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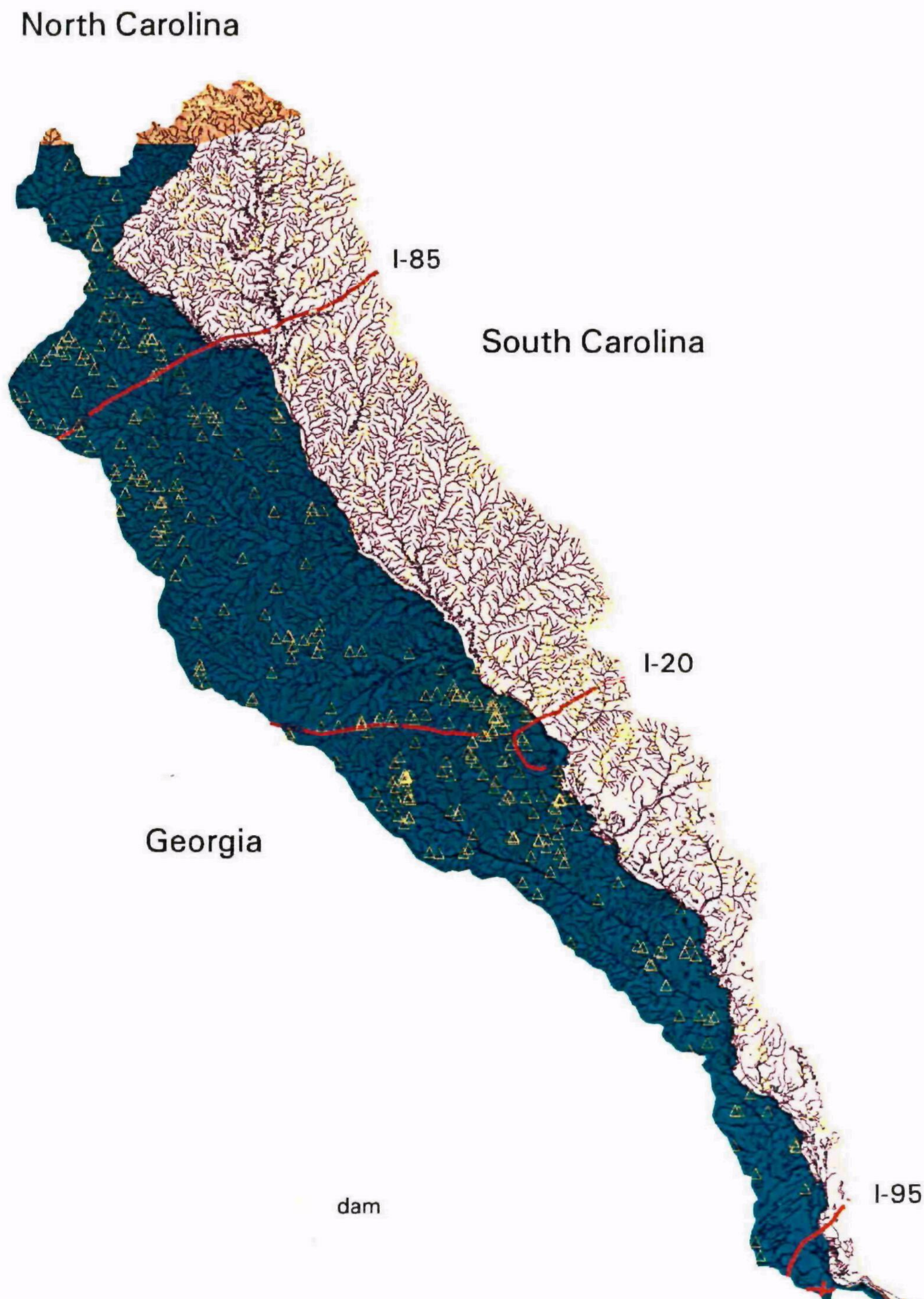
Savannah River Basin Landscape Analysis



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Savannah River Basin
Landscape Analysis

By

Deborah J. Chaloud, Curtis M. Edmonds, and Daniel T. Heggem

U.S. Environmental Protection Agency
Office of Research and Development
National Exposure Research Laboratory
Environmental Sciences Division
Landscape Ecology Branch
Las Vegas, Nevada

Notice

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Section 1

Introduction

Scientists from the U.S. Environmental Protection Agency (EPA), Region 4, Science and Ecosystem Support Division, enlisted the assistance of the landscape ecology group of U.S. EPA, Office of Research and Development (ORD), National Exposure Research Laboratory, Environmental Sciences Division (ESD), in conducting a landscape assessment of the Savannah River Basin as part of their ongoing Regional Environmental Monitoring and Assessment Program (REMAP) demonstration project. In the Scope of Work provided by Region 4, the goal was stated as "provide technical/scientific assistance ...to EPA Region 4 in assessing current wadeable stream conditions in the Savannah River Basin with landscape factors that may be contributing to these conditions or gradients." Three specific objectives were presented in the form of questions. These were:

- Are both the proportions of land uses and the spatial pattern of land uses important for characterizing and modeling stream condition in watersheds/ecoregions of different areas?
- Can land uses near the streams better account for the variability in ecological condition than land use for the entire watershed/ecoregion?
- Does the size of the watershed/ecoregion influence statistical relationships between landscape characteristics and ecological condition?

In addition, an assessment of landscape change was to be conducted as part of continuing ESD research in application of change detection techniques.

The data analysis plan developed to address the objectives given above called for calculation of a specific suite of landscape metrics for all nine United States Geological Survey (USGS) 8-digit hydrological unit codes (HUC; USGS, 1982), a selected subset of the 94 Georgia and South Carolina subbasins, and the riparian corridors in the HUCs and selected subbasins. The subbasins, shown in Figure 1, are generally equivalent in area to USGS 11-digit HUCs. The riparian corridor was defined as 100 meters on either

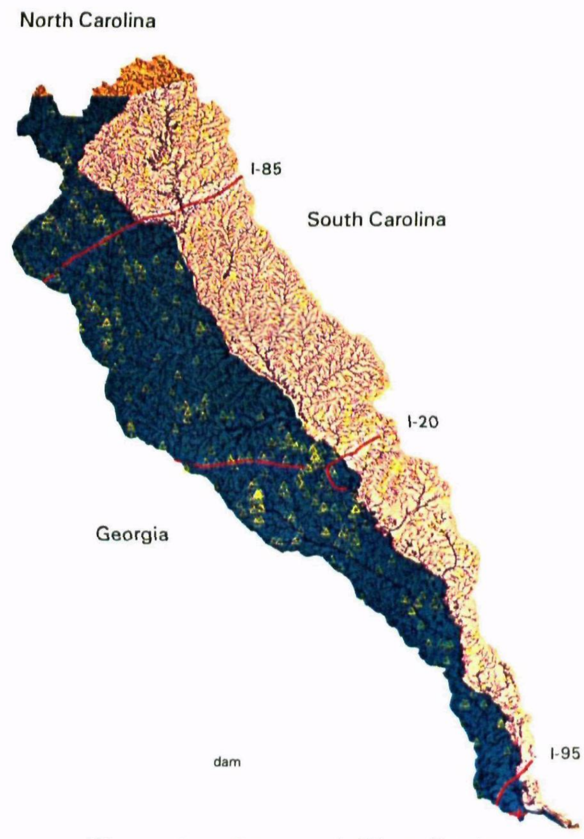

Figure 1. Savannah River Basin.

side of stream arcs; this size was selected from a review of state laws and literature available on the Internet (e.g., Santa Cruz County, 1998; U.S. EPA, 1998; South Carolina Department of Natural Resources, 1998). The suite of metrics included: landcover types, u-index,[1] agriculture on slopes greater than 3 percent, agriculture on highly erodible soils, agriculture on moderately erodible soils, agriculture on highly erodible soils with slopes greater than 3 percent, number of occurrences of roads crossing streams, and number of impoundments. Landscape metric statistics were also computed for the drainage areas and associated riparian corridors of a selected set of sites sampled by Region 4 using REMAP protocols. Region 4 provided an ARC/INFO coverage of the sampling locations and QuatroPro spreadsheets of the water quality and biotic measurements.

The Savannah River Basin is arrowhead-shaped, trending generally northwest to southeast. The basin is comprised of nine USGS 8-digit HUCs (numbered 3060101 through 3060109, hereafter referred simply by the last digit), spanning three ecoregions: Blue Ridge, Piedmont and Coastal Plains. As shown in Figure 2, HUCs 1 and 2 are primarily in the Blue Ridge ecoregion, HUCs 3, 4, 5, and 7 lie in the Piedmont, and the majority of HUCs 6, 8, and 9 are in the Coastal Plain.

Figure 2. Ecoregions of the Savannah River Basin.

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[1] A measure of anthropogenic influence, comprised primarily of agricultural and urban landcover classes.

Section 2

Methods

The selected landscape metrics are identical to, or based on, metrics used in the mid-Atlantic atlas (Jones et al, 1997). In the atlas, the metrics were calculated only for 8-digit HUCs; in this study, metrics are additionally calculated for smaller spatial units. The basic methodology is the same, however. In general, calculation of the landscape metrics involves ARC/INFO techniques of extracting or "cookie cutting" the desired area from a spatial data set. The data are formatted in an ARC/INFO grid of uniform cell size. In this study, a 30-m cell size is used for all grids. For metrics which are produced from more than one data set (e.g., roads crossing streams), ARC/INFO overlay and intersection techniques are used. A few metrics, used only on the drainage areas of the individual sampling sites, are produced from an in-house custom statistics program. These are metrics of fragmentation, i.e., the degree to which landcover types are present in patches rather than in continuous, homogenous blocks. The landscape change metric is produced from comparison of satellite imagery from two dates. This is the only metric which does not use ARC/INFO as the primary data analysis software. Landscape change assessment employs ENVI, an image processing software package available for PC or Unix systems.

2.1 Data Sets Used

The spatial data sets used are obtained from a variety of sources. The primary data sets used in this landscape assessment include: Multi Resolution Land Characteristics (MRLC) Interagency Consortium land cover/land use (Bara, 1994), State Soil Geographic data base(STATSGO)soils (Natural Resources Conservation Service, 1996), RF3 streams (U.S. EPA, 1997), USGS 8-digit HUCs, Georgia and South Carolina subbasins, Region 4 sampling site locational and sampling data, 30-m and 100-m digital elevation models (DEM; USGS, 1990), digital line graph (DLG) roads (USGS, 1989), and National Inventory of Dams impoundments (U.S. Army Corps of Engineers, 1997). Landscape change assessment used North American Land Characterization (NALC) imagery from the 1970s and 1990s (U.S. EPA, 1993). Data sets were subset to the area of interest using the basin boundary coverage.

Section 3

Results

3.1 Sampling Site Ranking, Selection, and Drainage Area Creation

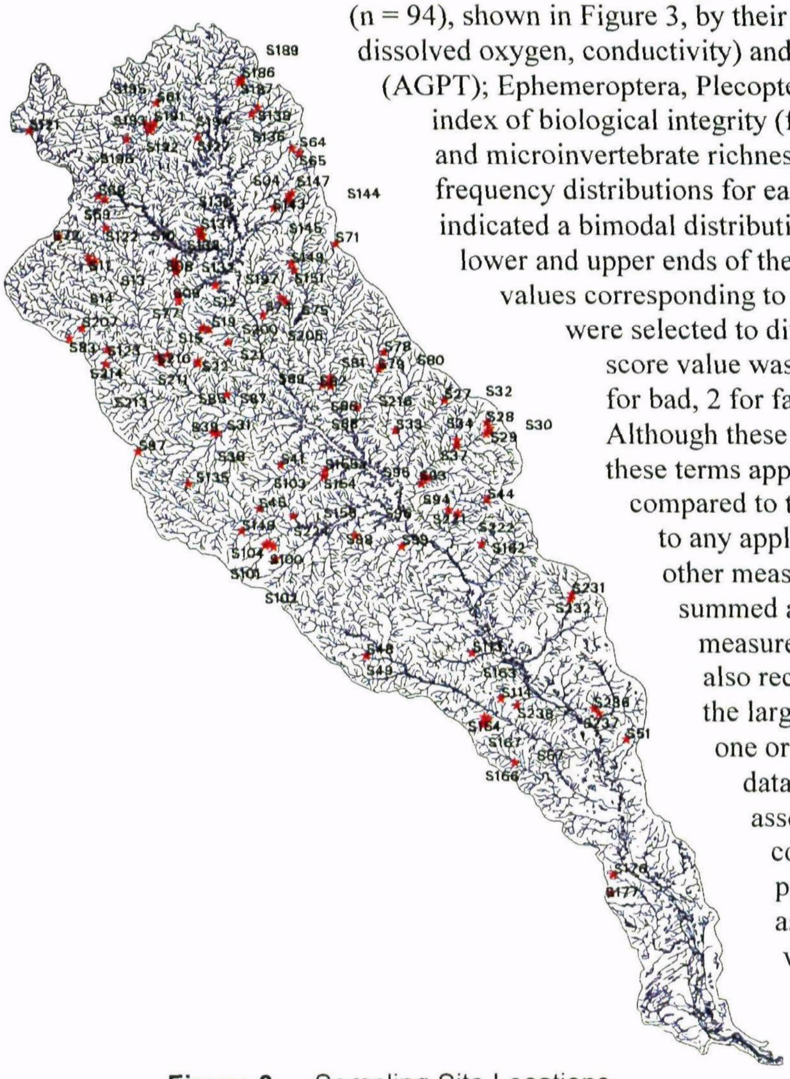


Figure 3. Sampling Site Locations.

A simple, unweighted scoring system was used to rank the sampling sites (n = 94), shown in Figure 3, by their results. Water quality variables (pH, dissolved oxygen, conductivity) and biota [algal growth potential test (AGPT); Ephemeroptera, Plecoptera, and Trichoptera index (EPT); fish index of biological integrity (fish_ibi), microinvertebrate habitat, and microinvertebrate richness] were scored separately. The frequency distributions for each variable was examined. Most indicated a bimodal distribution, with reduced frequencies near the lower and upper ends of the variable's range. Measurement values corresponding to the inflection points of the curve were selected to divide the range into three classes. A score value was ascribed to the measurement value, 1 for bad, 2 for fair, 3 for good, and 0 for missing data. Although these are labeled as good, fair, and bad, these terms apply to the measurement value compared to the range of measurement values, not to any applicable water quality standards or other measurement system. The scores were summed and recorded. The number of measurements used in the summation was also recorded; this was necessary because of the large number of sites missing results for one or more variables. The measurement data and scoring data were then associated with the site location coverage. Map compositions were prepared for each HUC, presented here as Figures 4 through 12. The figures were useful in characterizing relative conditions across the basin and making preliminary decisions about areas for further investigation.

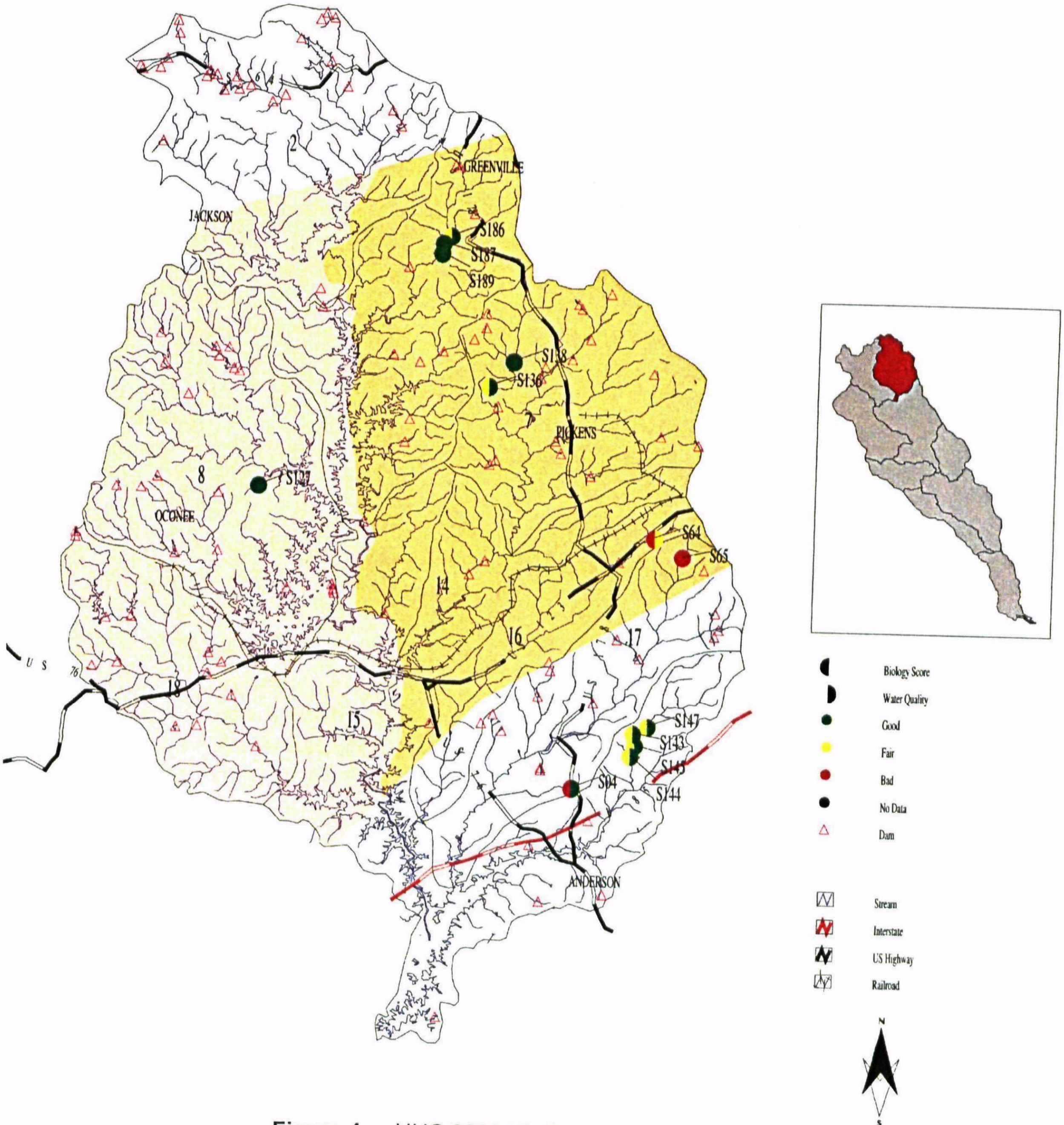


Figure 4. HUC 3060101 Sampling Site Results.

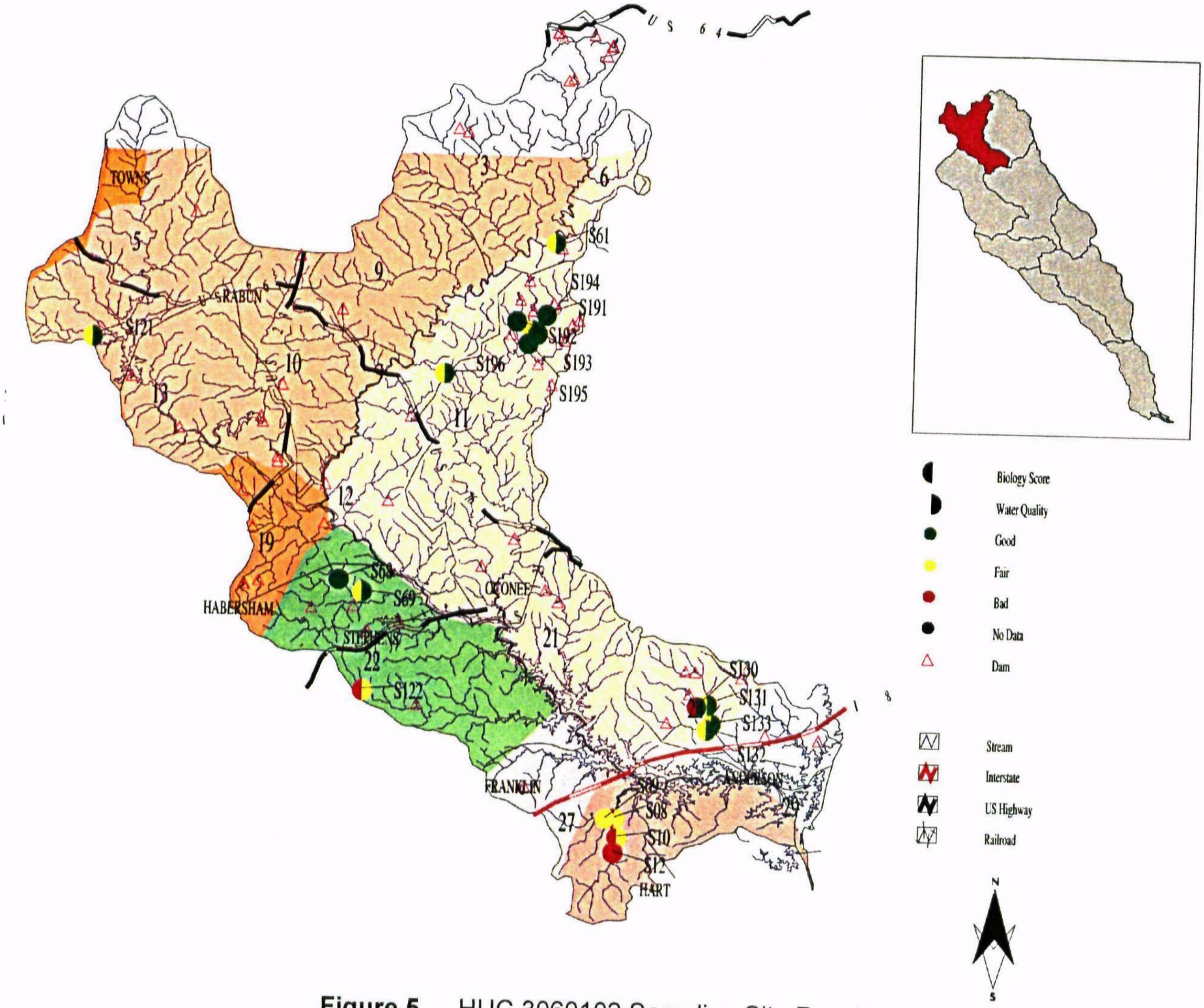


Figure 5. HUC 3060102 Sampling Site Results.

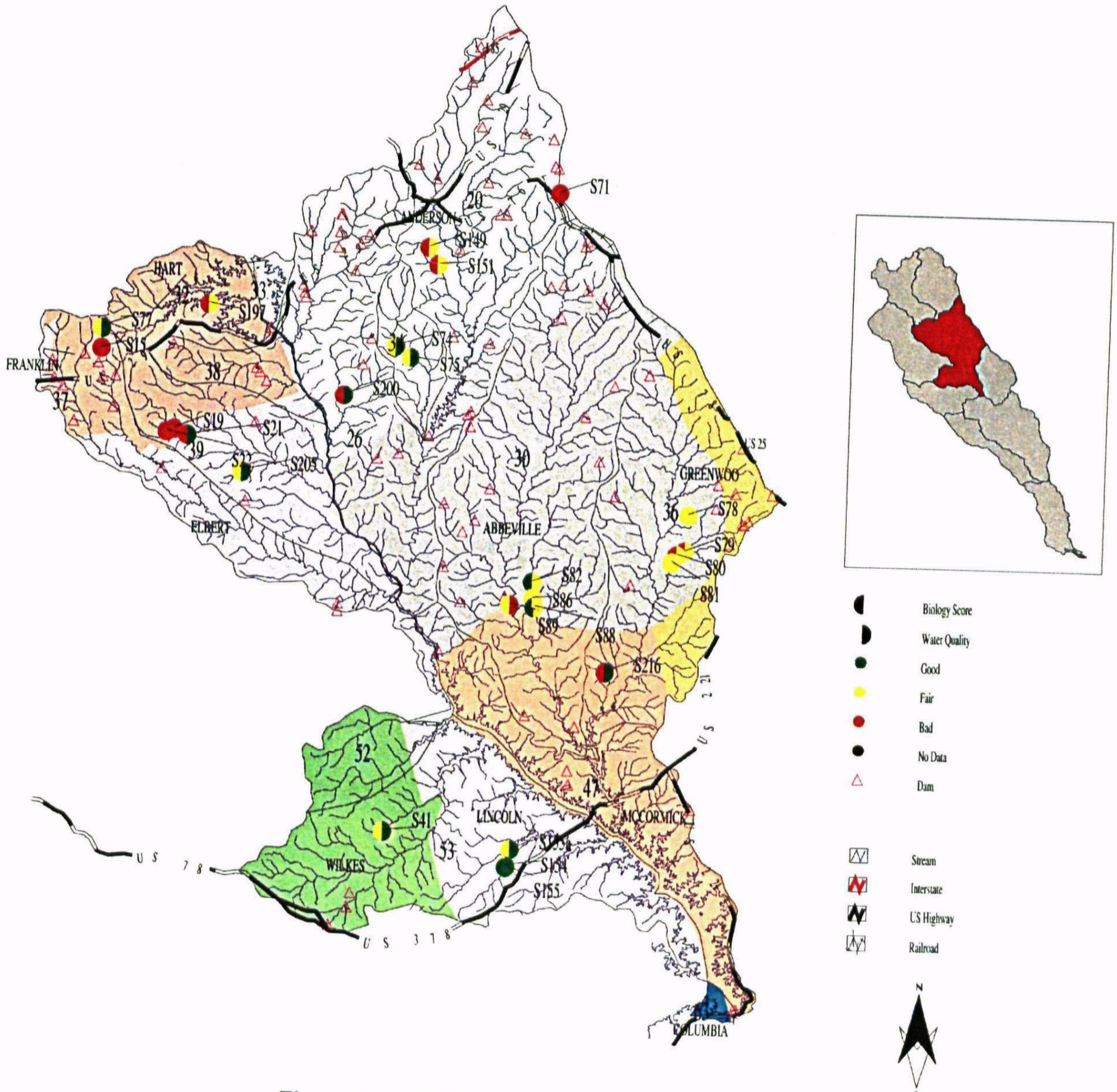


Figure 6. HUC 3060103 Sampling Site Results.

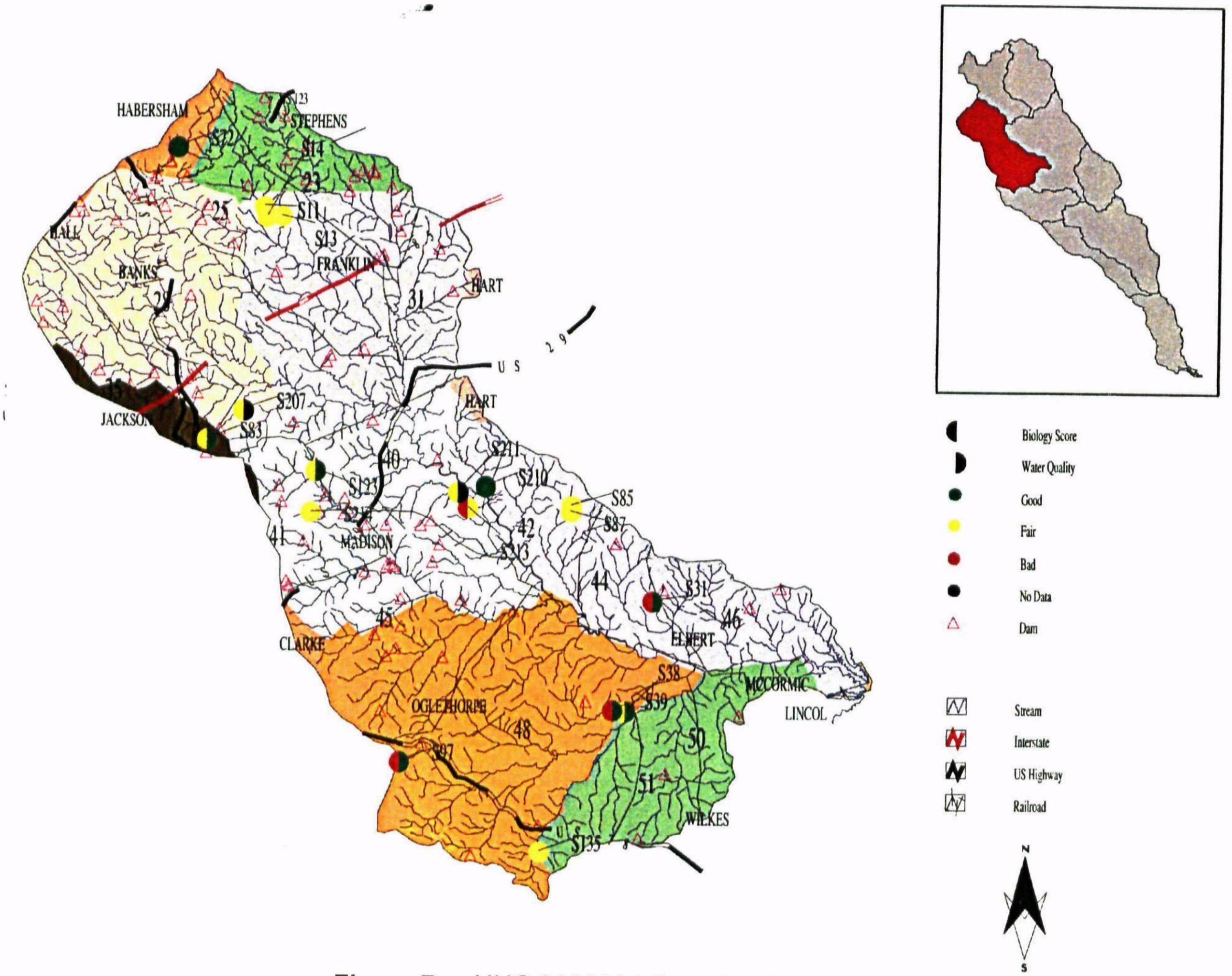


Figure 7. HUC 3060104 Sampling Site Results.

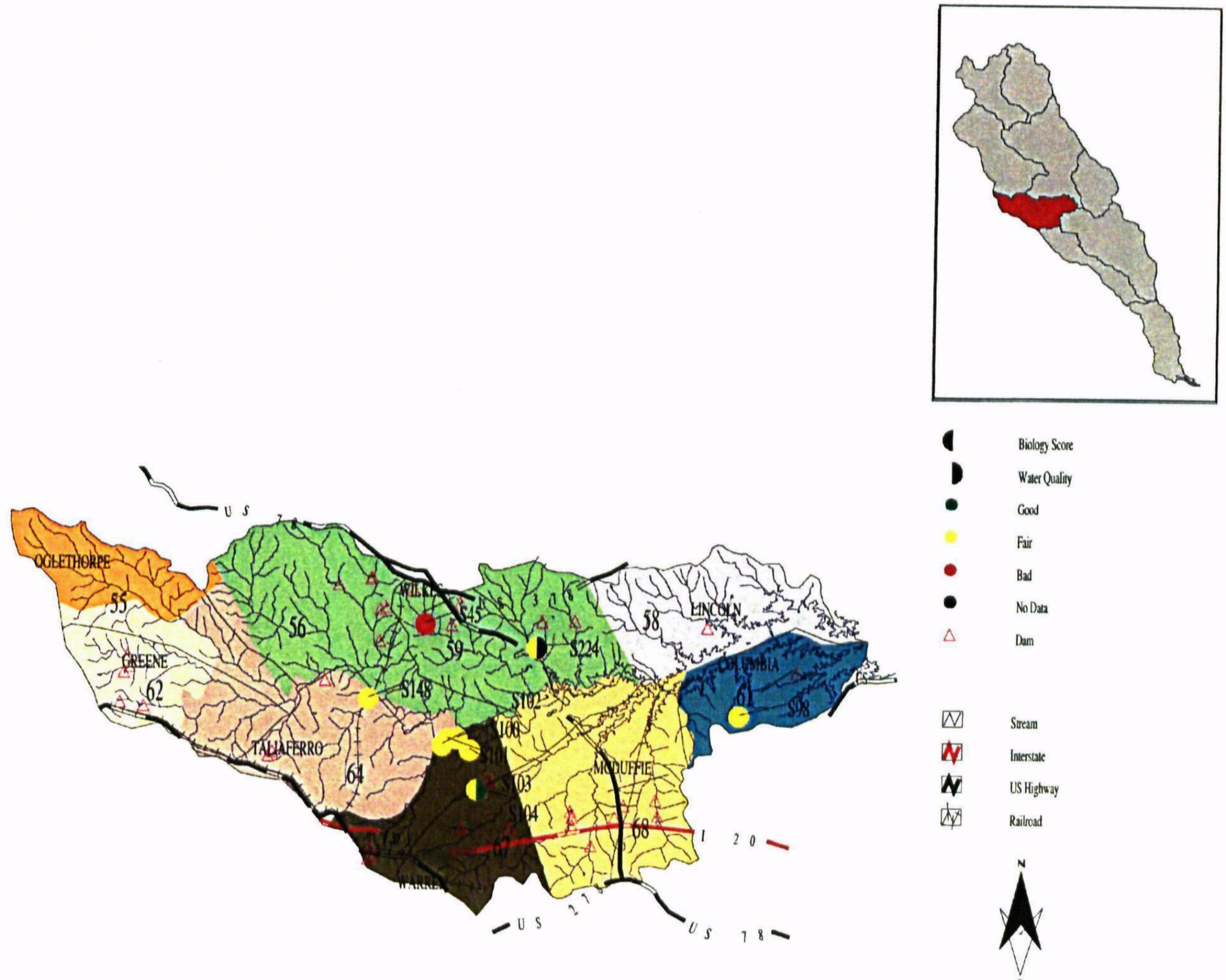


Figure 8. HUC 3060105 Sampling Site Results.

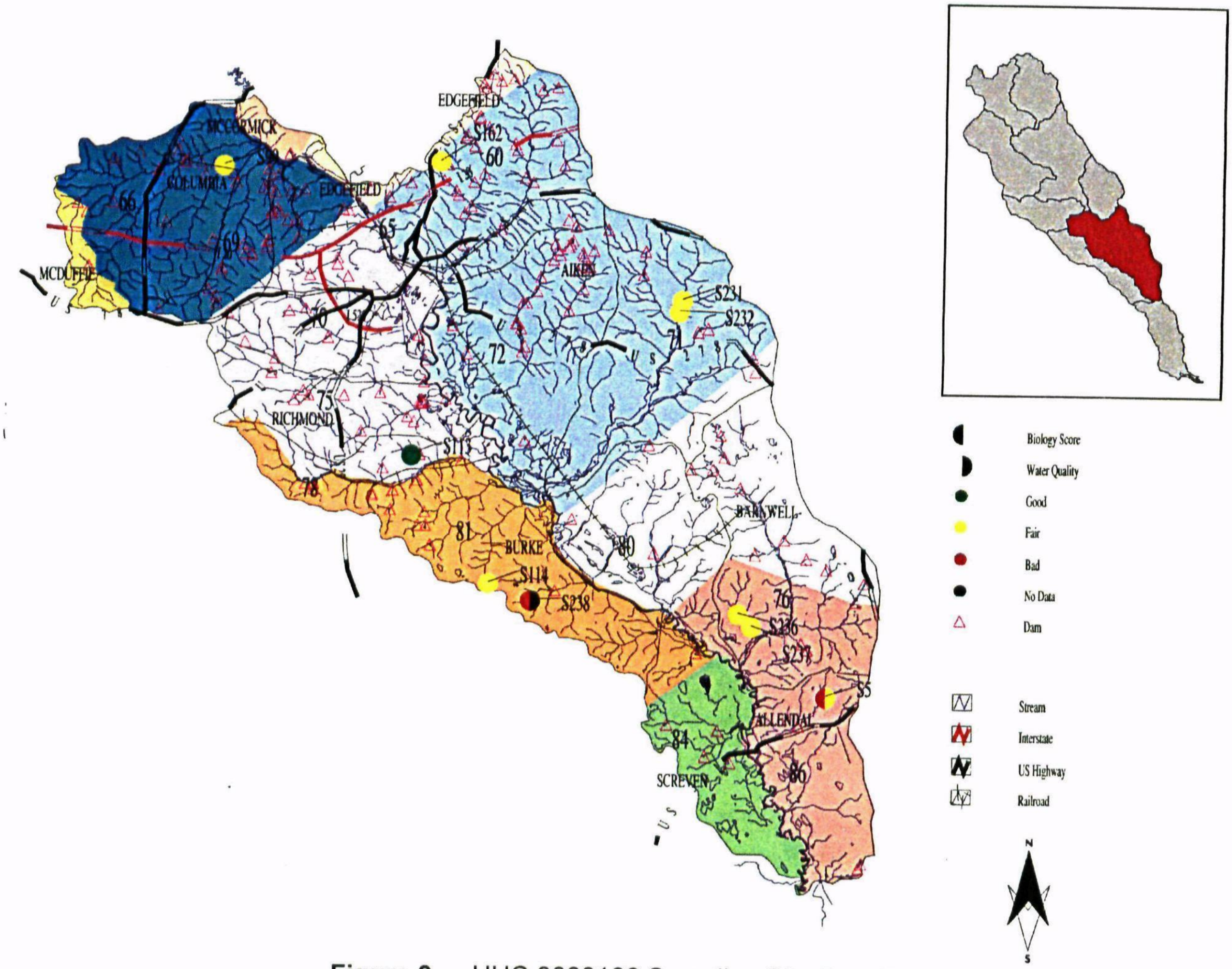


Figure 9. HUC 3060106 Sampling Site Results.

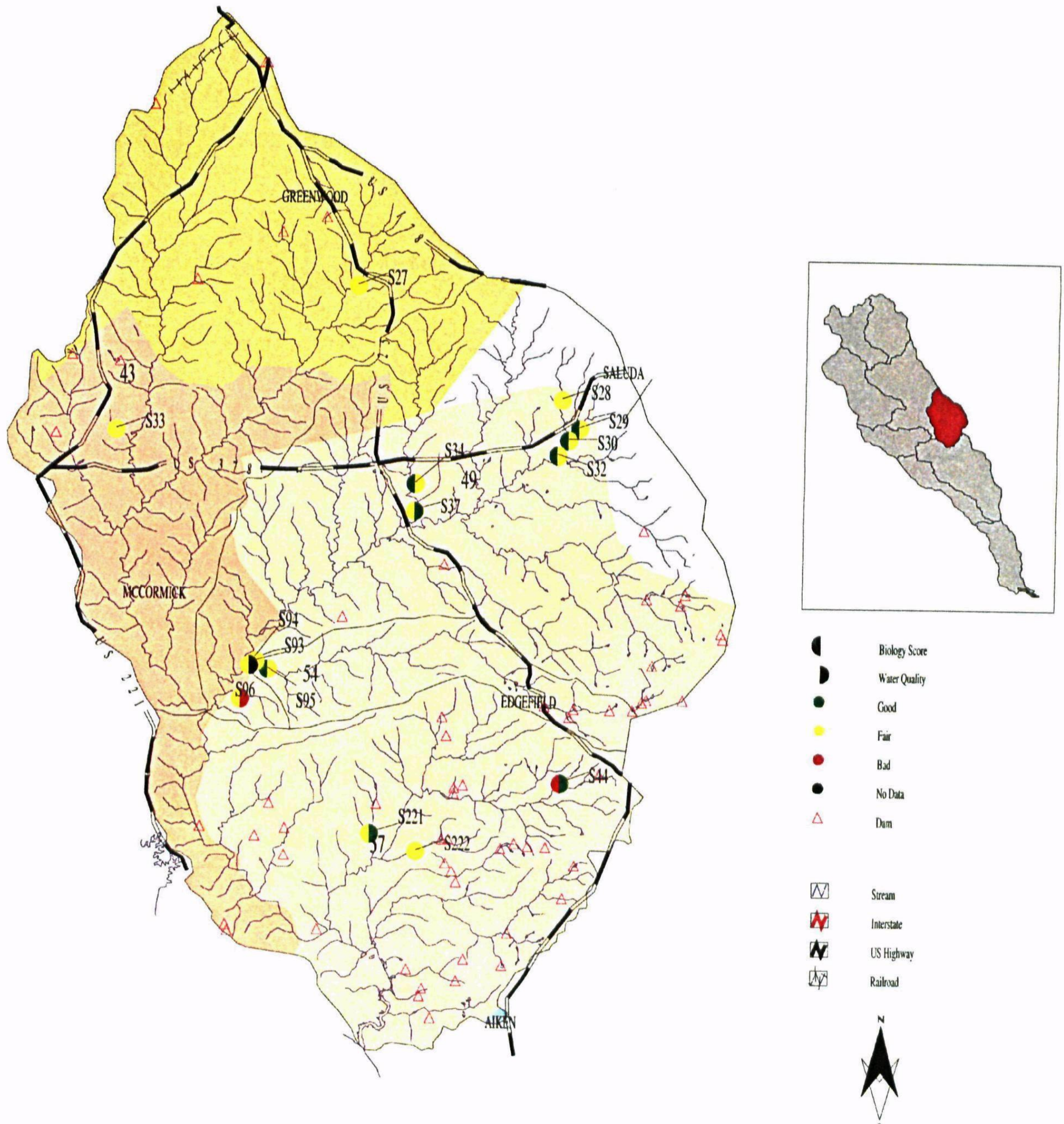


Figure 10. HUC 3060107 Sampling Site Results.

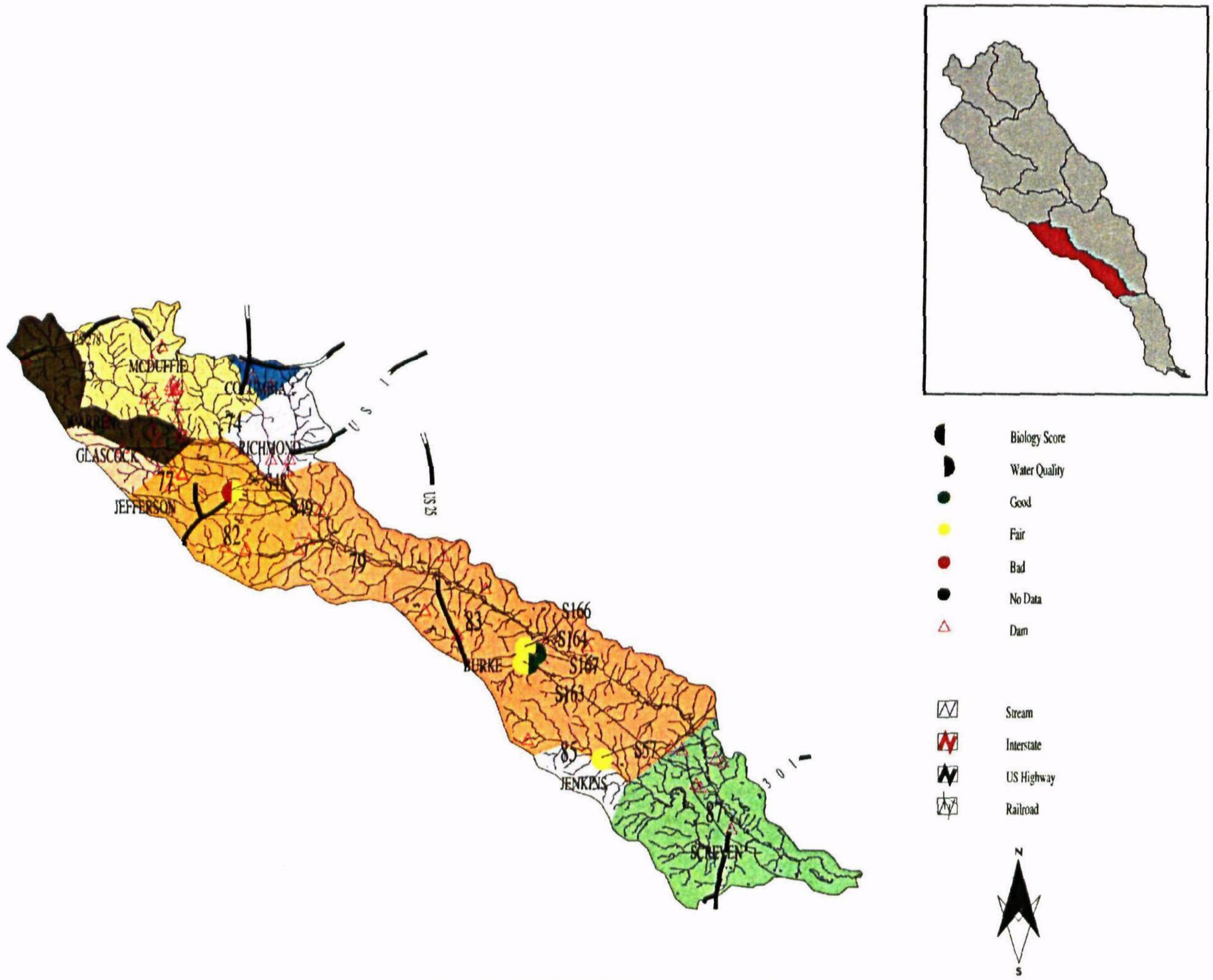


Figure 11. HUC 3060108 Sampling Site Results.

The sampling locations were selected by the Region using the EMAP site selection protocol. Several discussions and correspondences were conducted with a lead EMAP Statistician, Dr. Tony Olson, about the spatial area represented by the sampling sites. It was determined that it would be necessary to develop the specific drainage area of each sampling location and to treat the water quality and biota information as point data. Accurate drainage area computation requires DEMs of 30-m intervals or better; at the time of analysis, these were available for only portions of the Savannah River Basin, primarily the north end and part of the central area.

The process used to delineate the drainage areas employs hydrological analyses tools contained in the Grid module of ARC/INFO. First sinks in the DEMs are identified and filled. Flow direction is computed as the direction from each 30-m cell towards its steepest downslope neighbor. From the flow direction grid, a flow accumulation grid is created by calculation of the number of cells which flow into each downslope cell; this grid resembles the existing stream network. The sampling station locations are input as pour points. In some cases, the sampling point coordinates did not fall directly on a flow accumulation path; in these instances, the pour point was placed on the flow accumulation in the cell nearest to the given station coordinates.

In the selection of the subset of sites for landscape metric assessment, efforts were made to select sites that met the following criteria: 1. Full suite of stream measurement variables, 2. Located in the areas indicated to be of greatest interest to the Region, 3. 30-m DEM data available to use in drainage area determination, 4. Representation of the full range of condition gradient measurement values, and 5. Representation of first through third stream order classes. Using these criteria, sixteen sites were selected.

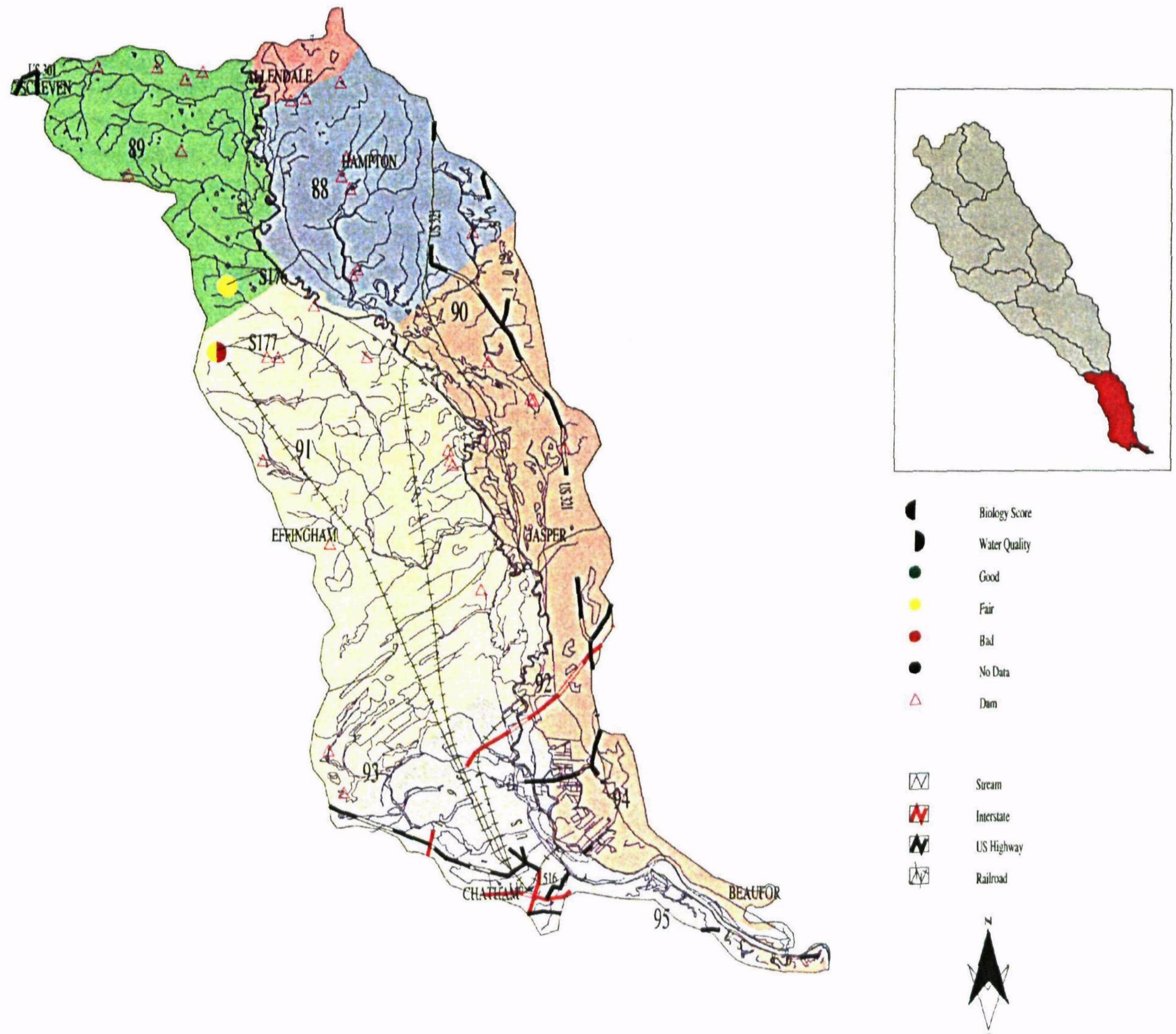


Figure 12. HUC 3060109 Sampling Site Results.

The selection of subbasins for presentation of landscape metrics was made after selection of the sampling sites. The selected subbasins are all in HUC 3060103 and each includes one or more of the sampling site subset. This provides the nested hierarchy of spatial units in the assessment. An arbitrary number was assigned to each subbasin after merging the separate Georgia and South Carolina coverages. The subbasins are shown in Figure 13.

Figure 13. HUCs and Subbasins.

Section 4

Landscape Assessment

4.1 HUC Metrics

The landscape assessment was begun by an analyses of the 8-digit HUCs. As shown in Table 1, the size of the HUCs varies from 200,987.55 ha (HUC 7) to 488,842.20 ha (HUC 6). Associated riparian areas vary from 31,324.14 ha (HUC 7) to 88,651.85 ha (HUC 3), based on a 100-m corridor on either side of all RF3 stream arcs.

Table 1. Physical Dimension Statistics for 8-digit HUCs

HUC	Total Area (ha)	Riparian Corridor (ha)	Stream Length (km)	Stream Density (m/ha)
3060101	272,812.23	55,585.95	3066.68	11.24
3060102	258,218.91	54,114.18	2994.61	11.60
3060103	483,189.03	88,651.85	4803.99	9.94
3060104	398,298.06	65,842.94	3463.28	8.70
3060105	204,446.97	32,453.26	1636.33	8.00
3060106	488,842.20	83,668.92	1765.63	3.61
3060107	200,987.55	31,324.14	4771.76	23.74
3060108	220,108.41	37,124.59	2044.32	9.29
3060109	248,158.71	47,316.49	2679.38	10.80

Landcover types are derived from MRLC data, nominal base year 1992. Differences among the three ecoregions are evident in the forest landcover statistics for the HUCs, Table 2. Deciduous and evergreen forests predominant in HUCs 1 through 5 and 7, the HUCs comprising the Blue Ridge and Piedmont ecoregions; all forest types account for 64.7 to 83.49% of the total land cover. Forest landcover accounts for 37.20 to 53.35% of the landcover in the Coastal Plain HUCs, with evergreen forests the predominant forest type. Wetland landcover types are found primarily in the Coastal Plain HUCs, accounting for 11.10 to 35.93% of the total landcover, most of it in woody wetlands. Wetlands comprise less than one percent of the landcover in the HUCs outside the Coastal Plains.

Table 2. Forest Cover Types, Percent Cover by HUC

HUC	Evergreen	Mixed	Deciduous	Woody Wetlands
3060101	23.36	10.45	37.92	0.62
3060102	25.66	12.15	45.68	0.27
3060103	28.35	11.07	25.28	0.55
3060104	23.72	9.65	38.66	0.36
3060105	39.95	8.85	28.57	0.69
3060106	33.39	7.22	12.74	11.54
3060107	50.21	9.72	18.69	0.74
3060108	24.17	7.50	15.38	10.86
3060109	25.24	4.63	7.33	31.46

Agricultural landcover types, Table 3, comprise 9.91 to 32.47% of the total landcover in each HUC. Pasture/hay is the dominant agricultural land use in the upper part of the basin, while row crops are the largest agricultural land use in the lower basin. Urban landcover types, Table 4, account for between 0.85 to 5.33% of the total land use in all HUCs. There is no ecoregion-related pattern to the distribution of urban landcover. Barren landcover types, Table 5, comprise less than one percent of the total landcover in HUCs 1 and 2, and approximately 2 to 10 percent of the landcover of the Piedmont and Coastal Plains HUCs.

Table 3. Agricultural Land Cover Types, Percent Cover by HUC

HUC	Pasture/Hay	Row Crops	Other Grasses
3060101	10.18	5.05	0.76
3060102	6.76	3.46	0.28
3060103	13.21	9.08	0.48
3060104	15.51	7.59	0.35
3060105	4.01	6.90	0.12
3060106	1.60	14.60	0.46
3060107	3.32	6.59	0.09
3060108	2.76	29.71	0.06
3060109	1.78	14.15	0.38

Table 4. Urban Land Cover Types, Percent Cover by HUC

HUC	Low Intensity Residential	High Intensity Residential	High Intensity Commercial/ Industrial
3060101	3.35	0.29	1.16
3060102	1.03	0.06	0.42
3060103	1.74	0.25	0.60
3060104	0.88	0.06	0.49
3060105	0.60	0.08	0.32
3060106	2.72	1.01	1.60
3060107	0.71	0.10	0.30
3060108	0.49	0.10	0.26
3060109	1.03	0.64	1.18

Table 5. Other Land Cover Types, Percent Cover by HUC

HUC	Water	Emergent Wetlands	Barren: Quarries/Strip Mines	Barren: Bare Rock/Sand	Barren: Transitional
3060101	6.41	0.04	0.19	<0.01	0.22
3060102	3.61	0.07	0.04	<0.01	0.49
3060103	6.60	0.03	0.14	<0.01	2.63
3060104	0.57	0.02	0.14	<0.01	1.98
3060105	4.87	0.03	0.19	<0.01	4.81
3060106	1.46	0.48	0.60	0.01	10.57
3060107	0.39	0.03	0.07	<0.01	9.04
3060108	0.47	0.24	0.54	<0.01	7.45
3060109	3.10	4.47	0.14	0.05	4.40

The patterns of landcover/land use within the riparian corridors, Table 6, are not substantially different than those for the HUCs overall, with the exception that water is an appreciable percentage of the landcover within riparian corridors in most HUCs. Agricultural land use within the riparian corridor ranges from 4.63% to 12.78% and urban land use ranges from 0.33% to 3.51%. Barren landcover ranges from less than 1% to a little more than 6%. The predominant landcover types in the HUC riparian corridors are forest and wetlands in the Coastal Plains and forest in the other ecoregions.

Table 6. Riparian Corridor Land Cover Types, Percent by HUC

HUC	Forest	Agriculture	Urban	Wetland	Barren	Water
3060101	71.96	8.16	3.19	1.92	0.44	14.51
3060102	79.06	7.03	1.31	1.09	0.33	11.20
3060103	70.63	10.10	1.38	1.77	1.26	14.86
3060104	83.20	12.16	0.76	1.21	0.64	2.04
3060105	76.83	4.84	0.57	2.23	4.17	11.33
3060106	48.79	6.54	3.51	28.90	6.23	6.06
3060107	86.00	4.63	0.40	1.99	5.51	1.50
3060108	48.53	12.78	0.33	32.43	4.20	1.77
3060109	24.13	6.38	1.34	57.23	2.48	8.44

While there is some variation in landcover types among the three ecoregions, overall the HUCs are relatively homogeneous in landcover/land use pattern. In all HUCs, natural landcover types comprise greater than 50% of the total landcover. Urban land uses account for only a small percent of the total landcover and agricultural uses account for 1/10 to approximately 1/3 of the total land cover/land use. These results contrast greatly with the results obtained for 8-digit HUCs in the mid-Atlantic region (Jones et al, 1997), where large differences were evident at this scale. The broad-scale patterns evident in the mid-Atlantic (e.g., intensive urbanization of the Coastal Plains, concentrated agricultural land uses in valleys, and isolation of forests to highland areas) are not in evidence in the Savannah River Basin.

The proportion of agriculture on slopes greater than 3% grade has been developed as a landscape metric because the potential for erosion increases significantly at this grade. Similarly, agriculture practiced on highly or moderately erodible soils has a higher potential for erosion. These metrics are developed from overlays of DEMs, MRLC land cover/land use, and erodibility factors contained in the STATSGO soils data base. Results for all of these metrics are generally low, as shown in Table 7. Only HUCs 3 and 4 showed greater than 20% total land area for any of the agriculture-soil-slope metrics, that being agriculture on moderately erodible soils, most of it in pasture/hay. Results for these metrics within the riparian corridors are lower, ranging from nonexistent to less than 12% agriculture on moderately erodible soil in HUC 4, as shown in Table 8.

Table 7. Agriculture on Slopes and Erodible Soils, Percent by HUC

HUC	Pasture/Hay on Slopes > 3%	Row Crops on Slopes > 3%	Pasture/Hay on Moderately Erodible Soils	Row Crops on Moderately Erodible Soils	Pasture/Hay on Highly Erodible Soils	Row Crops on Highly Erodible Soils
3060101	2.24	0.98	10.03	4.96	—	—
3060102	1.33	0.67	6.54	3.36	—	—
3060103	1.25	0.75	12.51	8.41	0.61	0.58
3060104	2.25	0.95	15.24	7.45	0.26	0.14
3060105	0.22	0.42	2.22	3.84	1.76	2.71
3060106	0.13	0.72	0.22	1.67	<0.01	0.02
3060107	0.10	0.26	4.20	3.06	—	—
3060108	0.03	0.47	0.48	3.23	—	—
3060109	<0.01	0.02	0.41	2.51	—	—

Table 8. Agriculture-Related Metrics in Riparian Corridors, Percent Buffered Area

HUC	Pasture/Hay on Slopes > 3%	Row Crops on Slopes > 3%	Pasture/Hay on Moderately Erodible Soils	Row Crops on Moderately Erodible Soils	Pasture/Hay on Highly Erodible Soils	Row Crops on Highly Erodible Soils
3060101	1.04	0.55	4.66	2.50	—	—
3060102	0.95	0.48	4.08	1.94	—	—
3060103	0.51	0.33	5.68	3.53	0.20	0.21
3060104	1.00	0.47	7.98	3.89	0.08	0.07
3060105	0.11	0.16	0.73	1.46	0.98	1.56
3060106	0.05	0.23	0.21	1.17	<0.01	0.01
3060107	0.03	0.12	1.88	1.78	—	—
3060108	0.01	0.10	0.25	1.35	—	—
3060109	<0.01	<0.01	0.21	1.30	—	—

Roads frequently cause increased runoff to streams and contribute pollutants washed off the road surfaces. This phenomenon is represented by the roads-crossing-streams metric, computed from intersecting digital line graph roads with RF3 stream arcs. As shown in Table 9, values for this metric range from 362 in HUC 5 to 1,914 in HUC 6. Normalizing these values to the number of road crossings per stream kilometer, as shown in Table 9, shows the greatest frequency of roads crossings per stream kilometer is in HUC 6 with more than one road crossing per kilometer of stream length. The lowest frequency is in HUC 7 with approximately one road crossing for every 8 kilometers of stream length. The remaining HUCs have frequencies in the range of one road crossing for every 2.5 to 5 kilometers of stream length.

Table 9. Roads Crossing Streams and Impoundments

HUC	Road Crossings	No. Crossings/Stream km	Dams	No. Dams/Stream km
3060101	1235	0.40	117	0.038
3060102	964	0.32	58	0.019
3060103	1487	0.31	98	0.020
3060104	1227	0.35	102	0.029
3060105	362	0.22	35	0.021
3060106	1914	1.08	191	0.108
3060107	637	0.13	60	0.013
3060108	842	0.41	52	0.025
3060109	723	0.27	31	0.012

Information for dams was obtained from the National Inventory of Dams which tracks all dams greater than 6 feet in height for inspection purposes. As shown in Table 9, the fewest number of dams in any HUC is 31 in HUC 9 while the greatest number is 191 in HUC 6. Normalizing by the total stream length within each HUC shows the greatest frequency of dams is also in HUC 6, with one dam for every 9 kilometers of stream length. The lowest frequencies of dams are in HUC 9 and HUC 7, with roughly one dam for every 80 kilometers of stream length. The locations of dams are depicted in Figure 1.

4.2 Subbasin Metrics

As discussed above, the landscape metrics at the HUC level show some variation among HUCs attributable to natural landcover variation at the ecoregion level. However, the patterns of land use are generally consistent across ecoregions and among HUCs. This section focuses on the next scale, the subbasin. Landscape metrics are presented for several subbasins of HUC 3. These particular subbasins were selected because they each contain one or more of the sampling sites selected for analysis. The landscape metrics produced for the subbasins are the same as those produced for the HUCs.

Physical dimensions of the selected subbasins are shown in Table 10. The total land area in each subbasin ranges from 17,195.76 ha in #32 to 68,295.33 ha in #53. The associated riparian corridors range from 4,311.00 to 12,800.34 ha.

Table 10. Physical Dimension Statistics for Selected Subbasins

Subbasin	Total Area (ha)	Riparian Corridor (ha)	Stream Length (km)	Stream Density (m/ha)
20	55,797.39	9,089.19	486.79	8.72
26	53,225.73	10,089.00	528.63	9.93
32	17,195.76	4,311.00	255.27	14.84
36	61,462.62	9,704.07	499.79	8.13
53	68,295.33	12,800.34	695.35	10.18

The landcover statistics for HUC 3 overall are 64.70% forest (approximately 28% evergreen, 25% deciduous and 11% mixed forest), 22.29% agriculture (approximately 13% pasture/hay and 9% row crops), 2.59% urban, 6.60% water, approximately 3% barren, and less than one percent wetlands. Among the subbasins, the forest landcover classes vary from 40.26% in #32 to 73.66% in #53. As shown in Table 11, evergreen forests are the largest forest class in #26, #36, and #53; deciduous is the largest class in #20 and #32. Agricultural land use in #26 is about the same as in the HUC overall (23.65% of which approximately 16% is in pasture/hay). Greater agricultural land use is evident in #20 (34.07% with about 20% in pasture/hay) and #32 (32.45% of which almost 18% is pasture/hay). Less landcover is in agricultural land uses in #36 (15.16%, with more than 8% pasture/hay) and #53 (11.58%, with row crops slightly exceeding pasture/hay). Urban land use is lowest in #53 at less than one percent and highest in #20 at 8.05%. The remaining three subbasins have urban land use in slightly higher percentages than for the HUC overall, ranging 3.05% in #36 to 4.81% in #32.

Table 11. Land Cover Types for Selected Subbasins, Percent Area

Land Cover Type	Subbasin				
	20	26	32	36	53
Water	1.30	8.11	20.59	0.57	9.36
Low Intensity Residential	5.60	2.87	3.34	2.10	0.45
High Intensity Residential	0.83	0.57	0.43	0.28	0.03
High Intensity Commercial/Industrial	1.62	1.23	1.04	0.67	0.15
Pasture/Hay	20.23	16.33	17.54	8.43	5.58
Row Crops	13.84	7.32	14.91	6.73	6.00
Other Grasses	1.53	0.95	0.75	0.36	0.14
Evergreen Forest	16.09	25.32	10.53	37.08	36.70
Mixed Forest	9.55	11.00	5.96	13.12	10.98
Deciduous Forest	28.30	21.12	23.77	24.61	25.98
Woody Wetlands	0.57	0.75	0.82	0.30	0.63
Emergent Wetlands	0.03	0.02	0.11	0.02	0.03
Barren: Quarries/Strip Mines	0.26	0.14	0.21	0.07	0.09
Barren: Transitional	0.24	4.27	<0.01	5.66	3.88

In the riparian corridors, forest comprises 53.02 to 85.52% of the total cover, with deciduous the most dominant forest cover type, as shown in Table 12. Agricultural land use within the riparian corridor ranges from 4.41% in #53 to 15.92% in #32 and urban land use comprises from 0.39% to 4.99% of the total riparian land cover. Wetlands account for approximately 3% or less of the riparian land cover types.

Table 12. Land Cover Types for Selected Subbasin Riparian Corridors, Percent Area

Land Cover Type	Subbasin 20	26	32	36	53
Water	5.89	22.38	25.31	2.25	18.58
Low Intensity Residential	3.97	1.68	1.82	1.36	0.31
High Intensity Residential	0.26	0.19	0.07	0.08	<0.01
High Intensity Commercial/Industrial	0.76	0.47	0.39	0.20	0.08
Pasture/Hay	8.84	8.68	7.60	3.84	1.94
Row Crops	5.54	3.40	8.32	2.84	2.47
Other Grasses	0.36	0.24	0.21	0.05	0.02
Evergreen Forest	15.78	18.59	14.30	25.59	29.40
Mixed Forest	12.76	12.30	8.49	15.37	10.54
Deciduous Forest	43.15	28.94	30.23	44.56	33.20
Woody Wetlands	2.11	1.69	2.73	0.79	2.27
Emergent Wetlands	0.09	0.05	0.37	0.04	0.10
Barren: Quarries/Strip Mines	0.34	0.06	0.15	0.03	0.02
Barren: Transitional	0.16	1.32	<0.01	2.99	1.07

The agriculture-soil-slope metric results for HUC 3 are 2% agriculture on slopes greater than 3%, approximately 21% agriculture on moderately erodible soils, approximately 1% agriculture on highly erodible soils, and less than 0.1% agriculture on slopes greater than 3% in highly erodible soils. Among the subbasins, #20, #26, and #32 have more agriculture on slopes greater than 3% and more agriculture on moderately erodible soil than for the HUC overall; the remaining two subbasins are substantially lower than the HUC overall for both these metrics, as shown in Table 13. Only #53 has any agriculture on highly erodible soil (about 7%) and agriculture on slopes greater than 3% and highly erodible soils (0.35%). Results for these metrics are lower for the riparian corridors, with only subbasins #20, #26, and #32 having more than 10% riparian land cover in agriculture on moderately erodible soils.

Table 14 provides results for the number and frequency of roads crossing streams and dams (Figure 14). Roads crossing streams ranges from 56 in #32 to 299 in #20. There are no dams in #32, but 19 dams in #20. The frequency of roads crossing streams is highest in #20 with approximately one road crossing for every 1.6 kilometers of stream length; the lowest frequency is in #53 with one road crossing per approximately 9 kilometers of stream length. The frequency of roads crossing streams for the HUC overall is approximately one crossing per 3 kilometers of stream length. The frequency of impoundments for the HUC overall is approximately one dam for every 50 stream kilometers. The frequency of dams is lower than for the HUC overall in #32 with no dams and in #53 with approximately one dam for every 167 kilometers of stream length. The greatest frequency of dams among the subbasins is in #20 with one dam per approximately 25 stream kilometers.

Table 13. Agriculture-Related Metrics for Selected Subbasins and Riparian Corridors

	Subbasin				
	20	**26**	**32**	**36**	**53**
Percent of Subbasin Total Area					
Agriculture on Slopes >3%	3.54	2.71	4.29	1.17	0.60
Agriculture on Moderately Erodible Soils	34.03	23.53	31.64	15.15	4.39
Agriculture on Highly Erodible Soils	—	—	—	—	7.11
Percent of Subbasin Riparian Corridor					
Agriculture on Slopes >3%	1.31	1.34	1.24	0.39	0.27
Agriculture on Moderately Erodible Soils	14.13	11.99	13.02	6.67	1.43
Agriculture on Highly Erodible Soils	—	—	—	—	2.61

Table 14. Roads Crossing Streams and Impoundments for Selected Subbasins

Subbasin	Total Area (ha)	Riparian Corridor (ha)	Stream Length (km)	Stream Density (m/ha)
20	299	0.61	19	0.039
26	227	0.43	15	0.028
32	56	0.22	0	—
36	170	0.24	13	0.026
53	82	0.11	4	0.006

At this scale, patterns which may impact water quality begin to be evident. In Figure 6, the sampling stations in #53 are indicated as fair to good (as compared to the overall data range). This subbasin has the highest proportion of landcover in forest among the subbasins, the lowest proportion of agriculture and urban land uses, and a low proportion of agriculture on slopes greater than 3%. Among the selected subbasins, it has the lowest frequency of roads crossing streams. Although is the largest of the subbasins in total area, this subbasin has only 4 dams. However, #53 is the only subbasin among those examined with agriculture on highly erodible soils and agriculture on slopes greater than 3% and highly erodible soils.

In contrast, the sampling sites in #32 and #20 rank as fair to bad compared to the overall data ranges. These two subbasins contain the greatest proportion of agriculture among the subbasins, 28 to 33% agriculture on moderately erodible soils, and 3 to 4% agriculture on slopes greater than 3%. In addition, #20 has the highest proportion of urban land use, the highest normalized roads crossing streams value, and the greatest frequency of dams among the selected subbasins.

Figure 14. Roads Crossing Streams and Dams in Selected Subbasins.

4.3 Sampling Site Drainage Landscape Metrics

One of the objectives of this project is to try to establish relationships among landscape metrics and water quality/aquatic biota metrics. The water quality data were collected at specific sampling sites. To investigate relationships with landscape metrics, it is necessary to delineate the drainage area to the individual sampling site. This was done for a subset of 16 sampling sites. The selection process was described earlier, as was the methodology for delineating the drainage areas.

The drainage areas for the sampling sites range from 122.58 to 10,665.18 ha, as shown in Table 15. In delineating the drainage areas, the locations for the sampling sites frequently did not lie on a stream arc, necessitating a best guess, based on the indicated stream order and proximity to stream arc, as to the point on the arc to use as the pourpoint. In addition to the landscape metrics calculated for the HUCs and subbasins, metrics of fragmentation were generated using a custom, in-house software program. For the fragmentation metrics, the 15 landcover/land use classes of the MRLC data were aggregated to six classes: water, urban, forest, agriculture, wetlands, and barren, as shown in Table 16 for the overall drainage area and in Table 17 for the riparian corridors. In these aggregated land cover types, other grasses are included in agriculture and woody wetlands are included in the wetlands cover type.

Table 15. Physical Dimension Statistics for Sampling Site Drainages, Percent Area

Site	Total Area (ha)	Riparian Corridor (ha)	Stream Length (km)	Stream Density (m/ha)
S22	973.98	149.85	7.34	7.54
S27	4,950.90	939.78	47.57	9.61
S68	468.09	88.65	4.34	9.28
S80	6,499.71	884.16	44.90	6.91
S81	6,612.21	908.01	45.85	6.93
S95	10,665.18	1,727.73	89.30	8.38
S103	572.76	69.30	3.32	5.80
S113	747.00	83.79	4.51	6.03
S130	1,169.73	163.80	8.68	7.42
S149	776.52	139.50	6.87	8.84
S151	1,076.22	191.88	9.53	8.85
S155	2,556.72	381.06	18.98	7.42
S195	4,279.41	860.94	46.05	10.76
S197	122.58	43.56	2.06	16.78
S200	1,798.47	377.37	19.11	10.62
S216	551.16	116.19	5.69	10.33

Table 16. Aggregated Land Cover Types for Sampling Site Drainages, Percent Area

Site	Water	Urban	Agriculture	Forests	Wetlands	Barren
S22	0.11	<0.01	59.40	40.21	0.24	0.04
S27	0.34	0.34	18.76	80.06	0.37	0.11
S68	<0.01	<0.01	0.27	96.01	<0.01	3.73
S80	0.56	7.75	18.28	72.71	0.45	0.26
S81	0.55	7.62	17.97	73.17	0.44	0.25
S95	0.62	2.84	8.40	81.52	0.87	5.75
S103	<0.01	<0.01	0.04	89.92	0.08	9.96
S113	0.59	2.80	23.70	61.78	4.56	6.55
S130	1.02	<0.01	62.27	36.28	0.40	0.03
S149	0.03	16.02	44.33	39.38	0.10	0.13
S151	0.09	13.01	40.59	46.00	0.19	0.10
S155	0.11	3.21	17.77	73.21	0.56	5.14
S195	0.85	0.44	3.45	94.49	0.04	0.73
S197	<0.01	5.50	42.59	51.62	0.29	<0.01
S200	0.19	6.77	47.64	42.37	0.23	0.11
S216	0.10	0.07	4.90	87.62	0.13	7.18

Table 17. Aggregated Land Cover Types for Sampling Site Riparian Corridors, Percent Area

Site	Water	Urban	Agriculture	Forests	Wetlands	Barren
S22	<0.01	<0.01	29.91	69.37	0.72	<0.01
S27	0.48	0.05	8.19	90.41	0.82	0.06
S68	<0.01	<0.01	0.41	99.19	<0.01	0.41
S80	2.28	6.17	11.81	78.70	0.92	0.11
S81	2.21	6.02	11.63	79.14	0.88	0.11
S95	2.97	2.06	2.83	88.22	1.79	2.14
S103	<0.01	<0.01	<0.01	95.84	0.13	4.03
S113	4.19	<0.01	4.72	60.36	29.53	1.18
S130	6.21	<0.01	25.60	66.60	1.59	<0.01
S149	<0.01	11.35	20.70	67.93	<0.01	<0.01
S151	<0.01	9.52	17.82	72.47	0.19	<0.01
S155	0.07	1.49	6.55	89.14	0.64	2.13
S195	4.21	0.08	7.07	87.39	0.09	1.15
S197	<0.01	9.09	10.75	80.17	<0.01	<0.01
S200	0.45	6.13	26.18	66.71	0.45	0.07
S216	0.08	0.15	2.47	92.56	0.23	4.49

Results for agriculture-related metrics over the entire drainage area and the riparian corridor are presented in Table 18. The number of road crossing streams and dams are shown in Table 19. Ten of the 16 sampling site drainages contain no dams; however, where dams are present, they are generally greater in frequency than in the HUC or subbasins overall. The frequency of roads crossing streams ranges from approximately one road crossing per 5.5 kilometers of stream length to a maximum of one road crossing for every stream kilometer.

Table 18. Agriculture-Related Metrics for Sampling Site Drainages and Riparian Corridors, Percent Area

	Total Area			*Riparian Corridor*		
Site	**Agriculture on Slopes > 3%**	**Agriculture on Moderately Erodible Soil**	**Agriculture on Highly Erodible Soils**	**Agriculture on Slopes >3%**	**Agriculture on Moderately Erodible Soils**	**Agriculture on Highly Erodible Soils**
S22	3.91	59.40	—	2.22	29.91	—
S27	0.26	18.69	—	0.03	8.19	—
S68	0.19	0.27	—	0.30	0.41	—
S80	1.57	17.72	—	0.66	11.64	—
S81	1.54	17.42	—	0.65	11.43	—
S95	0.28	5.87	—	0.02	2.30	—
S103	—	0.04	0.04	—	—	—
S113	2.14	—	—	2.04	—	—
S130	9.59	62.27	—	1.70	25.60	—
S149	1.85	41.40	—	0.32	18.83	—
S151	2.35	38.36	—	0.28	16.46	—
S155	1.07	17.33	17.33	0.02	6.38	6.38
S195	0.64	3.37	—	0.96	7.07	—
S197	9.92	42.59	—	0.21	10.75	—
S200	4.25	45.51	—	2.43	25.42	—
S216	0.09	4.90	—	0.15	2.47	—

Figures 15 through 20 depict six of the sampling station drainage areas. Sites S68, S113, and S195 are ranked as good data sites, based on the relative rankings of the data measurements. Site S68 is a small forested drainage located in HUC 2. Site 113 is also relatively small and is located in HUC 6; although agriculture and urban areas are evident within the drainage, they are fragmented as compared to the forest landcover; much of the riparian corridor is wetlands. Site S195 is a larger drainage and higher order stream located in HUC 2. All of the landcover types are present, as are a number of roads and a few dams. The predominant landcover, however, is unfragmented forest.

The remaining three figures are indicative of sites with fair to bad relative rankings. Site S22, located in HUC 3, subbasin # 39 has extensive agriculture, much of it in large blocks while the forest landcover types are fragmented. Site S80 is a large drainage area located in HUC 3 subbasin # 36; the sampling site is located in an area of unfragmented forest, but the upper reaches of the drainage, including the headwaters of most of the streams are dominated by urban and agricultural landcovers and extensive road networks. Site S149 is a fairly small drainage located in HUC 3, subbasin #20. There is extensive agriculture and urban land use; the forest landcover is highly fragmented. The headwaters of one of the two streams in the drainage is found in an area of high intensity commercial/industrial land use.

Table 19. Roads Crossing Streams and Impoundments for Sampling Site Drainages

Site	Roads Crossings	No. Crossings/ Stream km	Dams	No. Dams/ Stream km
S22	3	0.41	0	—
S27	21	0.44	1	0.021
S68	2	0.46	0	—
S80	30	0.67	6	0.134
S81	30	0.65	6	0.131
S95	37	0.41	4	0.045
S103	1	0.30	0	—
S113	1	0.22	0	—
S130	4	0.46	1	0.115
S149	5	0.73	0	—
S151	8	0.84	0	—
S155	4	0.21	0	—
S195	27	0.59	4	0.087
S197	1	0.49	0	—
S200	19	0.99	0	—
S216	1	0.18	0	—

Results for each landscape metrics were encoded into ARC/INFO Grids. A Grid stack was generated and used to develop a correlation matrix. A separate Grid stack was generated for the riparian corridors contained in the drainage areas for the sixteen sampling sites. With an n of 16, the correlation coefficients are significant at values greater than 0.666 for $\alpha = 0.005$, at values greater than 0.601 for $\alpha = 0.01$, at values greater than 0.507 for $\alpha = 0.025$, and at values greater than 0.425 for $\alpha = 0.05$. Using these values, a number of significant correlations between water quality/aquatic biology metrics and landscape metrics were indicated, as shown in Table 20. In general, correlations were the same or less for the riparian corridor than for landscape metrics over the whole drainage area. The primary exception is dissolved oxygen, which exhibited significant correlation only with total anthropogenic cover (U-index, comprised of an aggregation of urban and agriculture land cover types) in the riparian corridor. It should be noted that this analysis is preliminary and is based only on the nonrandomly selected subset of sixteen sampling locations. The data set size was insufficient to perform a cluster analysis. The strongest correlations were between landscape metrics; this is not surprising as several of the landscape metrics contain similar information. The redundancy is needed at this point in the research until the strongest and most sensitive relationships with aquatic metrics can be established.

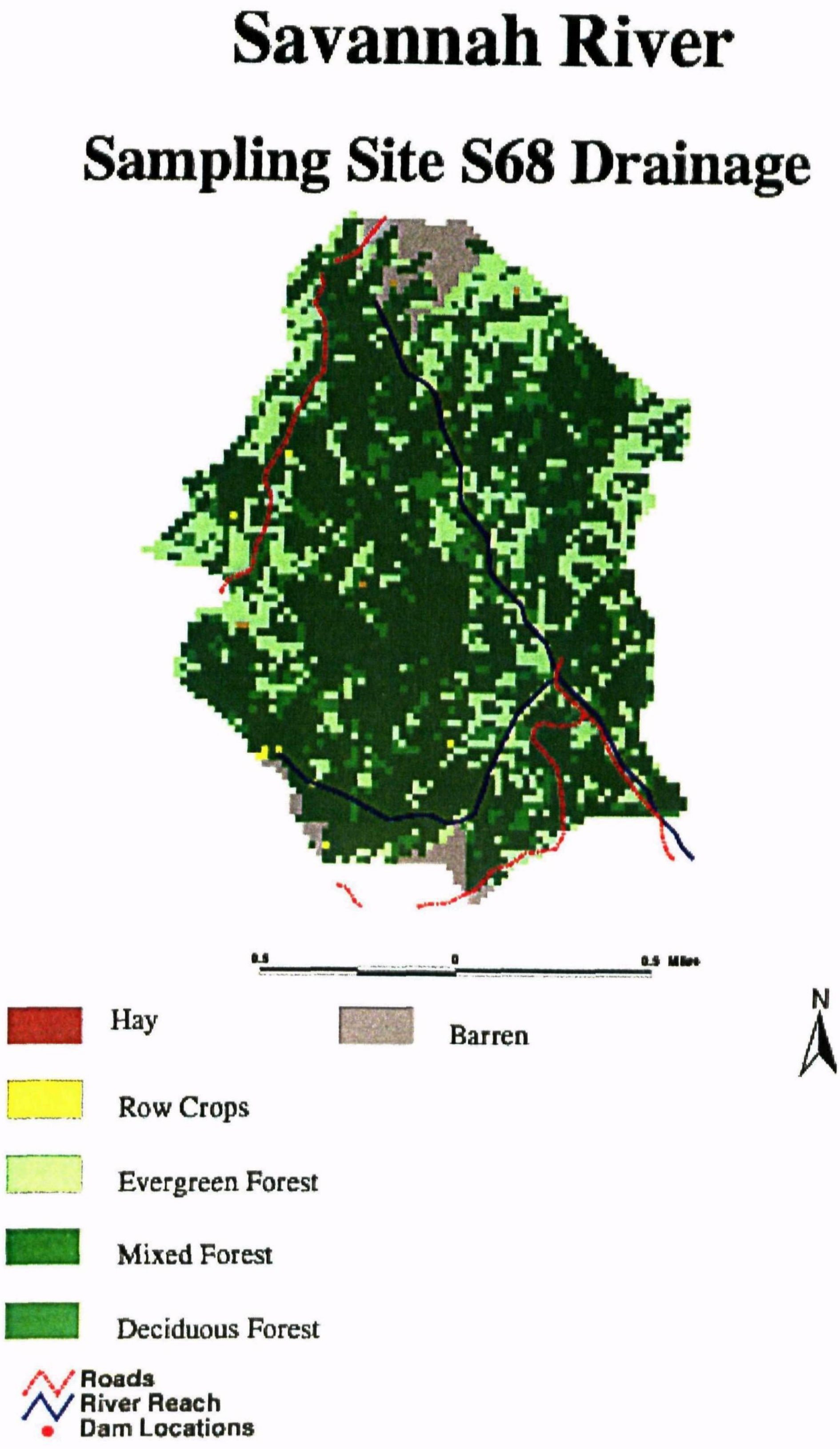


Figure 15. Sampling Site S68 Drainage.

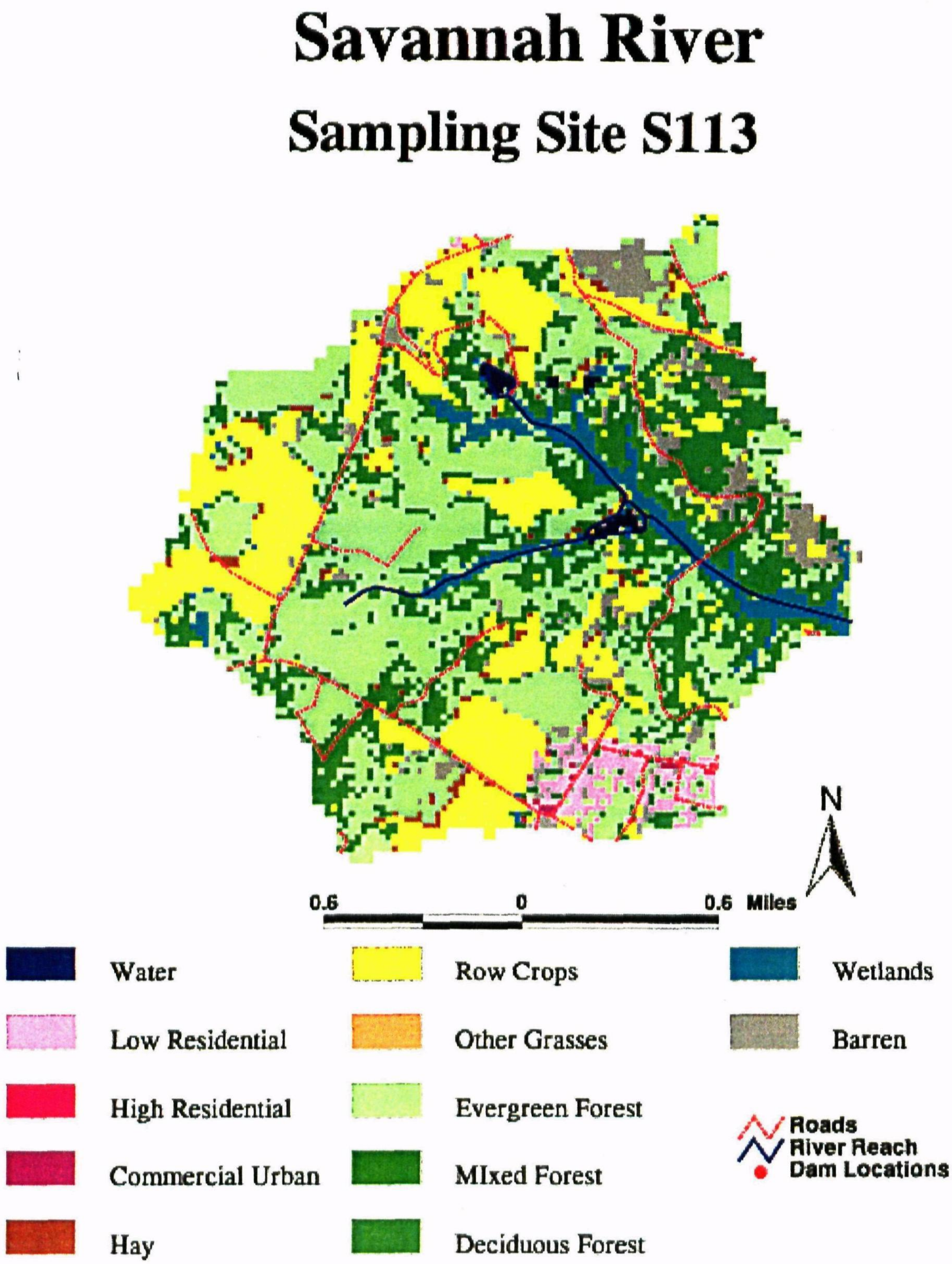


Figure 16. Sampling Site S113 Drainage.

Savannah River

Sampling Site S195 Drainage

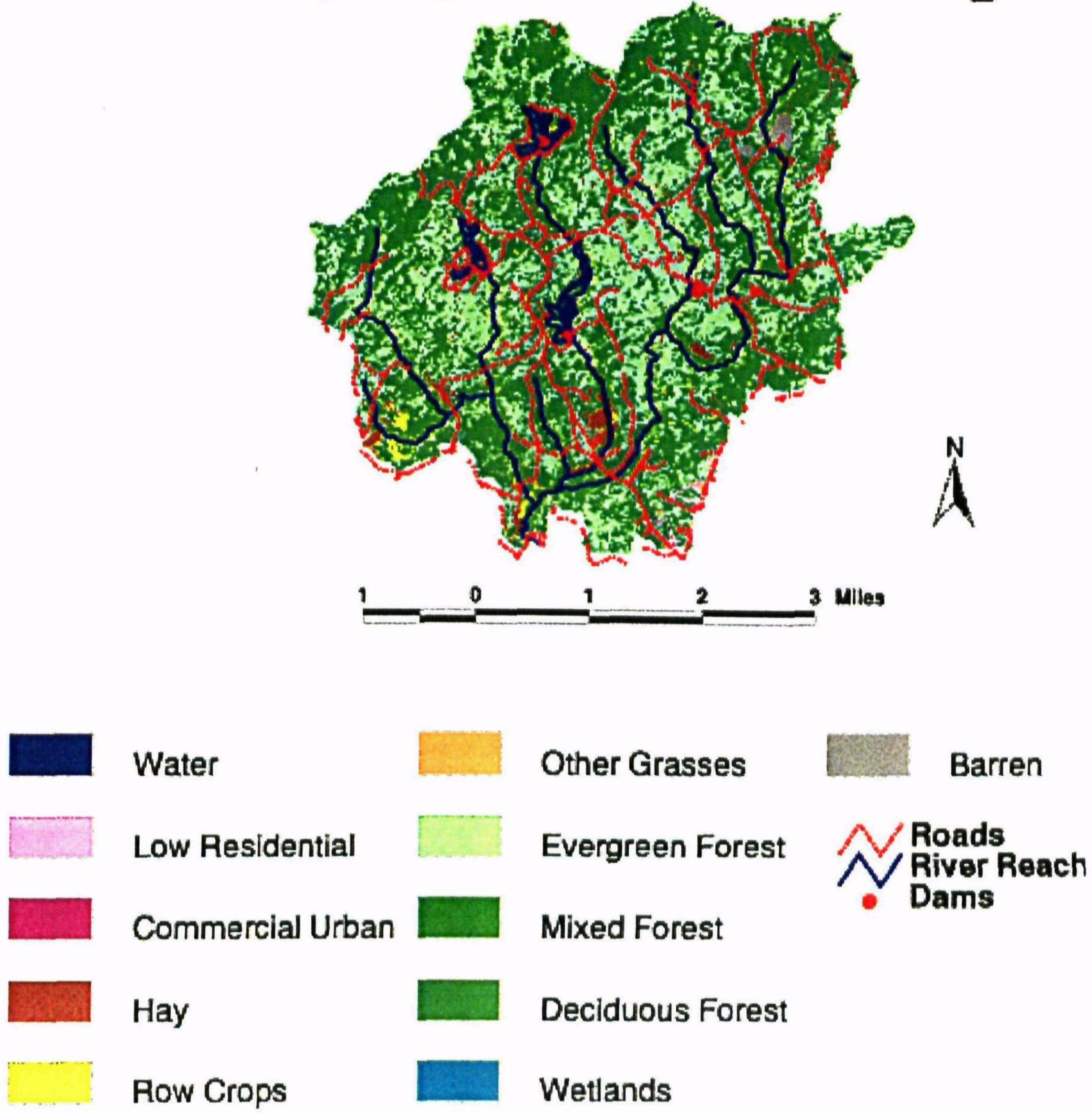


Figure 17. Sampling Site S195 Drainage.

Savannah River

Sampling Site S22 Drainage

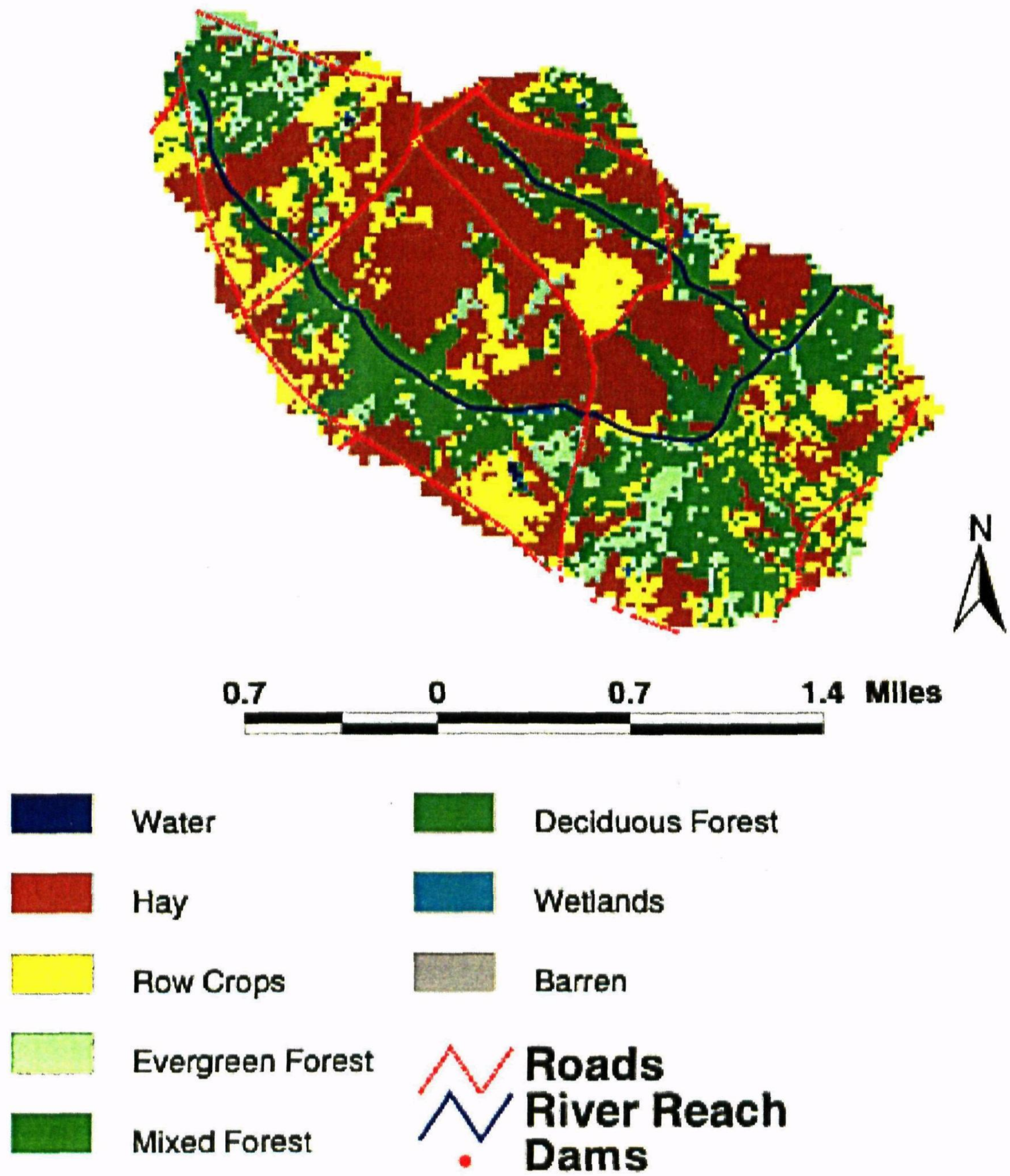


Figure 18. Sampling Site S22 Drainage.

Savannah River

Sampling Site S80 Drainage

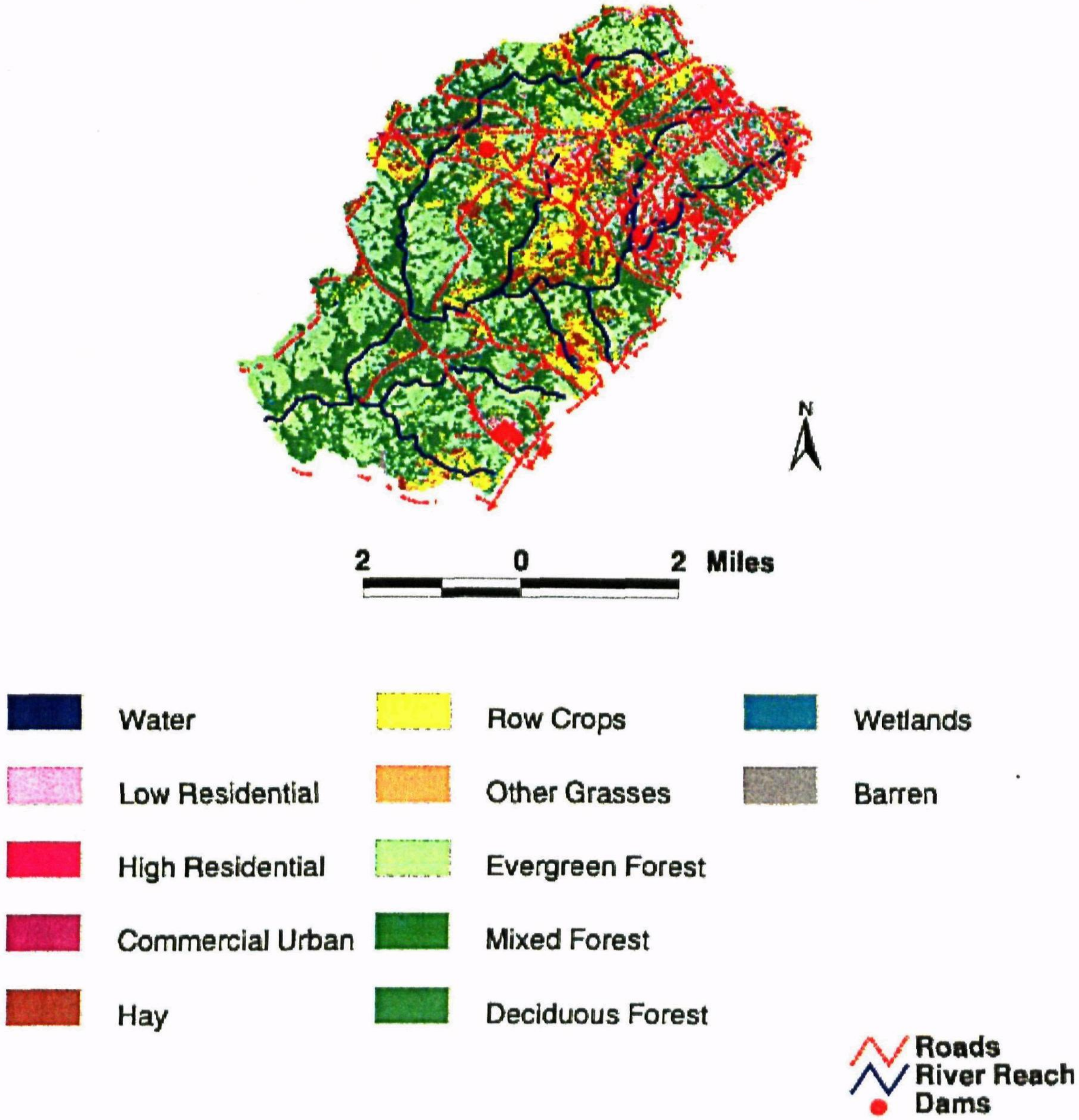


Figure 19. Sampling Site S80 Drainage.

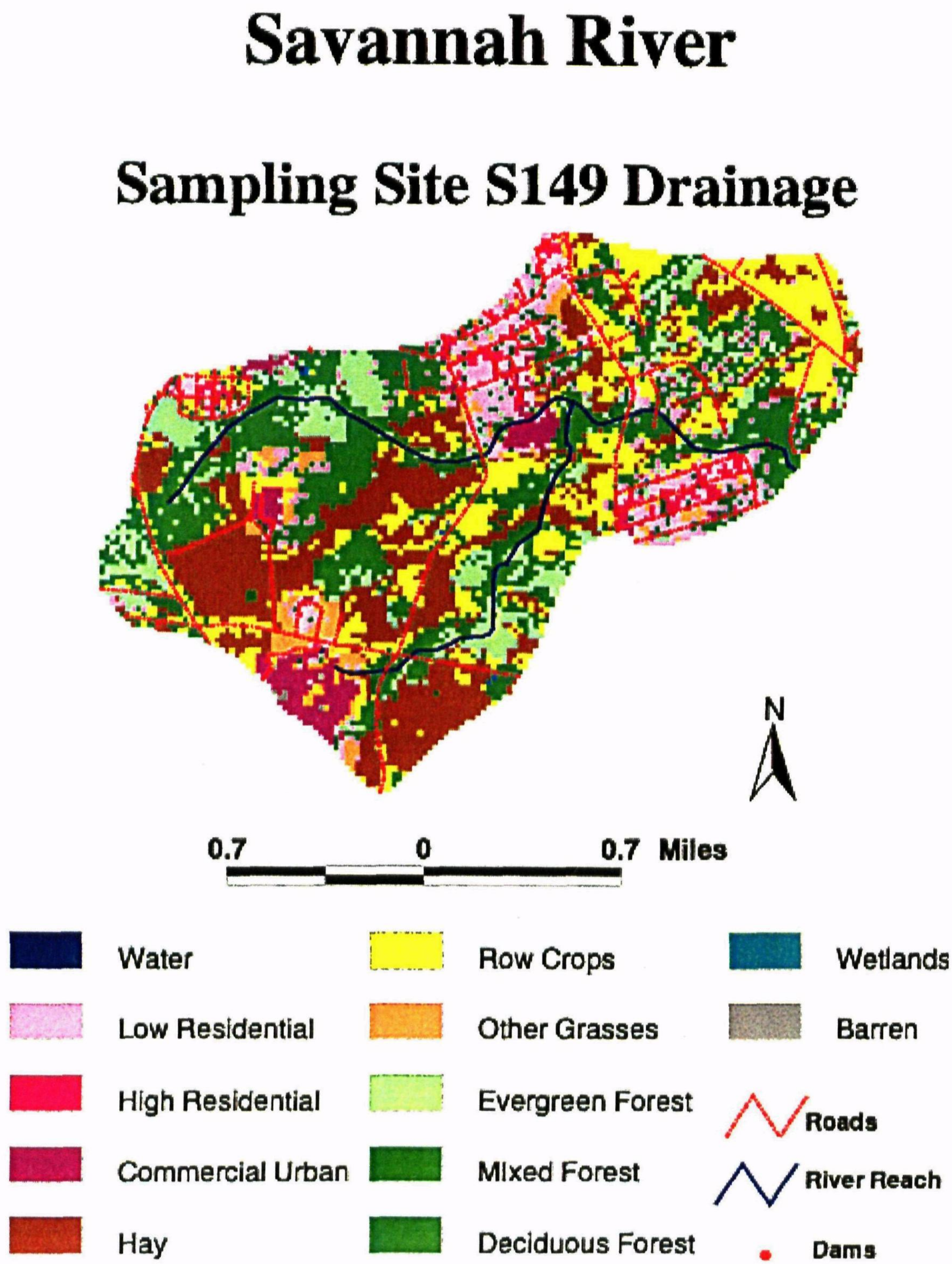


Figure 20. Sampling Site S149 Drainage.

Table 20. Correlation of Aquatic and Landscape Metrics for Sample Site Drainages and Riparian Corridors

Aquatic Metric	Landscape Metric	Direction of Correlation	Significance Level (α =)
AGPT	%Forest Landcover	negative	0.005/0.01R
	forest edge	negative	0.005/0.025R
	U-index	positive	0.005*
	ag_edge	positive	0.025/0.05R
	avg ag patch	positive	0.025
	avg forest patch	negative	0.025/0.01R
EPT	avg forest patch	positive	0.005/0.025R
	%forest cover	positive	0.01
	U-index	negative	0.01
	avg ag patch	negative	0.01
	forest edge	positive	0.025
	ag edge	negative	0.025
	ag on slopes > 3%	negative	0.05
Richness	%Forest cover	positive	0.025
	forest edge	positive	0.025
	U-index	negative	0.025*
	avg ag patch	negative	0.05
	avg forest patch	positive	0.05
	ag edge	negative	0.05
	ag on slopes > 3%	negative	0.05
Fish_ibi	avg forest patch	positive	0.025*
	forest edge	positive	0.05*
	%forest cover	positive	0.05
	U-index	negative	0.05
pH	roads/streams	positive	0.025
	%forest cover	positive	0.05
	forest edge	positive	0.05
	U-index	negative	0.05
	ag on slopes >3%	negative	0.05
Dissolved Oxygen	U-index	negative	–/0.05R
Habitat	avg forest patch	positive	0.025*
	ag edge	negative	0.025
	%forest cover	positive	0.05
	forest edge	positive	0.05
	U-index	negative	0.05/0.01R
Conductivity	%forest cover	negative	0.005
	ag on slopes >3%	positive	0.05

4.4 Landscape Change

Two mosaics were developed from the NALC data base for the 1970s (Figure 21) and the1990s (Figure 22) Savannah River Basin study area. The mosaics were matched to provide analysis across similar areas of the two mosaics. Both mosaics were processed into normalized difference vegetation index (NDVI) images and the values in the 70s mosaic was subtracted from the 90s. Positive numbers indicate gains in vegetation and negative numbers equate to losses in vegetation; in Figure 23 vegetation gains are shown in green while vegetation losses are shown in red. A standard deviation was calculated using n–1, for the entire change NDVI image. The Arc/Info grid coverages depicting the various areas of interest were then converted to image files (hereafter referred to as masks), and the UTM coordinates for each were recorded. The resolution for each mask was converted to 60 meters to match the resolution of the change NDVI image. The change NDVI image was repeatedly sub-sampled to select the matching areas of each mask. Each sub-sampled change NDVI image and its corresponding mask were then used as inputs to a custom in-house software program which calculates the amount of cells (pixels) that are inside the mask and groups them into 4 categories. They are: cells which are greater than or equal to 4 standard deviations of loss in vegetation, those cells which are greater than or equal to 2 standard deviations of loss in vegetation, and the corresponding numbers of cells for gains in vegetation. In the following tables the losses and gains have been grouped together and shown as either a negative number for percent of loss or a positive number for percent of gain.

An additional column is used to represent the cells removed from the study area, which contain negative NDVI indices in either the 70s or 90s NDVI image. Negative NDVI indices are generated by clouds, water and other non-vegetation. This also helps to remove erratic NDVI values caused by differences in solar illumination. However, sometimes these values are meaningful, as in the case where an impoundment may have been installed after the 70s image and before the 90s. An example of this is shown in Figure 24.

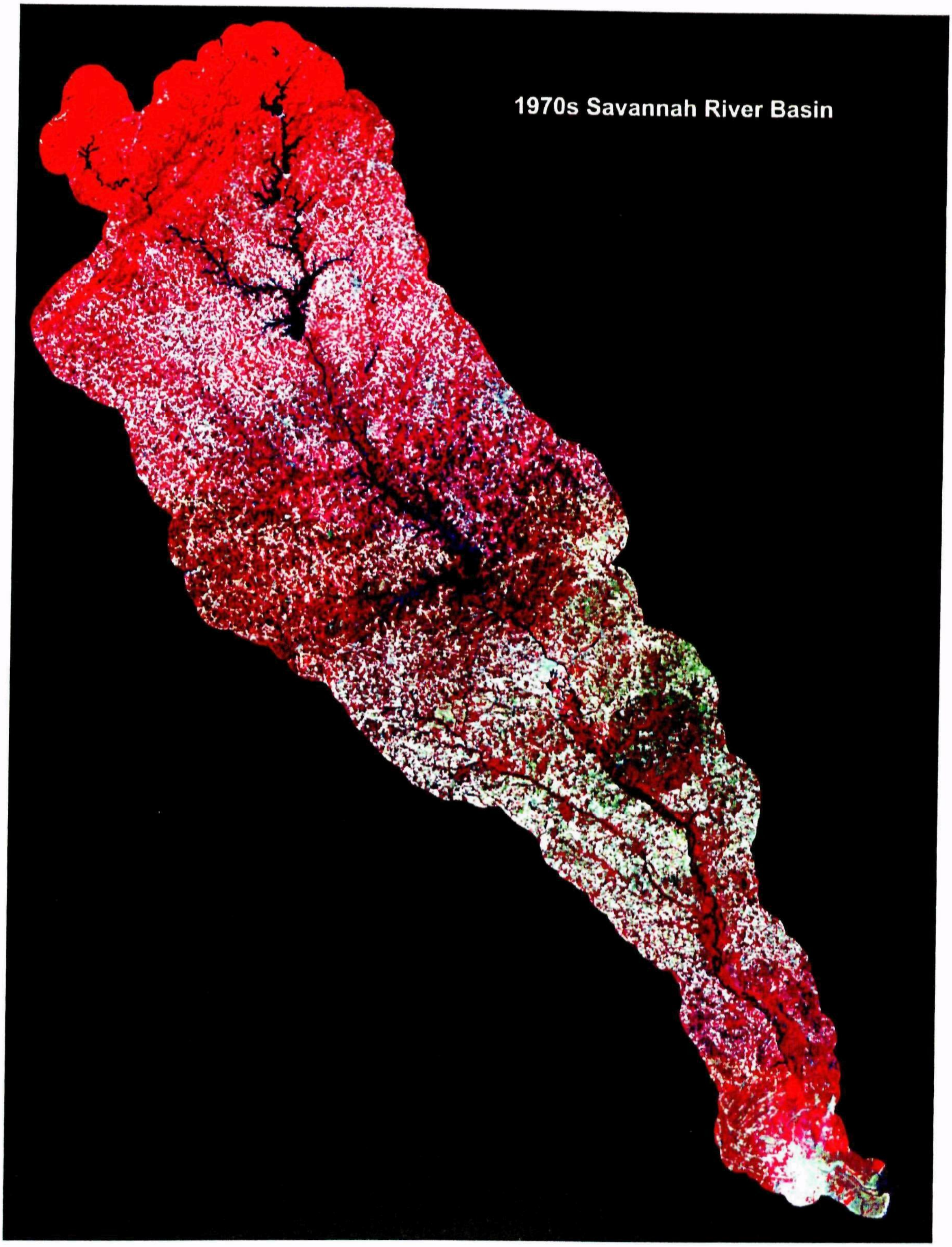


Figure 21. Mosaic of Circa 1970 NALC Images.

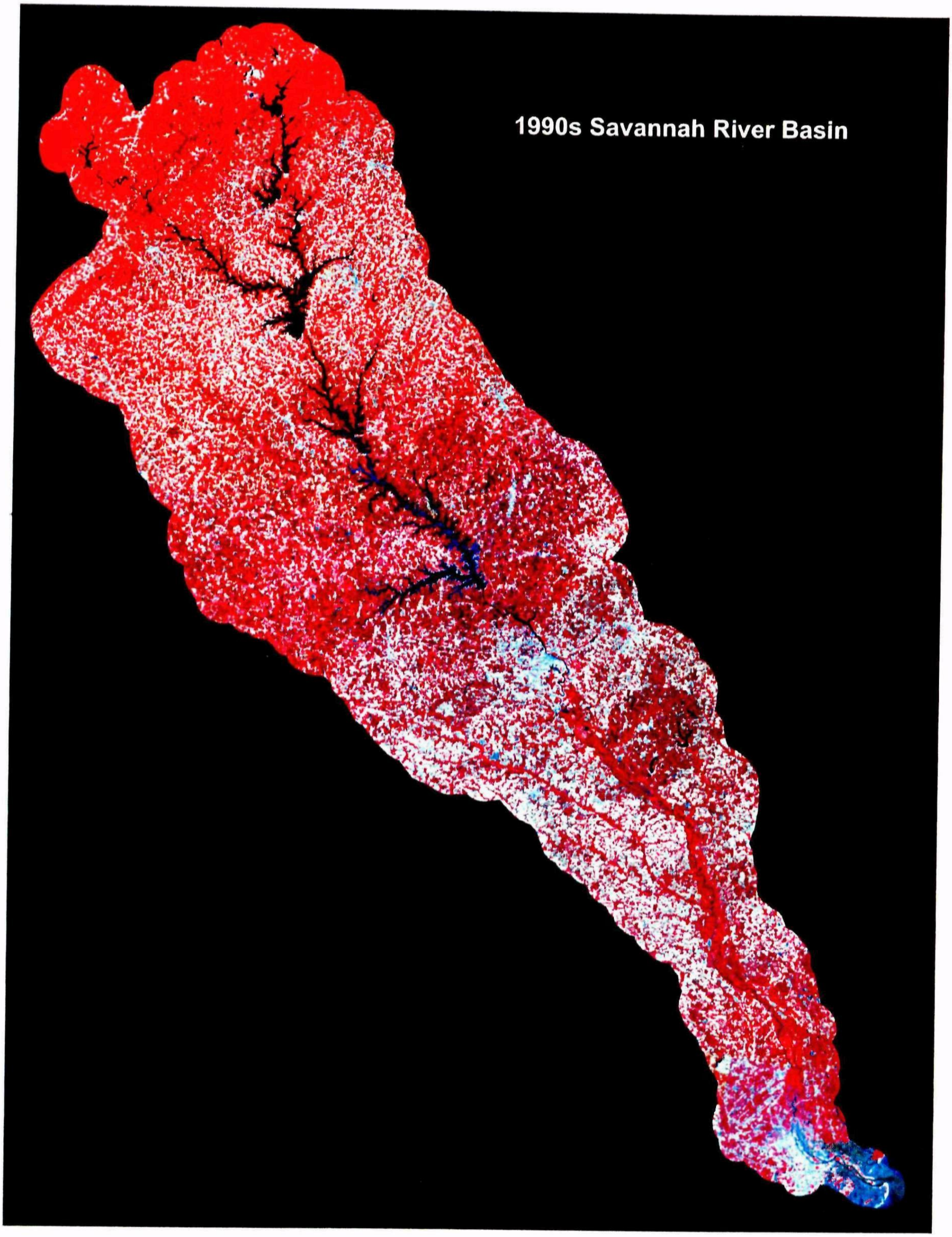


Figure 22. Mosaic of Circa 1992 NALC Images.

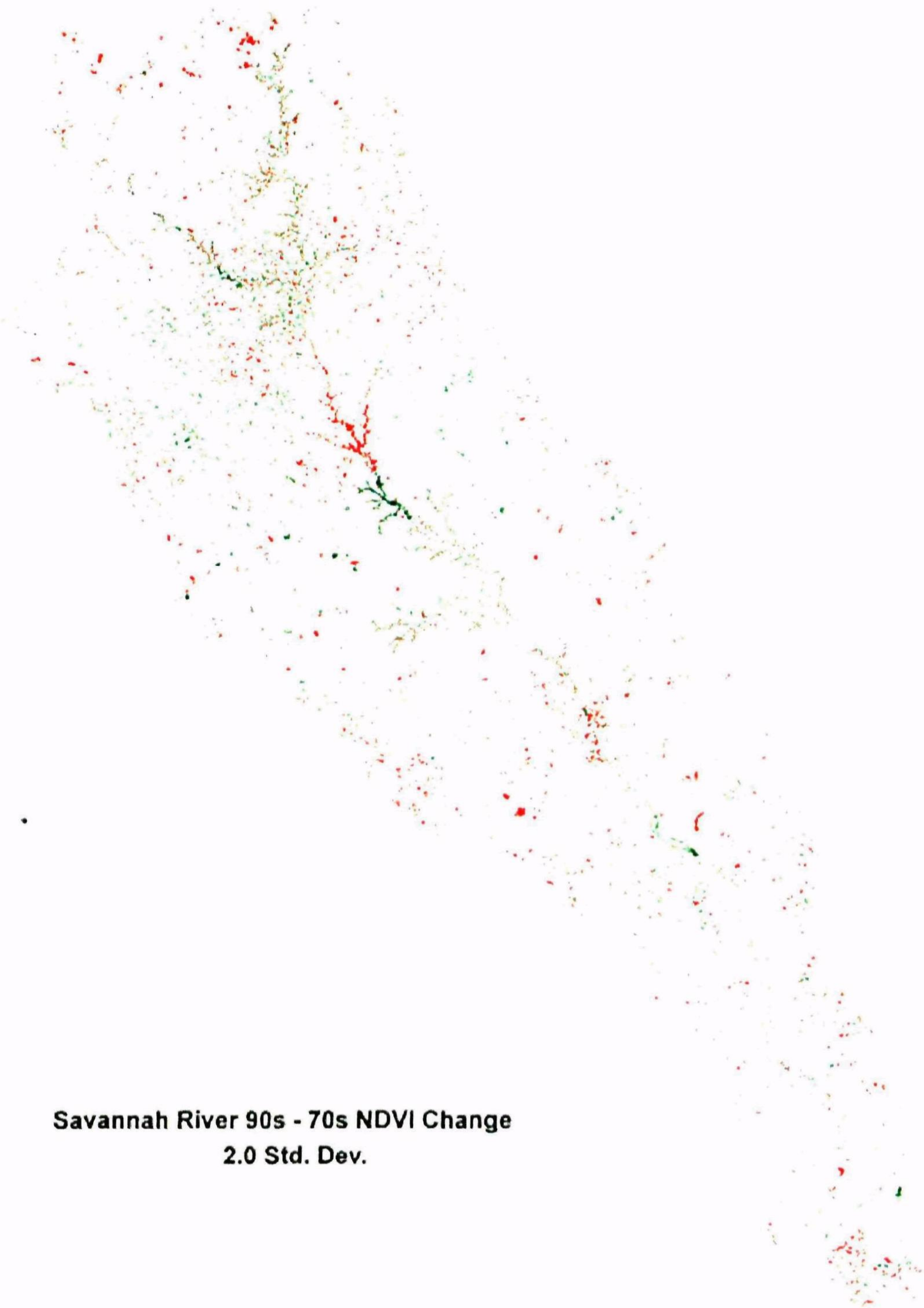
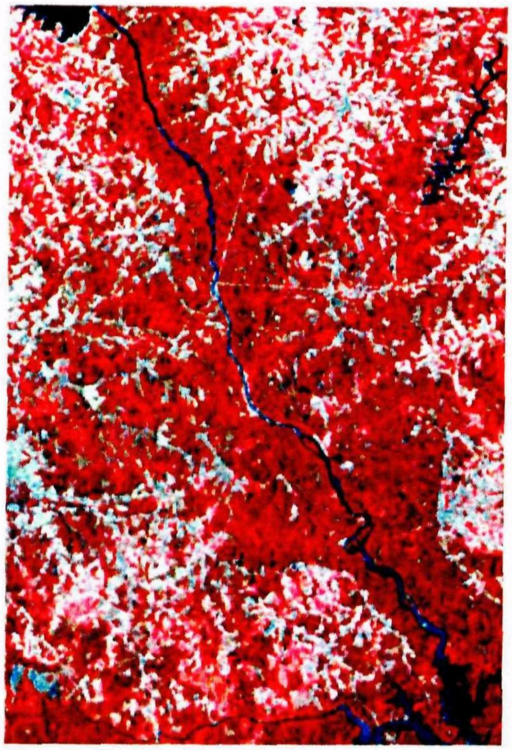


Figure 23. Gains (green) and Losses (red) in Vegetation, 1970s to 1990s.



1970s

1990s

Savannah River Basin

Figure 24. Lake Russell was Created between the 1970s and 1990s.

Table 21 depicts change in selected subbasins of HUC 3. Subbasin #26 reflects greater than 3% negative change, because an impoundment was installed between the 70s and the 90s image. Subbasin #26 is the white-shaded area shown in Figure 25.

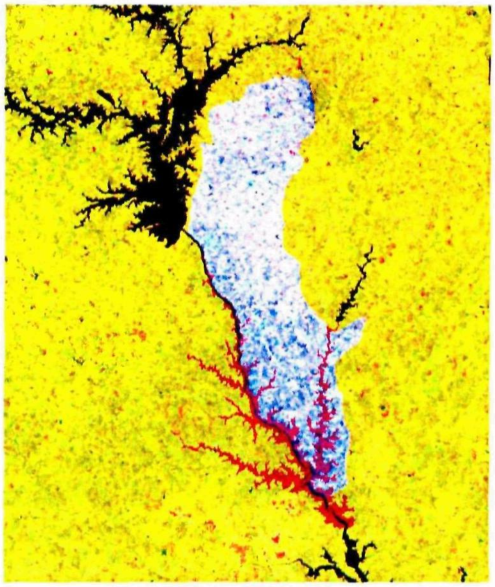


Figure 25. Land Surface Loss to Lake Russell in Subbasin #26.

Table 21. Landscape Change for Selected Subbasins

Subbasin	Percent NDVI Change	Percent NDVI Change, Negative Numbers Removed
20	-9.803	-9.670
26	-9.993	-6.838
32	0.661	-6.384
36	-2.695	-2.826
52	-0.366	-1.873

Subbasin # 32, differences in the water surface (solar glare) produced a positive change in vegetation which offset the loss in that area. When the water areas (negative NDVI numbers) were removed the overall sub-watershed had a loss of greater than 6%.

Table 22 shows the NDVI change in the drainage areas of the selected sixteen sampling sites.

Table 22. Landscape Change for Sampling Site Drainages

Site	Percent NDVI Change	Percent NDVI Change, Negative Numbers Removed
Class "Good"		
S155	-0.873	-0.859
S68	-0.613	-0.613
S195	-0.976	-1.245
S113	-4.193	-4.000
Class "Bad"		
S80	-2.975	-2.748
S197	-8.235	-8.235
S149	-8.994	-7.325
S22	-18.404	-17.591
Class "Fair"		
S81	-2.930	-2.707
S216	-1.235	-1.235
S103	-0.626	-1.627
S27	-4.717	-4.674
Class "Other"		
S151	-6.992	-5.721
S200	-4.528	-4.328
S130	-13.372	-11.149
S95	-2.932	-2.871

Section 5

Summary

The three questions posed as objectives by the Region can now be addressed:

> *Are both the proportions of land uses and the spatial pattern of land uses important for characterizing and modeling stream condition in watersheds/ecoregions of different areas?*

As shown in this landscape assessment, both the proportion and the patterns of land use are important in assessing impacts on streams. In the correlation analysis conducted on the sampling site drainages, both total landcover types (%forest, U-index) and pattern metrics (fragmentation metrics including average patch size, forest and agriculture edges) were found to correlate with aquatic metrics. A third important element is the scale at which analysis is done. In the analysis of selected subbasins, patterns of land use began to emerge; this scale may be sufficient to provide a generalized characterization of the basin.

> *Can land uses near the streams better account for the variability in ecological condition than land use for the entire watershed/ecoregion?*

In this particular assessment, landscape metrics for the riparian corridors did not provide stronger correlation with aquatic metrics, with the exception of dissolved oxygen. It should be remembered, though, that this is one analysis of a small spatial area in one region with a particular suite of metrics. In other situations the riparian corridor may be of greater importance than the overall watershed. Even in this region, the southern portion of the basin has riparian corridors dominated by wetlands. Only one site from this area was used in the analysis and the entire sampling data set contains only a few sites in this ecoregion. A separate analysis of wetlands-dominated systems is probably worthwhile.

> *Does the size of the watershed/ecoregion influence statistical relationships between landscape characteristics and ecological condition?*

There was no indication in this analysis of any relationship with the spatial extent of the drainage areas. This includes the landscape metrics developed for the HUCs and subbasins. In the sampling site analysis, one of the selection criteria was to include streams of varying order; by doing so, both small and large drainage areas were included. Drainage area was included in the correlation analysis; no correlation was shown with any of the aquatic metrics.

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