

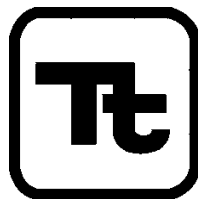
**Preliminary Findings Report:**

**Troublesome Creek Watershed  
and  
Little Troublesome Creek Watershed**

Prepared for

**NORTH CAROLINA  
WETLANDS RESTORATION PROGRAM**

Prepared by



**TETRA TECH, INC.**

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# 1 Introduction

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## 1.1 BACKGROUND & PURPOSE OF NCWRP LOCAL WATERSHED PLANNING

The NC Wetlands Restoration Program (NCWRP) has initiated comprehensive watershed planning efforts in certain high-priority local watersheds in order to meet the following primary objectives:

- 1) assessment of historical and current watershed conditions;
- 2) identification of the major causes and sources of watershed degradation (including water quality impairment, aquatic habitat degradation, and flooding problems);
- 3) involvement of local stakeholder groups in determining major watershed issues and high-priority focus areas;
- 4) prediction of future watershed conditions under alternative land use and watershed management scenarios;
- 5) development of a consensus-based package of watershed restoration and protection recommendations to be brought before local decision-making bodies, including:
  - a. identification of restoration, enhancement, and preservation opportunities
  - b. assisting the NC Department of Transportation (DOT) in meeting future compensatory mitigation needs for stream, riparian buffer and wetland impacts;
  - c. identification of non-traditional mitigation projects (e.g., stormwater BMPs, urban retrofits, agricultural practices) for targeted sites or sub-watersheds; and
  - d. identification of a longterm followup strategy to assist localities in implementation of the specific watershed protection recommendations developed during the planning process.

The NCWRP selected the Troublesome and Little Troublesome Creek watersheds (14-digit Hydrologic Units) as high-priority areas for watershed planning due to three primary factors: (1) documented water quality and aquatic habitat problems in selected stream segments; (2) the opportunity to partner with local agencies and municipalities that have already initiated watershed protection or restoration efforts; and (3) ongoing threats to local watershed health attributable to agricultural activities, urban/suburban development, planned highway construction projects, clearing of riparian buffers, and other nonpoint sources.

The NCWRP Local Watershed Planning (LWP) efforts are moving towards a watershed assessment approach that emphasizes lost or impaired (and restorable) *functions* of key watershed components (streams, riparian buffers, wetlands, and contributing uplands) -- within the context of an integrated landscape or ecosystem approach. These functions generally fall into three primary categories: water quality protection; habitat; and floodwater storage. These three functional areas are often the focus of watershed assessment and restoration efforts associated with the LWP process.

Whereas the NCWRP has funding to implement specific restoration, enhancement and preservation projects that may receive compensatory mitigation credit, the primary responsibility for watershed solutions that are *not traditional mitigation projects* (e.g., stormwater management practices) will rest with local governmental entities. As part of the development of Local

Watershed Plans, the NCWRP and its consultants will work with local stakeholder groups to recommend politically and financially feasible watershed solutions, including assistance in identifying possible funding sources for the recommended solutions.

## 1.2 MAJOR TASKS CONDUCTED BY THE WATERSHED ASSESSMENT CONSULTANTS

The NCWRP has retained Tetra Tech to conduct a technical assessment of watershed conditions within the LWP Study Area of the Troublesome and Little Troublesome Creek watersheds and to provide other support services in the development of the final Local Watershed Plan (LWP) for the study area. Tetra Tech's support services to the NCWRP began in November of 2001 and are scheduled for completion by June of 2003. The major tasks and subtasks of Tetra Tech's watershed assessment work are outlined below:

- 1.0 Scoping of Watershed Assessment and Planning Needs
  - 1.1 Review and Summarize Existing Assessment Information
  - 1.2 Establish Indicators and Targets
  - 1.3 Select/Refine Assessment Techniques
- 2.0 Detailed Watershed Characterization and Assessment
  - 2.1 Data Assembly
  - 2.2 Sub-Watershed Delineation
  - 2.3 Preliminary GIS Analysis
  - 2.4 Data Review and Identification of Missing Data
  - 2.5 Additional Data Collection
  - 2.6 Model/Assessment Tool Development
  - 2.7 Detailed Assessment of Current Conditions
    - 2.7.1 Water Quality Indicators
    - 2.7.2 Stream Channel and Riparian Corridor Assessment
    - 2.7.3 Wetland Restoration Assessment
  - 2.8 Assessment of Future Baseline Conditions
- 3.0 Targeting of Management
  - 3.1 Identify Highest Risks/Area Most in Need of Management
  - 3.2 Identify Restoration Opportunities
  - 3.3 Identify Protection Opportunities
  - 3.4 Target Areas and Issues for Management Strategy Development
- 4.0 Watershed Management Plan Development
  - 4.1 Develop Strategy for Addressing Existing Impairment
  - 4.2 Develop Strategy for Managing Future Land Use
  - 4.3 Transfer Watershed Management Plan Materials to NCWRP

## 1.3 PRELIMINARY FINDINGS REPORT

The purpose of this Preliminary Findings Report is to summarize pertinent and readily available sources of information from previous assessment efforts within the Troublesome and Little Troublesome Creek Watersheds. Based on that information, the report will recommend key indicators of water quality and overall watershed integrity for use in the detailed assessment phase of the Local Watershed Planning process. The report will also make recommendations regarding the assessment tools necessary to evaluate the response of key indicators to proposed management strategies. Based on the recommended indicators and assessment approach, the report will identify data gaps in the existing available data and outline the data collection plan necessary to support the final detailed assessment.

Delineation of subwatersheds within the Troublesome and Little Troublesome Creek watersheds will be presented in this report. Distinct subwatersheds will be utilized to rank and prioritize portions of the LWP study area for restoration and preservation efforts, as well as targeting of management measures to address sources of stream pollution and habitat degradation. In addition, the report will identify a site where a potential pilot restoration project may be initiated to meet near-term restoration goals.

Because the Troublesome and Little Troublesome Creek watersheds are separate drainages and have distinct individual characteristics, they are approached separately in this report.

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## 2 Preliminary Watershed Characterization of Troublesome Creek

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The preliminary watershed characterization of Troublesome Creek includes a description of the major physical features, a functional assessment based on currently available information, and conclusions regarding primary threats and areas in need of more detailed assessment.

### 2.1 PHYSICAL FEATURES

#### 2.1.1 Hydrology and Subwatershed Delineation

The Troublesome Creek watershed, shown in Figure 1, is slightly over 56 square miles in size with headwaters originating in the Stokesdale area of northwestern Guilford County. The narrow watershed trends east-northeast into Rockingham County to its widest portion, located immediately west of Reidsville, and then turns east-southeast and narrows to empty into the Haw River southeast of Reidsville. Troublesome Creek proper is approximately 24 miles in length with roughly 4.5 miles flooded toward the downstream end to form Lake Reidsville, the City of Reidsville's primary drinking water supply. With surface area of 750 acres, Lake Reidsville is the largest impoundment in the watershed, but other significant impoundments include Lake Hunt (180 acres), Lake Hester (21 acres), and Clarke Lake (14 acres). The Troublesome Creek watershed contains approximately 123 linear stream miles, with 35 miles classified as perennial and 80 miles classified as intermittent (8 miles have no classification), according to attributes contained in the USGS 1:24,000-scale digit line graph hydrography database.

For purposes of this Local Watershed Planning process, the Troublesome Creek watershed was delineated into 18 separate subwatersheds, which will be utilized to rank and prioritize portions of the LWP study area for restoration and preservation efforts. The subwatersheds will also be used to target management measures to address sources of pollution. The delineated subwatersheds are shown in Figure 2 and range in size from 0.8 (T17) to 11.5 (T9) square miles. Delineation was achieved by first identifying 34 separate subwatersheds (one for every tributary to Troublesome Creek proper, and one for each segment of Troublesome Creek between tributaries). Subwatersheds with similar landuse distributions and soil characteristics were then aggregated to arrive at the final 18. Areas of the watershed where significant landuse changes are expected were not aggregated because a finer resolution will provide a better estimate of the impacts of management and preservation. Detailed subwatershed maps are presented in Appendix A (Maps 1-5).

#### 2.1.2 Geology and Soils

The Troublesome Creek watershed lies within the Milton Belt, which is characterized by sandy, erodible soils formed in material weathered from acid, igneous, and metamorphic rock. Upland soils in the watershed are predominantly comprised of the Cecil-Pacolet-Applying grouping, which are gently sloping to steep, deep, well drained, and moderately to highly erodible. Floodplain alluvial soils are entirely comprised of the Chewacla-Congaree-Wehadkee grouping, which are nearly level, deep, well drained to poorly drained depending on topography, and are highly erodible (USDA-SCS, 1992; USDA-SCS, 1977). Along perennial stream courses, alluvial soils are almost entirely comprised of Group A and Group B hydric soils, and they are divided about evenly between those two hydric groups. Figure 3 shows a map of soils by K factor, which

indicates the susceptibility to erosion by water within the Troublesome Creek watershed. Preliminary GIS analysis of soils indicates that 57 percent of the soils within the watershed have K factors of 0.28 or greater, indicating high susceptibility to erosion.

### 2.1.3 Land Use and Land Cover

The headwater portion of the Troublesome Creek watershed contained within Guilford County constitutes only 4.2 square miles, or approximately 7.5 percent of the total watershed area, and the majority of that Guilford County portion, 3.4 square miles, is within the Town of Stokesdale. The Stokesdale portion of the watershed is contained entirely within Guilford County. The remaining majority of the watershed, 51.9 square miles (92.5 percent), is located within Rockingham County. Within that portion, an area of 1.1 square miles, or roughly 2 percent of the watershed's total area, falls within Reidsville city limits.

Preliminary GIS analysis of the circa 1992 National Land Cover Database (NLCD) from USGS and USEPA indicates that 57 percent of the entire watershed area remains as forest and wetland, 35 percent is used for agriculture, 5 percent is developed or disturbed, and 3 percent is open water. Within the agricultural portion, 76 percent is defined as row crop and 24 percent as pasture. NLCD landuse/land cover for Troublesome and Little Troublesome Creeks is depicted in Figure 4. Aggregated landuse data are presented for each subwatershed in the Troublesome Creek watershed in Table 1. Detailed maps of landuse by subwatershed are presented in Appendix A (Maps 8-12). It should be noted that the NLCD is the most recent landuse data available for the upper Piedmont region of North Carolina.

**Table 1. Landuse Summary for the Troublesome Creek Sub-basins (ac)**

Sub-basin	Area (ac)	Area (sq mi)	Forest	Residential	Commercial/Industrial	Agriculture	Wetlands	Other
T1	2952.74	4.61	51.29%	4.51%	1.85%	35.78%	3.70%	2.87%
T2	551.77	0.86	35.51%	16.97%	4.43%	38.33%	0.28%	4.47%
T3	1406.65	2.20	58.01%	3.21%	0.49%	33.74%	4.11%	0.44%
T4	600.24	0.94	57.28%	1.70%	0.59%	37.57%	0.18%	2.67%
T5	2566.43	4.01	57.18%	0.68%	0.17%	39.45%	1.23%	1.28%
T6	621.37	0.97	37.97%	1.86%	0.89%	55.12%	1.22%	2.94%
T7	2337.82	3.65	57.27%	0.00%	0.00%	33.71%	8.34%	0.68%
T8	2338.94	3.65	51.50%	0.58%	0.39%	44.38%	2.42%	0.74%
T9	7382.41	11.53	54.43%	0.60%	0.43%	39.96%	3.64%	0.94%
T10	1259.41	1.97	39.56%	1.66%	0.92%	53.38%	1.94%	2.54%
T11	1983.76	3.10	54.04%	0.00%	0.00%	40.94%	3.06%	1.96%
T12	1532.29	2.39	50.31%	2.63%	0.73%	35.78%	1.57%	9.00%
T13	1691.09	2.64	62.06%	5.26%	0.96%	27.66%	0.38%	3.68%
T14	535.97	0.84	79.96%	5.97%	1.00%	9.63%	0.62%	2.82%
T15	1490.93	2.33	65.20%	9.01%	3.70%	17.50%	0.58%	4.01%
T16	1210.48	1.89	61.79%	5.79%	3.07%	25.50%	1.08%	2.77%
T17	526.63	0.82	53.42%	0.13%	0.17%	44.30%	0.34%	1.65%
T18	4920.71	7.69	46.40%	5.85%	2.23%	25.21%	4.93%	15.38%

## 2.2 FUNCTIONAL ASSESSMENT

The primary watershed functions addressed in this study are water quality, hydrology, and habitat. The following subsections summarize the basis for assessment of watershed functions and the preliminary findings based on previous studies and additional scoping level assessment performed by Tetra Tech, Inc. The Detailed Assessment Report, scheduled for completion in early 2003, will include a more detailed evaluation of watershed functional indicators for selected high-priority subwatersheds and study sites.

### 2.2.1 Stream Classifications/Use Support Ratings

Rules contained in Section 15A NCAC 02B.0200 of the North Carolina Administrative Code describe a classification system by which NCDWQ is to assign use classifications to waterbodies across the state. These use classifications stipulate the specific best uses for each waterbody and determine the standards to which water quality is to be protected in order to maintain those uses. For more information on the NC DWQ's use support classifications for surface waters (and associated water quality standards) go to <http://h2o.enr.state.nc.us/admin/rules/>.

From its source to Lake Reidsville, Troublesome Creek is classified WS-III NSW, and from the lake to the Haw River it is classified C NSW. The best use assigned to Class WS-III waters is as a "water supply for drinking, culinary, or food processing purposes...and any other best usage specified for Class C waters." The best uses assigned to Class C waters are "aquatic life propagation and maintenance of biological integrity (including fishing and fish), wildlife, secondary recreation, agriculture, and any other usage except for primary recreation..." The supplemental NSW classification is assigned by virtue of the fact that Troublesome Creek is located within the Jordan Lake watershed. The Nutrient Sensitive Waters (NSW) rules for Jordan Lake outline a regulatory strategy to reduce phosphorus loads to the reservoir in order to prevent excess eutrophication. Primarily, the rules establish stringent limits on the concentrations of phosphorus that may be contained in wastewater discharges within the Jordan Lake watershed.

Section 305(b) of the Clean Water Act requires that states periodically evaluate each waterbody, and based on available data, determine whether water quality within the waterbody is adequate to support its designated uses. Per the 305(b) requirement, NCDWQ evaluates waterbodies across the state every two years and assigns use support ratings to each indicating whether they are "Fully Supporting," "Partially Supporting," or "Not Supporting" their designated uses. Section 303(d) of the Clean Water Act requires that states place waters that are rated "Not Supporting" or "Partially Supporting" on a list of Impaired Waters, referred to as the 303(d) List. Section 303(d) also requires that a Total Maximum Daily Load (TMDL) be determined for any waterbody that is impaired by a specific identifiable pollutant or pollutants. The intent of the TMDL is to identify sources for the specific pollutant(s) and reduce the pollutant loads from those sources to the extent necessary to improve water quality to a level that will restore the uses deemed impaired.

NCDWQ makes a concerted effort to consider all sources of data when determining the use support status of a given segment or portion of a waterbody. However, often no ambient water quality monitoring station is located within the area to be rated and no special studies have been performed there. In such cases, NCDWQ is left to rely on a limited amount of biological monitoring data to make judgments regarding use support. Typically, NCDWQ conducts widespread biological monitoring across each river basin within the state every five years as part of the basinwide management planning cycle.

Based on limited biological monitoring data collected by NCDWQ, a 15.6-mile segment of Troublesome Creek has been deemed "Partially Supporting" (NCDWQ, 2000b). The creek

segment from its source to Rockingham County SR 2423, has been listed on North Carolina's 1998 and 2000 303(d) Lists of Impaired Waters (refer to Figure 1). The 2000 List attributes the impairment to sediment and cites agriculture as a potential source. It should be noted that the downstream segment of Troublesome Creek, inclusive of Lake Reidsville, was de-listed from the 1998 to the 2000 list because new lake assessment and biological data warranted an updated use support rating. The 2000 305(b) Report and 303(d) List are available for download from NCDWQ at <http://h2o.enr.state.nc.us/wqs/>. The Draft 2002 Integrated 305(b) and 303(d) Report has recently become available from NCDWQ for public review comment, and the draft reflects no changes in the impaired listing status of Troublesome Creek upstream of Lake Reidsville (NCDWQ, 2002). The 2002 draft is not yet posted on the NCDWQ website.

Due the limited amount of data on which the "impaired" status of Troublesome Creek was based, there is some question as to whether or not that designation is appropriate. The following sections of this document are intended to present a more comprehensive assessment of water quality and aquatic habitat within Troublesome Creek, and to recommend the assessment methods and data collection necessary to produce a more reliable measure of the integrity of the watershed.

## 2.2.2 Investigations and Reports from Local Resource Agencies

In June 1979, the USDA - Soil Conservation Service (SCS) released a Preliminary Inventory Report for the Troublesome Creek watershed. The report indicated that at the time, 25 percent of the watershed was in cropland use, mostly for tobacco farming. Based on Universal Soil Loss Equation (USLE) estimates, the average rate of soil loss for cropland in this watershed was 12 ton/ac/yr. This is a high loss rate estimate, given that USLE soil loss tolerance factors for soils within the watershed range from 2 - 5 tons/ac/yr. The goal set forth by the SCS was to reduce this rate to 5 ton/ac/yr in 75 percent of the cropland. The study reported that 10 percent of the cropland was currently at or below the targeted loss rate and listed several agricultural BMPs that could be used to mitigate soil loss from the other areas. The report attributed soil loss to cropland, road banks, and unprotected areas (USDA-SCS, 1979).

It should be noted that watershed reconnaissance by SCS did not clearly confirm the report findings that agricultural lands were contributing the majority of the sediment load to Troublesome Creek. In a letter to George K. Desha, Head of Planning and Technology Staff in Fort Worth, Texas dated August 1979, a Land Treatment Specialist from SCS stated that, "An inventory of several crop fields was made during a reconnaissance of the watershed which revealed that the existing resource management systems in most cases were adequate to protect the resource base" (Richardson, 1979). In October 1979, a geologist from SCS wrote, "We saw the watershed following a rainfall of 6 inches in about 8 hours, which is a low frequency event. This storm occurred the week prior to our visit. Even though some of the fields had been harvested just prior to the storm, serious erosion of agricultural land was not evident. We did see some roadside erosion that was contributing directly to the stream system" (Nicholas, 1979).

As part of the Agricultural Sediment Initiative conducted by the Association of Soil and Water Conservation Districts (ASWCD), the Rockingham County District developed a Sediment Survey/Action Plan for the Troublesome Creek watershed (ASWCD, 1999). Section I of the survey states that, "There is no apparent sediment problem in the streambed of the impaired stream segment." This report divides the Troublesome Creek watershed into "Adjacent Land Area" and "Remaining Land Area." The adjacent land is the land draining to the stream that is ½ mile or less from the stream itself. The remaining area contains the remainder of the watershed.

The survey results indicate that, within both adjacent and remaining areas, 80 to 100 percent of the agricultural lands have a conservation plan for erosion control, and 80 to 100 percent of those

lands covered by conservation plans have the erosion control measures called for in the plans in place on the land. For the adjacent land area, the report states that, “generally sedimentation is non-agricultural,” and that it is more likely due to lot grading and utility installation. In the remaining areas, the report attributes sedimentation to ongoing construction, lot grading, and utility installation. Though the report indicates that sediment is not originating from agricultural sources, it does state that many BMPs in the area have met their life expectancy and will require maintenance in the near future.

### Background Note: Landscape History and Channel Alteration in the Piedmont Region

The condition of stream channels today depends not only on current watershed activities, but on historical land uses and management activities as well. The landscape of North Carolina’s Piedmont region, like much of the southern Piedmont, has been substantially altered over the past 200 years. These changes have had major impacts on past stream conditions and continue to affect how channel networks today react to ongoing watershed activities. While circumstances vary from one place to another, the basic outline of these historical changes is widely accepted (see Ferguson, 1997; Wilson, 1983; Jacobson and Coleman 1986; Simmons, 1993; Richter et al, 1995).

- Following widespread clearing of forests in the 19<sup>th</sup> century and subsequent intensive agricultural land use, extensive erosion of upland areas occurred throughout the southern Piedmont region. Conservation practices were virtually unknown prior to the 1930s (Trimble, 1974; Healy, 1985).
- The extent of cleared land peaked in the late 19<sup>th</sup> and early 20<sup>th</sup> centuries. For a variety of reasons, the amount of cultivated land in many parts of the Piedmont began to decline in the 1920s and 1930s, a trend that continues today. Much of this former cropland reverted to forest.
- With the advent of the soil conservation movement in the 1930s, tillage practices began to improve on the remaining cropland.
- During the period of most intensive agricultural activity, sediment filled many stream channels. The floodplains and lowland riparian corridors of many 3<sup>rd</sup> order and larger streams often aggraded (increased in elevation) by several feet to several meters in height due to the large volume of eroded soil transported from upland areas (e.g. see Wilson, 1983; Ferguson, 1997).
- Once upland erosion declined, streams began the process of removing the accumulated sediment. High sediment loads persisted for many years following the reduction in upland erosion as streams reworked the sediment stored on hill slopes and floodplains and within stream channels (Meade, 1982; Meade and Trimble, 1974).
- In many rural areas streams have substantially recovered from this sedimentation. They have restabilized and many now support healthy populations of fish and macroinvertebrates. These streams have not necessarily returned to their former condition, however, but often remain incised and retain a more sandy appearance than previously. In other rural areas the process of recovery still continues.

In addition to the stresses imposed by historic agricultural impacts, many streams have also been channelized (straightened, deepened or realigned) to reduce flooding or to maximize the land available for farming. Channelization often induces substantial sedimentation due to subsequent stream downcutting and widening. In some cases entire channel networks, which had previously filled with sediment, were channelized and remain unstable decades later.

Many of these watersheds have since undergone, or are currently experiencing, significant development as the Piedmont continues to grow. The major hydrologic changes that accompany development and the resulting physical and biological deterioration of stream channels are well known. However, the impact of urbanization is often made worse by the persistent effects of historical practices. Many streams are already incised and subject to ongoing bank erosion and sedimentation due to prior impacts from agricultural erosion and channel modification, leaving them extremely vulnerable to the altered hydrology brought on by urban and suburban growth. In highly impacted watersheds, the relative effects of these various disturbances can be difficult if not impossible to distinguish. It is clear, however, that the legacy of past land use practices is still with us, and that we cannot understand the current condition of many impaired streams without understanding the history of their watersheds.

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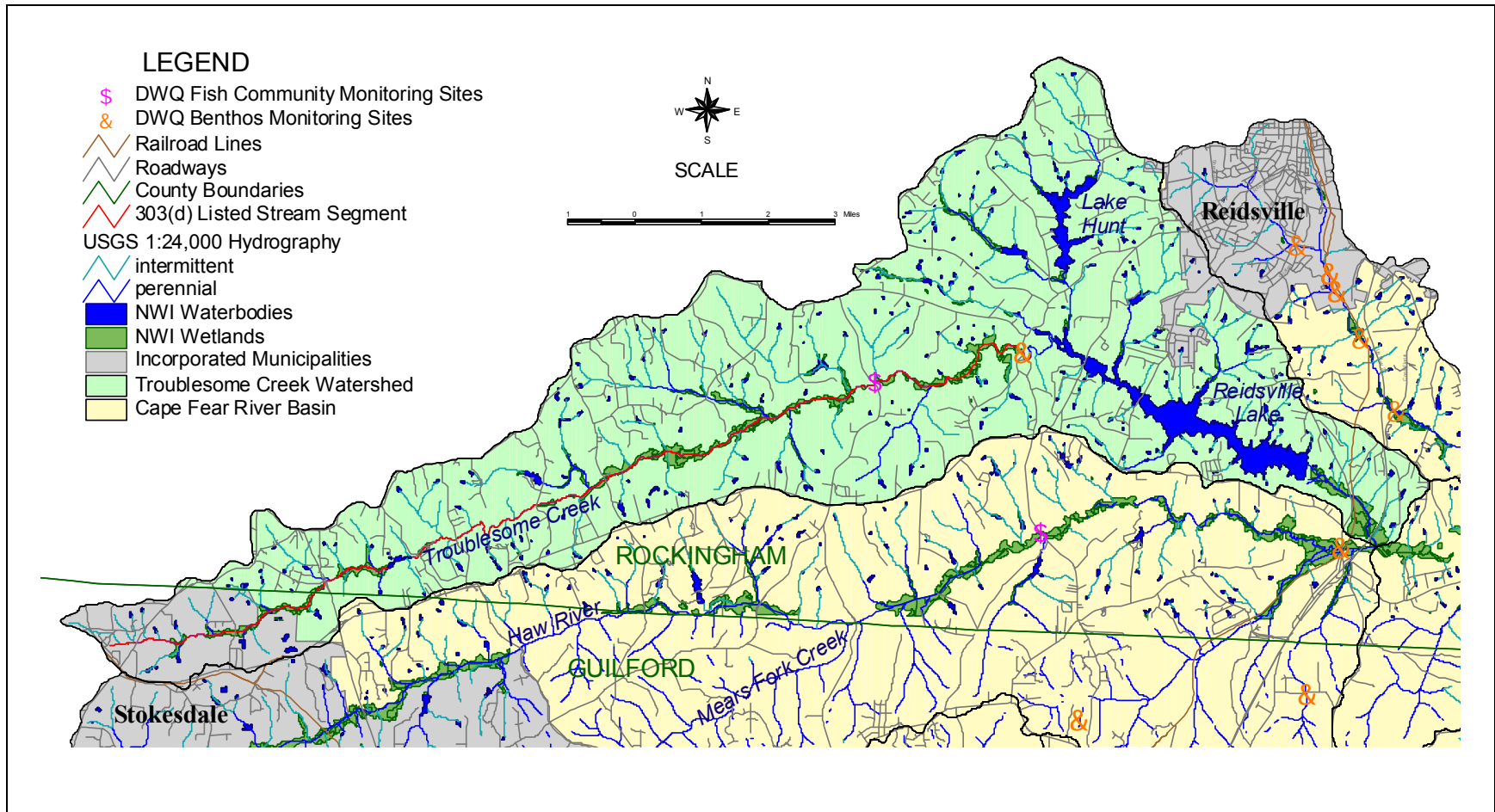


Figure 1. Troublesome Creek Watershed

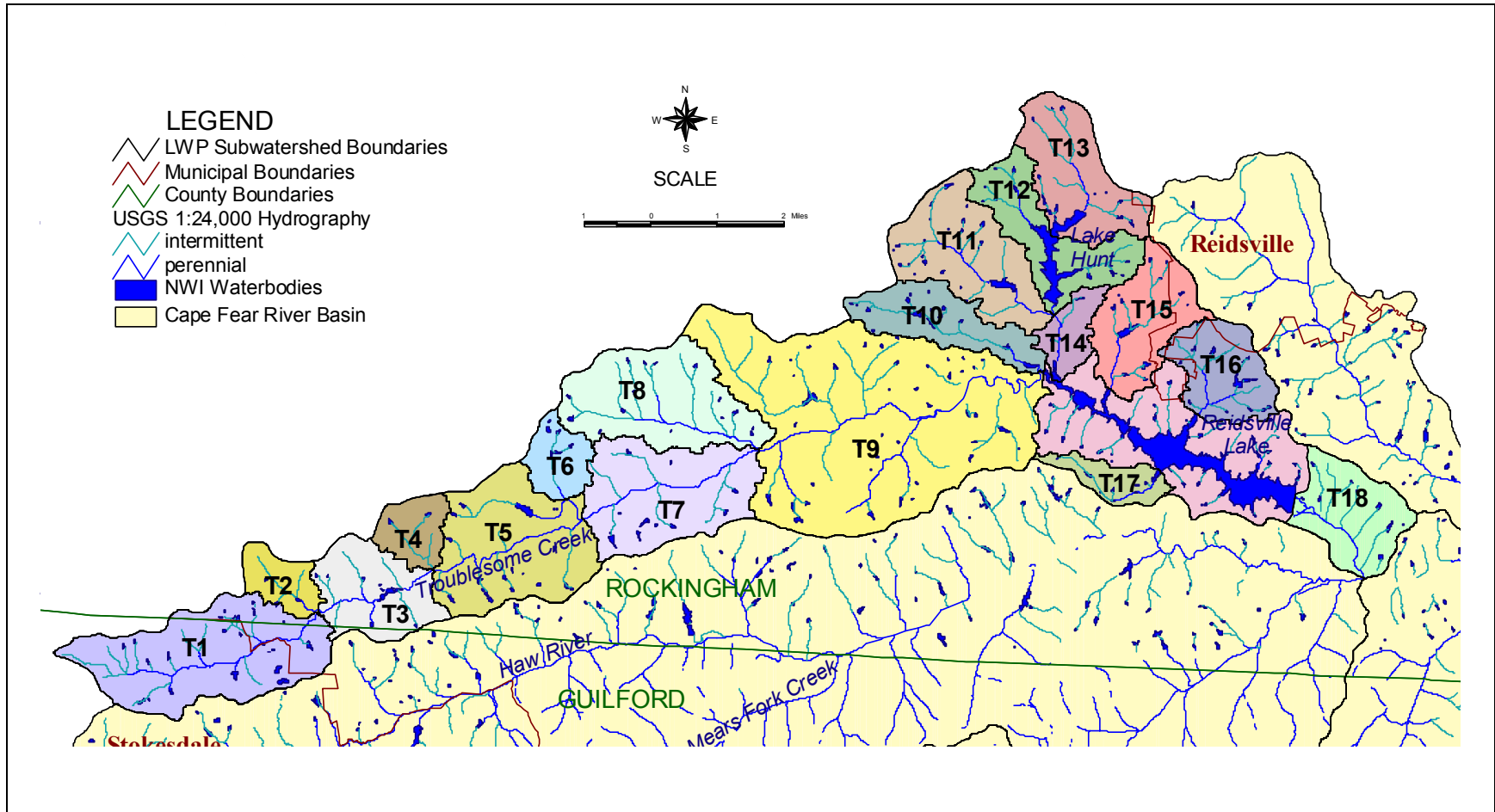


Figure 2. Troublesome Creek Subwatershed Delineation

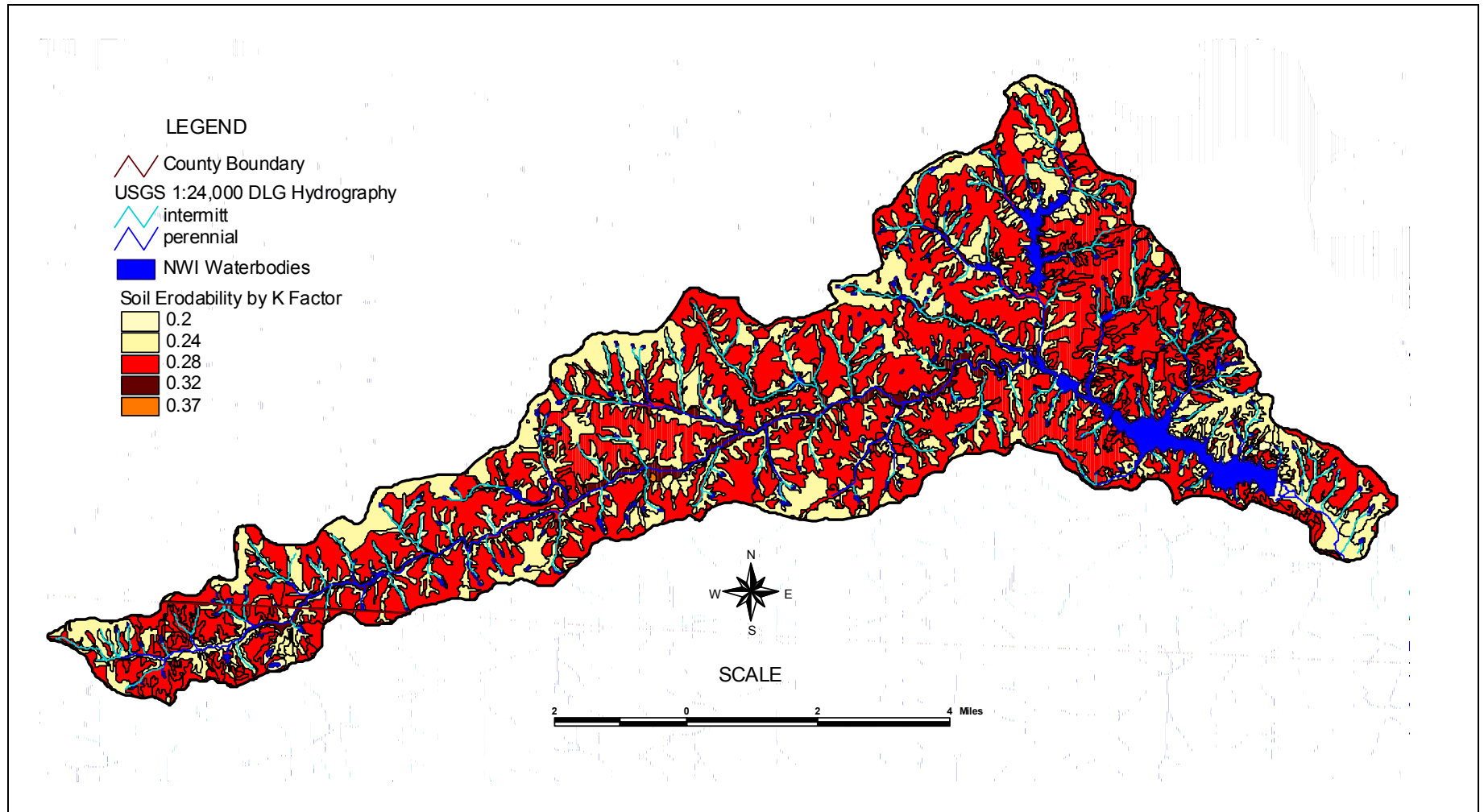


Figure 3. Soils within Troublesome Creek Watershed Mapped by K Factor

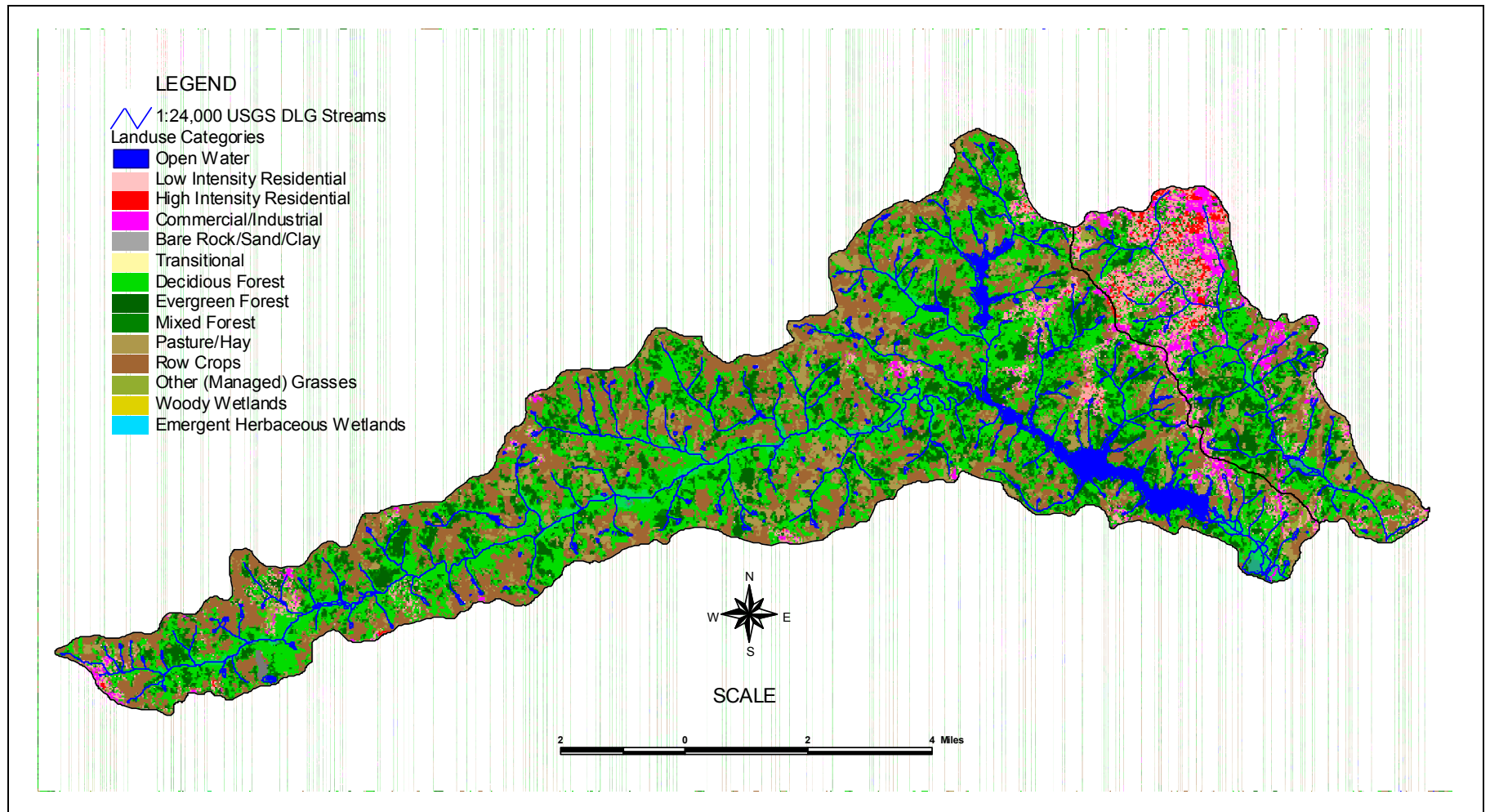


Figure 4. NLCD Land Cover within Troublesome and Little Troublesome Creek Watersheds

### 2.2.3 Biological Monitoring Information - Basinwide Assessment Document

The North Carolina Department of Environment and Natural Resources (NCDENR) Division of Water Quality has sampled one benthic community sampling site and one fish community sampling site within the Troublesome Creek watershed (refer to Figure 1). The benthic monitoring station is located at SR2422 just upstream of Lake Reidsville, and the site description in the Basinwide Assessment Document indicates that the site has a rocky substrate, reflecting a localized instance of Carolina Slate Belt geology. A recent photograph of the site (Figure 5) depicts intact stream banks and well-vegetated buffers. Benthic ratings at this station were “Good-Fair” in April 1993 and June 1998. Narratives from the 1998 sampling event indicate low EPT taxa richness was observed in 1998, but that several intolerant taxa were abundant (NCDENR, 1999).

The fish community sampling site is located upstream of the benthos site at SR 1001 in the Milton Belt, and the site description indicates that the substrate is comprised mostly of sand, silt, and clay. Fish community ratings were “Poor” in both 1993 and 1998. Narratives indicate that low numbers of species and individuals were collected on both occasions. Narratives from the 1995 Basinwide Assessment Document attribute the poor fish community rating in 1993 to habitat degradation from sediment. The document states, “The combination agricultural land use and highly erodible soils produces widespread nonpoint source problems in both the Haw River and Troublesome Creek watersheds” (NCDENR, 1995). Narratives pertaining to the SR 1001 results also mention that the trophic composition of the fish community indicated potential nutrient enrichment at that site.

### 2.2.4 Lakes Data and Lake Assessment Information

Through the NCDWQ Lakes Assessment Program, water quality in Reidsville Lake and Lake Hunt has been monitored occasionally since 1981. Lake Hunt was sampled at three stations, once per year in 1981 and 1988, and three times per year in 1991, 1992, 1993, and 1998. Reidsville Lake was sampled at two stations, once per year in 1981, 1987, 1988, and 1993 and three times in 1998. Lake-wide averaged results from those sampling efforts for several key parameters are presented in Table 2. N.C. Trophic State Index scores for the two reservoirs fall predominantly in the mesotrophic range with occasional variances into the oligotrophic range in Lake Hunt and into the eutrophic range in both Lake Hunt and Reidsville Lake. Note that the occasional scores reaching into the eutrophic range tend to be in the lower end of that range.

With only rare exceptions, average total phosphorus values reported for the two reservoirs do not exceed 0.05 mg/l and average total nitrogen values do not exceed 0.5 mg/l. No water quality standards or action levels have yet been developed for nutrients for North Carolina. However, an EPA survey of water quality scientists found that, on average, in-lake total phosphorus levels of 0.084 mg/l and total nitrogen levels of 1.9 mg/l or more were indicative of eutrophic conditions (USEPA, 2000). Both Reidsville Lake and Lake Hunt exhibit in-lake nutrient levels consistently below those thresholds.

On only one occasion in each waterbody has average chlorophyll *a* been reported at a level greater than 15 µg/l. For the State of North Carolina the water quality standard for chlorophyll *a* is 40 µg/l. Individual station data obtained from NCDWQ indicates that the maximum chlorophyll *a* value reported for Lake Hunt was 33 µg/l at one station in 1993, and the maximum value for Reidsville Lake was 25 µg/l at one station in July of 1998. Taken collectively, the data

indicate that degradation of water quality resulting from primary productivity has not been a significant issue in Lake Hunt or Reidsville Lake to date.



**Figure 5. Troublesome Creek at SR 2422**

A preliminary GIS analysis of landuse conversion was conducted by overlaying circa 2000 planimetric data from Rockingham County with circa 1992-1993 NLCD satellite-based land cover data for the Troublesome Creek watershed. The analysis indicated that from the date of origin of the NLCD data to that of the planimetric data (i.e., between 1993 and 2000), some areas of land in the western portion of the watershed, in the vicinity US Highway 220, had been converted from forest to suburban residential use. Personal communication with the Rockingham County District Conservationist, Kevin Moore, has also indicated that significant development has been occurring in that portion of the watershed. This residential development may be driven in part by the location of the new Federal Express hub near the Greensboro Airport in northwestern Guilford County. The new hub is within relatively short commuting distance down Highway 220 from southern Rockingham County (Moore, 2001). While eutrophication in Reidsville Lake has not been an issue yet, if development pressure continues to be exerted on the watershed by the northward growth of Greensboro, and rural land continues to be converted to suburban residential uses, increased nutrient loading to the lake will likely occur without additional management measures.

**Table 2. NCTSI Data for Reidsville Lake and Lake Hunt**

Reidsville Lake Data						
Date	NCTSI	Result	TP	TON	CHLA	SECCHI
8/3/98	no score		0.02	0.25	n/a	1.0
7/1/98	1.5	Eutrophic	0.05	0.42	19	1.2
6/2/98	-1.8	Mesotrophic	0.01	0.20	10	1.0
8/19/93	-0.9	Mesotrophic	0.02	0.24	12	1.4
8/16/88	-1.7	Mesotrophic	0.02	0.23	7	1.6
8/18/87	0.1	Eutrophic	0.03	0.38	12	1.3
7/15/81	-1.9	Mesotrophic	0.02	0.28	8	3.7
Lake Hunt Data						
Date	NCTSI	Result	TP	TON	CHLA	SECCHI
8/3/98	no score		0.01	0.23	n/a	1.0
7/1/98	1.6	Eutrophic	0.06	0.45	11	1.0
6/2/98	-1.5	Mesotrophic	0.01	0.2	11	0.8
8/19/93	-2.3	Oligotrophic	0.01	0.19	10	1.4
7/22/93	-1.6	Mesotrophic	0.02	0.18	6	1.2
6/16/93	0.9	Eutrophic	0.04	0.31	18	1.2
8/6/92	-1.2	Mesotrophic	0.01	0.27	11	1.3
7/17/92	0.6	Eutrophic	0.04	0.33	7	0.7
6/2/92	-0.3	Mesotrophic	0.02	0.31	10	1.2
8/21/91	-1.3	Mesotrophic	0.04	0.21	5	1.6
7/23/91	-2.0	Oligotrophic	0.01	0.27	8	2.1
6/24/91	0.0	Mesotrophic	0.07	0.24	8	1.8
8/16/88	-2.1	Oligotrophic	0.02	0.24	5	2.3
7/14/81	-1.9	Mesotrophic	0.02	0.32	10	3.8

Source: NCDWQ Cape Fear River Basinwide Assessment Document, 1999.

## 2.2.5 Additional Scoping Level Assessment of Troublesome Creek Watershed

While assessment documents have referred to sediment from agricultural activities as a source of impairment in Troublesome Creek, field reconnaissance efforts and recent surveys of agricultural practices within the watershed have failed to confirm this source. Project team members have conducted reconnaissance surveys on three recent occasions within the LWP study area in the interest of locating pilot restoration sites, and they have consistently observed a prevalence of “no till” practices where row crops are employed. In addition, agricultural land use constitutes a relatively small portion of the watershed (35 percent) and that portion is confined to upland areas, with only minimal disturbance to floodplains and riparian buffers. However, it should be noted that past agricultural practices may have contributed significant amounts of sediment to the streambeds within the watershed.

### 2.2.5.1 Land Cover Distribution – Percent Disturbance of Forest Cover

To assess current land disturbance in the Troublesome Creek watershed, NLCD landuse data was used to calculate the percentage of natural and disturbed area in 18 subwatersheds (shown in Figure 26). The natural area includes open water, forest, and wetlands; all other landuse types are classified as disturbed.

Troublesome Creek is a relatively undeveloped watershed. Only three subwatersheds have less than 50 percent natural area remaining: T2, T6, and T10. Subwatersheds T1, T4, T5, T8, T9, T11, and T17 have 50 percent to 60 percent natural area remaining. Subwatersheds T3, T7, T12, T13, T15, T16, and T18 have 60 percent to 70 percent natural area remaining, and Subwatershed T14 has 83 percent natural area remaining. The disturbed land in the Troublesome Creek watershed is mostly agriculture. The fraction of disturbed land in agriculture ranges from 54 percent to 99 percent for all 18 subwatersheds.

Figure 6 shows the percentage of each subwatershed in a disturbed landuse. Subwatershed T14 has the least amount of disturbed land and falls within the range of 17 percent to 27 percent. Subwatersheds T3, T7, T13, T15, T16, and T18 have 28 percent to 38 percent disturbed land. Subwatersheds T1, T4, T5, T8, T9, T11, T12, and T17 have 39 percent to 49 percent disturbed land. Subwatersheds T6 and T10, 50 percent to 60 percent disturbed land. T2 has more than 60 percent disturbed land.

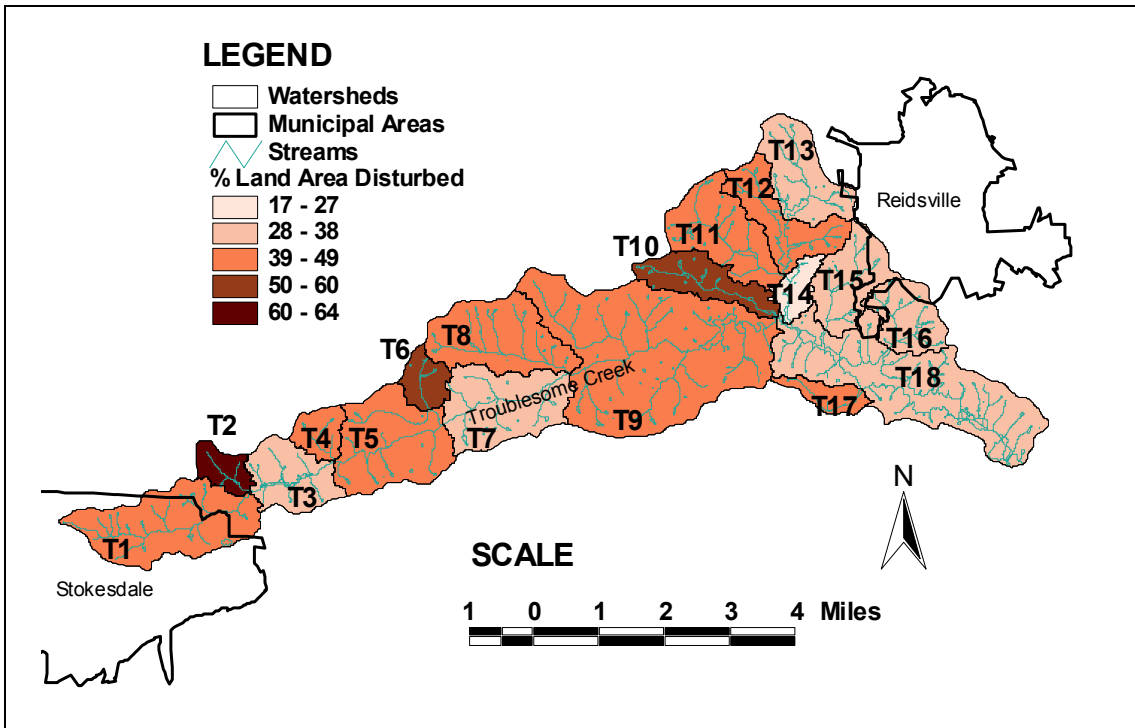


Figure 6. Percent of Land Area Disturbed in the Troublesome Creek Subwatersheds

### 2.2.5.2 Vegetative Status of Riparian Buffers

A preliminary GIS analysis of the vegetative status of buffer areas was performed by building a buffer polygon around all 1:24,000 stream reaches at a distance of 100 feet on each side of the stream. The ArcView Spatial Analyst extension was utilized to analyze the 1992 NLCD land cover composition within the defined buffer area. The level of resolution within the NLCD is 30 X 30 meter pixels, and each pixel is assigned a land cover category based on the cover type occupying the majority of the pixel. Given the coarse scale of this data, small disturbances of the forest cover occurring at the sub-pixel level are not always detectable.

Results of the buffer analysis for Troublesome Creek are presented Table 3. The analysis indicated that 90 percent of the buffer areas within 100 feet of 1:24,000 streams remain in a forested or wetland state within the Troublesome Creek watershed as a whole. Despite the small scale in which it is presented, visual observation of the NLCD land cover in Figure 4 shows substantial forest buffers on the majority of streams in the Troublesome Creek watershed.

The NLCD landuse data was also used to calculate the percent of land disturbed within 100-foot buffers of perennial and intermittent streams in each subwatershed. For purposes of this analysis, “disturbed” land is intended to mean those areas that have been converted from natural areas (forest/wetland) to other land uses (agricultural/residential/commercial) to a sufficient degree as to be detectable at the resolution of the NLCD. Figure 7 shows the degree of buffer disturbance in each subwatershed. Subwatersheds T14, T16, T7, and T9 have less than 6 percent of buffer area disturbed. Subwatersheds T4, T11, T15, T12, T18, T3, T13, T5, T10, and T17 have less than 15 percent of buffer area disturbed. Subwatersheds T18, T1, and T6 have between 16 percent and 22 percent buffer area disturbed. Subwatershed T2 has the highest disturbed buffer area at 49 percent; 63 percent of the T2 buffer disturbance is due to low-density residential development. Subwatershed T2 also has the highest total land area disturbed (64 percent).

**Table 3. Distribution of NLCD Land Cover Grid Cells within 100 Feet of 1:24,000 Streams in Troublesome Creek Watershed**

<b>Class Label</b>	<b>Percentages</b>
Low Intensity Residential	1.7
High Intensity Residential	0.0
Commercial/Industrial	0.3
<b>Developed Total</b>	<b>2.1</b>
Bare Rock/Sand/Clay	0.1
Quarries/Pits	0.0
Transitional	0.0
<b>Open Ground Total</b>	<b>0.1</b>
Deciduous Forest	56.3
Evergreen Forest	9.0
Mixed Forest	8.8
<b>Forested Total</b>	<b>74.1</b>
Pasture/Hay	1.8
Row Crops	6.5
Other (Managed) Grasses	0.0
<b>Agricultural Total</b>	<b>8.3</b>
Woody Wetlands	13.3
Emergent Herbaceous Wetlands	2.1
<b>Wetland Total</b>	<b>15.4</b>
<b>Grand Total</b>	<b>100.0</b>

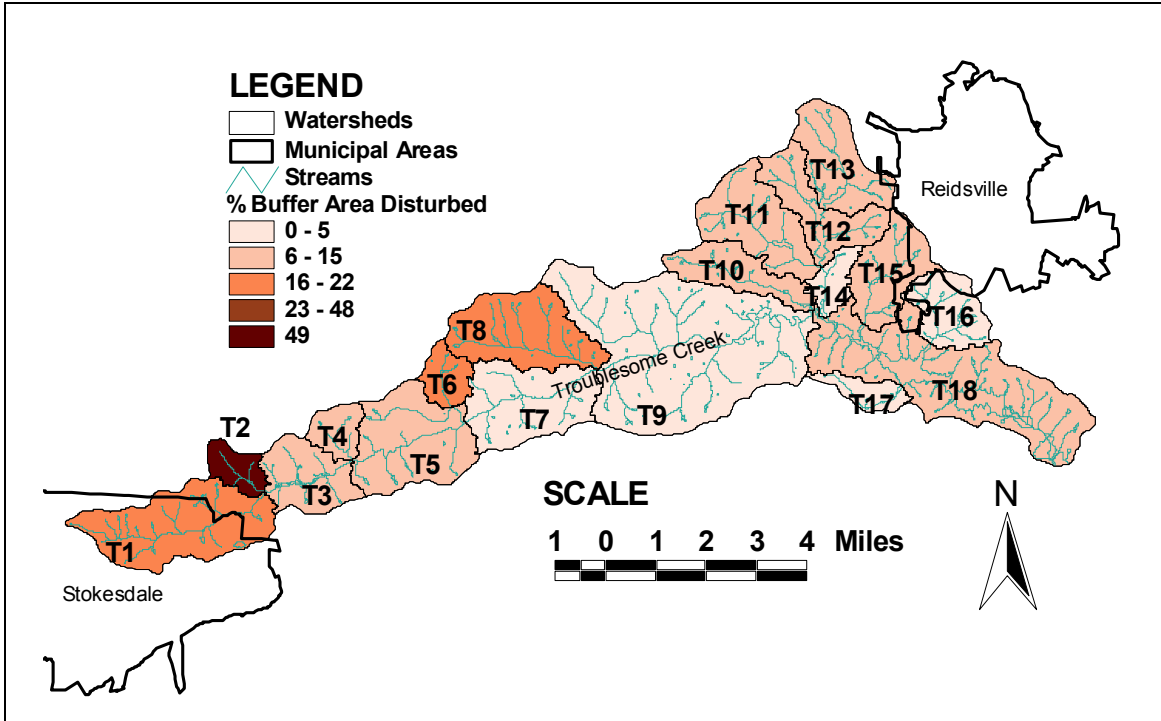


Figure 7. Percent of Buffer Area Disturbed in the Troublesome Creek Subwatersheds

### 2.2.5.3 Percent Imperviousness

Impervious surfaces in a watershed cause increases in runoff velocity, volume and power compared to natural, pervious surfaces. Changes in hydrology can diminish water quality and aquatic habitat by damaging stream banks and contributing to sediment loads. Under existing conditions, the Troublesome Creek watershed has a relatively low percentage of impervious cover. No subwatershed in this watershed has a percent impervious cover greater than 5.2 percent (Figure 8).

Subwatersheds T5 through T11, located in the central portion of the watershed, all have percent imperviousness less than or equal to 2 percent. Adjacent subwatersheds (T3, T4, T12, T14, and T17) have percent imperviousness ranging from 2.1 percent to 2.6 percent. Subwatersheds T1, T13, T16, and T18 have percent imperviousness ranging from 3 percent to 4 percent. Headwater subwatersheds T2 and T5 have the highest levels of imperviousness at 4.5 percent and 5.2 percent, respectively. Appendix B describes the methods used to estimate the percent of impervious cover for these subwatersheds.

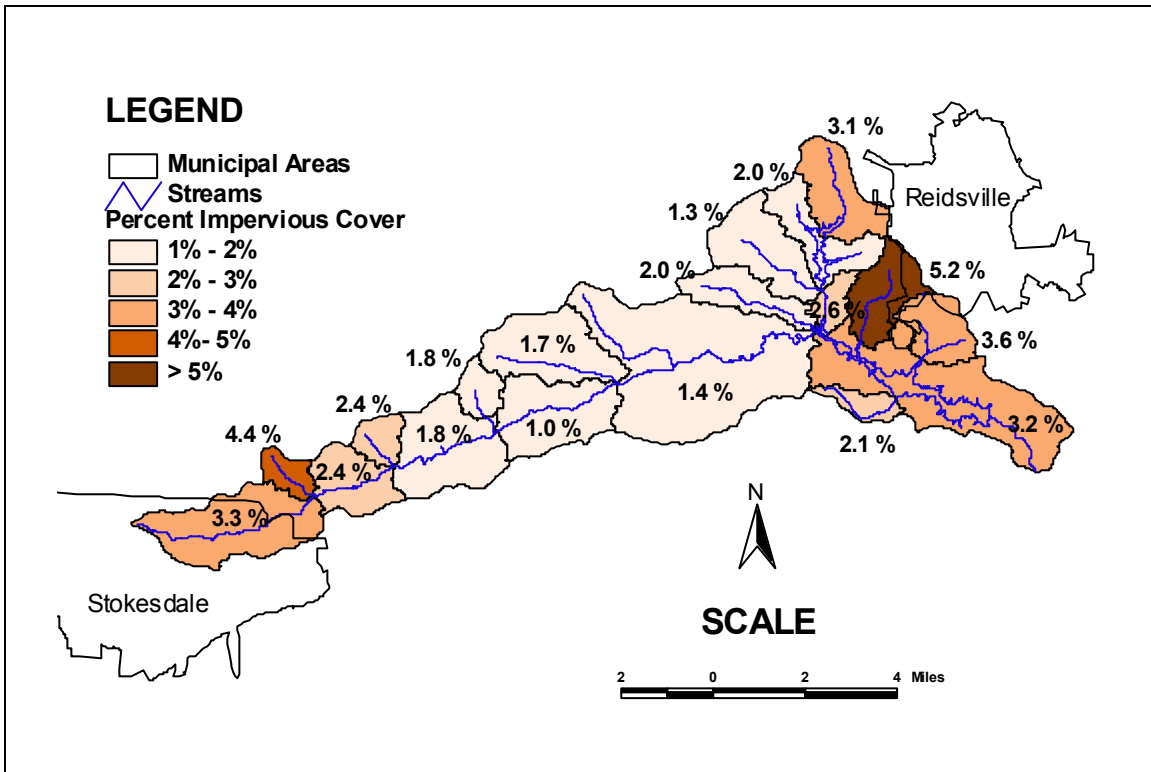


Figure 8. Percent Impervious Cover in the Troublesome Creek Watershed

### 2.2.5.4 Upland Sediment Delivery Potential

Upland sediment load refers to sediment that is washed from the land and delivered to stream channels. The delivery of upland sediment to streams is a function of soil erodibility, land use patterns, and topography.

A Soil and Water Assessment Tool (SWAT) model framework was developed for the Troublesome Creek watershed to examine these factors for each subwatershed and classify their relative potential for upland sediment delivery (Neitsch et al, 2000). The SWAT model was utilized to build a database that assigned area-weighted soil erodibility factors (USLE K factors), disturbed landuse percentages, and soil survey slopes for each subwatershed. The subwatersheds were then clustered into groups with similar disturbance levels, soil erodibility, and slopes. Each group was then assigned an erosion vulnerability classification ranging from low to high (Figure 9). Clustering was achieved by application of the *K Means Clustering* method contained within the software package, *Statistica* (StatSoft, 1995). Basically, subwatersheds with larger areas of disturbed land located on highly erodible and/or high slope soils were clustered into the group with high vulnerability to upland soil delivery. Subwatersheds with small areas of disturbed land with little or none of it located on highly erodible or high slope soils were clustered into the low vulnerability group.

Subwatersheds T14, T15, and T16 have relatively low upland sediment delivery potential. Subwatersheds T1, T3, T5, T7, T9, T11, T12, and T17 have medium upland sediment delivery potential. Subwatersheds T2, T4, T6, T8, T10, T13, and T18 have relatively high upland sediment delivery potential based on the combined effects of soil erodibility, land disturbance, and slope.

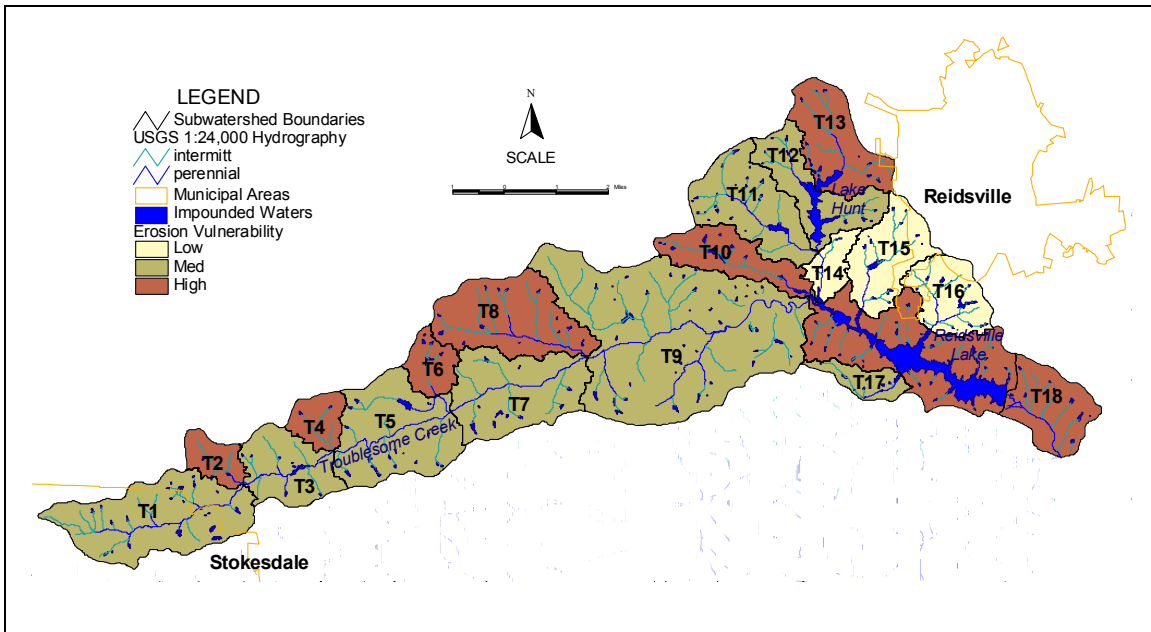


Figure 9. Upland Sediment Delivery Potential

## 2.3 CONCLUSIONS FROM PRELIMINARY CHARACTERIZATION OF TROUBLESOME CREEK

DWQ does not maintain an ambient water quality monitoring station on Troublesome Creek, and at the time the creek’s impaired status was determined, no ready source of instream physical or chemical data was available. For this reason, it could be concluded that the impaired designation was reached solely based on the biological monitoring data and supporting information presented in the Basinwide Assessment documents. If this is the case, then the presence of Troublesome Creek on North Carolina’s 303(d) list is a result of two biological monitoring instances at each of two locations. Given that the benthos in Troublesome Creek were rated “good-fair” and the fish community was rated “poor,” it is likely that the fish data were given more weight in the conclusion of impairment. Narratives in the 1995 Basinwide Assessment state, “The fish community may be more effective than the macroinvertebrate community in reflecting changes in habitat quality, indicating habitat degradation (sedimentation) in Troublesome Creek” (DENHR, 1995). However, the information presented appears to be somewhat anecdotal in nature, with no basis for the designation of sediment as the source of impairment other than the species assemblage at the particular monitoring site.

Based on the reports and reconnaissance information available, there is no conclusive evidence to suggest that agricultural sediment is currently a problem in this watershed, particularly given the small portion of land area actively used for agriculture. However, it is possible that historical sediment deposition from past agricultural activities has adversely impacted streams, or that the sediment is naturally occurring as a result of the erosive properties of the soils in the Milton Belt. Comparison with field data from undisturbed streams in this belt would offer some insight as to whether the stream is in equilibrium with its sediment load or whether human sources have caused additional sedimentation. Additional biological monitoring would help determine if the stream is actually impaired or if the “poor” fish community rating was due to localized conditions

at one point along the stream. It is recommended that NCWRP, WARP, and NCDWQ work together, with input from the LWP project team, to implement a combination biological and water quality monitoring effort to evaluate the validity of Troublesome Creek's 303(d) listed status. Monitoring data from Troublesome Creek could be compared to data from a reference stream in a relatively undisturbed watershed in the Milton Belt, provided that an appropriate reference stream could be located.

In addition to biological and water quality monitoring, the LWP process for Troublesome Creek should include assessments of morphology within stream segments throughout the watershed. Assessments of physical features, such as riffle-pool-run sequences and their distribution, would shed light on the possibility that historical sediment deposition has resulted in degraded habitat conditions within the Troublesome Creek system. Rosgen Level 1 analysis or NRCS Visual Stream Assessment Protocols may be effective for performing assessments of this nature.

A catalogue of available data for the Troublesome Creek watershed is presented in Appendix C.

### **2.3.1 Primary Threats to Water Quality, Hydrology and Aquatic Habitat**

LWP project team members from Tetra Tech and S&EC have conducted three separate field reconnaissance trips within the Troublesome Creek watershed for the purpose of locating eroded and unstable stream reaches that may be utilized as pilot restoration projects. At least seven individual stream reaches within Troublesome Creek and its perennial tributaries have been evaluated on a cursory level. Detailed survey work has not been initiated on any of the reaches because team members have consistently found stream segments that appeared entirely stable in nature with no visible signs of stream bank erosion and broad floodplain areas with no recent indications of disturbance. Not only have broad areas of the floodplains been found to be consistently vegetated, but at most sites, that vegetation consists of mature hardwood forest. GIS analysis of buffer vegetation and detailed evaluation of aerial photography in select portions of the LWP study area have re-enforced the impressions gained from early field reconnaissance. For these reasons, there is some concern that the limited fish community data that appears to form the basis for Troublesome Creek's impaired status may not accurately reflect the overall condition of the system as a whole.

In terms of restoration potential, given the condition of observed streams and the undisturbed nature of its floodplains, it is highly unlikely that significant areas suitable for stream or wetland restoration will be found in the Troublesome Creek watershed. It is recommended that NCWRP consider expanding the search area in order to meet future mitigation needs in the Upper Cape Fear River Basin. [Note: A second LWP project in the upper Cape Fear region (C.U. 03030002) was initiated in the Chapel Hill-Durham area in the summer of 2002.]

Given the highly erodible nature of Milton Belt soils, the floodplain buffer areas are of the utmost importance in maintaining water quality in Troublesome Creek. This importance is elevated further by the potential for new development within the watershed resulting from continued growth of the Greensboro-Triad metropolitan area. Local Watershed Planning efforts within the Troublesome Creek watershed should be focused on integrated efforts to protect stream buffers and preserve bottomland areas with high ecological value and high vulnerability to disturbance. The LWP process should also be focused on developing management recommendations aimed at controlling the adverse impacts of new development. The future potential for higher levels of nutrient loading to Reidsville Lake and the potential for stream bank erosion as a result of altered hydrology caused by increased impervious surface within the watershed are of particular concern.

## 2.3.2 Overall Goals for Detailed Assessment – Troublesome Creek

The riparian corridors within the Troublesome Creek watershed remain almost entirely undisturbed, and a substantial portion of the watershed is forested. The agricultural land uses within the watershed are mostly confined to upland areas and available information indicates that substantial erosion control practices are in place on those agricultural lands. However, as noted in Section 2.2.2, some agricultural sediment BMPs are approaching their life expectancy and will require maintenance to remain effective in the future. Beyond that need, collectively, existing conditions within the watershed present few current threats to water quality and/or aquatic habitat. As previously discussed, the primary threats to water quality and aquatic habitat within the Troublesome Creek watershed are associated with the continued growth and expansion of the Triad Metropolitan Region. Specifically, northward expansion of Greensboro is likely to continue spurring residential and commercial development within the watershed over the next 20 years and beyond.

The next stage of the local watershed planning process involves filling information gaps and performing detailed assessments to fully identify management opportunities for these primary issues of concern. Given the current watershed conditions and the anticipated impacts from new development, three principle phases are necessary for the detailed assessment portion of the Troublesome Creek Local Watershed Plan. The first phase will involve performing the necessary data collection and assessments to fully establish current baseline conditions within the watershed. One of the primary assessment goals within this first phase will be to identify subwatershed areas or stream segments where degradation of water quality and/or aquatic habitat has already occurred.

The second phase will involve building a detailed assessment framework to evaluate future conditions within the watershed and their potential impacts on water quality and aquatic habitat. This will involve the development of predictive modeling tools and monitoring to collect the data necessary to support those tools. This phase will also require the formulation, with stakeholder input, of a reasonable approximation of where and to what extent development will occur within the watershed over the next 20 years. An important portion of the predictive phase will be to perform an evaluation of the necessity for development controls or other management measures to prevent that growth from causing water quality and habitat degradation.

Some overlap of assessment objectives may occur between these first two phases of the detailed assessment. Some of the specific assessment objectives aimed at completing a detailed picture of current conditions may also identify subwatershed areas or stream segments that are more vulnerable to future degradation than others. When combined, the first two phases of the detailed assessment will generate the characterization elements and predictive results to meet the following intended goals of the LWP process:

- 1) Target and prioritize specific subwatershed areas where growth is expected and vulnerability to degradation has been identified for preservation efforts.
- 2) Target and prioritize specific subwatershed areas where growth is expected and vulnerability has been identified for BMP application, development controls, or other management efforts to prevent future degradation.
- 3) Identify currently eroded and unstable stream segments where restoration opportunities exist.

The third phase of the detailed assessment will involve the reconnaissance and field survey work to produce a thorough characterization of the potential restoration sites identified in the first two phases. This characterization will produce the assessment information necessary to prioritize

those restoration opportunities. The assessment methods and data collection plans for the third phase are not discussed in detail in this report because they will be established and refined during the first two phases of the detailed assessment.

In the following sections of this report, the detailed assessment phases outlined here are broken down into specific assessment objectives. The objectives are grouped according to whether they address both Troublesome and Little Troublesome Creek watersheds, or one of the two in particular.

## 3 Preliminary Watershed Characterization of Little Troublesome Creek

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The preliminary characterization of Little Troublesome Creek follows the same outline as that for Troublesome Creek, beginning with a description of primary physical features followed by a functional assessment and conclusions regarding primary threats and needs for additional assessment.

### 3.1 PHYSICAL FEATURES

#### 3.1.1 Hydrology and Subwatershed Delineation

The Little Troublesome Creek watershed, shown in Figure 10, is 12.7 square miles in size with headwaters originating on the west side of the City of Reidsville in southeastern Rockingham County. The watershed trends south-southeast toward Guilford County, but the creek empties into the Haw River just north of the county line, southeast of Reidsville. Little Troublesome Creek proper is roughly 8 miles in length from its source to the Haw River. The entire watershed contains approximately 28 linear stream miles, with 11 miles classified as perennial streams and 17 miles classified as intermittent, according to attributes contained in the USGS 1:24,000-scale digit line graph hydrography database. There are no impoundments greater than 10 acres in surface area within the Little Troublesome Creek watershed.

For purposes of this Local Watershed Planning process, the Little Troublesome Creek watershed was delineated into nine separate subwatersheds, which will be utilized to rank and prioritize portions of the LWP study area for restoration, preservation, and stormwater management efforts. The subwatersheds will also be used to target management measures to address sources of pollution. The delineated subwatersheds are shown in Figure 11, and range in size from 0.6 square miles (LT2) to 3.3 square miles (LT7). The first objective of the delineation was to reflect subwatersheds with distinct land use distribution and soil characteristics. The second objective was to provide a greater level of detail within the headwater portions of the watershed where urbanization is expected to have caused greater degradation of habitat and water quality. Detailed subwatershed maps are presented in Appendix A (Maps 6 and 7).

#### 3.1.2 Geology and Soils

The Troublesome Creek watershed lies predominantly within the Milton Belt, with some occurrences of Carolina Slate Belt geology and volcanic intrusions of granite rock. Milton Belt geology is characterized by sandy, erodible soils formed in material weathered from acid, igneous, and metamorphic rock. The primary soil groups within the Little Troublesome Creek watershed are identical to those within the Troublesome Creek watershed. Upland soils in the watershed are predominantly comprised of the Cecil-Pacolet-Appling grouping which are gently sloping to steep, deep, well drained, and moderately to highly erodible. Floodplain alluvial soils are entirely comprised of the Chewacla-Congaree-Wehadkee grouping, which are nearly level, deep, well drained to poorly drained depending on topography, and are highly erodible (USDA-SCS, 1992). Along perennial stream courses, alluvial soils are almost entirely comprised of Group A (highly permeable) and Group B (moderately permeable) hydric soils, and they are divided about evenly between those two hydric groups. As a result of the permeability of the alluvial soils, many of the immediate floodplain areas along Little Troublesome Creek remain

saturated for extensive periods forming riparian wetlands. However, in some sections, riparian wetland functions have been compromised or lost due to down-cutting of stream beds and lowered water tables. Due to the instances of slate belt geography and volcanic intrusions, a few streambed segments within the watershed are characterized by rocky substrates. Figure 12 shows a map of soils by K factor, which indicates the susceptibility to erosion by water, within the Little Troublesome Creek watershed. Preliminary GIS analysis of soils indicates that 70 percent of the soils within the watershed have K factors of 0.28 or greater, indicating high susceptibility to erosion.

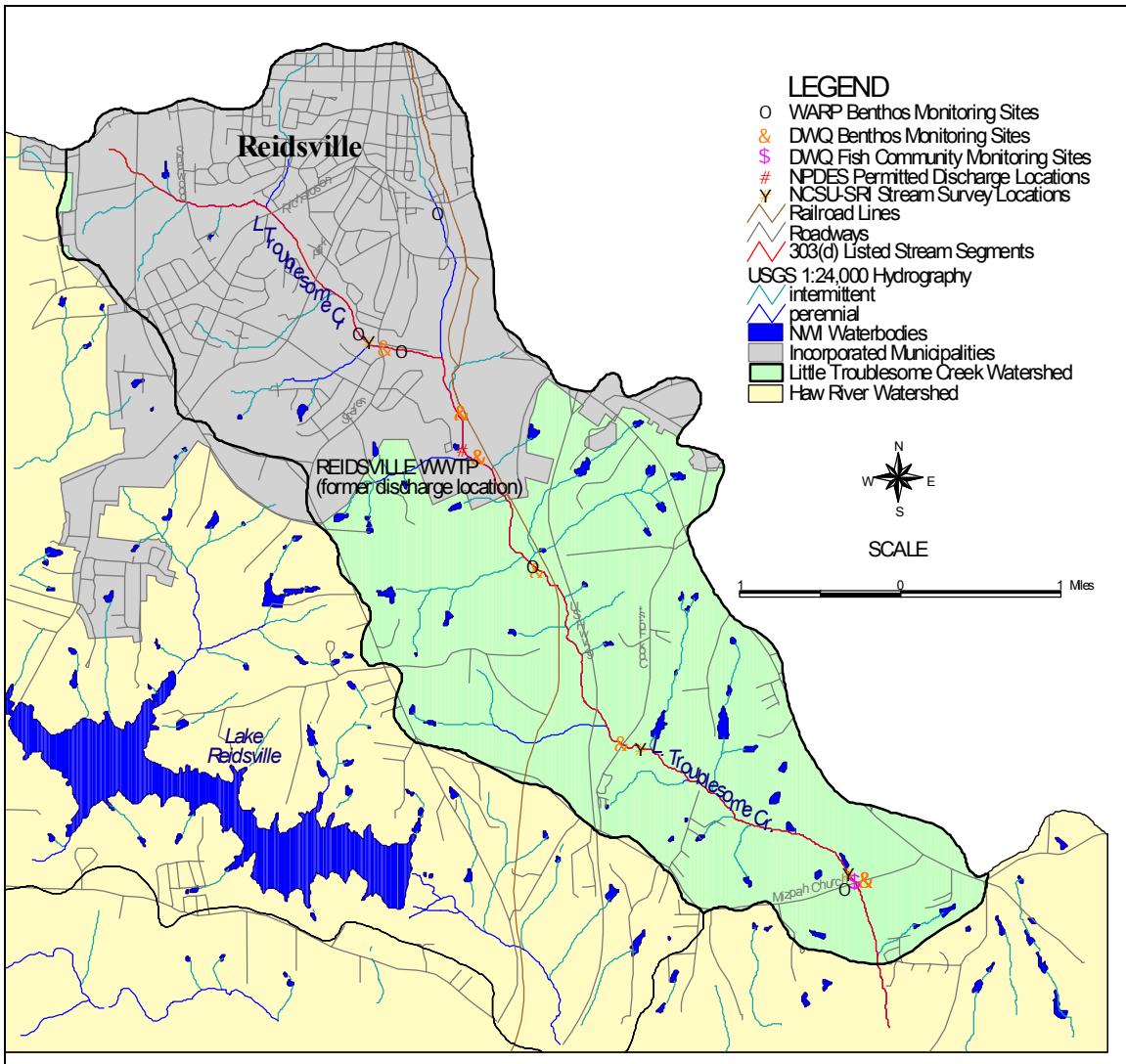


Figure 10. Little Troublesome Creek Watershed

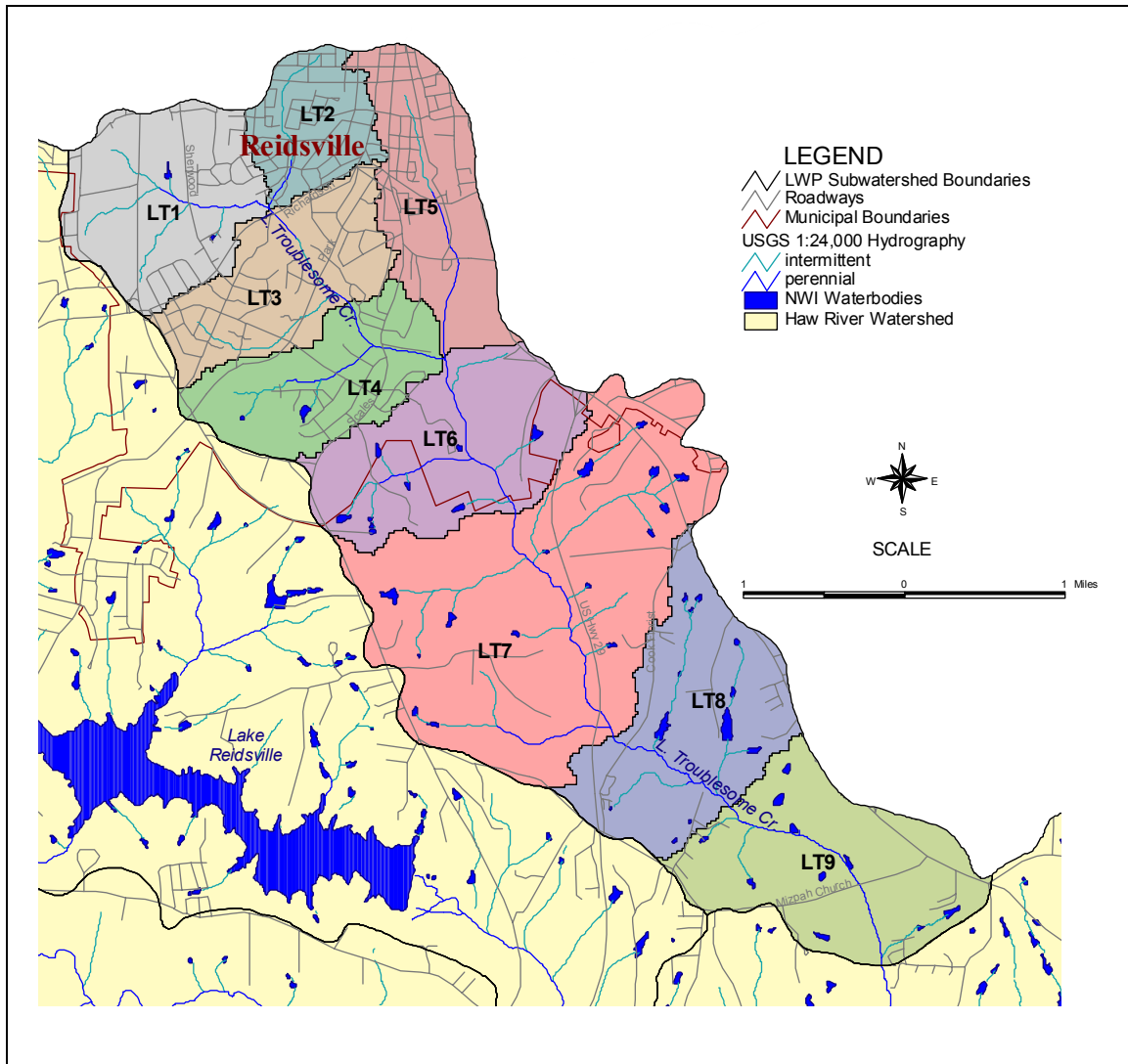


Figure 11. Little Troublesome Creek Subwatershed Delineation

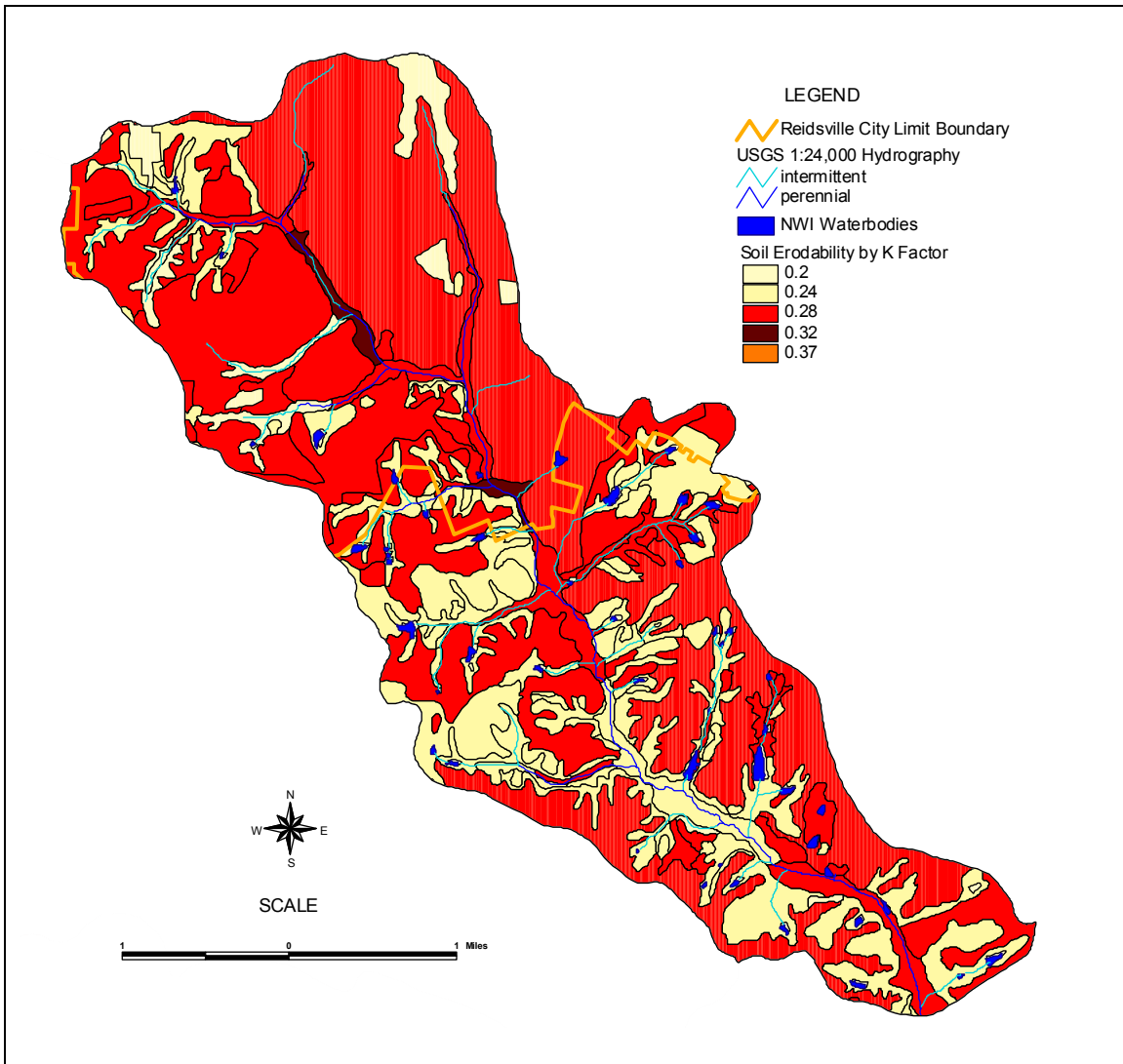


Figure 12. Soils within Little Troublesome Creek Mapped by K Factor

### 3.1.3 Land Use and Land Cover

The Little Troublesome Creek watershed is contained entirely within Rockingham County, and approximately six square miles, or just under half of the total watershed area, are within the city limits of the City of Reidsville. The northern half of the watershed is heavily urbanized because water and sewer services are available. Preliminary GIS analysis has indicated that, within Reidsville city limits, overall impervious cover is approximately 21 percent of the watershed area. The lower half of the Little Troublesome Creek watershed consists primarily of agricultural and forested land uses.

Preliminary GIS analysis of the circa 1992 National Land Cover Database (NLCD) from USGS and USEPA indicates that 49 percent of the total watershed area remains as forest and wetland, 21 percent is used for agriculture, and 30 percent is developed or disturbed. Within the agricultural portion, 69 percent is defined as row crop and 31 percent is pasture. NLCD landuse/land cover for Troublesome and Little Troublesome Creeks is depicted in Figure 4. Aggregated landuse data are presented for each sub-basin in the Little Troublesome Creek watershed in Table 4. Detailed maps of landuse by subwatershed are presented in Appendix A (Maps 13 and 14). It should be noted that the NLCD is the most recent landuse data available for the upper Piedmont region of North Carolina.

**Table 4. Landuse Summary for the Little Troublesome Creek Sub-basins (ac)**

Sub-basin	Area (ac)	Area (sq mi)	Forest	Residential	Commercial/Industrial	Agriculture	Wetlands	Other
LT1	786.83	1.23	46.27%	22.87%	7.29%	20.55%	0.14%	2.88%
LT2	374.96	0.59	28.71%	57.24%	12.93%	0.24%	0.00%	0.89%
LT3	671.85	1.05	28.24%	56.87%	7.81%	4.57%	0.00%	2.52%
LT4	629.82	0.98	42.83%	37.11%	10.77%	7.45%	0.18%	1.66%
LT5	683.64	1.07	27.42%	35.13%	27.88%	6.12%	0.46%	2.99%
LT6	907.59	1.42	59.62%	8.21%	8.65%	20.31%	0.25%	2.96%
LT7	2100.52	3.28	63.63%	4.94%	6.09%	21.57%	1.76%	2.01%
LT8	950.74	1.49	46.81%	7.86%	3.53%	33.43%	3.70%	4.68%
LT9	991.66	1.55	42.81%	8.39%	1.44%	43.28%	1.93%	2.15%

## 3.2 FUNCTIONAL ASSESSMENT

The primary watershed functions addressed in this study are water quality, hydrology, and habitat. The following subsections summarize the basis for assessment of those watershed functions, and the preliminary findings based on previous studies and additional scoping level assessment performed by Tetra Tech, Inc. The Detailed Assessment Report, scheduled for completion in early 2003, will include a more detailed evaluation of intended functional indicators for selected high-priority subwatersheds and study sites.

### 3.2.1 Stream Classifications/Use Support Ratings

Rules contained in Section 15A NCAC 02B.0200 of the North Carolina Administrative code describe a classification system by which NCDWQ is to assign use classifications to waterbodies across the state. These use classifications stipulate the specific best uses for each waterbody and determine the standards to which water quality is to be protected in order to maintain those uses. For more info on the NCDWQ's use support classifications for surface waters (and associated water quality standards) go to <http://h2o.enr.state.nc.us/admin/rules/>.

From its source to the Haw River, Little Troublesome Creek is classified C NSW. The best uses assigned to Class C waters are "aquatic life propagation and maintenance of biological integrity (including fishing and fish), wildlife, secondary recreation, agriculture, and any other usage except for primary recreation or as a source of water supply for drinking, culinary, or food processing purposes." Just as with Troublesome Creek, the supplemental NSW classification is assigned by virtue of the fact that Little Troublesome Creek is located within the Jordan Lake watershed. The Nutrient Sensitive Waters (NSW) rules for Jordan Lake outline a regulatory strategy to reduce phosphorus loads to the reservoir in order to prevent excess eutrophication. Primarily, the rules establish stringent limits on the concentrations of phosphorus that may be contained in wastewater discharges within the Jordan Lake watershed.

Section 305(b) of the Clean Water Act requires that states periodically evaluate each waterbody, and based on available data, determine whether water quality within the waterbody is adequate to support its designated uses. Per the 305(b) requirement, NCDWQ evaluates waterbodies across the state every two years and assigns use support ratings to each indicating whether they are "Fully Supporting," "Partially Supporting," or "Not Supporting" their designated uses. Section 303(d) of the Clean Water Act requires that states place waters that are rated "Not Supporting" or "Partially Supporting" on a list of Impaired Waters, referred to as the 303(d) List. Section 303(d) also requires that a Total Maximum Daily Load (TMDL) be determined for any waterbody that is impaired by a specific identifiable pollutant or pollutants. The intent of the TMDL is to identify sources for the specific pollutant(s) and reduce the pollutant loads from those sources to the extent necessary to improve water quality to a level that will restore the uses deemed impaired.

From its source to the former discharge location of the Reidsville WWTP, Little Troublesome Creek has been assigned a water quality use support rating of "Partially Supporting," and from the former WWTP discharge location down to the Haw River, it has been assigned a rating of "Not Supporting." For this reason, the entire length of Little Troublesome Creek has been listed on North Carolina's 1998 and 2000 303(d) Lists of Impaired Waters (refer to Figure 10). The 2000 List attributes the impairment to sediment in both segments, and additionally to fecal coliform in the lower segment, citing urban runoff and storm sewers as sources for both pollutants. As per 303(d) requirements, the NCDWQ has developed TMDL for fecal coliform in Little Troublesome Creek. The 2000 305(b) Report and 303(d) List are available for download from NCDWQ at <http://h2o.enr.state.nc.us/wqs/>.

The Draft 2002 Integrated 305(b) and 303(d) Report has recently become available from NCDWQ for public review comment. The draft list places the lower segment of Little Troublesome Creek, from the Reidsville WWTP to the Haw River, in Category 4a, waters for which a TMDL has been approved by EPA, but that are not yet meeting standards. However, the 2002 draft still lists entirety of Little Troublesome under Category 6, biologically impaired waters. The document notes that the Creek has been historically listed for sediment based on documented biological impairment, but that additional monitoring is needed to determine the best strategy to address the impairment. The 2002 draft is not yet posted on the NCDWQ website.

The following sections of this document present an assessment of water quality and aquatic habitat conditions within Little Troublesome Creek, including the data and information used to

arrive at the impaired designation of the Creek. The following sections will also summarize the fecal coliform TMDL document prepared by NCDWQ, as well address other factors resulting in water quality and habitat degradation of Little Troublesome Creek.

### **3.2.2 Historical Impact of Reidsville Wastewater Treatment Plant**

Until November 1998, the Reidsville wastewater treatment plant (WWTP) discharged to Little Troublesome Creek at a location approximately 1 mile downstream of the Scales Street crossing (location shown on Figure 10). According to NPDES permit records, the WWTP was permitted to discharge up to 5.0 MGD of wastewater, and during 7Q10 drought flow conditions the wastewater flow constituted over 90 percent of the flow in Little Troublesome Creek. As a result of the high instream waste concentration, the facility was required to meet advanced tertiary treatment limits for oxygen demanding pollutants and very stringent limits for whole effluent toxicity testing. Due to a significant portion of the facility's influent originating from heavy industrial sources, the WWTP experienced consistent problems complying with the effluent toxicity limits.

In November 1998, the outfall was relocated to the Haw River mainstem downstream of the confluence with Little Troublesome Creek, which is located outside of this study area. For several years prior to the relocation, the WWTP operated under a Special Order of Consent that waived the NPDES permit limit for effluent toxicity while requiring ongoing toxicity monitoring. Narratives from NCDENR's 1999 Basinwide Assessment document state that biological monitoring performed on multiple occasions prior to outfall relocation indicated that the benthic community showed clear signs of stress from instream toxicity attributed to the discharge (NCDENR, 1999). Monitoring data are discussed in detail in subsequent sections of this memorandum.

### **3.2.3 Biological Monitoring Information – Basinwide Assessment Document & WARP Data**

#### **3.2.3.1 NCDWQ Biological Monitoring Data**

Since 1987, NCDWQ has conducted benthic macroinvertebrate monitoring at several sites on Little Troublesome Creek, which are shown in Figure 10. Sites immediately upstream and downstream of the former Reidsville WWTP outfall were sampled for benthic macroinvertebrates during special studies in 1987, 1992, and 1994. Both stations received "fair" bioclassification ratings on all three occasions, but narratives indicate that changes in the community structure from upstream to downstream clearly indicate an adverse impact on instream fauna by the discharge (DENHR, 1995). For basinwide assessment, the furthest downstream site at SR 2600 was sampled in 1993, 1998, and 2000. "Poor" bioclassifications were assigned at this location in 1993 and 1998, and it is noted that the species assemblage consistently indicated impacts from organic enrichment, low dissolved oxygen, and instream toxicity. As a result of WWTP discharge being removed, the rating at SR 2600 improved to "fair" in 2000. Despite the improvement, it should be noted that "fair" ratings recently at SR 2600, and immediately above the WWTP dating back to 1987, indicate that the stream has been stressed by sources within the watershed over and above the impact of the discharge.

NCDWQ has also performed fish community sampling at the SR 2600 site on two occasions in spring and fall of 1998. On both occasions, the sampling resulted in "poor" bioclassifications at that site.

### 3.2.3.2 Watershed Assessment and Restoration Project Biological Monitoring Data

As part of their intensive study of Little Troublesome Creek, the North Carolina Division of Water Quality's Watershed Assessment and Restoration Project (WARP) conducted benthic macroinvertebrate sampling on one to three occasions, at each of five sites, during 2000 and 2001 (refer to Figure 10). The WARP data indicate that a variety of urban and agricultural nonpoint sources impact Little Troublesome Creek for its entire length. Beaver activity, unstable sand, low velocity, and low instream dissolved oxygen affect macroinvertebrate habitat in various portions of the Creek. Upstream stations were not assigned bioclassifications due to their smaller size, but the downstream sites that could be rated consistently received "fair" ratings.

One upper watershed station located at a city park near Scales Street contains a small area of rocky substrate atypical of Little Troublesome Creek. Despite relatively high habitat scores at this site, biotic indices remained similar to those from other sampling stations in the watershed, suggesting water quality and/or sediment transport have a greater effect on the aquatic fauna than habitat availability. The benthic sampling conducted by WARP shows that since removal of the Reidsville WWTP discharge, ratings have improved (from "poor" to "fair"), indicating that removal of the discharge was a positive step for the water quality in Little Troublesome Creek.

The unpublished memo communicating the WARP benthic sampling results states, "based on WARP benthic sampling conducted in 2000 and 2001, it is appropriate to consider Little Troublesome Creek as impaired for its entire length. All of the sites sampled were characteristic of an impacted stream." The memo also concludes, "There are a few scattered less tolerant species, but the dominant taxa throughout the system are tolerant to a variety of stressors including organic enrichment, low dissolved oxygen, and toxicity."

### 3.2.4 Water Quality Data – NCDWQ Ambient Data and WARP

NCDWQ has maintained a water quality monitoring station near the bottom of the Little Troublesome Creek watershed, at SR 2600, as part of its ambient monitoring system from 1968 to the present. Historical ambient data show elevated conductivity, ammonia, total nitrogen, and total phosphorus levels at SR 2600 during the time that the Reidsville WWTP discharged into Little Troublesome Creek. However, levels have declined after the relocation of the discharge (Tyndall, 2002). Figure 13 and Figure 14 are time series graphs with 12-month moving averages for conductivity and total phosphorus, respectively, from 1992 to 2001 at SR 2600. Note the sharp decline in reported values, and particularly in moving averages, for both parameters that occurs in the fall of 1998, when the discharge was removed.

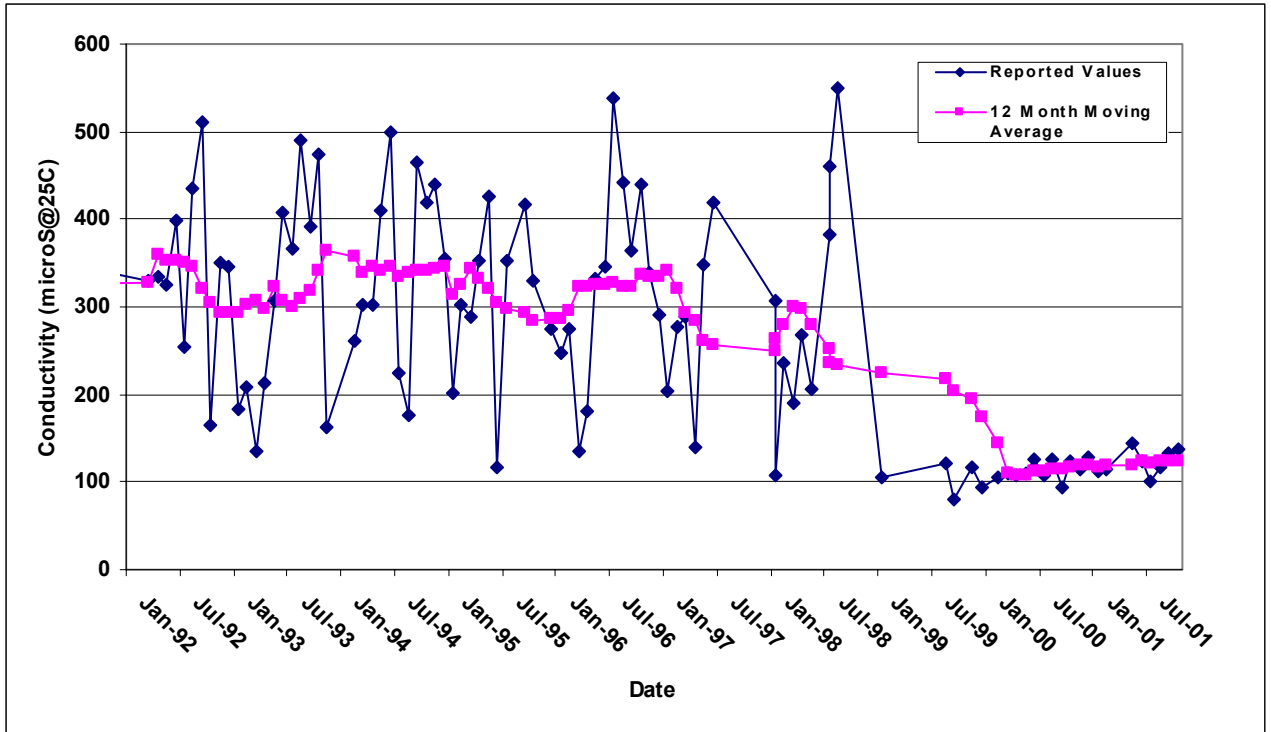


Figure 13. Conductivity in Little Troublesome Creek at SR 2600

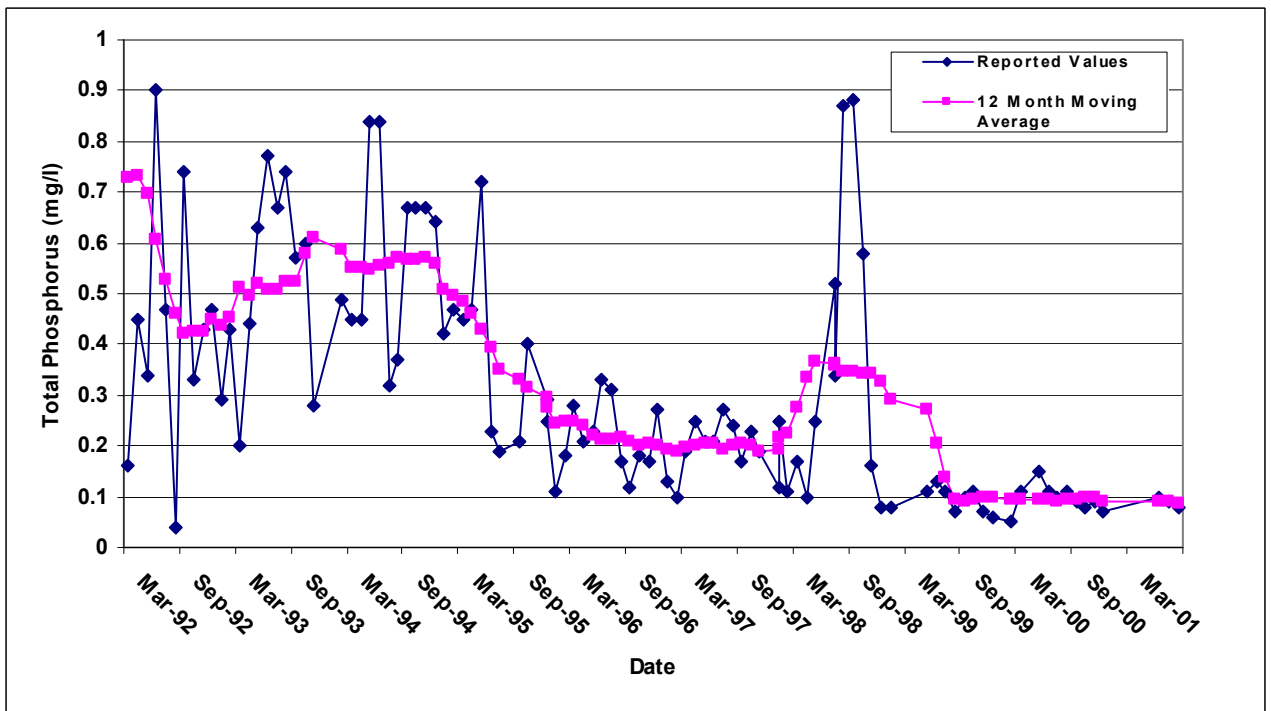


Figure 14. Total Phosphorus in Little Troublesome Creek at SR 2600

### 3.2.5 Summary of the NCSRI's Morphological Evaluation and Restoration Feasibility Assessment for Little Troublesome Creek

In order to assess the morphological condition and restoration potential of Little Troublesome Creek, the North Carolina Stream Restoration Institute (NCSRI) at North Carolina State University has conducted field studies at three potential restoration sites along the creek. The upstream site is located in Reidsville above Scales Street, the downstream site is located below Mizpah Church Road (SR 2600), and a midstream site is located below Cook Florist Road (SR 2598). All three sites showed signs of stream bank erosion, channel incision, poor stream bank vegetation, and impaired aquatic habitat. However, the morphological condition varied from site to site. The locations of the three survey sites are shown on Figure 10.

#### 3.2.5.1 Upstream Segment

The study site upstream of Scales Street is approximately 2,600 feet in length and has a drainage area of approximately 3.0 square miles (NCSRI, 2001a). Due to its location in the City of Reidsville, the majority of the landuse in this watershed is urban and suburban, and sewer lines run parallel along the right side of the channel. The percent imperviousness of the drainage area was estimated to be greater than 30 percent, although a detailed tabulation was not made at the time of the morphological survey.

This channel is classified as a Rosgen Type F5 (Rosgen, 1996): single thread channel, entrenched, moderate to high width-to-depth ratio, moderate sinuosity, slope less than 2 percent, and sandy bed material. The stream banks of this channel are eroding and point bars and mid-channel bars are present in the channel. Causes of instability are urban development, beaver activity, channelization, and loss of riparian vegetation. Stream bank erosion appears to be the major contributor to the sediment load in this reach.

Simple stabilization of the channel in its current state would only result in a short-term solution. More than likely, this stream will require construction of a Rosgen Type Bc channel (moderate sinuosity and a step pool) at the existing elevation. Reconnecting the channel with its original floodplain is not an option for this site because of the parallel sewer lines, adjacent residences, and steep hill slopes. These constraints also prohibit construction of a Type C (riffle/pool system with well-developed floodplain, meanders, and point bars) or Type E (slightly entrenched with low width/depth ratios, and moderate to high sinuosities – very typical of stable, natural conditions in NC Piedmont ecoregion) stream at current elevation due to their high sinuosity. Thus, the Type Bc stream will best fit the constraints of this system. Preliminary cost estimates provided by NCSRI are \$70 to \$105 per linear foot of stream.

#### 3.2.5.2 Midstream Segment

The midstream site is located below Cooks Florist Road and is approximately 2,000 feet in length (NCSRI, 2002). Land draining to this segment is primarily forest and pastureland with the exception of the urban development in the Reidsville area.

The upper 1,760 feet of this segment is a multi-thread, Rosgen Type D channel that extends to a head cut downstream. Two main channels extend from the head cut for approximately 350 feet where they join in a section of the channel that is relatively wide with severe stream bank erosion. This widened channel extends approximately 40 feet and then transitions to a more typical, single thread channel.

Downstream of the braided channel at a riffle, the stream was classified as a Rosgen Type E6: single thread channel, slightly entrenched, low width-to-depth ratio, high sinuosity, slope less than 2 percent, and silt/clay bed material. Stream bank erosion and channel incision are evident. Causes of instability may be the past removal of an old mill dam (unconfirmed), beaver activity, land clearing, recent logging activity, urbanization, and loss of riparian vegetation. Further study upstream and downstream of this segment will be required before restoration options are evident.

### 3.2.5.3 Downstream Segment

The downstream site above Mizpah Church Road is a 2,000-foot segment with a drainage area of 12 square miles (NCSRI, 2001b). Land draining to this site is primarily forest and pastureland with some urban/suburban development in the headwaters at Reidsville. The percent impervious area is estimated to be 10 percent.

This channel is classified as a Rosgen Type E5: single thread channel, slightly entrenched, low width to depth ratio, high sinuosity, slope less than 2 percent, and sandy bed material. A type E channel is typically stable, but this channel is not. As with the upstream site, the banks of this channel are eroding, and mid-channel bars are developing. In addition, cattle access is contributing to mass wasting of the stream banks. This previously incised channel is eroding its stream banks in an attempt to reestablish its floodplain and sinuosity at the lower elevation. As a result of the bank erosion, the channel is filling in. Instability of this segment may be due to channelization, land clearing, upstream degradation, beaver activity, and loss of riparian vegetation. The majority of the sediment load may be associated with stream bank erosion.

This section of the stream could be restored in one of three ways: connecting the stream to its original floodplain, constructing a meandering channel at current elevation, or constructing a step-pool channel at current elevation. The first two options involve construction of a type E stream, which is consistent with the channel's natural design. Cost of restoration is estimated by NCSRI to range from \$70 to \$110 per linear foot of stream.

### 3.2.5.4 Conclusions from Morphological Assessments

The three potential restoration sites along Little Troublesome Creek will all require restoration techniques that go beyond simple stabilization at the current state. In the upstream segment, construction of a step-pool channel at existing elevation is feasible. In the downstream segment, a meandering channel may either be constructed at the current elevation or reconnected with the original floodplain. The midstream segment will require further study to properly assess restoration options.

## 3.2.6 Summary of TMDL for Fecal Coliform and Implementation Proposal

The lower five miles of Little Troublesome Creek are impaired by fecal coliform and do not meet the water quality standards for a stream with a designated use of "secondary recreation." The discharge point of the City of Reidsville WWTP was moved from Little Troublesome Creek to the Haw River in 1998. There are currently no point source discharges to the creek, so all fecal coliform contamination originates from nonpoint sources.

The water quality target for fecal coliform is a geometric mean of 200 cfu's/100 mL over a 30 day period (cfu = colony forming unit, also considered a count). According to the TMDL for fecal coliform (NCDENR, 2002), the current geometric mean is 280 counts/100 mL. Given a margin of safety of 15 percent, the final target is 170 counts/100 mL.

In order to achieve this target, a 40 percent reduction in fecal coliform loading is required. The TMDL divides the nonpoint source loads of fecal coliform for the Little Troublesome Creek watershed into three main categories and lists their predicted, existing loads as a count per 30-day period. Runoff from all lands has a predicted load of 12 trillion counts per 30-day period and includes contributions from livestock, wildlife, urban development, sanitary sewer overflows and leaks, and pet waste. Leaking septic systems are predicted to contribute 25.7 billion counts/30d. Miscellaneous sources have a predicted load of 270 billion counts/30d and include loadings from livestock in streams, point sources with general permits, and unknown instream sources.

A Section 319 grant proposal for a fecal coliform TMDL implementation plan for Little Troublesome Creek was submitted to NCDWQ by Piedmont Triad Council of Governments in April 2002 (PTCOG, 2002). Section 319 of the Clean Water Act established a grant program for funding innovative nonpoint source (NPS) management strategies for use as demonstrations. Section 319 grants are awarded from the USEPA based on the recommendations of the NPS Working Group within NCDWQ. The proposal was selected to receive 319 grant monies in summer of 2002 and scheduled for funding in calendar year 2003. This proposal outlines a monitoring plan that will help identify sources and locations of fecal coliform contamination in the watershed.

The 319 proposal outlines a variety of structural and non-structural BMPs that will be utilized to reduce coliform inputs into Little Troublesome Creek and its tributaries. They are as follows:

- Structural:
  - (1) Constructed wetlands – up to 2 acres.
  - (2) Rain gardens/Bio-retention areas – up to 10 acres.
  - (3) Cash incentives:
    - (a) Fencing for keeping cattle/animals out of streams.
    - (b) Fixing septic systems.
- Non-structural:
  - (1) Riparian Buffers.
  - (2) Education:
    - (a) Pet waste - posters/signs/pet waste stations in parks.
    - (b) Storm drain stenciling.
  - (3) Kennel/vet/animal operations ordinance/procedures.
  - (4) Identification and enforcement of illegal discharges.
  - (5) Review Reidsville/Rockingham County ordinances and suggest changes to improve water quality.
  - (6) Map storm water system and septic tanks in Reidsville and Rockingham County.
  - (7) Monitoring.

Language in the grant proposal stresses the need to obtain all available information from other study efforts within the Little Troublesome watershed and mentions this LWP study effort in specific. LWP project team members have already begun regular communication with PTCOG staff and, wherever possible, implementation of the 319 grant will be fully integrated in the LWP for this watershed.

## 3.2.7 Additional Scoping Level Assessment of Little Troublesome Creek

### 3.2.7.1 Field Reconnaissance

LWP Project Team members and WARP staff have both conducted field reconnaissance surveys of extensive portions of Little Troublesome Creek. Observations from those surveys have shown that significant portions of Little Troublesome Creek have been straightened. Figure 15 shows a section of the Creek in the vicinity of Industrial Drive where straightening has occurred, and the image is unfortunately typical of substantial portions of Little Troublesome Creek. No accounts have been located to date that would indicate when or why this hydro-modification of the stream took place, but the age and extent of floodplain vegetation indicate that it occurred at least 40-50 years ago.



*Photo courtesy of NCDWQ Watershed Assessment & Restoration Project*

**Figure 15. Straightened Section of Little Troublesome Creek**

Field reconnaissance efforts have also revealed an active head cut making its way up Little Troublesome Creek in the area of the NCSRI midstream segment survey. Figure 16 shows one of the worst parts of the head cut working upstream on one of the channel braids within that segment. In addition, reconnaissance efforts have revealed several areas of severe and active bank erosion as well as occurrences of catastrophic bank failure. Stark examples of these phenomena are illustrated in Figure 17 and Figure 18, respectively. The extensive areas of bank erosion have resulted in deposition of a large amount of fine sediment in the bed of Little Troublesome Creek. Figure 19 shows a metal sampling rod inserted in the bed of the stream.

The four-foot rod was inserted two to three feet or more into the streambed sediments with relative ease. This illustration is representative of substantial portions of the creek.

Taken collectively, reconnaissance efforts have shown Little Troublesome Creek to be a highly unstable system that is actively eroding and unstable throughout the majority of its length. Extensive morphological stream restoration will be required to bring the creek into a state of equilibrium with its sediment load and to re-establish stability.



*Photo courtesy of NCDWQ Watershed Assessment & Restoration Project*

**Figure 16. Head Cut on Little Troublesome Creek near Cook Florist Road**



*Photo courtesy of NCDWQ Watershed Assessment & Restoration Project*

**Figure 17. Severe Bank Erosion on Little Troublesome Creek near Mizpah Church Road**

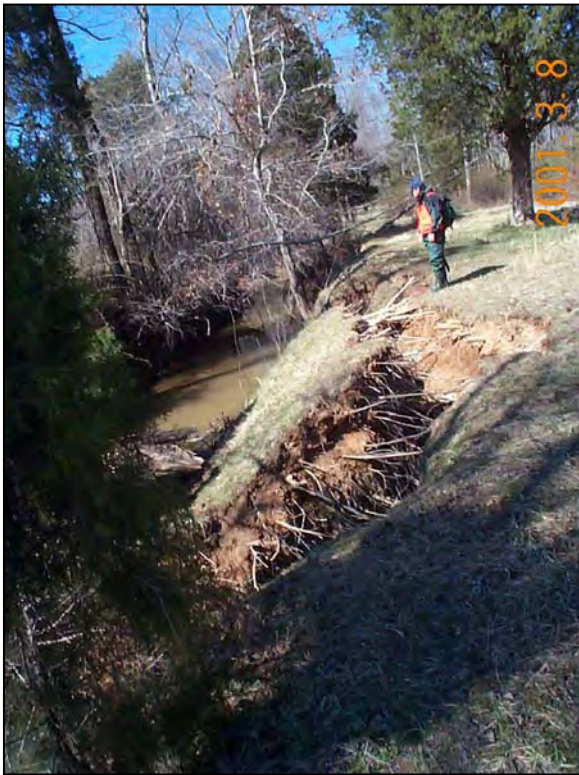


Photo courtesy of NCDWQ Watershed Assessment & Restoration Project

**Figure 18. Bank Failure on Little Troublesome Creek near Mizpah Church Road**



Photo courtesy of NCDWQ Watershed Assessment & Restoration Project

**Figure 19. Sampling Rod Inserted in Little Troublesome Creek Stream Bed**

### 3.2.7.2 Land Cover Distribution – Percent Disturbance of Forest Cover

To assess current land disturbance in the Little Troublesome Creek watershed, NLCD landuse data was used to calculate the percentage of natural and disturbed area in the nine subwatersheds (shown in Figure 9). The natural area includes open water, forest, and wetlands; all other landuse types are classified as disturbed.

Seven of the nine subwatersheds (LT1 through LT5 and LT8 and LT9) have less than 52 percent of natural land remaining. Disturbed landuses within the City of Reidsville (LT1 through LT5) are primarily residential, commercial, and industrial development (56 percent to 98 percent of disturbance). Subwatersheds LT8 and LT9 (lower reaches of Little Troublesome Creek) are primarily disturbed by agriculture (69 percent to 79 percent of disturbance). Subwatersheds LT6 and LT7 (middle reaches of Little Troublesome Creek) are the least disturbed in this watershed with percent natural areas ranging from 60 percent to 66 percent. Of the disturbed land in these two subwatersheds, 51 percent to 64 percent is agriculture.

Subwatersheds LT1 through LT5 are located completely within the City of Reidsville. As expected, these subwatersheds have the highest percentage of disturbed area in the watershed (49 percent - 72 percent). The two subwatersheds located on the southern border of Reidsville (LT6 and LT7) have the smallest percentage of disturbance (34 percent - 40 percent) in the watershed. Though much of the area in these two subwatersheds remains in a natural state, the percent of land disturbed is relatively high compared to less developed watersheds. The percent of land disturbed increases in the southern portion of the watershed due to agriculture. Subwatersheds LT8 and LT9 have percent disturbances ranging from 41 percent to 54 percent. Figure 20 shows the intensity of disturbed land in each subwatershed.

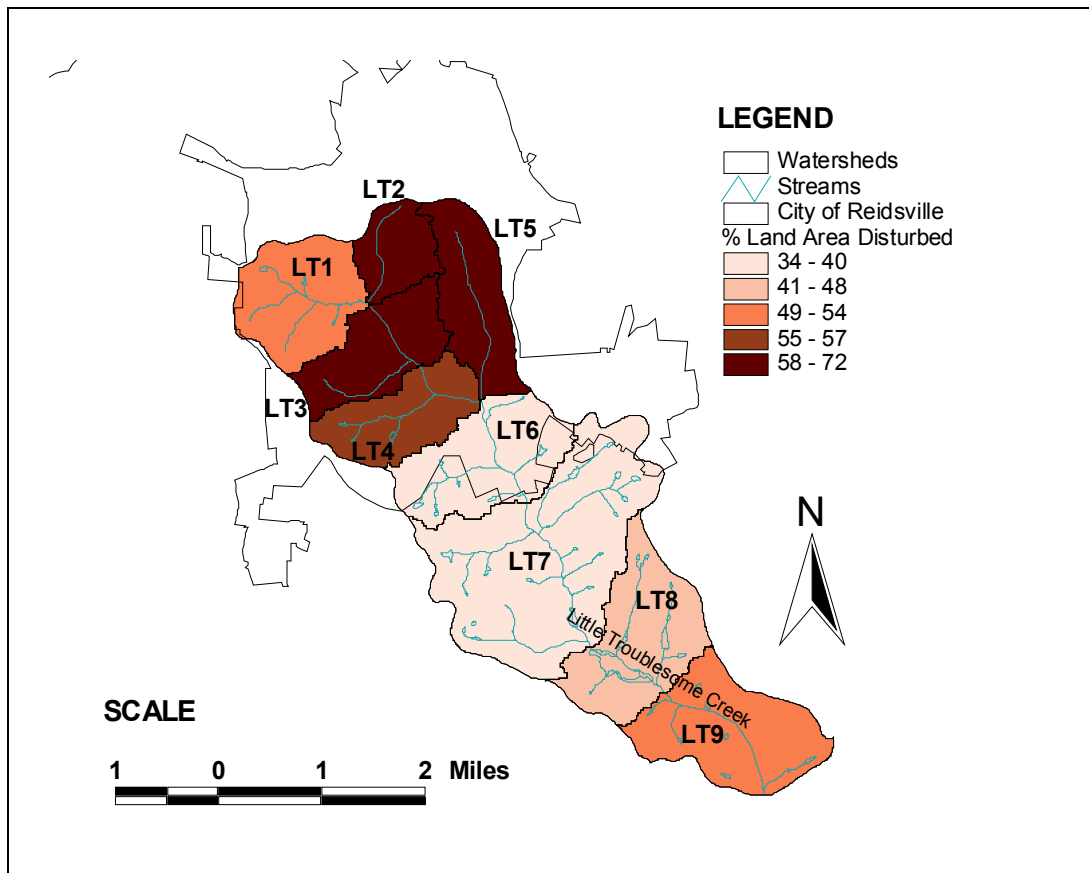


Figure 20. Percent of Land Area Disturbed in the Little Troublesome Creek Subwatersheds

### 3.2.7.3 Vegetative Status of Riparian Buffers

The NLCD landuse data was also used to calculate the percent of land disturbed within 100-foot buffers of perennial and intermittent streams in each subwatershed (refer to Section 2.2.5.2). Again, the highest percentages of disturbance occur in the subwatersheds within the City of Reidsville. Subwatersheds LT2 through LT5 have 24 percent to 59 percent of buffer area disturbed. The exception is LT1, which has a relatively low buffer disturbance (8 percent - 9 percent) compared to the rest of the watershed. With such low levels of riparian buffer disturbance, LT1 may be a prime area for greenway preservation efforts. Subwatersheds LT6, LT7, and LT8 have percent disturbances ranging from 8 percent to 11 percent. Subwatershed LT9 has a higher percentage of buffer disturbance (12 percent - 23 percent) due to agriculture in this subwatershed. Figure 21 shows the degree of buffer disturbance in each subwatershed.

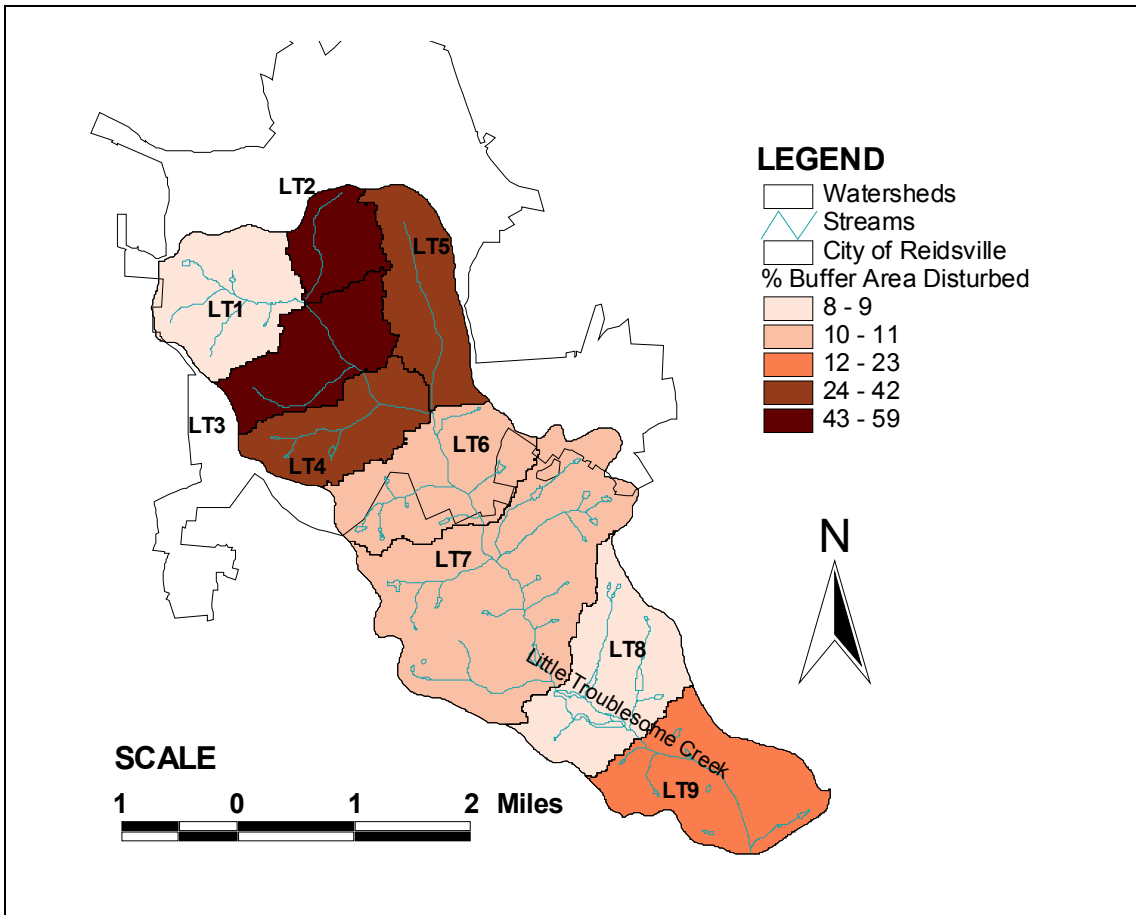


Figure 21. Percent of Buffer Area Disturbed in the Little Troublesome Creek Subwatersheds

### 3.2.7.4 Percent Imperviousness

Percent impervious area in the Little Troublesome Creek watershed decreases with distance from the City of Reidsville (Figure 22). Subwatersheds LT2 and LT5 have 25 percent and 35 percent impervious cover, respectively. The remaining subwatersheds within the city (LT1, LT3, and LT4) have a percent imperviousness ranging from 17 percent to 19 percent. Subwatershed LT6 on the southern boundary of the city has a percent imperviousness of 11 percent. Subwatersheds LT7, LT8, and LT9 each have a percent imperviousness of 5 percent, 3 percent, and 2 percent,

respectively. Though subwatersheds LT8 and LT9 have higher portions of disturbed area than subwatersheds LT6 and LT7, the disturbance is primarily due to agriculture, which is not impervious. Thus, the percent impervious cover is relatively low. Appendix B describes the methods used to estimate the percent of impervious cover for these subwatersheds.

The Center for Watershed Protection holds that, “Imperviousness is a very useful indicator with which to measure the impacts of land development on aquatic systems” (Shuler and Holland, 2000). As the amount of imperviousness in a watershed increases, the volume of rainwater that flows directly into the stream network, rather than infiltrating into groundwater, increases. In order to accommodate the increased runoff volume, the cross-sectional area of the streams has to increase. This increase is achieved through widening of the stream banks, or downcutting of the stream bed, or as is often the case, both. Instability and erosion of this nature result in the loss of aquatic habitat functions within the affected streams through sediment loading and the disturbance of riffle-pool sequencing. Numerous studies have documented this phenomenon at imperviousness thresholds as low as 10% (Shuler and Holland, 2000). In addition to increasing runoff volumes, impervious surfaces accumulate pollutants from vehicles and the atmosphere over time, which are subsequently washed into streams by storm events. Studies have also linked increases in imperviousness to excessive warming of water temperatures in aquatic systems (Shuler and Holland, 2000).

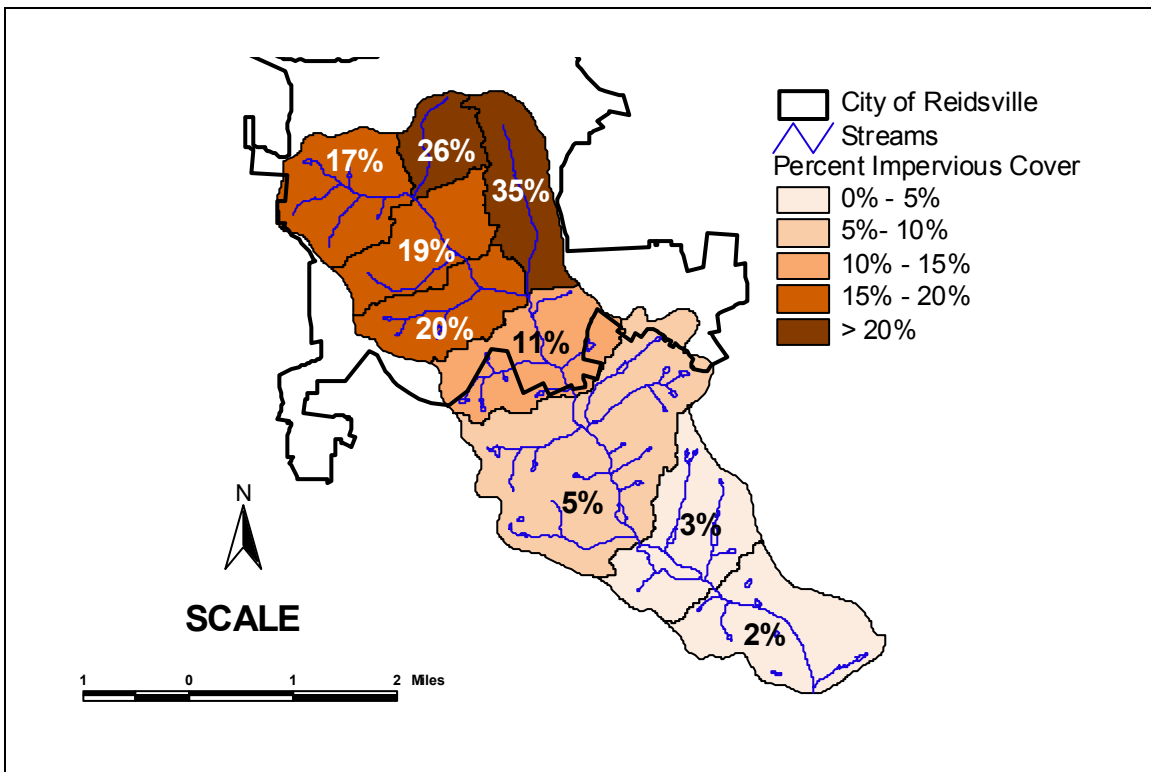


Figure 22. Percent Impervious Cover in the Little Troublesome Creek Watershed

### 3.3 CONCLUSIONS FROM PRELIMINARY CHARACTERIZATION OF LITTLE TROUBLESOME CREEK

Available data for Little Troublesome Creek clearly show a stream where water quality has improved as a result of removal of a major point source discharge. However, recent chemical and biological data suggest that the system still exhibits impairment from historical impacts and from the ongoing effects of nonpoint source pollution. A catalogue of available data for the Little Troublesome Creek watershed is presented in Appendix C.

In terms of its physical state, Little Troublesome Creek has undergone substantial geomorphological change due to anthropogenic impacts. The geology of the area, in particular the highly erodible nature of the alluvial soils, places the stream at risk for bank erosion and instability. The development of the City of Reidsville over time has given rise to large amounts of impervious surface in the headwater portion of the watershed. The increased imperviousness has resulted in much greater stormwater volumes and velocities than the system was capable of withstanding. The shearing potential of these stormwater flows has been amplified by the straightened portions of the stream, and the impact on Little Troublesome Creek has been severe, as is clearly illustrated by the pictures in this report.

Local Watershed Planning efforts in Little Troublesome Creek should concentrate on alleviating the adverse impacts, both chemical and physical, of urban stormwater from existing and future development within the watershed. In the lower, more rural, half of the watershed planning efforts may also need to emphasize measures to address agricultural non-point source impacts through means such as fencing cattle away from streams or updating aging sediment BMPs.

#### 3.3.1 Primary Threats to Water Quality, Hydrology and Aquatic Habitat

Physical restoration is needed throughout the vast majority of Little Troublesome Creek, but the process by which that restoration should occur is complicated by three factors. The first complicating factor is the volume of sediment deposited throughout the length of the stream. If restoration were to begin in any downstream segment, it is entirely possible that the restored segment would be loaded by the sediment transported from upstream reaches in future bankfull events, resulting in a loss of the equilibrium established by the restoration, and an effective loss of the capital resources invested. In order to maximize the potential long-term success of restoration in Little Troublesome Creek, it most likely needs to begin in the headwater portions and proceed downstream.

The second factor complicating restoration of Little Troublesome Creek is the mosaic of land ownership surrounding the headwater portion of the stream. Almost half the length of the Little Troublesome Creek mainstem is within the City of Reidsville limits as is the entire length of its largest tributary. Preliminary GIS analysis of the Rockingham County tax parcel database has indicated that, within Reidsville city limits there are 69 individual parcels bordering Troublesome Creek and its main tributary. Those 69 parcels, which are most likely to be affected by any restoration activities, are highlighted in yellow in Figure 23. The 69 parcels have a mean acreage of 8.2 acres, but if the six largest are excluded, the 63 remaining parcels have a mean acreage of only 4.0 acres. Each parcel encompasses 383 linear stream feet, on average. This factor may be the single largest challenge to implementing an effective restoration plan for Little Troublesome Creek. Efforts throughout the Local Watershed Planning process should be focused on identifying, educating, and enlisting the support of these landowners. Implementation of a pilot restoration project within the watershed and utilization of that project as a public education tool to

help build consensus among key landowners would greatly enhance the chances of implementing a restoration plan successfully for the Little Troublesome Creek corridor as a whole. The pilot restoration site recommended for consideration in the following section of this memorandum offers an excellent opportunity in that respect.

The third factor complicating restoration of Little Troublesome Creek is the degree to which the constraints of the physical environment hinder restoration in the upstream portions of the watershed. While the discharge outfall for the Reidsville WWTP was removed from Little Troublesome Creek, the treatment plant itself remains in operation on the bank of the stream at the lower edge of the city limits. The city’s entire wastewater collection system drains to a main trunk line that follows closely alongside the creek for most of its length. In addition, a considerable number of homes, roads and other manmade structures exist within the immediate floodplain. In many areas, these constraints will preclude the implementation of Rosgen Priority 1 and Priority 2 restoration projects that are preferred for mitigation. Rather, Priority 3 stream restoration, or construction of narrowly constrained step-pool stream types with narrow or no immediate flood plains (Rosgen Class B or Bc), will need to be applied. Priority 4 restoration, or stream bank hardening, may be necessary in some segments. While not optimum, restoration of segments by such means will be necessary in headwater areas of the stream, in order to ensure that downstream restorations are not impacted by excess sediment from upstream.

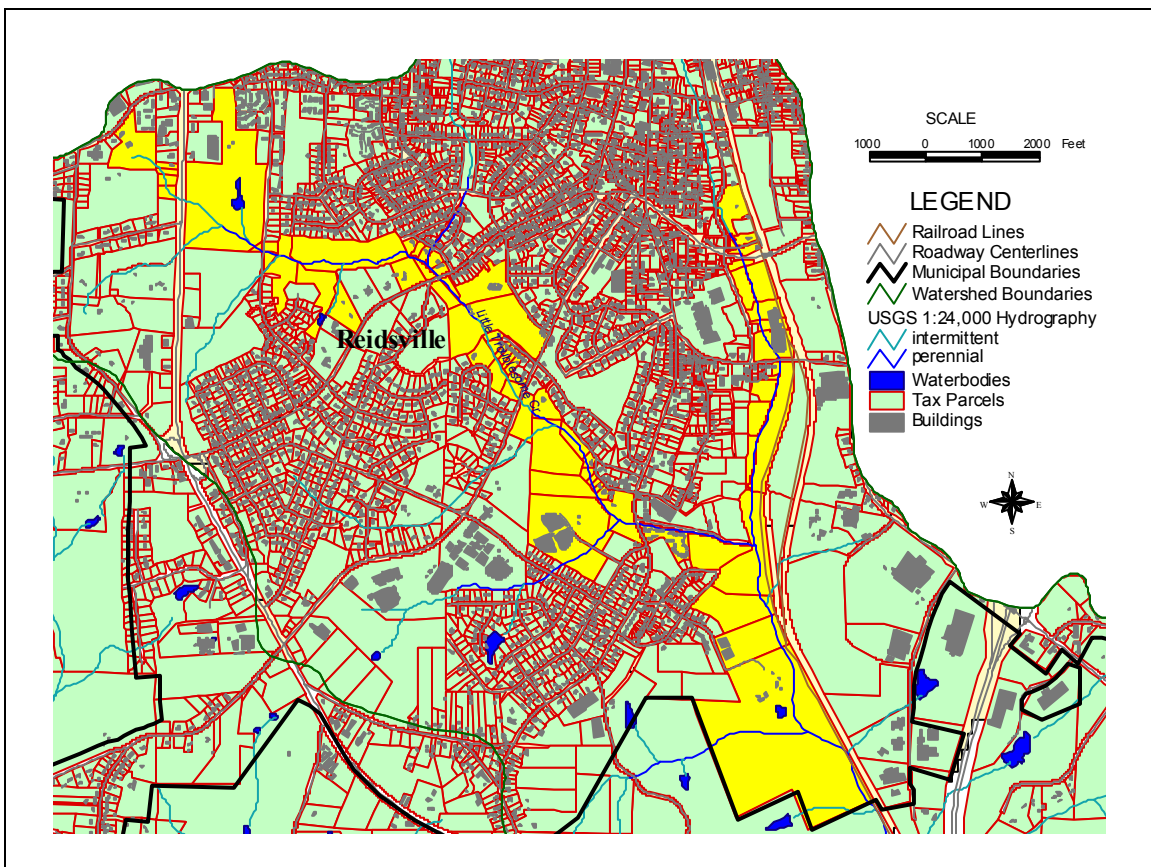


Figure 23. Parcels Bordering Little Troublesome Creek within Reidsville

### 3.3.2 Overall Goals for Detailed Assessment – Little Troublesome Creek

Available assessment information and field reconnaissance have shown that water quality and aquatic habitat have already been diminished in substantial portions of Little Troublesome Creek. Several segments of the creek have been channelized, and the subsequent morphological adjustment to the channelized conditions has resulted in stream segments that are unstable and actively eroding. In addition, as Reidsville has developed, imperviousness within the headwater portions of the watershed has increased drastically over time causing peak storm flows to become larger and more frequent. Combined, these factors have resulted in a stream system that is morphologically out of equilibrium with its current hydrology and sediment load.

The overall goal of the detailed assessment process will be to develop an effective stepwise strategy to restore morphological stability to Little Troublesome Creek. This stability will only be achieved through a deliberately coordinated effort to mitigate the damaging storm flows entering the stream network while restoring the dimension, pattern, and profile that are appropriate for the new flow regime and associated sediment load. As previously discussed, to be successful, the restoration strategy will most likely have to begin in the tributary and headwater portions of the watershed, such that sediment loads are controlled in those areas prior to affecting restoration of downstream portions. Through the detailed assessment process the headwater segments of Little Troublesome Creek proper and each of its tributaries will be thoroughly evaluated in order to determine which segments exhibit the greatest degree of instability and active erosion. In addition, the restoration feasibility of each of these headwater segments will be evaluated by factors such as infrastructure constraints, fragmentation of ownership and estimated cost of restoration. These two factors of “need for restoration” and “feasibility of restoration” will be combined to prioritize a stepwise restoration strategy for Little Troublesome Creek.

Measures such as stormwater retrofits and construction/restoration of riparian wetlands are also likely to be integrated components of a successful restoration strategy for Little Troublesome Creek. The detailed assessment approach will be designed to identify the optimum locations for retrofits and other structural stormwater BMPs, and to compare potential implementation scenarios on the basis of benefit/cost ratios.

In addition to stream restoration and stormwater management efforts, riparian buffer protection and restoration should be integrated into the overall restoration plan for Little Troublesome Creek. Despite the surrounding urban development, riparian buffers within the headwater areas of Little Troublesome Creek in the southwestern portion of Reidsville remain relatively undisturbed, as do the buffers in the lower portions of the watershed. However, the middle sections of Little Troublesome, located in southeastern Reidsville, exhibit much higher levels of buffer disturbance (refer to section 3.2.7.3). The scenario offers a strong opportunity for greenway planning to establish protections for the undisturbed riparian buffer areas and provide for restoration of the disturbed sections. This potential opportunity is further enhanced by the City’s ownership of extensive right-of-ways along Little Troublesome Creek and its tributaries for sewer and water lines.

In Chapter 4 of this report, the detailed assessment phases outlined here are broken down into specific assessment objectives. The objectives are grouped according to whether they address both Troublesome and Little Troublesome Creek watersheds or one of the two in particular.

### 3.3.3 Recommended Pilot Restoration Site

Within the scoping phase of the LWP process, the project team was charged with the task of identifying a potential pilot restoration site within the targeted watersheds. The purpose of the

pilot project would be to give NCWRP the ability to establish restoration activities in the study area early in the LWP process. Such early restoration activities would provide educational opportunities to build an understanding of, and support for, stream and wetland restoration among targeted landowners, in specific, and with the public as a whole. In that interest, project team members from Soil and Environmental Consultants, PA have systematically searched the upstream portions of Little Troublesome Creek, and its tributaries, for potential pilot restoration sites. During the field reconnaissance, several possible restoration sites were located and evaluated within the watershed. One of these sites, in particular, appears to be an appropriate “pilot project” because it may integrate several of the watershed goals (i.e., restoration, stormwater treatment, etc.) as defined by the NC Wetlands Restoration Program.

The potential restoration site consists of two individual stream channels that flow through a Reidsville City Park, Courtland Park, eventually joining at the southern park boundary adjacent to Green Street. The location of the park in relation to the Little Troublesome Creek Watershed and the City of Reidsville is shown in Figure 24 and Figure 25, respectively. The main creek flows from the north to the south through the middle of Courtland Park and is flanked by picnic shelters, parking lots, and playground equipment (Figure 26 through Figure 28). After flowing under Courtland Avenue via two crushed corrugated metal pipes, the creek becomes constrained between Green Street (Figure 29) and a sanitary sewer line. As the reconnaissance photos indicate, the main stem is incised and bank erosion is prominent throughout this section of the park, although the channel does possess some meandering pattern and active floodplain areas. The bank erosion will continue until channel equilibrium is reached and a new lower floodplain is created. The culvert pipes located at the origin and terminus of the channel reach are acting as grade control, limiting further incision and degradation. This reach would be an excellent Priority 2 candidate, which would entail designing an “E” or “C” type channel within an excavated active flood plain bench. There are no apparent constraints (i.e., utilities, etc.) immediately adjacent to the channel that would impede the restoration design.

The second restoration opportunity consists of a first-order stream that, as mentioned before, intersects the main channel at the park’s southern property boundary. This small stream appears to have been channelized and diverted when the neighborhood was developed. It possesses several head cuts, but it is not yet incised within the park property. The reach of interest originates at Crescent Drive and flows southwest (Figure 30), then turns to the west, eventually joining the main creek described in the previous paragraph. This reach could be restored as a Priority I restoration and offers the additional possibility of creating wetlands immediately adjacent to the restored channel by excavating down to existing hydric soil indicators. The wetland restoration potential would require more intensive field studies (hydric soil delineation, groundwater investigation, etc.) prior to formalizing the acreage yield and practicality. Other limitations to this option may include the economic feasibility, considering the scale of the site, and the potential for social resistance to the proposal. Social resistance may stem from the cultural bias toward viewing an uninterrupted panorama of the park or the desire for the “manicured” appearance of regularly mowed stream banks.

In addition to the potential stream and buffer restoration, the site could also be utilized to treat stormwater runoff. These streams apparently receive a significant amount of stormwater, which is conveyed through the network of pipes and storm drains. This storm drainage network may present an opportunity to intercept and treat urban runoff utilizing an array of stormwater BMPs (e.g., bio-retention cells, rain gardens, constructed wetlands). The stormwater BMPs could be easily integrated into the restoration design, providing an additional water quality function without significantly increasing construction costs.

In summary, Courtland Park, could offer approximately 1,600 to 1,800 linear feet of Priority 1 and Priority 2 stream restoration with associated buffer restoration, approximately 1 to 1.5 acres

of wetland restoration/creation, and the opportunity to treat urban runoff. Based on this field assessment, and comparison to other restoration sites evaluated, the Courtland Park Site has few constraints, and it is held by a single owner (the City of Reidsville). The streams in question drain approximately one quarter of the downtown area and are obviously impacted by stormwater. This site is recommended for consideration as a pilot restoration site because it could potentially fulfill several of the mitigation objectives expressed by the NC Wetlands Restoration Program. It should be noted that more detailed field surveys would be necessary to fully examine the restoration opportunity and develop an appropriate restoration strategy for this site.

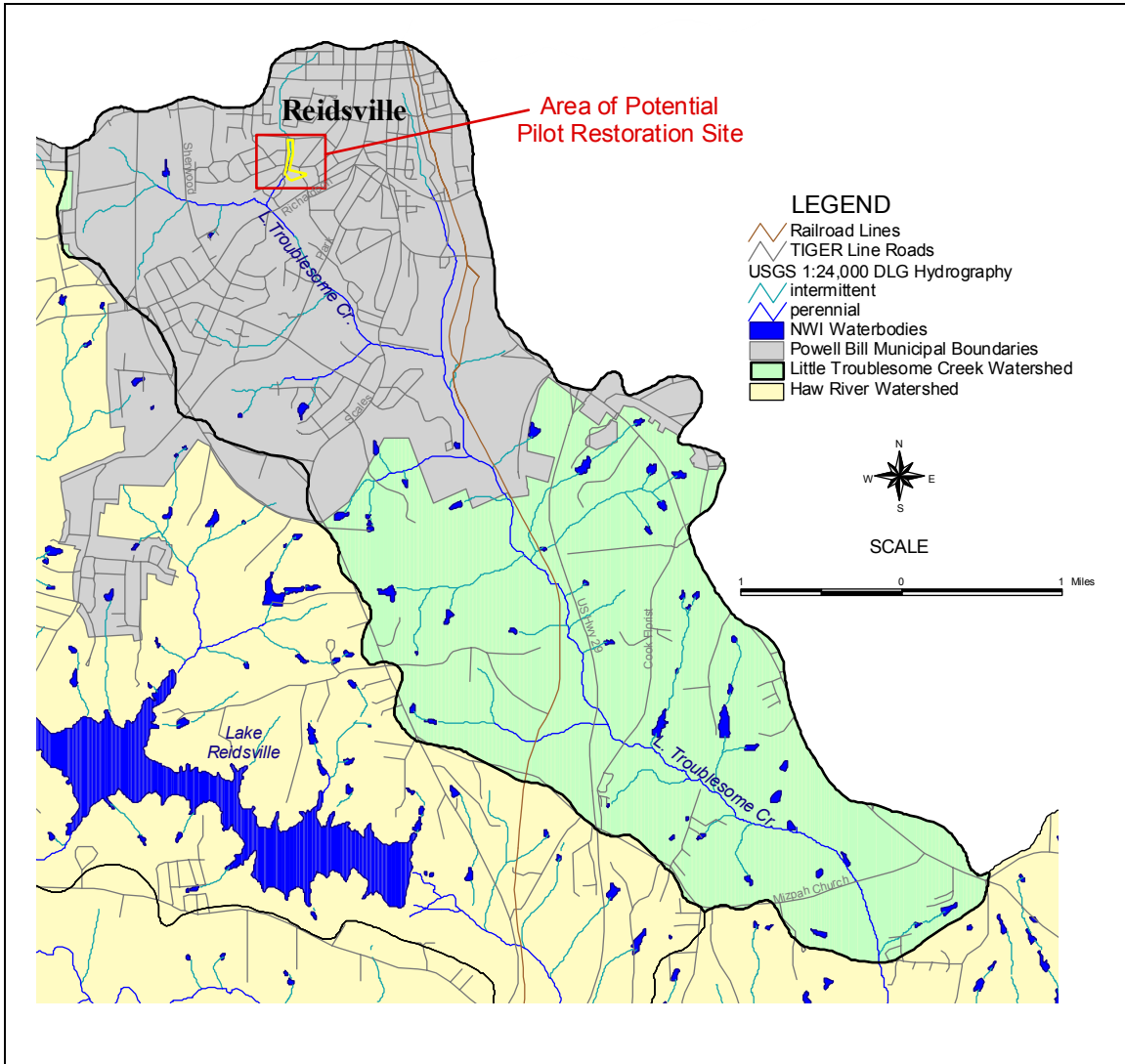


Figure 24. Location of Potential Pilot Restoration Site in Relation to the Little Troublesome Creek Watershed



**Figure 25. Location of Potential Pilot Restoration Site in Relation to the City of Reidsville**



**Figure 26. Upper Section of Unnamed Tributary (UT) to Little Troublesome Creek in Courtland Park**



Figure 27. Middle Section of UT to Little Troublesome Creek in Courtland Park



**Figure 28. Lower Section of UT to Little Troublesome Creek in Courtland Park**



**Figure 29. UT to Little Troublesome Creek below Courtland Avenue**



**Figure 30. First Order Tributary at Crescent Drive**

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## 4 Detailed Assessment Objectives with Recommended Indicators, Targets, and Assessment Techniques

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As demonstrated in the previous chapters of this report, watershed characterization and impact assessment involve characterizing the interactions among watershed functions (water quality, hydrology, and habitat), human activity and landuse, and assessing their impacts on each of the management objectives. However, many objectives are difficult to measure directly. For example, there is no single metric that directly measures watershed function. Instead, we tend to use several parameters to measure different aspects and then make an overall assessment of function. Therefore, we need to establish a series of indicators that provide a means for detailed assessment of current and future watershed functions to support development of meaningful management strategies for the local watershed plans.

In this context, the term "indicator" is used to mean a quantifiable or subjectively rankable measure that provides a means of evaluating watershed condition and functioning, and that can be predicted in response to management options. Examples of indicators include water quality parameters (e.g., DO, temperature, nutrients, metals), percent imperviousness, percent disturbed buffer, sediment load, channel bank stability, and chlorophyll *a*. Linking management objectives to water quality and aquatic habitat impacts through the use of indicators provides decision-makers with meaningful information to support specific management decisions.

This section of the report provides the indicators recommended for detailed assessment and planning in both the Troublesome Creek and Little Troublesome Creek watersheds. For each primary management objective, indicators are identified and the proposed means for assessing those indicators are described. The key to the detailed assessment will be establishing management targets for each indicator. The term "target" is used here to mean the value of the indicator needed to achieve the objective. Potential targets are identified in this report where possible, but part of the detailed assessment process will be obtaining information and working with stakeholders to establish appropriate targets.

### 4.1 DETAILED ASSESSMENT OBJECTIVES FOR BOTH TROUBLESOME AND LITTLE TROUBLESOME CREEK

**OBJECTIVE #1: Determine which LWP study area subwatersheds are more or less likely (under existing conditions) to have diminished water quality or aquatic habitat as a result of extensive disturbance of forest cover or riparian buffer disturbance, and prioritize those subwatersheds for restoration, preservation, or other management efforts.**

*Stressors: Disturbance of natural forest and wetland cover, stormwater volumes and velocities, increased pollutant loads to streams, increased sedimentation from stream channel erosion.*

*Watershed Functions Affected: Aquatic Habitat, Terrestrial Habitat, Water Supply, Hydrology.*

Indicators	Assessment Tool(s)	Purpose
Percentage of Disturbed Landuses	GIS Analysis, MRLC and planimetric data	Characterization
Riparian Buffer Disturbance	GIS Analysis, Aerial Imagery, Field Survey	Characterization
Habitat Suitability	NCBI/EPT/HSI Monitoring by NCDWQ	Characterization
Fish Community Ratings	NCIBI Monitoring by NCDWQ	Characterization

Subwatersheds in which significant areas of natural forest and wetland cover have been converted to “disturbed” land uses have a greater degree of vulnerability to degradation of water quality and habitat. As the proportion of land within a given subwatershed devoted to agricultural, residential, or commercial land uses increases, so does the likelihood that streams will have become unstable or increased pollutant loads will have been delivered to streams and other waterbodies. This likelihood increases even more if the riparian vegetation within that subwatershed has been subject to significant loss or disturbance. Within the LWP process, subwatersheds with higher degrees of disturbance of natural land cover or riparian vegetation will be identified and prioritized for further field reconnaissance and investigations. The purpose of such investigations will be to identify opportunities to restore stream segments or improve water quality and habitat through other site specific management measures such as stormwater retrofits or reestablishment of riparian vegetation.

Subwatersheds with high levels of disturbed upland and riparian buffer areas can be identified through GIS analysis of MRLC land cover data (described in Sections 2.2.5.1 and 3.2.7.2) and of planimetric data supplied by Rockingham and Guilford County GIS departments. Planimetric data reflects building footprints, and given that the planimetric data sets for the study are of more recent vintage (circa 1999-2001) than the land cover data (circa 1993), they can be used to identify more recent areas of disturbance. The same data sets can be used to identify areas where riparian buffers appear to have been disturbed within 100-200 feet on either side of streams; but given the coarse scale of the data in question, such disturbances will have to be verified with analysis of aerial imagery and field reconnaissance.

The initial GIS characterizations for disturbed upland and riparian buffer areas have already been performed and results have been presented by subwatershed in this report, so the data for these analyses do not constitute a data gap. Rather, they are discussed here to provide the reader with an inventory of the information that will be utilized to rank and prioritize subwatersheds in the detailed assessment phase of the LWP process.

Habitat suitability and fish community ratings are two indicators that integrate biological function and physical habitat condition.

The species composition and abundance of benthic macroinvertebrate communities reflect the chemical, geomorphological, and physical conditions in stream ecosystems. Many taxa are known to be either tolerant or intolerant of various environmental stressors. Intolerant macroinvertebrates are often very dependent on coarse substrate habitats, making them susceptible to substrate embedding by fine sediments. Using macroinvertebrates as a numeric target serves as a linkage between watershed stressors and the support and/or recovery of designated uses because: 1) the composition of the invertebrate communities indicates physical and chemical conditions and the type and availability of habitat, and 2) populations of invertebrates are an indicator of broader habitat quality and ecological functionality of streams. Benthic macroinvertebrate populations are shaped by subtle changes in water quality. Since many

taxa in a community have life cycles of six months to one year, the effects of short-term stressors will not be detected until the next generation. The benthic community integrates the effects of a wide array of potential environmental stressors. However, the effect of sediment and nutrient loading on benthic communities is more pronounced in environments that favor development of embedded substrates or substantial growth of attached algae.

The North Carolina Division of Water Quality has established protocols for collection and analysis of benthic macroinvertebrate samples. Generally, sampling would be conducted in the first year to establish a baseline and re-collected at regular intervals to monitor trends. Each sample is given a bioclassification ranging from Poor to Excellent based on the number of taxa present and their tolerance rating. The taxa richness of the intolerant groups Ephemeroptera, Plecoptera and Trichoptera is the basis of a more rapid assessment index (EPT). The North Carolina Biotic Index (NCBI) summarizes tolerance data for all taxa in each collection. The two indices are given equal weight in final site classification for the qualitative (10-sample) method. An abbreviated (4-sample) EPT method uses just the EPT criteria. Higher taxa richness values are associated with better water quality. Sediment loading may not be assessed as well by a taxa richness analysis unless embedding of substrate or erosion to bedrock occurs. Different criteria have been developed for different ecoregions (mountains, piedmont and coastal) within North Carolina for freshwater flowing waterbodies. Included in this procedure is completion of a habitat assessment at sample locations. This habitat suitability index (HSI) describes substrate condition, obvious bank instability, channel modifications, instream habitat, riparian vegetation, canopy cover, and dense growth of benthic algae. Details of benthos sampling, criteria, and data analysis can be found in the Biological Monitoring SOP Manual (DEHNR, 2001), available online at: <http://www.esb.enr.state.nc.us/BAUwww/benthossop.pdf>.

**OBJECTIVE #2: Identify sites or stream segments where wetland function has been lost and/or where restoration potential exists.**

*Stressor: Wetland loss.*

*Watershed Functions Affected: Aquatic Habitat, Terrestrial Habitat, Water Supply, Hydrology.*

Indicators	Assessment Tool(s)	Purpose
Wetland Vegetation Disturbance	GIS Analysis of NWI, MRLC & Aerial Imagery	Characterization
Hydric Soil Inclusions	GIS Analysis of SSURGO Soils	Characterization
Detailed Soil and Plant Community Evaluations	Field Survey	Characterization

A 3-Tier GIS screening analysis to identify areas where wetland function may have been diminished or lost can be performed with data already obtained for the LWP. Tier 1 screening will be performed by overlaying the coverage of the National Wetlands Inventory (NWI) obtained from the U.S. Fish and Wildlife Service over hydric soils from the coverage of the SSURGO soils database (USDA – SCS, 1992). Spatially cross-referencing these two data sets will allow for identification of “Areas of Interest” where hydric soils were present within the riparian corridor but where wetlands were not formally identified by the NWI. The premise behind this screening analysis is that some disturbance of vegetation or alteration of the hydrologic function within these areas might have changed their character to such a degree as to result in no wetland designation where a wetlands may have existed historically.

Tier 2 of the GIS screening process will involve overlaying the boundaries of the NWI wetland polygons and hydric soils over satellite-based National Land Cover Database (NLCD) data obtained from the USEPA-USGS Multi-Resolution Land Characteristics (MRLC) Consortium. The purpose of this screening tier will be to evaluate the status of vegetation within the riparian corridors identified in Tier 1 as “Areas of Interest.”

Tier 3 screening will be performed where Tier 2 screening indicated significant disturbance of forest and wetland vegetation within the hydric soil regions of the riparian corridor. For purposes of Tier 3, the “Areas of Interest” will be broken down into smaller segments and mapped with aerial photograph images to allow detailed visual evaluation of the focus area. The aerial image maps can also be overlaid with boundaries showing hydric soil regions and NWI wetlands. In addition, the aerial images can be overlaid with GIS tax parcel boundaries in order to identify areas where it might be feasible to obtain significant land acreage for restoration purposes.

Field identification of potential wetland restoration sites will involve confirmation of results from GIS based targeting procedures. This detailed assessment will confirm the potential for creation of appropriate wetland hydrology (defined by reference wetlands), evidence of past or current presence of hydric soils, and assessment of local wetland plant seed banks. The detailed assessment of wetland hydrology will include a simple water budget using GIS analysis of annual hydrologic delivery from upland areas, annual evapotranspiration rates, and annual rates of groundwater infiltration based upon soil permeability. Further assessment of hydrology, including prediction of water levels, will depend on wetland design and should be included in site-specific wetland restoration plans from future contractors.

The detailed assessment of potential wetland restoration sites will also include an appraisal of past alterations of wetland hydrology, including assessment of the presence of drainage tiles, ditches, and other manmade structures designed to enhance drainage. The detailed assessment of wetland soils will include evaluation of current and relic indicators of hydric soils including listing of local soil series on state hydric soils lists, low chroma layers, mottled soils, manganese nodules, etc. In cases where hydric soils have never occurred on a site, the permeability of local soils and suitability for ponds, dikes, and other water control structures will be assessed. Evaluation of the local seed bank will also be utilized and will include a synoptic survey of wetland species found in adjacent parcels, including invasive wetland species. A list of desirable wetland species can be developed using synoptic surveys of reference wetland systems within a reasonable vicinity. Detailed plans for the restoration of plant communities should also be part of site-specific wetland restoration plans provided by future contractors.

**OBJECTIVE #3: Within subwatersheds where future residential and commercial development is predicted to be most likely, identify large undisturbed tracts of riparian corridor with minimal or no fragmentation of ownership for potential preservation targets.**

Indicators	Assessment Tool(s)	Purpose
Length of Undisturbed Riparian Corridor	GIS Analysis of MRLC Landuse & Aerial Imagery	Characterization
Fragmentation of Ownership	GIS Analysis of Parcel Database	Characterization

GIS analysis can be utilized to identify large areas of uninterrupted forest cover along riparian corridors. These corridor segments can be overlaid with tax parcel boundaries to identify large contiguous parcels to target for preservation opportunity.

**OBJECTIVE #4: Identify riparian corridor preservation targets that possess high ecological, aesthetic or historical value in order to prioritize preservation opportunities.**

Indicators	Assessment Tool(s)	Purpose
Natural Heritage Element Occurrences	GIS Analysis of Natural Heritage Database	Characterization
Sites of Historical/Archeological Significance	Communication with NC Department of Cultural Resources	Characterization
Sites of Historical/Archeological Significance	Communication with local preservation authorities and organizations.	Characterization
Recreational Value	Stakeholder Input & Professional Judgment	Characterization

As development pressure is exerted on the watershed, one of the most effective means to prevent degradation of water quality and aquatic habitat is through preservation of open space along riparian corridors (assuming stormwater is not routed directly to streams through these zones). Given that the majority of the riparian corridors along Troublesome Creek and its tributaries remain undisturbed, the watershed is likely to yield valuable preservation opportunities. Such preservation efforts can be achieved through land purchases or conservation easements. In the detailed assessment phase of the LWP process, GIS analysis of natural heritage element occurrences (NHEOs) within riparian corridors will be conducted in order to prioritize areas with high ecological value. NHEOs include recorded occurrences of endangered or threatened species, as well as species characterized as “species of concern” by the NC Wildlife Resources Commission, and unique ecological communities.

In addition, project team members will research records within the NC Department of Cultural Resources and local historic preservation authorities and organizations to determine if any sites of historical or archeological significance exist within candidate preservation areas (e.g., old ironworks mill). Candidate preservation areas will also be prioritized based on stakeholder and project team assessment of recreational and aesthetic value.

**OBJECTIVE #5: Identify stream segments where aquatic habitat and water quality are likely to be subject to future degradation due to stream instability and the associated physical stream alteration (e.g., bank erosion and/or entrenchment).**

*Stressor: Erosive stream velocities, increased sediment in streambed from bank erosion.*

*Watershed Functions Affected: Aquatic Habitat, Hydrology.*

Indicators	Assessment Tool(s)	Purpose
Percent Imperviousness (Future)	GIS Analysis	Predictive
Channel Stability	1) Allowable Velocity from HEC-HMS/HEC-RAS	Predictive
	2) Stream Power Estimates from HEC-HMS/HEC-RAS	Predictive
Transportation Improvement Project database	GIS Analysis	Predictive

Conversion of land to commercial and residential uses will lead to a substantial increase in impervious surface in portions of the watershed where development occurs, which can lead to increased frequency and magnitude of peak flow events instream. Increased stormwater velocities will cause greater shear stress resulting in increased rates of bank erosion and potentially leading to unstable and eroded conditions in receiving streams. As noted by the Center for Watershed Protection, numerous studies have documented such stream erosion resulting from imperviousness thresholds as low as 10% (Shuler and Holland, 2000). Through GIS analysis of future landuse/growth projections, the percent imperviousness can be estimated for subwatersheds or selected catchments within them. The future imperviousness estimates will be utilized directly, as indicators of the potential for stream erosion, and indirectly to develop runoff inputs for hydrologic modeling within the study area.

The development that results in land conversion and increased imperviousness is more likely to occur in areas where improvements to the transportation infrastructure have occurred. GIS analysis of the Transportation Improvement Projects (TIP) database maintained by the NC Department of Transportation will be used to identify subwatersheds where development is most likely to occur.

A variety of quantitative approaches exist to predict channel stability. These approaches generally utilize stream velocity, shear stress, and stream power. These methods are summarized in SCS (1977), USACE (1994), and FISWRG (1998). A useful assessment tool is found in the allowable stream velocity-depth relationships developed by USDA-SCS (1977) for the design of open channels. The relationships were based on empirical data that provide for both cohesive and non-cohesive materials. For coherent materials in the sand-clay range, allowable velocities are approximately 4.2 fps at channel forming flows. These values increase with depth. Storm events where stream velocities exceed critical velocities for a given bed material are likely to result in channel erosion.

Channel-forming flow is often considered to be synonymous with bankfull discharge. Stream velocities at bankfull discharge can be estimated from Manning's equation using field-derived estimates of bankfull height as follows:

$$V = \frac{\theta}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$$

where  $\theta = 1.49$  for U.S. units or 1.0 for metric units,  $n$  is the Manning's roughness coefficient for bankfull conditions,  $R$  = the hydraulic radius associated with bankfull depth and width, and  $S$  = slope. The average boundary shear stress on the cross section can be estimated from:

$$\tau = \gamma RS$$

where  $\gamma$  = specific weight of water; R and S are defined above.

Brookes (1990) suggested the product of bankfull velocity and shear stress, which is equivalent to stream power per unit bed area, as a practical criterion for stream restoration initiatives. Streams with powers less than 1.0 lb/sec/ft<sup>2</sup> generally failed through deposition and aggradation, while powers greater than 3.4 lb/sec/ft<sup>2</sup> failed due to erosion. Streams where power ranges from 1.0 to 3.4 lb/sec/ft<sup>2</sup> at channel forming flow are generally in a state of dynamic equilibrium.

The rate of change in stream power or critical velocity is a significant indicator of more generalized patterns of erosion or deposition along a stream reach. A stream reach that exceeds the critical threshold, and shows a pattern of increasing stream power with decreasing channel elevation, is likely to be consistently erosional along its length. Conversely, a stream reach that exceeds critical thresholds at channel-forming flows but shows a pattern of decreasing power may experience deposition of courser particles in downstream areas. These analyses will provide a relative measure of expected changes in stream stability accompanying changes in land use and implementation of best management practices.

Hydrologic modeling, utilizing a combination of the HEC – Hydrologic Modeling System (HEC-HMS) and HEC – Riverine Analysis System (HEC-RAS), will allow for a detailed evaluation of the vulnerability to stream bank erosion associated with land use changes. With the application of HEC-RAS, stage height-to-volume rating curves can be generated for selected points throughout the watershed. The rating curves can be combined with field survey data identifying bank full stage and the cross sectional area at that bankfull stage for those same points to calculate stream velocities and estimates of shear stress and stream power during bank full events.

Using allowable velocity and stream power criteria in conjunction will provide for a robust assessment of future erosion potential by allowing for cross-checking of each individual criterion with the indications of the other.

**OBJECTIVE #6: Identify potential locations where stormwater BMPs would be advantageous for mitigating impacts of current and future development in terms of controlling peak flow and preventing adverse water quality and aquatic habitat impacts.**

*Stressor: Erosive stream velocities, increased sediment in streambed from bank erosion.*

*Watershed Functions Affected: Aquatic Habitat, Hydrology.*

Indicators	Assessment Tool(s)	Purpose
Future Bank Erosion Potential	1) Critical Velocity from HEC-HMS/HEC-RAS	Predictive
	2) Stream Power Estimates from HEC-HMS/HEC-RAS	Predictive

Once stream segments have been identified to be at risk for bank erosion under future land use conditions by the analysis described under OBJECTIVE #5, a variety of approaches are available to prevent the predicted stream erosion. Measures such as density restrictions on new development, enhanced stream buffer protection requirements, structural stormwater BMPs, or performance standards for control of peak stormwater runoff from new development can be utilized to prevent the bank erosion and down-cutting that can adversely impact streams after their watersheds are developed.

The predictive tools and indicators described for OBJECTIVE #5 can be used to evaluate a variety of “what if” scenarios incorporating individual management measures or combinations of measures such as those described above. The LWP project team will work closely with stakeholders, not only to develop the future land use scenarios for the watershed, but also to develop management strategies that are appropriate and desirable to local interests.

## 4.2 DETAILED ASSESSMENT OBJECTIVES FOR TROUBLESOME CREEK

**OBJECTIVE #1: Identify stream segments where aquatic habitat and water quality are already diminished due to stream instability and the associated physical stream alteration (e.g., bank erosion and/or entrenchment).**

*Stressors: Erosive stream velocities, increased sedimentation from stream erosion.*

*Watershed Functions Affected: Aquatic Habitat, Hydrology.*

Indicators	Assessment Tool(s)	Purpose
Percent Imperviousness (Existing)	GIS Analysis	Characterization
Riparian Buffer Disturbance	Aerial Imagery, Field Survey	Characterization
Stream Bank Condition	BEHI from Field Surveys	Characterization
Stream Bed Stability	Entrenchment Ratio/Bank Height Ratio	Characterization

Subwatersheds or portions of subwatersheds with greater percentages of impervious surface have higher levels of vulnerability to stream bank erosion and stream channel incision caused by increased stormwater volumes and velocities. An analysis of percent imperviousness by subwatershed has been performed and results are presented in Sections 2.2.5.3 and 3.2.7.4. The methods used in the impervious analysis are described in detail in Appendix B of this report. Given that no subwatershed within the Troublesome Creek watershed was found to have imperviousness greater than 5%, imperviousness is not expected to be an indicator of restoration potential at the subwatershed scale. However, the same data and methods used to determine subwatershed imperviousness could be utilized to evaluate smaller portions, or catchments (i.e., drainage areas less than 1 square mile), within subwatersheds. Evaluation at this catchment level would enable the project team to determine if the percent imperviousness at the catchment scale is high enough to result in significant vulnerability to stream erosion from increased stormwater inputs.

Stream segments in which riparian buffer vegetation has been subject to significant loss or disturbance have a much higher vulnerability to stream instability. Stream segments in which the GIS analysis of land cover within riparian buffers described under OBJECTIVE #1 in Section 4.1 has determined the buffer vegetation is disturbed will be slated for more detailed scrutiny of buffer status via GIS analysis of aerial imagery. Detailed aerial images obtained from the Rockingham County GIS Department and the N.C. Center for Geographic Information and Analysis (for Guilford County) can be utilized to confirm or refute the findings of the preliminary GIS analysis. Stream segments in which the buffer disturbance is confirmed by aerial images will be scheduled for field survey to assess their condition.

Stream segments that have been confirmed to have disturbed riparian corridors will be subject to field surveys to evaluate their level of stream stability. Stream stability is said to occur when the

processes of sediment erosion and deposition are in a state of dynamic equilibrium over time. When more sediment enters a stream than the stream can clear, the stream aggrades, filling in pools, altering substrate and destroying habitat. When the stream’s sediment transport capacity exceeds sediment supply, the stream will create additional sediment supply through channel erosion. Channel erosion occurs through three primary processes: widening, down-cutting, and mass wasting of bank material. Mass wasting creates large pulses of sediment into streams. The contribution of channel erosion to sediment loading in streams is largely a function of stream class, stage of channel evolution, and channel stability. Stream stability will be evaluated through measures of stream bank condition and streambed stability.

Stream bank condition will be evaluated using the bank erosion hazard index (BEHI) method (Rosgen, 2001), which is based upon channel evaluation methodologies of Pfankuch (1978). The BEHI evaluates key stream bank characteristics sensitive to the various processes of erosion including: bank height ratio (stream bank height/maximum bankfull depth), ratio of rooting depth/bank height, rooting density, percent surface area of bank protected, bank angle, number and location of various soil composition layers or lenses in the bank, and bank material composition. The BEHI values are converted to a risk rating of very low, low, moderate, high, very high, and extreme potential erodibility. BEHI ratings can be calculated for different vegetative cover scenarios that would reflect the implementation of various BMPs including cattle exclusion from stream bank areas.

Streambed instability occurs when sediment loads are greater than, or less than, sediment transport capacity at channel form flows. Instability is characterized by streambed aggradation, when sediment load exceeds transport capacity or by down cutting and head cutting when transport capacity exceeds sediment load. Aggradation impacts habitat suitability by embedding substrate and filling in pools. Channel down-cutting and head-cutting can sever connectivity of a stream from its flood plain. This has the effect of preventing movement of floodwater into wetland areas and lowers ground water tables below the root zone where many nitrogen transformation processes occur. This can severely curtail the water quality protection functions of adjacent wetlands and riparian corridors.

Qualitative characterization of bed stability can be performed with several indicators proposed in the Level II and Level III assessment procedures developed by Rosgen (1996). Most relevant among these are entrenchment ratio, which is a measure of the containment of a river channel within its flood plain, and bank height ratio (a measure of channel incision).

**OBJECTIVE #2: Determine which study area subwatersheds have significant potential for delivery of upland sediment to streams under existing and future conditions.**

*Stressor: Increased sediment delivered to streams from areas where land cover is disturbed.*

*Watershed Functions Affected: Aquatic Habitat, Water Supply.*

Indicators	Assessment Tool(s)	Purpose
Potential for Upland Sediment Delivery (Existing & Future)	GIS Analysis of Landuse/Soil Combinations with SWAT framework	Characterization/ Predictive

The preprocessing routines of the SWAT model used to delineate subwatersheds can also provide a means for the estimation of upland sediment erosion using the Modified Universal Soil Loss Equation (MUSLE). Digital elevation models, hydrographic coverages, and county level soil

surveys were already input into the SWAT preprocessor for watershed delineation. Within each subwatershed, unique land use and soil series combinations were identified and assigned a hydrologic response unit (HRU) code. The land area of each HRU was calculated and entered into a database. Existing databases provide MUSLE coefficients for each HRU, and integrated MUSLE routines in SWAT can then predict upland sediment erosion based on various climate and management scenarios. The upland soil erosion predictions for existing land use conditions within the watershed have already been generated, and are presented in Section 2.2.5.4 of this report. This information will be utilized as a ranking factor in prioritizing subwatersheds for restoration and preservation activities. In addition, the SWAT modeling framework will be utilized to predict upland soil erosion by subwatershed for future conditions, once future landuse scenarios are developed with stakeholder input. These future predictions will be used to identify and prioritize areas with high erosion potential for recommendation of additional controls on new development or additional management measures to prevent sedimentation.

**OBJECTIVE #3: Determine if future land use conversion from forested or agricultural uses to developed uses has the potential to cause excess eutrophication in Lake Hunt or Lake Reidsville.**

*Stressor: Increased nutrient loads to reservoirs as a result of land use changes.*

*Watershed Functions Affected: Aquatic Habitat, Water Supply.*

Indicators	Assessment Tool(s)	Purpose
Eutrophication /Chlorophyll a	GIS Analysis of Watershed Landuse & Predictive Eutrophication Modeling with Eutromod	Predictive

As development encroaches on the watershed, the number of septic tanks will increase, as will the amount of fertilizer used on lawns, and together these sources will have the potential to increase the nitrogen and phosphorus loads delivered to Reidsville Lake. However, there is a degree of uncertainty involved in predicting the magnitude of load increase due to varying relationships between land use types and nutrient loading. Depending on the nutrient management practices employed on each landuse type, residential land may yield lower nutrient loads than agricultural land such that watershed scale conversion of agricultural lands to residential uses may decrease overall nutrient loads. On the other hand, conversion of forested land to residential use could significantly increase the level of nutrient loading unless mitigative measures are undertaken. An additional uncertainty exists in that the conversion of lands to residential and commercial uses has the potential to substantially alter the flow regimes of the tributaries to the lake by increasing storm flows and decreasing base flows. The net result of the altered flows may decrease the average residence time (of water in the reservoir) and thereby reduce the potential for eutrophication within Reidsville Lake.

Past assessments have shown that Reidsville Lake is consistently in a mesotrophic state. To date, no analysis has been performed to determine the magnitude of nutrient loading increase necessary to cause problematic water quality conditions within the reservoir. Rather than employing a more complex modeling approach, a scoping level nutrient analysis will be performed on Reidsville Lake. The scoping level analysis will be accomplished with Eutromod (Reckhow et al., 1992), a spreadsheet-based eutrophication modeling framework that includes watershed nonpoint and point source loading and lake response modules. Eutromod was developed specifically for

southeastern impoundments, and could be applied without a large investment of resources. A modeling framework of this nature could be used to examine various “what if” scenarios to determine the degree of landuse conversion that would be required to result in problematic levels of nutrient loading to the reservoir.

**OBJECTIVE #4: Establish baseline water quality conditions at locations across watershed for comparison to future conditions as land use changes occur.**

Indicators	Assessment Tool(s)	Purpose
Instream Water Quality Data	Synoptic monitoring by WARP Staff	Characterization
Instream Stormflow Data	Storm event sampling by WARP Staff	Characterization
Lake Water Quality Data (Lake Hunt & Lake Reidsville)	Storm Event Sampling by WARP Staff or NCDWQ Lakes Monitoring Program	Characterization
Benthic Macroinvertebrate Ratings	NCBI/EPT Monitoring by NCDWQ	Characterization
Fish Community Ratings	NCIBI Monitoring by NCDWQ	Characterization

NCDWQ does not maintain an ambient water quality monitoring station on Troublesome Creek or on any of its tributaries, and no detailed water quality studies have been conducted within the watershed. Benthic macroinvertebrate and fish community sampling have been conducted on Troublesome Creek, but as discussed in Section 2.2.3 of this report, each of these biological monitoring efforts have been conducted repeatedly at the same two respective sites. Consequently, very little data exists to characterize water quality and habitat conditions within the Troublesome Creek watershed as a whole. Comprehensive water quality and biological monitoring will be conducted by NCDWQ staff at sites throughout the watershed in order to establish baseline water quality conditions. Ideally, staff and resources permitting, some monitoring instances during storm flow conditions would be desirable. Recommendations for monitoring sites and parameters are provided in detail in Section 5.1.

### 4.3 DETAILED ASSESSMENT OBJECTIVES FOR LITTLE TROUBLESOME CREEK

**OBJECTIVE #1: Identify potential locations for stormwater BMP retrofits and determine which locations and what types of retrofits will provide the greatest benefits in terms of peak flow control vs. capital cost.**

Indicators	Assessment Tool(s)	Purpose
Peak Flow – Bankfull Storm Event	HEC-HMS/HEC-RAS	Predictive
Bank Erosion Potential	1) Critical Velocity from HEC-HMS/HEC-RAS	Predictive
	2) Stream Power Estimates from HEC-HMS/HEC-RAS	Predictive
Estimated Cost of BMP	Engineering Cost Analysis	Predictive

An investigation of alternatives to capture a portion of the runoff and mitigate peak flow impacts downstream will be performed. Alternatives investigated shall include engineered control devices and other stormwater best management practices, including detention/retention basins, wetland restoration, and channel restoration. As previously discussed, in order to be successful, the investigated alternatives to mitigate peak flow will most likely have to begin in the tributary and headwater portions of the watershed. Selection of potential locations for stormwater BMP retrofits is limited by topography and the extent of development within the watershed. Wherever possible, emphasis will be placed on retrofit scenarios that provide for the greatest reductions in sediment loading.

Upon identification of potential sites, analyses will be performed to determine the benefits of the alternatives in mitigating peak flow impacts to Little Troublesome Creek. A planning level cost estimate for each viable alternative will be prepared. Alternative selection will be performed based upon the ratio of the anticipated benefit vs. the capital cost.

**OBJECTIVE #2: Identify which headwater streams within the watershed are experiencing the greatest degrees of instability and associated stream erosion and prioritize them for restoration activities.**

Indicators	Assessment Tool(s)	Purpose
Percent Imperviousness (Existing)	GIS Analysis	Characterization
Riparian Buffer Disturbance	Aerial Imagery, Field Reconnaissance	Characterization
Stream Bank Condition	BEHI from Field Surveys	Characterization
Stream Bed Stability	Entrenchment Ratio & Bank Height Ratio	Characterization
Overall Stream Stability	Rosgen Level III Field Survey	Characterization
Rate of Stream Erosion	Direct Field Measure – Bank Pins & Scour Chains	Characterization

In order to determine which headwater and tributary segments of Little Troublesome Creek exhibit the greatest need for restoration, a stepwise series of analyses will be utilized which will apply an increasing level of characterization detail to prospective restoration segments. Initially, GIS analysis of remote sensed data will be used to provide scoping level indicators of where segments may be most in need of restoration. Assessments of imperviousness and riparian buffer disturbance have already been performed and presented in this report, and these assessments will be applied to individual stream segments to provide initial indicators of restoration potential.

In order to develop the HEC-HMS/HEC-RAS modeling framework necessary to fulfill OBJECTIVE #1 above, several cross sections will have to be surveyed on Little Troublesome Creek and its tributaries. At each of those cross section locations stream bank condition will be evaluated using the bank erosion hazard index (BEHI) method (Rosgen, 2001), which is based on the channel evaluation methodologies of Pfankuch (1975). The BEHI evaluates key stream bank characteristics sensitive to the various processes of erosion including bank height ratio (stream bank height/maximum bankfull depth), ratio of rooting depth/bank height, rooting density, percent surface area of bank protected, bank angle, number and location of various soil composition layers or lenses in the bank, and bank material composition. The BEHI values are converted to a risk rating of very low, low, moderate, high, very high, and extreme potential erodibility.

Qualitative characterization of bed stability can be performed with several measures proposed in the Level II and Level III assessment procedures developed by Rosgen (1996). Most relevant among these is the entrenchment ratio, which is a measure of the containment of a river channel within its flood plain, and the bank height ratio, which is a measure of channel incision. The data generated from the cross section surveys will also be utilized to generate these indicators of streambed stability in order to evaluate the need for restoration.

For the segments in which the above indicators show the greatest need for restoration, as project resources permit, full Rosgen Level III assessments of morphological condition will be performed. Detailed morphological field surveys will allow for an assessment of the degree of stream instability and will aid in estimating the projected cost of restoration for OBJECTIVE #3 below. In addition, where appropriate sites are discovered, quantitative assessment of bank erosion rates will be performed using bank pins and scour chains. Permanent transects with bank pins and scour chains will allow quantitative assessment of bank erosion rates and rates of substrate aggradation or degradation.

**OBJECTIVE #3: Determine which headwater segments exhibit the greatest degree of feasibility for restoration.**

Indicators	Assessment Tool(s)	Purpose
Infrastructure Constraints	GIS Analysis of Infrastructure	Characterization
Fragmentation of Ownership	GIS Analysis of Parcel Database	Characterization
Estimated Cost of Restoration	Field Survey/Professional Judgment	Characterization

The headwater portions of Little Troublesome Creek will present a challenging environment for stream restoration efforts, as is the case with restoration in most urban settings. The growth of the City of Reidsville over time has resulted in many facets of the urban infrastructure being located in the immediate riparian corridor. Water lines, sewer lines, roadways, and even buildings are located within the immediate corridor in many areas. Lateral constraints created by such manmade structures often limit the degree of meander that can be established in a stream restoration project, which reduces the types of restoration approaches that can be used. GIS coverages of these infrastructure features have been obtained from city and county GIS departments and will be utilized to evaluate and prioritize candidate restoration segments.

In addition to physical infrastructure, land ownership presents a challenge to restoration in urban settings. Ownership in much of the headwater areas of Little Troublesome Creek is fragmented among many small private landowners. GIS analysis of Rockingham County tax parcel records will be utilized to identify and prioritize candidate restoration sites that have the least fragmentation of ownership.

**OBJECTIVE #4: Continue water quality monitoring at a limited number of locations within watershed to track changes in water quality conditions and build on the database of water quality data begun by the Watershed Assessment and Restoration Program.**

Indicators	Assessment Tool(s)	Purpose
Instream Water Quality Data	Synoptic Monitoring by WARP Staff	Characterization
Instream Stormflow Data	Storm Event Sampling by WARP Staff	Characterization
Lake Water Quality Data (Lake Hunt & Lake Reidsville)	Storm Event Sampling by WARP Staff and/or NCDWQ Lakes Monitoring Program	Characterization
Benthic Macroinvertebrate Ratings	NCBI/EPT Monitoring by NCDWQ	Characterization
Fish Community Ratings	NCIBI Monitoring by NCDWQ	Characterization

NCDWQ maintains an ambient water quality monitoring station at the Mizpah Church Road crossing near the mouth of Little Troublesome Creek. In addition, several intensive study efforts have been undertaken to investigate the water quality and aquatic habitat problems in the creek. Over the last two years, WARP has developed an extensive database of physical, chemical and biological data from several sites within the watershed. Comprehensive water quality and biological monitoring by WARP staff should continue at a few select sites throughout the watershed in order to continue tracking changes in water quality conditions. Just as in the Troublesome Creek watershed, staff and resources permitting, some monitoring instances during storm flow conditions would be desirable. Recommendations for monitoring sites and parameters are provided in detail in Section 5.1.

## 5 Missing Data/Additional Data Needs

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The purpose of this section is to identify additional data needed to complete detailed assessment and development of local watershed plans for the study area watersheds. As previously discussed, the availability of water quality data in the Troublesome Creek watershed is fairly limited, while a great deal of data is available to characterize Little Troublesome Creek. Biological monitoring data tend to follow the same pattern in terms of availability in the two watersheds. The data needs described in this section are intended to provide the data to adequately describe baseline water quality and biological habitat conditions in Troublesome Creek, and to enhance the existing databases of water quality and biological data available for Little Troublesome. Additional data needs for this study fall into three primary categories:

- ◆ Biological and chemical monitoring data required for assessing use support within the study watersheds.
- ◆ Water chemistry and channel morphology data required to develop modeling tools that can identify the sources of aquatic habitat and water quality impairment, and to predict the effects of future land use and BMP scenarios.
- ◆ Data required for geomorphological characterization of stream channels and assessment of channel stability.

### 5.1 MONITORING DATA REQUIREMENTS

The primary objective of monitoring in the Troublesome Creek watershed is to effectively establish baseline water quality and biological conditions in order to assess the effect of changing land use patterns on water quality and biological community support over time. Ten monitoring sites were selected to collect data that would reflect a variety of landuse conditions within the watershed, and to strategically monitor areas where the greatest degree of landuse change is expected, such as the US Highway 220 corridor in the upper Troublesome Creek watershed. Some monitoring sites were specifically selected to monitor water quality immediately upstream or downstream of Lake Hunt and Lake Reidsville.

The primary objective of monitoring in Little Troublesome Creek is to continue enhancement of the existing databases of water quality and biological data accumulated through the efforts of NCDWQ, and in specific, the WARP program. In the interest of conserving staff and project resources, the monitoring effort recommended for Little Troublesome Creek has been reduced from the ten sites monitored with varying methods by WARP staff, to basic physical/chemical monitoring at five sites. In addition to the five monitoring sites recommended here, NCDWQ maintains an ambient water quality monitoring station at the Mizpah Church Road crossing near the mouth of Little Troublesome Creek. The combined set of monitoring sites recommended for the two watersheds are enumerated in Table 5 and shown on the map in Figure 31.

The importance of storm events in nutrient and sediment export from these watersheds is likely to be significant. A combination of monthly ambient sampling with seasonal storm peak samples is proposed. Storm peak samples should be taken either as multiple grab samples at each station, or preferably with automatic samplers. Seven stations are recommended for storm sampling which are shown in Figure 31, and the stations are assigned numeric rankings to indicate their strategic priority for storm sampling in Table 5. It is recommended that storm sampling be conducted at the NCDWQ ambient monitoring station at Mizpah Church Road in order to enhance monitoring at that site. NCDWQ/WARP stream sampling protocols should be followed for all monitoring. A field log entry and/or observation sheet should be completed at each sampling site.

**Table 5. Sites Proposed for Additional Water Quality Monitoring**

Site	Stream	Primary Landuse	Latitude	Longitude	Metals Site	Storm Sampling (Priority)
2	Troublesome Creek	Urban/Suburban	79 56 53 W	36 14 43 N	Y	Y (1)
6	Troublesome Creek	Composite	79 53 22 W	36 15 56 N		
9	Troublesome Creek	Composite	79 50 59 W	36 16 44 N		
12	UT to Troublesome Creek	Agriculture	79 49 20 W	36 17 49 N		Y (2)
15	Troublesome Creek	Agriculture	79 46 39 W	36 18 00 N		
20	Troublesome Creek	Composite	79 44 16 W	36 18 26 N	Y	Y (1)
21	Glady Creek	Agriculture	79 44 8 W	36 18 45 N		Y (3)
23	UT to Lake Hunt	Suburban	79 43 4 W	36 20 56 N	Y	Y (3)
24	UT to Troublesome Creek	Composite	79 43 32 W	36 19 17 N		
26	Troublesome Creek	Composite	79 38 59 W	36 16 36 N	Y	
29	Little Troublesome Creek	Urban/Suburban	79 40 38 W	36 20 34 N		
32	Little Troublesome Creek	Urban	79 39 37 W	36 19 49 N	Y	Y (2)
34	UT to Little Troublesome Creek	Urban	79 39 30 W	36 19 50 N	Y	Y (2)
37	Little Troublesome Creek	Urban/Suburban	79 38 54 W	36 18 41 N	Y	Y (1)
39	Troublesome Creek	Composite	79 36 41 W	36 16 57 N		Y (2)

The recommended water quality parameters for this monitoring effort were selected from among the suite of standard WARP monitoring parameters. The parameters were selected to assess relationships between land use patterns and nutrient, sediment, and fecal coliform bacteria concentrations. This dataset will also provide a baseline for assessment of future changes in stream water quality. The recommended parameters are enumerated in Table 6. The metals parameters listed are intended to apply only to those sites where metals monitoring is specified in Figure 31.

Cross-section surveys to support hydrologic modeling (refer to Section 4.2) will occur in the immediate vicinity of these sites and biological monitoring by DWQ will coincide with several of the recommended sites. The DWQ Biological Assessment Unit may take additional benthic samples from unspecified sites within the study area and in adjacent watersheds, and fish community monitoring may be conducted in each watershed on a limited basis.

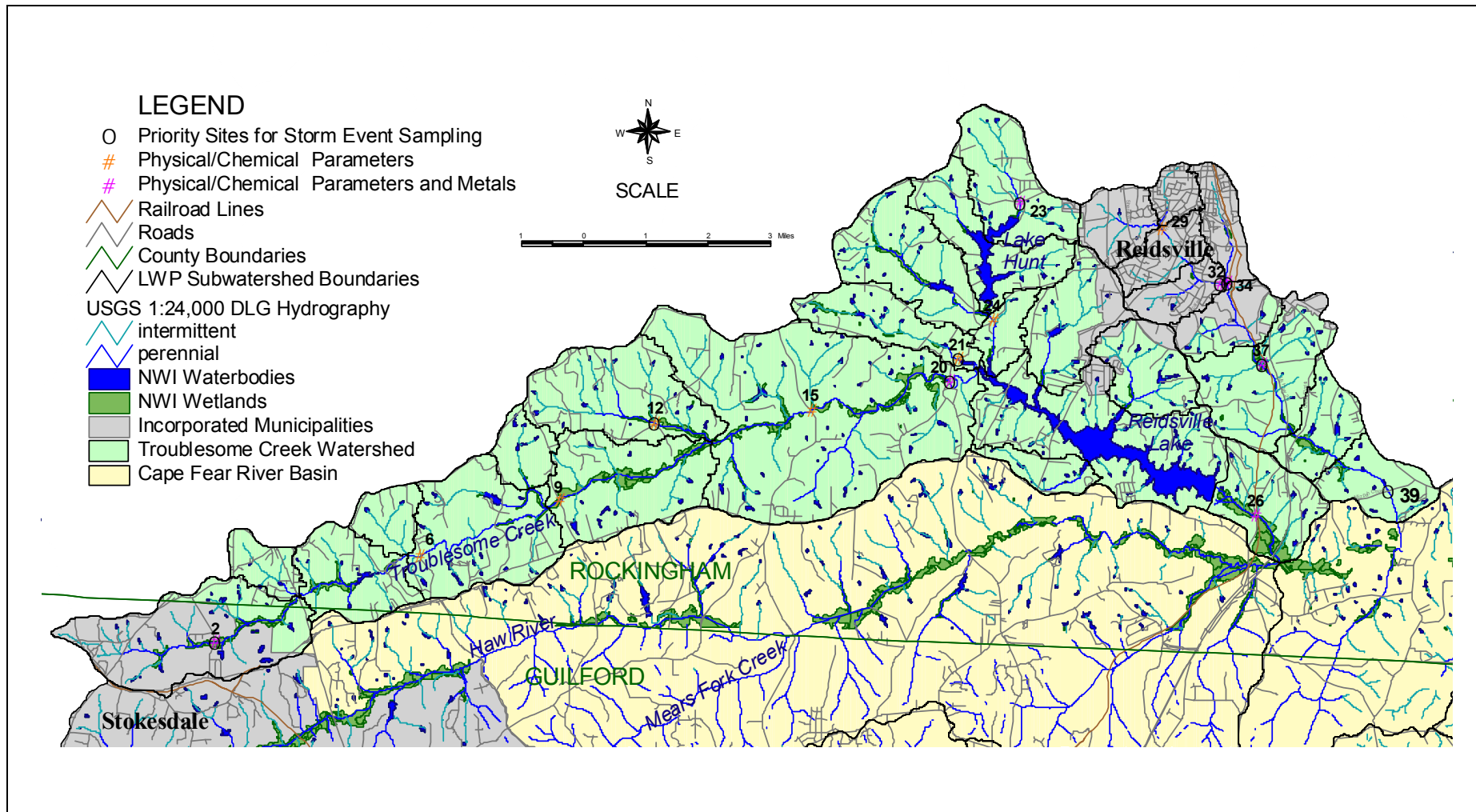


Figure 31. Sites Proposed for Additional Water Quality Monitoring

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**Table 6. Recommended Water Quality Parameters for Additional Monitoring**

Constituent	STORET Code	Purpose	Priority
Water Temperature, °C	00010	Biological Support	All Sites
Conductance	00094	Physical chemistry	All Sites
Dissolved Oxygen	00300	Biological Support	All Sites
pH	00400	Physical chemistry	All Sites
Turbidity	00076	Water Clarity	All Sites
Residue, Suspended	00530	Total suspended solids	All Sites
Residue, Volatile	00535	Organic suspended sediment	All Sites
Residue, Fixed	00540	Mineral suspended sediment	All Sites
Ammonia Nitrogen	00610	Inorganic Nitrogen	All Sites
Total Kjeldahl Nitrogen	00625	Organic Nitrogen	All Sites
Nitrite/Nitrate	00630	Inorganic Nitrogen	All Sites
Total Phosphorus	00665	Total Phosphorus	All Sites
Fecal Coliform	31616	Fecal loads	All Sites
BOD <sub>5</sub>	00310	Oxygen Demand	All Sites
Total Aluminum	00310	Aluminum Loading	Metals Sites Only
Total Arsenic	01002	Arsenic Loading	Metals Sites Only
Total Cadmium	01027	Cadmium Loading	Metals Sites Only
Total Calcium	00916	Calcium Loading	Metals Sites Only
Total Copper	01042	Copper Loading	Metals Sites Only
Total Iron	01045	Iron Loading	Metals Sites Only
Total Lead	01051	Lead Loading	Metals Sites Only
Total Magnesium	00927	Magnesium Loading	Metals Sites Only
Total Manganese	01055	Manganese Loading	Metals Sites Only
Total Mercury	32209	Mercury Loading	Metals Sites Only
Total Nickel	01067	Nickel Loading	Metals Sites Only
Total Silver	01077	Silver Loading	Metals Sites Only
Total Zinc	01092	Metals	Metals Sites Only

## 5.2 MODELING DATA REQUIREMENTS

Development of the HEC-HMS/HEC-RAS modeling framework for the two watersheds will require surveys of stream cross-sections at regular intervals throughout the study area. Cross-sectional area data will also be required to generate velocity and stream power estimates for use as indicators of erosion potential (refer to section 4.1, Objective #5). Beyond the cross-section data, measurements of stream channel slope will be required at each location for which stream power estimates will be generated.

Thirty-six sites throughout the Troublesome Creek and Little Troublesome Creek watersheds have been selected as locations for the required cross-section surveys and associated velocity and stream power estimates. The selected sites are enumerated in Table 7 and mapped in Figure 32. The sites were selected to provide the degree of spatial resolution necessary to support model development and to reflect a variety of soil types and landuse conditions within the study area. Accessibility was also a primary factor in site selection, so many of the survey sites are located near roadway crossings. For those locations, actual survey data will be measured at sufficient distances away from bridges and culverts to reflect natural stream conditions. Surveys at each site will consist of one pool and one rifle cross-section. Within the constraints of accessibility, an effort was made to locate at least one survey site within each LWP subwatershed.

Channel cross-sections will extend past the top of bank by a minimum of 50 feet on each side, and will identify all changes of grade, each top of bank, and all edges of water. If elevation reference marks are easily accessible, the surveys will be referenced to the known elevation datum. In addition to the cross-section and channel slope data necessary to support model development, a bank erosion hazard index (BEHI) will be estimated at each survey site. BEHI estimates will be developed according to the methods defined by Rosgen (2001). The data collected at each survey site will also allow for calculation of bank height ratio and entrenchment ratio.

Several of the Assessment Objectives enumerated in Chapter 4 involve prediction of impacts associated with future landuse conditions within the two watersheds. In order to generate such predictions, it will be necessary to develop a realistic projection of future landuse within the study area. One hypothetical "buildout scenario" can be easily generated by assuming that all parcels would be developed to their maximum capacity according to current zoning. While this scenario may be useful for illustrating the predicted impacts of future growth, it is hardly realistic. For instance it is highly unlikely that owners of larger homes and lots in the southwestern portion of the City of Reidsville, near the golf course and country club, will suddenly begin subdividing their properties in order to achieve maximum allowable housing densities. By the same token, the majority of the Troublesome Creek watershed is zoned RA (Rural-Agricultural) according to Rockingham County zoning ordinances, which allows up to 12% impervious cover. It is unlikely that the whole watershed would be developed uniformly to this level, which generally corresponds to 1-2 acre lot sizes. Rather, it is much more realistic that some areas of the watershed, where factors like topography and infrastructure are less accommodating to development, will maintain their rural character, while other areas are developed to suburban landuses with some higher density commercial development to serve those populations. Formulation of a realistic future landuse scenario will require the active input of local planners and stakeholders, and the LWP project team will work with them to cultivate that input and develop realistic projections of future landuse.

### 5.3 STREAM CHANNEL GEOMORPHOLOGY DATA REQUIREMENTS

Detailed geomorphological assessments may be performed on selected stream reaches throughout the study area as deemed necessary. In the course of performing the initial cross-section surveys described above, project team members may identify stream segments that are actively unstable and in need of restoration. After subwatersheds have been prioritized for restoration activities and stream segments have been identified within those subwatersheds as having significant restoration potential, to the extent allowed by remaining project resources, detailed geomorphological surveys will be performed to quantify that restoration potential and estimate the associated costs.

Field data requirements for assessment of geomorphology using the Rosgen Level II and Level III techniques can be summarized with the terms dimension, pattern, and profile. Dimension refers to the cross-sectional dimension of the stream channel using survey tapes and levels. Pattern represents the plan view of stream, or its pattern on the land. Profile refers to the channel gradient, or elevation profile.

Detailed geomorphological surveys may include stream class, slope, shape, sinuosity, meander width, channel cross-section, flood prone width, entrenchment ratio, width/depth ratio, channel materials, riparian vegetation, flow regime, debris characterization, stream size and order, stream bank erosion potential (BEHI), channel stability rating, sediment size median (D50) and size distribution, and sediment depth. Geomorphological data will be collected using techniques described by Rosgen (1996) and Pfankuch (1975).

**Table 7. Sites Proposed for Stream Cross-section Surveys**

Site	Stream	Location	Longitude	Latitude
1	Troublesome Creek	NC Highway 68	79 58 28 W	36 14 33 N
2	Troublesome Creek	Southard Rd.	79 56 53 W	36 14 43 N
3	Troublesome Creek	US Hwy 220	79 55 27 W	36 15 22 N
4	UT to Troublesome Creek	US Hwy 220	79 55 28 W	36 15 25 N
5	Troublesome Creek	Price Mill Rd.	79 53 57 W	36 15 44 N
6	Troublesome Creek	Haynes Rd.	79 53 22 W	36 15 56 N
7	Troublesome Creek	Hudson Rd.	79 52 4 W	36 16 24 N
8	UT to Troublesome Creek	Hudson Rd.	79 51 57 W	36 16 40 N
9	Troublesome Creek	Witty Rd.	79 50 59 W	36 16 44 N
11	Troublesome Creek	South of Pinewood Rd. dead end, upstream of UT	79 48 24 W	36 17 33 N
12	UT to Troublesome Creek	Brown Rd.	79 49 20 W	36 17 49 N
13	UT to Troublesome Creek	Near mouth, south of Pinewood Rd. dead end	79 48 23 W	36 17 35N
14	Troublesome Creek	South of Pinewood Rd. dead end, downstream of UT	79 48 19 W	36 17 33 N
15	Troublesome Creek	Woolen Store Rd.	79 46 39 W	36 18 00 N
16	UT to Troublesome Creek	South from end of Wright Dairy Rd.	79 46 9 W	36 17 30 N
18	UT to Troublesome Creek	Near mouth, upstream of Troublesome Creek	79 45 48 W	36 17 55 N
20	Troublesome Creek	Monroeton Rd.	79 44 16 W	36 18 26 N
21	Gladly Creek	Iron Works Rd.	79 44 8 W	36 18 45 N
22	UT to Troublesome Creek	Boyd Rd.	79 43 51 W	36 19 24 N
23	UT to Lake Hunt	Irvin Farm Rd.	79 43 4 W	36 20 56 N
24	UT to Troublesome Creek	Iron Works Rd.	79 43 32 W	36 19 17 N
25	UT to Lake Reidsville	0.5 miles downstream of Clark Lake Rd.	79 42 39 W	36 18 37 N
26	Troublesome Creek	US Hwy 29 - Business	79 38 59 W	36 16 36 N
27	Little Troublesome Creek	Sherwood Dr.	79 41 16 W	36 20 38 N
28	UT to Little Troublesome Creek	Coach Rd.	79 40 40 W	36 20 39 N
29	Little Troublesome Creek	Richardson Dr.	79 40 38 W	36 20 34 N
30	Little Troublesome Creek	Park Dr.	79 40 21 W	36 20 13 N
31	Little Troublesome Creek	City park upstream Scales St.	79 39 58 W	36 19 52 N
32	Little Troublesome Creek	End of Industrial Dr.	79 39 37 W	36 19 49 N
33	UT to Little Troublesome Creek	Turner Dr.	79 39 25 W	36 20 20 N
34	UT to Little Troublesome Creek	Near mouth at end of Industrial Dr.	79 39 30 W	36 19 50 N
35	Little Troublesome Creek	At Reidsville WWTP	79 39 21 W	36 19 17 N
36	UT to Little Troublesome Creek	Near mouth at Reidsville WWTP	79 39 21 W	36 19 15 N
37	Little Troublesome Creek	NC Hwy 87	79 38 54 W	36 18 41 N
38	Troublesome Creek	Cook Florist Rd.	79 38 15 W	36 17 41 N
39	Troublesome Creek	Mizpah Church Rd.	79 36 41 W	36 16 57 N

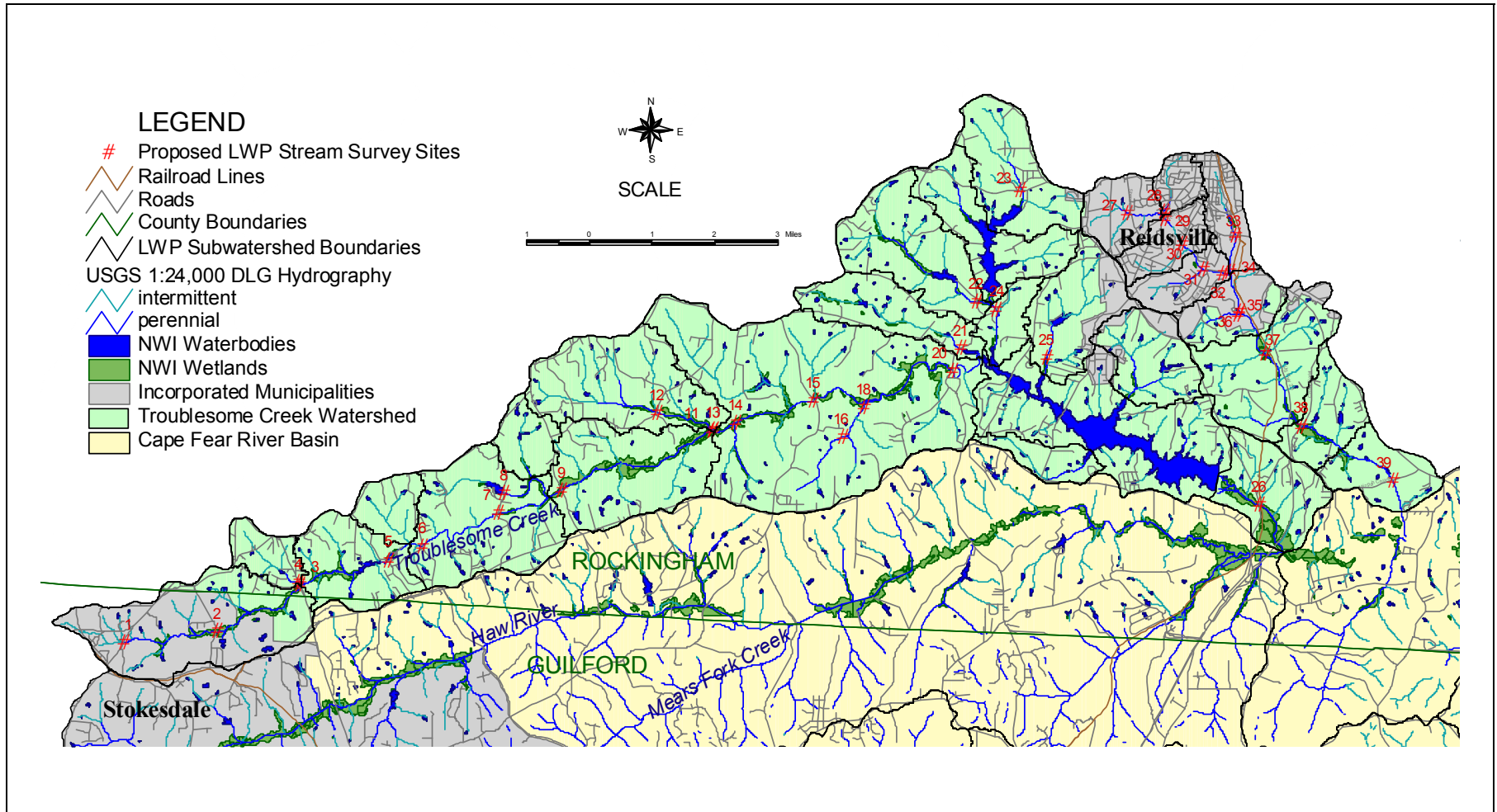


Figure 32. Sites Proposed for Stream Cross-section Surveys

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## Appendix A. Detailed Subwatershed Maps

- Map 1 Troublesome Creek Headwaters Subwatersheds T1-T4
- Map 2 Upper Troublesome Creek Subwatersheds T5-T8
- Map 3 Middle Troublesome Creek Subwatersheds T9-T10
- Map 4 Lake Hunt Vicinity Subwatersheds T11-T14
- Map 5 Lake Reidsville Vicinity Subwatersheds T15-T19
- Map 6 Upper Little Troublesome Creek Subwatersheds LT1-LT6
- Map 7 Lower Little Troublesome Creek Subwatersheds LT7-LT9
- Map 8 Landuse/Land Cover within Troublesome Creek Watershed Subwatersheds T1-T4
- Map 9 Landuse/Land Cover within Troublesome Creek Watershed Subwatersheds T4-T8
- Map 10 Landuse/Land Cover within Troublesome Creek Watershed Subwatersheds T9-T10
- Map 11 Landuse/Land Cover within Troublesome Creek Watershed Subwatersheds T11-T14
- Map 12 Landuse/Land Cover within Troublesome Creek Watershed Subwatersheds T14-T19
- Map 13 Landuse/Land Cover within Little Troublesome Creek Watershed Subwatersheds LT1-LT6
- Map 14 Landuse/Land Cover within Little Troublesome Creek Watershed Subwatersheds LT7-LT9

(Attached separately)

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## Appendix B. Detailed Analysis of Impervious Surfaces

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# 1 Methods

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## 1.1 OVERVIEW

Man-made impervious cover can be divided into two classes – rooftops and transport systems (Schueler, 1995). Rooftops are easy to locate, and municipalities and counties frequently compile this information, called planimetric data, for zoning purposes. Recent planimetric coverages were available for the entire study area. However, the transport system portion (roads, sidewalks, parking lots) can be more difficult to quantify. While coverages showing road locations are usually available, the actual surface areas of roads, parking lots, sidewalks, and other impervious surfaces are rarely compiled into GIS coverages. Other impervious surfaces may also be significant, such as patios and swimming pools.

The majority of work in this analysis involved estimating the amount of imperviousness from transport systems and other sources. For the purposes of this document, “extra imperviousness” means the combination of impervious surfaces from transport systems and other sources – in other words, anything beyond rooftop area. High-resolution aerial photographs were available for much of the study area, and these were used to locate additional impervious surfaces. These surfaces were sampled, and mathematical and statistical methods were used to estimate extra imperviousness for the remainder of the study area.

Road coverages with right-of-way boundaries were used to estimate the roadway contribution to imperviousness. Several samples of road width were taken in the City of Reidsville and Rockingham County to determine average road width.

A parcel coverage of Rockingham County (with zoning class defined for each parcel) was used as the basis for sampling the remaining extra imperviousness. Extra imperviousness is directly related to how a landowner uses the parcel, which is usually related to its zoning class. For instance, a farm will have very little extra imperviousness, since dirt and gravel roads predominate. A single-family detached home will have a moderate amount of extra imperviousness, depending on whether the driveway is paved and the relative size of sidewalks and patios. A shopping center will have a high degree of extra imperviousness due to the size of the parking area needed to serve the building. As a result, zoning classes with a large number of parcels were sampled, and best-fit statistical relationships were developed separately for each zoning class.

Once extra imperviousness was estimated for each parcel using the relationships, these estimates were imported back into the GIS parcel coverage. Total imperviousness was then measured for each subwatershed as the sum of building areas (as defined from the planimetric coverages), the estimate of roadway imperviousness, and the estimate of extra imperviousness within each parcel.

GIS data used in this analysis are described in Table B-1. The most upstream portion of the Troublesome Creek watershed is located in Guilford County, whose GIS data differed somewhat from the Rockingham County GIS Data. Calculations were performed using Rockingham County data first, and then the methods were modified for the Guilford County data.

**Table B-1. GIS Data Used in Imperviousness Analysis**

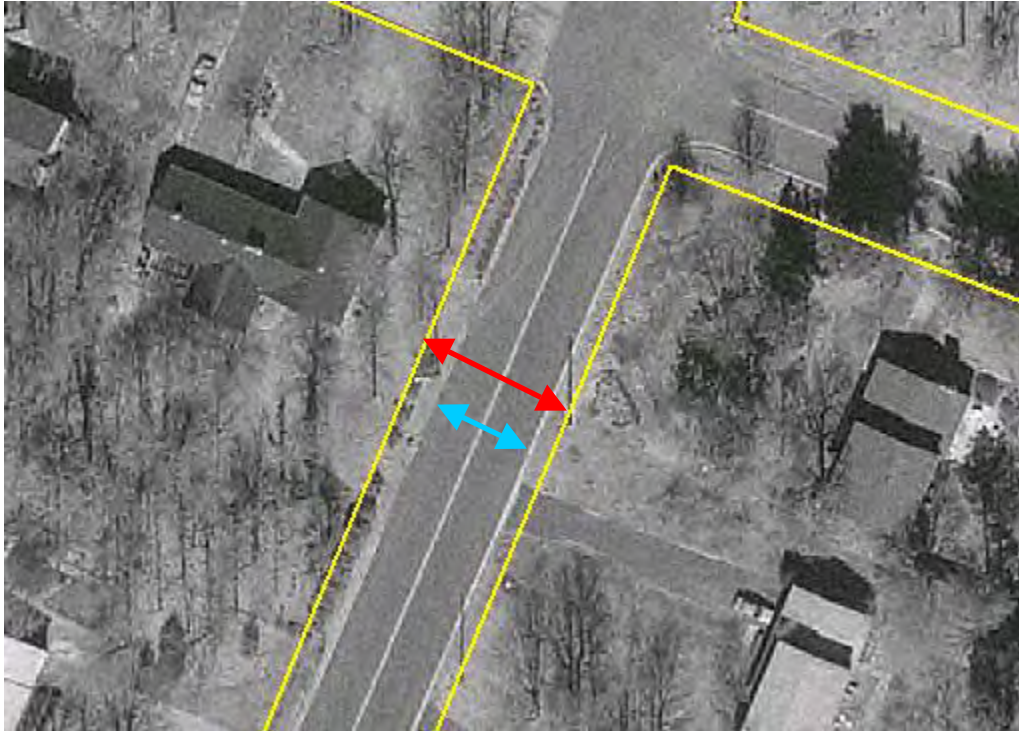
Type	Location	Description
Watershed Boundaries	Study Area	Outer boundary from USGS coverage of 14-digit HUC boundaries. Inner subwatershed boundaries determined by flow accumulation algorithm using ArcView Spatial Analyst on USGS 1:24,000 DEMs. Subwatershed boundaries were delineated specifically for this watershed planning effort (see Sections 2.1.1 and 3.1.1).
Aerial Photographs	Rockingham County	Digital ortho photographs, black and white. Combination of 1/16 <sup>th</sup> quads, 1/4 quads, and entire quads. Source was Rockingham County GIS Dept. Data from 1993.
Parcel	Rockingham County	Parcel coverage of Rockingham County. Ancillary data included zoning class (city or county). Source was Rockingham County Planning Dept. Data from 2001.
Zoning	Guilford County	Zoning coverage of Guilford County and Stokesdale area (parcel data not available). Source was Guilford County. Data from late 2001.
Planimetric	Rockingham County	Planimetric coverage of Rockingham County. Source was Rockingham County Planning Dept. Data from 2000-2001.
Planimetric	Guilford County	Planimetric coverage of Guilford County. Source was Guilford County. Data from 1995.
Roads	Rockingham County	Road right-of-way polygon coverage of Rockingham County. Right-of-way polygons were extracted from the Rockingham County parcel coverage.
Roads	Guilford County	Road centerline coverage of Guilford County. Source was Guilford County. Data from late 2001.

## 1.2 ESTIMATION OF ROADWAY IMPERVIOUSNESS

### 1.2.1 Reidsville City and Rockingham County

The Rockingham County right-of-way coverage contained polygons that defined the extent of the right-of-way surrounding all roads. A random sample of road widths and right-of-way widths was taken (48 samples in the county, 12 samples in Reidsville, and 10 samples of the Highway 29 right-of-way). An example is shown in Figure B-1. The right-of-way coverage (yellow outline) includes the road and surrounding pervious areas. The width of right-of-way (red arrow) and the road (blue arrow) were measured in ArcView. A ratio of impervious width to right-of-way width was calculated (0.390 for the county, 0.666 for Reidsville, and 0.402 for the Highway 29 right-of-way). The Reidsville ratio was utilized for the portion of the right-of-way coverage falling within the city limits in the Little Troublesome Creek watershed. The Highway 29 ratio was used specifically for the portion of the right-of-way coverage surrounding Highway 29. The county ratio was utilized in the remainder of the study area.

The subwatershed coverage was intersected with the right-of-way coverage to find the right-of-way area within each subwatershed. The product of those areas and the road to right-of-way ratio provided an estimate of the area of roadway imperviousness within each subwatershed.



**Figure B-1. Example of Right-of-Way Imperviousness Measurement**

## 1.2.2 Guilford County

A right-of-way coverage was not available for Guilford County, so the Guilford County road centerline coverage was used instead. An average of the road width measurements collected in Rockingham County (24.4 ft) was used as a surrogate for road width in Guilford County. The two subwatersheds with portions in Guilford County were intersected with the road centerline coverage. The total length of all the roads in each of the two subwatersheds was summed and multiplied by the average road width to obtain an estimate of the area of roadway imperviousness within each subwatershed.

## 1.3 ESTIMATION OF EXTRA IMPERVIOUSNESS

### 1.3.1 Reidsville City and Rockingham County

A coverage of the study area was intersected with the Rockingham County parcel coverage to define the extent of parcels to be used in the analysis. A list of unique zoning codes was obtained from the new parcel coverage. A few zoning classes were combined; for instance, all that had a conditional use subclass (CU) were combined with their parent groups. The resulting list, and the number of acres of each in the study area, is presented in Table B-2. Some codes were not documented in city or county ordinances. The county zoning class RA (Residential-Agricultural District) occupies the majority of the study area, 80%.

**Table B-2. Reidsville City and Rockingham County Zoning Codes Evaluated in the Study Area**

Zoning	Acres	% of Area	Description	Used by
CB/RD	5.2	0.01%	Business, Central	City
CS	3.1	0.01%	Community Shopping District	County
GB/RD	115.2	0.29%	Business, General	City
HB/RD	281.8	0.71%	Business, Heavy	City
HC	19.0	0.05%	Highway Commercial District	County
HI	134.3	0.34%	Heavy Industrial District	County
I1LTR	779.5	1.97%	Light Industrial	City
I2H1R	234.8	0.59%	Heavy Industrial	City
LI	63.6	0.16%	Light Industrial District	County
MH/RD	0.8	0.00%		Unknown
MIXED	178.3	0.45%		Unknown
NB/RD	8.8	0.02%	Business, Neighborhood	City
OI	56.2	0.14%	Office and Institutional District	County
OI/RD	42.5	0.11%	Combines City and County Code	Unknown
R12RD	601.4	1.52%	Residential, Medium Density	City
R20RD	1,815.4	4.60%	Residential, Low Density	City
R6RD	215.8	0.55%	Residential, High Density	City
RA	31,575.3	79.99%	Residential-Agricultural District	County
RA/HI	1.2	0.00%	See RA and HI	County
RA/OI	18.1	0.05%	See RA and OI	County
RA/RM	68.9	0.17%	See RA and RM	County
RA/RP	394.6	1.00%	See RA and RP	County
RA20R	819.9	2.08%	Residential Agricultural	City
RM	342.8	0.87%	Residential-Mixed Residential District	County
RP	1,406.2	3.56%	Residential-Protected District	County
RS12R	245.7	0.62%	Residential, Medium Density	City
SC/RD	46.1	0.12%		Unknown

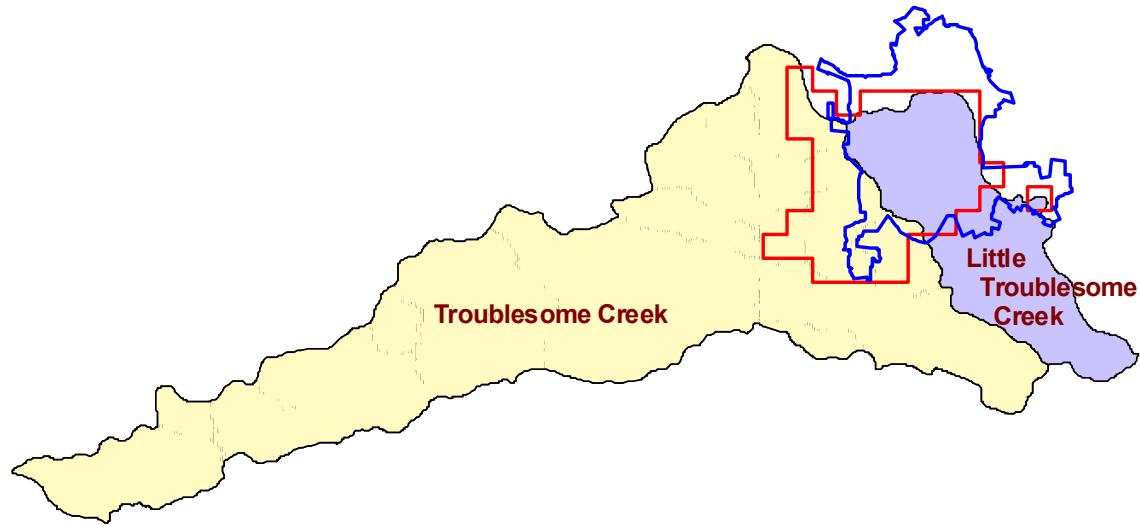
The underlying assumption is that extra imperviousness is related to the zoning class. Therefore, extra imperviousness was always determined for individual parcels, not for specific areas. This was done in ArcView by digitizing with a mouse the impervious areas within specified parcels. An example of this is shown in Table B-2; the red boundaries define parcels which were sampled for extra imperviousness, the blue hatched zones are building planimetric areas, and the green hatched zones were digitized by drawing around the areas that looked like pavement, patios, swimming pools, out-buildings not defined in the planimetric data, etc. For the purposes of this analysis, the Project Team assumed that unpaved areas, such as dirt or gravel driveways, were somewhat permeable to rainfall and therefore not included in estimates of extra imperviousness. This analysis will be used to assess risk and prioritize areas for restoration, so the assumption that unpaved roads are pervious does not adversely affect the results. However, some adjustment should be made to the results if the impervious estimates are used in modeling applications.



**Figure B-2. Example of Sampled Parcels, Building Planimetrics, and Digitized Extra Impervious Areas**

This method has several limitations. Some features were difficult to digitize; for instance, sidewalks in residential areas were generally not included. It was difficult to establish “exact” boundaries due to time constraints, so a balance between accuracy and utility had to be made. It was frequently difficult to tell if a driveway or parking lot was paved or unpaved. The method was limited for the most part to those areas where the highly detailed 1/16<sup>th</sup> ortho photos were available (red outline in Figure B-3). The lower resolution photos lacked the clarity needed to identify impervious areas. Generally the 16<sup>th</sup> ortho photos were located near Reidsville, shown with the blue outline. However, the majority of the study site was located in the county, outside of the area where parcels could be sampled readily. As a result, extra effort was expended on sampling parcels in the RA zoning class, which comprised the majority of the study site.

Each zoning class was evaluated individually to determine the appropriate sampling method. Some zoning classes could be partially or wholly sampled. Other zoning classes had many parcels, making it impossible to sample all the parcels within those classes. In those cases, a random number generator (Press et al., 1986) was used to select approximately 10%, 20%, or 35% of the parcels within a class. Parcels were not uniform in size in some of those classes, and did not necessarily follow normal distributions, so the Kolmogorov-Smirnov test was used to ensure that the cumulative distribution function of the sample was not significantly different from the population from which it was drawn. Table B-3 shows details of the sampling methodology for each zoning class. Note that most samples were taken in the area of high resolution aerial photography. A few of the classes were not sampled since none of their parcels fell within the high resolution zone.



**Figure B-3. Location of High Resolution Ortho Photos (red) and City of Reidsville (blue)**

After extra imperviousness was digitized in each of the sampled parcels, the total area of building footprints and total area of extra imperviousness was found for each parcel using ArcView. These figures and the parcel area were exported for statistical analysis.

The basis of the statistical analysis was the assumption that extra imperviousness is related to parcel size and/or to building area, and that these relationships can be measured statistically. For instance, a farm might be large or small, but the amount of impervious surface (mostly driveways) is likely related to the presence and size of the buildings. On the other hand, an office park could have impervious surfaces (mostly parking lots) related to the parcel size or building area, or both.

Single and multiple regression were chosen as the appropriate tools for developing these relationships. The extra impervious area was the dependent variable and building area and parcel area were independent variables. The intercept was set to zero in the regression so that the model would more closely represent the real relationships between the variables. In a zero-intercept model, the dependent variable approaches zero as the independent variables approach zero. This makes sense for the model, since extra impervious area should be zero when the parcel area is zero.

**Table B-3. Proportion of Zoning Classes Sampled and Sampling Methodology for Each Zoning Class.**

Zoning	Total Parcels	Sampled Parcels	% Parcels Sampled	% Area Sampled	Sampling Method
CB/RD	17	12	70.6%	69.7%	Sample all in high resolution zone
CS	7	2	28.6%	21.6%	Sample all in high resolution zone
GB/RD	160	38	23.8%	19.8%	Sample ~20% in high resolution zone
HB/RD	114	18	15.8%	13.6%	Sample ~20% in high resolution zone
HC	20	0	0.0%	0.0%	Sample none
HI	20	20	100.0%	100.0%	Sample all in study area
I1LTR	132	32	24.2%	9.5%	Sample ~20% in high resolution zone
I2H1R	25	25	100.0%	100.0%	Sample all in study area
LI	8	0	0.0%	0.0%	Sample none
MH/RD	1	1	100.0%	100.0%	Sample all in study area
MIXED	9	9	100.0%	100.0%	Sample all in study area
NB/RD	26	26	100.0%	100.0%	Sample all in study area
OI	56	25	44.6%	41.4%	Sample ~35% in high resolution zone
OI/RD	60	29	48.3%	31.6%	Sample ~35% in high resolution zone
R12RD	901	86	9.5%	7.4%	Sample ~10% in high resolution zone
R20RD	900	66	7.3%	2.9%	Sample ~10% in high resolution zone
R6RD	696	156	22.4%	21.8%	Sample ~20% in high resolution zone
RA	2646	209	7.9%	5.9%	Sample all in high resolution zone
RA/HI	1	0	0.0%	0.0%	Sample none
RA/OI	1	0	0.0%	0.0%	Sample none
RA/RM	3	0	0.0%	0.0%	Sample none
RA/RP	34	12	35.3%	65.6%	Sample all in high resolution zone
RA20R	217	40	18.4%	11.6%	Sample ~20% in high resolution zone
RM	189	11	5.8%	1.9%	Sample all in high resolution zone
RP	1004	42	4.2%	2.5%	Sample ~10% in high resolution zone
RS12R	411	65	15.8%	11.2%	Sample ~20% in high resolution zone
SC/RD	6	6	100.0%	100.0%	Sample all in study area

The appropriateness of a single or a multiple regression model was evaluated for each zoning class. Initially, the multiple regression was performed. In most cases, the  $\beta$  (model coefficient) of one of the independent variables would have a highly significant probability value (p-value) while the other independent variable would have a p-value with poor significance. A highly significant p-value indicates there is a very low probability that the relationship between the variables is caused by chance, while a poorly significant p-value indicates a high probability that the relationship is caused by chance. A simple regression was then performed with the independent variable with the highly significant p-value. The models were compared, and the “best” one selected for estimating extra impervious area in the unsampled parcels.

The models were compared by calculating the  $F_p$  statistic for comparing the full (two independent variable) and reduced (one independent variable) models (Kleinbaum et al., 1998):

$$F_{p(k-p, n-k-1)} = \frac{\left[ \frac{SSE_p - SSE_k}{k - p} \right]}{MSE_k}$$

where

- k = number of independent variables in the full model
- p = number of independent variables in the reduced model
- n = number of observations
- SSE<sub>k</sub> = residual sum of squares for the full model
- SSE<sub>p</sub> = residual sum of squares for the full model
- MSE<sub>k</sub> = mean squared error for the full model

The F<sub>p</sub> statistic can be translated into a p-value. If the p-value is not significant (indicating a high probability that the relationship is caused by chance), then the one variable model should be selected. The critical p-value was chosen as p < 0.20 – in other words, less than a 20% probability that the relationship is caused by chance.

While the intercept was set to zero, variability in the model leads to cases where the model may calculate negative impervious area or imperviousness greater than the parcel area. Numerical adjustments were made to prevent this from occurring. Details of those adjustments and an evaluation of their influence on the results follow.

The models and related statistics are presented in Table B-4. Some of the zoning classes had too few (or no) parcels to develop models, so models from similar zoning classes were applied to those classes (Table B-5). The remaining classes were entirely sampled (Table B-5). The HB/RD (Heavy Business, City) model was applied to the CS (Community Shopping, County) and HC (Highway Commercial, County) classes because the classes were similar and they had comparable percent impervious totals from building areas. The IILTR (Light Industrial, City) model was applied to the LI (Light Industrial, County) class. The RA (Residential-Agricultural, County) model was applied to several categories all of which were a composite of the RA class and other county classes. One of those was the RA/RP class, 65% of which was sampled on an area basis. There were too few parcels in the 65% to produce a good model, so the RA model was selected for the remaining 35%. The RP (Residential-Protected, County) model was applied to the RM (Residential-Mixed, County) class. The few parcels of the RM class that could be sampled did not appear to be representative from a visual examination of the study area. The RA model was considered, but parcels in the RM class tended to be associated with or located near RP parcels, so the RP model was chosen.

**Table B-4 Zoning Class Regression Model and Statistics**

Zoning	Parcel $\beta$	Building $\beta$	Model p-level	Std error (ft <sup>2</sup> )	Parcel p-level	Building p-level
CB/RD	0.4335		<0.001	4767	<0.001	
GB/RD	0.4262	0.3838	<0.001	5549	<0.001	0.165
HB/RD		2.348	<0.001	7751		<0.001
I1LTR		0.4222	<0.001	15665		<0.001
OI		1.628	<0.001	6813		<0.001
OI/RD	0.1993	1.304	<0.001	5023	0.004	0.013
R12RD	0.1550		<0.001	5690	<0.001	
R20RD		0.6417	<0.001	1450		<0.001
R6RD		0.3199	<0.001	849		<0.001
RA	-0.000364	0.4435	<0.001	4814	0.194	<0.001
RA20R		0.5627	<0.001	1688		<0.001
RP		0.4436	<0.001	993		<0.001
RS12R		0.2664	<0.001	603		<0.001

**Table B-5. Models Applied to Remaining Zoning Classes, and Classes not Requiring Models**

Zoning	Model
CS	HB/RD
HC	HB/RD
LI	I1LTR
RA/HI	RA
RA/OI	RA
RA/RM	RA
RA/RP	RA
RM	RP
HI	n/a*
I2H1R	n/a*
MH/RD	n/a*
MIXED	n/a*
NB/RD	n/a*
SC/RD	n/a*

\* All parcels sampled, no model needed.

The regressions coefficients were used to estimate extra imperviousness for the parcels that were not sampled. There were two potential problems that were corrected. It was possible for some of the models to predict negative extra impervious area. In those cases, the extra impervious area was set to zero. It was also possible to estimate extra impervious area such that the sum of building and extra impervious area was greater than the parcel size. In those cases the extra impervious area was reduced to the difference between parcel size and building area.

Within sampled parcels, 92.8 acres of impervious area were measured. For the remaining parcels, 327.0 acres of extra impervious area were estimated. The overall change in estimated impervious area by applying the two corrections was +1.76 acres (+3.23 for removing negative impervious area and -1.47 acres for the parcel size correction). The overall change represents less than 1% of the estimated area.

Modeled and measured extra impervious area was imported back into ArcView. The modified parcel coverage was intersected with the subwatershed coverage to obtain parcels within each subwatershed. Many parcels spanned subwatershed boundaries, so the areas of those parcels were recalculated to apportion their areas between the subwatersheds. Imperviousness was also apportioned between subwatersheds in those cases, and a final extra impervious area was calculated for each subwatershed. In the Little Troublesome Creek watershed, extra impervious area was also calculated separately for the areas inside and outside the Reidsville city limits.

## 1.4 GUILFORD COUNTY

Estimating extra impervious area in Guilford County was more challenging, since there was neither high-resolution aerial photography available nor a true parcel coverage. A zoning coverage was available, which tended to have parcels of identical zoning aggregated together. A building planimetric coverage was also available.

The project team assumed that relationships developed in Rockingham County would be applicable in Guilford County. The portion of the study area in Guilford County is small relative to the overall study area (6.7%), and most of the Guilford County portion is rural and should have a low amount of extra imperviousness, so the error is likely to be minimal.

Any relationship applied to the Guilford County data must be based on building area since parcel area is not available. Guilford County zoning codes contained in the study area and the models selected are shown in Table B-6. Many of the regression models are based on building area and not parcel area, so those models appropriate to the zoning class were used on the zoning polygons. The overall ratio of extra impervious area to building area for the HI class (which was sampled entirely) was used for the Heavy Industrial Guilford County zoning classes. The RP model was used for residential classes, the OI model was used for general business, office, and institutional classes, and the IILTR model was used for the Light Industrial class.

Extra impervious area was processed in an identical manner as discussed previously, except that the models were applied to the zoning polygons instead of individual parcels. The overall change in estimated impervious area after the two corrections were applied was zero acres – none of the parcels required adjustment.

## 1.5 ESTIMATION OF BUILDING IMPERVIOUSNESS

Both the Rockingham County and Guilford County building planimetric coverages were intersected with the subwatershed coverage, and the building areas totaled for each subwatershed. In the Little Troublesome Creek watershed, building area was also calculated separately for the areas inside and outside the Reidsville city limits.

**Table B-6. Guilford County Zoning Codes and Models Applied to Them**

Zoning	Description	Building $\beta$	Comment
AG	Agricultural	0.4174	RA building only model*
CU-LO	Limited Office	n/a	No buildings, extra imperv set = 0
CU-PD-M	Planned Unit - Mixed	0.4434	RP model
GB	General Business	1.628	OI model
GO-M	General Office	1.628	OI model
HB	Highway Business	1.628	OI model
HI	Heavy Industrial	0.504	HI extra/blg ratio
LB	Limited Business	1.628	OI model
LI	Light Industrial	0.4222	I1LTR model
PI	Public/Institutional	1.628	OI model
RS-30	Large Lot Residential	0.4434	RP model
RS-30-MH	Large Lot Res - Manuf. Home	0.4434	RP model
RS-40	Low Density Residential	0.4434	RP model
RS-40-MH	Low Density Res - Manuf. Home	0.4434	RP model
SC	Shopping Center	n/a	No buildings, extra imperv set = 0

\* RA building only model was reduced regression without parcel area

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## 2 Results and Discussion

Percent imperviousness in each subwatershed of Troublesome Creek and Little Troublesome Creek is presented in Table B-7 and Table B-8, broken down by source. The results for subwatersheds 1 and 3 are a combined total of Rockingham and Guilford County numbers. The same results are presented for areas inside and outside Reidsville for the entire Little Troublesome Creek watershed (Table B-9). Overall percent imperviousness is shown graphically in Figure B-4 and Figure B-5.

Overall imperviousness ranges from 1.04% in one of the least developed subwatersheds of Rockingham County to 34.94% in Reidsville. Imperviousness tends to be higher near Stokesdale in Guilford County, whose influence is strongest in subwatershed T2 (4.48% impervious). The influence of Reidsville is seen in subwatersheds T15, T16, and in most of the Little Troublesome Creek subwatersheds. Imperviousness reaches 21.03% within the city limits of Reidsville in the Little Troublesome Creek watershed. Also of interest is the way development influences the ratio of extra impervious area to building impervious area. In rural areas, the ratio stays close to 0.50, but it increases to a maximum of 1.60 in developed subwatersheds.

**Table B-7. Percent Impervious Totals in the Troublesome Creek Subwatersheds**

SubWws	Area (ac)	Overall % Impervious	Source			Ratio Extra/Blg
			Roadways	Buildings	Extra	
T1	2,955	3.32%	1.58%	1.14%	0.60%	0.52
T2	549	4.45%	2.90%	1.07%	0.48%	0.45
T3	1,472	2.36%	1.21%	0.83%	0.32%	0.38
T4	602	2.40%	1.41%	0.70%	0.29%	0.42
T5	2,571	1.75%	1.07%	0.49%	0.19%	0.39
T6	619	1.76%	1.01%	0.54%	0.21%	0.38
T7	2,333	1.02%	0.63%	0.28%	0.11%	0.39
T8	2,343	1.70%	1.12%	0.42%	0.16%	0.39
T9	7,385	1.44%	0.84%	0.43%	0.17%	0.39
T10	1,264	1.96%	1.22%	0.54%	0.20%	0.37
T11	1,980	1.30%	0.85%	0.33%	0.12%	0.36
T12	1,533	2.00%	1.11%	0.63%	0.26%	0.42
T13	1,692	3.06%	1.43%	1.12%	0.51%	0.45
T14	531	2.58%	1.32%	0.90%	0.36%	0.40
T15	1,495	5.21%	1.81%	1.55%	1.85%	1.19
T16	1,207	3.56%	1.48%	1.00%	1.08%	1.07
T17	526	2.05%	1.06%	0.69%	0.30%	0.43
T18	4,922	3.16%	2.09%	0.74%	0.33%	0.44
Total	35,979	2.31%	1.28%	0.67%	0.36%	0.53

**Table B-8. Percent Impervious Totals in the Little Troublesome Creek Subwatersheds**

SubWs	Area (ac)	Overall % Impervious	Source			Ratio Extra/Blg
			Roadways	Buildings	Extra	
LT1	783	17.43%	6.60%	4.53%	6.30%	1.39
LT2	373	26.39%	9.56%	9.35%	7.48%	0.80
LT3	668	18.95%	8.33%	5.83%	4.79%	0.82
LT4	634	19.70%	5.95%	6.92%	6.83%	0.99
LT5	681	35.60%	10.73%	9.33%	15.54%	1.67
LT6	909	10.83%	4.45%	3.55%	2.83%	0.80
LT7	2095	5.38%	3.47%	1.06%	0.85%	0.80
LT8	948	3.16%	2.05%	0.79%	0.32%	0.41
LT9	989	1.89%	1.03%	0.57%	0.29%	0.50
Total	8080	12.24%	4.91%	3.52%	3.81%	1.08

**Table B-9. Percent Impervious Totals in the Little Troublesome Creek Watershed**

Location	Area (ac)	Overall % Impervious	Source			Ratio Extra/Blg
			Roadways	Buildings	Extra	
Reidsville	2,955	21.03%	7.59%	6.51%	6.93%	1.06
County	549	3.73%	2.47%	0.80%	0.46%	0.58
Total	1,472	11.98%	4.91%	3.52%	3.55%	1.01

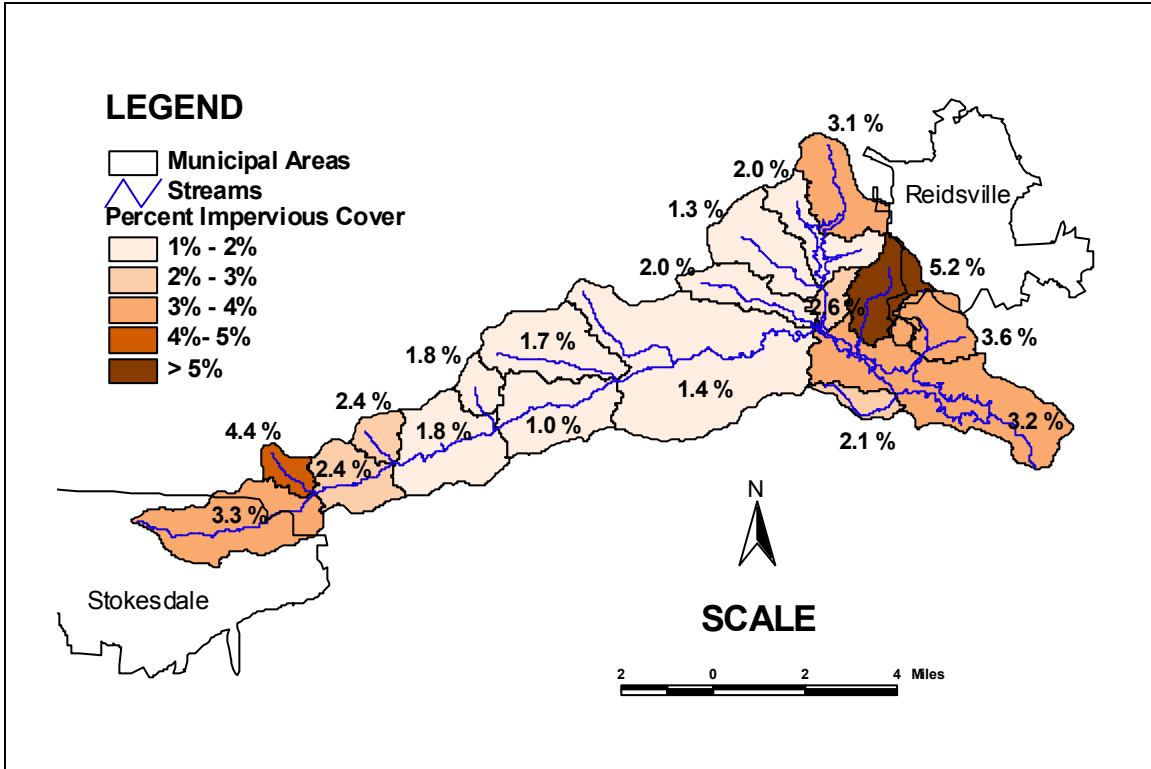


Figure B-4. Overall Percent Imperviousness in Troublesome Creek Subwatersheds

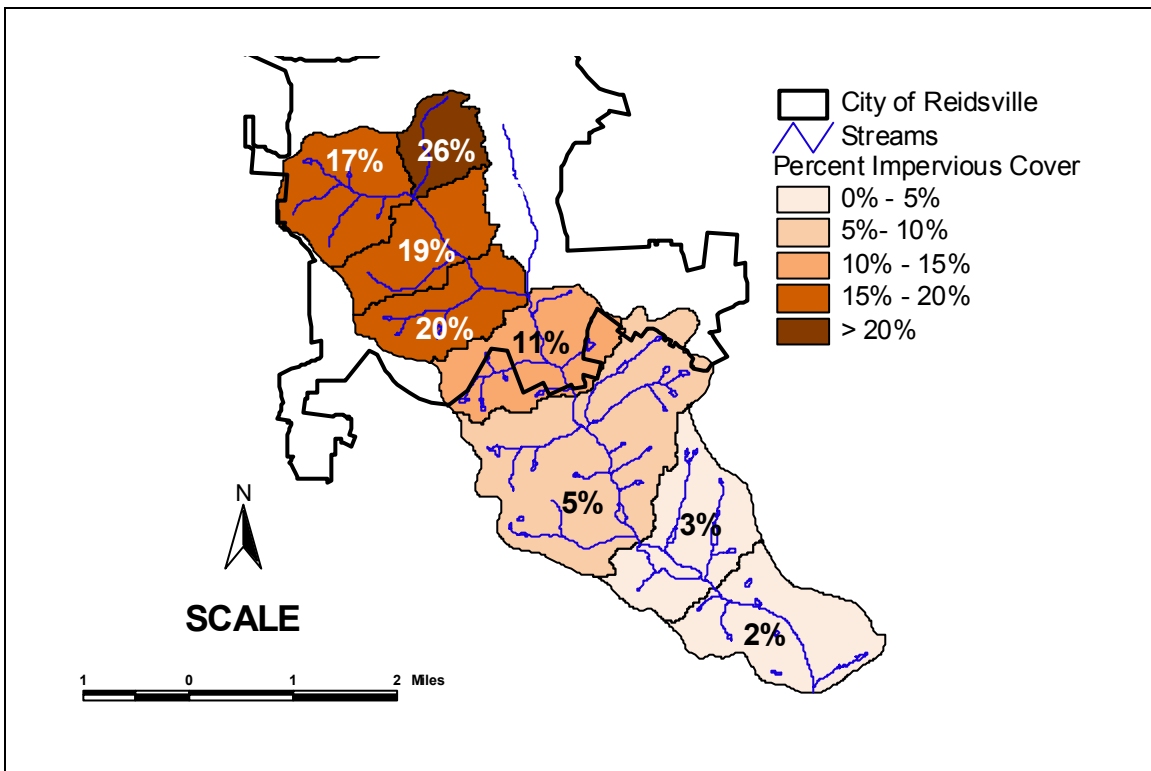


Figure B-5. Overall Percent Imperviousness in Little Troublesome Creek Subwatersheds

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## References

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## Appendix C. Project Data Catalogue

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## ArcInfo Coverages & ArcView Shapefiles

No.	File Name	Description	Source	Metadata Contact
1	awqms.shp	Point locations for NC DWQ ambient water quality monitoring stations throughout NC (2000 update)	BasinPro 2.1	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>
2	anops9_2000.shp	Point coverage of all registered Confined Animal Feeding Operations within the State of NC (2000 update)	NCDWQ	Michelle Woolfolk
3	building.shp	Polyline outlines of building footprints for Guilford Co. (native projection)	Guilford County GIS	<a href="http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm">http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm</a>
4	cfwaterbodies_sp83m	Polygon coverage of 1:100,000 scale waterbodies for the Cape Fear River Basin	TJCOG	Jeff Essick
5	dcms.shp	Point locations for discharger coalition water quality monitoring stations throughout NC	BasinPro 2.1	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>
6	dem1000mask.shp	Polygon built with Buffering tool and merged with NC state polygon to mask features beyond 1000 meters outside 14-digit HUC boundaries for study area	Tetra Tech - RTP	Jason Doll
7	gc_surgo_slope.shp	Guilford Co. soil survey coverage with key soil attributes added from Soilcodes.xls	Tetra Tech - RTP	Jason Doll
8	gcbldgs_sp83m.shp	Polyline outlines of building footprints for Guilford Co. reprojected to units = meters.	Guilford County GIS	<a href="http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm">http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm</a>
9	gcbldgs_trouble.shp	gcbldgs_sp83m.shp clipped to extent of Troublesome and Little Troublesome Creek watersheds (see #8)	Guilford County GIS	<a href="http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm">http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm</a>
10	GCStrts_102501_polyline.shp	Center lines for Guilford Co. streets (native projection)	Guilford County GIS	<a href="http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm">http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm</a>

11	GCStrts_102501_region.shp	Polygons of impervious surfaces pertaining to Greensboro Airport (native projection)	Guilford County GIS	<a href="http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm">http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm</a>
12	gc zoning_sp83m.shp	Polygon coverage of zoning classifications for unincorporated portions of Guilford Co. reprojected to units = meters	Guilford County GIS via PTCOG	Carol Patrick -PTCOG/Guilford County GIS
13	gc zoning_trouble.shp	gc zoning_sp83m.shp clipped to extent of Troublesome and Little Troublesome Creek watersheds (see #12)	Guilford County GIS via PTCOG	Carol Patrick -PTCOG/Guilford County GIS
14	Gfordn_text.shp	Georeferenced label point coverage for GCStrts_102501_polyline.shp	Guilford County GIS	<a href="http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm">http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm</a>
15	guilford_strts_sp83m.shp	Center lines for Guilford Co. streets reprojected to units = meters.	Guilford County GIS	<a href="http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm">http://www.co.guilford.nc.us/government/infoservices/GISwebpage/0main.htm</a>
16	guilfordzoning.shp	Polygon coverage of zoning classifications for unincorporated portions of Guilford Co. (native projection)	Guilford County GIS via PTCOG	Carol Patrick -PTCOG/Guilford County GIS
17	guilrock_ssurgo.shp	Merged coverage of Guilford and Rockingham County SSURGO soil surveys created after key soil attributes were added individually to each county coverage	Tetra Tech - RTP	Jason Doll
18	haw303d_sp83m	Polyline coverage of 303d listed stream segments within the Haw River watershed	Research Triangle Institute	Ann Marie Miller
19	hawhy24l_sp83m	Polyline coverage of 1:24,000 scale DLG hydrography for Haw River watershed with attributes added to flag perennial and intermittent streams	TJCOG	Jeff Essick
20	haw-phwys_sp83m.shp	Polyline coverage of primary highways within the Haw River watershed	NC CGIA via TJCOG	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>

21	hawsub01_lulc.shp	Polygon coverage of NC LULC database for NCDWQ Subbasin 030601 (Upper Haw River)	NCCGIA via NCWRP	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>
22	hunc.shp	Polygon coverage of USGS 14-digit hydrologic units for North Carolina	BasinPro 2.1	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>
23	lakes_allstations_83.shp	Point coverage of all NC DWQ lake water quality monitoring stations	NCDWQ	Debra Owen (NC DWQ)
24	lmcos.shp	Polygon coverage of Lands Managed for Conservation and Open Space throughout the State of NC	NCCGIA via NCWRP	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>
25	mrlc_0303002	Grid segment of National Land Cover Database coverage for the 8-digit USGS hydrologic unit corresponding to the Haw River watershed	USGS/USEPA MRLC	<a href="http://www.epa.gov/mrlc/">http://www.epa.gov/mrlc/</a>
26	municipalbound.shp	Polygon coverage of NC municipal boundaries as per Powell Bill (1999 update)	BasinPro 2.1	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>
27	nc24nl.shp	Polygon coverage of neat line boundaries for USGS 7.5 minute series topographic quadrangles with any portion intersecting the State of NC	BasinPro 2.1	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>
28	nhdrc-haw_nad83m.shp	Polyline coverage of stream reaches extracted from the National Hydrography Database coverage for the Haw River watershed	USGS/USEPA NHD	<a href="http://nhd.usgs.gov/index.html">http://nhd.usgs.gov/index.html</a>
29	nhdwb-haw_nad83m.shp	Polygon coverage of waterbodies and wetlands extracted from the National Hydrography Database coverage for the Haw River watershed	USGS/USEPA NHD	<a href="http://nhd.usgs.gov/index.html">http://nhd.usgs.gov/index.html</a>
30	npdes1.shp	Point locations of major NPDES permitted discharge locations throughout NC	BasinPro 2.1	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>
31	npdes2.shp	Point locations of minor NPDES permitted discharge locations throughout NC	BasinPro 2.1	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>
32	nwi_belews_sp83m.shp	Polygon coverage of National Wetlands Inventory for USGS 7.5 minute topo quad, Belews, reprojected to NC State Plane, NAD 1983, units = meters	USFWS-NWI	<a href="http://www.nwi.fws.gov/">http://www.nwi.fws.gov/</a>

33	nwi_bethany_sp83m.shp	Polygon coverage of National Wetlands Inventory for USGS 7.5 minute topo quad, Bethany, reprojected to NC State Plane, NAD 1983, units = meters	USFWS-NWI	<a href="http://www.nwi.fws.gov/">http://www.nwi.fws.gov/</a>
34	nwi_ellisboro_sp83m.shp	Polygon coverage of National Wetlands Inventory for USGS 7.5 minute topo quad, Ellisboro, reprojected to NC State Plane, NAD 1983, units = meters	USFWS-NWI	<a href="http://www.nwi.fws.gov/">http://www.nwi.fws.gov/</a>
35	nwi_lakebrandt_sp83m.shp	Polygon coverage of National Wetlands Inventory for USGS 7.5 minute topo quad, Lake Brandt, reprojected to NC State Plane, NAD 1983, units = meters	USFWS-NWI	<a href="http://www.nwi.fws.gov/">http://www.nwi.fws.gov/</a>
36	nwi_reidsville_sp83m.shp	Polygon coverage of National Wetlands Inventory for USGS 7.5 minute topo quad, Reidsville, reprojected to NC State Plane, NAD 1983, units = meters	USFWS-NWI	<a href="http://www.nwi.fws.gov/">http://www.nwi.fws.gov/</a>
37	nwi_summerfield_sp83m.shp	Polygon coverage of National Wetlands Inventory for USGS 7.5 minute topo quad, Summerfield, reprojected to NC State Plane, NAD 1983, units = meters	USFWS-NWI	<a href="http://www.nwi.fws.gov/">http://www.nwi.fws.gov/</a>
38	nwi_troublesome_sp83m.shp	Merged polygon coverage of National Wetlands Inventory water bodies and wetlands for all USGS 7.5 minute topo quads with any portion overlapping the Troublesome and Little Troublesome Creek watershed study area	Tetra Tech - RTP	Jason Doll
39	nwi_williamsburg_sp83m.shp	Polygon coverage of National Wetlands Inventory for USGS 7.5 minute topo quad, Williamsburg, reprojected to NC State Plane, NAD 1983, units = meters	USFWS-NWI	<a href="http://www.nwi.fws.gov/">http://www.nwi.fws.gov/</a>
40	primary_roads.shp	Polyline coverage of primary highways throughout NC	BasinPro 2.1	<a href="http://www.cgia.state.nc.us/cgd/b/datalist.html">http://www.cgia.state.nc.us/cgd/b/datalist.html</a>
41	rc_bldgs_sp83m.shp	Polygons of building footprints for Rockingham Co. reprojected to units = meters	Rockingham County GIS via PTCOG	Carol Patrick - PTCOG/Rockingham County GIS
42	rc_surgo_slope.shp	Rockingham Co. soil survey coverage with key soil attributes added from rcsoils.txt	Tetra Tech - RTP	Jason Doll
43	rc_tgrds_sp83m.shp	Polylines of road and street center lines for Rockingham County reprojected to NC State Plane, NAD 1983, units = meters	US Census Bureau - TIGER GIS database	<a href="http://www.census.gov/geo/www/cob/">http://www.census.gov/geo/www/cob/</a>

44	rockco_tigerrds.shp	Polylines of road and street center lines for Rockingham County (native projection)	US Census Bureau - TIGER GIS database	<a href="http://www.census.gov/geo/www/cob/">http://www.census.gov/geo/www/cob/</a>
45	rr24_100.shp	Polyline coverage of railroad lines throughout NC created by combination of 1:24,000 and 1:100,00 scale DLG files	BasinPro 2.1	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>
46	sumfzone.shp	Polygon coverage of zoning classifications for the Summerfield area of Guilford Co. (native projection)	Guilford County GIS via PTCOG	Carol Patrick -PTCOG/Guilford County GIS
47	trouble_bldgs.shp	rc_bldgs_sp83m.shp clipped to extent of Troublesome and Little Troublesome Creek watersheds (see #41)	Tetra Tech - RTP (extracted from Jlsed97x.shp)	Jason Doll
48	trouble_c-lines_sp83m.shp	Polylines of road and street center lines for Rockingham County reprojected to units = meters and clipped to extent of Troublesome and Little Troublesome Creek watersheds	Rockingham County GIS via PTCOG	Carol Patrick - PTCOG/Rockingham County GIS
49	trouble_ctour5.shp	Polyline coverage of 5 ft interval contours generated from GRIDNAME with Arcview Spatial Analyst Extension	Tetra Tech - RTP	Jason Doll
50	trouble_dem	Grid coverage Digital Elevation Model for Troublesome Creek LWP study area developed by edge matching 5 USGS 1:24,000 scale DEMs with Avenue Mosaic script	Tetra Tech - RTP	Jason Doll
51	trouble_mask.shp	Union of polygons for state of NC and USGS 14-digit HUCs for Troublesome and Little Troublesome Creeks created to mask features beyond study area boundary	Tetra Tech - RTP	Jason Doll
52	trouble_parcel.shp	Polygon coverage of Rockingham County tax parcels within Troublesome and Little Troublesome Creek watersheds (native projection)	Rockingham County GIS via PTCOG	Carol Patrick - PTCOG/Rockingham County GIS
53	trouble_parcel_sp83m.shp	Polygon coverage of Rockingham County tax parcels within Troublesome and Little Troublesome Creek watersheds projected to units = meters	Rockingham County GIS via PTCOG	Carol Patrick - PTCOG/Rockingham County GIS

54	trouble_pcls_data.shp	trouble_parcels_sp83m.shp with polygons denoting transportation right-of-ways removed and parcel attribute data added from taxdata2.txt	Tetra Tech - RTP	Jason Doll
55	trouble_row.shp	Polygon coverage of transportation right-of-ways created from trouble_parcels_sp83m.shp	Tetra Tech - RTP	Jason Doll
56	trouble_surgo.shp	guilrock_ssurgo.shp clipped to extent of Troublesome and Little Troublesome Creek watersheds (see #17)	Tetra Tech - RTP	Jason Doll
57	troublesome_centerline.shp	Polylines of road and street center lines for Rockingham County clipped to extent of Troublesome and Little Troublesome Creek watersheds	Rockingham County GIS via PTCOG	Carol Patrick - PTCOG/Rockingham County GIS
58	troublesome_huc14.shp	Individual coverage of USGS 14-digit HUCs for Troublesome and Little Troublesome Creeks created from statewide 14-digit HUC Coverage (hunc.shp)	BasinPro 2.1	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>

## Digital Ortho Photos

No.	File Name	Description	Source	Metadata Contact
1	reidv1.jpg	JPEG compressed format digital aerial photo representing one fourth of the USGS 1:24,000 scale topo quad, Reidsville (black & white, 1993-1995 reconnaissance)	NCCGIA via NCWRP	<a href="http://www.cgia.state.nc.us/cgdb/datalist.html">http://www.cgia.state.nc.us/cgdb/datalist.html</a>
2	reidv2.jpg	""	""	""
3	reidv3.jpg	""	""	""
4	reidv4.jpg	""	""	""
5	bethan1.jpg	JPEG compressed format digital aerial photo representing one fourth of the USGS 1:24,000 scale topo quad, Bethany (black & white, 1993-1995 reconnaissance)	""	""
6	bethan2.jpg	""	""	""

7	bethan3.jpg	""	""	""
8	bethan4.jpg	""	""	""
9	ellibo3.jpg	JPEG compressed format digital aerial photo representing one fourth of the USGS 1:24,000 scale topo quad, Ellisboro (black & white, 1993-1995 reconnaissance)	""	""
10	ellibo4.jpg	""	""	""
11	sumfld1.jpg	JPEG compressed format digital aerial photo representing one fourth of the USGS 1:24,000 scale topo quad, Summerfield (black & white, 1993-1995 reconnaissance)	""	""
12	sumfld2.jpg	""	""	""
13	wlmsbg3.jpg	JPEG compressed format digital aerial photo representing one fourth of the USGS 1:24,000 scale topo quad, Williamsburg (black & white, 1993-1995 reconnaissance)	""	""

## Water Quality Data Files

No.	File Name	Description	Source	Metadata Contact
1	B0160000.xls	Physical, nutrients, metals, and fecal coliform data from 1968 to 2000, approximately monthly.	NCDENR-DWQ	Jay Sauber
2	Combined NCTSI Data.xls	NCTSI, trophic status, and nutrients data from 1981 to 1998, approximately every 1 to 5 years, 1 to 3 times per year.	Tetra Tech - RTP	Jason Doll
3	Lake Data.xls	Physical, nutrients (photic zone and bottom), and metals from 1981 to 1998, approximately every 1 to 5 years, 1 to 3 times per year, 3 samples per date.	NCDENR-DWQ	Debra Owen
4	LT ambient 98-01.xls	Physical, nutrients, metals, and fecal coliform data from 1998 to 2001, approximately monthly.	NCDENR-DWQ	Debra Owen
5	LT data spreadsheet.xls	Physical, nutrient, metals, and organics from 2000 to 2001, parameters vary by station:  LTLT01 and 03: physical, nutrients, metals, and organics  LTLT02A, 05, and 06: physical, nutrients, and metals  LTLT08 and 03A,B: physical and metals  LTLT02 and 04: physical  LTLT000: metals	NCDENR-DWQ/NCWRP	Jim Blose
6	LTC historical_7mar02.xls	Species, community, habitat, and physical data from 1985 to 2001, every 2 to 5 years (3 times during 2000 and 2001).	NCDENR-DWQ	Cathy Tyndall
7	LTCwarptaxa_7mar02.xls	Species, community, habitat, and physical data from 2000 to 2001, once or twice per year.	NCDENR-DWQ	Cathy Tyndall
8	UCFRB Data.xls	Physical, nutrients, metals, and fecal coliform data from 2000 to 2001, approximately monthly.	TJCOG	Pat Davis