LAND CONSERVATION, RESTORATION, AND STORMWATER MANAGEMENT PRIORITIES FOR THE UPPER LITTLE TALLAPOOSA RIVER, GEORGIA

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INTRODUCTION

This report summarizes the initial phase of mapping and modeling for the "Protecting the Source" project funded by the US EPA. It describes the (1) compilation of spatial data, (2) necessary modifications of coordinate and classification systems, (3) GIS-based overlay process used to identify key areas for source water protection, (4) preliminary findings, and (5) plans for additional analyses in support of the Stewardship Exchange and source water protection efforts.

SITE DESCRIPTION

The upper Little Tallapoosa (ULT) River flows from headwater areas north of towns of Villa Rica and Temple, southwest through the city of Carrollton, then across the Georgia border into Alabama (Figure 1). The watershed area above the city of Carrollton water supply intake is 246.2 km^2 (~61,000 acres). As the Atlanta metropolitan area has grown and the regional economy has changed, development pressure has reached the ULT watershed. These changes, patterns, and trends are evident in the comparison of 1990 and 1998 land cover data presented below. The apparent rate of forest conversion and development argues for timely and substantial action to conserve land and water resources.

In general, the ULT watershed has areas of rolling hills and flat terrain interspersed with wetlands, streams, lakes, and ponds. Soils are generally fine textured and subject to rapid rates of erosion when vegetation is removed or site conditions are drastically altered (e.g., forest clearing for residential construction) (USDA SCS 1971). The watershed is largely rural with approximately 50% forest land, 30% agricultural and open land, 10% urban, and a variety of other land covers (Figure 2). Centuries of land use have already altered the quantity, quality, and timing of water flow. Poorly planned residential, commercial, and industrial development could accelerate unfavorable changes in ULT watershed and lead to a wide range of interconnected environmental impacts. One of the most significant and costly consequences of losing farms and forests will be in relation to drinking water supplies and aquatic ecosystems.

CHANGES IN LAND COVER – 1990 TO 1998

We assembled the most current spatial data available for the ULT watershed to quantify recent changes in land use. The 1990 land cover layer was generated from 30 meter resolution Landsat imagery as part of a state-wide wildlife habitat assessment project. It was archived at 60 meter resolution, presumably to save storage space and speed retrieval and calculations when most computers had storage and processing limitations. Unfortunately, the original 30 meter resolution 1990 data layer was not retained. Therefore, in order to make a direct comparison between the two layers, we had to aggregate the 30 meter 1998 data up to the 60 meter grid cell size. We also needed to use more general land cover classes in order to reconcile two slightly different systems (Table 1).

Naturally, differences in the original Landsat imagery (e.g., time of year, sun angle, cloud cover, etc.), project goals and objectives, and classification methods and accuracy combine to influence the depiction of land cover. Hence, our simplification of the 1990 and 1998 images could reduce or eliminate some sources of error while amplifying others. For example, the classification of forests of different types notwithstanding, it is likely the overall reduction in mature forest cover is real (Figures 3 and 4, Table 2). This is corroborated by the increase in clearcuts, exposed soil, or young forests (seedling and sapling stands). By contrast, combining several categories of developed land together to determine urban land cover in 1998 is likely to overestimate the total area.

The net change in mature forests (-12%) and urban land (+7%) is most apparent (Tables 1 and 2). The re-distribution of open land between cover types (clearcuts or young forests, pasture, and row crops) is more noteworthy than the small net change (3%) in area. High resolution (0.5 or 1 meter) digital aerial photography is needed to accurately quantify current conditions and establish a reference point for change detection. Beyond mapping and modeling, digital orthophotographs (spatially corrected to match USGS map and State Plane survey bench marks) also are a cost-effective resource for watershed planning and management.

TABLE 1 – Summary of land cover statistics (1990 and 1998) for the upper Little Tallapoosa River, Georgia. Source: Georgia GIS Data Clearinghouse

Land cover 98 code		Area (1998)		Area (1990)	
		km^2	%	km^2	%
11	Open water	5.9	2.4	4.4	1.8
18	Transportation	20.5	8.3	*	*
20	Utility swaths	2.6	1.0	*	*
22	Low intensity urban	5.4	2.2	9.7	3.9
24	High intensity urban	4.0	1.6	3.1	1.2
31	Clearcut/sparse	22.0	8.9	2.7	1.1
33	Quarries/strip mines	0.04	0.02	*	*
41	Deciduous forest	73.7	29.9	49.8	20.2
42	Evergreen forest	43.5	17.8	35.1	14.3
43	Mixed forest	13.5	5.5	76.9	31.2
80	Pasture	44.7	18.2	42.3	17.2
83	Row crop	2.4	1.0	19.2	7.9
91	Forested wetland	8.0	3.2	2.9	1.2
Totals		246.2	100.0	246.1	100.0

* not applicable

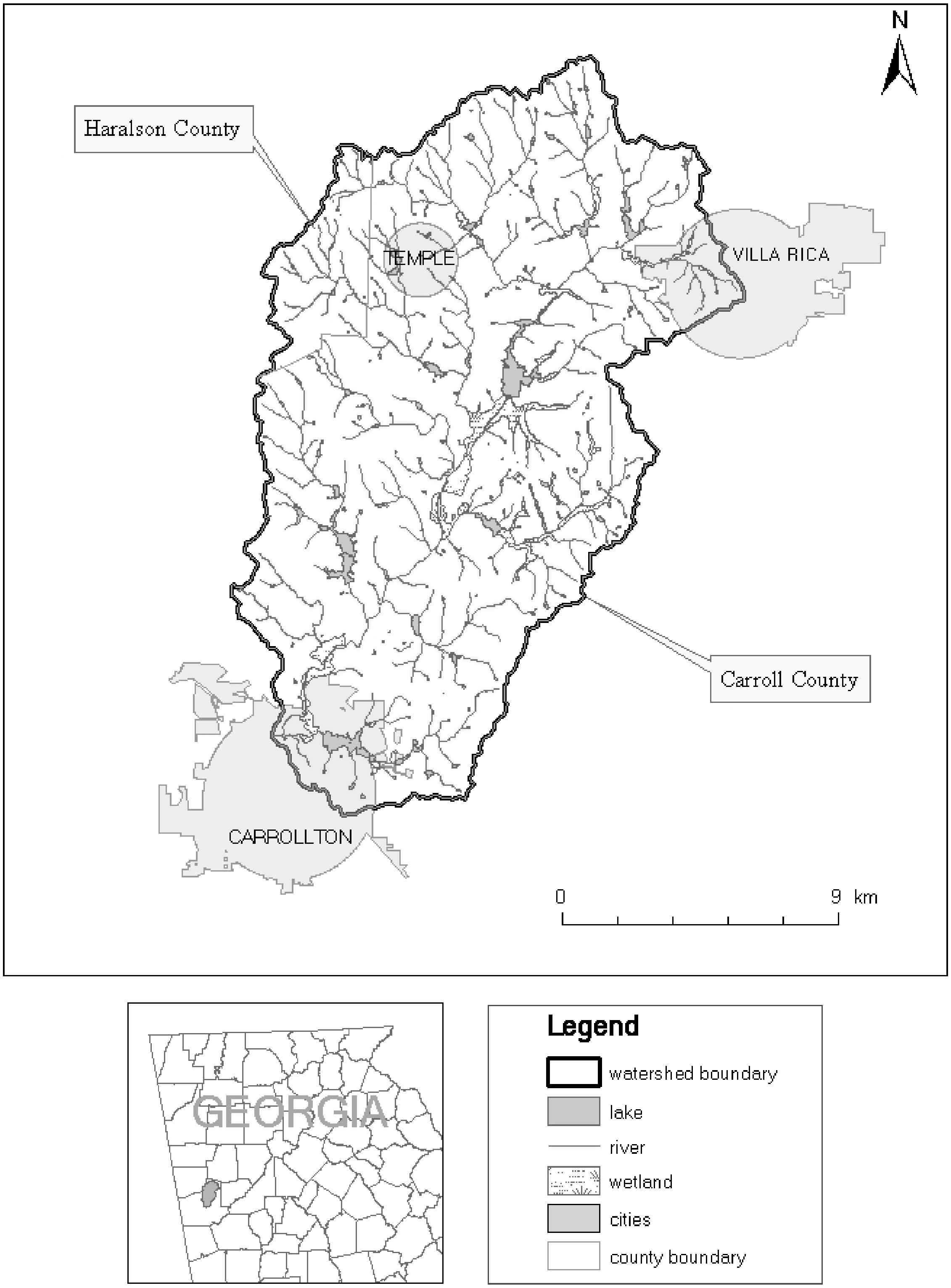


FIGURE 1 – The upper Little Tallapoosa River watershed, Georgia. Produced at the University of Massachusetts with spatial data from the Georgia GIS Data Clearinghouse.

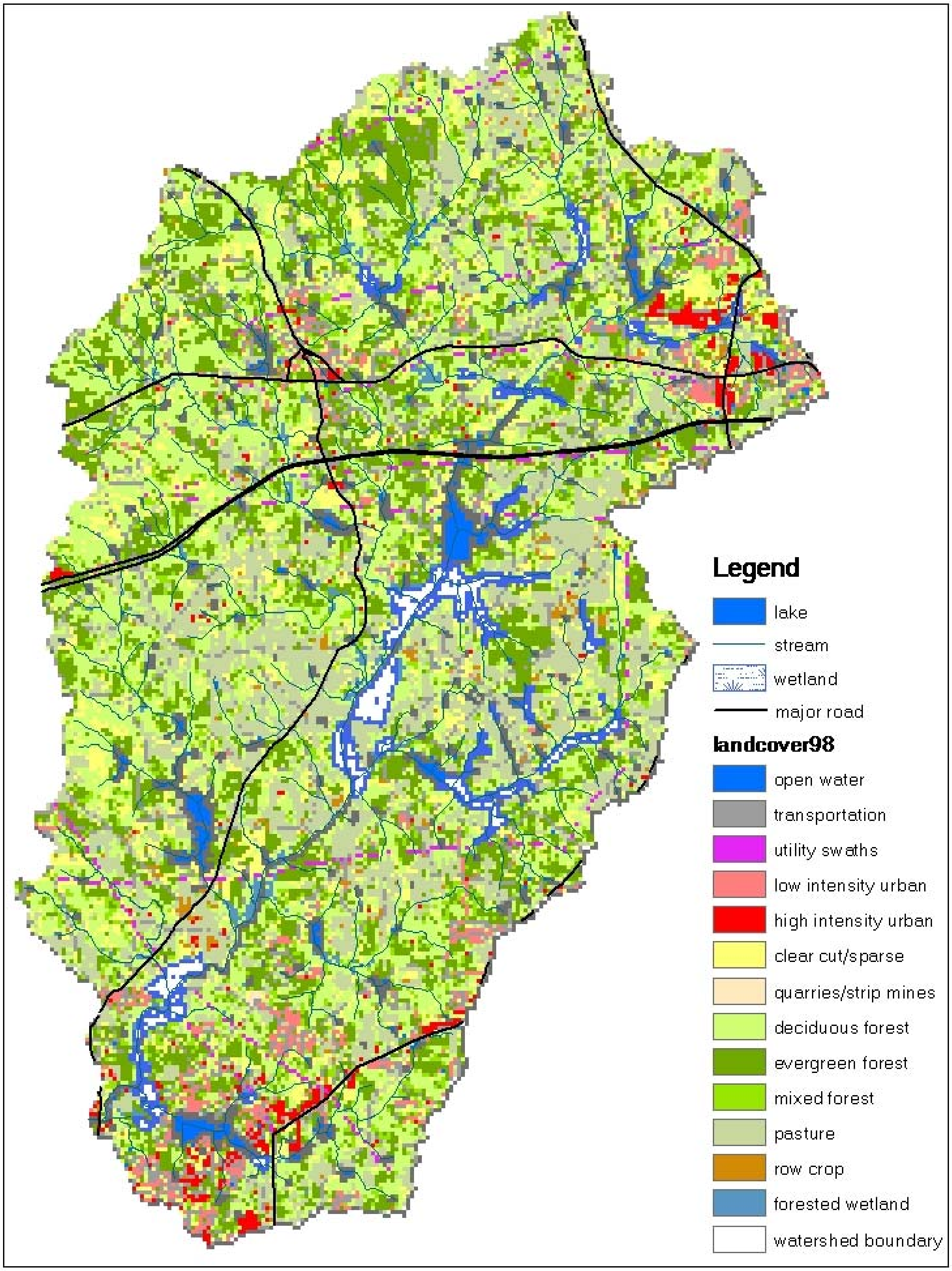


FIGURE 2 ─ Land cover (1998) in the upper Little Tallapoosa River watershed near Carrollton, Georgia. Data source: Georgia GIS Data Clearinghouse, Landsat Thematic Mapper imagery, 30 meter resolution, 7 spectral bands, classification by the University of Georgia Institute of Ecology.

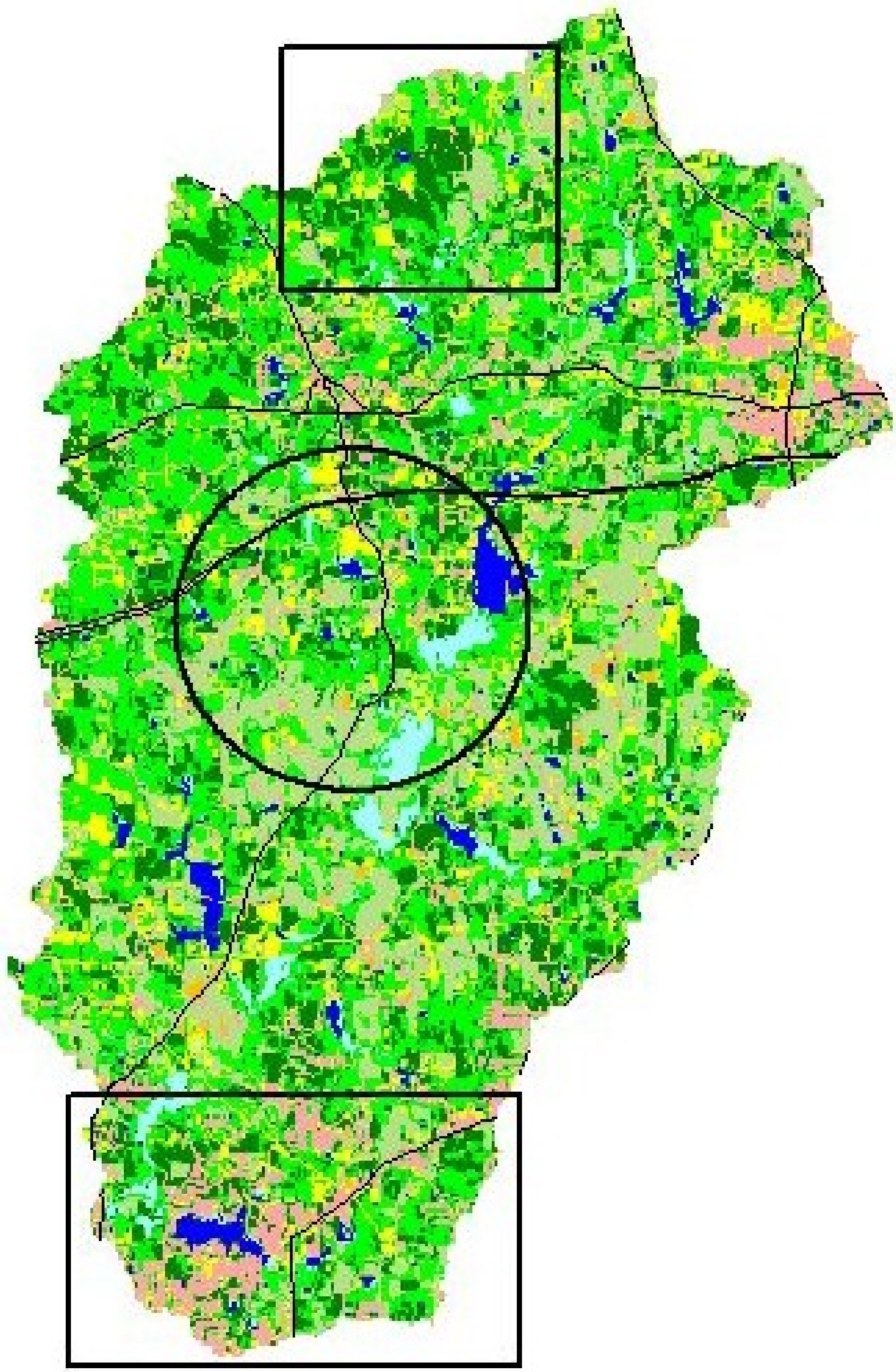


FIGURE 3 — Generalized land cover (1998) in the upper Little Tallapoosa River watershed near Carrollton, Georgia. Data source: Georgia GIS Data Clearinghouse, Landsat Thematic Mapper imagery aggregated to 60 meter resolution and reclassified for comparison with 1990 imagery. The spatial extent of urban areas is probably overestimated. Key: light green = deciduous forest, medium green = mixed forest, dark green = coniferous forest, dark blue = water, light blue = wetlands, pink = urban, orange = row crops/exposed soil, yellow = clearcuts or young forest, olive = pasture.

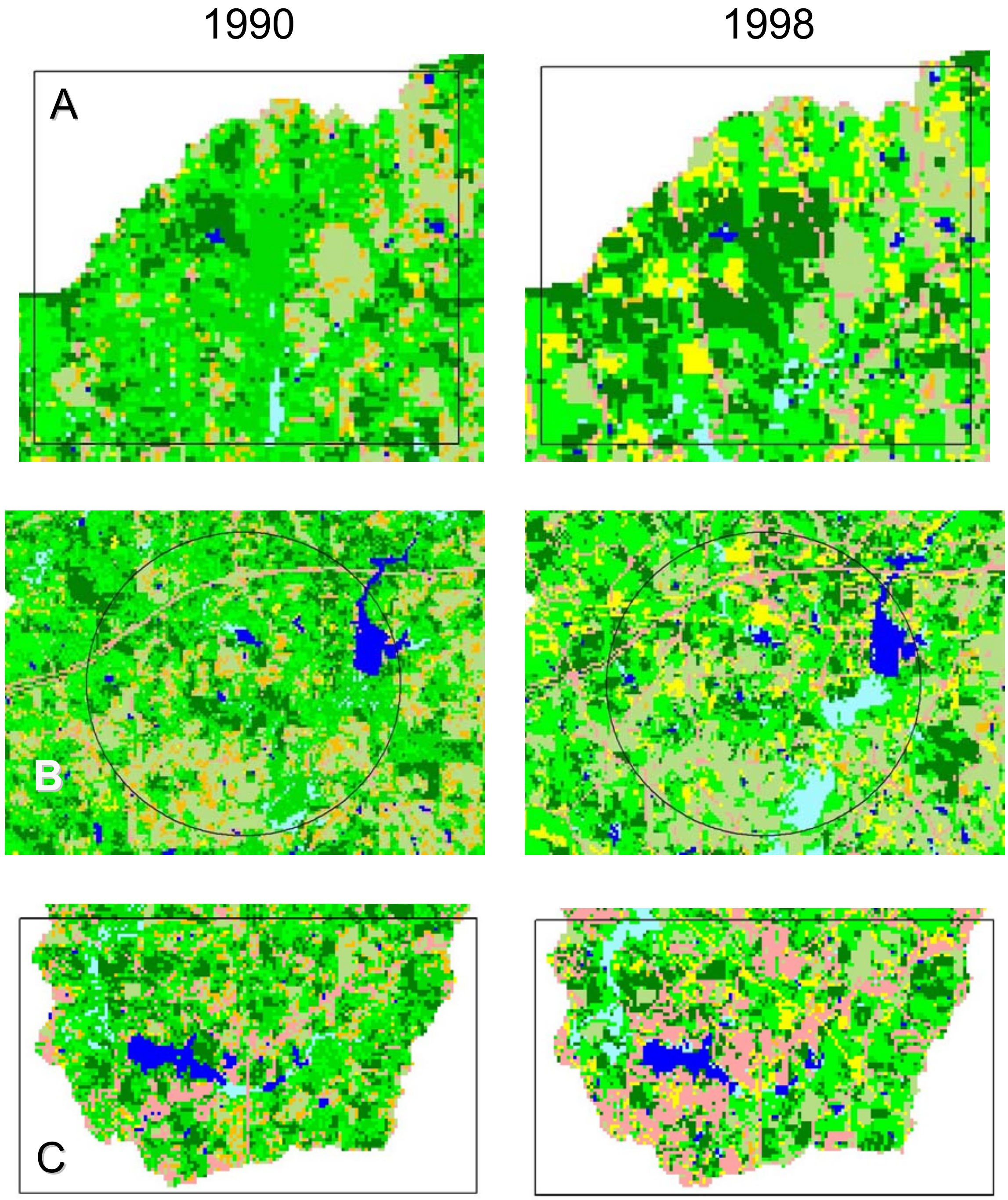


FIGURE 4 – Enlarged areas of the 1990 and 1998 land cover layers for the upper Little Tallapoosa River watershed, Georgia. Area A shows timber harvesting and/or forest conversion in the northern section of the watershed; Area B shows similar patterns in the vicinity of US Interstate Route 20; Area C shows changes in developed areas in Carrollton. Aggregation from 30 to 60 meters and reclassification of the 1998 imagery for comparison with 1990 imagery is likely to overestimate the area of urban land. Key: light green = deciduous forest, medium green = mixed forest, dark green = coniferous forest, dark blue = water, light blue = wetlands, pink = urban, orange = row crops/exposed soil, yellow = clearcuts or young forest, olive = pasture.

Table 2 – Summary of generalized 1990 and 1998 land cover statistics (using the equivalent classification systems and 60 meter resolution data) for the upper Little Tallapoosa River watershed, Georgia. (* differences in forest type are more likely to be related to classification algorithms than field conditions)

Land cover type	Proportion of watershed (%)		
	1990	1998	change
1. open water	2	2	0
2. regen. Forest	1	10	+9
3. pasture	17	19	+2
4. row crops	8	1	-7
2 + 3 + 4 =	26	29	+3
5. urban	*5*	*12*	+7
6. wetlands	1	3	+2
7. evergreen forest	14	18	*
8. mixed forest	31	5	*
9. deciduous forest	20	31	*
7 + 8 + 9 =	66	53	-12

SPATIAL DATA INCONSISTENCIES

Because GIS databases for watershed assessment are usually compiled from variety of sources it is common for maps and images to be referenced to different coordinate or map projection systems. Hence, before any valid quantitative analysis can be done, all data layers must be converted to a single standard. We selected the Universal Transverse Mercator (UTM) system used by the U.S. Geological Survey (USGS) and other international organizations. Because of their unparalleled surveying, mapping, and database management standards and expertise, the USGS digital elevation model (DEM, the digital equivalent of USGS 7.5 minute topographic maps) was used as the reference GIS layer. When compared with the USGS DEM, both primary GIS layers (Carroll County soils and Georgia Land Cover – 1998) evinced systematic errors after re-projection in UTM. The relative position of small water bodies in the soils layer, before and after correction, is shown in Figure 5. Small water bodies in the 1998 land cover layer were displaced about 100 meters north of the reference position. Both the soils and land cover polygons were brought into alignment with the USGS DEM using a mathematical process in ArcInfo called "rubber sheeting" – an elusion to stretching or compression of polygons needed in different parts of the image to achieve an optimal fit. Failing to recognize and correct this substantial source of error introduces mapping errors that are so large (100 to 300 meters) they would override the 30 meter resolution of subsequent analyses and invalidate the results. These errors also would be very large relative to the scale of human activity in parts of the watershed (e.g., residential use).

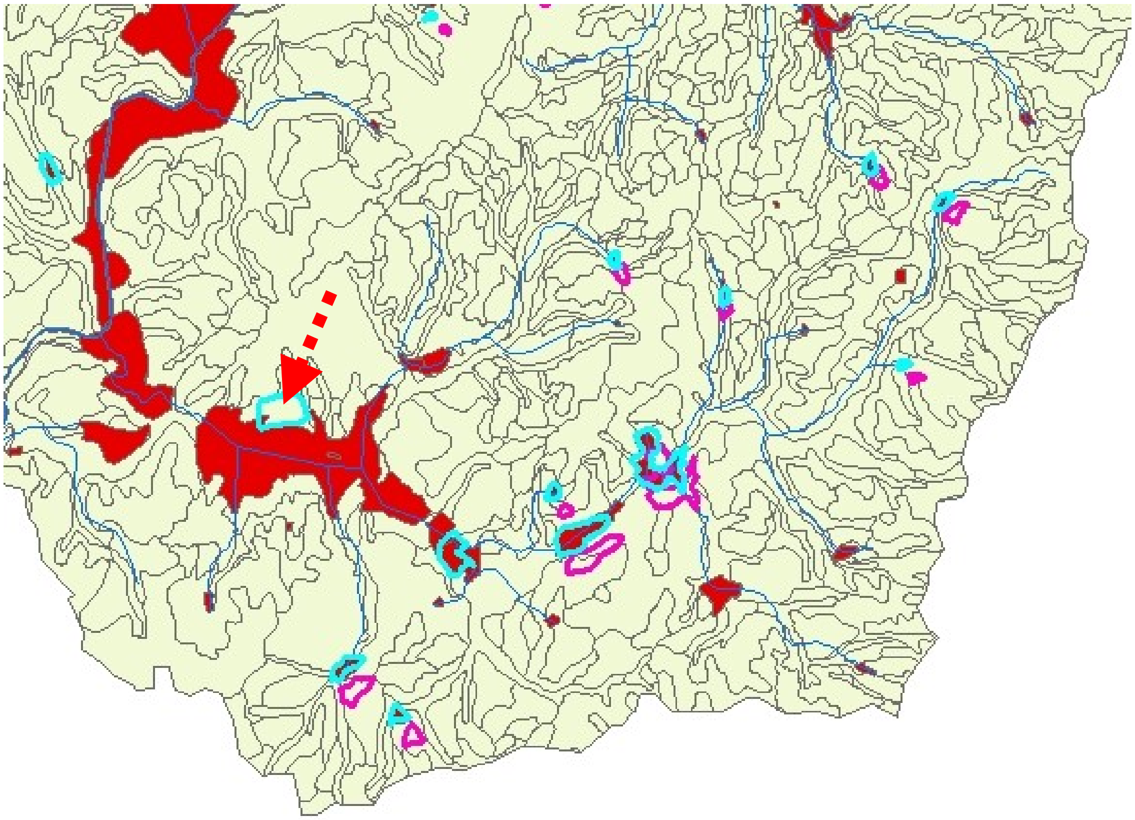


FIGURE 5 – An example of spatial data inconsistencies associated with the compilation of the GIS layers from multiple sources for the upper Little Tallapoosa River watershed database (after re-projection in the Universal Transverse Mercator [UTM] coordinate system). The black lines show the boundaries of soil mapping unit polygons. The polygons highlighted in purple show the original position of water bodies in the soils layer (Carroll County, up to 300 meters SSE of actual location). The light blue polygons show the corrected position relative to the US Geological Survey reference coordinates and water body polygons (shown in red) derived from the USGS digital elevation model. All soil polygons move together in a mathematical correction process called "rubber sheeting" (ESRI 2002). The area indicated by the dashed arrow is an athletic field that was mis-classified as a water body.

PRIORITY INDICES FOR SOURCE WATER PROTECTION

This report will summarize the information presented in Barten et al. (2002) and at the Kickoff Meeting in July. Both the modeling overview and the Powerpoint presentation used during the Kickoff Meeting can be found on the Trust for Public Land web site.[2]

The GIS layers used in the preliminary estimation of the Conservation (CPI), Restoration (RPI), and Stormwater Management Priority Indices (SMPI) for the ULT watershed were

[2] www.tpl.org …click on "Land & Water" …click on "Demonstration Projects."

retrieved from the Georgia GIS Data Clearinghouse or obtained directly the staff of Carroll Tomorrow. After reviewing the attribute data provided with the GIS layers and consulting other sources (e.g., USDA SCS 1971), we assigned priority index scores (Tables 3, 4, and 5). All three indices include slope, soil properties, the appropriate land cover classes, the 100 year recurrence interval (0.01 probability) floodplain, and consideration of the distance to streams, lakes, and wetlands. The CPI overlay sequence also includes a layer created by intersecting a 30 meter buffer along the road network with forests and wetlands. This represents the higher marginal value of roadside versus interior parcels (Table 3). The layers were assembled into a computational model in ArcView (Figure 6). This flowchart details the sequence of vector to raster conversions (polygons to grid cells), assignment of 3-2-1 scores, and finally, the arithmetic overlay process that generates a priority index score for each 30 x 30 meter grid cell in the ULT watershed.

TABLE 3 – Construction of the Conservation Priority Index (CPI) for the upper Little Tallapoosa River watershed, Georgia.

CPI Score → GIS Layer ↓	3 (high)	2 (intermediate)	1 (low)	0 (n/a)
Forest-Road edge	Within 30 meters of a road	-	-	all other land cover classes and locations
Slope (%)	□6	2 ≤ x ≤ 6	□2	-
Soil permeability profile* (soil series)	Chewacla, Congaree, Iredell, Musella	Augusta, Davidson, Grovere, Hulett, Madison, Masada, Tallapoosa, Wilkes, Worsham	Buncombe, Louisa, Louisburg	-
Seasonal depth to water table* (soil series)	Augusta, Chewacla, Worsham	Buncombe, Congaree, Iredell	Davidson, Grover, Hulett, Louisa, Louisburg, Madison, Masada, Musella, Tallapoosa, Wilkes	-
Land cover (1998)	▪ Deciduous forest ▪ Evergreen forest ▪ Mixed forest ▪ Forested wetland	-	-	All other land cover classes
100 year Recurrence Interval floodplain (FEMA)	Flooded area	-	-	Upland area
Distance to water (meters)	≤ 30	30 – 60	60 - 90	> 90

* The soil attribute layers weighted by 0.5 in the overlay process to yield a total influence equal to the other watershed characteristics.

TABLE 4 – Construction of the Restoration Priority Index (RPI) for the upper Little Tallapoosa River watershed, Georgia.

RPI Score → GIS Layer ↓	3 (high)	2 (intermediate)	1 (low)	0 (n/a)
Slope (%)	□6	2 ≤ x ≤ 6	□2	-
Soil permeability profile* (soil series)	Chewacla, Congaree, Iredell, Musella	Augusta, Davidson, Grovere, Hulett, Madison, Masada, Tallapoosa, Wilkes, Worsham	Buncombe, Louisa, Louisburg	-
Seasonal depth to water table* (soil series)	Augusta, Chewacla, Worsham	Buncombe, Congaree, Iredell	Davidson, Grover, Hulett, Louisa, Louisburg, Madison, Masada, Musella, Tallapoosa, Wilkes	-
Land cover (1998)	▪ Utility swaths ▪ Quarries/strip mines ▪ Pasture ▪ Row crops ▪ Clearcut/sparse	-	-	All other land cover classes
100 year Recurrence Interval floodplain (FEMA)	Flooded area	-	-	Upland area
Distance to water (meters)	≤ 30	30 – 60	60 - 90	> 90

* Soil attribute layers weighted by 0.5 in the overlay process

The soil permeability profile and depth to seasonal water table layers were derived from data in the Carroll County Soil Survey (USDA SCS 1971). The former represents the likelihood that soil permeability (infiltration capacity and percolation rate) will lead to the generation of overland flow. The depth to seasonal water table layer represents the likelihood that a soil will saturate from below and generate overland flow during the dormant season, hurricanes and tropical storms, or low frequency precipitation events. In either case – whether infiltration or soil water storage capacity is limiting – overland flow could cause soil erosion and transport sediment, nutrients, and pathogens to streams, wetlands, lakes, and the Little Tallapoosa River. Because digital soils data are not available for Haralson County (a small part of the ULT watershed; Figure 1), potential scores are reduced by 1 to 3 points in the northwest corner of the watershed. We will scale the results of this area to account for this difference in the number of layers.

Pastures are ranked with a 3 because of the scope and scale of livestock operations in the ULT watershed and the *Cryptosporidium* outbreak that occurred in Carrollton in the

1980s. Utility swaths also are ranked with a 3 because of the potential for pesticide contamination from airborne drift or movement by overland or subsurface flow where they intersect streams and rivers.

TABLE 5 – Construction of the Stormwater Management Priority Index (SMPI) for the upper Little Tallapoosa River watershed, Georgia.

SMPI Score → GIS Layer ↓	3 (high)	2 (intermediate)	1 (low)	0 (n/a)
Slope (%)	□6	2 ≤ x ≤ 6	□2	-
Soil permeability profile* (soil series)	Chewacla, Congaree, Iredell, Musella	Augusta, Davidson, Grovere, Hulett, Madison, Masada, Tallapoosa, Wilkes, Worsham	Buncombe, Louisa, Louisburg	-
Seasonal depth to water table* (soil series)	Augusta, Chewacla, Worsham	Buncombe, Congaree, Iredell	Davidson, Grover, Hulett, Louisa, Louisburg, Madison, Masada, Musella, Tallapoosa, Wilkes	-
Land cover (1998)	High Density Urban	Low Density Urban	-	All other land cover classes
100 year Recurrence Interval floodplain (FEMA)	Flooded area	-	-	Upland area
Distance to water (meters)	≤ 30	30 – 60	60 - 90	> 90

* Soil attribute layers weighted by 0.5 in the overlay process

At the watershed scale, the results of the overlay process show general areas that could have a disproportionate (positive *or* negative) influence on water quality (Figures 7 and 8). Enlargements of smaller areas show the level of detail and differentiation that is possible at 30 meter resolution (Figures 9, 10, 11, and 12). The juxtaposition of forests and agricultural land can have a range of consequences. For example, a large intact block of forest can assimilate and transform nonpoint source (NPS) pollution from agriculture, construction, or timber harvesting (Figure 10). Alternatively, inappropriate land use may pollute water above or below a forested reach (Figure 11). Headwater tributaries may exhibit substantially different flow regimes and ambient water quality because of the contrast between land cover and land use (Figure 9). In sum, the enlarged areas show subwatersheds, stream reaches, and lake shores that comprise reasonable units for field inspections, water quality sampling, analysis of aerial photographs, and other methods by which watershed management plans can be designed and implemented.

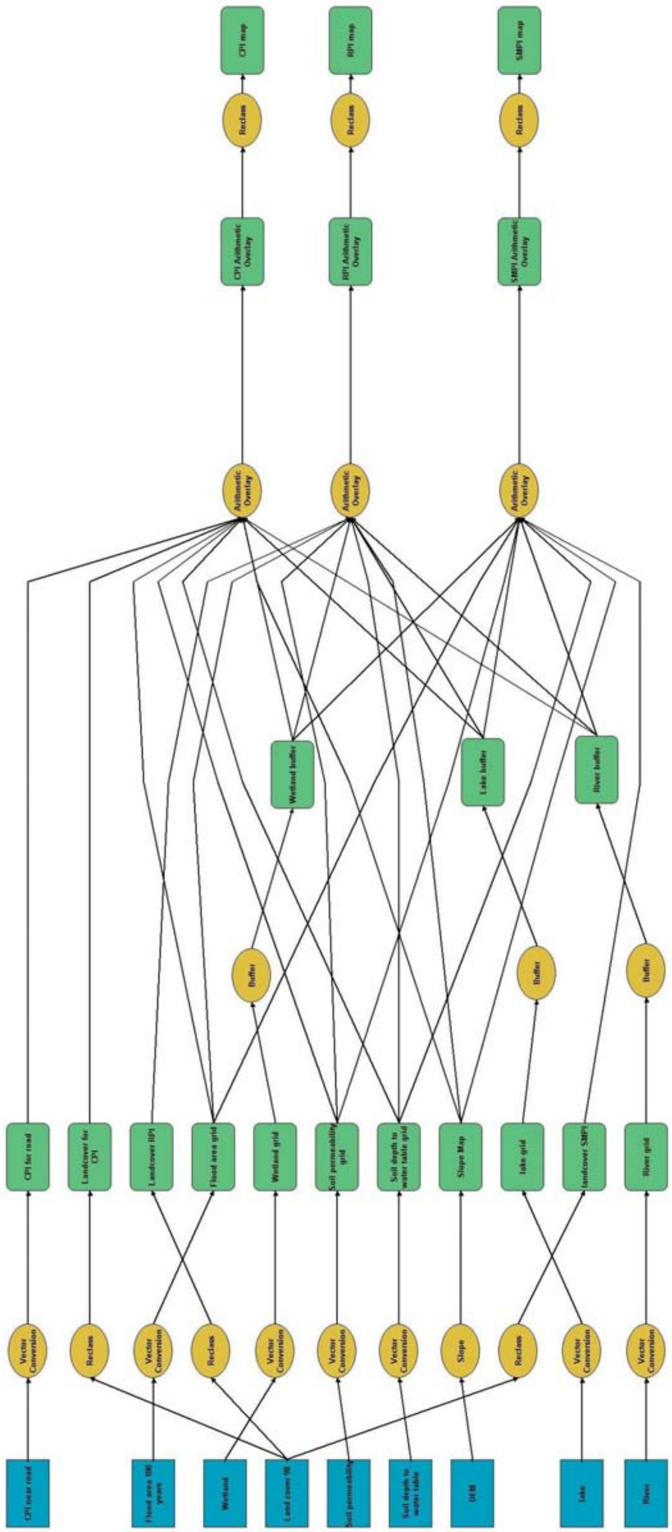


FIGURE 6 – Model schematic for Conservation (CPI), Restoration (RPI), and Stormwater Management (SMPI) Priority Indices for the upper Little Tallapoosa River watershed, Georgia. The model structure may change as additional salient data become available.

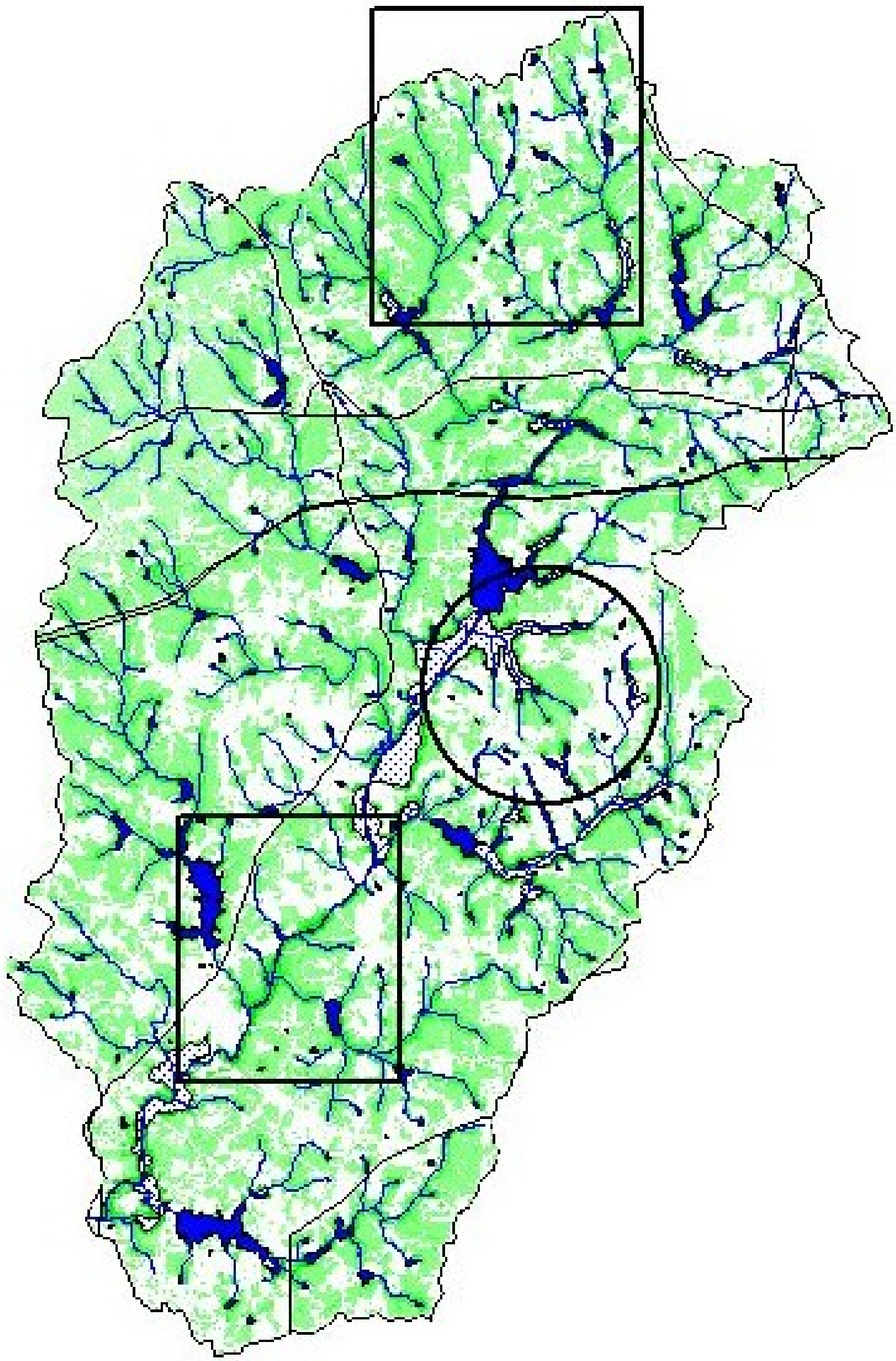


FIGURE 7 – Conservation Priority Index for forests and wetlands in the upper Little Tallapoosa River watershed, Georgia. The darkest hues have the greatest potential importance for source water pollution prevention or mitigation. Enlarged areas follow in figures 9, 10, and 11.

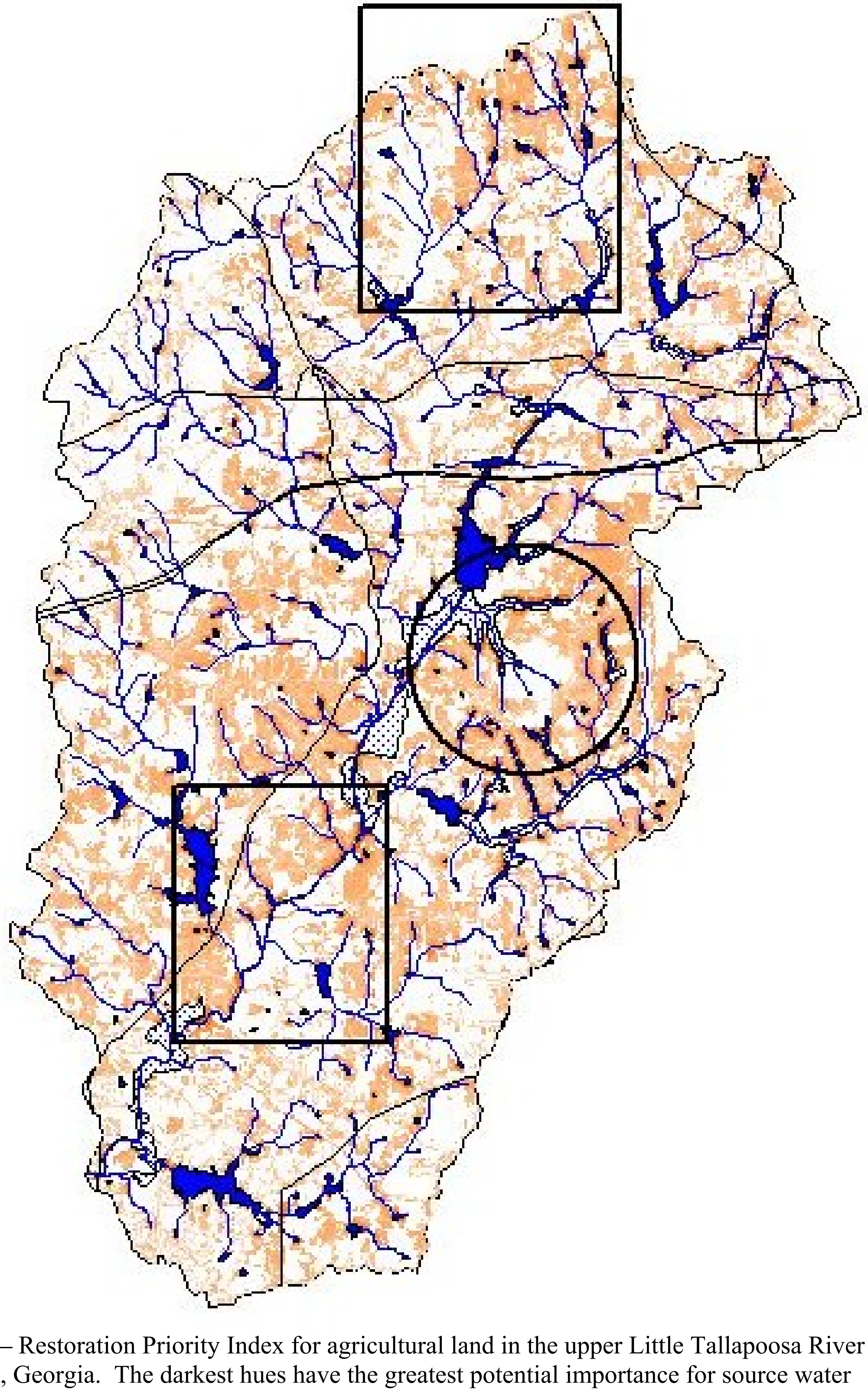
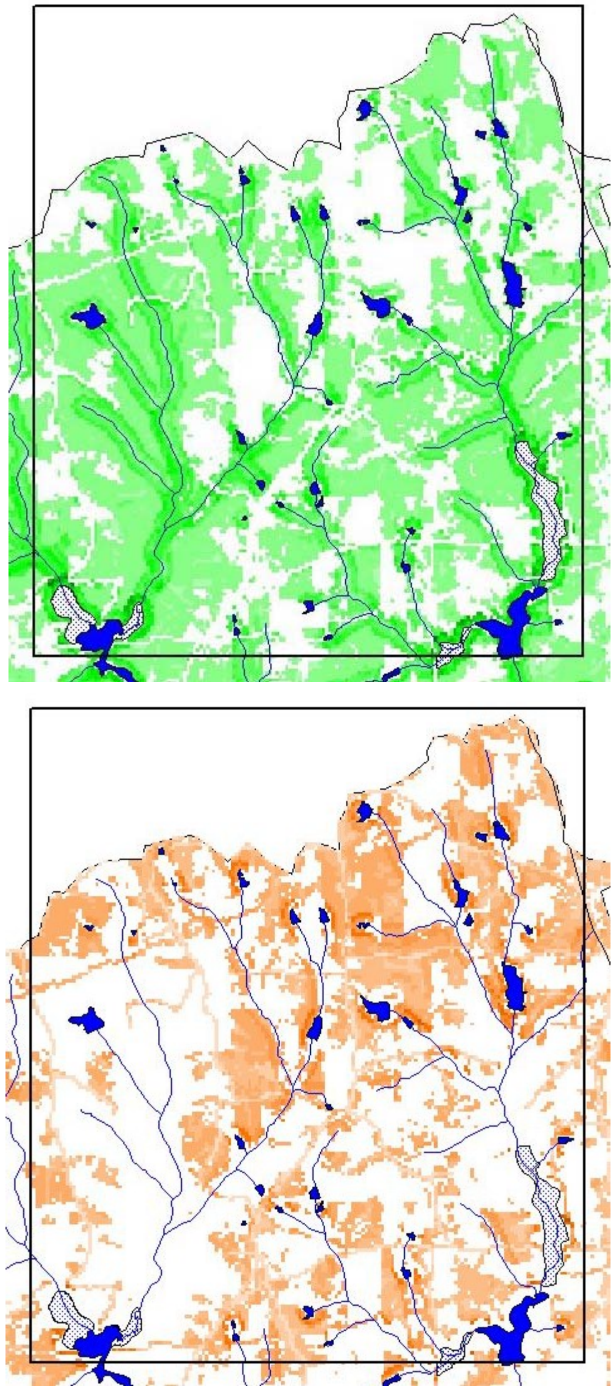


FIGURE 8 – Restoration Priority Index for agricultural land in the upper Little Tallapoosa River watershed, Georgia. The darkest hues have the greatest potential importance for source water pollution prevention or mitigation. Enlarged areas follow in figures 9, 10, and 11.



A

B

FIGURE 9A – Headwater tributaries of the Little Tallapoosa River with high CPI scores; 9B – Headwater areas with high RPI scores, near Temple, Georgia.

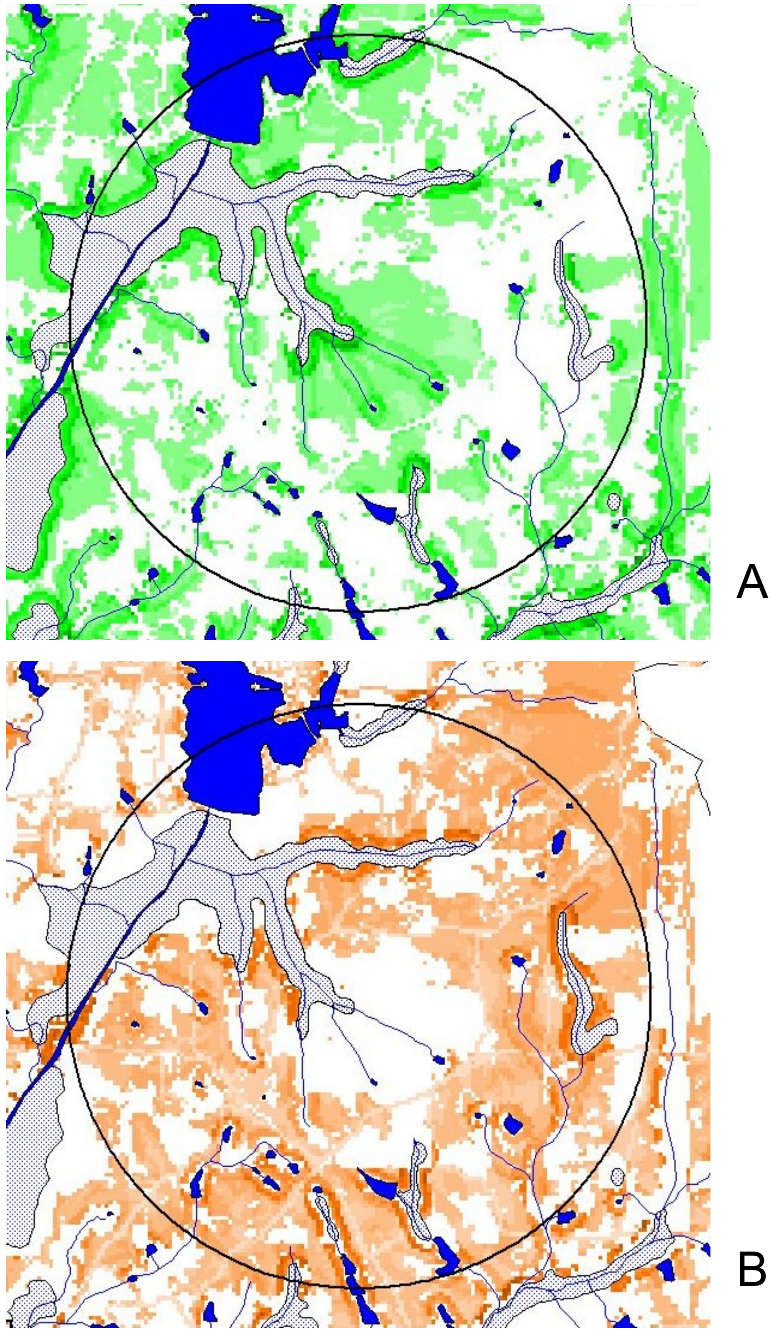


FIGURE 10A – High CPI score in a contiguous block of forest in the middle reaches of the upper Little Tallapoosa River; 10B – high RPI scores in the same vicinity.

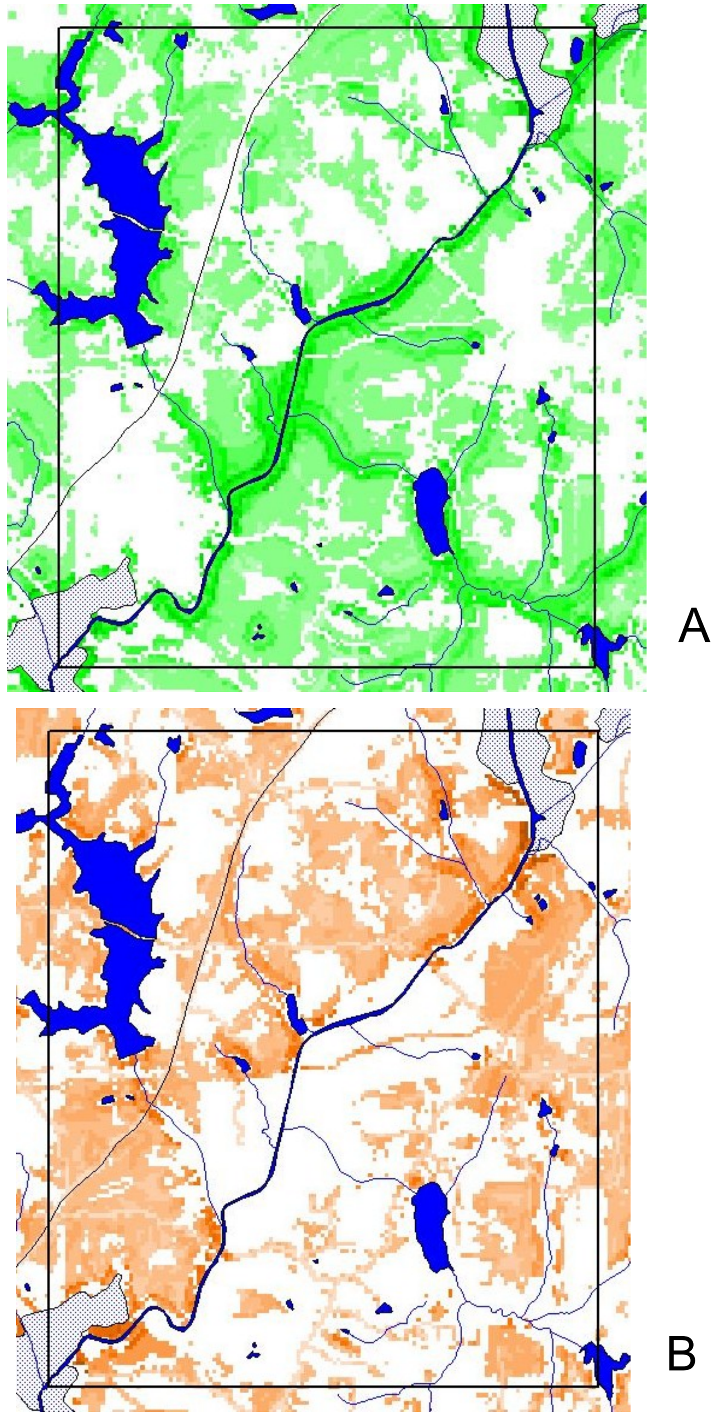


FIGURE 11A – High CPI values along the main stem of the Little Tallapoosa River near Carrollton, Georgia; 11B – high RPI values both upstream and downstream of the forested reach.

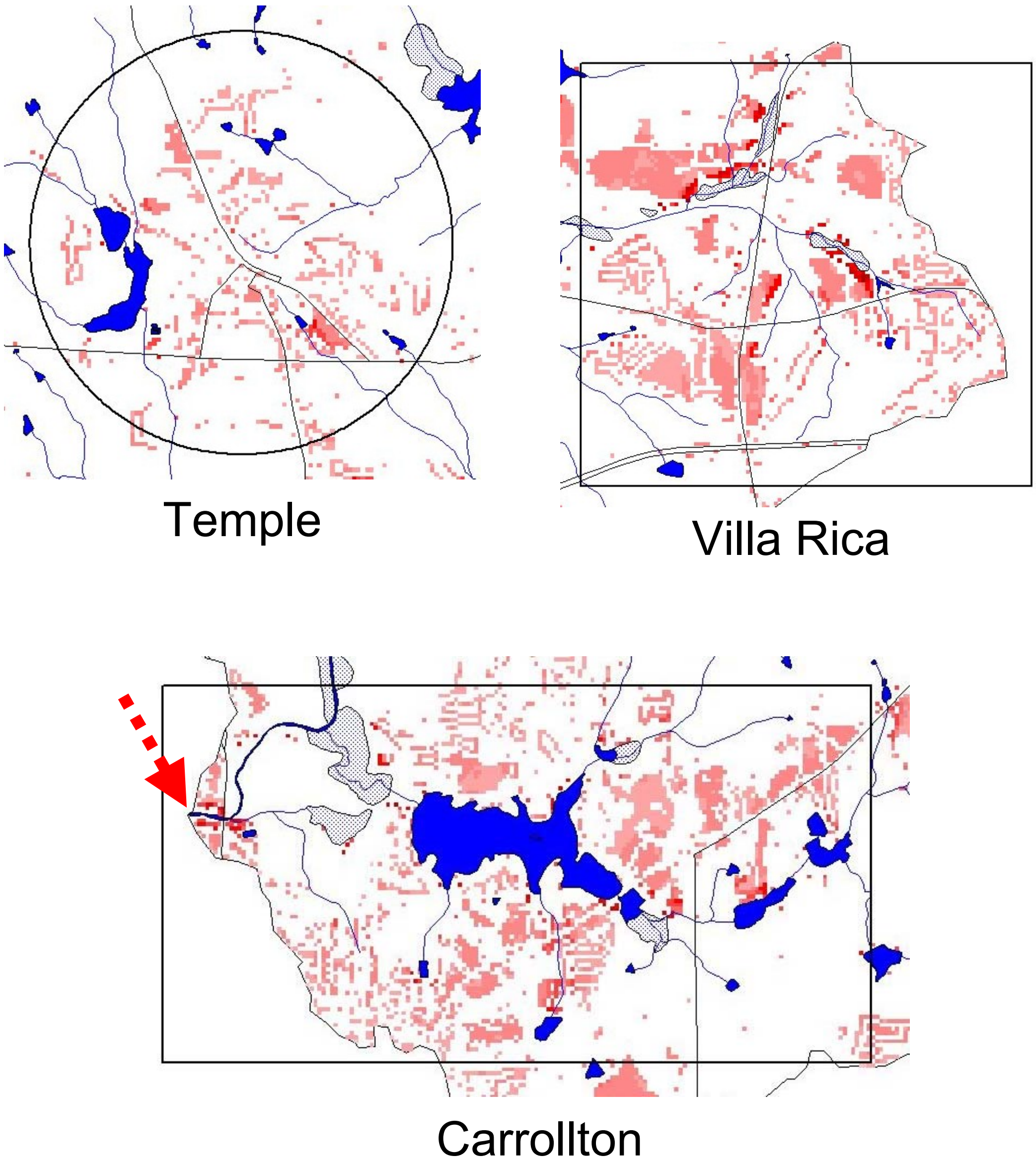


FIGURE 12 – Stormwater Management Priority Indices (SMPI) for Carrollton, Temple, and Villa Rica, Georgia. The dashed red arrow shows the location of the city of Carrollton municipal water supply intake.

In addition to the detailed review of GIS layers, CPI, RPI, and SMPI scores also can be evaluated with basic statistical methods (Figure 13). As expected, the frequency distributions for the priority indices are negatively skewed – *many* ordinary values, *few* exceptional values. By design, the GIS overlay process highlights the sites with combined characteristics and that warrant special attention. For example, a forested grid cell that is within 30 meters of a stream, in the 100-year floodplain, with a slope greater than 6%, and poorly drained, fine-textured soil would yield a CPI score of 15; one of 945 grid cells out of 154,549 in the ULT watershed. By contrast, there are 44,001 cells with a score of 7.

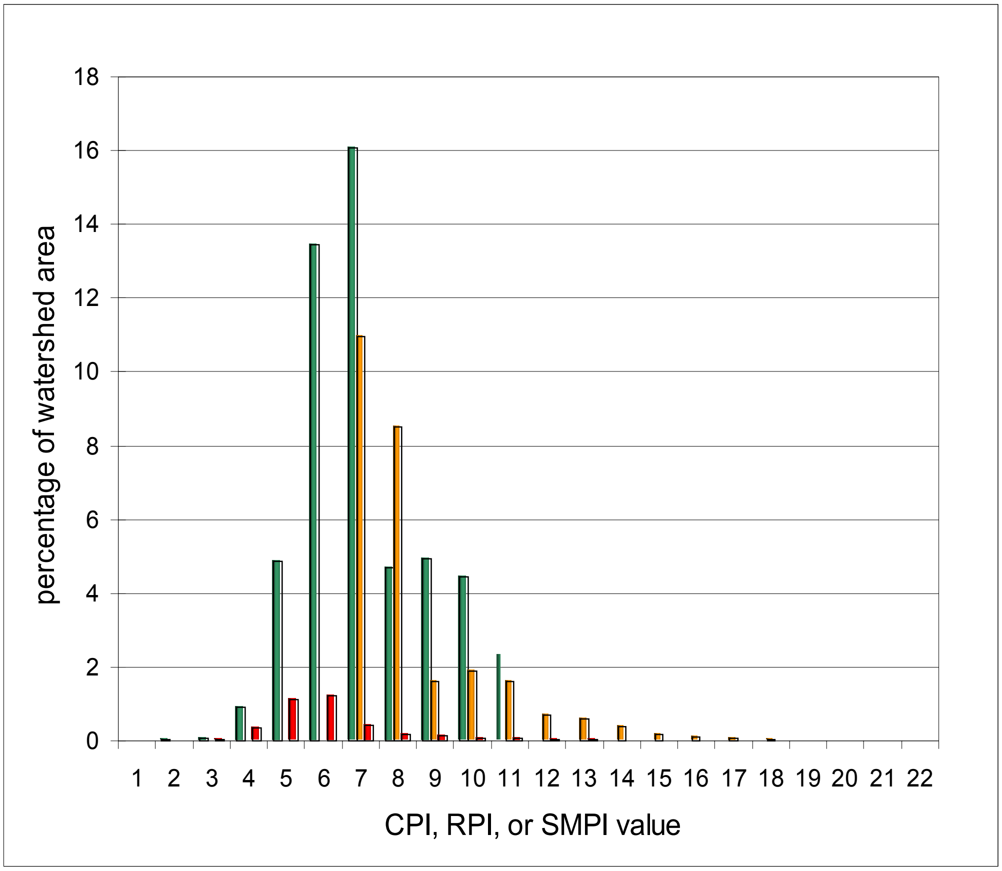


FIGURE 13 – Frequency distributions of Conservation (CPI, green), Restoration (RPI, orange), and Stormwater Management (SMPI, red) Priority Indices for the upper Little Tallapoosa River watershed, Georgia.

The 90th percentile (the top 10% of CPI, RPI, and SMPI scores) can be used to focus land conservation, pollution prevention, and pollution mitigation efforts on areas that should generate the greatest return on investment. When plotted as cumulative frequency distributions[3], percentile ranks can be readily determined for all three indices (Figure 14). Interpreting and using both frequency distributions is directly analogous to the process by which teachers assign letter grades in relation to total numerical scores …90% and higher, A, 80 to 90%, B, 70 to 80%, C …and so forth. The GIS can be used to generate a customized map of the highest scores (e.g., 80th and 90th percentiles) in relation to streams, lakes, wetlands, and roads (Figures 15 and 16). This process can be incremented by different multiples and done separately or simultaneously for the three indices to enumerate and explore a range of management options.

[3] A cumulative frequency distribution is developed by beginning with the lowest score and adding the total number of grid cells in each successive class until reaching the highest score and 100th percentile (e.g., 22 for CPI). This is the same procedure used to report standardized test scores such as the SATs or as a reference for children's height and weight at annual physical examinations.

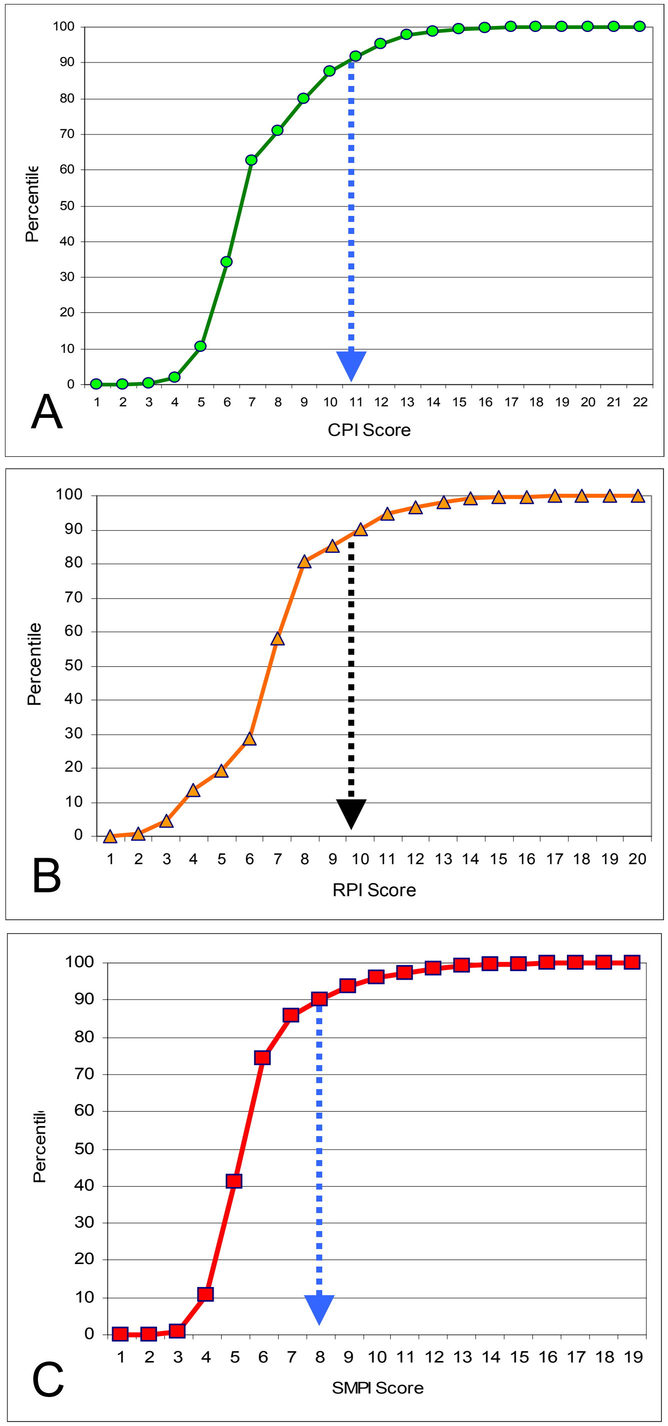


FIGURE 14 – Cumulative frequency distributions for Conservation (“A”), Restoration (“B”), and Stormwater Management (“C”) Priority Indices for the upper Little Tallapoosa River watershed, Georgia. As an example, the dashed line shows the 90th percentile score for each index as an initial threshold to guide field assessments, additional GIS analyses, outreach activities, and watershed management plans and programs.

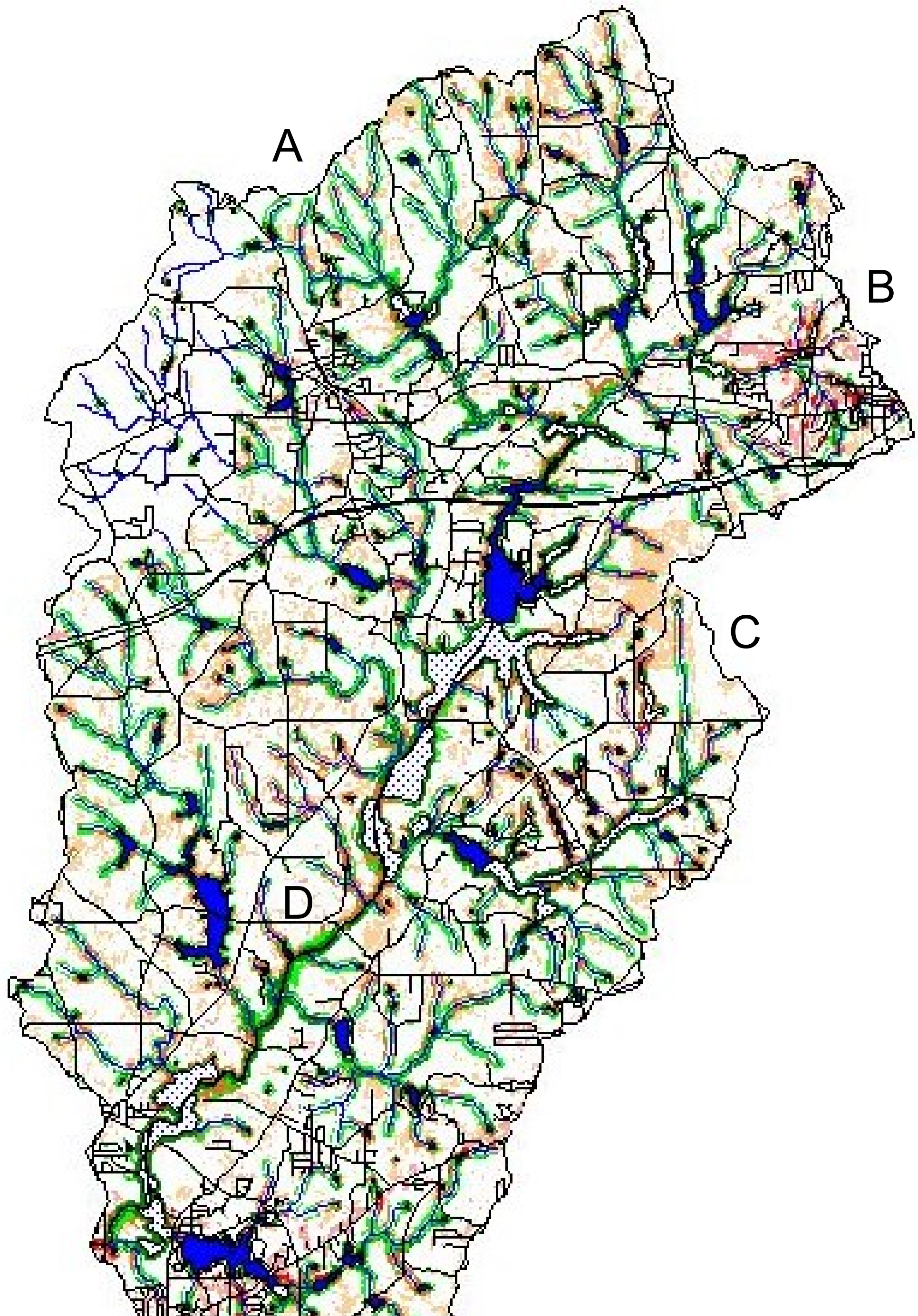


FIGURE 15 – Conservation, Restoration, and Stormwater Management Priority Indices (green, orange, and red, respectively) in the ≥ 80th or ≥ 90th percentile (light hues and dark hues, respectively) for the upper Little Tallapoosa River, Georgia. Also shown are roads, streams, lakes, ponds, and wetlands. The labels (A, B, C, D) refer to enlargements in Figure 16.

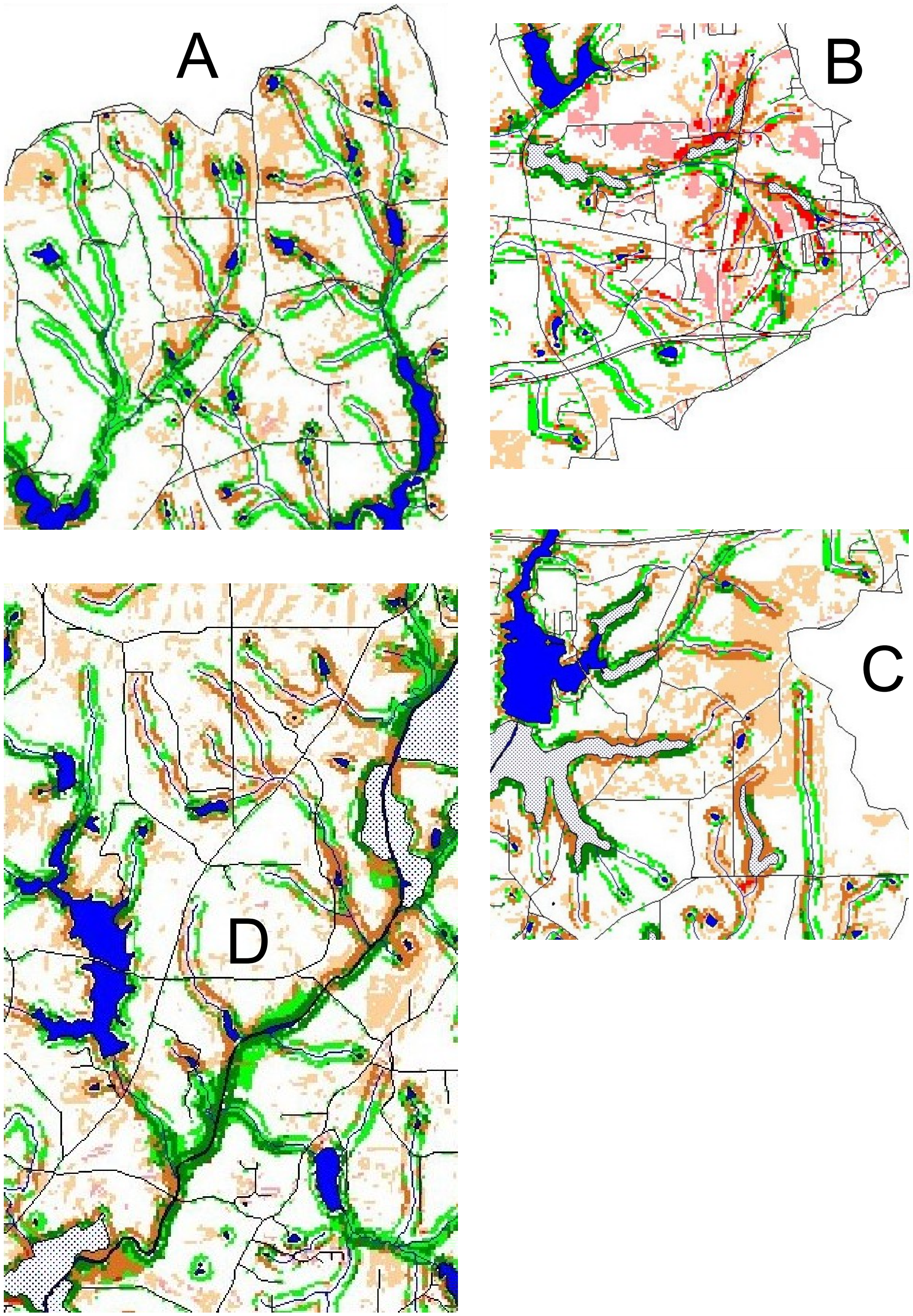


FIGURE 16 – Enlarged areas (from Figure 15) showing Conservation, Restoration, and Stormwater Management Priority Indices (green, orange, and red, respectively) in the ≥ 80th or ≥ 90th percentile (light hues and dark hues, respectively) for the upper Little Tallapoosa River, GA.

WATERSHED MANAGEMENT IMPLICATIONS

Systematic changes in land cover (Figure 3 and Table 2) and the landscape-scale patterns revealed by the initial GIS overlay process (Figures 15 and 16) lead to several findings.

1. The conversion of forest and farm land to residential and other uses will inexorably lead to changes in streamflow volumes, timing, and quality. In general, as development increases larger quantities of lower quality water flows more rapidly to the watershed outlet. As a result, the range of variation between seasonal low flows and high flows also increases. Unfortunately, water demands (municipal supply, irrigation, recreation, instream flows to maintain aquatic ecosystems, etc.) reach their peak during the growing season when volume *and* quality are most limited. To avoid or reverse these changes, it is imperative to retain forests and wetlands in fully functioning condition while planning for growth and development in relation to site-specific watershed conditions.

2. The upper Little Tallapoosa watershed still has high conservation value forests along many streams, lakes, ponds, and wetlands. In other cases, agricultural land is immediately adjacent to water features (Figure 16). A watershed management approach that simultaneously conserves existing forests *and* restores riparian forests buffers will improve source water quality. However, doing one without the other is likely to generate little, if any, net benefit. For example, the effects of conserving the floodplain forest highlighted in Figure 16D may be negated by NPS pollution entering the Little Tallapoosa immediately downstream (high RPI scores on both banks).

3. Although the ULT watershed is largely rural, because of its constituent chemistry and rapid and direct delivery to streams, urban stormwater comprises a disproportionate threat to water quality (Figures 12 and 16B). However, the significance of high SMPI scores should be interpreted with respect to distance from water supply intakes. For example, the potential influence of development in the immediate vicinity of the city of Carrollton's intake (Figure 12) may far outweigh the net effect of urban stormwater that flows from Villa Rica in the headwaters (Figure 16B) …through a series of wetlands and lakes and miles of stream channels before reaching Carrollton. The somewhat unusual geography of the Villa Rica water supply system (the reservoir and intake is *downstream* of the community) clearly provides the best incentive for source water protection.

4. The ULT watershed displays the full suite of challenges and opportunities that define watershed management. Because changes in land and resource use are incremental it is difficult for most communities to appreciate the one-directional net effect of unplanned development on source water quality, public health, and quality of life. The patterns and trends described in this report, and earlier by the West Georgia Watershed Assessment, should communicate a sense of urgency about the need for source water protection. They also should communicate a

sense of optimism about the expected benefits and results of proactive watershed management and land conservation. "The glass is [still] at least half full."

NEXT STEPS

The Watershed Issues meeting on October 22, 2002 and the Stewardship Exchange in January 2003 will provide venues for the review, discussion, and refinement of the preliminary analyses presented in this report. Both meetings will, no doubt, generate questions and ideas for additional analyses. For example, it may be possible to augment the ULT database with new layers. A "protected lands" layer could be included in the overlay process to identify opportunities to link and consolidate open space or conservation easements with new purchases. Parcel maps could be used to identify owners of key areas. Summing the priority index scores by parcel (polygon) would yield an objective way to compare properties of different sizes, shapes, and locations within the ULT watershed.

REFERENCES

Environmental Systems Research Institute (ESRI), 2002. ArcInfo, ArcGIS, and ArcView documentation.

USDA Soil Conservation Service (SCS), 1971. Soil Survey of Carroll County, Georgia, US Government Printing Office.