35.2	47.3	28.3	52.6

TABLE H.4. WEIGHT OF NITROGEN IN BELOW-GROUND BIOMASS AS A FUNCTION OF DEPTH AND COVER TYPE FOR THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

		Potassium (kg/ha)					
		Upland oak - mixed hardwoods		Mesophytic hardwoods		Pine	
Component	Depth (cm)	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek
Fibrous roots	0-10	9.1	16.3	16.4	15.0	11.8	12.9
	10-30	17.9	12.0	6.8	8.9	21.9	18.8
	30-50	7.0	8.8	5.6	20.0	6.3	9.0
	50-70	4.0	8.9	2.7	8.6	1.9	11.0
	70-100	5.8	7.9	2.6			5.5
Root crown		0.14	0.11	0.32	0.10	0.52	0.12
Total		43.9	54.0	34.4	52.6	42.4	57.3

TABLE H.5. WEIGHT OF NITROGEN IN BELOW-GROUND BIOMASS AS A FUNCTION OF DEPTH AND COVER TYPE FOR THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

		Magnesium (kg/ha)					
		Upland oak - mixed hardwoods		Mesophytic hardwoods		Pine	
Component	Depth (cm)	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek
Fibrous roots	0-10	7.4	12.4	15.7	14.3	7.5	12.7
	10-30	8.6	9.8	5.8	6.2	10.3	12.4
	30-50	3.6	7.0	4.1	10.5	2.3	8.0
	50-70	2.0	8.1	2.1	6.3	0.8	10.5
	70-100	1.8	5.4	1.1			0.9
Root crown		0.08	0.09	0.28	0.07	0.23	0.11
Total		23.5	42.8	29.1	37.4	21.1	44.6

TABLE H.6. WEIGHT OF NITROGEN IN BELOW-GROUND BIOMASS AS A FUNCTION OF DEPTH AND COVER TYPE FOR THE CAMP BRANCH AND CROSS CREEK WATERSHEDS

		Calcium (kg/ha)					
		Upland oak - mixed hardwoods		Mesophytic hardwoods		Pine	
Component	Depth (cm)	Camp Branch	Cross Creek	Camp Branch	Cross Creek	Camp Branch	Cross Creek
Fibrous root	0-10	29.0	79.1	39.5	79.1	25.1	105.0
	10-30	52.6	52.4	36.9	34.4	32.8	80.4
	30-50	16.6	38.6	14.9	61.6	10.2	60.9
	50-70	5.4	37.4	4.0	25.0	2.6	41.7
	70-100	4.8	19.7	4.1			2.8
Root crown		0.35	0.49	0.94	0.07	0.80	1.91
Total		108.8	227.7	100.3	200.2	71.5	292.7

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

This project is part of the EPA-planned and coordinated Federal Interagency Energy/Environment R&D Program.

16. ABSTRACT

Small experimental watersheds in the eastern United States, which define practical ecosystems, are used to study and evaluate (1) the impact of anthropogenic emissions on individual ecosystem processes and (2) the integrated response of the total system. The watershed approach to evaluating biochemical processes integrates several long- and short-term studies. This study evaluates chronic rather than acute effects. Therefore, two study areas were prepared so that an impacted area could be compared with a background area. The Cross Creek watershed has been subjected to about 30 years of sulfur and nitrogen input from the Widows Creek coal-fired power plant. The Camp Branch watershed, located in a relatively remote area, away from the influence of any major anthropogenic sulfur or nitrogen source, is being used to represent background conditions. A comparative study of these two sites will (1) contribute needed information on the cycling of chemical elements in natural systems and (2) enable construction of empirical models with which to predict the ecological effects of man's activities. This information can then be used in the legislative process to determine and promulgate atmospheric emission standards. The objectives of the project, the facilities that have been developed, and the ecological characteristics of each watershed are described.

17. (Circle One or More) KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Ecology Environments Earth Atmosphere Environmental Engineering Geography Hydrology, Limnology Biochemistry Earth Hydrosphere Combustion Refining Energy Conversion Physical Chemistry Materials Handling Inorganic Chemistry Organic Chemistry Chemical Engineering Other:	Control Technology: Energy Extraction Coal Cleaning Flue Gas Cleaning Direct Combustion Synthetic Fuels Nuclear Thermal Improved Efficiency Advanced Systems Processes & Effects: Transport Processes Ecological Effects Charac., Meas & Monit Health Effects Integrated Assessment Energy Cycle: Extraction Processing Conversion Utilization Fuel: Coal Oil/Gas Oil Shale Nuclear Geothermal Solar Waste as Fuel Hydroelectric Multi-fuel (5 or more) Other:	6F 8A 8F 8H 10A 10B 7B 7C 13B

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