THE PREDICTION OF SEDIMENT AND NUTRIENT TRANSPORT IN THE BUFFALO RIVER WATERSHED USING A GEOGRAPHIC INFORMATION SYSTEM

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CHARACTERIZATION OF THE SOILS, ELEVATIONS AND LANDUSE IN THE BUFFALO RIVER WATERSHED USING A GEOGRAPHIC INFORMATION SYSTEM

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INTRODUCTION

The Buffalo River was established by Congress in 1972 as the first National River in the United States. It is one of the few remaining free-flowing streams in northern Arkansas. The river originates in the higher elevations of the Boston Mountains in Newton County, and generally flows northeastward, intersecting the Springfield and Salem Plateaus as it drops from approximately 2000 feet in the headwaters to around 500 feet at the confluence with the White River in Marion County. It is considered by many to be one of Arkansas' greatest natural treasures, and therefore, there is strong interest in protecting it from undue influences of man. One of the best general descriptions of the area within the Buffalo River watershed was given by Smith (1967).

In recent years, there has been increased emphasis placed on maintaining the Buffalo National River in its natural state. Two principal activities of man that affect the water quality of the Buffalo River are the clearing of land within the watershed and increased recreational use on and around the river. These landuse changes and increased use of the area have resulted in increased potential of altering the water quality within the watershed. Landuse outside of the National Park boundaries, but still within the Buffalo River watershed should have a direct influence on water quality of the river.

Clearing of forest lands has removed mostly hardwood trees and converted the land to pasture. For optimum establishment, these pastures are well fertilized. One concern with the clearing activities is the potential erosion of soil from the cleared lands during the time between the clearing operations and the establishment of the forage.

This erosion can result in increased sediment loads in the streams within the watershed. Conversion of the forested lands to pasture may also lead to increased numbers of cattle which may contribute significantly to the non-point sources of pollution of the Buffalo River.

Recreational use of the Buffalo River has also increased dramatically. Pressures of increased use and activity around the river but still within the watershed have the potential of altering water quality. The addition of camp sites, dirt roads and paths, increased canoeing on the river, and the recreational use of adjacent lands results in additions of sediment, nutrients and bacteria to the river.

One of the best ways to assess landscape parameters affecting water quality in the Buffalo River Watershed is to develop accurate and complete digital databases linked with a Geographic Information System (GIS). Such databases are of invaluable use to state and federal agencies concerned with the Buffalo National River, and the impact of landuse within the watershed on water quality of the river.

LITERATURE REVIEW

There have been numerous reports of research studies conducted on the Buffalo River that relate to this work. In this report, we will review the previous work in only two areas: those that involved some aspect of the water quality of the Buffalo River and its tributaries, and those reports associated with archeological investigations along the Buffalo River.

Water Quality

A preliminary reconnaissance of the water quality of the Buffalo National River was conducted by the Arkansas Water Resources Center (AWRC) in 1973 and 1974 (Babcock and MacDonald, 1973; Babcock and MacDonald, 1975). In these reports are the results of several baseline studies on the physical, chemical and biological characteristics of the Buffalo River at several sampling stations along the river. The purpose of these studies was to survey several water quality characteristics of the Buffalo River before the expected increased pressures due to recreation. In the 1973 report, Parker found that concentrations of nitrate nitrogen, alkalinity, hardness, electrical conductivity, total solids orthophosphate were highest in the two downstream locations nearest the White River. He found that the total coliform count in the river at Jasper and at Mill Creek was relatively high. Nix collected 34 samples from a reconnaissance of the main portion of the river within a 5-day period in May 1973. The relatively high dissolved oxygen and low total organic carbon concentrations indicated that initial organic loading to the river was minimal.

The 1975 AWRC report states that the analyses indicated that with one exception the water quality of the Buffalo River was good. The one exception was the fecal contamination present in the river possibly caused by direct body contact through recreational use of the river, improper or inadequate sewage treatment facilities, or the absence of sanitary facilities in remote areas. The authors concluded that the chemistry of the Buffalo River seemed to be responsive to the geologic environment, and inflow during periods of runoff. Elemental concentration gradients were found along the river and the river responds to the particular geologic formation through which it flows. During periods of high flow and runoff, the river was heterogeneous with Na and K which were thought to originate in the watershed immediately adjacent to the river.

Parker and Strain (1978) examined the effects of cattle grazing and rainfall on the concentrations of fecal coliform within the Buffalo National River Park land. They found that fecal coliform concentrations in the Buffalo River were often greater than state water quality standards under certain rainfall and distance conditions such as (1) after rainfall events of 0.5 inches or greater, and (2) within 100 feet below areas that cattle had direct access to the stream. They found that fecal coliform concentrations were generally within state water quality standards at sampling stations below areas where the cattle were kept at least 50 feet from the stream, and where cattle do not have direct access to the stream within 5000 feet upstream from the sampling station. Within 36 hours after a rainfall event of 0.5 inches or more the fecal coliform concentrations were much higher than in those samples collected during dry weather. Within some tributaries of the Buffalo National River where livestock had direct access to streams, fecal coliform counts exceeded limits for class AA and A waters set by the Arkansas Department of Pollution Control and Ecology (Strain, 1977).

Mott and Steele (1991) reported on upstream and downstream sampling of the Buffalo River in the Boxley Valley. Higher fecal coliform and total Kjeldahl nitrogen (TKN), ammonium, and total phosphate were found at the downstream sampling site. These higher concentrations were associated with high rainfall events which resulted in the large volumes of flow. In general, they occurred during the winter season when vegetative ground cover was sparse, the cattle were present, or when there had been a relatively long dry period. The positive correlation between concentrations of fecal coliform organisms, ammonium and total phosphorus with discharge was greatest on the rising portion of the storm hydrograph. Concentrations of fecal coliform were better correlated with turbidity, TKN and total phosphate than with dissolved constituents suggesting that the fecal coliform were more likely associated with suspended solids than as free floating organisms. Average TKN concentrations for the waters draining from Boxley Valley were approximately two times greater than the background concentrations. The changes in fecal coliform and nutrient concentrations between the two sites were attributed to cattle grazing.

A 5-year report on the water quality of the Buffalo River was prepared for the National Park Service by Mott (1991). The summary spanned from 1985 to 1990. In the report, Mott states that "the Boxley Valley is the only area directly adjacent to the river corridor contributing measurable amounts of pollutants directly to the river. In most other cases, water quality impairment appears to result from the confluencing of more degraded tributaries with the river which have a higher percentage of agriculture." Public use areas were not found to directly contribute to water quality impairment. Mott concluded that the Buffalo River remains in a state of near pristine water quality.

Several water quality studies have been conducted on the nearby Beaver Lake Watershed which encompasses similar soils and geology in

Northwest Arkansas. Highly permeable soils overlying carbonate terrains have been shown to be highly susceptible to infiltration of pollutants in Northwest Arkansas (Steele and Adamski, 1987; MacDonald et al., 1976; Leidy and Morris, 1990; Steele and McCalister, 1991). In 1986, the Soil Conservation service estimated that non-point sources are responsible for 37% of total P entering Beaver Reservoir (SCS, 1986). Phosphorus is most often transported with sediment from non-point sources such as road surfaces, road banks and agricultural practices. When loading rates derived from monitoring natural runoff from selected landuse were compared, "sediment yield and total phosphorus loss was directly proportional to runoff" (Daniel et al., 1982). Digital databases of the soils, geology and landuse characteristics of the Beaver Lake Watershed were developed by Scott and McKimmey (1993), McKimmey and Scott (1994), and McKimmey (1994). The raster-based GIS software used in these studies was GRASS.

Archeological Investigations

Numerous archeological studies have been conducted along the Buffalo National River, particularly during the last 25 years. Klinger and Ayres (1989) examined the pre-historic archeological sites at the North Maumee Put-In area in north central Searcy County, north of Marshall and south of Yellville. Impacts of the planned development for recreational purposes included significant ground disturbance, river access ramps, parking lots and pit toilets as well as increased collector activities. They also summarized the extensive archeological work conducted within Searcy County by various state and federal agencies. A previous archeological inventory and summary report of the area was presented by Wolfman (1974).

The GIS software known as GRASS was used to aid in the archeological investigation of the Rush Development Area on the Buffalo National River (Sabo et al., 1990). Environmental parameters were characterized and an intersite analysis of aboriginal use of the Rush Locality was conducted.

OBJECTIVES

The objectives of this research were to: (1) develop digital databases for use by those concerned with the Buffalo River Watershed, (2) characterize selected attributes of the watershed, and (3) use the digital databases and GIS techniques to show examples of how they can be used as a working management tool for the watershed.

DEVELOPMENT OF THE DIGITAL DATABASES

The digital databases consist of spatially and/or temporally distributed attributes of the Buffalo River Watershed. The databases allow not only spatial characterization of natural and water resources and landuse within the watershed but also the identification of potential sources of sediment and nutrients within the watershed, and sites of particular interest such as towns, roads, streams and frequently used recreational areas.

This research project benefitted greatly from the two Water Resources Research projects on the Beaver Reservoir watershed (Scott and McKimmey, 1992; McKimmey and Scott, 1993). Techniques of scanning the soils were perfected during these research projects. In addition, ongoing work with incorporating computer simulation models into the GIS environment has been improved. The addition of the Buffalo National River Watershed digital databases means that three of the more important watersheds in northwest Arkansas have selected GIS databases completed, and thus, are ready for use by state and federal agencies.

The project involved entering the primary attributes of elevation, soils, and landuse of the Buffalo River Watershed into a GIS computer database. In addition, other attributes available for use in this project included hydrography, surficial geology and transportation. Areal statistics of each primary attribute were calculated to gain a quantitative description of the watershed. When the databases are completed a list of attribute occurrence at any location can be compiled, i.e. surficial geology, slope, soil mapping units and soil properties, proximity to other sites and areas of interest and landuse.

GIS Software

The GIS software used in this research is known by the acronym GRASS which stands for Geographical Resources Analysis Support System. GRASS was developed by the Army Corps of Engineers at Champaign, IL. It is public domain software and version 4.1 was installed on a SUN Sparcstation model 10. The Soil Physics group in the Department of Agronomy has extensive experience with this GIS software and has several recent publications and reports in which GRASS was used to characterize the landscape attributes of a watershed (Scott, et al. 1991; Scott et al. 1992; Smith and Scott, 1994).

Database Development and Characterization of the Study Area

One of the major concerns in the development of a GIS database is the precision and accuracy of the data. Data for the Buffalo River Watershed were acquired in a number of formats and scales from various sources. Discussion of each data layer's precision is presented under each heading.

Data currently available in digital format were acquired from the Center for Advanced Spatial Technologies (CAST). CAST has developed and acquired a statewide digital archive for Arkansas from a variety of sources such as U.S. Geological Survey (USGS) and Bureau of Census have been acquired and are maintained in a public data base system at CAST on the University of Arkansas campus. Data acquired from these sources were developed according to national standards of the source agency.

Combining primary and secondary data layers allows generation of yet more possible attributes such as the combination of slopes, hydrology and soil attributes. Once the primary attributes were input in digital form, secondary data attributes were developed by interrelating primary and other secondary attributes. These data were used to develop landscape characteristics of the Buffalo River watershed.

Elevation, Streams, and Park Boundary

Digital Elevation Models (DEMs) at a resolution of 30m were available for the entire study area. They were acquired as individual 7.5-min topographic quadrangles from the Arkansas databases maintained by CAST and originated from the USGS. Individual quadrangles were patched together and any gaps resolved to form a seamless coverage for the watershed. From the DEMs, additional data layers of slope and aspect were calculated using the GRASS module r.slope.aspect.

Hydrology data were also available through CAST from the USGS as Digital Line Graphs at a 1:100,000 scale. These digital data were added to the data base on the Buffalo River Watershed.

The Park Boundary was digitized from 1:24,000 scale 7.5 minute quadrangles on a previous research project of the Archeological Survey (Sabbo III et al., 1990). The file was acquired from the Archeological Survey and added to the database of the Buffalo River Watershed.

Soils

Soil mapping units were scanned at 400 dpi into the computer at a scale of 1:20,000 from one-third quadrangle format mylar soil maps compiled from orthophotographic bases. Source material was provided by the Soil Conservation Service (SCS) at Little Rock. Once scanned, the maps were edited using LTPlus. Soil lines were isolated from any additional information on the sheets such as roads and streams. Individual neatlines were removed, the one-third sheets patched together into full 7.5-min quadrangles and a computer generated neatline added. If the quadrangles encompassed areas crossing county boundaries, county lines digitized from 7.5-min quadrangles were patched. The assembled full soil quadrangle was then exported into GRASS for labeling. Individual quadrangles were plotted to check the quality and accuracy of both linework and labels. The quadrangles were then patched together to form a continuous soil coverage of the Buffalo River watershed. Each 7.5-min soil quadrangle exists as its own entity within the database as well as the patched version covering the total watershed. This scheme provides soil data in a format which matches nationally accepted boundaries, allows separate manipulation and combination of quadrangles, and adds to a detailed digital library of soil information for Arkansas.

From the primary data attributes, secondary data layers were generated to indicate areas of particular soil characteristics. For example, in conjunction with the SCS county soil survey publications, soil mapping units can be reclassified into, but not limited to, any of the following dominant soil series characteristics: texture, bulk density, pH, depth to bedrock, drainage, etc.

Landuse and Watershed Boundaries

Source material covering three time periods of landuse and watershed boundaries were furnished by the National Park Service at an approximate map scale of 1:48,000. The landuse maps were produced by photo-interpretation of uncontrolled aerial photography ranging in scale from 1:20,000 (1965-67), 1:40,000 and 1:80,000 (1974), to a Landsat Return Beam Vidiocon image (1977-79). The photo-interpreted polygons were then transferred to mylar overlays using a stereo zoom transfer scope to correct for distortion. The individual regional maps for each year were scanned, edited, and edge-matched across maps to produce a full coverage for the entire watershed. Because of the disparity of scales used for the three different periods of time, categories were collapsed, and transportation/utility interpretation accumulated to obtain uniform reporting across the years. The United States National Park Service compared the variations in area between years for the entire Buffalo River Watershed against the mean acreage for the entire watershed and found the resulting error of 0.09% of the total acreage

+/- 2 standard deviations to be acceptable (U.S. National Park Service Memorandum, 1981). The USGS landuse/landcover during 1972 was obtained in raster format at a 1:250,000 scale from CAST. These digital data were also included in the landuse database of the Buffalo River Watershed.

Human and Animal Population Statistics

Annual summaries of the cattle and hog populations in Newton, Searcy and Marion Counties were obtained with the assistance of Mr. Carroll Garner, Northwest Area Extension Economist. The summaries began in 1965 and continued until 1994. In addition, summaries of the human populations of these same counties were obtained on a decade basis beginning in 1950. These data were used to determine the temporal growth and decay relationships of these populations in the three counties.

RESULTS AND DISCUSSION

Physical Geography

The Buffalo National River Watershed consists of 857,607 acres and occupies all or a portion of 42 7.5-minute topographic USGS quadrangles (Figure 1) and nine counties in northern Arkansas (Figure 2). The majority of Newton and Searcy Counties is contained within the watershed (Table 1). Together, these two counties comprise over 83% of the watershed. The third largest area is in Marion County which contains about 11% of the watershed. Collectively, Marion, Newton and Searcy counties comprise about 94.5% of the land area in the Buffalo River Watershed.

Table 1. Areal extent of the counties in the Buffalo River Watershed.

County	County area	Area in watershed	% of county in watershed	% of watershed
Baxter	372,301	22,014	5.91	2.57
Boone	386,639	6,703	1.73	0.78
Madison	537,430	2,250	0.42	0.26
Marion	409,393	95,541	23.34	11.14
Newton	522,120	395,327	75.72	46.10
Pope	531,858	7,912	1.49	0.92
Searcy	427,115	319,371	74.77	37.24
Stone	389,543	6,851	1.76	0.80
Van Buren	468,445	1,417	0.30	0.17

The Buffalo River is formed in the Boston Mountains, the highest level of the Ozark Plateaus in Newton County, Arkansas (Figure 3. It generally flows northeastward, dissecting the Springfield Plateau. According to the DEM database, the Buffalo River drops from an elevation of approximately 1863 feet above sea level in the headwaters to around 354 feet at its confluence with the White River. Almost half of the watershed is in the Springfield Plateau region of the Ozarks, and about a third is in the Boston Mountains region (Table 2). The remainder of the watershed is in the Salem Plateau.

Table 2. Areal extent of the Buffalo Watershed in three physiographic regions of northern Arkansas.

Region	Acres	% of watershed
Boston Mountains	293,065	34.17
Springfield Plateau	400,004	46.64
Salem Plateau	164,539	19.19

The areal extent of the state-level surficial geology within the watershed is presented in Table 3, and the spatial distribution shown in Figure 4. These data show that the largest proportion of the watershed is in the Boone Formation. The next geological unit in terms of area is the Bloyd shale plus the Prairie Grove member of the Hale formation and this is followed by the Pitkin limestone, the St. Peter sandstone, and the Everton formations.

Table 3. Areal extent of the surficial geology in the Buffalo River Watershed.

Formation	Acres	% of watershed
Terrace deposits	300	<.01
Atoka Formation	52,009	6.1
Bloyd shale, Prairie Grove member of the Hale Formation	160,170	18.7
Cane Hill member of the Hale Formation	80,886	9.4
Pitkin limestone	111,213	13.0
Ruddell shale	15,880	1.9
Boone Formation	272,910	31.8
Lafferty, St. Clair and Brassfield limestone	2,083	0.2
Cason shale, Fernvale, Kimmswick, and Plattin limestone, and Joachim dolomite	50,698	5.9
St. Peter sandstone and Everton Formation	105,519	12.3
Powell dolomite	5,939	0.7

The sub-basins of the Buffalo National River Watershed are shown in Figure 6 and the areal extent of each sub-basin is presented in Table 4. There are 91 sub-basins in the Buffalo River Watershed. The largest sub-basin is Little Buffalo River which occupies 10.76% of the watershed. This is closely followed by the sub-basins Big Creek II (10.06%) and Richland Creek (9.8%). The main channel of the Buffalo

River occupies about 7.9% of the total area of the watershed. The smaller sub-basins are mostly located along the Buffalo River.

The National Park boundaries are shown in Figure 6. A total of 94,525 acres are within the boundaries of the National Park Service which represents about 11% of the watershed. Approximately 132 miles of the Buffalo River are included in the Buffalo National River Park System with an additional 10 to 12 miles of the river in the Ozark National Forest above the boundary of the lands administered by the U. S. Park Service.

Elevation

The elevations of the land within the Buffalo River Watershed are shown in Figure 7. The elevations range from 2576 ft above sea level in the Boston Mountains to 351 ft above sea level in the Salem Plateau where the Buffalo River empties into the White River.

The area surrounding the Buffalo National River is characterized by steep, forested hills. The hills, or ridge tops are usually narrow and winding; the sides alternate in steep slopes and vertical escarpments. At the base of the hills, the country opens into narrow river valleys or rolling hills. Immediately above the river and its beaches, usually at bends, are somewhat level river terraces which frequently flood. Along the Buffalo River, the hills drop steeply to the river bed and in many cases the river is flanked by cliffs that rise in one instance 525 feet above the river. The only level stretches are those at bends where the river terraces are located. In cliffs along the river and its tributaries are a number of rock shelters, caves and springs.

Table 4. Areal extent of the sub-basins in the Buffalo National River Watershed.

Sub-basin	Acres
Little Buffalo River	92,309
Upper Buffalo River	34,455
Arrington Creek	1,869
Bear Creek I	955
Bear Creek II	58,610
Beech Creek I	12,581
Beech Creek II	1,091
Big Creek I	57,664
Big Creek II	86,311
Boat Creek	2,496
Brush Creek I	12,848
Brush Creek II	1,685
Brush Creek III	1,570
Cabin Creek	985
Calf Creek	31,516
Cave Creek	33,553
Cecil Creek	14,913
Cedar Creek	3,181
Clabber Creek	16,735
Clark Creek	1,376
Cow Creek	2,150
Davis Creek	17,826
Dry Creek I	807
Dry Creek II	1,080
Dry Creek III	6,947
Gosha Creek	310
Hickory Creek	2,688
Hoskin Creek	1,340
Indian Creek	1,579
Ingram Creek	1,845
Jamison Creek	5,026
Kimball Creek	814
Leatherwood Creek I	1,181
Leatherwood Creek II	8,144
Lick Creek	2,928
Little Rocky Creek	2,077
Middle Creek	7,248
Mill Creek I	13,422
Mill Creek II	10,005
Moore Creek	3,705
Panther Creek	4,279
Ponca Creek	2,961
Richland Creek	84,141
Rock Creek I	3,827
Rock Creek II	2,999
Rocky Creek	3,750

Table 4 continued.

Running Creek	2,866
Rush Creek	10,233
Shop Creek	810
Short Creek	1,342
Smith Creek	5,451
Sneeds Creek	2,831
Spring Creek	8,447
Steel Creek	2,164
Stewart Creek	1,765
Tomahawk Creek	23,822
Water Creek	24,556
Wells Creek	7,783
Whitely Creek	3,528
Ben Branch	705
Cane Branch	4,725
Mill Branch	2,412
Sheldon Branch	1,907
Webb Branch	2,063
Bear Cave Hollow I	239
Bear Cave Hollow II	1,144
Bear Hollow	583
Big Hollow	361
Boomer Hollow	1,021
Caney Hollow	497
Cecil Hollow	316
Clemmon Hollow	367
Cliff Hollow	931
Cook Hollow	1,302
Fishtrap Hollow I	348
Fishtrap Hollow II	880
Green Haw Hollow	1,533
Hage Hollow	3,302
Hancoch Hollow	942
Hemmedin Hollow	609
Hogskin Hollow	244
Jackies Big Hollow	244
Jim Hollow	603
Lonely Hollow	256
Peter Hollow	277
Rocky Hollow	2,643
Roughhedge Hollow	1,845
Sawmill Hollow	1,344
Silver Hollow	425
Stillhouse Hollow	499
Sweet Gum Hollow	290
Buffalo River - Main Channel	67,470

The areal extent in the watershed in several slope categories are presented in Table 5 and the spatial distribution of the slopes are shown in Figure 8. These data show that steep slopes are found on a large portion of the watershed. Slopes greater than 15% occupied 61.6% of the land area within the watershed; whereas, slopes less than 5% occupied only about 10.3% of the watershed.

The areal extent of the slope aspect is presented in Table 6, and the spatial distribution within the watershed in shown in Figure 9. These results indicate that slope aspect is uniformly distributed within the watershed, and therefore, slopes occur in all directions.

Table 5. Areal extent of several slope categories in the Buffalo River Watershed.

Slope category	Acres	% of watershed
%		
0 - 2	21,988	2.56
3 - 5	66,720	7.78
6 - 10	86,337	10.06
11 - 15	154,608	18.03
16 - 20	159,505	18.60
21 - 25	129,287	15.08
26 - 44	194,227	22.65
> 45	44,934	5.24

Table 6. Areal extent of the aspect of the Buffalo River Watershed.

Direction	Acres	% of watershed
East	116,889	13.63
Southeast	111,752	13.03
South	103,877	12.11
Southwest	106,326	12.40
West	108,443	12.65
Northwest	100,639	11.74
North	98,418	11.48
Northeast	107,750	12.56

Soils

The soils in the Buffalo River Watershed are those mapped in the three physiographic regions of the Ozarks in northern Arkansas. The areal extent of the soil associations, as given in the 1:250,000 state-scale map, is presented in Table 7. The locations of these soil associations within the watershed are shown in Figure 10.

The two most extensive soil associations in the watershed are the Enders-Nella-Mountainburg-Steprock association which occurs in the Boston Mountains, and the Clarksville-Nixa-Noark association which occurs in the Springfield Plateau. Together, these two soil associations cover about 76% of the land area in the Buffalo River Watershed.

Table 7. Areal extent of the soil associations of the state-scale map in the Buffalo National River Watershed.

Soil association	Areal extent	% of watershed
Clarksville-Nixa-Noark	291,021	33.9
Arkana-Moko	30	0
Captina-Nixa-Tonti	2,670	.3
Eden-Newnata-Moko	28,321	3.3
Estate-Portia-Moko	123,701	14.4
Linker-Mountainburg-Sidon	49,313	5.8
Enders-Nella-Mountainburg-Steprock	362,751	42.3

The digital soils database at the 1:20,000 scale of the Buffalo River Watershed was examined more extensively. There are 64 dominant taxonomic soil units mapped within the Buffalo River Watershed (Table 8). The three most extensive are the Nella-Steprock-Mountainburg complex, Noark, and the Clarksville which occupies 15.2, 15.1 and 13.6% of the land area, respectively.

Table 8. Areal extent of the taxonomic soil units within the Buffalo National River Watershed.

Soil series	Areal extent
Arkana	599
Arkana-Moko complex	32,631
Britwater	1,117
Brockwell	40
Cane	334
Captina	262
Ceda	1,676
Ceda-Kenn complex	2,891
Clarksville	116,561
Eden-Moko association	311
Eden-Newata complex	15,921
Eden-Newata-rock complex	632
Elsah	2,116
Enders	43,753
Enders-Leesburg complex	31,411
Enders-Mountainburg association	1,739
Enders-Nella complex	15,658
Enders-Nella-Steprock complex	17
Enders-Steprock complex	139
Estate-Lily-Portia complex	9,486
Estate-Lily-Udorthents complex	15,594
Estate-Portia-Moko association	53,150
Healing	1,603
Leadvale	888
Leesburg	4
Leesburg-Enders association	123
Lily-Udorthents-Rock outcrop	8,029
Linker	15,486
Linker-Mountainburg complex	16,785
Linker-Mountainburg association	912
Moko-Rock Outcrop complex	8,790
Moko-Rock Outcrop-Eden complex	4,691
Mountainburg	4,371
Nauvoo	7,459
Nella	9,791
Nella-Enders complex	58,592
Nella-Enders association	2,713
Nella-Enders-Mountainburg association	568
Nella-Mountainburg complex	1,372
Nella-Mountainburg association	137
Nella-Steprock complex	20,103
Nella-Steprock-Mountainburg complex	130,247

Table 8 continued.

Newnata-Eden-Moko complex	16,238
Newnata-Eden-Moko association	474

Newnata-Summit complex	4,985
Nixa	18,465
Nixa-Noark complex	6,171
Noark	129,291
Peridge	1,250
Portia	5,720
Razort	10,286
Riverwash	3,560
Rock Outcrop	1,051
Samba	1,029
Secesh	1,980
Sidon	5,730
Spadra	3,788
Spadra-Ceda association	269
Steprock	1,437
Steprock-Mountainburg-Rock Outcrop complex	68
Steprock-Linker complex	26
Steprock-Mountainburg complex	214
Summit	523
Widemann	3,501
Water	2,849

The digital soil mapping units of the Buffalo River Watershed are presented in Table 9 and their spatial distribution in Figure 11. There are 167 mapping units within the watershed. This shows that the area within the watershed is highly complex and variable with regard to soil characteristics.

Soil mapping units have sets of inter-related properties that are characteristic of soil as a natural body. A map unit is a collection of areas defined and named the same in terms of their soil components or miscellaneous areas or both (SCS, 1993). Each map unit differs in some respect from all others and is uniquely identified on a soil map. Each individual area on the map is a delineation.

Map units consist of one or more components. An individual component of a map unit represents the collection of polypedons or parts of polypedons that are members of the taxonomic unit or a kind of miscellaneous area. A delineation of a map unit generally contains the

Table 9. Areal extent of the soil map units in the Buffalo River Watershed.

Mapping unit	acres
Arkana very cherty silt loam, 3 - 8% slopes	599
Arkana-Moko complex, 3 - 20% slopes	894
Arkana-Moko complex, 8 - 20% slopes	4,246
Arkana-Moko complex, 20 - 40% slopes	27,492
Britwater silt loam, 1 - 3% slopes	38
Britwater silt loam, 3 - 8% slopes	476
Britwater gravelly silt loam, 3 - 8% slopes	603
Brockwell sandy loam, 3 - 8% slopes	32
Brockwell gravelly sandy loam, 8 - 20% slopes	6
Captina silt loam, 1 - 3% slopes	116
Captina silt loam, 2 - 7% slopes	99
Captina silt loam, 3 - 8% slopes	46
Clarksville very cherty silt loam, 20 - 50% slopes	116,561
Eden-Moko association, very steep	311
Elsah cherty loam, frequently flooded	153
Elsah cherty silt loam, frequently flooded	1,962
Estate-Lily-Portia complex, 8 - 20% slopes	5,238
Estate-Lily-Portia complex, 20 - 40% slopes	4,248
Estate-Lily- Udorthents complex, 3 - 15% slopes	2,846
Estate-Portia-Udorthents complex, 15 - 35% slopes	12,747
Estate-Portia-Moko association, rolling	12,052
Estate-Portia-Moko association, steep	41,097
Healing silt loam, 1 - 3% slopes	3
Healing silt loam, occasionally flooded	1,600
Lily-Udorthents-Rock outcrop complex, 8 - 20% slopes	1,760
Lily-Udorthents-Rock outcrop complex, 20 - 4% slopes	6,269
Moko-Rock outcrop complex, 15-40% slopes	852
Moko-Rock outcrop complex, 15-50% slopes	7,938
Moko-Rock outcrop-Eden complex, 40-60% slopes	4,691
Newnata-Eden-Moko complex, 3 - 20% slopes	10,110
Newnata-Eden-Moko complex, 20 - 40% slopes	6,128
Newnata-Eden-Moko association, rolling	47
Newnata-Eden-Moko association, steep	427
Nixa very cherty silt loam, 3 - 8% slopes	2,315
Nixa very cherty silt loam, 5 - 12% slopes	394
Nixa very cherty silt loam, 8 - 12% slopes	15,756
Nixa-Noark complex, 3 - 8% slopes	70
Nixa-Noark complex, 8 - 20% slopes	6,101
Noark very cherty silt loam, 3 - 8% slopes	23,188
Noark very cherty silt loam, 8 - 20% slopes	78,259
Noark very cherty silt loam, 20 - 40% slopes	27,845

Table 9 continued

Peridge silt loam, 1 - 3% slopes	1
Peridge silt loam, 1 - 5% slopes	1,106
Peridge silt loam, 3 - 8% slopes	143
Portia sandy loam, 3 - 8% slopes	1,053
Portia sandy loam, 8 - 12% slopes	1,136
Portia fine sandy loam, 3 - 8% slopes	1,358
Portia fine sandy loam, 8 - 12% slopes	2,172
Razort loam, occasionally flooded	4,584
Razort loam, frequently flooded	4,509
Razort silt loam, frequently flooded	1,193
Riverwash, frequently flooded	3,560
Rock outcrop, very steep	1,051
Secesh silt loam, frequently flooded	1,980
Sidon, fine sandy loam, 3 - 8% slopes	169
Sidon gravelly fine sandy loam, 3 - 8% slopes	90
Summit silty clay loam, 3 - 8% slopes	108
Summit silty clay loam, 8 - 12% slopes	143
Wideman loamy fine sand, frequently flooded	2,137
Wideman sandy loam, frequently flooded	1,364
Cane loam, 3 - 8% slopes	282
Cane loam, 8 - 12% slopes	52
Ceda cobbly loam, frequently flooded	1,377
Ceda very cobbly loam, frequently flooded	299
Ceda-Kenn complex, frequently flooded	2,891
Eden-Newnata complex, 8 - 20% slopes	8,378
Eden-Newnata-complex, 20 - 40% slopes	7,543
Eden-Newnata-Rock outcrop complex, 40 - 60% slopes	632
Enders very stony sandy loam, 8 - 20% slopes	288
Enders very stony sandy loam, 20 - 40% slopes	980
Enders gravelly fine sandy loam, 3 - 8% slopes	205
Enders gravelly loam, 3 - 8% slopes	7,633
Enders gravelly loam, 8 - 12% slopes	3
Enders gravelly loam, 8 - 15% slopes	949
Enders gravelly loam, 8 - 20% slopes	3,455
Enders stony loam, 3 - 12% slopes	17
Enders stony loam, 3 - 20% slopes	24,474
Enders stony loam, 20 - 40% slopes	5,478
Enders-Leesburg stony loams, 8 - 20% slopes	21,431
Enders-Leesburg stony loams, 20 - 40% slopes	9,980
Enders-Nella stony loams, 3 - 20% slopes	9,870
Enders-Nella stony loams, 20 - 40% slopes	4,225
Enders-Nella complex, 8 - 20% slopes	976
Enders-Nella complex, 20 - 40% slopes	587
Enders-Nella-Steprock complex, 8 - 20% slopes	17
Enders-Steprock complex, 8 - 20% slopes	139
Enders-Steprock complex, 20 - 40% slopes	1
Leadvale silt loam, 3 - 8% slopes	888
Leesburg stony loam, 8 - 12% slopes	4
Leesburg-Enders association, steep	123

Table 9 continued.

Linker fine sandy loam, 3 - 8% slopes	1,668
Linker gravelly fine sandy loam, 3 - 8% slopes	5,611
Linker gravelly fine sandy loam, 8 - 12% slopes	1,140
Linker loam, 3 - 8% slopes	3,167
Linker gravelly loam, 3 - 8% slopes	3,050
Linker-Mountainburg complex, 3 - 8% slopes	7,359
Linker-Mountainburg complex, 8 - 20% slopes	9,117
Mountainburg very stony sandy loam, 3 - 15% slopes	370
Mountainburg very stony sandy loam, 15 - 40% slopes	207
Mountainburg very stony sandy loam, 20 - 40% slopes	12
Mountainburg gravelly fine sandy loam, 3 - 8% slopes	675
Mountainburg gravelly fine sandy loam, 8 - 12% slopes	17
Mountainburg very gravelly fine sandy loam, 3 - 8% slopes	276
Mountainburg very stony fine sandy loam, 3 - 8% slopes	263
Mountainburg very stony fine sandy loam, 8 - 20% slopes	1,111
Mountainburg very stony fine sandy loam, 20 - 40% slopes	1,110
Mountainburg gravelly loam, 3 - 8% slopes	255
Mountainburg stony loam, 3 - 20% slopes	64
Mountainburg very stony loam, 20 - 50% slopes	11
Nauvoo fine sandy loam, 2 - 7% slopes	7,459
Nella gravelly fine sandy loam, 8 - 12% slopes	44
Nella gravelly loam, 3 - 8% slopes	263
Nella gravelly loam, 3 - 12% slopes	2,646
Nella gravelly loam, 8 - 15% slopes	294
Nella gravelly loam, 12 - 20% slopes	261
Nella stony loam, 3 - 15% slopes	1,711
Nella stony loam, 8 - 20% slopes	4,362
Nella stony loam, 20 - 40% slopes	210
Nella-Enders stony loams, 8 - 20% slopes	38,349
Nella-Enders stony loams, 20 - 40% slopes	20,089
Nella-Enders complex, 8 - 20% slopes	52
Nella-Enders complex, 20 - 40% slopes	101
Nella-Enders association, rolling	310
Nella-Enders association, steep	2,403
Nella-Enders-Mountainburg association, very steep	568
Nella-Mountainburg complex, 20 - 40% slopes	1,372
Nella-Mountainburg association, rolling	79
Nella-Mountainburg association, steep	58
Nella-Steprock complex, 3 - 20% slopes	6,652
Nella-Steprock complex, 8 - 20% slopes	13,016
Nella-Steprock complex, 20 - 40% slopes	435

Table 9 continued.

Nella-Steprock-Mountainburg very stony loams, 20 - 40% slopes	41,220
Nella-Steprock-Mountainburg very stony loams, 20 - 60% slopes	57,989
Nella-Steprock-Mountainburg complex, 20 - 40% slopes	12,651
Nella-Steprock-Mountainburg complex, 40 - 60% slopes	18,387
Newnata-Summit silty clay loams, 3 - 8% slopes	2,205
Newnata-Summit complex, 8 - 15% slopes, eroded	1,525
Newnata-Summit complex, 15 - 25% slopes, eroded	1,256
Samba silty clay loam, 0 - 2% slopes	1,029
Sidon loam, 2 - 6% slopes	4,528
Sidon silt loam, 3 - 8% slopes	943
Spadra loam, 1 - 5% slopes	1,152
Spadra loam, 2 - 5% slopes	629
Spadra loam, occasionally flooded	1,870
Steprock gravelly loam, 3 - 8% slopes	1,332
Steprock stony loam, 3 - 12% slopes	105
Steprock-Mountainburg-Rock outcrop complex, 40 - 60% slopes	68
Summit silty clay loam, 3 - 8% slopes, eroded	271
Enders gravelly fine sandy loam, 3 - 8% slopes	30
Enders gravelly fine sandy loam, 8 - 12% slopes	124
Enders stony fine sandy loam, 12 - 45% slopes	117
Enders-Mountainburg association, rolling	550
Enders-Mountainburg association, steep	1,189
Linker fine sandy loam, 3 - 8% slopes	693
Linker fine sandy loam, 8 - 12% slopes	58
Linker gravelly fine sandy loam, 3 - 8% slopes	93
Linker gravelly fine sandy loam, 8 - 12% slopes	7
Linker-Mountainburg complex, 3 - 8% slopes	148
Linker-Mountainburg complex, 8 - 20% slopes	161
Linker-Mountainburg association, gently rolling	130
Linker-Mountainburg association, rolling	783
Spadra loam, occasionally flooded	136
Spadra-Ceda association, occasionally flooded	269
Steprock-Linker complex, 3 - 8% slopes	26
Steprock-Mountainburg complex, 3 - 8% slopes	52
Steprock-Mountainburg complex, 8 - 20% slopes	162

dominant components in the map unit name, but it may not always contain a representation of each kind of inclusion.

Landuse

The Buffalo River Watershed is heavily forested with about 85% of the land area in the forest category in 1965 (Table 10). The spatial distribution of the landuse characteristics within the watershed is shown by year in Figures 12, 13, 14, and 15. These data show that while forest dominate the landscape the areal extent within the various landuse categories is dynamic. The most extensive temporal changes occur in the categories designated as agricultural (mostly pasture) and forest. The ratio of forest to agricultural within the watershed was 5.93 in 1965, and declined to 3.85 by 1979. Over this 14-year period, the annual changes in areal extent in the categories designated as agricultural could be described by the linear equation

$$Y = 122,724,576 + 3,811*t \qquad [1]$$

where t is the number of years since 1965. The coefficient of determination for this relationship was 0.98. The slope of the line was positive which indicates that the acreage in the watershed designated as agriculture increased during this period of time, and at an average rate of about 318 acres per month.

Linear regression of the areal extent of the forest category over the same 14-year period resulted in the linear equation

$$Y = 728,100 - 4,005*t \qquad [2]$$

The coefficient of determination for this relationship was 0.94. With the forest category, the slope of the line was negative which indicates that the forested acreage in the watershed decreased during this period

Table 10. Landuse characteristics of the Buffalo National River Watershed.

Landuse category	1965	1972	1974	1979
	acres			
Urban	1,282	3,362	3,326	2,214
Agricultural	122,983	146,034	161,008	175,195
Forest	728,879	704,385	683,826	675,162
Barren	1,503	1,121	2,112	1,078
Transitional	633	31	3,443	103
Transportation	2,295	2,366	3,812	3,812

of time, and at an average rate of about 333 acres per month.

It is interesting to note that the annual increase in land area designated as agricultural was about the same as the annual decrease in land area designated as forest. This indicates that the rate the trees were removed and the rate of increase in agricultural uses such as pasture were similar. For the most part, it suggests that the land removed from forest was converted to agricultural uses.

The next landuse characteristic that we examined was the landuse within the National Park lands. These results are presented in Table 11. As noted within the entire watershed, forests dominate the area within the National Park to a greater extent than outside the park boundaries. However, the landuse ratio within this area also has changed over the years. In 1965, the ratio of forest to agricultural uses in the National Park was 7.0. The ratio declined to 5.4 by 1979 which indicates that there were changes in the landuse characteristics within the park boundaries.

Linear regression of the areal extent was also computed on the areas designated as agriculture and forestry within the National Park.

For agriculture, the line could be described with the following equation

$$Y = 11{,}435 + 212*t \quad [3]$$

where t is the number of years since 1965. The coefficient of determination for this line was 0.99. The slope indicates that the area in agriculture increased at an average rate of about 18 acres per month. For forestry, the line could be described with the equation

$$Y = 80{,}288 - 205*t \quad [4]$$

The coefficient of determination for this line was 0.80. The slope indicates that the area in forest decreased at an average rate of about 17 acres per month.

Therefore, as in the entire watershed, there are temporal changes in the landuse within the National Park lands. For the most part, these changes indicate that the land area lost in the forest category and gained in agriculture category were similar. The changes in landuse characteristics were dynamic both within the Buffalo River Watershed and the National Park boundaries.

Table 11. Landuse characteristics within the Buffalo National Park.

Landuse category	Year 1965	1972	1974	1979
	acres			
Urban	3	62	99	40
Agricultural	11,518	10,939	13,235	14,470
Forrest	80,724	81,550	77,621	77,956
Barren	1,416	1,109	2,099	1,072
Transitional	59	0	470	0
Transportation	358	358	544	544

Human and Animal Populations

Another interesting aspect of the area is the temporal characteristics of the human and cattle populations of the three counties within the Buffalo National River Watershed. Even though we showed previously that not all of these counties are located within the watershed, it is instructive to examine the trends in population over time in the three counties that comprise the majority of the watershed.

The human population in the Marion, Newton and Searcy counties since 1950 by decade are presented in Table 12. The population of Marion County increased by 3392 residents over the 40-year period. Using the 1950 data as the basis of comparison, this represented a 39.4% increase in population over the 40 years, or almost 1% per year. In contrast, the populations of Newton and Searcy counties decreased during this time period. For Newton County, the decrease was 1019 residents which represented a 11.7% decrease or about 0.3% of the population per year on the average. For Searcy County, the population decrease was greater and was 2583 residents. This represented a 24.8% decrease or about 0.6% of the population per year on the average.

Table 12. Summary of the human populations of three counties in the Buffalo River region in northern Arkansas since 1950. The source of these data are from the Bureau of Census, U. S. Commerce.

	Population			
Year	Marion	Newton	Searcy	Total
1950	8609	8685	10424	27,718
1960	6041	5963	8124	20,128
1970	7000	5844	7731	20,575
1980	11334	7756	8847	27,937
1990	12001	7666	7841	27,508

For the decade after 1950 all three counties lost population. The total population was stagnant between 1960 and 1970 with the increase in population in Marion County offsetting the losses in population in Newton and Searcy Counties. By 1980, however, the total population of the three counties had increased to about the same as found in 1950. This increase in population was led by Marion County. For the decade after 1980, the total population of the three counties was stagnant.

The annual summary of the number of milk cows on the farms in the three counties are presented in Table 13. The time period of study begins in 1966 and ends in 1994. The data indicate that the annual number of milk cows was quite dynamic. In general, large declines were found in the number of milk cows in Newton and Marion counties; whereas, the number of milk cows in Searcy County remained about the same since 1966.

The annual summary of the number of cattle and calves on farms in the three counties is presented in Table 14. The number of milk cows are included in these data. In Newton and Marion counties, the number of cattle and calves increased until the mid 1970s. After this time, the population trend was

Table 13. Summary of the annual number of milk cows on farms in three counties of Arkansas. These data were compiled by Carroll R. Garner, Area Farm Management Specialist, Cooperative Extension Service, University of Arkansas. The sources of the data were the Arkansas Agricultural Statistics, Various Report Series.

	Milk Cows on Farms County		
Year	Newton	Marion	Searcy
	- - - - Number of head - - - -		
1966	1400	2500	2000
67	1300	2300	1900
68	1200	2000	1700
69	1200	1900	1600
70	700	1800	1700
71	700	2000	1800
72	600	1800	1700
73	600	1900	1700
74	600	2000	1900
75	600	2100	2100
76	500	1700	2000
77	500	1700	1900
78	1000	1400	1500
79	1400	1300	1300
80	1100	1300	1500
81	500	1500	2100
82	500	1600	2200
83	500	1500	2200
84	700	1500	1950
85	600	1300	1800
86	500	1300	1800
87	500	800	1000
88	500	800	2000
89	500	800	1800
90	600	700	1800
91	600	700	1800
92	500	700	1800
93	200	600	2000
94	200	600	2200

Table 14. Summary of the annual number of cattle and calves on farms in three counties in Arkansas. These data were compiled by Carroll R. Garner, Area Farm Management Specialist, Cooperative Extension Service, University of Arkansas. The sources of the data were the various Arkansas Agricultural Statistics, Report Series.

	All Cattle and Calves on Farms		
	County		
Year	Newton	Marion	Searcy
	- - - - - - Number of head - - - - - -		
1966	14300	18900	20400
67	14900	19300	20800
68	15600	21600	22400
69	15000	23400	24500
70	14900	24400	25000
71	15000	25700	26200
72	15000	28500	28900
73	15600	29500	29700
74	16300	32600	32500
75	21300	41200	45000
76	17600	42500	33600
77	20000	43500	35000
78	18500	35500	38000
79	17000	34500	36500
80	18500	34000	40000
81	20800	38000	50400
82	19900	36200	48000
83	16000	30000	40500
84	29000	40000	47000
85	21600	29100	26900
86	14000	27500	30000
87	15000	24000	50000
88	15000	22000	52000
89	15000	22000	44000
90	15000	19000	46000
91	14000	20000	42000
92	15000	20000	43000
93	15000	23000	45000
94	16000	23000	45000

downward to a population only slightly higher than found in 1966. In contrast, Searcy County had approximately the combined cattle and calf populations of Newton and Marion Counties. The highest population of cattle in Searcy County occurred in 1981. Since that time, the cattle population in this county has declined slightly. Over the time period given in Table 14, the population of cattle and calves in Searcy County more than doubled.

The annual summary of the number of hogs and pigs on farms in the three counties is presented in Table 15. These data show that the population of these animals in each county increased between 1966 and 1977, and this was followed by a decrease to almost one-half that highest population in 1984 in Newton and Marion Counties and about three-fourths in Searcy County. The highest and lowest populations of hogs and pigs were in Newton and Marion Counties, respectively.

SUMMARY

In this report, we have presented our initial efforts toward developing a digital characterization of several attributes of the Buffalo River Watershed. The attributes added to the database included boundaries of the entire watershed, sub-basins, and the National Park, 30m elevations, soils, and landuse.

The Buffalo River Watershed contains over 857,000 acres in nine counties and occurs in all three provinces of the Boston Mountains in northern Arkansas. Over 83% of the Buffalo Watershed is within the counties of Newton, ~~Marion~~ and Searcy. There are 64 dominant soil series, and 167 soil mapping units with the Nella-Steprock-Mountainburg complex,

Table 15. Summary of the annual number of hogs and pigs on farms in three counties in Arkansas. These data were compiled by Carroll R. Garner, Area Farm Management Specialist, Cooperative Extension Service, University of Arkansas. The sources of the data were the various Arkansas Agricultural Statistics, Report Series.

	Hogs and Pigs on Farms County		
Year	Newton	Marion	Searcy
	- - - - - - - Number of head - - - - - - -		
1966	6700	2500	3000
67	7300	2800	3300
68	9500	3600	4000
69	11500	4000	4700
70	16600	5700	6700
71	17100	6200	7300
72	16800	4200	4800
73	13200	1300	3700
74	14100	2800	3100
75	16300	3600	3200
76	16300	3600	3200
77	17900	5600	7600
78	13100	4600	6200
79	14000	5000	5500
80	n.r.	n.r.	n.r.
81	n.r.	n.r.	n.r.
82	n.r.	n.r.	n.r.
83	n.r.	n.r.	n.r.
84	8300	2600	5800
85	8000	1700	5000
86	7000	1200	3000
87	9000	1400	3300
88	9000	1400	4200
89	10000	1500	5000
90	11000	1600	6800
91	11000	1400	6600
92	10500	1400	6400
93	10000	1300	6500
94	10000	1500	6500

n.r. - Not reported due to individual disclosure rules.

Noark, and Clarksville series occupying almost 44% of the watershed. The watershed is dominantly in forest, however, the linear trends indicated a decrease in forest (33 acres/month) and an increase in pasture (318 acres/month) between 1965 and 1979. The magnitudes of these changes were about the same during this 14-year period.

Between 1965 and 1979 there was an increase in the human and cattle population within Newton, Marion and Searcy counties. Between 1970 and 1980 the total population of humans in the three counties increased by about 36% and the total head of cattle increased by about 44%. The ratio of pasture area to cattle ranged from about 2.3 acre per head in 1965 to about 2.0 acres per head in 1979. This similar ratio indicated that the concentration of these animals per unit land area was not significantly changed. Since 1979, however, the human population and total head of cattle in these three counties has remained about the same. Remaining work to be completed on the Buffalo Watershed includes the development of additional landscape attributes and landuse characterization since 1979.

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Legend of the Figures

Figure Number	Legend

1. The spatial distribution of the 42 7.5-minute topographic USGS quadrangles in the Buffalo River Watershed.

2. The location of the Buffalo River Watershed within the nine counties of northern Arkansas.

3. The location of the Buffalo River Watershed within the three physiographic regions in northern Arkansas.

4. The surficial geology of the Buffalo River Watershed. This map was taken from the state-scale geology map.

5. The sub-basins and streams of the Buffalo River Watershed.

6. The boundaries of the National Park within the Buffalo River Watershed.

7. Elevations of the land within the Buffalo River Watershed.

8. The slopes of the Buffalo River Watershed.

9. The slope aspect of the Buffalo River Watershed.

10. The soil associations of the Buffalo River Watershed. This map was taken from the state-scale map.

11. The soil taxonomic units of the Buffalo River Watershed.

12. Land use in the Buffalo River Watershed in 1965.

13. Land use in the Buffalo River Watershed in 1972.

14. Land use in the Buffalo River Watershed in 1974.

15. Land use in the Buffalo River Watershed in 1979.

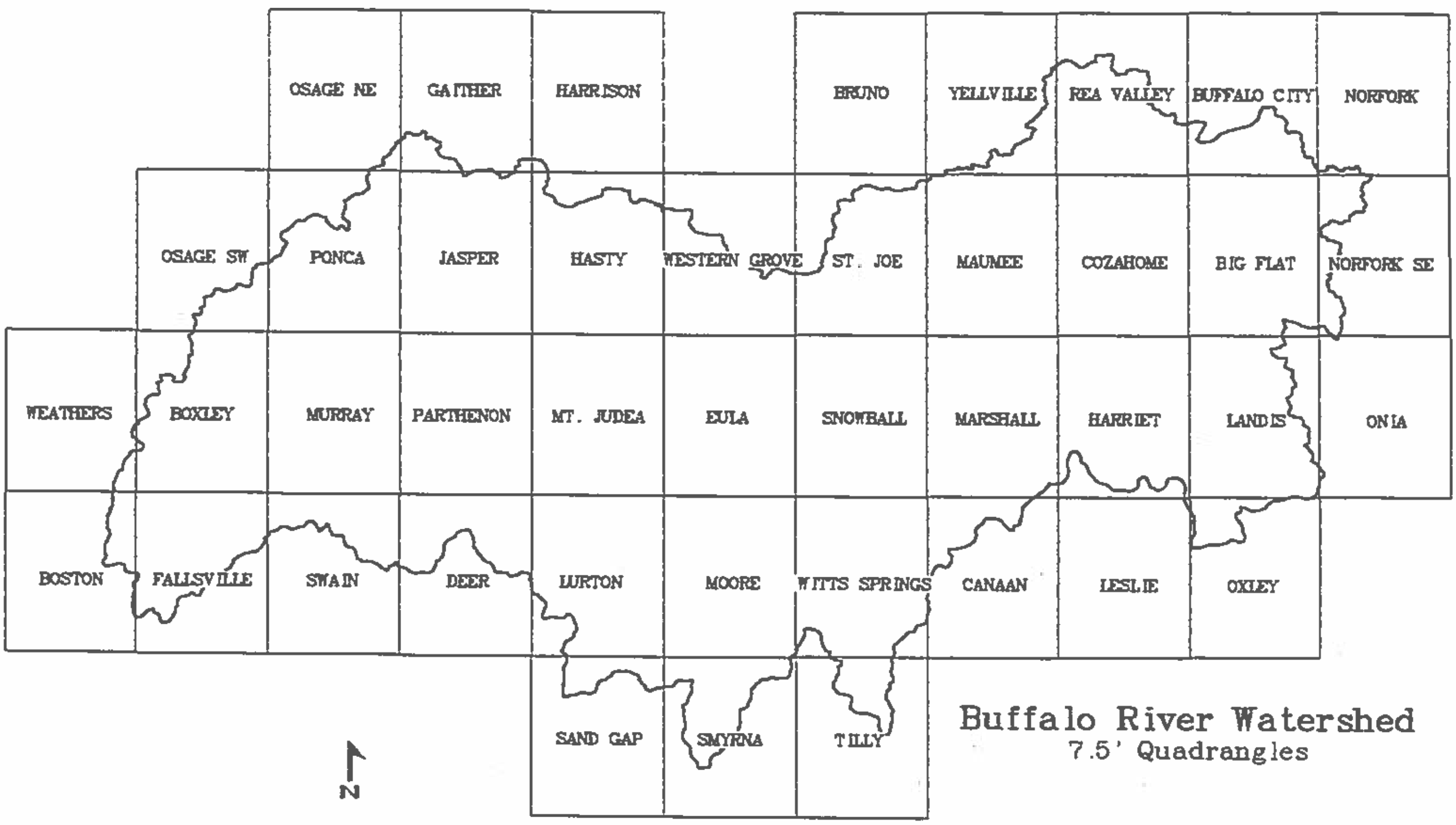

Figure 1. The spatial distribution of the 42 7.5-minute topographic USGS quadrangles in the Buffalo River Watershed.

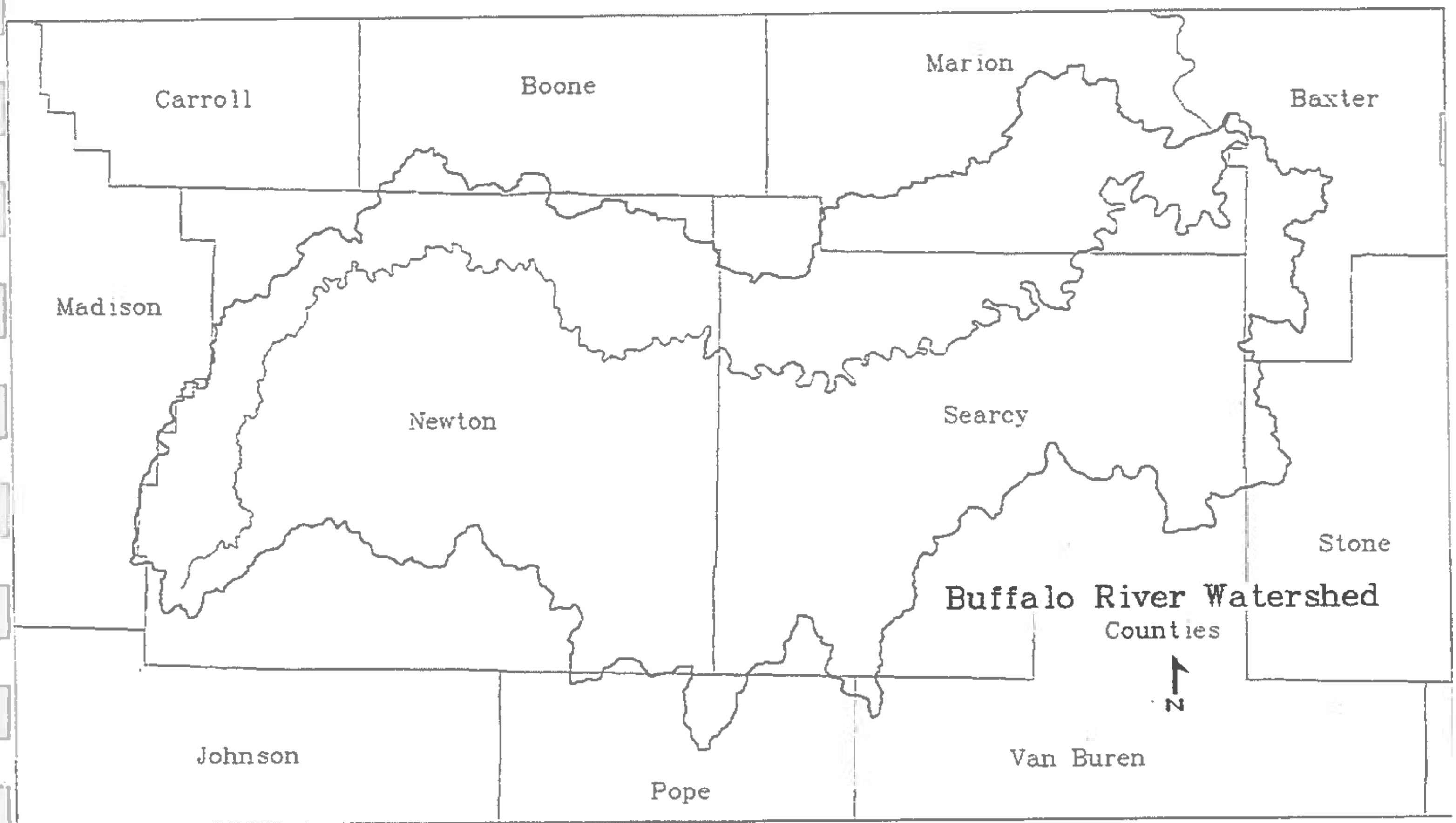

Figure 2. The location of the Buffalo River Watershed within the nine counties of northern Arkansas.

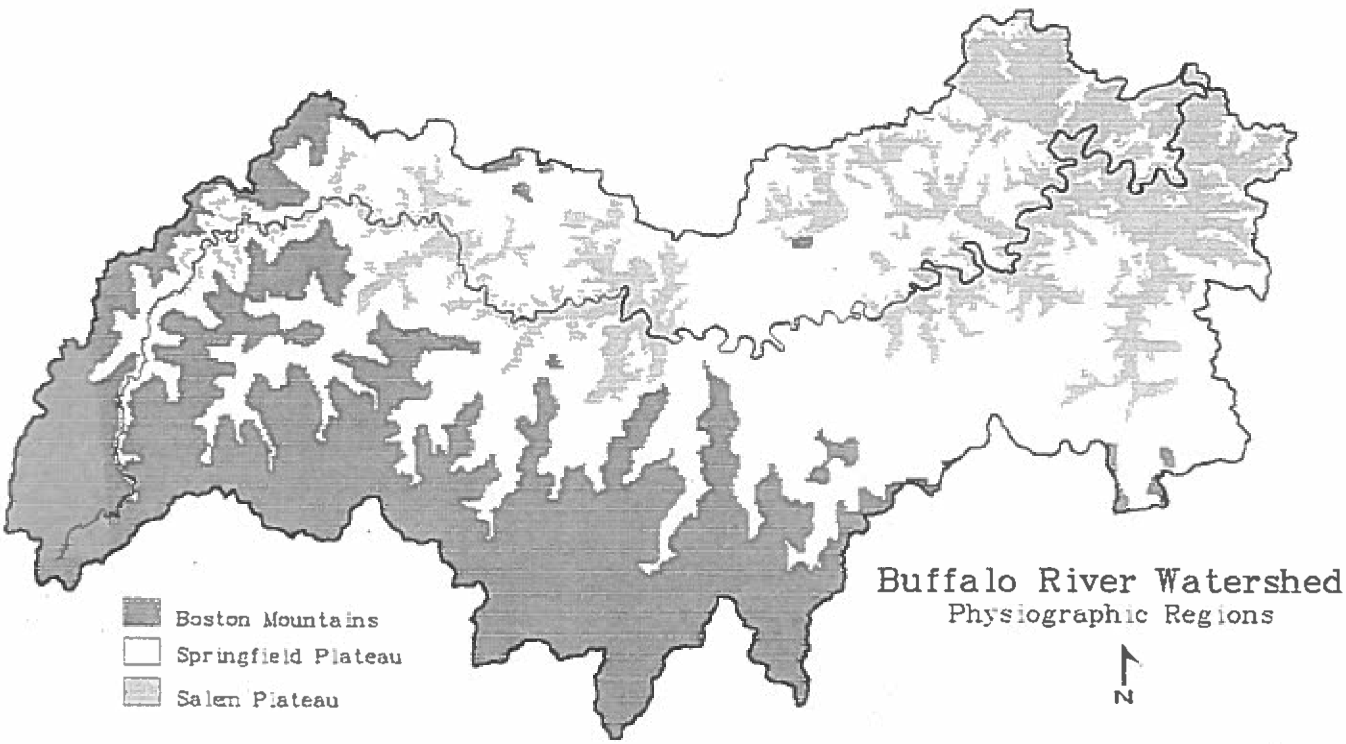

Figure 3. The location of the Buffalo River Watershed within the three physiographic regions in northern Arkansas.

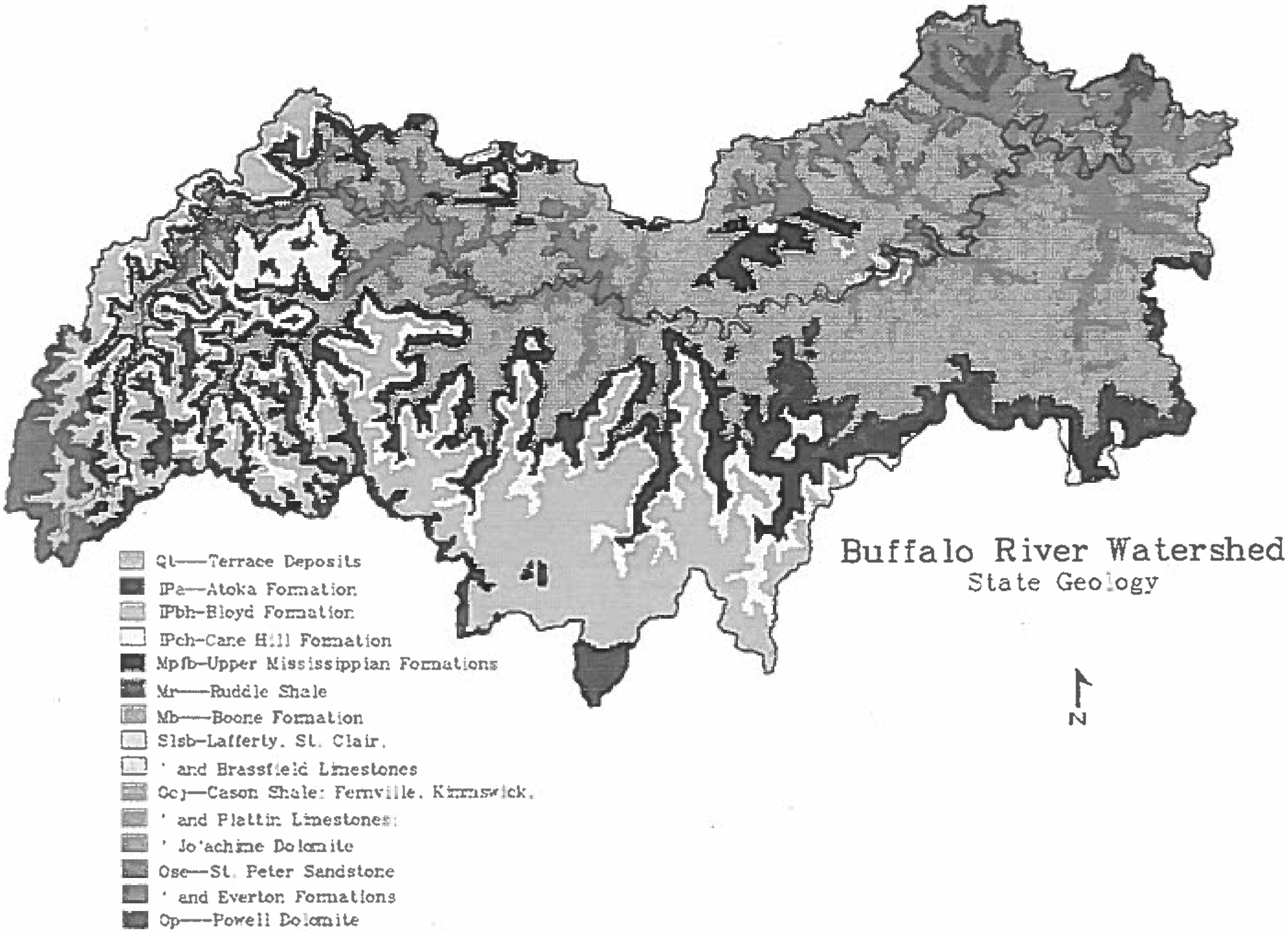

Figure 4. The surficial geology of the Buffalo River Watershed. This map was taken from the state-scale geology map.

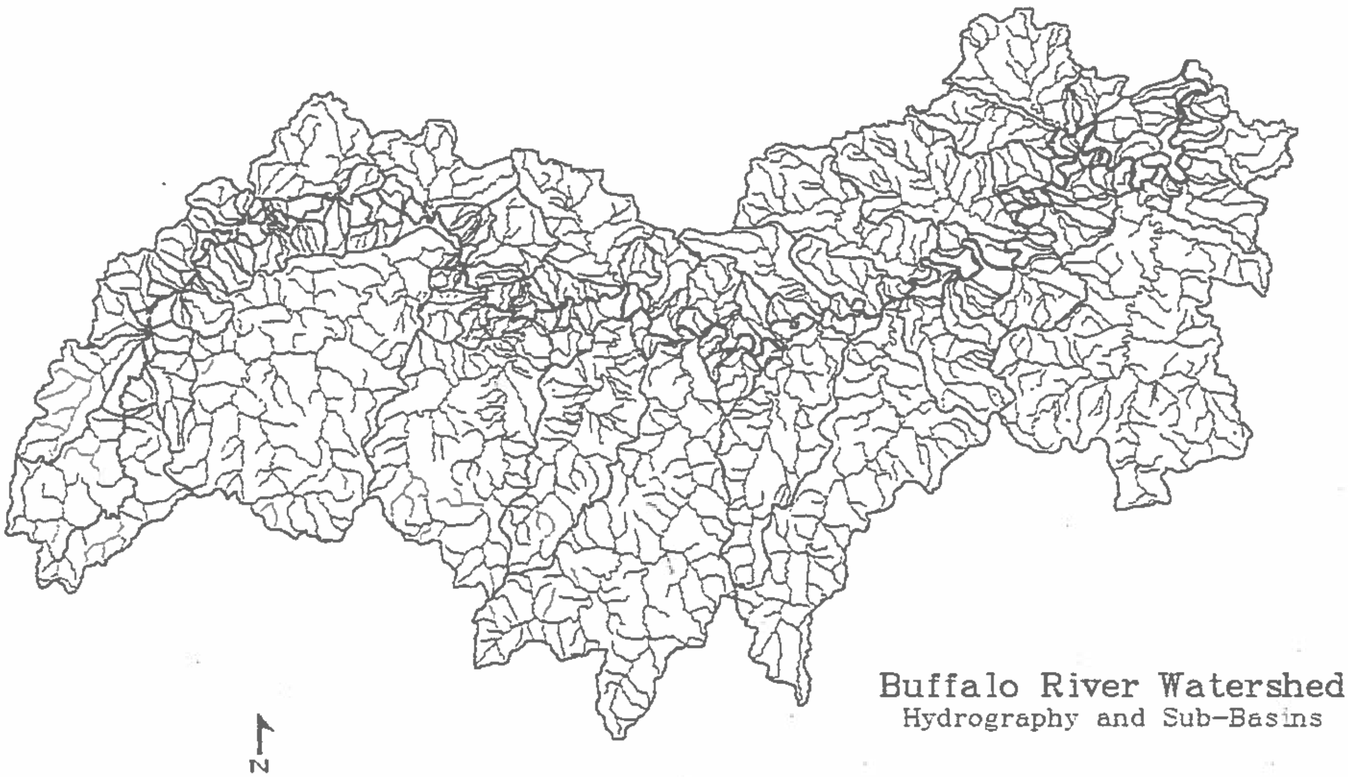

Figure 5. The sub-basins and streams of the Buffalo River Watershed.

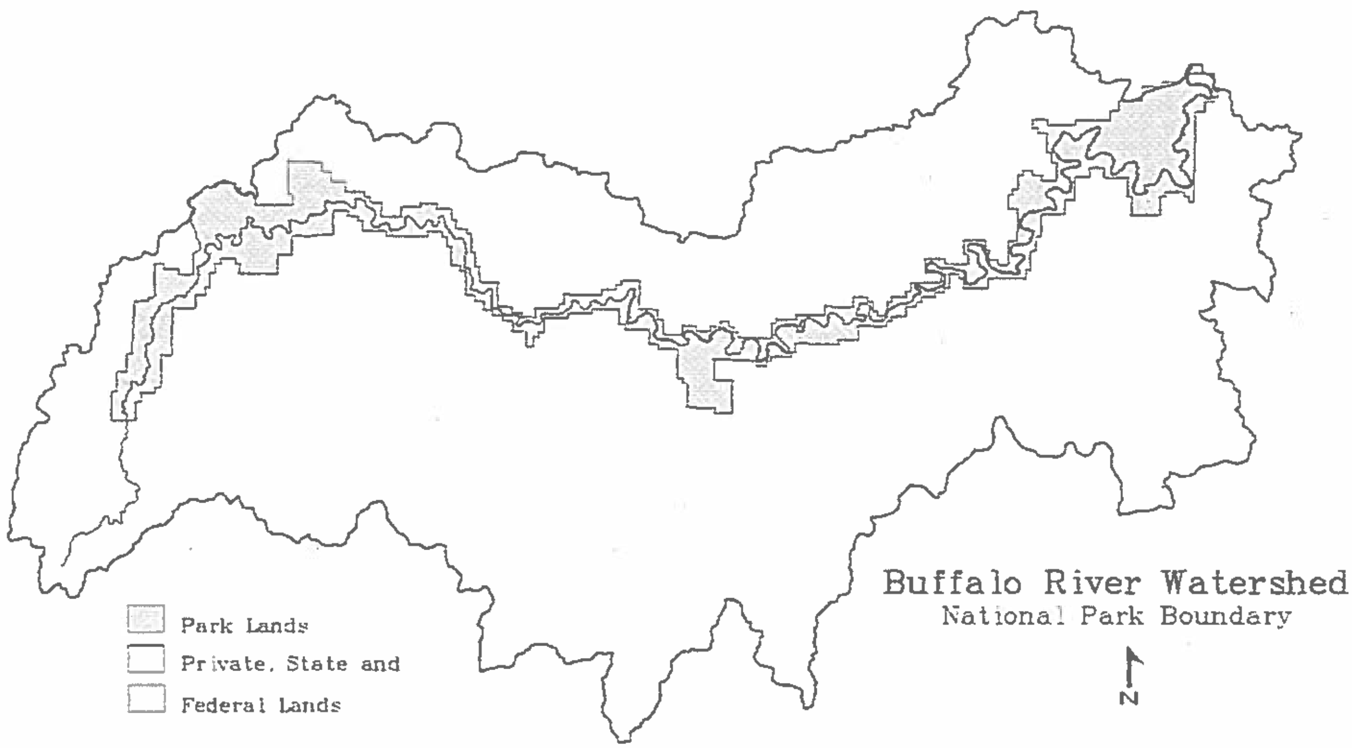

Figure 6. The boundaries of the National Park within the Buffalo River Watershed.

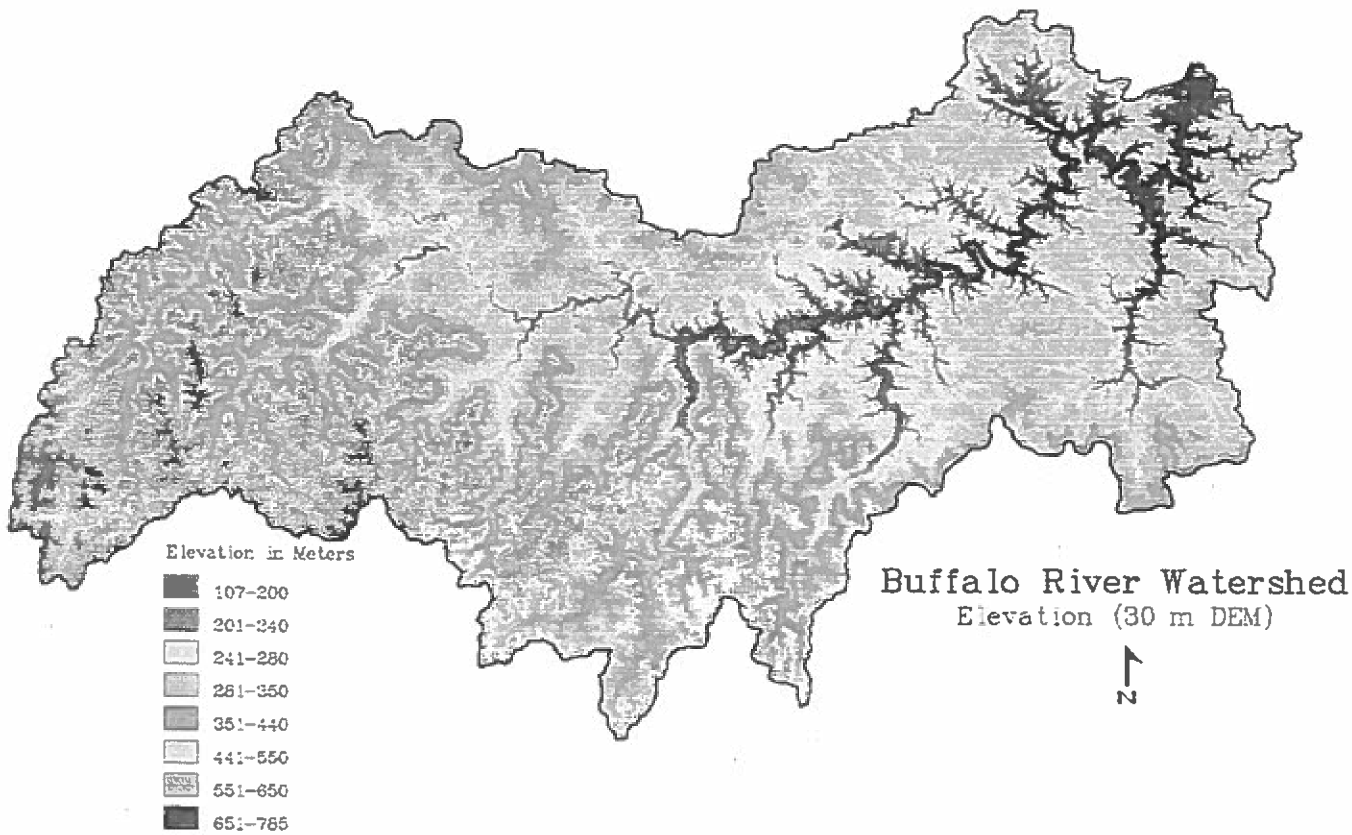

Figure 7. Elevations of the land within the Buffalo River Watershed.

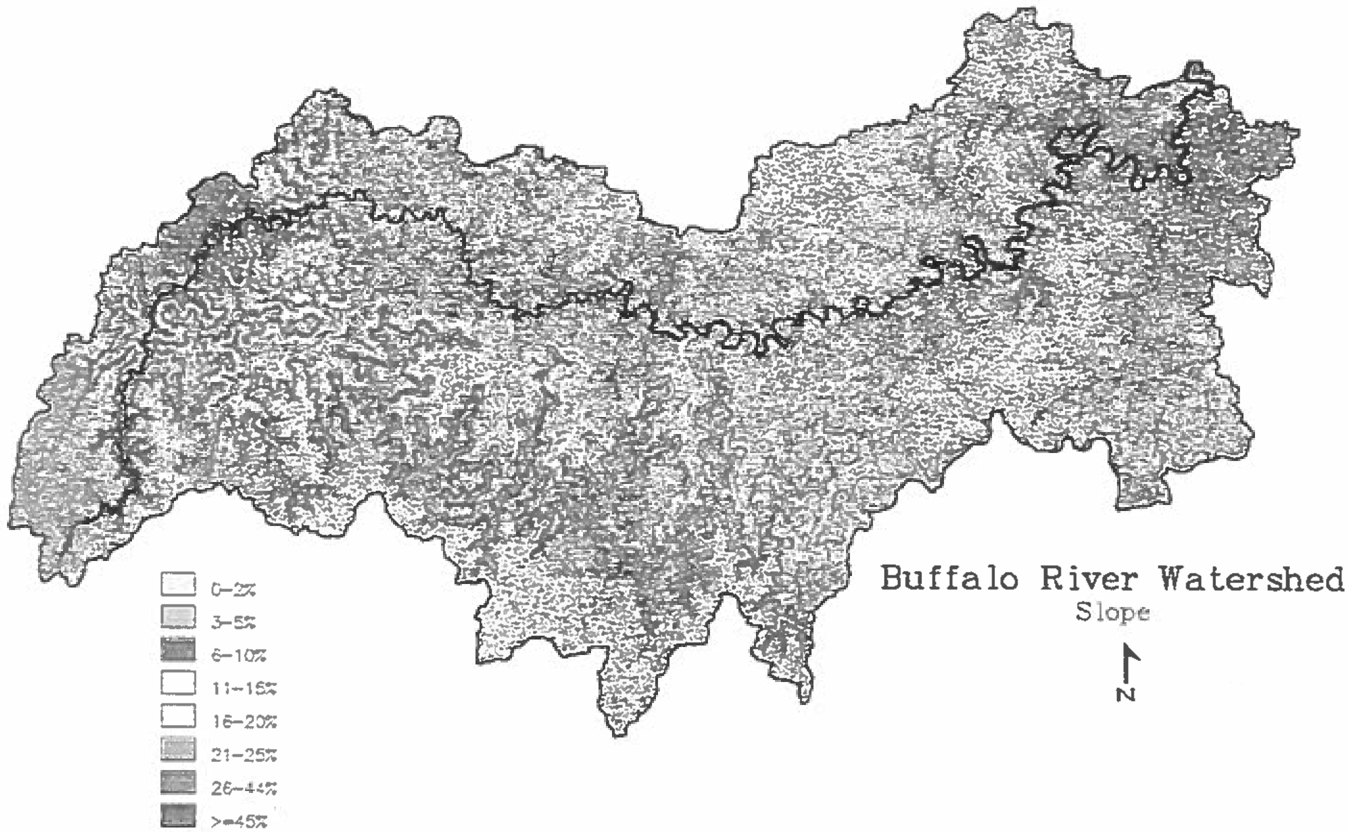

Figure 8. The slopes of the Buffalo River Watershed.

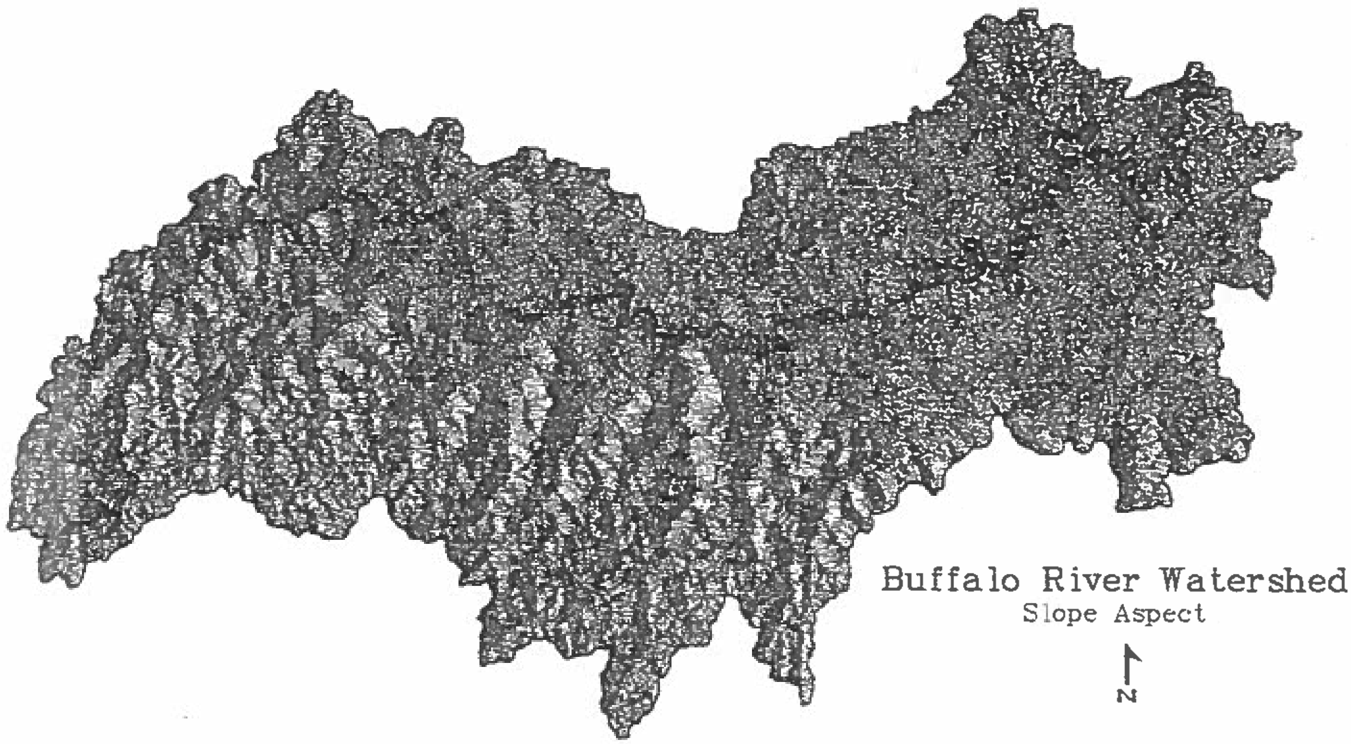

Figure 9. The slope aspect of the Buffalo River Watershed.

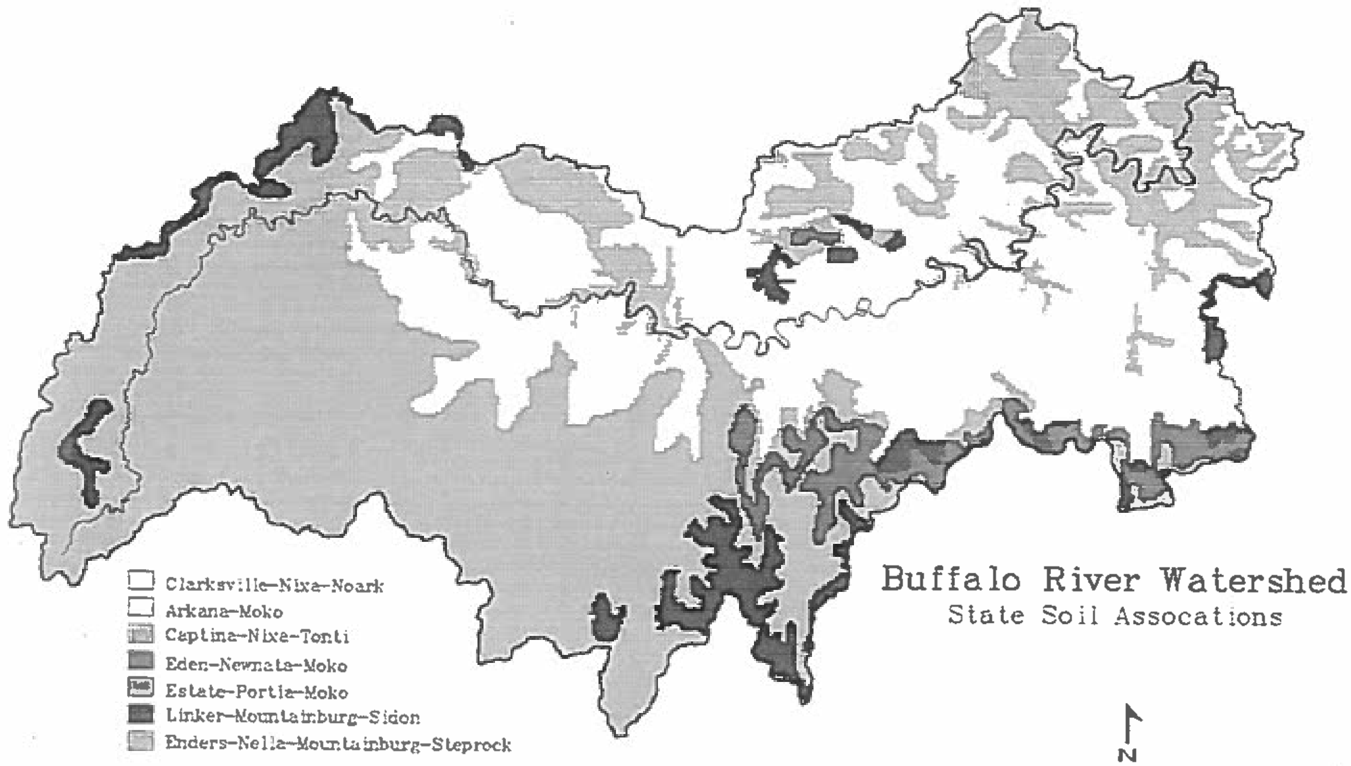

Figure 10. The soil associations of the Buffalo River Watershed. This map was taken from the state-scale map.

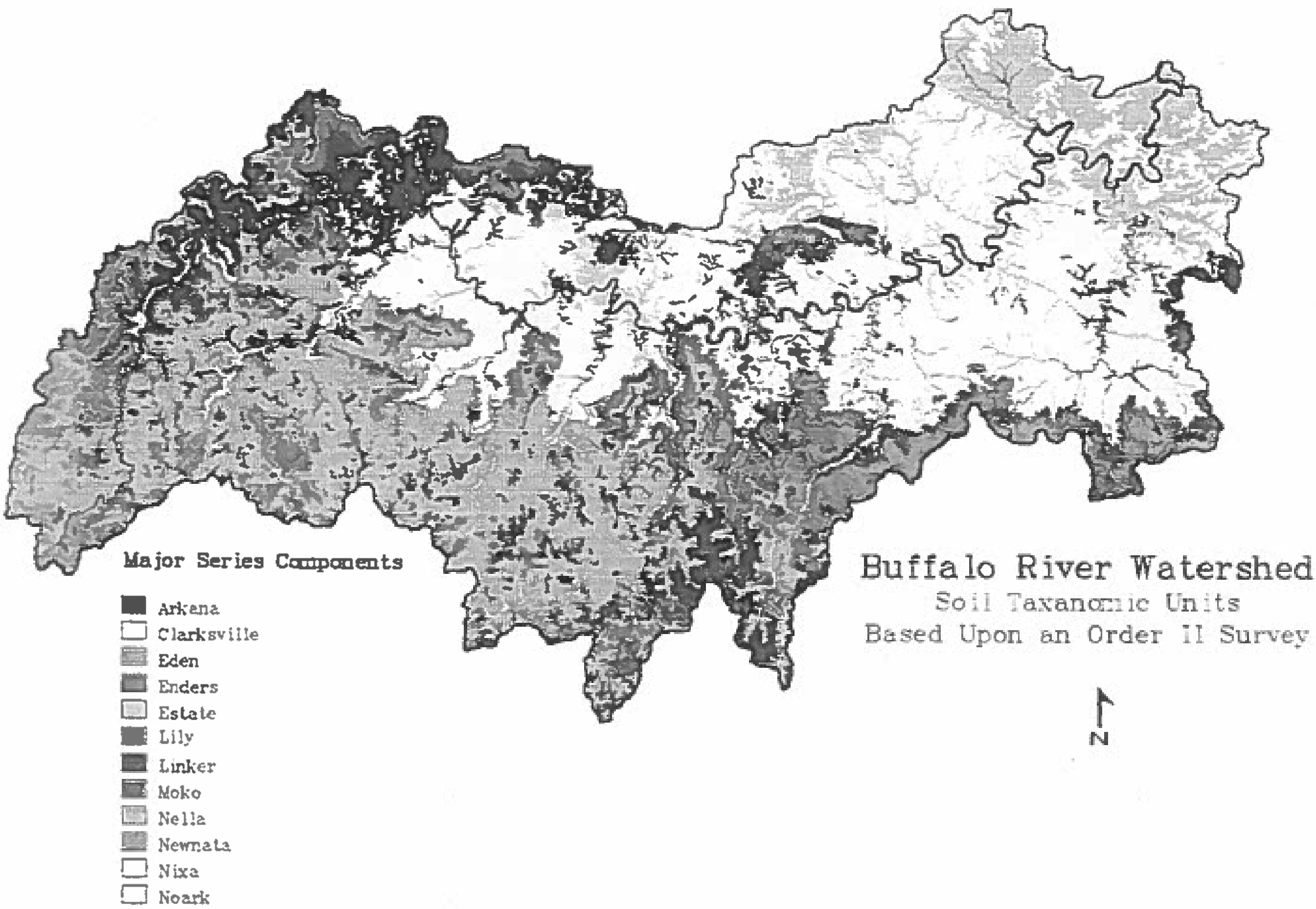

Figure 11. The soil taxonomic units of the Buffalo River Watershed.

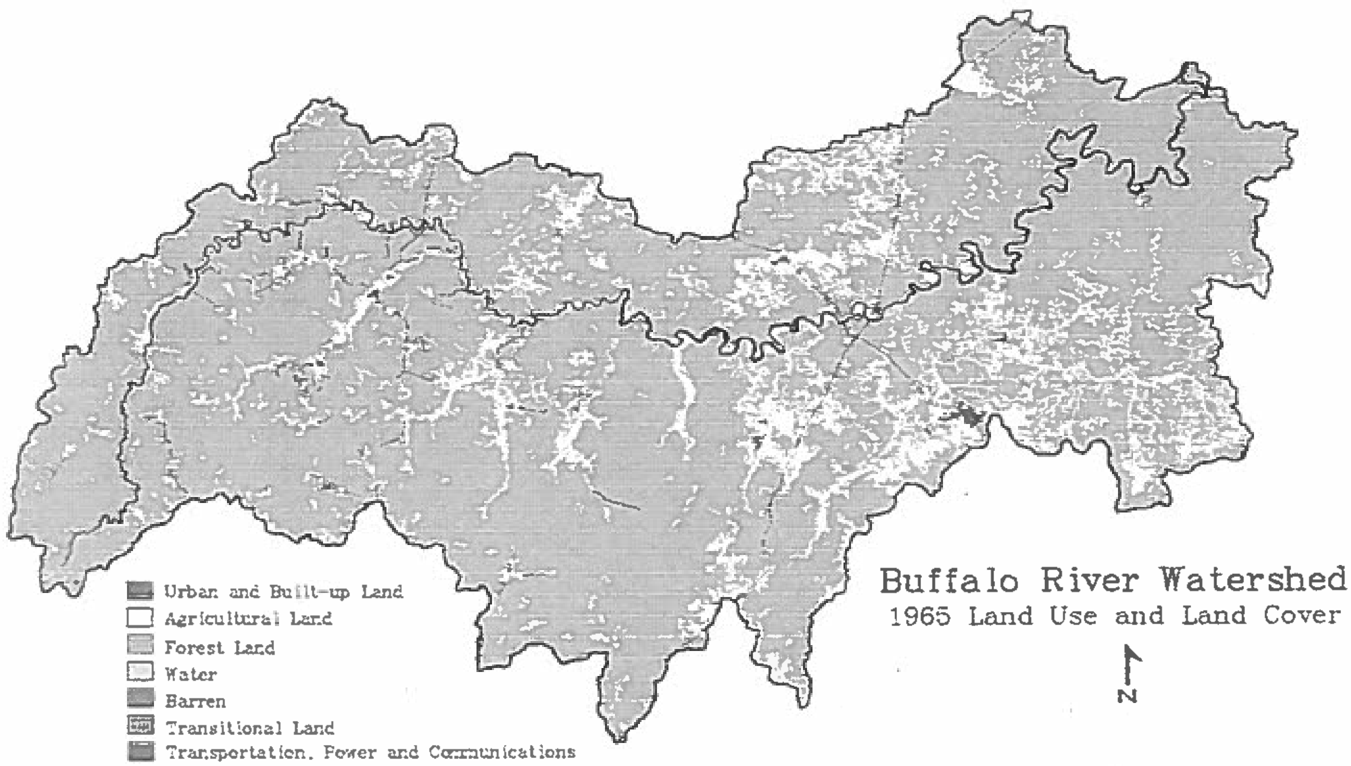

Figure 12. Land use in the Buffalo River Watershed in 1965.

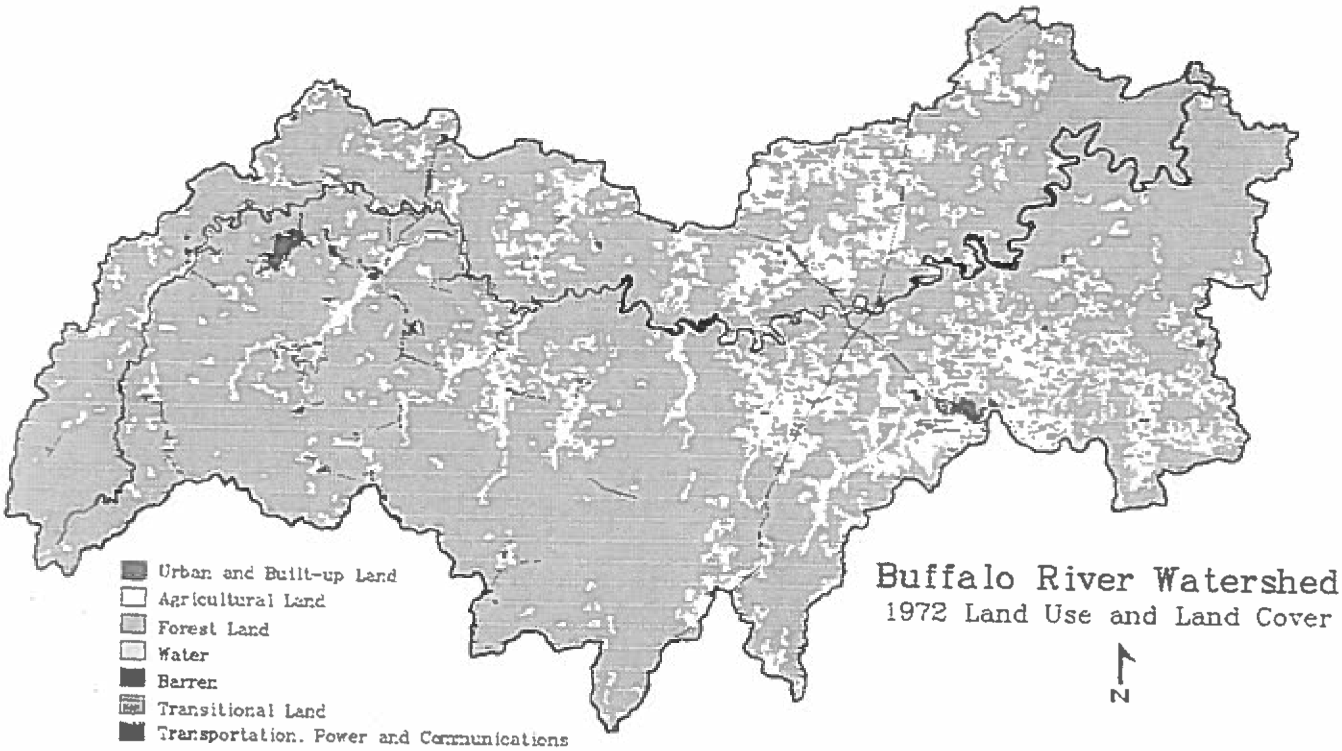

Figure 13. Land use in the Buffalo River Watershed in 1972.

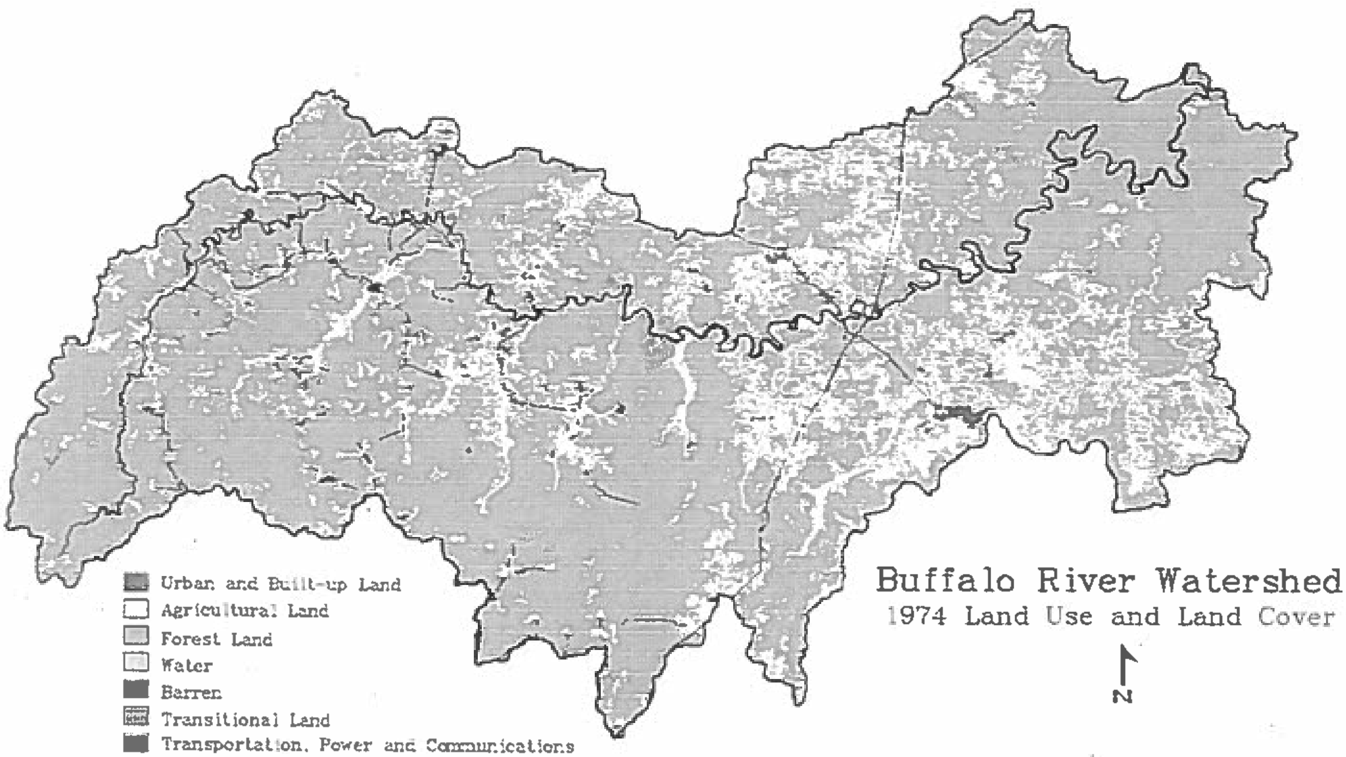

Figure 14. Land use in the Buffalo River Watershed in 1974.

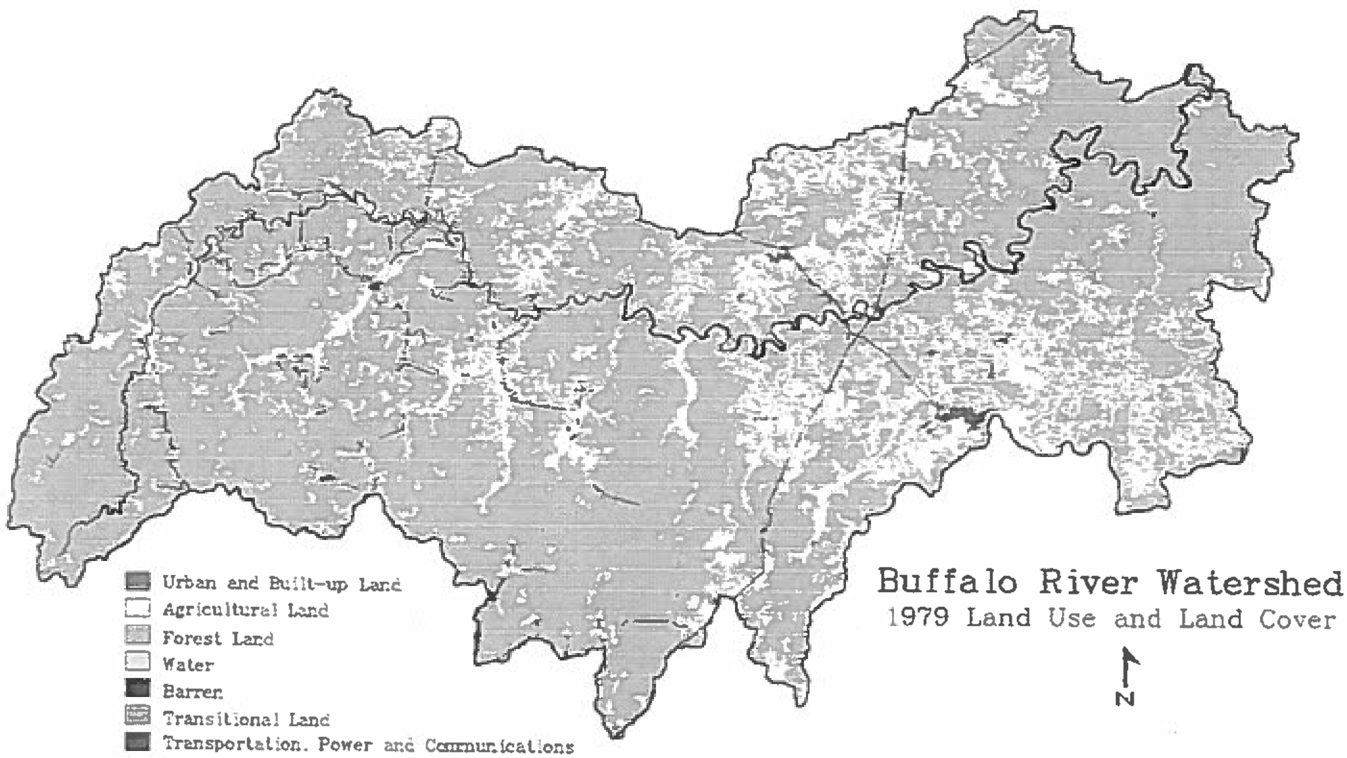

Figure 15. Land use in the Buffalo River Watershed in 1979.