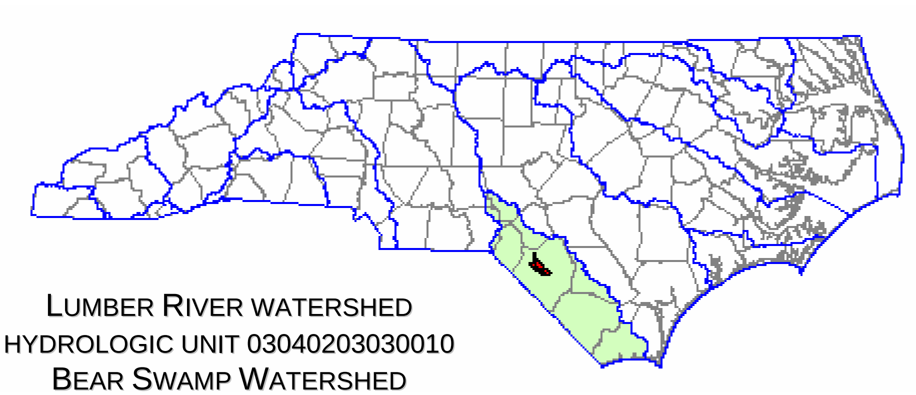
LUMBER RIVER TECHNICAL WATERSHED ASSESSMENT

CRITICAL AREA ANALYSIS



LUMBER RIVER WATERSHED
HYDROLOGIC UNIT 03040203030010
BEAR SWAMP WATERSHED
HYDROLOGIC UNIT 03040203050010
ROBESON COUNTY, NORTH CAROLINA

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SEPTEMBER 2005

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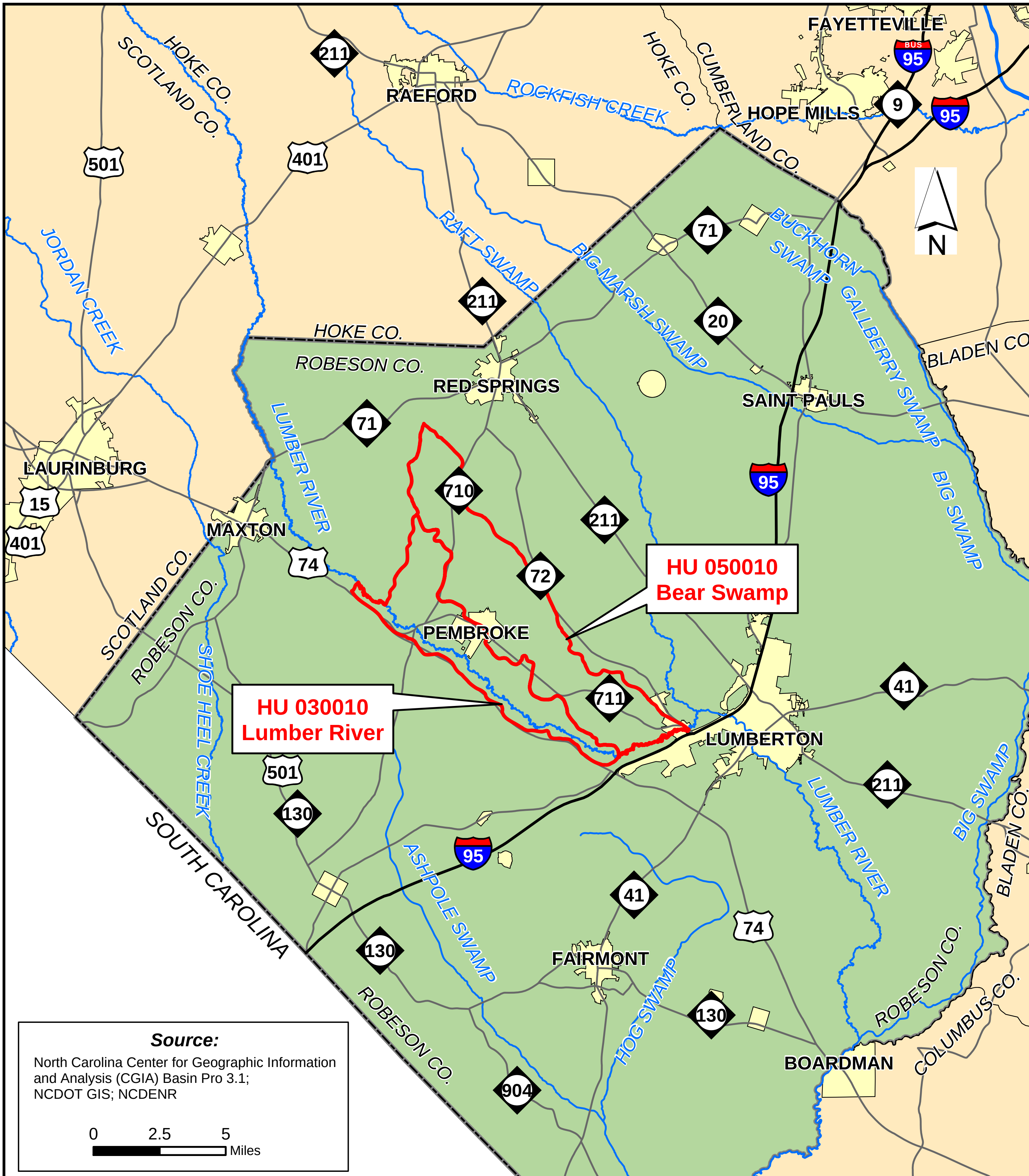
1.0 PURPOSE AND SCOPE

The North Carolina Ecosystem Enhancement Program (EEP) selected two hydrologic units (HU) within the Lumber River Basin of North Carolina for detailed technical watershed assessments. These two HUs are the Lumber River (HU 03040203030010) and the Bear Swamp (HU 03040203050010) (**Figure 1**). The selection was based on the 303(d) status of all the major drainages in these HUs as well as on the compensatory mitigation needs at the cataloging unit (CU) scale of the NC Department of Transportation for anticipated impacts to streams and wetlands. The purpose of this assessment is to characterize these two HUs, identify problem areas related to ecological functions, determine how to address these problems, and develop a watershed management plan that includes specific solutions to the problems. The overall approach includes methods of watershed assessment that focus on ecological functions of the watershed.

The assessment has been scoped in three phases. Phase 1 was the *Initial Watershed Characterization (IWC)*, submitted in February 2004. That report was a compilation of existing published data regarding land use, water quality, ecosystem functions, current management measures, and existing restoration and protection needs. Through visual observation in the HUs and analysis of the existing data, the current conditions and functional status of the HUs were evaluated. Limited interviews with local stakeholders and resource agencies were conducted in this phase of reporting, mainly to determine the current status of the drainage district and habitat suitability for threatened and endangered species. The HUs were delineated into 11 sub-watersheds (SWs), which were classified based on functional status and ranked for future studies. Preliminary watershed management goals were also identified. Extensive field studies were not included in this phase of the assessment. The ecological basis for the functional assessment approach is described in Section 3.0 of the *IWC*. The three main functions (water quality, hydrology, and habitat) and their indicators are summarized in Table 1 of that document.

Phase 2 is documented in this report, the *Critical Area Analysis (CAA)*, which is submitted at this time in draft form. It will be finalized for inclusion in the Phase 3 report, the *Watershed Management Plan*.

This *CAA* summarizes the data and findings of the water quality and biological monitoring and field assessment activities in selected sub-watersheds of the Lumber River and Bear Swamp HUs. The goal of the *CAA* was to further elucidate the causes of functional degradation in selected SWs and to determine the areas on which to focus future watershed management and restoration efforts.



Source:

North Carolina Center for Geographic Information and Analysis (CGIA) Basin Pro 3.1; NCDOT GIS; NCDENR

0 2.5 5 Miles

Ecosystem Enhancement PROGRAM

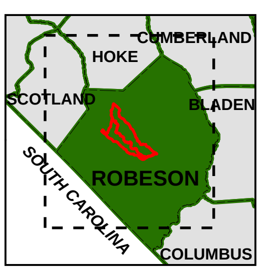


FIGURE 1
VICINITY MAP

Lumber River Local Watershed Plan
Critical Area Analysis
HU 030010 & HU 050010
Robeson County, North Carolina

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The *CAA* also includes the identification of potential project sites that may serve as solutions to the degradation problems identified during the *IWC* and subsequent detailed field assessment. These potential project sites should also serve to meet compensatory mitigation needs. Functional degradation concerns identified in the *IWC* were as follows:

- Lack of forested riparian buffers
- Fragmentation and loss of terrestrial habitat and wetlands through clearing and draining for agricultural lands
- Conversion of agricultural lands to residential/commercial uses (increased impervious surface)
- Loss of in-stream habitat as a result of channelization

Selection of the targeted sub-watersheds was guided by the findings of the GIS-based *IWC*. The relative sub-watershed functional status classification results from the *IWC* were as follows:

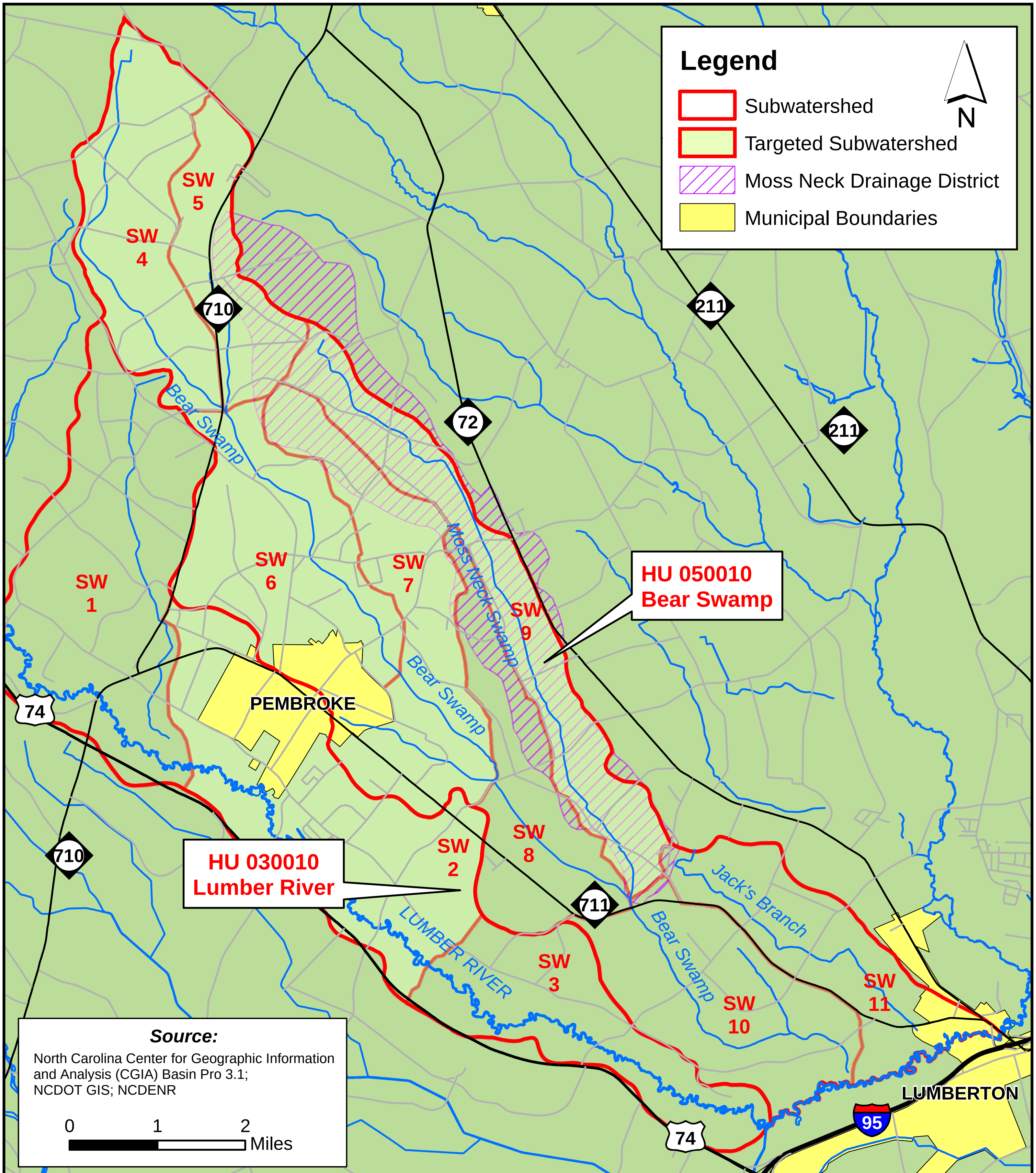
- High - SWs 03 and 10
- Medium - SWs 01, 02, 07, 08 and 11
- Low - SWs 04, 05, 06, and 09

The SWs with Low functional status were targeted for the detailed functional assessment described in the Methods section. SWs 02 and 07 in the Medium category were also targeted so that all SWs draining the town of Pembroke would be included in the assessment. This decision was based on the assumption that impervious surface was likely to increase in the Pembroke area and management strategies should include the town as a whole rather than just SW 06. **Figure 2** shows the targeted sub-watersheds.

Field assessment protocols for this *CAA* were developed by ecologists from East Carolina University (ECU) and implemented by Earth Tech. The sampling scheme proposed in the *IWC* was developed before it was decided that ECU would be contracted by EEP to develop a Coastal Plain assessment method. Because of time and budget constraints, it was discarded and Earth Tech collected only the data required for the ECU protocol. Some supplemental notes were taken during field sampling on the project potential of the sample sites.

The Methods section of this report summarizes Earth Tech's activities in implementing the field assessment method developed by ECU. Details of the method are included in the full report by ECU entitled *Applying Ecological Assessments to Planning Stream Restorations in Coastal Plain North Carolina* in **Appendix A**. Also, ECU submitted all the raw data and analysis on CD as Appendix B of the original document. For convenience, Earth Tech has included a raw data summary table (Table B-1) sorted by sub-watershed as **Appendix B** to this report. Table B-2 of that same appendix is a summary of channel and riparian zone condition scores and composite function scores sorted from highest to lowest composite function score. Divisions for the condition categories are also shown.

The DWQ monitoring protocol is also summarized here, with details given in the full report in **Appendix C**. The findings of these field sampling activities and their relationship to the identification of potential project sites are discussed in the Results and Discussion section of this report.



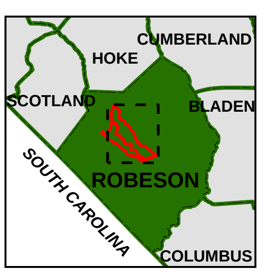


FIGURE 2
TARGETED SUB-WATERSHEDS
Lumber River Local Watershed Plan
Critical Area Analysis
HU 030010 & HU 050010
Robeson County, North Carolina

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2.0 METHODS

Two field assessments were performed to determine the degree of stream function degradation the Lumber River and Bear Swamp HUs. As part of the Initial Watershed Characterization, a non-random visual assessment of stream condition was performed by Earth Tech in 2003 at road crossings. (Obtaining landowner permission for more extensive access to streams was not feasible or necessary at this phase of the project). A second study, a randomized functional assessment, was designed by ECU and implemented by Earth Tech in 2004 to obtain more detailed information about stream and riparian condition in selected sub-watersheds of these HUs.

2.1 VISUAL ASSESSMENT METHODOLOGY

A windshield survey of the two HUs was initially performed by Earth Tech in 2003. Geographic Information System technology (GIS) was first used to locate road crossings of perennial streams. These locations were then field assessed to determine the condition of a variety of indicators of stream health and to determine if the streams offered potential stream restoration opportunities. This assessment method, which covered both HUs in their entirety, is described in greater detail in the February 2004 *IWC*. The only application of this assessment to the current study was to provide additional information about potential project sites if a survey point occurred near a site sampled for the ECU protocol or for potential project sites that were identified by GIS methods as described in Section 4.0.

2.2 ECU COASTAL PLAIN STREAM FUNCTIONAL ASSESSMENT

A functional assessment in the targeted SWs (02 of the Lumber River HU; 04, 05, 06, 07, and 09 of the Bear Swamp HU) was performed by Earth Tech in 2004 utilizing a protocol developed by East Carolina University (ECU). This assessment is detailed in the report in **Appendix A**, which documents a rapid assessment method for estimating the ecological condition of riparian ecosystems in the inner coastal plain of North Carolina. This methodology rates functional degradation indicators in relation to an unaltered reference system and calculates a score representing the stream and riparian condition for a stream reach. These scores can be compiled within a watershed to enable comparisons between watersheds and within a watershed through time.

GIS Updates

Because of the inconsistencies of the county soil survey mapping and USGS topographic mapping, a system was adopted to more accurately map the true extent of perennial streams in the watershed. This was accomplished by extending the reaches of streams that had: (1) two or more topographic contours showing a V-shaped deflection of $< 90^\circ$ from the general trend of the contour line, (2) a slope of greater than 0.5%, and (3) a downstream connection to a mapped stream not more than two stream orders higher than the added stream. The hydrography layer in the GIS was updated to reflect these additions.

Sample Points

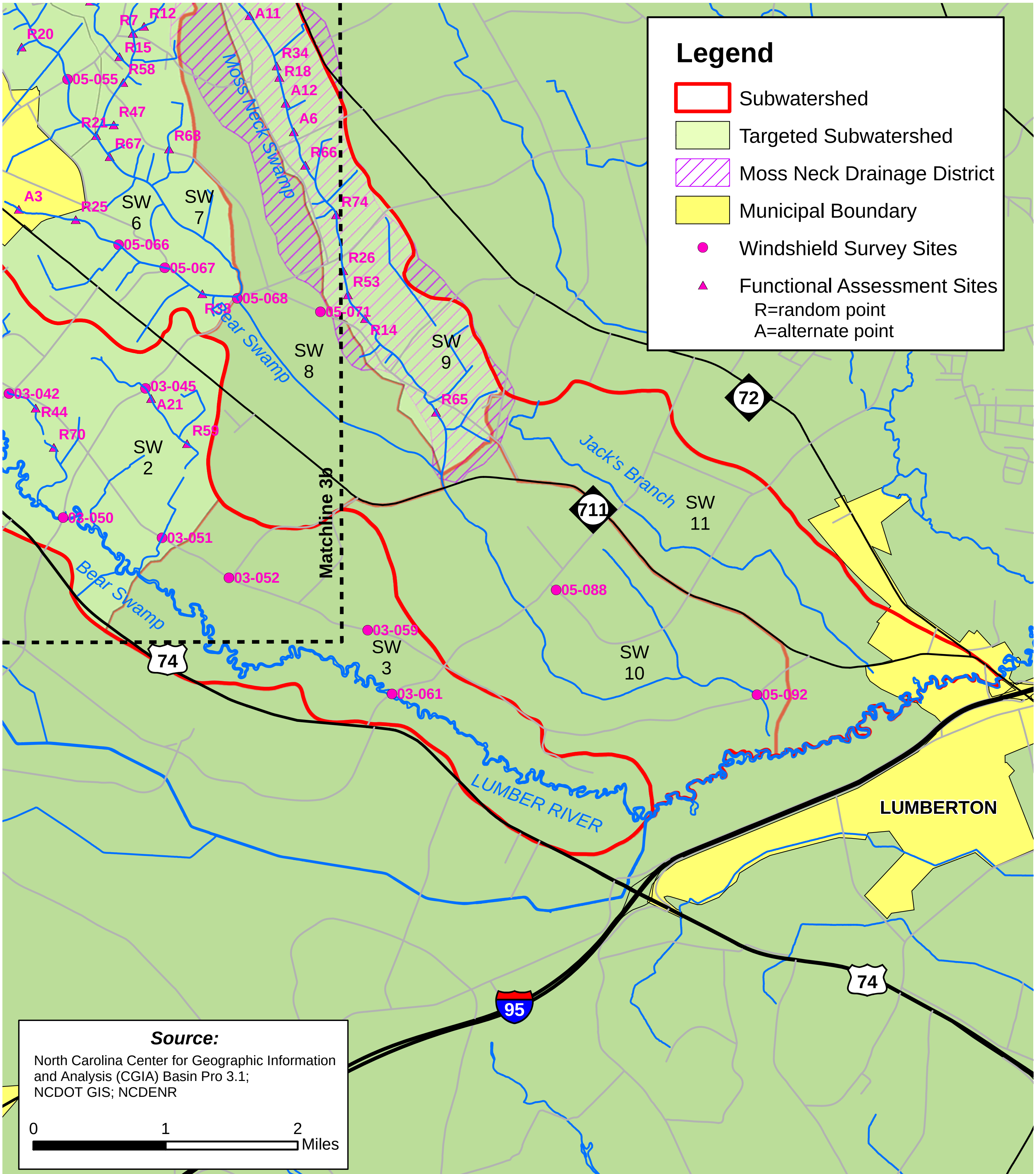
Using the modified hydrology layer, two sets of sampling sites were generated randomly on perennial streams at a density of approximately one per kilometer of stream length. The second or alternate set of points was selected to be utilized in case a point from the previous series had to be rejected. **Figures 3a, 3b, and 3c** show locations of the sampling points. If a random site was inaccessible or otherwise did not meet the criteria for an acceptable site according to the protocol (stream was actually a ditch, ephemeral, or culverted), an alternate point was selected for sampling.

Assessment

A two-person team navigated to each pre-determined sample point using a Global Positioning System (GPS). At each sample point, a 300-foot reach was assessed by the team. Stream and riparian condition indicators at each site were scored on a scale of 0 to 100 with 0 representing a severely altered condition and 100 a relatively unaltered condition. A scaling system was developed by ECU to reflect the varying degrees of alteration of each assessed indicator: 0-29 (Severely Altered), 30-59 (Altered), 60-89 (Somewhat Altered), and 90-100 (Relatively Unaltered). Conditions receiving a score of 59 or less are significantly altered and represent opportunities for stream restoration or enhancement credits, or for implementation of Best Management Practices (BMPs). Separate scoring guides were used for rural high order streams, rural low order streams, and urban low order streams. There were no urban high order streams in the sample set. The scoring guides are included in **Appendix A**. Scores were recorded onto field data sheets designed by ECU. These sheets are also included in **Appendix A**.

Indicator Descriptions

Nine stream and riparian condition indicators were assessed: riparian zone cover (RZC), near stream cover (NSC), instream woody structure (IWS), sediment regime (SR), channel-riparian zone connection (CZRC), pollution affecting the stream (PAS), factors affecting the riparian zone (FARZ), habitat quality of riparian zone (HQRZ), and stream bank stability (SBS). The relationship between these indicators and stream channel and riparian zone functions are shown in **Table 1**. Individual function scores are the average of columns (Avg.). Mean function scores are averages of the Hydrology, Biogeochemical, and Habitat function scores. The stream and riparian condition indicators and scoring methods are described below in further detail. The scoring guides in **Appendix A** show the various stages of alteration depicted by each indicator and the approximate score each level of alteration receives.



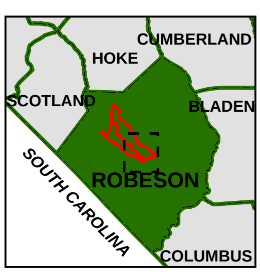


FIGURE 3a
SAMPLING LOCATIONS
Lumber River Local Watershed Plan
Critical Area Analysis
HU 030010 & HU 050010
Robeson County, North Carolina

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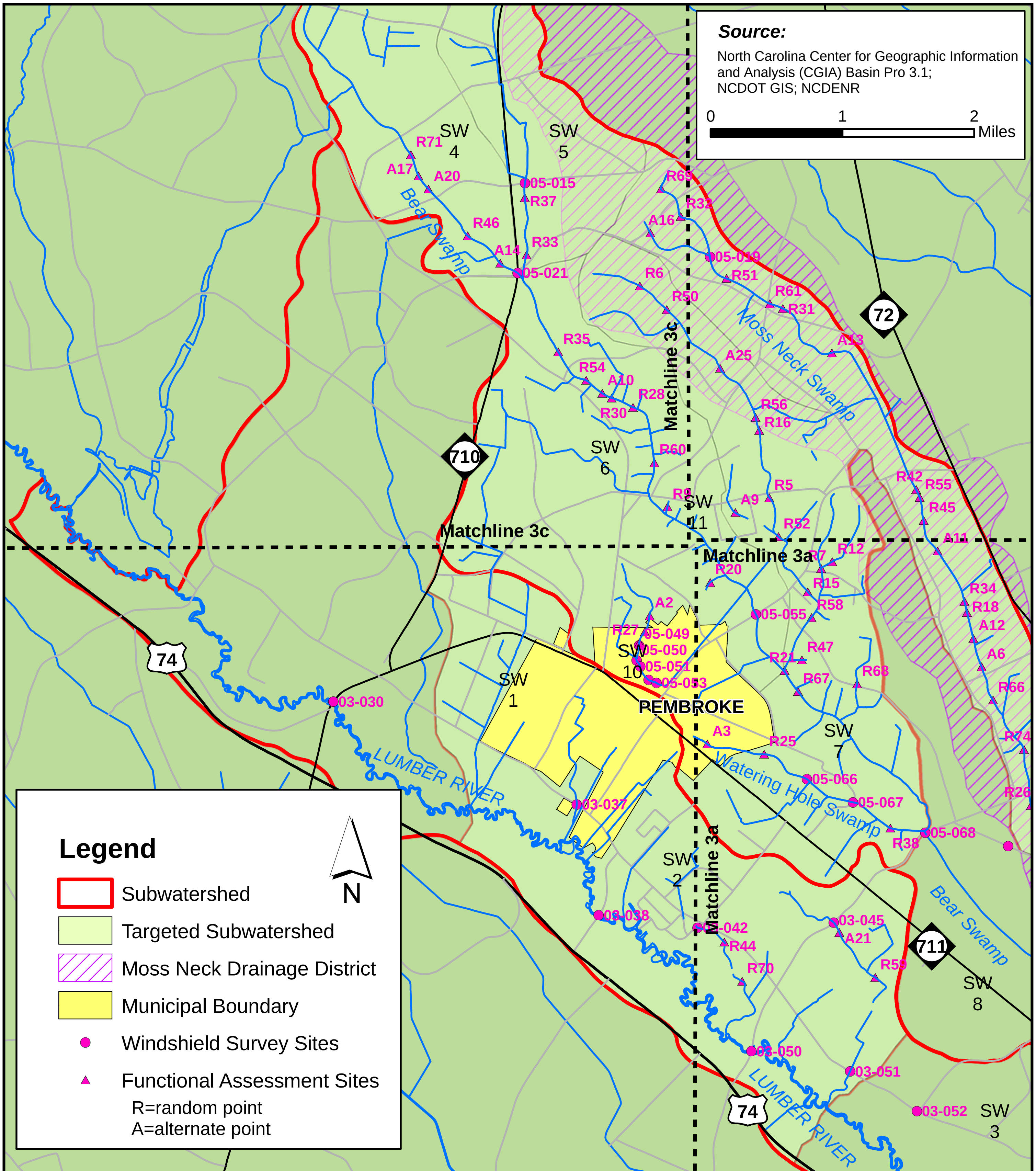

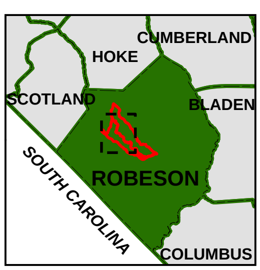

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FIGURE 3b
SAMPLING LOCATIONS
Lumber River Local Watershed Plan
Critical Area Analysis
HU 030010 & HU 050010
Robeson County, North Carolina

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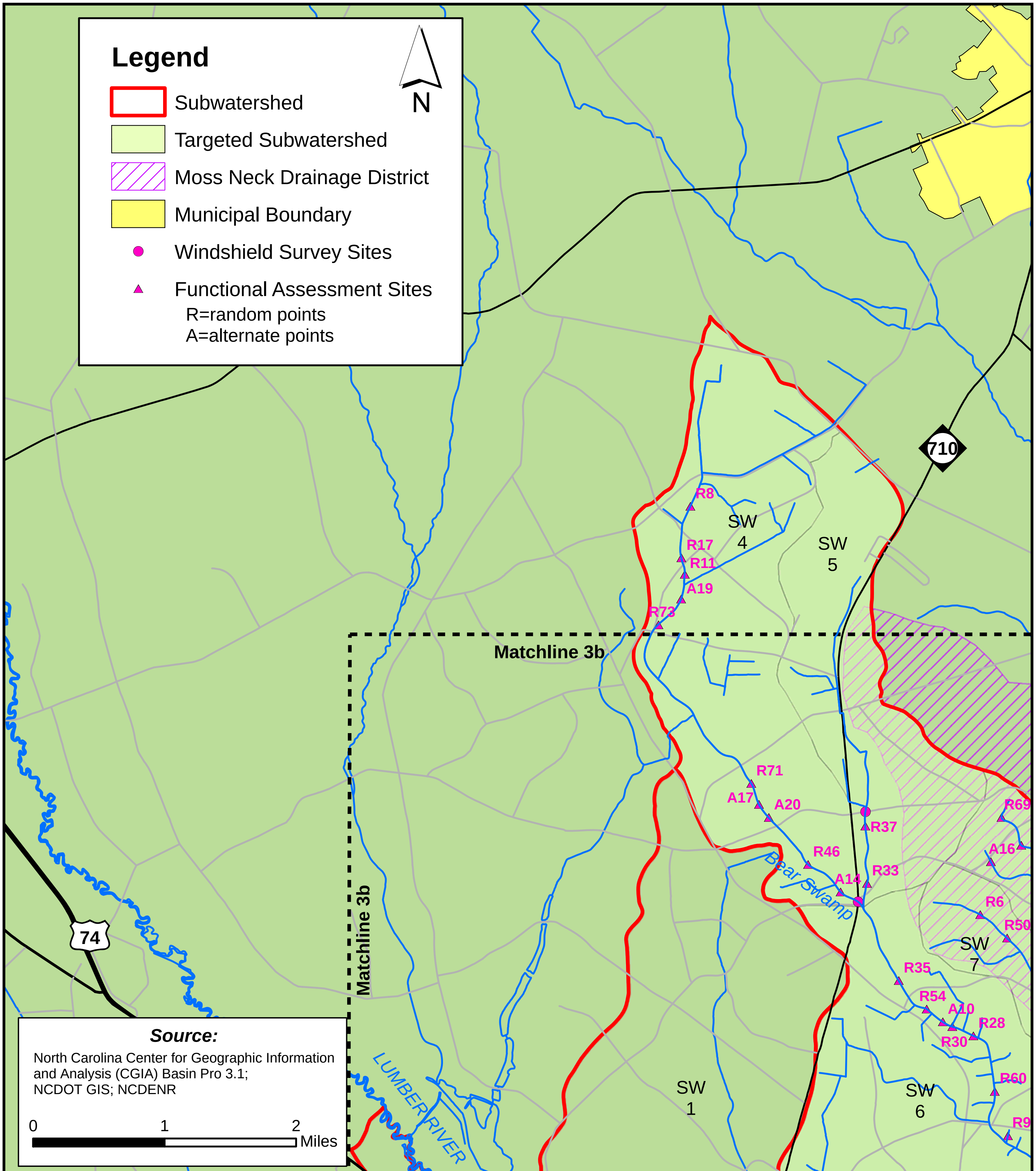

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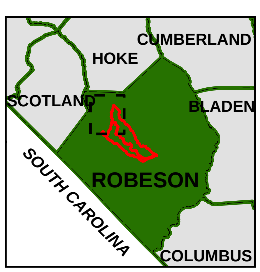

FIGURE 3c
SAMPLING LOCATIONS
Lumber River Local Watershed Plan
Critical Area Analysis
HU 030010 & HU 050010
Robeson County, North Carolina

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Table 1. Relationship Between Indicators And Function Scores.

INDICATORS	STREAM CHANNEL			RIPARIAN ZONE		
	Hydrology	Biogeo-chemistry	Habitat	Hydrology	Biogeo-chemistry	Habitat
Riparian zone cover (RZC)				X	X	X
Near-stream cover (NSC)		X	X			
Instream woody structure (IWS)	X	X	X			
Sediment regime (SR)		X				
Channel-riparian zone connection (CRZC)	X	X	X	X	X	X
Pollution affecting stream (PAS)	X	X	X			
Factors affecting riparian zone (FARZ)				X	X	X
Habitat quality of riparian zone (HQRZ)						X
Stream bank stability (SBS)		X	X			
Function Score: Mean of all appropriate indicator scores for each function and location (stream vs. riparian zone).	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.
	Mean Function Score for Stream Channel Condition			Mean Function Score for Riparian Zone Condition		
	Composite Function Score					

<u>*Riparian Zone Cover*</u>: The riparian zone cover indicator provides information on the general structure of vegetation adjacent to the stream channel. Mature forested riparian zones are of higher quality than young forested riparian zones or those that lack vegetation or contain impervious surfaces. Infiltration and interception are greater in riparian zones under forested conditions than other land cover types and evapotranspiration rates also tend to be higher than other land cover types. Overland flow may be more effectively intercepted, dispersed, and absorbed by forest cover. Degraded conditions such as impervious surfaces disrupt groundwater infiltration, and can contribute to increased flashiness and channel incision by preventing infiltration and by rapidly delivering water to streams via surface flows. Riparian zone condition affects not only the suite of vertebrate and invertebrates occupying the riparian zone but also the biogeochemistry in forested riparian zones. These zones are well known for their ability to trap sediments and intercept nutrients carried by surface and groundwater flow. Forested cover also maintains microbial processes at greater rates than areas without forested cover.

The riparian zone was defined as a 90-ft zone adjacent to a stream. The zone was divided into 3 distinct zones: 90-ft, 50-ft, and 10-ft zones. The 90-ft outer riparian zone boundary was chosen for RZC because the riparian zone would likely be influenced by surrounding forest, which in this region can generally be 90-100 feet high. Therefore, a 90-ft tall tree growing in the 90-ft riparian zone would have more than a 50% chance of falling into the riparian zone. Some trees falling within the riparian zone would be capable of contributing wood to the stream channel. A 50-ft zone was chosen to correspond with North Carolina buffer rules and a 10-ft zone was chosen as the zone that would be most likely to affect channel processes. The 50 and 90-ft zones are scored together as the RZC and the 10-ft zone is scored in the NSC category. Each side of the stream is evaluated separately. The cover type is placed in ranked categories from old forest (>75 yrs) to annual row crop and impervious surface. Old forest is ranked the highest and impervious surface is ranked the lowest. A percentage of each cover type is assigned in the field for each zone. This proportion is multiplied by the cover type factor to determine a score for each zone. Cover scores for all zones are tallied on each side of the stream and combined to give the total RZC score.

Near Stream Cover: This indicator provides information on the structure of vegetation within 10-feet of the channel. Biogeochemistry and habitat of the stream are influenced more by near stream cover than the riparian zone as a whole. Vegetation in close proximity to the stream contributes litterfall to the channel for microbial and other food webs, stabilizes the stream banks reducing erosion and nutrient laden sediment inputs, provides shade to regulate water temperature, and contributes large downed wood (LDW) to the channel for instream habitat complexity.

Scoring for NSC is the same as described above but multiplied by 2.5 to convert the NSC total score to a 0-100 scale.

Instream Woody Structure: Instream woody structure plays an important role in hydrologic, biogeochemical, and biological systems in free-flowing aquatic systems. Instream woody structure assists in dissipating the energy of flowing water, the storage of sediment, and the storage of water during low flow periods. Additionally LDW affects biogeochemistry by providing a substrate for microbial activity and a potential source of dissolved organic carbon to drive microbial processes. LDW also provides habitat for aquatic flora and fauna. A relatively unaltered stream would be expected to have large amounts of LDW in the channel and along the banks. This LDW would represent a variety of decay classes and a mix of sizes. Little or no instream woody debris in the stream channel reflects the depletion or absence of a riparian zone and its subsequent input of LDW into the channel. It may also reflect mobilization of LDW.

Factors measured to determine the adequacy of instream woody debris include the amount of LDW in the stream channel and along the banks in addition to the presence of trees in three size classes (0-3.9 inch DBH, 4.0-7.9 inch DBH, 8.0 + inch DBH) that grow along each stream bank. The relative abundance of LDW based on these identifiable factors produced the score used in determining the stream and riparian condition.

Sediment Regime: The sediment regime of a stream system is extremely sensitive to inputs from exterior sources and changes in flow rate which can cause changes in stream morphology and have detrimental effects on biotic and chemical cycles in a stream. Relatively unaltered streams are characterized by water that runs clear even during periods of high flow. The channel bottom may be sandy or clayey but have little or no silt in the channel bottom or on the floodplain. Excessive sedimentation in a stream channel can arise from many causes such as ditches that drain roadsides and agricultural fields, overland flow from sparsely vegetated fields through inadequate riparian zones, and cattle access to the stream. These indicators may show erosion problems within and upstream from a given stream reach.

Factors measured in the field include the presence and relative quantity of silt and sand carried by a stream and the thickness of silt or sand deposited on channel bars, bank edge, or the floodplain. Sediment thickness layers were placed in three groupings for scoring the degree of alteration (no apparent sediment, < 1 inch thick, 1-2 inches thick, > 2 inches thick). Water clarity was also rated and combined with thickness factors to produce a score for sediment regime condition.

Channel-Riparian Zone Connection: The channel-riparian zone connection plays an important role in water storage and energy dissipation during high flow events. The floodplain and wetlands remove sediment and pollutants during high flow events that would normally be transported downstream. Stream dwelling biota also use the floodplain and wetlands as habitat and a connection allows movement of mobile organisms between the two locations. Channelization or excess incision of the stream channel results in greater flow capacity and decreases the duration and frequency of flooding. A lowered water table may result in reduced anaerobic activity in the floodplains and a reduction of denitrification in the channel and riparian zone. Ultimately this will lead to a biogeochemical system that is more oxidized which reduces the capacity to accumulate organic matter.

Degradation of the channel-riparian zone connection was identified in the field by the presence of numerous indicators of reduced stream interaction with the riparian zone. A relatively unaltered stream will have strong evidence of overbank flow (*i.e.*, wrack or sediment on floodplain), high water marks on trees and no apparent channelization or incision. Altered streams exhibit evidence of overbank flow only after rare flood events, have signs of channelization or incision (*i.e.*, spoil berms, deep channel), evidence of filling or leveling of the floodplain, artificial levees, or other channel containment structures.

Pollution Affecting the Stream: Stream-borne pollutants interfere with normal biogeochemical cycling in a stream system and also affect the instream biota. Nutrient input can cause algal blooms and the resultant anoxia.

A relatively unaltered condition would be recognized by unaltered stream morphology, a lack of pollution entering the stream within a reach or within 1500 feet upstream from the reach, and no livestock access to channel or animal operations located upstream from the reach. Stretches that were considered altered exhibited evidence of pollutants entering the stream. This included the presence of roadside ditches emptying directly into the stream, pollutants from confined animal operations entering directly into the channel, livestock access to the stream or near-stream zones, overland flow from agricultural fields, and sediment input from construction activities.

Factors Affecting the Riparian Zone: The importance of the riparian zone has been previously discussed. Alterations to the riparian zone include grading, filling, excavation, cultivation, and conversion to other non-forest land uses. Channelization also reduces the riparian-stream interactions by reducing the frequency of overbank flow thus degrading the riparian zone as described earlier.

The extent of the riparian zone investigated differs on low and high order streams. On low order streams an area extending 50 feet from the stream was investigated and an area 90 feet wide was investigated along higher order streams. Each streambank was scored separately due to the independence of riparian zone conditions on each streamside. A relatively unaltered riparian zone would be a component of a stream that has not been channelized, is vegetated in natural plant communities, and has no livestock access to the riparian zone or pollutant inputs. An altered riparian zone may have pollutants (*i.e.*, sewage, animal waste) entering directly in the riparian zone, alteration of more than 5% of the riparian zone, or livestock access to the riparian zone with signs of grazing and trampling.

Habitat Quality of Riparian Zone: Evaluation of this function concentrated on the amount of disturbance to the natural vegetation and the pressure of exotic or invasive plant species within the riparian zone. The riparian zone investigated differs on low and high order streams in its extent. On low order streams an area extending 50 feet from the stream was investigated and an area 90 feet wide was investigated along higher order streams.

Each streambank was scored separately due to the independence of riparian zone conditions on each streamside. Habitat quality in a relatively unaltered riparian zone would be dominated (> 95% of the area) by mature native forest with little or no exotic vegetation. Stretches that are considered altered are indicated by a riparian zone that is covered by less than 75% forest and one stratum that is composed of more than 25% by an exotic or aggressive species. An altered forest may also cover up to 95% of the riparian zone but have at least one stratum underrepresented due to artificial manipulation.

Stream Bank Stability: Stream bank stability plays an important role in the biogeochemistry and habitat functions of streams. As stream discharge increases, the energy is dissipated along stream banks and on LDW and roots in the stream channel. Some of the energy causes bank erosion, root exposure, bank slumping, and tree fall when excessive. If the channel is not incised, high flows associated with overbank flow transfers stream energy to the floodplain where it is dissipated without erosion and protects the channel from scouring. Although some erosion and sediment distribution is natural even in unaltered streams, it is minor in coastal plain low-gradient streams. Alteration of normal condition is assumed if erosion, slumping, and undercutting are excessive. Alterations in bank stability lead to excessive introduction of sediment to the channel, which is transported to downstream ecosystems.

Each stream bank was scored separately due to the independence of bank and vegetation conditions on each streamside. In a relatively unaltered stream, relatively little or no evidence of erosion or bank failure would be evident (< 10% of length) and streamside vegetation tightly binds the soil along the banks. An altered or severely altered stream is characterized by at least 25% of the stream bank exhibiting erosion and slumping especially at locations other than cut banks. If trees are present along the banks, many large roots (> 1 inch in diameter) are exposed and some to many trees are toppled into the stream due to undercutting.

Data Analysis

Earth Tech entered the scores from the field data sheets into Excel spreadsheets set up by ECU and submitted the electronic file along with copies of the field data sheets to ECU. ECU analyzed the data on an indicator basis and a whole watershed basis, with comparisons among watersheds studied by other consulting firms. This report is limited to a discussion of their findings for the Lumber River and Bear Swamp watersheds only. Earth Tech did some additional data analysis to compare functional status among sub-watersheds. Details of the ECU data analysis are found beginning on p. 14 of their report in **Appendix A**. Earth Tech sorted the sample point data by sub-watershed and averaged the indicator scores and the function scores for stream channel and riparian zone condition, and calculated a composite function score for each sub-watershed.

ECU Methodology Limitations

This ECU methodology was designed to give an overall functional assessment of the stream and riparian conditions found in coastal plain watersheds. This methodology is not intended to be nor is it adequate for obtaining the details necessary for restoration project design. Neither is it sufficient for identifying all potential project locations in a study area because only random points are sampled. It is quite useful, however, for identifying functional deficiencies on a particular reach and relating those deficiencies to restoration techniques or Best Management Practices (BMPs). It is also useful for determining differences in functional status among watersheds to prioritize where restoration efforts should occur.

The indicator-based scoring system can provide relatively detailed information about particular stream and riparian conditions found at the sampling sites. These indicator scores can be used individually or as composite scores to generate overall rankings and summaries of stream and riparian conditions either among watersheds or among sites. This information can be directly related to functional degradation factors present at a site or throughout a watershed. Individual sites with these degradation factors can then be investigated for suitability as mitigation projects or for implementation of BMPs. Because Earth Tech's scope included the identification of potential restoration project sites, the results of the ECU assessment were used to determine project suitability at random sample points. Earth Tech also assessed sites not visited during the field survey by relating certain indicators to site characteristics observable by GIS analysis and/or visual analysis of aerial photography. The process of site selection is discussed in more detail in Section 4.0 and **Appendix D**.

2.3 SUPPLEMENTAL INFORMATION

The ECU protocol was developed for the purpose of assessing ecological function and not for the purpose of identifying potential project sites. To take advantage of the wide exposure to the watershed afforded by the ECU field assessment, Earth Tech recorded supplemental notes at the random sampling points to assist in identifying potential project sites. These notes included mitigation project potential, obvious site constraints such as presence of utilities in a potential project area, habitat potential for threatened and endangered species, presence of exotic invasive plant species, and a cursory species list of vegetative cover in the riparian zone.

A Horiba Instruments U-22 water quality meter was used to measure conductivity, pH, temperature, and turbidity at each sampling point. These measurements were solely for the purpose of alerting the field crew to anomalous conditions, such as high specific conductivity, that would warrant further investigation of the surroundings of the sampling point. The measurements were taken only once on the day of sampling and were not used in the scoring or site selection. Detailed water quality and biological sampling conducted by DWQ is described below in Section 2.4.

Upstream, downstream, right bank, and left bank views of each sample site were photographed with a digital camera. These photos are archived on a CD submitted with this report.

2.4 DWQ STUDIES

The DWQ Biological Assessment Unit (BAU) conducted biological sampling at four locations in the Lumber River and Bear Swamp HUs in March 2004. Benthic macroinvertebrates were collected in the upper reaches of the watersheds where there was adequate flow and distinct channels.

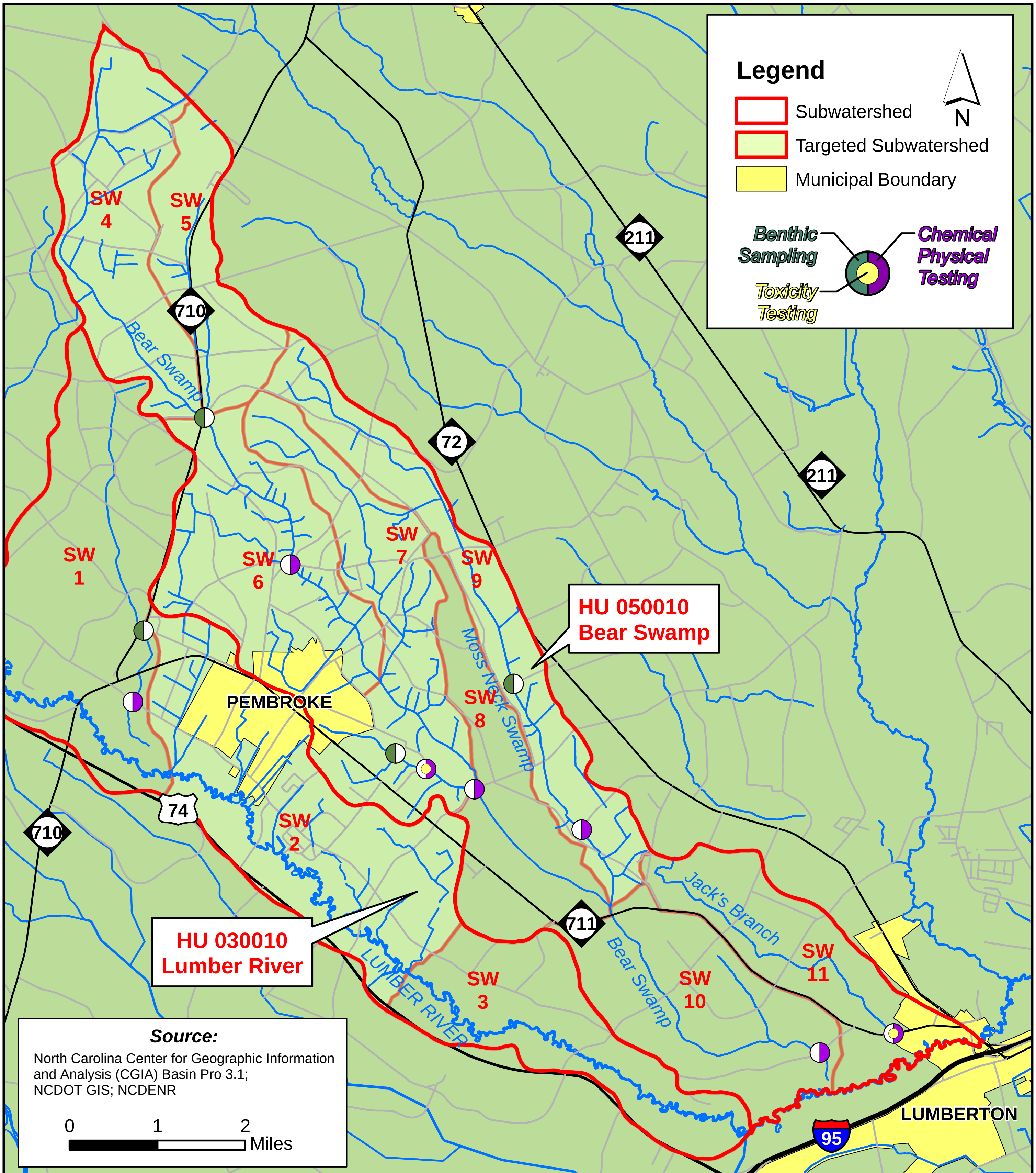
Chemical-physical sampling was conducted by the DWQ Watershed Assessment Team at seven stations from January through September 2004. Metals, nutrients, and field variables (dissolved oxygen, water temperature, turbidity, specific conductance, and pH) were monitored at these locations during base flows on a monthly basis. Storm flow samples were collected once on August 12, 2004. Additional storm flow samples were collected at Watering Hole Swamp and Jack's Branch on January 13, 2004 for *Daphnia magna* feeding inhibition toxicity testing.

Table 2 below lists the monitoring station locations. See **Figure 4** for a map of monitoring station locations. Details of sampling methodologies and findings are given in the full reports in **Appendix C.**

Table 2. Monitoring Station Locations

Stream	Location	SW	Benthic Sampling	Chemical-Physical Sampling	Toxicity Testing
Bear Swamp	NC 710	4	X		
Watering Hole Swamp	Joseph H. Rd.	7	X		
Moss Neck Swamp	SR 1570 (Alvin Rd.)	9	X		
Mill Branch	NC 710	1	X		
Lower Bear Swamp	SR 1339	10		X	
Upper Bear Swamp	Saint Anna Rd.	6		X	
Jack's Branch	NC 711	11		X	X
Lumber River	SR 1003	2		X	
Mill Branch	SR 1339	1		X	
Moss Neck Swamp	Holly Swamp Church Rd.	9		X	
Watering Hole Swamp	Jones Rd.	7		X	X

Results of biological and water quality monitoring were not included in the scoring of field assessment sites. Monitoring sites were limited to a few sub-watersheds and results from one site generally can not be extrapolated throughout a watershed or even throughout a stream reach. However, the results were used to inform the interpretation of the field assessment.



Ecosystem Enhancement PROGRAM

FIGURE 4
DWQ MONITORING LOCATIONS
Lumber River Local Watershed Plan
Critical Area Analysis
HU 030010 & HU 050010
Robeson County, North Carolina

3.0 RESULTS AND DISCUSSION

3.1 FIELD ASSESSMENT RESULTS

Earth Tech sampled 4 points in the selected sub-watersheds of the Lumber River HU and 64 in the Bear Swamp HU for a total of 68 assessed points in an area of 28.5 square miles (73.7 square kilometers). Four points were not assessed further after the presence of a floodplain impoundment was determined. Fourteen points were rejected (two ephemeral streams, 12 ditches) before obtaining the total of 68 appropriate points. The reach classification of the sample points is shown below in **Table 3.**

Table 3. Reach Classification of Sample Points

Rural Low Order	Urban Low Order	Rural High Order	Urban High Order	Total
45	1	22	0	68

The analysis provided by ECU reports that the Composite Function Scores of the 68 sample points ranged from 13 to 85. The distribution of scores by alteration class is shown below in **Table 4.**

Table 4. Composite Function Score Distribution by Alteration Class

Condition (Score Range)	Relatively Unaltered (90-100)	Somewhat Altered (60-89)	Altered (30-59)	Severely Altered (0-29)
# of points (% of total points)	2 (3%)	16 (24%)	24 (35%)	26 (38%)

Table 16 in the ECU report (**Appendix A)** shows the mean scores for each indicator. **Table 5** below is an adaptation of that table, with the indicators sorted from highest to lowest mean score.

Table 5. Mean Indicator Scores in Rank Order

Indicator	Stream bank stability (SBS)	Instream woody structure (IWS)	Pollution affecting stream (PAS)	Near-stream cover (NSC)	Factors affecting riparian zone (FARZ)	Riparian zone cover (RZC)	Channel-riparian zone connection (CRZC)	Habitat quality of riparian zone (HQRZ)	Sediment regime (SR)
Mean Score	74	55	50	47	44	43	37	32	30
Range	50-100	0-100	0-100	7-95	0-100	5-94	0-100	0-100	0-100

These results show that although the selected sub-watersheds are predominantly rural, they have been subjected to fairly extensive alterations, as measured by the indicators used in this assessment. Seventy-three percent of the points sampled scored in the Altered and Severely Altered Categories (**Table 4**). All nine indicators had mean scores that indicate at least somewhat altered conditions.

The three lowest scoring indicators were channel-riparian zone connection (CRZC), riparian zone habitat quality (HQRZ), and sediment regime (SR). These indicator scores are a reflection of field observations that most streams are deeply channelized, with extremely limited overbank flow; riparian zones are generally very narrow and often consist only of herbaceous vegetation; and the straightened, channelized streams do not transport sediment efficiently. The relatively high score for stream bank stability (SBS) is probably an artifact of a low number of sample points, none of which were on low order streams by design. SBS was not an applicable indicator for low order streams because the stream energy is so low that erosion generally is not a concern. The higher order reaches that were sampled mostly occurred at the lower end of the Bear Swamp HU where conditions are more swamp-like and stream energy is dissipated over the floodplain. The reaches that occurred in drainage districts were not mowed very often, so vegetative cover was fairly abundant although it was mostly herbaceous rather than woody.

ECU reported that stream channel and riparian zone indicators tended to be positively correlated, probably because most alterations affect more than one indicator. This was shown to be true among all the watersheds included in the ECU study, as well as within individual watersheds. Figure 12 on page A-37 of **Appendix A** shows the linearity of channel condition plotted versus riparian condition for the sample sites in the Lumber River and Bear Swamp HUs.

Earth Tech calculated composite function scores by sub-watershed. **Table 6** below shows the results of that calculation, with the sub-watersheds sorted from lowest to highest composite function score. Mean scores for individual indicators, individual functions in both the riparian zone and the stream channel, and the mean score for all functions in the riparian zone and stream channel are also shown for each sub-watershed.

Table 6. Functional Status of Sub-watersheds

Sub-watershed (SW)	**9**	**5**	**2**	**7**	**4**	**6**
Number of Sample Points	**21**	**2**	**4**	**18**	**10**	**13**
Mean SW Score by Indicator						
Total Riparian Zone Cover (RZC)	35	15	29	42	54	59
Total Near Stream Cover (NSC)	35	19	42	46	60	65
In-stream Woody Structure (IWS)	31	65	73	49	76	80
Sediment Regime (SR)	12	10	55	29	55	41
Channel-Riparian Zone Connection (CRZC)	6	10	45	48	43	73
Pollution Affecting Stream (PAS)	44	40	48	45	47	71
Factors Affecting Riparian Zone (FARZ)	14	28	39	53	54	78
Habitat Quality of Riparian Zone (HQ)	14	5	26	31	47	55
Stream Bank Stability (SBS)	67			60		93
Mean SW Score by Function						
Stream Channel						
Hydrology	27	48	55	48	55	75
Biogeochemistry	30	38	49	44	56	68
Habitat Quality	34	39	50	47	57	73
Riparian Zone						
Hydrology	18	21	32	48	50	70
Biogeochemistry	18	21	32	48	50	70
Habitat Quality	17	16	30	44	49	66
Mean SW Channel Function Score	30	41	52	47	56	72
Mean SW Riparian Zone Function Score	18	20	31	47	50	69
Composite Function Score	24	31	41	47	53	70

SW 9, which includes most of the Moss Neck Swamp drainage district, scored in the Severely Altered category (0-29). The main alteration throughout the drainage district, channelization, directly affects the channel-riparian zone connection, which is used as an indicator of all three ecological functions in both areas. The extremely low average for this indicator in SW 9 (CRZC=6), therefore, had the most influence on the Composite Function Score. Refer back to **Table 1** for the relationship of indicators to functions.

Subwatersheds 5, 2, 7, and 4 scored in the Altered category (30-59). The lowest individual indicator score for these SWs varied, and the land use characteristics were also somewhat varied. SW 5 includes Little Bear Swamp, a headwater tributary of Bear Swamp. It is partially within the Moss Neck drainage district. Its lowest indicator was Habitat Quality. Both sample reaches lacked a forested buffer on one or both banks. SW 2, which includes tributaries to the Lumber River, also lacks forested buffer on the majority of sample reaches. The lowest indicator score was also Habitat Quality. SW 7 includes a well-forested mid-reach of Bear Swamp, largely non-forested tributaries to Bear Swamp that fall within the drainage district, and Watering Hole Swamp. The lowest indicator score for this SW was Sediment Regime. This may be a reflection of the watershed position, downstream of a predominantly agricultural landscape. SW 4 includes the Bear Swamp headwaters, which are channelized but, in general, are adequately buffered. The lowest indicator score was Channel-Riparian Zone Connection.

SW 6 scored in the Somewhat Altered category (60-89). It includes a middle reach of Bear Swamp that is well-forested. There are also two tributaries, one of which drains the Town of Pembroke. The lowest indicator score was Sediment Regime, which again may reflect the position of the sub-watershed downstream of agricultural areas, as well as the position of one of the tributaries in an urban area with little bank protection.

This calculation of sub-watershed average scores may be useful as an *a priori* framework for prioritizing either additional studies or efforts for implementation of projects. However, a correlation between the Composite Function Score of a sub-watershed and the number of projects identified within that sub-watershed should not be expected. (Project identification is described in detail in Section 4.0 and **Appendix D.**) The EEP project standards of a 2000-foot minimum stream length with 5 or fewer landowners are not accounted for in the functional assessment protocol, but these practical factors are the primary filter for site selection. In this study, SW 9 had the lowest Composite Function Score (24) as well as the highest number of potential projects (9), but for the remaining sub-watersheds there is no similar correlation. See **Table 7** below.

Table 7. Relationship of Composite Function Score to Sub-watershed Project Potential

SW	**9**	**5**	**2**	**7**	**4**	**6**
Composite Function Score	24	31	41	47	53	70
# of Potential Projects	9	2	5	6	2	5

3.2 DWQ RESULTS

Biological Monitoring

Historical sampling of Bear Swamp at SR 1339 was conducted in 1996 and twice in 2001 (winter and summer). This location is at the farthest downstream road crossing on Bear Swamp and is located 0.5 miles above the confluence with the Lumber River. The bioclassifications of the 1996 and winter 2001 samples were both “Natural,” with sample characteristics similar to reference stream conditions. The 2001 summer sample could not be rated due to its small size.

Sampling at the SR 1339 station was not repeated in 2004 for this study, but a more upstream location on Bear Swamp (NC 710) was sampled. The bioclassification was “Good-Fair,” indicating a minimally to moderately impacted watershed. Bear Swamp may stop flowing during the summer months, and this could result in the lower taxa richness. Some intolerant and unusual caddisfly taxa were collected at this location.

Only one EPT taxon was collected at Watering Hole Swamp, so the sample could not be rated. Watering Hole Swamp has a small drainage area (less than 1 square mile), probably has low or no flow in the summer, and drains the Town of Pembroke. These factors may explain the low number and diversity of taxa.

The sample collected at Moss Neck Swamp was rated Good-Fair. Some pollution-intolerant caddisflies were also collected here. Flow is likely present year-round, and although the stream is channelized and the habitat is very poor, the water quality supports a Good-Fair benthic community.

Although the habitat rating for the Mills Branch station was similar to the Bear Swamp and Watering Hole Swamp stations, and much higher than the Moss Neck Swamp rating, the bioclassification was only Fair. No intolerant species were collected at this station.

The conclusions of the BAU report state that there are no indications of severely degraded water quality in the sampled watersheds, rather that samples are indicative of moderate impacts. The rating criteria were for coastal plain streams rather than swamps, and may have resulted in lower ratings than the streams actually merited. If there is a seasonal cessation of flow, and the streams can actually be classified as swamps, this would explain a lower abundance and richness of taxa. The small drainage areas of the watersheds may also contribute to a lower abundance and richness. Toxicity at Watering Hole Swamp may be a possibility because of its position downstream of the Town of Pembroke.

Table 8 below gives the highlights of results for the biological monitoring. The complete data analysis is provided in the report in **Appendix C.**

Table 8. Biological Monitoring Results

Location	Bear Sw. SR 1339 3/14/96	Bear Sw. SR 1339 2/8/01	Bear Sw. SR 1339 7/18/01	Bear Sw. NC 710 3/4/04	Watering Hole Sw. Joseph H. Rd. 3/4/04	Moss Neck Sw. SR 1570 3/4/04	Mill Branch NC 710 3/4/04
Bioclassification	Natural	Natural	Not Rated	Good-Fair	Not Rated	Good-Fair	Fair
Habitat Score*	--	--	--	63	61	39	61
Sample Type	Swamp	Swamp	EPT	EPT	EPT	EPT	EPT

*from BAU Habitat Assessment Field Data Sheet for Coastal Plain Streams

Water Quality Monitoring

In general, the results of the monitoring show that the overall water quality in the Bear Swamp and Lumber River HUs is not particularly degraded, with the exception of the Watering Hole Swamp and Jack's Branch stations. (Jack's Branch is not in a targeted sub-watershed.) Nutrient and metal concentrations were highest and dissolved oxygen and pH were lowest more frequently at Jack's Branch than at other sampling stations on the same dates. Ambient toxicity testing also indicated water quality impacts at Jack's Branch and Watering Hole Swamp.

Several field and laboratory results fell outside the accepted range of state water quality standards, EPA benchmarks, or EPA reference values on various sampling dates at various stations. Dissolved oxygen, pH, and some metals (copper, iron) exceeded the accepted state water quality standard, most often at Jack's Branch, followed by Watering Hole Swamp. Turbidity (storm flow only at Jack's Branch) was equal to the state standard. Elevated iron concentrations are not a concern because of the high iron content in soils in the watershed. Copper exceeded state standards in only one sample from Jack's Branch. Copper is one of the more toxic metals, but a cause for the apparently anomalous reading was not determined. The practical quantitation limit (PQL) for cadmium is equal to the state standard, and the PQL for mercury is 20 times greater than the state standard; therefore, levels may exist that are higher than the state standard, but are undetectable.

Nutrient and turbidity levels repeatedly exceeded the EPA reference values on at least one baseflow sampling occasion at every station. Nutrients measured included ammonia nitrogen, Kjeldahl nitrogen (TKN), nitrate + nitrite nitrogen, total nitrogen, and total phosphorus. Jack's Branch and Watering Hole Swamp samples exceeded reference values on all 8 samples taken. The one-time stormflow samples exceeded reference values for all nutrients at all locations, except for ammonia nitrogen, which was exceeded at only 2 of 5 stations sampled.

Only four of thirteen metals analyzed were present at detectable levels (above the PQL). Copper exceeded both chronic and acute benchmark toxicity levels in one sample taken at Jack's Branch. As discussed above, this was considered most likely an anomalous reading. All aluminum measurements exceeded the chronic benchmark value; two baseflow and three stormflow samples exceeded the acute benchmark value at Moss Neck Swamp and Watering Hole Swamp. Eighteen of 44 iron analyses, including 4 of 5 stormflow samples, exceeded the chronic benchmark value. No acute value is published. Only three manganese samples (two baseflow samples at Upper Bear Swamp and Jack's Branch, one stormflow sample at Lower Bear Swamp) exceeded the chronic benchmark value and none exceeded the acute value. Aluminum, iron, and manganese are all common components of the soils in the watersheds and are not of particular concern in terms of toxicity to biological communities.

Feeding inhibition toxicity tests seemed to support the field and laboratory data that indicated possible water quality problems at Jack's Branch and Watering Hole Swamp. Jack's Branch is downstream of a golf course and may receive pesticide runoff. Watering Hole Swamp is downstream of the Town of Pembroke and may receive urban runoff laden with dissolved organic compounds and other substances toxic to aquatic life.

Detailed documentation of the sampling results is included in the full DWQ report in **Appendix C.**

3.3 DISCUSSION OF FINDINGS

The findings of this study confirm that the sampled sub-watersheds show signs of moderate to severe functional degradation in terms of water quality, hydrology, and habitat. Each of the functional degradation concerns identified in the *IWC* were detected and confirmed by the functional assessment and/or the DWQ monitoring.

<u>*Lack of forested buffers*</u>: Forested buffers influence water quality, hydrology, and habitat. The low mean scores for Riparian Zone Cover (43) and Habitat Quality (32) indicate that throughout the watersheds riparian cover is inadequate. Where it does exist, the quality is poor, consisting mostly of herbaceous vegetation rather than mature forest. Overall water quality in the Lumber

River and Bear Swamp HUs was not found to be particularly poor, but the station downstream of Pembroke in SW 7 more often had parameter values outside accepted ranges than other monitoring stations. Only 24% of the total area of SW 7 is forested cover and only 35% of total stream length has a forested buffer at least 50 feet wide (Table G-2 in *IWC*). The average Riparian Zone Cover score for this sub-watershed is 42. The lower water quality in this sub-watershed is probably mostly attributable to urban runoff from impervious surfaces, but the lack of forested buffers to filter the runoff also is likely to contribute to the higher level of pollution.

Fragmentation and loss of terrestrial and wetland habitat: The Channel-Riparian Zone Connection indicator had a mean score of 37 for all sample points. The sub-watershed average score for SW 9, which contains the majority of the Moss Neck Swamp drainage district, was 6. These scores reflect the channelized condition of the streams throughout the watershed and in SW 9in particular. The extensive channelization has lowered the water table so that the formerly extensive wetlands have been reduced to small areas along the downstream end of major drainages. Only two sites were identified in the six sampled sub-watersheds where it appeared feasible to restore wetland hydrology. The assessment protocol was not set up to determine habitat fragmentation, but terrestrial habitat fragmentation and losses can be inferred from the lack of adequate riparian cover as discussed above. Also, the forested cover in the sampled sub-watersheds ranges from only 17% to 29% (Table G-1 in *IWC*) of total watershed area.

Conversion of agricultural lands to impervious surface: The assessment protocol was not designed to quantify this degradation concern. It was observed, however, during the course of the field work that some development is occurring in SWs 2 and 7. As reported in the *IWC*, the percentage of watershed area in impervious cover in SWs 2 (8%) and 6 (10%) is at or near the 10% threshold beyond which water quality may be expected to degrade. SW 7 had 4% impervious cover as reported in the *IWC*, but that number has increased, based on the field observations. There is a DWQ monitoring station in SW 7 but not in SW 2, so it is not possible to directly relate the higher impervious surface of both these watersheds to lower water quality. However, as noted above, the water quality at the station in SW 7 is definitely poorer than at the other monitoring stations, mostly likely as a result of its position downstream from Pembroke.

Loss of in-stream habitat as a result of channelization: None of the functional assessment indicators directly address in-stream habitat. However, some conclusions about habitat can be inferred from the Sediment Regime indicator. The mean score for Sediment Regime (30) was the lowest of all the indicators and just barely above the Severely Altered category. This heavy sediment load throughout the watershed would certainly have an effect on the in-stream habitat by filling in micropools as well as meander pools, affecting light penetration (and therefore temperature, photosynthesis, and other energy-conversion processes) by increasing turbidity, and abrading sensitive organisms with the suspended sediment. The biological monitoring results support this finding. The ratings of Good-Fair to Fair indicate that the benthic communities are moderately impacted. The DWQ habitat rating, which does directly address diversity of in-stream habitat, for the station on Moss Neck Swamp (SW 9) was 39 out of a possible 100 points. The sub-watershed average score for the Sediment Regime indicator was 12. These scores reflect the condition of Moss Neck Swamp as a deeply channelized, maintained stream with poor sediment transport, no overbank events that would deposit excess sediment, and possible sediment inputs as a result of the periodic maintenance. DWQ habitat ratings for other monitoring stations were not quite as low, but still only ranging from 61 to 63.

All of the sampled sub-watersheds offer some opportunity for better management of land and water resources. Projects in these sub-watersheds should provide an optimal mix of mitigation credit potential and functional improvement potential. Ideally, they should also serve to raise public awareness of watershed health issues and possibly provide other public benefits such as recreation or urban renewal. The following section details the process of identifying potential projects and attempts to show how the process relates to the functional assessment and to mitigation potential.

4.0 POTENTIAL PROJECT IDENTIFICATION

As stated in Section 1.0, the scope of this *CAA* includes the identification of potential project sites that may serve as solutions to the degradation of water quality, hydrology, and habitat functions as determined by the GIS analysis and field work. To the extent possible, the identification of potential projects was based on the framework of the functional assessment. The presence of alterations as indicated by stream and riparian condition (SRC) indicator scores was related to established compensatory mitigation techniques and criteria where possible. The possibility of receiving credit for "flexible mitigation" practices was also considered when identifying potential projects. Detailed definitions of conventional and flexible mitigation criteria (taken from *Stream Mitigation Guidelines* published by the US Army Corps of Engineers and others in 2003) are provided in **Appendix D**.

An attempt was also made to relate the SRC indicators to GIS screening methods so that potential projects could be identified in areas that were not visited as part of the random field assessment. With the mapping currently available, this could only be consistently done with Riparian Zone Cover, Habitat Quality of Riparian Zone, and Pollution Affecting Stream. Riparian buffer widths, cover types, and ditch inputs to streams are readily detectable with the available mapping. It was expected that spoil berms would be detectable with the 1-foot contour interval provided by the LIDAR data, but they were not consistently visible along streams where they were known to occur. The available LIDAR consisted of only one ground band and tree cover may have obscured topographic detail in some areas.

4.1 POTENTIAL MITIGATION PRACTICES

A variety of practices aimed at restoring one or more identified functional degradations may qualify for stream restoration or enhancement. A possible enhancement or restoration practice that will help restore the instream woody structure is the planting of trees in the 50-ft riparian zone (buffer restoration). This practice is also recommended to correct an inadequate quality of habitat in the riparian zone by increasing the habitat complexity normally found in those areas. More extensive restorative activities will need to be taken to restore a degraded channel-riparian zone connection (restoration of channel dimension, pattern, and profile). Fill or berm removal may be needed to restore access to floodplains, and restoration may be needed where streams have been channelized or have become deeply incised.

The combination of restorative practices for which a particular type of compensatory mitigation credit may be awarded is summarized in **Table 9** below.

Table 9. Criteria for Conventional Mitigation Types

Mitigation Category	Buffer Restoration	Dimension Restoration	Pattern Restoration	Profile Restoration	Wetland Vegetation Restoration	Wetland Hydrology Restoration
Stream Restoration	X	X	X	X		
Stream Enhancement I	X	X		X		
Stream Enhancement II	X	X				
Wetland Restoration					X	X
Wetland Enhancement*					X	X

*Restoration of just one or the other of these criteria is sufficient for enhancement

Other practices are available that could improve the water quality of a stream system, but if implemented alone may not qualify for stream mitigation credits. Methods for correcting a detrimental sediment input include implementation of sediment and erosion control BMPs adjacent to and upstream of a reach identified as having an altered sediment regime. Ditch and agricultural BMPs are also useful in correcting problems associated with pollution affecting the stream via ditch inputs and nutrient inputs from fields and livestock operations. Removal of cattle from the riparian zone will lessen nutrient inputs to a stream system as well. Opportunities exist for local entities to implement BMPs to assist in the water quality improvements in their areas of interest.

The relationship between SRC indicators and mitigation types is shown in **Table 10** on the following page.

Table 10. Relationship Between SRC Indicators and Mitigation Types

Functional Indicator	Alteration Characteristics	Alteration Correction Techniques	Stream Restoration	Stream Enhancement I	Stream Enhancement II	Wetland Restoration	Wetland Enhancement	Agricultural BMP	Livestock BMP	Stormwater BMP	Buffer Restoration	Buffer Enhancement
RZC	**S**uccessional or recently cleared riparian zone **I**mpervious surfaces within riparian zone **R**ow crops or maintained lawns within riparian zone	**I**mpervious surface removal **P**lant trees in riparian zone	X	X	X						X	X
NSC	**S**uccessional or cleared riparian zone (within 10 ft) **I**mpervious surfaces in riparian zone **R**ow crops or maintained lawns in riparian zone	**I**mpervious surface removal **P**lant trees in riparian zone	X	X	X						X	X
IWS	**F**ew or no large downed wood (LDW) in channel **N**o large trees (>4 inch DBH) along banks **S**tream channelized and periodically cleared of debris	**P**lant trees in riparian zone **R**estore stream dimension, pattern, and profile	X	X	X						X	X
SR	**S**ilt and sand carried by stream **E**vidence of sand or silt deposits being generated by upstream activities	**S**tormwater and agricultural BMPs, vegetation plantings in riparian zone, stream pattern, dimension and profile restoration	X	X	X			X	X	X	X	X
CRZC	**C**hannel is deeply incised or channelized **C**hannel containment structures or spoil berms present **F**illing or leveling of floodplain	**R**emove berms, fill, or containment structures **R**estore stream dimension, pattern, and profile	X	X	X							
PAS	**W**ater from roadside ditch empties into stream **O**verland flow from agricultural field **L**ivestock access or generated pollutants **S**ediment input from construction activities	**S**tormwater and agricultural BMPs, buffer restoration, livestock exclusion, stream bank stabilization				X	X	X	X	X	X	X
FARZ	**S**tream channelized or deeply incised, overbank flow rare **S**ewage or animal operation discharge into riparian zone **M**ore than 25% of riparian zone converted to non-forested land covers	**R**estore stream dimension, pattern, and profile **S**tormwater and agricultural BMPs **P**lant trees in riparian zone	X	X	X	X	X	X	X	X	X	X
HQRZ	**I**ntact forest covers < 75% of the riparian zone **E**xotic species present **O**ne understory stratum absent or under-represented	**V**egetation plantings in riparian zone, exotic species removal									X	X
SBS	**G**reater than 25% of stream bank eroded; **B**ank erosion, slumping, and undercutting prevalent **M**any tree roots exposed with trees toppled into stream **H**ard engineering present to stabilize stream bank	**R**estore stream dimension, pattern, and profile **R**emove hard engineering features, natural stabilization techniques, plant trees along stream banks	X	X	X							

4.2 METHODOLOGY

The list of potential projects was developed without consulting any landowners or local resource professionals. It takes into consideration information from the random sites sampled as part of the functional assessment. General site information obtained during the windshield survey was used to a lesser extent to verify observations at random sites when they occurred close together, or to make judgments about site suitability if no random sample point was in the vicinity.

Base mapping for the analysis was developed using BasinPro 3.1 and other sources according to procedures documented in the *Initial Watershed Characterization*. Data sources and modifications are described in Appendix A of that document. Additions to this document include the parcel data obtained from Robeson County and the locations of the functional assessment points. Screening for this project list was limited to the sub-watersheds selected for detailed analysis and functional assessment following the initial HU characterization. Those focal sub-watersheds are 2, 4, 5, 6, 7, and 9 (**Figure 2**).

The initial screening identified segments of perennial stream that are a minimum of 1500 feet in length with 5 or fewer associated parcels. These segments and the associated parcels were highlighted to define a potential project area. Drainages classified as ditches in the GIS were also highlighted to assess ditch inputs into true streams.

Field data sheets from the Earth Tech windshield survey and/or the ECU functional assessment were consulted to verify functional degradation at highlighted segments. Data points with a composite function score of less than 50 (Altered category) by the ECU method generally indicated the presence of one or more functional degradation factors that could be reversed or improved through a stream restoration technique or Best Management Practice (BMP), assuming cooperative landowners. In cases where there was no functional assessment point on a highlighted segment, data from a point within close proximity upstream or downstream was used. Descriptions from windshield survey points could also be used to verify certain conditions such as buffer width or channel incision.

Potential project areas identified from this screening were those areas with minimum 1500-foot lengths of stream, 5 or fewer landowners, and one or more of the following functional degradation indicators:

- Channelized stream (CRZC)
- Inputs from field or roadside ditches (PAS)
- Forested buffer less than 50 feet wide on one or both banks(HQRZ)
- Little or no instream woody debris (IWS)
- Cattle access to stream (PAS)

A second screening included sites that had the same characteristics as listed above, except that the stream is currently mapped as intermittent. Determination of perennial or intermittent status was not included in the scope of this study, so the sites were flagged in case a future determination shows them to be perennial and therefore eligible for mitigation credit under current policy. In any case, some entity other than EEP may be interested in applying stream or buffer enhancements even on intermittent streams to provide additional functional improvements to the watershed and a possible cushion against future watershed development.

A third level of screening identified areas of commercial or residential development and/or areas with ditch networks not associated with previously identified project sites. Neither field assessment was specifically oriented toward stormwater impacts or the functional assessment of ditches, so these potential project areas were selected on the assumption that the unbuffered ditches and developed areas are contributing sediment, pollutants, and/or excess runoff volume to the receiving streams. They were flagged for stormwater BMP retrofits and/or agricultural BMPs to enhance the functional status of their receiving streams. They are comprised of many parcels, and may not be suitable for implementation by EEP. Also, under current policy, EEP is not likely to receive mitigation credit for ditch or stormwater BMPs alone, but some other local entity may wish to consider undertaking these projects as part of an overall watershed management plan, or to buffer against future impacts.

GIS-based Project Site Selection

Not all sites were visited during field work. Some sites were selected based on visual similarity to sampled sites as determined by examining aerial photography. Color infrared aerial photography (1998), Robeson County parcel data, USGS 1:24,000 topographic mapping and BasinPro 3.1 stream mapping were utilized to select areas that exhibited characteristics similar to potential project sites that had been ground-truthed and had data demonstrating degradation of stream and riparian condition. For sites that were visited for the functional assessment, reaches of only 300 feet in length were sampled, so the remaining 1200 or more feet of potential stream project segments were assumed to have similar conditions to the sampled reach.

Wetland Restoration Project Site Selection

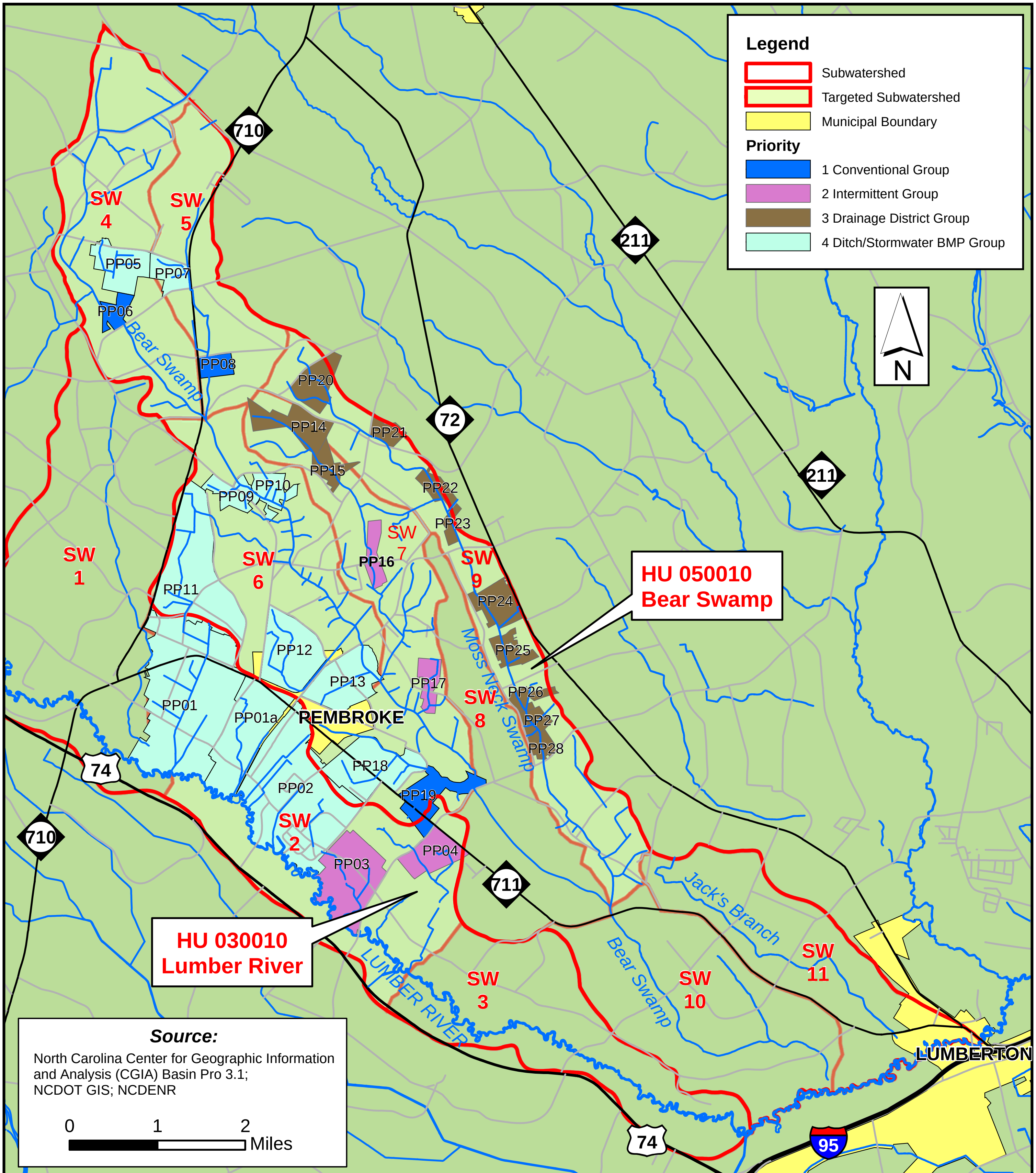
At the time the field work was conducted, only riparian wetlands were needed for compensatory mitigation, so there was no separate effort to locate potential non-riparian wetland restoration sites. The functional assessment protocol was directed exclusively towards the assessment of streams, but riparian wetland restoration potential was determined at each random sample site by checking for hydric soils and hydrophytic vegetation. General observations were also made in reference to the potential of hydrologic trespass if the wetlands were restored.

Project Constraints

An environmental hazard analysis and full investigation of project constraints was beyond the scope of this report. Any potential constraints observed during field sampling were noted and are included in the narrative descriptions of the sample sites.

4.3 POTENTIAL PROJECT PRIORITIZATION

Twenty-nine sites were identified by the methodology described above. The sites were prioritized into 4 groups based on the assessment of the identified potential project sites. These groups are based on shared characteristics and mitigation potential and provide a framework for EEP to initiate the mitigation site selection process. A general map of potential project site locations is shown on **Figure 5**.



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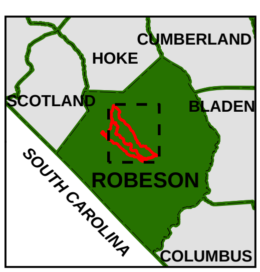

FIGURE 5
POTENTIAL PROJECT LOCATIONS
Lumber River Local Watershed Plan
Critical Area Analysis
HU 030010 & HU 050010
Robeson County, North Carolina

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The potential projects are grouped and prioritized as follows:

Priority 1-Conventional Group*:* These sites are suitable for conventional stream and wetland restoration under current EEP and regulatory agency guidelines.

Priority 2-Intermittent Group*:* Sites in this group have the same characteristics as the Priority 1 group, except that the streams are mapped as intermittent. If the Priority 1 sites do not meet the needs of the EEP mitigation program, it is recommended that perennial/intermittent determinations be made on the stream segments in this group. If a segment is found to be perennial, then the site would meet the criteria for conventional mitigation.

Priority 3-Drainage District Group: This group of sites was identified in the same manner as the Priority 1 and 2 groups, but were set apart because they fall within the Moss Neck Drainage District. The stream segments are all channelized and most lack an adequate woody buffer on one or both banks as a result of regular maintenance. Some have ditch inputs from agricultural fields. Assuming cooperation from the drainage district and agency approval, it may be possible to obtain mitigation credit for a combination of agricultural BMPs related to the ditches, buffer enhancement on at least one bank, and stream engineering that improves habitat, hydrologic, and water quality functions without creating adverse conditions on adjacent farm fields.

Priority 4-Ditch/Stormwater BMP Group: These sites were identified as having a ditch or network of ditches leading to a stream, and/or a concentrated area of impervious surface draining to a stream, as in a commercial or residential area. Agricultural or roadway ditch BMPs and/or stormwater BMP retrofits are recommended in these potential project areas to reduce sediment and pollution inputs and decrease runoff. BMPs alone are not likely to be eligible for mitigation credit, so implementation would fall to some entity other than EEP, unless mitigation policy changes. Also, some of these areas encompass large numbers of parcels and are more suitable for initiatives at the local level.

The individual projects are listed and described in **Table E-1** of **Appendix E**. Abbreviations, Definitions, and Narrative Site Descriptions follow the table. More detailed maps showing potential projects within individual SWs are included in **Appendix E**. A list of landowners associated with each project (obtained from county tax data) was submitted in a separate document for internal EEP use, but for privacy reasons is excluded from this report.

Detailed descriptions of restoration techniques and Best Management Practices will be included in the final section of this document, the Watershed Management Plan. The appropriate application, pollutant removal efficiencies, costs, and other topics will be discussed.

APPENDIX A

ECU Report:

Applying Ecological Assessments to Planning Stream Restoration in Coastal Plain North Carolina

Report to the Ecosystem Enhancement Program
North Carolina Department of Environment
and Natural Resources*

Applying Ecological Assessments to Planning Stream Restorations in Coastal Plain North Carolina

5 August 2005

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ABSTRACT

A reference framework was used to structure a rapid assessment method for estimating the ecological condition of riparian ecosystems in the inner coastal plain of North Carolina. Four versions with identical format were developed for low order (first and second) and high order (third and fourth) rural landscapes, and for low and high order urban landscapes. Assessments were conducted in six watersheds: four in the Tar-Pamlico basin, one in the Neuse River basin, and one in the Lumber River basin. Sampling sites were selected randomly within each of the watersheds at a density of approximately one per kilometer of stream length. A sampling unit for assessment was 100 yards in length, usually requiring less than 0.5 h for a pair of experienced professionals to assess. Indicator scores were then assembled to combine those that were pertinent to the stream channel and to the riparian zone for the 277 assessed reaches. The condition of reaches varied widely along the scale of relatively unaltered to severely altered conditions. Indicators for stream channels and for riparian zones tended to be positively correlated. Part of this correlation was due to the fact that most alterations affect more than one indicator. Better correlations between rural than between urban indicators indicate that the urban method needs to be better calibrated. The calibration process was applied to the rural but not the urban settings. The distribution of conditions differed among watersheds based on aggregate scores of the 8 or 9 indicators. At a site scale, scores of indicators suggest types of restoration procedures, but rapid assessment results are not intended to be adequate for details necessary for restoration project design. At the watershed scale, aggregate scores showed differences among watersheds that could be used to prioritize restoration efforts and could be monitored over time to detect change at small watershed scales (<100 km^2).

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INTRODUCTION

Reference-based Assessment

Reference-based assessment protocols were developed for intermittent and perennial riparian ecosystems located in the inner coastal plain of North Carolina. The assessments were designed to evaluate the condition of riparian ecosystems at the reach scale (100 yards) relative to unaltered reaches of the same type. Scoring of indicators of condition ranged between 0 and 100, where the indicators for the most altered reaches received a score of zero and the least altered (reference standard) received a score of 100. Indicators from a randomly chosen set of reaches were used to determine overall riparian condition within a watershed. Indicators were combined to reflect logical contributions toward ecosystem functions. These were also scaled from least altered to severely altered for the stream channel and riparian zone individually and as composite condition.

Riparian ecosystem functioning depends upon the condition of the stream itself, which incorporates onsite and upstream influences, and upon the condition of the riparian zone, which is affected by both channel condition and human activities in the riparian zone. The assessment procedure was designed to provide data to evaluate both components of the ecosystem (stream channel and riparian zone) in order to diagnose problems and identify potential solutions. The current study was conducted in small watersheds using randomly selected stream reaches. The results thus provide an estimate of the condition of riparian ecosystems for a watershed, not simply individual sites.

Classification

Based on differences in land-use in coastal plain watersheds and stream order, four classes of riparian ecosystems were identified. Different assessment procedures were developed for and applied to each class. Because land-use is a major determinant of condition, reaches were classified as primarily occurring either in an urban/suburban landscape or in a rural landscape. The urban versus rural differentiation was necessary because stresses imposed upon riparian ecosystems in the two types of landscapes differ. For example, urban watersheds have more impervious surface than rural watersheds. This results in stormwater being more rapidly carried to channels in urban areas, making urban stream flows more flashy and energetic than rural ones, particularly in headwater areas where low order streams are truncated by conversion to drainage pipes. This increased flashiness causes a suite of other problems in urban streams that are not as apparent or common in rural streams, including bank erosion and incision, among others. By applying different assessment protocols for urban and rural reaches, we were able to calibrate indicators of alterations typical for urban watersheds in ways that would not have been very sensitive in rural watersheds.

Stream size was another factor influencing the classification. Low (first and second) order streams differ hydrologically from higher (third and fourth) order streams in both rural and urban landscapes. Low order streams have intermittent flow, are primarily driven by groundwater discharge, and receive surficial groundwater that has passed through organic-rich surface soils and root zones (except where streams are channelized). Higher order streams have intermittent to perennial flow, are also supplied with groundwater and, under unaltered conditions, generate sufficient peak flows to put them in contact regularly with their floodplains.

Given these hydrologic differences, assessments were developed for the channel and riparian zones for four classes of riparian ecosystems: rural and urban low order streams, and rural and urban high order streams. Indicators of condition were identified and calibrated for each class with scoring ranging between 0 and 100 (representing most to least altered). The same indicator names were used for all classes, but the narrative for each indicator was adjusted to represent the specific conditions and variation observed in reference sites within each class.

Reach-scale Assessments

Riparian assessments were designed to be applied at the scale of a 100-yard reach. For each reach, 8-9 condition indicators were evaluated, depending on riparian class. Condition indicators are summarized in Table 1 to illustrate which parts of the stream-riparian zone they affect and which of the functions they evaluate. (Definitions of indicators, rationale for their use, and details of field measures are provided in Appendix A). The indicators "Sediment regime" (SR), "Channel-riparian zone connection" (CRZC), and "Stream bank stability" (SBS) are not evaluated if the channel is impounded. Some of the indicators are used to evaluate either channel condition or riparian zone condition, but not both (Appendix A). Other indicators are used to evaluate both components because alterations measured by some indicators affect both stream channel and riparian zone condition. For example, channelization increases stream flow duration and discharge of intercepted groundwater, but also drains normally wet riparian zones by increasing groundwater slope toward the channel.

Except for the indicator "Stream bank stability," indicators are used to evaluate more than one function, but the rationale for use in each function score is different. For example, wood in a stream channel affects hydrology by creating pool and riffle sequences that dissipate the energy of flowing water and store water in pools during low flows. Wood in channels affects biogeochemistry by providing a surface for microbial activity and a potential source of dissolved organic carbon (DOC), which is slowly released into the water over long periods. The rationale for matching indicators with functions is provided in more detail in Appendix A.

Although beaver impounded floodplains were explicitly excluded from the assessment procedure for all classes, beaver-influenced reaches were assessed if only the channel and not the floodplain was impounded. In such instances, three indicators of channel condition – "Sediment regime" (SR), "Channel-riparian zone connection" (CRZC), and "Stream bank stability" (SBS) – were not evaluated because fluvial indicators would either be underwater where they could not be observed or channel processes would be modified to such a degree that the indicators would not be an appropriate measure of condition.

The "Stream bank stability" (SBS) indicator is not evaluated in the rural low order class because hydrologic energy is often too low to overwhelm the binding capacity of streamside vegetation, even herbaceous vegetation. However, SBS is measured in the urban low order class because runoff from impervious surfaces in urban watersheds causes flashy hydrodynamics that destabilize banks and causes excessive erosion.

Table 1. Condition indicators as they relate to three general ecosystem functions: hydrology, biogeochemistry, and habitat. The rationale is briefly described, differs slightly by class (e.g., rural low order, urban high order, etc.), and is described in more detail in Appendix A. Even though many indicators are repeated for each function, the rationale for their use differs by function.

Stream Channel		
Function	**Indicator**	**Rationale**
Hydrology	Instream woody structure	Wood in channel creates riffle and pool sequences that dissipate energy of flowing water and store water in pools during low flows.
	Channel-riparian zone connection	Overbank flow dissipates energy, thus reducing channel incision and bank erosion. Storage of water in floodplains reduces downstream flood peaks and contributes to de-synchronization of flood pulses at watershed scales.
	Pollution affecting stream	Impervious surfaces increase flashiness of flow and may lead to channel incision, bank erosion, and a decrease in groundwater discharge.
Biogeo-chemistry	Near-stream cover	Plants nearest the stream channel provide the channel with organic matter from litterfall for microbial metabolism, stabilize banks to reduce sediments from entering stream, contribute organic matter to soil for denitrifiers, and take up nutrients for plant growth.
	Instream woody structure	Wood provides surfaces for microbial activity and may release dissolved organic carbon slowly over time.
	Sediment regime	Excessive sediment may transport phosphorus and heavy metals to the channel.
	Channel-riparian zone connection	Overbank flow contributes to the deposition of sediments and associated nutrients and metals that would otherwise be transported downstream. Wetlands in riparian zones contribute to nitrate removal in floodwaters.
	Pollution affecting stream	Pollutant sources interfere with normal biogeochemical cycling.
	Stream bank stability	Excessive bank erosion leads to sediment transport downstream. (Not used in rural low order streams because of difficulty in assessing.)
Habitat	Near-stream cover	Plants nearest the stream provide shade to reduce extremes in water temperature and organic matter to drive detrital food webs.
	Instream woody structure	Wood provides structural habitat complexity for epifauna and epiphytes. In larger streams, fish and invertebrates use woody structure for resting during high flows and shelter during low flows.
	Channel-riparian zone connection	Hydrologic connection contributes to the exchange of mobile organisms (some species of fish and invertebrates) between the channel and floodplain.
	Stream bank stability	Degree of bank erosion, when excessive, increases suspended sediments downstream. (Not used in rural low order streams because of difficulty in assessing.)

Table 1. Concluded.

Riparian Zone		
Function	**Indicator**	**Rationale**
Hydrology	Riparian zone cover	Forested riparian zones contribute to infiltration of precipitation, groundwater storage, and evapotranspiration.
	Channel-riparian zone connection	Overbank flow transports water and sediments to floodplains that contribute to groundwater storage and development of hydric soils.
	Factors affecting riparian zone	Alterations, ranging from conversion to impervious surface to filling with spoil, interfere with hydrologic functioning.
Biogeo-chemistry	Riparian zone cover	Plants in the riparian zone act as buffers to protect stream condition. Alteration usually reduces the capacity for denitrification and uptake by vegetation.
	Channel-riparian zone connection	Overbank flow contributes to high water tables and saturated conditions that are essential for wetland biogeochemical processes that depend upon reduced oxidation-reduction potentials.
	Factors affecting riparian zone	Most human activities contribute to nutrient loading rather than acting as buffers to reduce pollutant sources.
Habitat	Riparian zone cover	Riparian forest contributes to habitat complexity for vertebrates and invertebrates.
	Channel-riparian zone connection	Water from overbank flow contributes to saturated conditions for hydrophytes and ponding for aquatic organisms.
	Factors affecting riparian zone	Most human activities in the riparian zone degrade or eliminate forest habitat.
	Habitat quality of riparian zone	Forest species composition, forest age, and 3-D structure contribute to nesting, foraging, and denning opportunities that are otherwise absent in altered forests.

The indicator “Stream bank stability” is also used to evaluate condition in high order classes (both urban and rural) because larger streams have sufficient hydraulic energy to cause bank erosion problems. Bank condition is important because eroding banks contribute sediment to channels, which detrimentally affects biogeochemistry and aquatic habitat.

No attempt was made to weight the contribution of indicators to specific functions, mainly because the technical basis is lacking for doing so. However, some indicators carry more weight than others simply because they either logically affect more than one function or they represent a different proportion of the total number of indicators linked to a specific function (Table 2). In the former case, “Channel-Riparian Zone Connection” (CRZC) carries the greatest weight overall because it directly influences all functions. In the latter case, the biogeochemical function of the stream channel has six indicators that are averaged for the function score. Consequently, each indicator carries only half the weight of indicators influencing hydrology of the stream channel, which has only three indicators assigned to it.

Table 2. Relationship between indicators and function scores, following the logic described in Table 1. Function scores are the average of columns (Avg.). Mean function scores are averages of the Hydrologic, Biogeochemical, and Habitat function scores.

	STREAM CHANNEL			RIPARIAN ZONE		
INDICATORS	Hydrology	Biogeo-chemistry	Habitat	Hydrology	Biogeo-chemistry	Habitat
Riparian zone cover (RZC)				X	X	X
Near-stream cover (NSC)		X	X			
Instream woody structure (IWS)	X	X	X			
Sediment regime (SR)		X				
Channel-riparian zone connection (CRZC)	X	X	X	X	X	X
Pollution affecting stream (PAS)	X	X	X			
Factors affecting riparian zone (FARZ)				X	X	X
Habitat quality of riparian zone (HQRZ)						X
Stream bank stability (SBS)		X	X			
Function Score: Mean of all appropriate indicator scores for each function and location (stream vs. riparian zone).	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.
	Mean Function Score for Stream Channel			Mean Function Score for Riparian Zone		

METHODS DEVELOPMENT AND REFINEMENT

Training

Natural resource professionals from three consulting companies were trained in applying the assessment methods to the four riparian classes. Training involved two days of classroom training and two days of field training at various reference sites. These consultants were contracted by EEP to assess a random selection of reaches in one or more assigned watersheds and to provide the raw field data to ECU for analysis. ECU field teams assisted the consultant teams for several days in the field to answer remaining questions that consultants might have in interpreting indicator scores, recognizing criteria for rejecting points, or moving randomly assigned points.

Statistical Design for Watershed Sampling

To obtain an unbiased assessment of watershed condition, 300-ft reach locations within each watershed were randomly chosen for assessment by consultants. Random sampling was chosen because we thought this would provide the best basis for comparison of condition between watersheds by revealing the distribution of conditions within a watershed. From this approach, one can infer that results would be representative of the distribution of conditions present within the watershed as a whole.

Two stratified random sampling designs were considered, one based on randomizing points within stream order and the other based on randomizing within the sub-watersheds characterized by consultants. Stratified random sampling based on stream order was rejected because we suspected that stream orders would vary among watersheds in their proportion of total stream length, and *a priori* stratification would not account for such discrepancies. In contrast, a strictly random sampling design would be expected to distribute points among stream orders in proportion to the distribution of stream length by stream order. In other words, if 60% of the total stream length were first-order streams, then approximately 60% of random points would be expected to fall on first-order streams. Had one instead chosen to *a priori* sample 50% of points as first order streams, then the resulting watershed data would have under-represented the condition of first order streams.

Stratification by subwatershed was rejected because of the small size of some of the subwatersheds identified by consultants in Phase I of the project. Some of these subwatersheds were so small (1-3 km^2) that they would have had only one or two sample points assigned to them, which would not have been adequate to allow comparisons among subwatersheds. Increasing the sampling density above 1 site/km^2 catchment area could have overcome this problem, but would also have resulted in a much larger number of sample sites, and an unacceptable increase in cost.

Because of the unstratified random sampling strategy adopted, several tributaries were not assigned sampling points by chance. In retrospect, another approach would have been to adopt a stratified random sampling design stratified by subwatershed, but using larger sub-watersheds than the consultants originally circumscribed. This would have insured that each major tributary (as defined within a subwatershed) would have been assessed at a reasonable sampling density, and would have allowed comparison of its condition with other subwatersheds.

A refinement of the chosen sampling strategy would be to adopt a hierarchical approach. This approach is similar to that now used by EEP Planning. At the coarsest spatial scale, the least intensive assessment effort (Level I: using existing data, remote sensing data in GIS layers, etc.) is used in a manner similar to what is now done during Phase I by EEP, to identify areas in which to focus more intensive assessment. At an intermediate scale, a more intensive assessment effort (Level II: the ECU riparian assessment or similar method; present Phase II by EEP) is used with a stratified random approach based on subwatersheds (comprising major tributaries) to provide a basis for comparison among sub-watersheds and to conduct even more intensive assessment. At the finest scale, it may be appropriate to evaluate the entire stream length to identify specific restoration opportunities (as in the present Phase III by EEP). Such a hierarchical approach uses an appropriate level of assessment at a given spatial scale to provide information needed for a progressive narrowing of focus.

Random Assignment of Sampling Points in Watersheds

Sampling density of random points was approximately one point per km^2 of watershed area. For a drainage density of 1.0 km/km^2, this resulted in sampling density of one reach per 1 km of stream length. Since the assessment method evaluates a 300 ft reach, this means that approximately 10% of the total watershed stream length was assessed.

To assign random points for assessment, a GIS algorithm available from the web page of Environmental Systems Research Institute (ESRI) was used (Brooks et al. 2004) (*http://arcscripts.esri.com/details.asp?dbid=10296*). The algorithm uses an Avenue script that places random points on line shapefiles derived from USGS 1:24,000 scale maps (7.5-minute quadrangle series). In ground-truthing the hydrography, we found that the USGS 1:24,000 hydrography network in the coastal plain omits many headwater intermittent streams and includes many ditches that were never part of the natural stream network. Although those ditches contribute to the hydrologic and biogeochemical condition of their watersheds, they were not assessed because they were never streams, and are not considered candidates for restoration. In contrast, ditched reaches of once natural streams were assessed because they were a part, albeit an altered part, of the original stream network.

To incorporate the above inconsistencies in the hydrographic data, we modified the digital hydrography by manually adding and deleting streams. Because a final determination would be made in the field as to whether a randomly selected reach was or was not a part of the natural stream network, we decided to be conservative in our modifications (i.e., apply a method that would tend to add ephemeral channels to the network rather than exclude true streams).

Several approaches for extending the stream network were tested. First, we manually digitized additional headwater streams from county soil survey maps (USDA Soil Conservation Service, now Natural Resources Conservation Service), which often show headwater streams not included on USGS quads. (Digital soil survey hydrographic data are not presently available for most counties in NC.) In a test using one of the six assessed watersheds (Cow Swamp), we determined that manually digitizing additional streams would be too time consuming.

In the second method tested, we used digital elevation models (DEMs) constructed using high-resolution LIDAR data available from the NC Floodplain Mapping Program (a cooperative program involving local governments, agencies of the State of North Carolina and the Federal Emergency Management Agency (FEMA) (*http://www.ncfloodmaps.com*)). LIDAR DEMs were processed using ArcGIS 9 and a geospatial hydrologic modeling extension (HEC-GeoHMS) developed by the U.S. Army Corps of Engineers (*http://www.hec.usace.army.mil/software/hec-hms/hechms-geohms.html*). The resulting stream network was ground-truthed with another watershed in the study area (Green Mill Run). Despite manipulation of model parameters (primarily the flow-initiation threshold), we were unable to reasonably replicate the stream network. At low values of the flow-initiation threshold, many streams were generated by the model that did not exist. Raising the threshold would reduce the number of non-existent streams added, but would also increase the number of true streams not identified. A suitable intermediate threshold could not be found that would prevent the addition of non-existent streams without removing streams known to exist. The flat topography of the coastal plain is probably the main reason this method failed to reliably identify the true stream network.

The third method tested, and eventually adopted, was to predict additional streams from existing topographic maps. Most unmapped streams observed by us in previous surveys had occurred in topographic linear depressions (visible on topographic maps as a crenulation, or “draw”). From this observation, and previously collected slope data for headwater streams (Rheinhardt et al. 1998, Brinson et al. in preparation), we developed criteria for manually extending streams headward and removing ditches, based on topography. For a linear depression to indicate the presence of an intermittent or perennial stream it had to have: (1) two or more topographic contours showing a v-shaped deflection of <90° from the general trend of the contour line (i.e., lines tangent to the inflection point of the deflected portion of the contour line had to intersect at an angle of <90°), (2) a slope of greater than 0.5%, and (3) a downstream connection to a mapped stream not more than two stream orders higher than the added stream (i.e., 1st order added streams could connect to a 1st, 2nd or 3rd order stream, but not to a 4th or higher order stream and 2nd order added streams could not connect to 5th or higher order streams). This connection rule was developed to avoid adding streams where groundwater tables, controlled (lowered) by the higher order stream, would have been too deep to contribute to flows of an added tributary. However, a few additional streams may have been missed using this criterion. Figure 1 shows an example of streams added using the topographic rules outlined above. Figure 2 shows the resulting digital stream network for the Cow Swamp watershed.

Once the modified hydrography data layer was completed for each watershed, a random point algorithm was run to generate random points along streams in the watershed at a density of 1 point per km of stream length (roughly 1 point per km^2 of watershed area, given that stream density of the watersheds is approximately 1 km/ km^2). Because we suspected that some of the random points would not lie on true streams and would have to be rejected for other reasons, an alternate set of random points was also generated. Figure 3 shows the modified hydrography and primary, alternate, and assessed random points for the Cow Swamp watershed. For comparison of the watershed scale and stream network topology, Figure 4 shows the adjusted stream networks and random points assessed for all six watersheds.

Watershed-scale Assessments

Two hundred seventy-seven (277) randomly chosen reaches were assessed by consultants in six watersheds (Table 3). Four watersheds were in the Tar basin, one in the Neuse, and one in the Lumber. Drainage basins ranged from 23-78 km^2 in size. There were 161 rural low order reaches assessed, 43 urban low order reaches, 50 rural high order, and 23 urban high order reaches. Stream length within a watershed ranged from 37-91 km (Table 4). Because assessment reaches were randomly assigned, watershed assessment results are proportional to stream length. For example, because 18 of 67 reaches (26.9%) in the Stoney Creek watershed were urban low order (Table 4), then urban low order reaches represent 24 km (90.7 km x 0.269) of stream length in the watershed. Discrepancies in the distributions between the assigned reaches and the sampled reaches (Table 4) were due to there being a higher proportion of low order reaches rejected in the field than higher order reaches, i.e., most rejections were due to headwater reaches not being true streams.

Protocol Testing

Thirty reaches of the 277 reaches assessed by consultants were chosen randomly for re-assessment by the authors (ECU team) (Table 5). All reaches randomly chosen for re-assessment by the ECU team were distributed by watershed and riparian class in roughly the same proportion as they were originally assigned to consultants. Re-assessment was designed to test whether the protocol was calibrated and written clearly enough for the consultants to arrive at the same answers as the authors. From 66

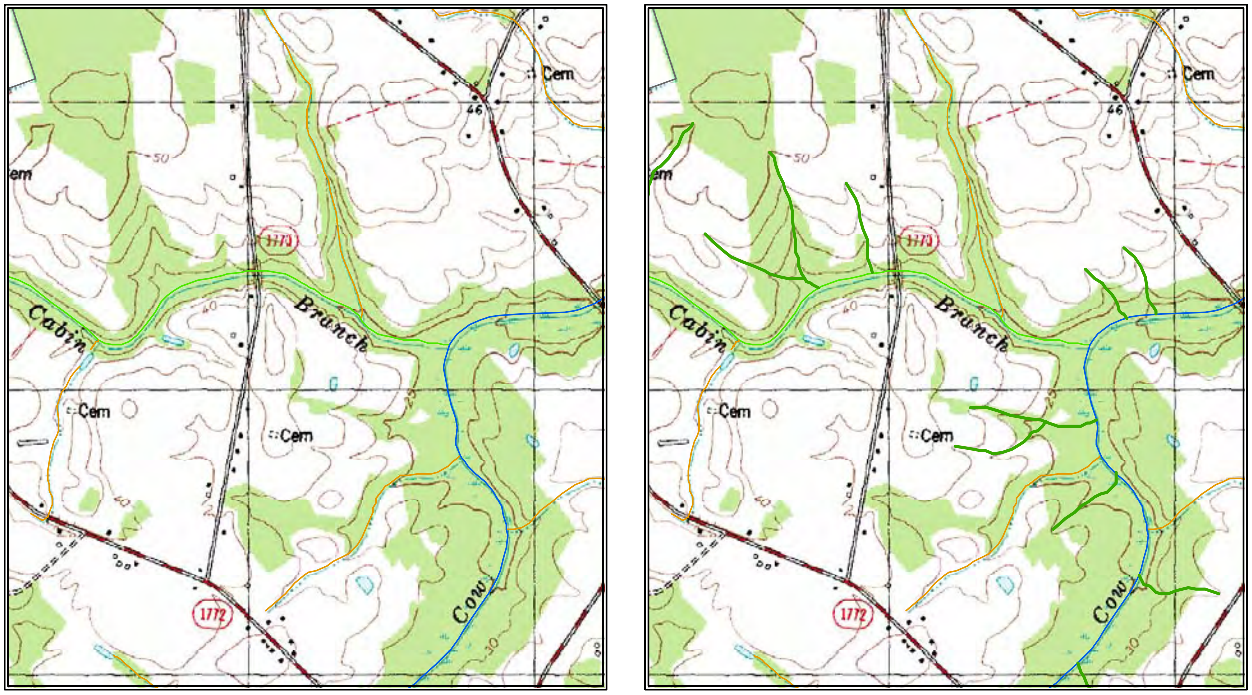

Figure 1. Example of USGS topographic map excerpt showing additional streams (thick, green lines) visually added based on topographic rules. Left image is the original map; right image is the modified map. The fine-lined grid is the UTM grid; lines are 1 km apart.

Table 3. Watershed area and number of reaches assessed by consultants in each watershed. Eighty-nine additional reaches were rejected.

		Number of reaches assessed by type				
	Watershed area (km^2)	Rural Low Order	Urban Low Order	Rural High Order	Urban High Order	Total # reaches
Cow Swamp	44.5	34	0	6	0	40
Crisp Creek	45.9	35	0	10	0	45
Green Mill Run	22.9	5	18	0	11	34
Hendricks Creek	34.4	9	6	0	8	23
Stoney Creek	77.5	33	18	12	4	67
Lumber Sub-basin*	73.7	45	1	22	0	68
Total	298.9	161	43	50	23	277

*Bear Swamp and Moss Neck Swamp

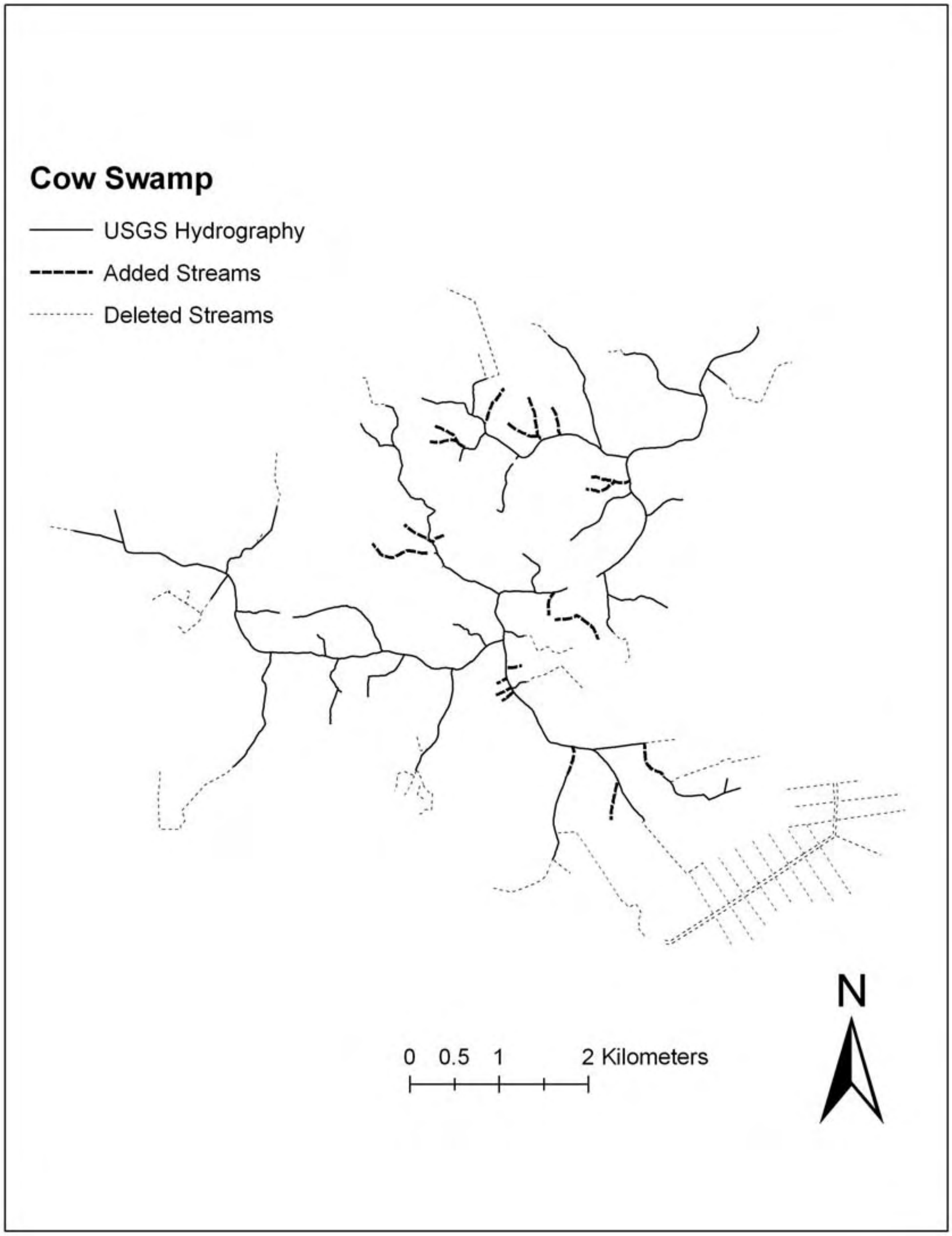

Figure 2. Stream drainage network of the Cow Swamp drainage after adjusting hydrographic data to better model the true stream network. Solid lines are original USGS 7.5-minute (1:24,000) hydrography, heavy dashed lines are streams added from topography, and light dotted lines are ditches removed from original hydrography. The gap in the stream network is an impounded reach.

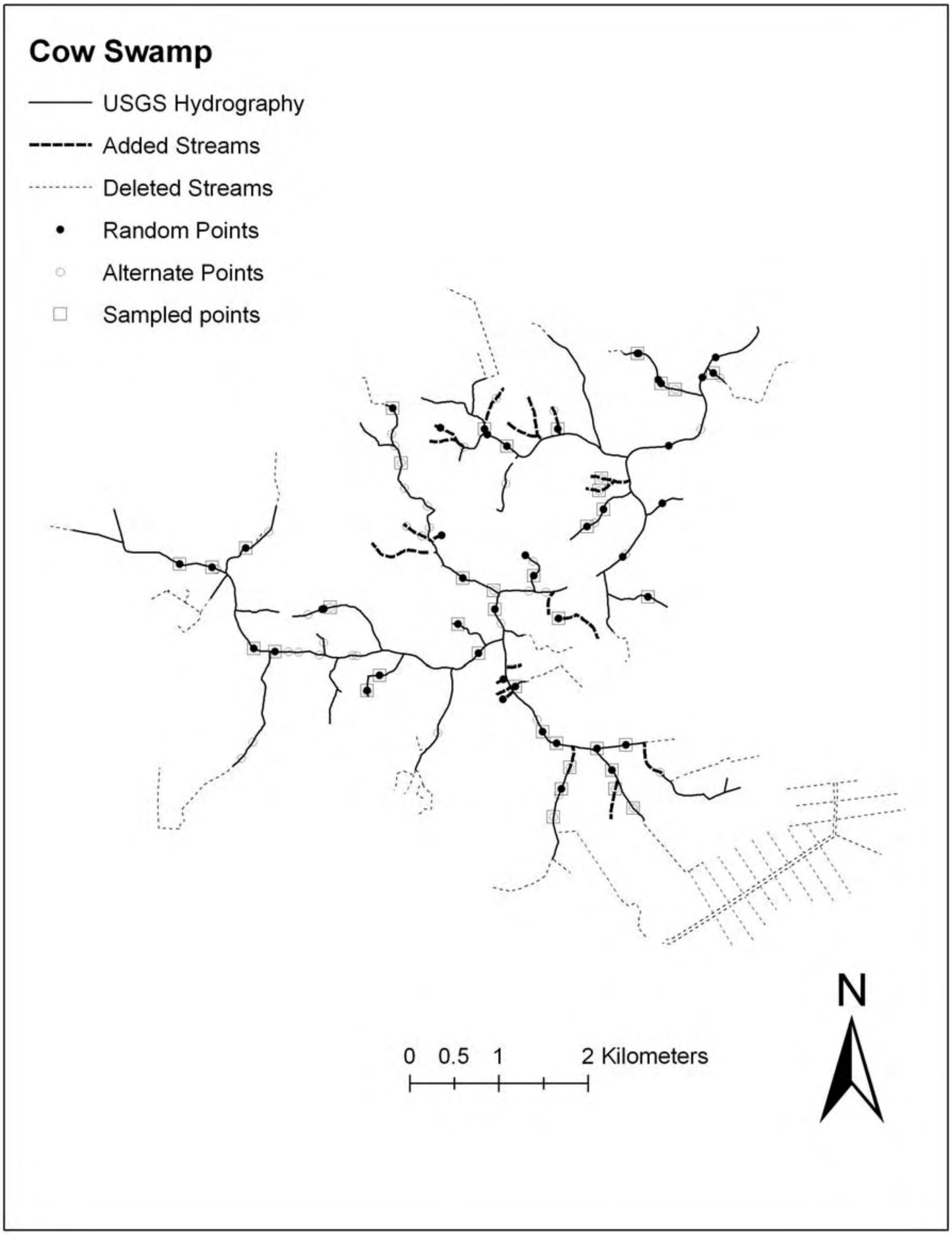

Figure 3. Adjusted Cow Swamp stream drainage network with random assessment points. Solid dots are the initial set of random points, open circles are the alternative set of random points, dots and circles surrounded by a square are the points actually assessed.

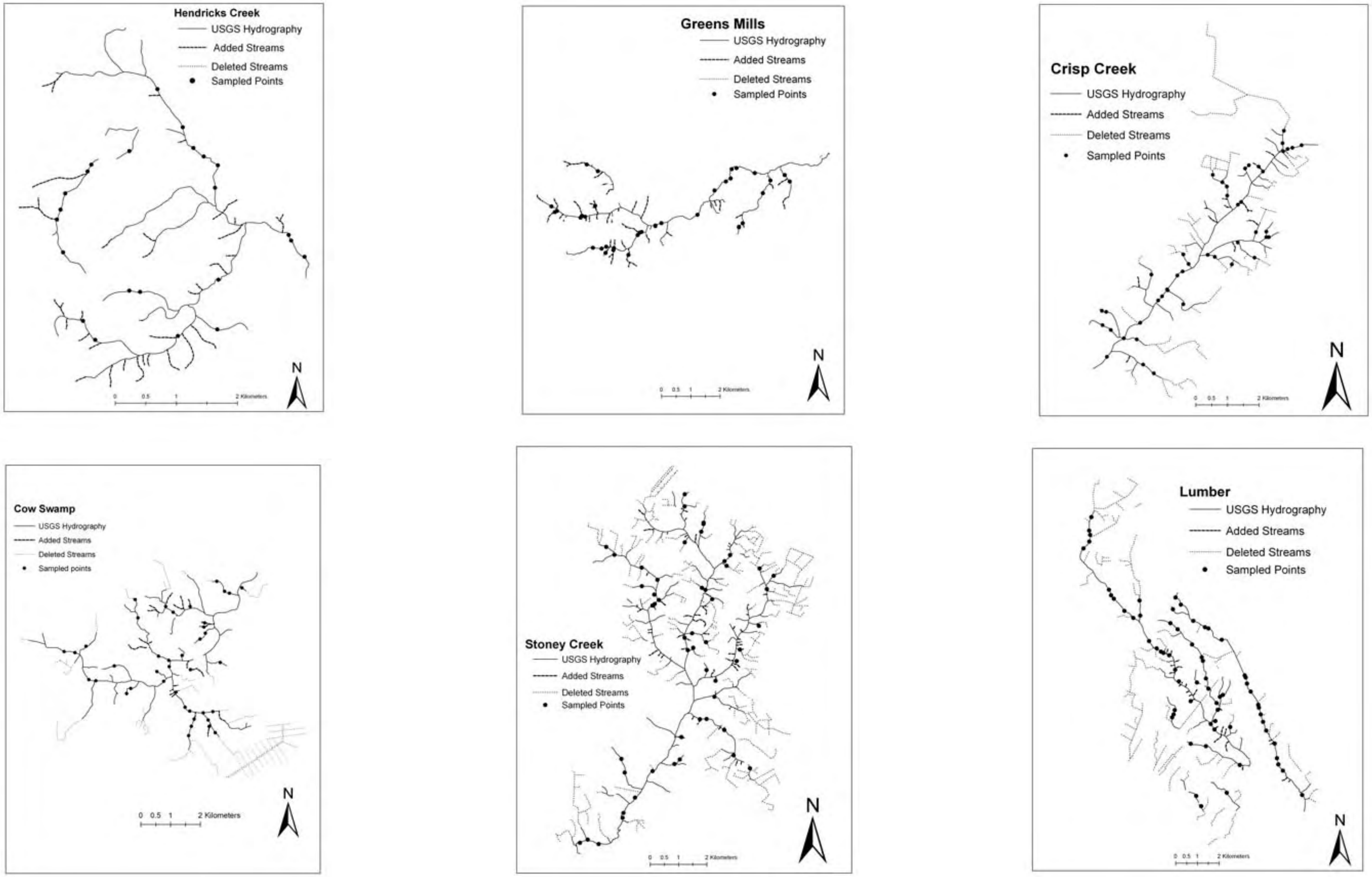

Figure 4. Adjusted stream drainage networks for all six watersheds for comparison of stream network scale and topology. Dots indicate the random points actually assessed.

reaches that had been rejected by the consultants for being a ditch, an ephemeral stream, or a culverted reach (Table 6), eight were randomly chosen to see if they should have indeed been rejected. This was to test whether the rejection criteria (Appendix A) were clear enough to enable users to correctly reject sites.

Table 4. Stream lengths and percent of reaches by assessed type and watershed. Distribution among riparian classes differs somewhat from the randomly assigned distribution due to the rejection of many headwater reaches.

Watershed	Total stream length (km)	% Reach Type Rural Low Order	Urban Low Order	Rural High Order	Urban High Order	% Total Low Order	% Total High Order
Cow	47.5	85.0	0.0	15.0	0.0	85.0	15.0
Crisp	41.2	77.8	0.0	22.2	0.0	77.8	22.2
Green Mill	36.6	52.9	14.7	0.0	32.4	67.6	32.4
Hendricks	38.1	39.1	26.1	0.0	34.8	65.2	34.8
Stoney	90.7	49.3	26.9	17.9	6.0	76.1	23.9
Lumber	74.8	66.2	1.5	32.4	0.0	67.6	32.4
Mean %		62.8	10.8	18.1	8.3	73.6	26.4

Table 5. Number of sites re-sampled by watershed and riparian type. An additional reach that was assessed, but should have been rejected, was not included here. Compare with initial sample size by watershed, Table 3.

	Rural Low Order	Urban Low Order	Rural High Order	Urban High Order	Total
Cow	2	0	2	0	4
Crisp	3	0	0	0	3
Green Mill Run	0	3	0	1	4
Hendricks	1	0	0	1	2
Stoney	6	2	1	1	10
Lumber	4	0	2	0	6
Total	16	5	5	3	29

Table 6. Distribution of reaches rejected by watershed and rejection criterion. Reasons for rejection not included here were lack of access (n=1), overlap with another reach (n=4), or floodplain flooded by beaver impoundment (n=18).

	Ditch	No stream or ephemeral draw	Culverted or piped	Total
Cow	3	5	0	8
Crisp	1	3	0	4
Green Mill	0	6	2	8
Hendricks	2	9	3	14
Stoney	0	5	13	18
Lumber	12	2	0	14
Total	18	30	18	66

Data Analysis

Indicator analysis -- A matrix was generated of indicator scores for each reach. Individual indicator scores were averaged for each watershed to be able to compare watersheds at the basic level of indicators. Indicators were then combined and averaged following the logic in Table 7 to compare watersheds by Hydrologic, Biogeochemical, and Habitat function scores within both the Stream Channel and the adjacent Riparian Zones. The three resulting function scores for Stream Channel and for Riparian Zone were then averaged to obtain a mean function score for those two components. A Composite Function score was then calculated by averaging all function scores (Table 7, bottom row) for each reach. A mean Composite Function score was then calculated for each watershed.

Simple linear correlations were used to determine if any indicator scores within a riparian class co-varied with others. We expected that there would be co-variance because human alterations tend to change many variables at once. Unexpected patterns might reveal differences in effects of alteration among riparian classes, problems with the calibration of indicators, and/or problems with the way indicator conditions were defined in the field sheets (Appendix B3).

Watershed analysis -- Watersheds were evaluated relative to the condition of the Channel and Riparian Zone, as outlined in Figure 5, by graphing the distribution of Channel and Riparian condition scores for all reaches in a watershed. Composite Function scores in Figure 5 are delineated by dashed lines into condition categories carried over from stream riparian condition categories in the field sheets: 0-29 (severely altered), 30-59 (altered), 60-89 (somewhat altered), and 90-100 (relatively unaltered) (Appendix A). Note that reaches tend to cluster along a line with a slope of 1. This is because alterations to the channel affect the riparian zone and visa versa. For example,

Table 7. Relationship between indicator scores and function scores. Indicator scores are averaged by (columns) to obtain Hydrologic, Biogeochemical, and Habitat mean function scores. A Composite Function score is average of all Function Scores (bottom row), i.e., 29 in this example. "Stream bank stability" is not measured in rural low order class.

INDICATORS	STREAM CHANNEL			RIPARIAN ZONE		
	Hydrology	**Biogeo-chemistry**	**Habitat**	**Hydrology**	**Biogeo-chemistry**	**Habitat**
Riparian zone cover (RZC)				44	44	44
Near-stream cover (NSC)		45	45			
Instream woody structure (IWS)	10	10	10			
Sediment regime (SR)		10				
Channel-riparian zone connection (CRZC)	30	30	30	30	30	30
Pollution affecting stream (PAS)	40	40	40			
Factors affecting riparian zone (FARZ)				10	10	10
Habitat quality of riparian zone (HQRZ)						10
Stream bank stability (SBS)		50	50			
Function Score: Mean of all appropriate indicator scores for each function and whether for stream channel or riparian zone.	27	31	35	28	28	24
	Mean Function Score for Channel = 31			**Mean Function Score for Riparian Zone = 27**		
	Composite Function Score = 29					

channelization usually is associated with removing riparian zone vegetation for maximizing cropland along low order reaches, maintaining access for channel dredging equipment along high order reaches, and severing channel-riparian zone connection along both types of reaches.

Because the data represent a random selection of reaches in the watershed, one can infer that the distribution of points represents the condition of the watershed. Using Figure 5 data as an example, because 6% of the randomly sampled reaches were in a severely altered condition, one can infer that 6% of the total stream length of the watershed is severely altered. (The percent of reaches sampled in each category is provided for all categories.) This same logic can be applied to any summary score for a watershed, including Composite Function scores, as long as the assessment data represent a random selection of reaches in the watershed (as was true for this study).

To provide a composite picture of each watershed and have a metric to compare watersheds, all Composite Function scores for reaches within a watershed were averaged to obtain a mean Composite Function score. To help identify sources of problems within reaches and watersheds, indicator scores for reaches were sorted by riparian class and averaged across all reaches within a class in each watershed.

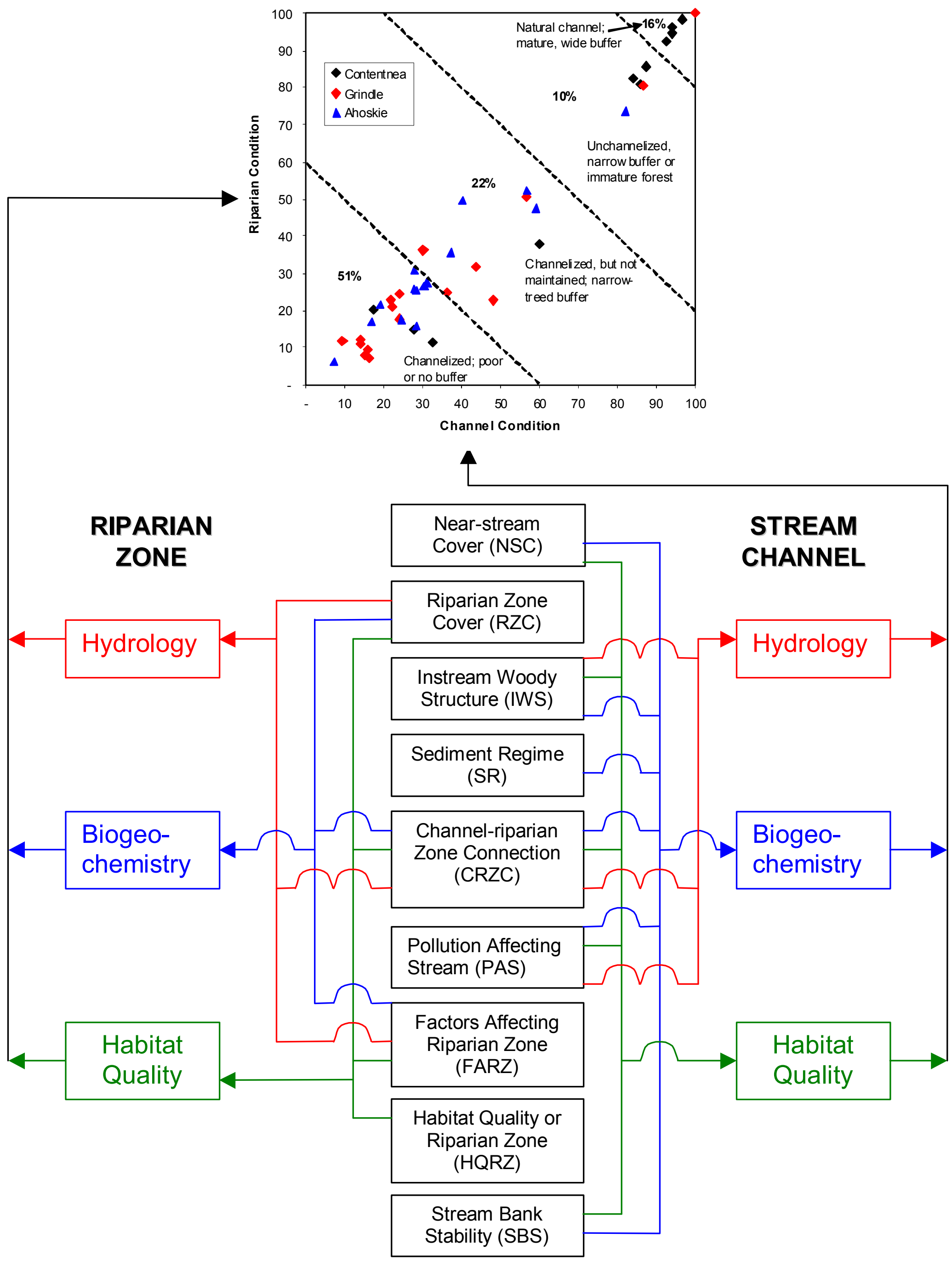

Figure 5. Relationship between indicators, functions, and the condition of channel and riparian zone. For each reach assessed, function scores are the mean of selected indicators (Table 2). The x and y axes in the graph are the averages for each of the three function scores. Three coastal plain watersheds are used to illustrate this. From Rheinhardt et al. (in review).

The ECU team re-assessed a sub-sample of reaches assessed by consultant teams. Two-tailed sample t-tests were performed to determine if there were any significant differences between the indicator scores recorded by consultant teams and those recorded by the ECU team, i.e., by testing the null hypothesis of no difference between scores. Channel-riparian zone connection was scored for both sides only in the urban high order reaches and were pooled for the comparison. Reaches influenced by beaver impoundments flooding the channel were not scored.

RESULTS AND DISCUSSION

A Composite Function score, the average of all function scores within a reach (*sensu* Table 7), can be used to quantify changes within a reach over time (either impacts from projects or improvements from restoration) or rank reaches relative to one another (e.g., for comparing project-related alternatives). In this report, only ranking of reaches will be presented. Composite Function scores ranged from a low of 8 in a reach of the Crisp Creek watershed to a high of 95 in a reach of the Stoney Creek watershed. (Raw indicator and function scores and other converted data are provided for all watersheds in files on an accompanying CD-ROM.) Only eleven of the 277 assessed reaches (4%) scored >89 (relatively unaltered condition).

Table 8 provides the distribution of Composite Function scores within watersheds, by categories, from relatively unaltered to severely altered. This distribution of scores can be used to evaluate a given watershed or compare scores among watersheds. For example, Stoney Creek had the highest percentage of reaches in a relatively unaltered condition (10.4%) whereas Crisp Creek had the highest percentage of severely altered reaches (62.2%). For Crisp, this is equivalent to 25.6 km of stream length being severely altered (41.2 km * 0.622).

For making broad-scale comparisons among watersheds, one can compare mean Composite Function scores across watersheds. Mean Composite Function scores for watersheds ranged from 28 for Crisp Creek to 67 for Stoney Creek (Table 9). These scores reflect the condition of a given watershed in relation to its potential (100) and can also be used to make general comparisons among watersheds, but at the level of individual functions. However, because calibration of indicators differs among each of the four riparian classes and every watershed varies in proportion of four riparian classes, comparisons between predominantly rural and predominantly urban watersheds are not meaningful, except for comparing how closely the watersheds are to realizing their potential (least altered) condition.

For diagnosing problems within a reach or for developing restoration strategies for that reach, one should evaluate the condition of individual indicators. (Assessment of specified reaches for targeted restoration would not use the random sampling approach for watersheds described in this study.) For example, for reach #43 in Crisp Creek, “Sediment regime” (SR) was relatively unaltered, but the other indicators were scored as altered or extremely altered (Figure 6). This suggests that in restoring functions to the reach, one would not implement practices to control sediment, but the other indicators of condition could be improved. (Indicators scores for all reaches are provided in files on an accompanying CD-ROM.)

Table 8. Percent of reaches by watershed and condition category, based on Composite Function scores. This is equivalent to % stream length by watershed and condition category.

Watershed	% Reaches, by Condition category Relatively unaltered (90-100)	Somewhat altered (60-89)	Altered (30-59)	Severely altered (0-29)
Cow	0.0	15.0	35.0	50.0
Crisp	0.0	2.2	35.6	62.2
Green Mill Run	0.0	23.5	70.6	5.9
Hendricks	4.3	43.5	47.8	4.3
Stoney	10.4	55.2	28.4	6.0
Lumber	2.9	23.5	35.3	38.2

Table 9. Mean Composite Function scores by watershed. Composite Function scores are derived from the average of all function scores within a reach (see Table 2). Mean Function scores (columns) for relatively unaltered watersheds would score 90 or greater for all functions. Sample size provided in Table 3.

	STREAM CHANNEL			RIPARIAN ZONE			Mean Composite Function scores
	Hydrology	Biogeo-chemistry	Habitat	Hydrology	Biogeo-chemistry	Habitat	
Cow	40	39	40	31	31	31	35
Crisp	35	35	35	20	20	21	28
Green Mill	55	54	58	51	51	44	52
Hendricks	63	63	63	63	63	63	62
Stoney	64	63	66	72	72	69	67
Lumber	48	46	49	42	42	39	44

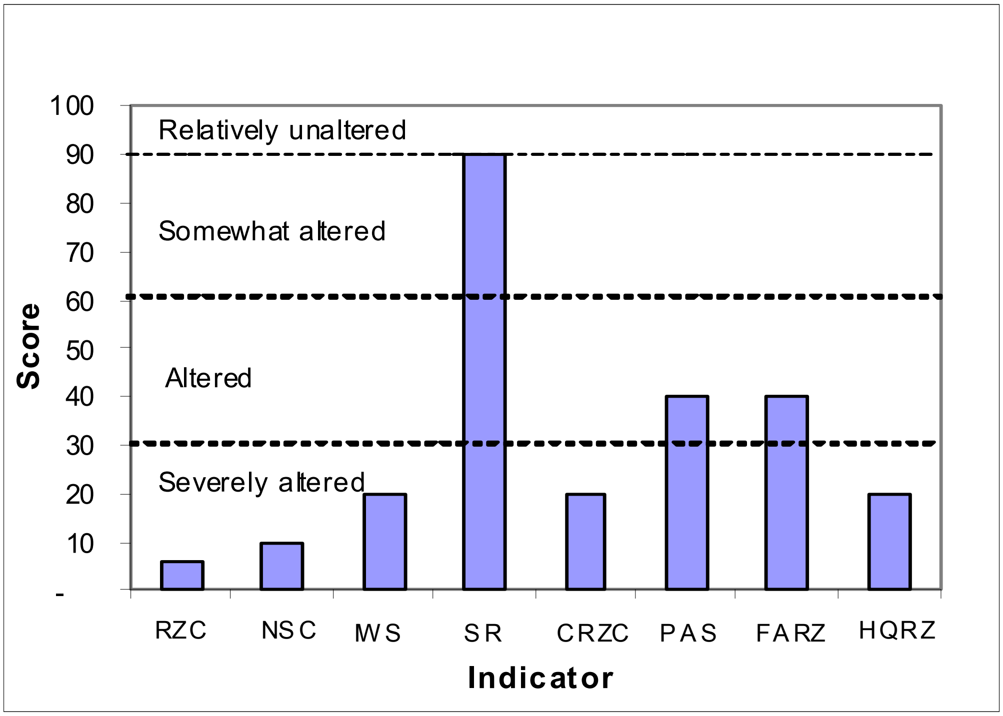

Figure 6. Indicator scores for reach #43 in the Crisp Creek watershed. Indicator abbreviations defined in Table 7. Each Condition category spans a range of Indicator scores: 90-100 (relatively unaltered), 60-89 (somewhat altered), 30-59 (altered), 0-29 (severely altered).

Indicator scores averaged by watershed can indicate, in general, what opportunities for restoration exist in the various watersheds (Table 10). For example, more opportunities for improving riparian zone cover probably exist in the watersheds of Crisp Creek (mean RZC score=31) and Cow Swamp (mean= 38) than in Stoney Creek (mean=70) or Hendricks Creek (mean=64). Mean indicator scores for watersheds ranged from 10 ("Channel-riparian zone connection" for Crisp Creek) to 79 ("Near-stream cover" for Green Mill Run and "Factors affecting riparian zone" in Stoney Creek) (Table 10). As was true for Composite Function scores, mean indicators scores are not meaningful for comparing predominantly rural watersheds with urban ones. In each case, however, the scores are representative of the condition relative to what they would be if fully restored.

Table 10. Mean of indicator scores for each of the six sampled drainage basins.

Watershed	Riparian zone cover (RZC)	Near-stream cover (NSC)	Instream woody structure (IWS)	Sediment regime (SR)	Channel-riparian zone connection (CRZC)	Pollution affecting stream (PAS)	Factors affecting riparian zone (FARZ)	Habitat quality of riparian zone (HQRZ)	Stream bank stability (SBS)
Cow	38	41	45	31	25	49	29	34	45
Crisp	31	37	44	32	10	45	17	22	44
Green Mill	71	79	66	33	43	54	38	25	45
Hendricks	64	73	61	57	62	65	59	25	31
Stoney	70	72	66	51	67	59	79	60	57
Lumber	43	47	55	30	37	50	44	32	74

Cow Swamp, Tar River Basin

Cow Swamp and its main tributary, Cabin Branch, drain a small, rural watershed in Pitt County. The watershed is part of the Tar River drainage basin. Low order reaches comprise 85% (i.e., 40 km) of the total stream length (Table 4). Only 2 of the 44 assigned reaches (4.5%) were rejected by the consultant team because both their floodplains and channels were flooded by beaver; one assessed reach was flooded only in its channel.

Channel and riparian condition for all the higher order reaches were in an altered or severely altered condition, scoring <50 for both categories (Figure 7). The Mean Composite Function score for the 42 reaches in the watershed was 35 (Table 9), ranging between 10 and 88 (see accompanying CD-ROM for raw data on reaches). Composite Function scores for the high order streams suggest that they were all altered or severely altered in that none scored >37 (Figure 7). Most of the lower order reaches were in altered or severely altered condition as well. Only 15% (6/40) of the all the randomly assessed reaches were somewhat altered (i.e., Composite Function score between 60 and 89), while none of the reaches sampled scored in the relatively unaltered category (Table 8). The remaining 85% of reaches scored in the altered or severely altered categories.

Both lowest and highest mean indicator scores were found in the rural high order category: a low of 6 for “Channel-riparian connection” (CRZC) and a high of 57 for “Pollution affecting stream” (PAS) (Table 11). In fact, none of the indicators scored very high, on average. The CRZC indicator scored particularly low for high order reaches because the larger streams (third to fourth order sections) were channelized (probably in the 1960s) and are now maintained by the Pitt County Drainage District. Sediment regime also scored low for the watershed (mean=22) because many of the channelized sections showed evidence of sediment deposition in the channel bottoms of the higher order reaches. Much of the sediment probably originated from sloughing of banks along the side that is cleared for maintenance access (i.e., sloughing was usually restricted to the side of channel where mowing is conducted to maintain access for channel maintenance).

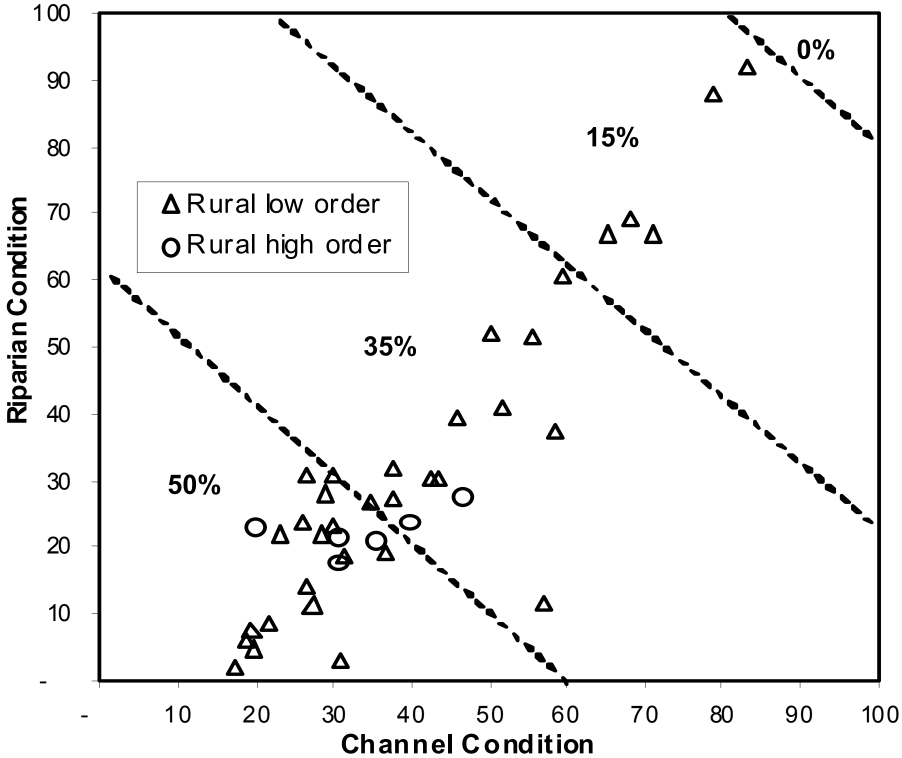

Figure 7. Condition of Cow Swamp watershed (n=40). Channel and Riparian condition for each reach was based on average function scores for channel and riparian zone. Lines delineate reaches by condition category using Composite Function scores. Percent of reaches in each category (equivalent to % stream length) is provided here and compared with other watersheds in Table 8.

Because most, if not all, of the higher order reaches are maintained in a channelized condition by a drainage commission, functional improvements could be made to the channelized reaches by diverting roadside ditches and channelized tributaries to former floodplains. In some sections where buffers are sufficiently wide, it might be possible to work with the local drainage district to install check dams (grade control devices). This would likely require buy-in by drainage district commissioners. Convincing evidence from hydrologic models would be needed to show that flooding would not detrimentally affect nearby cropland.

Buffer and channel condition could also be improved along the lower order tributaries of Cow Swamp (85% of total stream length). Improvements to the condition of lower order reaches would also reduce the drainage requirements of the higher order reaches if the restored reaches detain additional storm water in riparian areas.

Table 11. Mean indicator scores, by riparian class, for Cow Swamp watershed. Table 3 provides sample sizes, which affects the mean score.

	Riparian zone cover (RZC)	Near-stream cover (NSC)	Instream woody structure (IWS)	Sediment regime (SR)	Channel-riparian zone connection (CRZC)	Pollution affecting stream (PAS)	Factors affecting riparian zone (FARZ)	Habitat quality of riparian zone (HQRZ)	Bank stability (SBS)
Rural Low Order	37	42	48	33	28	48	32	33	NA
Urban Low Order	NA	NA	NA	NA	NA	NA	NA	NA	NA
Rural High Order	41	39	25	22	6	57	13	38	45
Urban High Order	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mean	38	41	45	31	25	49	29	34	45

Crisp Creek, Tar River Basin

Crisp Creek, located between Tarboro and Bethel, is part of the Tar River drainage basin and comprises approximately 41.2 km of total stream length. Like Cow Swamp, the watershed is entirely rural. The lower reaches (third to fourth order) were channelized and now maintained by the Edgecombe and Martin County Drainage Districts. Seventy-eight percent (35/45) of the randomly sampled reaches were low order streams (Table 4). None of the reaches were rejected because both floodplains and channels were flooded by beaver; two reaches were only flooded in their channels.

Channel and Riparian condition generally scored low (Figure 8), with only one site scoring above 35 for riparian condition and 65 for channel condition. The mean Composite Function score for the 45 reaches in Crisp Creek watershed was 28 (Table 9), ranging between 8 and 80 (see accompanying CD-ROM for raw data on reaches). None of the reaches scored as relatively unaltered and only one reach out of 45 was scored as somewhat altered (Table 8). The remaining 98% of random reaches scored in the altered or severely altered categories. This suggests that there is a lot of potential for improving conditions of streams in the watershed.

Mean indicator scores for the watershed ranged from 6 for “Channel-riparian zone connection” (CRZC) to 65 for “Instream woody structure” (IWS), both of which were in high order reaches (Table 12). The CRZC indicator score was low also for low order reaches due to widespread channelization throughout the watershed. “Habitat quality of the riparian zone” (HQRZ), “Riparian zone cover” (RZC), and “Near-stream cover” (NSC) indicators also scored low (score= 20, 25, 30, respectively) for low order reaches due to conversion of headwater reaches to cropland. RZC and NSC scored higher in the high order reaches (51 and 62, respectively) because one side of the stream was usually forested; perennial vegetation was typically maintained along one side to allow access for channel maintenance.

The main stem of Crisp Creek was deeply channelized. In fact, the channelization seemed to have been over-engineered, particularly considering that along most, if not all of its main-stem length, agricultural fields are located at a great distance from the channel. The channel apparently was dug from an upstream point to a downstream point without any regard to the location of the original channel. In fact, many portions of the channel were cut through uplands leaving a relic channel on the former floodplain.

Almost all of the lower order tributaries were channelized along their entire length and culverted under the spoil berm of Crisp Creek mainstem. Restoration options include restoring channel grades in low order reaches (perhaps with check dams in some places), improving buffers, and shunting tributary drainage to the former floodplain of Crisp Creek for processing before being released into the creek.

Hydrologic modeling could be used to estimate the degree to which the main stem has been over-channelized and to indicate the types of restoration options that would raise the channel bed without interfering with district drainage goals. Restoration of low order tributaries could further alleviate the need for such intense drainage in the main stem and should be included in any modeling effort.

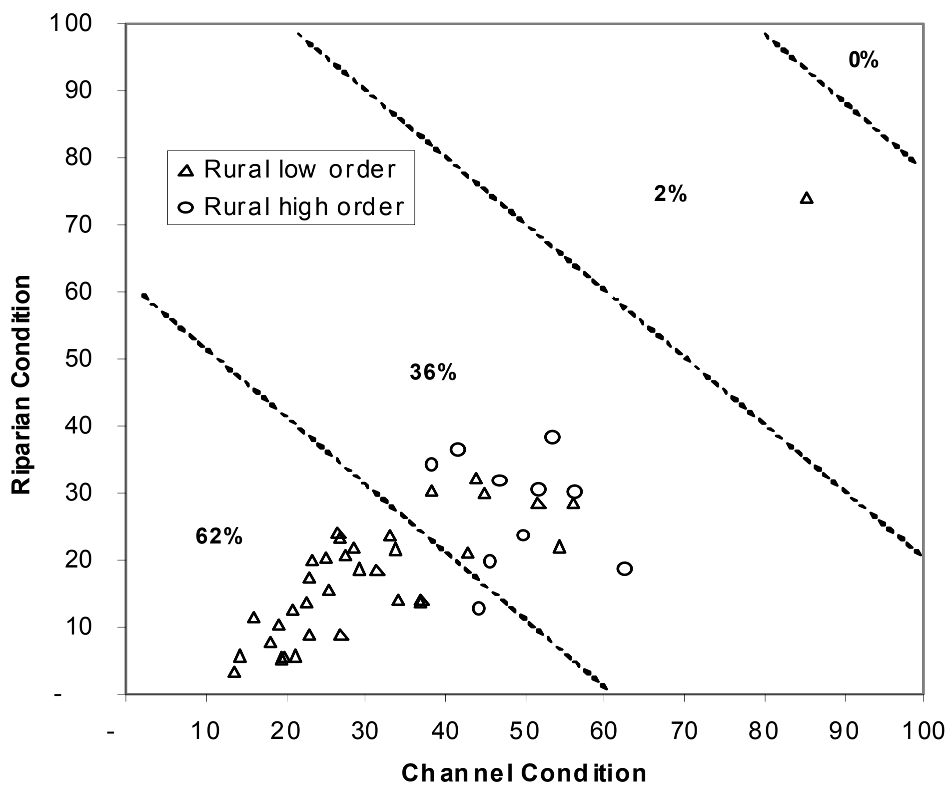

Figure 8. Condition of Crisp Creek watershed (n=45). Channel and Riparian condition for each reach was based on average function scores for channel and riparian zone. Lines delineate reaches by condition category using Composite Function scores. Percent of reaches in each category (equivalent to % stream length) is provided here and compared with other watersheds in Table 8.

Table 12. Mean indicator scores, by riparian class, for Crisp Creek watershed. Table 3 provides sample sizes, which affects the mean score.

	Riparian zone cover (RZC)	Near-stream cover (NSC)	Instream woody structure (IWS)	Sediment regime (SR)	Channel-riparian zone connection (CRZC)	Pollution affecting stream (PAS)	Factors affecting riparian zone (FARZ)	Habitat quality of riparian zone (HQRZ)	Stream bank stability (SBS)
Rural Low Order	25	30	37	34	11	43	19	20	NA
Urban Low Order	NA	NA	NA	NA	NA	NA	NA	NA	NA
Rural High Order	51	62	65	24	6	51	14	31	44
Urban High Order	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mean	31	37	44	32	10	45	17	22	44

Green Mill Run, Tar River Basin

Green Mill Run drains to the Tar River within the city limits of Greenville. The watershed consists of urban low and high order and rural low order reaches. None of 34 randomly chosen reaches was rejected due to impoundments on floodplains, but two reaches did have their channels impounded by beaver. Low order reaches comprised 68% of the total stream length of 36.6 km in the watershed (Table 4). This proportion was lower than most rural coastal plain watersheds, probably due to truncation of headwater reaches by development, i.e., headwater reaches are the first ones culverted and piped during urbanization.

Channel and riparian condition scored highest for urban high order reaches and lower for low order urban and rural reaches (Figure 9). In general, channels seemed to be in better condition than riparian areas for most reaches. The mean Composite Function score for the watershed was 52 (Table 9), ranging from 30 to 83 (see accompanying CD-ROM for raw data on reaches). In examining Composite Function scores, none of the randomly assessed reaches were in a relatively unaltered condition, while 23% (8/34) were somewhat altered, and 77% (26/34) were altered to severely altered (Table 8).

Mean indicator scores ranged from 21 for “Habitat quality of riparian zone” (HQRZ) in urban high order reaches to 89 for “Near-stream cover” (NSC) in urban low order reaches (Table 13). The habitat scores in the high order reaches was probably affected by high invasive species cover. The low order reaches had fairly high vegetated cover along their banks because land owners have no need to clear trees; this is in contrast to rural watersheds where riparian zones are typically converted to cropland. (See the high RZC and NSC scores for the urban low order section in Green Mill Run.)

Bank stability indicators also scored low, a likely effect of urbanization in the watershed. The lower portion of the watershed has already undergone suburban and urban development with many headwater reaches covered by impervious surfaces. Other headwater streams have been piped, and thus have not been mapped. The upper end of the watershed was being developed along the same trajectory at the time of this study. The banks of many streams are highly unstable due to poor stormwater management.

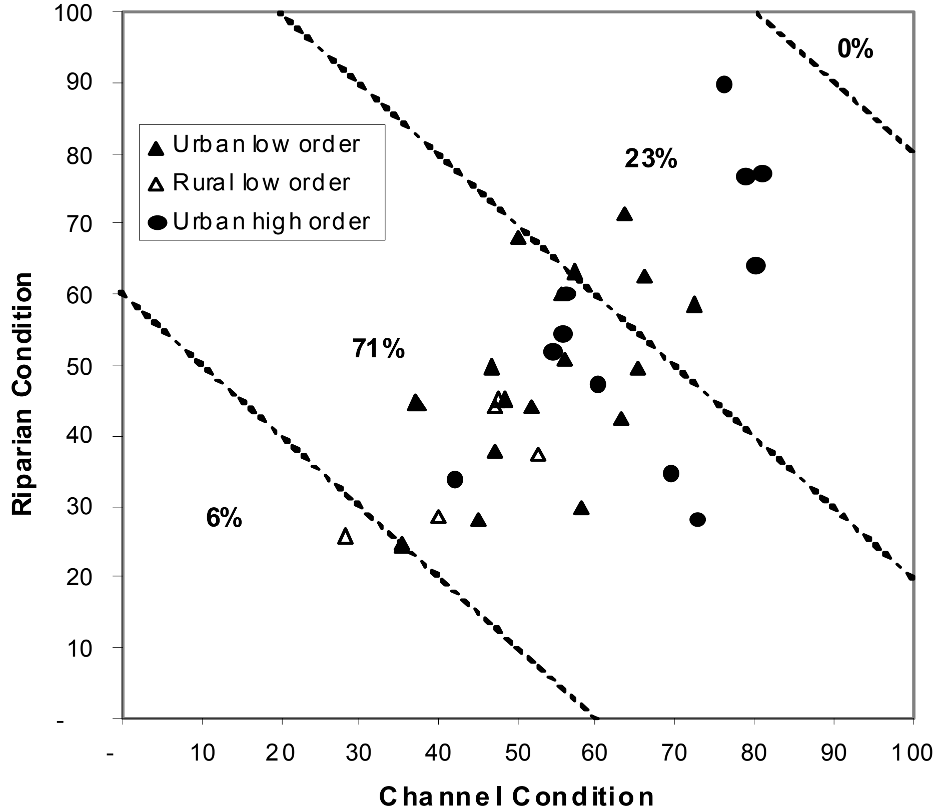

Figure 9. Condition of Green Mill Run watershed (n=34). Channel and Riparian condition for each reach was based on average function scores for channel and riparian zone. Lines delineate reaches by condition category using Composite Function scores. Percent of reaches in each category (equivalent to % stream length) is provided here and compared with other watersheds in Table 8.

Many stormwater detention ponds, even in the more recently developed areas, were improperly constructed or are not effective (observations during summer, 2004). Thus, many of the opportunities for restoring riparian functions would involve improving stormwater detention in already-developed areas and better design and oversight of detention basin construction in developing areas.

Water quality benefits could be obtained by diverting stormwater runoff, particularly from roadside ditches, into former floodplains of channelized reaches. In most cases, water from roadside ditches is presently shunted directly into stream channels. Sediment, toxic chemicals, and nutrients are thus discharged directly into streams, which both detrimentally affects water quality and causes flashier hydrographs and channel incision. Shunting runoff onto former floodplains (ones no longer hydrologically connected to the channel via overbank flow) would improve stream water quality by processing stormwater before reaching the channel. Re-engineering roadside ditches and other storm runoff conduits will require working with municipal and state transportation authorities in retrofitting existing ditches.

Table 13. Mean indicator scores, by riparian class, for Green Mill Run watershed. Table 3 provides sample sizes, which affects the mean score.

	Riparian zone cover (RZC)	Near-stream cover (NSC)	Instream woody structure (IWS)	Sediment regime (SR)	Channel-riparian zone connection (CRZC)	Pollution affecting stream (PAS)	Factors affecting riparian zone (FARZ)	Habitat quality of riparian zone (HQRZ)	Stream bank stability (SBS)
Rural Low Order	44	46	82	48	45	76	41	35	NA
Urban Low Order	80	89	63	33	34	52	34	25	44
Rural High Order	NA	NA	NA	NA	NA	NA	NA	NA	NA
Urban High Order	69	77	64	28	59	47	43	21	45
Mean	71	79	66	33	43	54	38	25	45

There are serious problems associated with tributaries feeding into Green Mill Run in the more-downstream, urban reaches near the Tar River. These tributaries enter the main stem at a very steep gradient. This is due to the topography of the south side of the major rivers in eastern North Carolina, which are higher in elevation than those on the north side. Because south-side tributaries have naturally steep gradients, they are much more susceptible to incision, particularly after the streams erode through the shell-rich, Yorktown formation. Once the Yorktown formation has been breached, the tributaries incise quickly. High, sustained discharges that cause incision can be reduced by detaining stormwater and by re-establishing channel grade at a higher level, where possible, especially where former floodplains can be reconnected during overbank flow. Hydrologic modeling would be needed to design a system that would not flood infrastructure.

Hendricks Creek, Tar River Basin

Hendricks Creek drains to the Tar River through Tarboro, North Carolina. The watershed consists of urban low and high order and rural low order reaches. None of 23 randomly chosen reaches was rejected due to impoundments on floodplains, but one assessed reach was so close to the Tar River that it is affected by flooding from the Tar when the Tar is at high stages (i.e., by backwater flooding). This reach was assessed as though its channel were impounded by beaver. Low order reaches comprised 65% of the total stream length of 36.7 km in the watershed, while higher order reaches comprised 35% (Table 4). Like the Green Mill Run watershed, the proportion of stream length comprising low order was low relative to more rural watersheds, probably due to truncation of headwater reaches by development.

For Channel and Riparian condition, the highest scoring reaches (relatively unaltered and somewhat altered) were mostly low order reaches (Figure 10). The Mean Composite Function score for the 23 reaches in the watershed was 62 (Table 9), ranging from 26-88 (see accompanying CD-ROM for raw data on reaches). Composite Function scores for the watershed show that only one of the 23 randomly assessed reaches was in a relatively unaltered condition (Figure 10). Forty-three percent (10/23) were considered somewhat altered (Table 8), and most (7/10) of these were rural low order reaches. However, one of the urban low order reaches scored at the high end (88) of the somewhat altered category. The remaining 52% (12/23) of reaches were considered altered to severely altered.

Mean indicator scores for the watershed ranged from 23 for “Habitat quality of riparian zone” (HQRZ) in both urban low and high order reaches to 94 for “Channel-riparian zone connection” (CRZC) in rural low order reaches (Table 14). Habitat quality scored about twice as high (44) in rural low order reaches than in urban reaches, although RZC and NSC scored higher in urban reaches. Although forest cover was lower, on average, in low order reaches, the forest canopy remaining in rural reaches tended to be more intact than in urban reaches.

The upper end of the Hendricks Creek drainage basin is in a mostly rural landscape, but one that is being rapidly developed. The lower portion of the watershed is in a suburban and urban landscape, including almost all of the higher order sections. Like Green Mill Run, lack of effective stormwater management is a major source of poor water quality in the urban, suburban, and developing rural areas, leading to channel incision and high sedimentation. This is reflected in the mean indicator scores for “Channel-riparian zone Connection” (CRZC) and “Sediment regime” (SR) for urban reaches (Table 14). Thus, many of the opportunities for restoring riparian functions would involve improving stormwater detention in already-developed areas and providing better oversight of detention basin construction in developing areas.

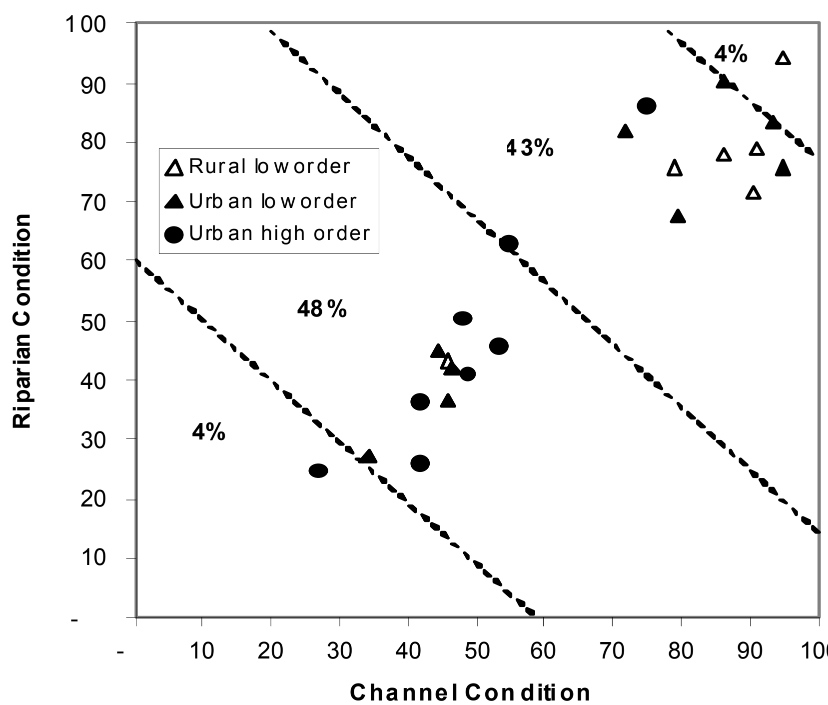

Figure 10. Condition of Hendricks Creek watershed (n=23). Channel and Riparian condition for each reach was based on average function scores for channel and riparian zone. Lines delineate reaches by condition category using Composite Function scores. Percent of reaches in each category (equivalent to % stream length) is provided here and compared with other watersheds in Table 8.

Table 14. Mean indicator scores, by riparian class, for Hendricks Creek watershed. Table 3 provides sample sizes, which affects the mean score.

	Riparian zone cover (RZC)	Near-stream cover (NSC)	Instream woody structure (IWS)	Sediment regime (SR)	Channel-riparian zone connection (CRZC)	Pollution affecting stream (PAS)	Factors affecting riparian zone (FARZ)	Habitat quality of riparian zone (HQRZ)	Stream bank stability (SBS)
Rural Low Order	45	49	89	87	94	88	92	44	NA
Urban Low Order	80	87	35	45	46	60	44	23	72
Rural High Order	NA	NA	NA	NA	NA	NA	NA	NA	NA
Urban High Order	74	89	49	30	38	43	34	23	41
Mean	64	73	61	57	62	65	59	31	25

As in Green Mill Run, and presumably in other urban areas in the inner coastal plain, water quality benefits could be improved by diverting stormwater runoff, particularly from roadside ditches and developed areas, into former floodplains of channelized reaches rather than shunting water directly into stream channels. Sediment, toxic chemicals, and nutrients discharged directly into streams detrimentally affect water quality and cause flashier hydrographs, thus exacerbating incision. Shunting runoff onto former floodplains (ones no longer hydrologically connected to the channel via overbank flow) would partially restore hydrologic and biogeochemical functions in the floodplain and improve stream water quality by processing the stormwater and its constituents before reaching the channel. Re-engineering roadside ditches and other storm runoff conduits will require working with municipal and state transportation authorities in retrofitting existing ditches.

Stoney Creek, Neuse River Basin

Stoney Creek drains to the Neuse River through Goldsboro, North Carolina. This watershed was the only one of the six that encompassed all four riparian classes (Tables 3 and 4). Ten of the 77 (13%) randomly assigned reaches were rejected due to impoundments on floodplains, and one reach was assessed that had only its channel backed up. Low order reaches comprised 76% of the total stream length of 90.7 km in the watershed (Table 4). Like Green Mill Run and Hendricks Creek watersheds, the lower portion of the watershed is urban. Unlike those watersheds, a large section of the lower reach of Stoney Creek runs through a city park and federal land (Seymour Johnson Air Force Base), thus protecting some of the riparian zone from intensive development.

Channel and Riparian condition of low order reaches spanned the entire range along the continuum of alteration, but high order reaches tended to score toward the least altered end of the range (Figure 11). The mean Composite Function score for the 67 assessed reaches in the watershed was 67 (Table 9), ranging between 12 and 95 (see accompanying CD-ROM for raw data on reaches). Composite Function scores showed the highest scores for the six watersheds of the study. In comparing Composite Function scores, 10% (7/67) of the randomly assessed reaches were in a relatively unaltered condition, 55% (37/67) were considered somewhat altered, and the remaining 34% (23/67) of reaches were considered altered to severely altered (Table 8).

Mean indicator scores for the watershed ranged from 24 for “Pollution affecting stream” (PAS) for urban high order reaches to 93 for “Factors affecting riparian zone” (FARZ) in rural high order reaches (Table 15). It appears that channelization was not as widespread in low order rural reaches in this watershed as in most others in the inner coastal plain (“Channel-riparian zone connection” (CRZC) scored 73 for rural reaches), although there was evidence of widespread channel incision in urban reaches (means of CRZC ranged from 51-58) (Table 15). Although riparian zone indicators (RZC and NSC) scored well for most riparian classes, the rural low order class scored at the lower end of the somewhat altered category. Other indicators that scored in the altered category (30-59) included “Sediment regime” (SR), especially for high order reaches, “Habitat quality of riparian zone” (HQRZ) for urban reaches, “Pollution affecting stream” (PAS) for urban low order reaches, and “Instream woody structure” (IWS) for urban low and high order reaches.

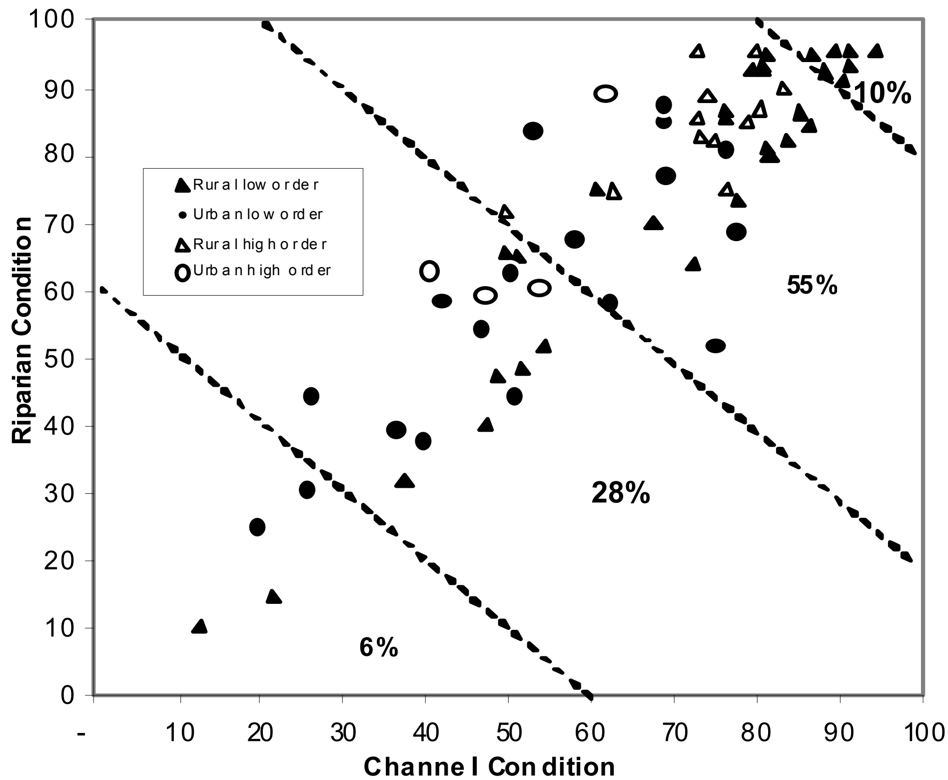

Figure 11. Condition of Stoney Creek watershed (n=67). Channel and Riparian condition for each reach was based on average function scores for channel and riparian zone. Lines delineate reaches by condition category using Composite Function scores. Percent of reaches in each category (equivalent to % stream length) is provided here and compared with other watersheds in Table 8.

Table 15. Mean indicator scores, by riparian class, for Stoney Creek watershed. Table 3 provides sample sizes, which affects the mean score.

	Riparian zone cover (RZC)	Near-stream cover (NSC)	Instream woody structure (IWS)	Sediment regime (SR)	Channel-riparian zone connection (CRZC)	Pollution affecting stream (PAS)	Factors affecting riparian zone (FARZ)	Habitat quality of riparian zone (HQRZ)	Stream bank stability (SBS)
Rural Low Order	61	62	79	57	73	64	85	64	NA
Urban Low Order	72	78	41	39	51	50	62	38	49
Rural High Order	86	86	76	56	73	71	93	88	68
Urban High Order	88	89	50	33	58	24	64	49	60
Mean	70	72	66	51	67	59	79	60	57

As in other urban watersheds assessed, water quality benefits could be improved by diverting stormwater runoff, particularly stormwater runoff and water from roadside ditches, into former floodplains of channelized reaches. Instituting such BMPs would require working with municipal and state transportation authorities in retrofitting existing ditches and other stormwater conduits in developing areas. Much of the upper part of the watershed of Stoney Creek is rural and so improving water quality in rural areas will require protecting existing buffers, re-vegetating riparian corridors without buffers, and effectively managing stormwater runoff in new developments.

Bear Swamp and Moss Neck Swamp, Lumber River Basin

Bear Swamp and Moss Neck Swamp drain to the Lumber River west of Lumberton. The watershed consists primarily of rural low and high order riparian classes, with one urban low order reach. Four of the 72 (6%) randomly assigned reaches were rejected due to impoundments on floodplains, and 8 reaches were assessed that had only their channels backed up.

Low order reaches comprised 68% of the total stream length of 74.8 km in the watershed (Table 4). The proportion of total stream length comprising low order reaches was much lower than the other basins and possibly lower than is typical for rural watersheds in the inner coastal plain. This may be a result of the configuration of the stream network, which consists of many tributaries feeding directly to two main channels: Bear Swamp and Moss Neck Swamp. This configuration reflects the geology of the drainage basin, which consists of sandy soils and a large number of Carolina Bays interspersed throughout the basin.

Channel and Riparian condition for reaches of all riparian classes were fairly well distributed across the continuum of alteration (Figure 12). The average Composite Function score for the 68 assessed reaches in the watershed was 44, ranging between 13 and 85 (see accompanying CD-ROM for raw data on reaches). In comparing Composite Function scores for the watershed, only 3% (2/68) of randomly assessed reaches were in a relatively unaltered condition, 23% (16/68) were considered somewhat altered, and the remaining 74% (50/68) were considered altered to severely altered (Table 8).

There was only one urban reach sampled in the watershed (low order); impervious rooftops occurred near the stream along one side of the reach. Therefore, indicator data for this category can only be used for a site-specific diagnosis. Mean indicators scores for the other riparian classes ranged from 22 for “Sediment regime” (SR) in low order reaches to 75 for “Stream bank stability” (SBS) in high order reaches (Table 16). Most of the other mean indicator categories showed altered conditions (30-59). Channelized sections were not very well maintained by the local drainage district. Evidence of sediment deposition in channel bottoms in higher order reaches was prevalent. In many places, small trees grew in channel bottoms. Some of the sediment may have originated from sloughing banks along the side mowed for channel access, but that indicator (Stream bank stability) scored fairly high (75). Other sources of sediment are roadside ditches and agricultural fields.

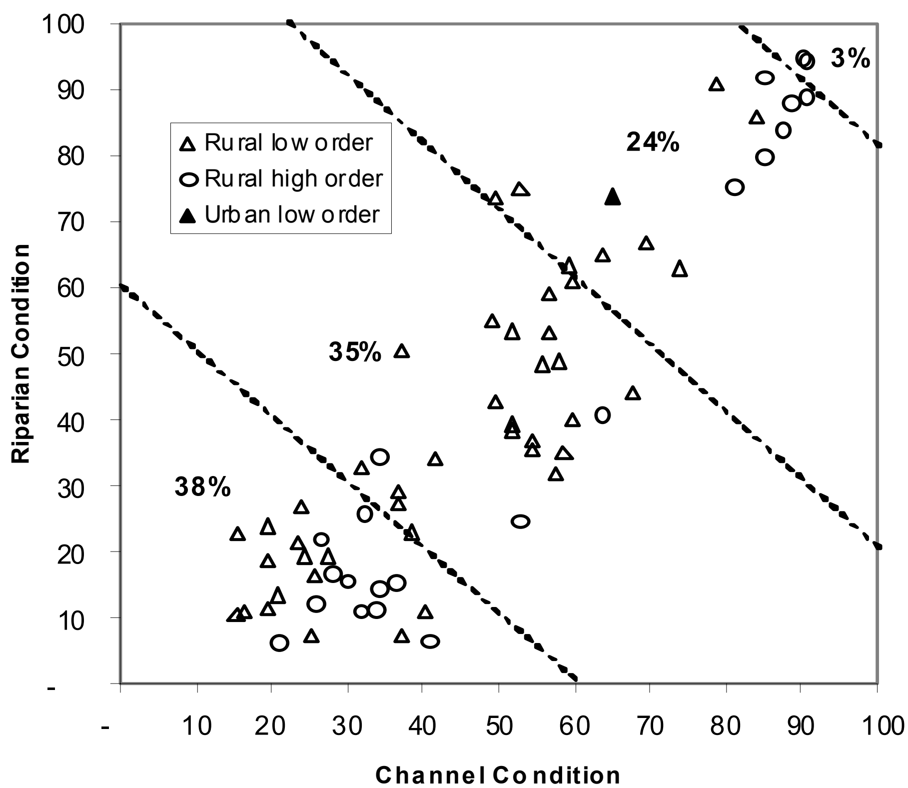

Figure 12. Condition of Bear and Moss Neck Swamp watershedS (n=68). Channel and Riparian condition for each reach was based on average function scores for channel and riparian zone. Lines delineate reaches by condition category using Composite Function scores. Percent of reaches in each category (equivalent to % stream length) is provided here and compared with other watersheds in Table 8.

Table 16. Mean indicator scores, by riparian class, for Bear and Moss Neck Swamp watersheds. Table 3 provides sample sizes, which affects the mean score.

	Riparian zone cover (RZC)	Near-stream cover (NSC)	Instream woody structure (IWS)	Sediment regime (SR)	Channel-riparian zone connection (CRZC)	Pollution affecting stream (PAS)	Factors affecting riparian zone (FARZ)	Habitat quality of riparian zone (HQRZ)	Stream bank stability (SBS)
Rural Low Order	37	43	52	35	38	47	46	29	NA
Urban Low Order	94	95	90	10	60	45	85	10	60
Rural High Order	53	54	61	22	35	57	40	38	75
Urban High Order	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mean	43	47	55	30	37	50	44	32	74

Beaver have started to dam some sections of the tributaries, potentially providing some water quality improvement. Probably little can be done to restore channel morphology in the mainstem reaches. However, water from tributaries, stormwater runoff, and roadside ditches could be diverted onto former floodplains where present. For low order reaches, improving riparian zone condition and taking measures to raise the channel bed would also improve conditions in the watershed.

Protocol Testing

Relationships among indicators -- As expected, indicator condition co-varied significantly (P>0.05) among all indicators in the rural low order class (Table 17). This was expected because alterations to a reach tend to affect more than one variable. For example, a channelized stream is also often de-snagged, banks are de-stabilized, riparian habitat is degraded, and sediment and other pollutants are washed into streams. However, functions could be improved by enhancing condition of one or more indicators without improving the condition of all indicators simultaneously. In addition, although the indicators co-vary, each indicator provides a different insight into what might be in need of improvement along a given reach.

In the rural high order (RHO) class, only three relationships were insignificant and all were associated with bank stability. Sediment sources in RHO reaches were likely derived as much from upstream sources as from bank erosion within the reaches. There were many more insignificant relationships in the two urban classes (Table 17). However, in contrast to the rural protocol, we developed the urban protocol without the advantage of having built a robust reference set covering the range in types of alterations. Consequently, the lack of a rigorous reference framework for urban streams and riparian zones may have contributed to inconsistencies in calibrating indicators, which may have led to the reduced level of co-variation. Urban riparian systems are affected by a complex array of stressors in their watersheds and we do not yet have a good understanding of how they affect one another and the indicators designed to measure them. The discrepancy between rural and urban results means that the urban assessment protocol should be based on a wider array of reference sites and a better understanding of processes unique to urban streams.

Table 17. Matrix of correlation coefficients depicting relationships among indicators, by riparian class. Non-significant relationships are in bold italics. CV= Critical value of r $_{0.05(2)}$. SRC-2, SRC-3, and SRC-7 were not scored in reaches where channel was flooded by a beaver impoundment. For rural low order (RLO), n=161 w/beaver, n=155 w/o beaver; for rural high order (RHO), n= 40 w/ beaver, n=42 w/o beaver; for urban low order (ULO), n=43; for urban high order (UHO), n=23 w/ beaver, n=21 w/o beaver.

		CV	Indicator	RZC	NSC	SRC-1	SRC-2	SRC-3	SRC-4	SRC-5	SRC-6	SRC-7
RLO	Riparian Zone Cover	0.154	RZC	1.000	-	-	-	-	-	-	-	-
	Near stream Cover	0.154	NSC	0.960	1.000	-	-	-	-	-	-	-
	Instream woody structure	0.154	SRC-1	0.534	0.524	1.000	-	-	-	-	-	-
	Sediment regime	0.154	SRC-2	0.374	0.354	0.615	1.000	-	-	-	-	-
	Channel/riparian connection	0.154	SRC-3	0.499	0.502	0.641	0.478	1.000	-	-	-	-
	Conditions affecting stream	0.154	SRC-4	0.292	0.249	0.468	0.481	0.380	1.000	-	-	-
	Conditions affecting riparian zon	0.154	SRC-5	0.516	0.488	0.663	0.583	0.772	0.571	1.000	-	-
	Habitat quality of riparian zone	0.154	SRC-6	0.727	0.652	0.651	0.472	0.536	0.469	0.637	1.000	-
	Bank stability	0.154	SRC-7	NA	NA	NA	NA	NA	NA	NA	NA	1.000
RHO	Riparian Zone Cover	0.279	RZC	1.000	-	-	-	-	-	-	-	-
	Near stream Cover	0.279	NSC	0.948	1.000	-	-	-	-	-	-	-
	Instream woody structure	0.279	SRC-1	0.614	0.662	1.000	-	-	-	-	-	-
	Sediment regime	0.304	SRC-2	0.691	0.671	0.548	1.000	-	-	-	-	-
	Channel/riparian connection	0.304	SRC-3	0.743	0.738	0.757	0.630	1.000	-	-	-	-
	Conditions affecting stream	0.279	SRC-4	0.476	0.397	0.616	0.524	0.665	1.000	-	-	-
	Conditions affecting riparian zon	0.279	SRC-5	0.823	0.766	0.701	0.690	0.930	0.627	1.000	-	-
	Habitat quality of riparian zone	0.279	SRC-6	0.902	0.838	0.618	0.693	0.825	0.569	0.879	1.000	-
	Bank stability	0.304	SRC-7	***0.294***	***0.280***	0.488	***0.223***	0.607	0.414	0.443	0.331	1.000
ULO	Riparian Zone Cover	0.301	RZC	1.000	-	-	-	-	-	-	-	-
	Near stream Cover	0.301	NSC	0.871	1.000	-	-	-	-	-	-	-
	Instream woody structure	0.301	SRC-1	0.426	0.427	1.000	-	-	-	-	-	-
	Sediment regime	0.301	SRC-2	***(0.176)***	***(0.158)***	***(0.220)***	1.000	-	-	-	-	-
	Channel/riparian connection	0.301	SRC-3	0.331	***0.227***	***0.208***	***0.162***	1.000	-	-	-	-
	Conditions affecting stream	0.301	SRC-4	0.357	0.353	***0.209***	***0.096***	***0.327***	1.000	-	-	-
	Conditions affecting riparian zon	0.301	SRC-5	***0.064***	***(0.062)***	0.116	***0.045***	0.634	***0.241***	1.000	-	-
	Habitat quality of riparian zone	0.301	SRC-6	0.606	0.442	0.265	(0.083)	0.570	***0.299***	0.454	1.000	-
	Bank stability	0.301	SRC-7	***0.035***	***0.134***	***(0.185)***	0.405	***0.216***	***0.192***	***0.007***	***0.016***	1.000
UHO	Riparian Zone Cover	0.413	RZC	1.000	-	-	-	-	-	-	-	-
	Near stream Cover	0.413	NSC	0.749	1.000	-	-	-	-	-	-	-
	Instream woody structure	0.413	SRC-1	0.484	0.504	1.000	-	-	-	-	-	-
	Sediment regime	0.433	SRC-2	***(0.151)***	***0.086***	***0.167***	1.000	-	-	-	-	-
	Channel/riparian connection	0.433	SRC-3	0.512	***0.310***	0.565	***(0.226)***	1.000	-	-	-	-
	Conditions affecting stream	0.413	SRC-4	***0.299***	***0.280***	***0.136***	***(0.209)***	***0.236***	1.000	-	-	-
	Conditions affecting riparian zon	0.413	SRC-5	0.783	0.547	0.564	***(0.066)***	0.658	***0.189***	1.000	-	-
	Habitat quality of riparian zone	0.413	SRC-6	0.643	0.479	***0.405***	***0.068***	0.540	***(0.143)***	0.582	1.000	-
	Bank stability	0.433	SRC-7	***0.143***	***(0.050)***	***(0.247)***	***(0.151)***	***0.334***	***(0.128)***	***0.140***	***0.244***	1.000

Test of the assessment method -- As indicated previously, 277 randomly assigned reaches were assessed by consultant field teams (Table 3), plus 89, which were rejected (not assessed) for reasons outlined in the rejection criteria we provided the consultants. Of the 89 reaches rejected, 66 were rejected because they were a ditch (n=18), an ephemeral draw (n=30), or were piped or culverted (n=18) (Table 5). Of the eight reaches randomly chosen by ECU from the 66 rejected reaches to determine if they had been rejected correctly, all were indeed correctly rejected. This suggests that the rejection criteria were sufficiently clear.

Of the 30 assessed reaches randomly re-assessed by ECU (Table 5), only one had been assessed by consultants that should have been rejected (it was an ephemeral draw). For the remaining re-assessed reaches, indicator scores recorded by consultant teams were generally not significantly different (P<0.05) from those recorded by the ECU team, except for two indicators. This suggests that the protocols are precise (repeatable). The two exceptions were that the ECU team measured significantly higher scores for “Instream woody structure” in the rural low order class and significantly lower scores for “Channel-riparian zone connection” for the urban high order class. All indicator sheets have since been revised to better clarify condition categories and scoring criteria (Appendix A). For “Instream woody structure,” decay classes of large down wood (LDW) have now been more narrowly defined, which may improve precision for scoring that indicator. Discrepancies in scoring “Channel-riparian zone connection” in the urban high order reaches are more problematic and may be attributable to the difficulty in determining the degree to which incision (typical for urban reaches) is affecting the frequency or duration of overbank flow. On one hand, an urban stream becomes incised because an increase in impervious surface causes unnaturally large flow pulses during storm runoff. On the other hand, these high flow pulses are more likely to reach overbank stage (leaving indicators on the floodplain) before flow subsides.

During low flows, the floodplain is drained more than normal due to the increase in the groundwater slope toward the channel of incised streams. Therefore, indicators of overbank flow (wrack, sediment, water marks) may not reliably signify a normal connection between the riparian zone and channel in incised, urban streams. The negative correspondence between scoring by ECU vs. consultant teams indicates that the “Channel-riparian zone connection” indicator is in need of additional calibration in urban streams. At this time, we do not have data to adequately explain the relationship between channel incision and riparian zone hydrologic regime in urban coastal plain streams. Further research is needed in this regard. In fact, further work is needed on the urban assessment protocol, in general, because the reference data set used to calibrate indicators was limited.

Application and Limitation of Approach

The condition indicators and their logical connection with ecosystem functioning, as described in Table 1, are based on a very large body of research literature, including our own recent studies in the Neuse River basin on headwater streams (Brinson et al. in preparation). The uncertainty with the urban method is understandable, as described above, given the lack of a robust reference system. The relatively good correspondence between different consultant teams and the ECU team for rural stream indicators suggests that there is also consistency among consultant teams, given adequate training.

The degree of difference among watersheds is confounded by differences in the proportion of rural and urban sites because indicators are scaled differently. However, Cow Swamp and Crisp Creek are both entirely rural, and thus can be compared. Further, both drainages have large areas in rowcrop agriculture, the streams have been extensively channelized, and the channels continue to be maintained by active drainage commissions. Both were found to have a high proportion of severely altered sites, with Crisp Creek having only one site ranking in the “somewhat altered” category, and Cow Swamp with merely 5 sites (of 42) in this category based on Composite Function scores (Figures 7 and 8). The difference between the two watersheds appears to be due largely to Cow Swamp having a greater proportion of sites in better condition.

Ultimately, the assessment method should be able to track net change over time in small watersheds due to stream-riparian improvement (from restoration) and degradation (from continuing alterations). Comparison of composite scores among watersheds is but one approach. This could lead to prioritization of plans for restoration, depending upon policy guidelines. Comparison of indicator scores (Table 10) is another approach, although this comparison is more useful in understanding which specific factors are responsible for degraded conditions than in comparing conditions among watersheds. A high frequency of low scores could lead to identifying prescriptions for restoration. Just as human-induced alterations degrade more than one aspect of stream-riparian systems, as reflected in the correlation among indicator scores, restoration activities may serve to improve several indicators at once. In other words, the components of stream-riparian systems are highly integrated functionally, as suggested by the correlation between channel condition and riparian condition.

The assessment described in this report qualifies as a Level 2 "rapid assessment" (requires a field visit and less than 0.5 day, excluding travel) in contrast with Level 1 (uses remote sensing, i.e., no field visit) and Level 3 (requires more than a day with intensive data collection) (Brooks et al. 2004). When applied to individual sites, rapid assessments are generally regarded as a screening procedure for planning, and have insufficient detail to serve as a design for a restoration project. Rather, the rapid assessment described in this report is an attempt to assess stream-riparian systems at a watershed scale from an unbiased population of sites. The method will not necessarily identify the most degraded sites in a watershed simply because such sites may have gone unsampled by chance due to the random selection of reaches.

The three levels of assessment allow validation of one level by the next more detailed level (Brooks et al. 2004). The amount of validation needed for a rapid assessment may vary depending on how the information is used (Wakeley and Smith 2001). On one hand, it could be argued that validation is always necessary. On the other hand, the need for validation in the present case is partly alleviated by two factors: (1) the large array of research studies that have demonstrated the negative effects on aquatic condition of buffer removal and stream channelization, and (2) the use of a reference framework that provides a context for ranking condition of sites based on the degree of alteration, in the present case from severely altered to relatively unaltered. For the former, few of the landmark studies on riparian buffers were conducted on first and second order intermittent streams. That is why it was necessary to conduct the study preliminary to this project (Brinson et al. in preparation). For the latter, a reference framework of field sites ranging between extremes of condition is fundamental for stabilizing a condition assessment so that individual indicators are scaled to stay within bounds of the natural and human-induced sources of variation. It is our experience that qualified professionals will agree on what constitutes a "good" site and what constitutes a highly degraded site. Consensus is much more difficult for individual indicators as they often lead to a logic of "more or bigger is better" rather than actual condition of sites in the field. Regardless, validation of the method developed and applied in this report has not been carried out. Validation may be based on other indicators of integrity, such as benthic invertebrate composition. However, the difficulty of applying an Index of Biotic Integrity (IBI) in coastal plain streams of the Southeast needs to be recognized (Davis et al. 2003).

Management Implications

In the coastal plain of North Carolina, headwater (low order) reaches tend to occur in between the flat, inter-stream divides and the bottomlands of the higher order streams. Most of the agriculture in the coastal plain occurs in these middle regions because soils there are better-drained than either the bottomlands or the flats. As a consequence, most headwater streams have been channelized and have had their buffers removed to expand available land for rowcrop agriculture. During this process, dredged material from channel deepening and widening was used to fill adjacent floodplains. Material from surrounding upland fields was also usually graded onto the former floodplains to create a level surface from the channel edge to surrounding uplands. This conversion of headwater reaches to field ditches was a common practice. As a consequence, few headwater reaches (<5%) are still intact. In some cases, where clearing has ceased, shrubs and trees colonize the channel and near-stream riparian zone. Once they grow too large to be removed with a brush hog, they tend to persist as a narrow buffer.

Restoration of low order riparian systems can potentially take several forms along a continuum from altered to relatively unaltered. Buffers can be restored by allowing succession to take place and/or by planting native trees, especially those with heavy mast (oaks, etc.) that would have difficulty re-establishing quickly. Channel morphology could be restored by installing grade control structures to simultaneously lower channel grades and hydrologically reconnect channels with their riparian zones. Re-vegetating buffer zones and installing grade control structures would probably be the most cost-effective solution for restoring a large number of stream miles in a watershed, since approximately 75-85% of total stream length is low order.

The higher order reaches, to which the low order streams feed, tend to be deeply channelized and maintained by drainage commissions. Spoil from channelizing the streams was placed on one or both sides of their channels and typically the near-channel area of one side is kept clear of trees to allow access by channel maintenance equipment. Sometimes, these channelized reaches have wide forested buffers because the former floodplain remains too wet to farm. In other cases, especially in 3rd order reaches, all trees were removed and the former floodplain was filled to expand arable cropland. In either case, riparian zones along the higher order reaches are no longer hydrologically connected to their channels by overbank flow and they are often drained more than normal due to the increase in the groundwater slope toward the channels (due to channelization) or as a consequence of being filled.

Many of the higher order streams appear to have been over-channelized based on our perception that a lesser degree of channelization would have accomplished agricultural drainage goals. In areas where a wide buffer exists between channel and cropland, restoration could involve placing grade control structures in the channel. Stakeholder buy-in, especially by the drainage district commissions, would be required. Assuring land owners that increased flooding of forested riparian zones would not flood adjacent cropland would probably require evidence from watershed hydrologic models and demonstration projects. Because restoration of low order tributaries further upstream would also store water longer and further reduce the need for such intensive channelization downstream, effects of low order restoration should be included in developing hydrologic models.

Drainage from roadside ditches is another source of pollution and hydrologic stress to streams. Drainage from roadside ditches causes more flashy hydrographs downstream from road crossings. Ditch water delivered to streams also transports sediment and excess nutrients, some of which may originate in field ditches of the drainage network. Hydrologic and biogeochemical functions of affected streams could be partially restored by shunting water from roadside ditches to floodplains so that it can be processed before entering channels. This is a particularly attractive approach for channelized high order streams because their floodplains no longer receive water from overbank flow. Similar options may not be feasible for urban streams where floodplains have been greatly altered.

Channelized, low order tributaries that feed into channelized high order streams, like roadside ditches, also bypass high order floodplains. Water tends to be shunted under spoil banks through culverts directly to streams. Like water from roadside ditches, shunting the water to former floodplains, particularly where relic channels remain, would be an attractive option for partially restoring floodplain hydrologic and biogeochemical functions, while at the same time ameliorating pollution stress on receiving streams. Similar opportunities may be available for urban streams without altering urban infrastructure.

The assessment procedure was designed to characterize reaches in a way that would diagnose the above-described conditions and rate reaches and watersheds relative to one another, thus offering guidance for viable restoration options. Although the protocol was designed to assess reaches of 100-yd, many of the indicators can be used to evaluate longer or shorter reaches and so can be adapted to assess pre-and post-project condition and can be used to monitor success of specific project sites. Thus, this protocol provides one tool, among others, useful for diagnosing problems and offering solutions.

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APPENDICES

Appendix A. Revisions of protocols and field data sheets based on suggestions by consultants and other improvements. Revisions were relatively minor, and consisted mostly in improving the narrative descriptions of condition indicators.

Appendix B. Data files and other files on enclosed CD

1. RZC Calculator (Folder) for calculating RZC and NSC scores
   - Rural RZC Calculator.xls
   - Urban RZC Calclulator.xls
2. Summary Data (Folder)
   - Cow Swamp.xls: Summary data for Cow swamp reaches
   - Crisp Creek.xls: Summary data for Crisp Creek reaches
   - Green Mill Run.xls: Summary data for Green Mill Run reaches
   - Hendricks Creek.xls: Summary data for Hendricks Creek reaches
   - Stoney Creek.xls: Summary data for Stoney Creek reaches
   - Lumber River.xls: Summary data for Bear & Moss Neck Swamps
   - Resampled Reaches t-test.xls: Data for applying t-tests
3. Original Protocols & Field Sheets (Folder) (used for data collection, 2004)
   - Rural Low Order Riparian Assessment Protocol, V. 1.1
   - Rural High Order Riparian Assessment Protocol, V. 1.1
   - Urban Low Order Riparian Assessment Protocol, V. 1.1
   - Urban High Order Riparian Assessment Protocol, V. 1.1
4. Revised Protocols & Field Sheets (Folder) (Improvements since data collection; electronic copies of Appendix A)
   - Rural Low Order Riparian Assessment Protocol, V. 2.0
   - Rural High Order Riparian Assessment Protocol, V. 2.0
   - Urban Low Order Riparian Assessment Protocol, V. 2.0
   - Urban High Order Riparian Assessment Protocol, V. 2.0

Rural High Order Riparian Assessment Protocol, V. 2.0

1. Background

This assessment protocol was designed for assessing the condition of 3rd to 4th order riparian ecosystems that originate in the coastal plain of North Carolina, with emphasis on landscapes dominated by forest or rowcrop agriculture. It was prepared to aid in filling out the field sheets for the Rural High Order Riparian Assessment Version 2.0. It was not explicitly developed for landscapes dominated by urban/suburban development or affected by other types of development activities.

This assessment method was also not designed for evaluating beaver impoundments that have flooded *both* the channel and floodplain. However, it can be used to assess beaver-modified reaches where *only* the channel has been backed up by a downstream impoundment, i.e., where water has not inundated the adjacent floodplain except following a heavy rainfall event. In such cases, Stream and Riparian Condition (SRC) indicators Sediment Regime (#1), Channel-riparian Zone Connection (#3), and Stream Bank Stability (#7) (pages 4 and 5) should not be assessed either because fluvial features are underwater or channel processes have been modified.

This assessment method is not appropriate for riparian ecosystems in other physiographic provinces or for headwater (1st – 2nd order) riparian systems or for larger river systems such as the Tar or Neuse Rivers. Although developed in coastal plain drainage basins in North Carolina, it would probably be applicable to other coastal plain regions in the Southeast.

High order streams in the coastal plain include 3rd to 4th order perennial streams. They tend to occur between the flats of inter-stream divides and most are named streams on USGS 1:24,000 topographic maps. In agricultural landscapes, high order riparian ecosystems range in condition from natural, un-channelized stream channels with broad, forested floodplains to deeply channelized systems with only herbaceous vegetation or rowcrop in their riparian zones. Relatively unaltered high order riparian ecosystems are rare in the coastal plain. Most were deeply channelized to rapidly convey water from agricultural areas to major rivers. Most are still actively managed by county drainage districts. Many are impounded by beaver, especially the remaining unchannelized reaches.

2. Office and Field Methods

Reasons for conducting an assessment should be clearly established. They may include the following:

- documenting baseline conditions along a given reach
- determining types and degree of alteration in a drainage basin by assessing multiple sites
- determining how a proposed project will alter riparian condition
- comparing several reaches as part of an alternatives analysis
- identifying specific actions that could be taken to minimize project impacts

- determining the effects of specific manipulations following restoration or other management practices.

Defining objectives of an assessment may reduce misunderstanding among stakeholders and other interested parties. It will also focus the interpretation of assessment results on the specific requirements of a project.

For some assessment parameters, we used field data to validate relationships between riparian condition and water quality (biogeochemical and biotic). In other cases, relationships are based on information published in scientific literature. Finally, best professional judgment was employed where there are as yet no data to validate relationships. However, all parameters are calibrated and field tested against reference sites that range between relatively unaltered to severely altered.

2.1. Office preparation

Maps and photographs are useful in characterizing a reach for assessment. They provide such information as project boundaries, location of jurisdictional wetlands, and location of proposed alterations or restoration. Geographic features are needed in evaluating some of the indicators such as the presence of roads, ditches, buildings, tributary streams, land use, land cover, and other pertinent features. Some useful sources are (a) high-resolution aerial photographs, such as DOQQs, (b) county soil surveys, (c) topographic maps (USGS 1:24,000), and (d) drainage maps. While the field assessment may be completed without these sources during the field visit, field time can be shortened considerably by having access to remotely acquired information. For areas that may contain both rural and urban drainages, criteria for choosing the right set of field sheets is provided on the last page of this protocol (2.4).

Equipment should be assembled before the field visit. Essential items are a GPS unit, shovel or trowel, hand-held laser level, stiff tape measure or meter stick, and 300 ft tape.

2.2 Guidelines for rejecting or moving sites

A watershed can be characterized by assessing a statistically robust number of reaches and using the data from the assessed watershed to make inferences about riparian areas in the watershed as a whole. Various random and stratified random approaches could be used depending on the questions being posed. Regardless of the method applied for randomly selecting reaches for sampling, in some cases, a randomly assigned reach will occur at a place that the assessment procedure was not designed to assess (e.g., in a beaver impoundment) and so must be moved or rejected.

If a reach is rejected or moved, the reason for rejection should be noted on the data sheet in the space provided on page 1 (Part A). The following guidelines for moving or rejecting reaches should be followed in the sequence in which they appear. These criteria will probably only be applied in cases where one is assessing randomly-selected reaches. Items 1 and 2 are mapping exercises for the office. The remainder are conducted in the field.

1. If a random point marking the center of a reach is located within 300 ft of another random point, it should be rejected and another random point should be substituted.

2. If a stream junction occurs less than 150 ft downstream of the randomly selected point, the reach should be moved upstream until the entire 300-ft reach is above the junction. If a junction occurs less than 150 ft upstream from the random point, then the 300-ft reach should encompass the main stem (the same stem on which the random point falls).

3. If the randomly selected 300-ft reach falls entirely with in beaver impoundment (where both channel and floodplain are impounded) or other type of impoundment, the site should be rejected and no substitution should be made for the point.

4. If the random center point is <150 ft from the upstream or downstream boundary of a beaver or other impoundment, the point should be moved upstream or downstream in the un-impounded reach to allow assessment of an un-impounded 300 ft reach. (If moved upstream, the channel may be backed-up, thus requiring that Stream Riparian Conditions #2, #3, and #7 be omitted.) In many cases, beaver impoundments show a stepwise pattern in which the upper end of one impoundment is adjacent to the dam of the next impoundment upstream. In such cases, moving the reach upstream or downstream will still place it in an impoundment and so the site should be rejected. If rejected, no substitution should be made for the point.

2.3 Data collection and observations on-site

If none of the above-described rejection criteria are met, then rural high order reaches should be assessed as outlined below. Field sheets are referred to by page number below:

Page 1, Reasons for rejecting or moving a randomly assigned reach (Part A). The top section provides boxes for recording whether a randomly assigned reach has to be rejected or moved for occurring at a place that the assessment procedure was not designed to assess. A reach that is specifically chosen for assessment would presumably not be rejected and a "0" would be recorded in each box. However, for reaches randomly chosen from maps that that must be rejected or moved (see above listed criteria), Part A provides a format for recording the reason for rejection or distance and reason moved (if the reach should be moved).

Page 1, Upstream and Downstream Influences on Reach (Part B). This category provides information on whether the reach is hydrologically affected by an impoundment. First, record if the channel is backed up by a beaver or other impoundment. Standing, non-flowing water in the channel suggests that there is an impoundment downstream from reach. A channel can be affected by an impoundment without a dam occurring within the assessed reach or even if there is no impounded water on the floodplain. (Note: even an impounded reach may begin to flow during high rainfall events). Although this assessment method was not developed for assessing the condition of impoundments, a channel that is backed up should be assessed if its riparian zone is not impounded, but SRC indicators #2 , #3, and #7 (pp. 4 and 5) should not be assessed.

Instead, “Bv” should be recorded in the appropriate data boxes on page 3. Care should be taken to make sure standing, non-flowing water is not simply a result of channel bed scour that creates an elongated pool of stagnant water.

Next, record if the reach was formerly and recently impounded by beaver, but has been abandoned (or dam removed). An abandoned beaver impoundment should be assessed as un-impounded.

Page 1, General Channel Condition (Part C). Part of characterizing channel condition requires determining the general condition of the stream channel: presence of large downed wood (LDW), channelization , or degree to which the near-channel zone is vegetated. Record these conditions in the boxes in Part C.

Channelization can usually be identified by the presence of spoil piles or berms along one or both sides of the channel, and by the level of the adjacent historic floodplain being positioned below that of the berm. Channel incision can be recognized by a deep channel (deeper than expected for the size of the drainage basin) that lacks adjacent spoil piles. Incision is often caused by an increase in the volume of peak flows due to a decrease in infiltration resulting from the expansion of facilitated drainage and compaction of soils.

Both channelization and incision tend to reduce or eliminate the frequency of overbank flow, thus eliminating contact between floodwater and the floodplain. In some 2nd - 4th order systems, the original stream channel can still be found on the floodplain, but it is much more narrow and shallow than the channelized section and usually has little or no flow.

Another factor in characterizing channel condition requires determining if there is large downed wood (LDW) in the stream channel. If there is none, search the stream banks for sawed-off pieces of logs in the floodplain. Sawed-off large wood indicates that LDW has been removed from the stream (“de-snagged”) to facilitate flow.

Page 2, Site Sketch. The sketch provides a grid on which to map the relative area of cover types within 90 ft of each side of the stream and for less-detailed information or notes about conditions from 90-300 ft. Sixty 30 x 30 ft grids have been pre-drawn on the page to facilitate sketching a 90-ft riparian zone on each side of the stream channel.

The sketch map is to be drawn facing downstream with the center of the reach positioned at the midpoint (+) in the center of the map. Marks are also provided for the 10 ft, 50 ft, and 90 ft riparian zones. Sixty 30 x 30 ft grids have been pre-drawn on the page to facilitate sketching a 90-ft riparian zone on each side of the stream channel. Notes on the condition of the 90 – 300 ft zone should be made to the left and right of the grids.

Cover types should be marked with abbreviations provided in Part D, page 2 (OF, MF, YF, etc.), along with a north arrow. If a stream meanders or curves along the 300 ft reach, the sketch should be adjusted so that it is shown as straight. The meander can be drawn in the box located on the right side of the sketch map. Likewise, the channel cross-section can be drawn in the other box. Rough estimates of dimensions can be made (depth from bank top to channel bottom, width of channel, height of berm above floodplain, etc.).

Page 2, Riparian Zone Cover (Part D). This indicator provides information on the general structure of vegetation in zones adjacent to the stream channel. Information needed for recording attributes can be obtained from the Site Sketch grid (above) on page 2. Riparian Zone Cover influences the condition of all aspects of riparian zone. For hydrology, infiltration in the riparian zone is greater under forested conditions than for other land covers. Also, evapotranspiration rates tend to be higher than some of the other cover types that have lower biomass and especially those that have impervious surfaces. Overland flow from adjacent land uses may be more effectively intercepted, dispersed, and absorbed by forest cover as long as gullying does not occur. (Gullying is not as great a problem in most areas of the coastal plain as it is in piedmont riparian zones.) Impervious surfaces disrupt groundwater flow paths by preventing infiltration and by shunting water to streams via surface flows. This also contributes to increased flashiness and potentially to channel incision.

Biogeochemistry is similarly affected by riparian zone condition because forested riparian zones are well known for their capacity to trap sediments and to intercept nutrients transported by surface and ground water through the riparian zone. In addition, microbial processes are maintained by organic matter produced above and belowground, both of which are greater under forested conditions than other cover types.

For habitat maintenance, mature riparian forests provide the structure for riparian-dependent animals. In addition to the canopy trees and other strata, snags and downed wood are essential for maintaining a suite of vertebrates and invertebrates that depend upon large detritus for food and cover. Both vertical and horizontal structural complexity is higher in forests than in other cover types.

Calibration of cover types within a column was based on our study data for live aboveground biomass and for detrital biomass (both aboveground detritus and shallow soil organic matter) with differences among cover types related to variations in total biomass. Calibrations across rows (distances from stream) are scaled to indicate reduced influences with distance from the stream. An assumption is made here that variations in total biomass and distance from stream channel together combine to affect hydrology, water quality, and habitat quality.

The 90 ft riparian zone outer boundary was chosen for RZC because the riparian zone would likely be influenced by surrounding forest, which in this region, can generally reach 90-100 ft in height. Therefore, if growing within the 90-ft riparian zone, a 90-ft tree would have more than a 50% chance of falling into the riparian zone. Of those that fall into the riparian zone, some would be capable of contributing wood to the stream channel. The 50-ft inner zone was chosen to correspond with the NC buffer rules and the 10-ft zone was chosen to correspond to the zone that would most likely affect channel processes (see Near-stream Cover, below).

Because property boundaries often occur along streams, management activities may differ on each side of the stream. Therefore, riparian cover is assessed for each side separately, with a maximum score of 50 for each side and 100 for both sides. A score of 100 means that riparian zone cover is similar to relatively unaltered reference standard sites.

To evaluate riparian zone cover, the site sketch should be filled out first. From this, the percent cover of the condition (rows) of each zone (columns) should be identified and entered in the adjacent blank cell for each condition identified. One or more cover types could occur in any given zone. By entering the percent cover for each type within a zone, the calculated RZC score is based on a weighted average of all cover types present. The assessor should verify that multiple cover types add up to 100 percent for each column.

An example of scoring is as follows: Suppose that on the left side of the stream bank, Mature Forest (MF) occurs from the bank edge to 20 ft, Young Forest (YF) from 20-30 ft, and Perennial Herb (PH) extends from 30-60 ft, and Annual Rowcrop (AR) extends from 60-90 ft (Table 1). In this scenario, MF covers 100% of the 0-10 ft zone and 25% of the 10-50 ft zone (10-20 ft). YF covers 25% and PH covers 50% of the remainder of the 10-50 ft zone (20-30 ft and 30-50 ft, respectively). PH also covers 25% of the 50-90 ft zone (50-60 ft) while AR covers 75% of the zone (60-90 ft). The percent cover of each cover type is multiplied by the appropriate RZC score and summed across all cover types within a zone. Therefore, the column total for each zone must always equal 100%. In the example, the LEFT side RZC score would be 27.5 (17+10.5). For the 10-50 ft zone, 10.5 is derived by summing: (0.25*22)=5.5, (0.25*16)=4.0, and (0.50*2)=1.0. The sum of zone scores for LEFT and RIGHT is used to assign the total riparian zone cover score when computing functioning. In the example below, the total RZC score fro the LEFT and RIGHT sides would be 66.0 (27.5+38.5). These calculations may be conducted in the office.

Table 1. Calculation of Near Stream Cover (NSC) and Riparian Zone Cover (RZC) indicators. Total reach score for each is the sum of the LEFT and RIGHT sides.

Land use by cover type	LEFT SIDE ZONE (distance from stream)							RIGHT SIDE ZONE (distance from stream)					
	0-10 ft	%	10-50 ft	%	50-90 ft	%		0-10 ft	%	10-50 ft	%	50-90 ft	%
Old Forest (>75 yr)	20		25		5		OF	20	*100*	25	*50*	5	
Mature Forest (50-75 yr)	17	*100*	22	*25*	4		MF	17		22		4	
Young Forest (25-50 yr)	13		16	*25*	3		YF	13		16	*25*	3	
Successional Forest (5-25 yr)	7		9		2		SF	7		9		2	
Recently Harvested (0-5 yr)	3		4		1		RH	3		4	*25*	1	*100*
Shrubs/Saplings	3		3		1		SS	3		3		1	
Perennial Herb, incl. residential lawns	2		2	*50*	0	*25*	PH	2		2		0	
Annual Rowcrop	1		1		0	*75*	AR	1		1		0	
Impervious	0		0		0		IP	0		0		0	
Total % (If < 100, correct data entry)		*100*		*100*		*100*			*100*		*100*		*100*
	NSC=	42.5			RZC=	27.5		NSC=	50.0			RZC=	38.5

Page 2, Near-stream Cover (Part D). This indicator provides information on the structure of vegetation nearest the stream channel (within 10 ft). Both biogeochemistry and habitat of the stream channel are more greatly influenced by the proximity of the near-stream cover than the riparian zone as a whole. Vegetation nearest to the stream channel affects in-stream habitat by contributing leaves for shredder biota, a source of LDW to the channel for instream structural habitat complexity, and by providing shade that ameliorates stream water temperature for stream biota. Near-stream vegetation also provides litterfall to the channel as a relatively labile source or organic matter for microbial and other food webs. Streamside vegetation is important in stabilizing stream banks, thus reducing erosion and preventing nutrient–laden sediment from entering streams. In addition, vegetation nearest a stream provides the best opportunity for nutrient uptake and transformation because it is often closest to the areas of groundwater discharge into streams. In low order streams, tree roots extend into the stream channel, creating small pools that trap leaf litter.

Scoring for Near-stream Cover (NSC) is derived from the RZC scores for the LEFT and RIGHT 0-10 ft zones. The score for the 0-10-ft zone must be multiplied by 2.5 to covert the NSC total score to a 0 to 100 scale. Scores for each side range from 50 (Old Forest) to 0 (Impervious). Applying the RZC scenario presented above, the LEFT NSC score would be 42.5 (i.e., 17*2.5) and the RIGHT NSC score would be 50 (i.e., 20*2.5). Again, these calculations can be performed in the office.

Page 3, Summary Sheet. This page provides space for recording RZC and NSC scores and information from Part E, Stream and Riparian Condition. This allows pages 4 and 5 to be used repeatedly. All summary data, except RZC and NSC scores, should be filled in before leaving the site to make sure nothing is missed.

Pages 4 and 5, Stream and Riparian Condition (SRC) Scores (Part E). The seven indicators in this section are scored to determine the condition of the stream channel and its riparian zone. Scores should be entered on page 3, Summary Sheet.

Stream and Riparian Condition (SRC) scores, along with RZC and NSC scores, can be used to estimate condition. Each column describes four discrete categories from relatively unaltered to severely altered. Each category can be further assigned a condition from high to low within a category.

At the top of each indicator category from unaltered to severely altered is a general description of the indicator's condition. Below each general description are more specific descriptions of field indicators, each proceeded by a letter (a-d). On the Summary Sheet (p. 3), space is provided to record one or more of the letters (each which corresponds to specific indicator) that best describes the site's condition. Verbiage in brackets ([ ]) provide some guidance on scoring.

Each stream riparian condition indicator is related to slightly different aspects of the three categories of function: hydrology, biogeochemistry, and habitat. Some are related only to stream channel condition, some only to riparian zone condition, and some to both. A general outline of the rationale for the seven indicators is provided below. Together with the Near Stream Condition and the Riparian Zone Condition, the indicators are assembled in Table 2 into the function categories.

1. *Instream woody structure.*
This indicator is related to all three functions, but for stream channel condition only. Wood in the stream channel affects hydrology by creating pool and riffle sequences that dissipate energy of flowing water and stores water in pools during low flows. In small, unchannelized streams, live tree roots may play this role. Woody structure

affects biogeochemistry by providing a surface for microbial activity and a potential source of dissolved organic carbon (DOC), which is released into the water slowly over long periods of time. DOC can be used as an energy source for denitrification and other microbial processes. Instream wood also provides structural habitat complexity for epifauna and epiphytes. In larger streams, fish and invertebrates may use woody structure for resting during high flows and for hiding (shelter).

Table 2. Example of how indicator scores are averaged to obtain various function, channel condition, and riparian zone condition scores. Indicator scores are averaged by function (columns) to obtain Hydrologic, Biogeochemical, and Habitat mean functions.

	STREAM CHANNEL			RIPARIAN ZONE		
INDICATORS	**Hydrology**	**Biogeo-chemistry**	**Habitat**	**Hydrology**	**Biogeo-chemistry**	**Habitat**
Riparian zone cover				44	44	44
Near-stream cover		45	45			
Instream woody structure	10	10	10			
Sediment regime		10				
Channel-riparian zone connection	30	30	30	30	30	30
Pollution affecting stream	40	40	40			
Factors affecting riparian zone				10	10	10
Habitat quality of riparian zone						10
Stream bank stability		50	50			
Function Score: Mean of all appropriate indicator scores for each function and whether for stream or riparian zone.	27	31	35	28	28	24
	Mean Function Score for Channel = 31			Mean Function Score for Riparian Zone = 27		
	Composite Function Score = 29					

2. *Sediment regime.*

This indicator is related only to the biogeochemistry of free-flowing stream channels. It should not be used to assess channels that have been backed up by an impoundment. In such cases, indicators either fail to develop adequately or are not readily observed. Excess sediment in free-flowing headwater reaches may come from roadside ditches that enter streams at road crossings, from field ditches that connect directly to channels, and from overland flows that transport surface water from sparsely vegetated agricultural fields through poorly vegetated riparian zones to stream channels. Thus, excess sediment indicates erosional problems within a reach and upstream from the assessed reach. Sediments influence channel biogeochemistry by acting as a carrier of sediment-bound phosphorus, the major mechanism by which phosphorus (and heavy metals) are transport by fluvial systems. Phosphorus enrichment may change the N/P ratio of the stream and enrichment with heavy metals may harm intolerant aquatic biota. Stream channel habitat is normally compromised when excess sediments lower water transparency, suppress primary production of epiphytic algae, and bury the habitat of benthic and epiphytic organisms. We have not incorporated this indicator into habitat of the stream channel function, however, because "4. Pollution affecting the stream" addresses many of the same stream habitat conditions. Further, the sediment regime indicator is not indicated for the hydrology function in the stream channel. We acknowledge that excessive sediment deposits in channels reduce bankfull channel flow capacity. For channelized streams, filling contributes positively to channel-riparian zone connection indicator, described next.

3. Channel-riparian zone connection.
This indicator is based on the degree to which a free-flowing stream channel is incised. It is related to all functions for both stream channels and riparian zones. (The indicator should not be used to assess channels that have been backed up by an impoundment for reasons stated above.) The indicator's application to all functions reflects the fact that the connection between channel and riparian zone is fundamental to the characteristic functioning of riparian ecosystems. The degree of channel incision determines the degree to which functioning is impaired in both the stream channel and riparian zone. Channelized streams and channels incised by high flow velocities affect hydrology by transporting water more rapidly through the system during high flows and by increasing the groundwater slope toward the channel during low flows. Both types of alterations reduce the residence time of water in the system by increasing water flows and reducing storage.

Greater channel capacity of channelized and incised streams, compared to natural channels, requires greater flow volumes to reach a stage at which overbank flow is initiated. This can greatly reduce the duration and frequency of flooding or eliminate it altogether. Overbank flow is the major mechanism by which the channel and riparian zone are hydrologically connected. This in turn affects biogeochemistry in at least two ways: the lowered water table may eliminate contact of surficial groundwater with the organic rich surface horizons of the soil, thus reducing the potential for denitrification in both the channel and riparian zone. A lowered water table also exposes the soil column to greater aeration, thus suppressing anaerobic processes that are common in the floodplains of headwater streams. For biogeochemical processes as a whole, the system becomes more oxidized, which reduces the capacity to accumulate organic matter.

Hydrologic alterations caused by channelization or incision also adversely affect habitat for aquatic and wetland-dependent species. In the riparian zone, hydrophytes are less likely to occur. Within the stream, greater flow velocities, especially during storm flows, increase sediment concentrations through re-suspension and scour, thus degrading habitat.

4. Pollution affecting the stream.
This indicator is related to all three functions, but for channel condition only. A pollutant source for assessment purposes is herein defined as runoff from roadside ditches, channelized tributaries originating in agricultural fields, drainage from impervious surfaces, and flows containing sewage and livestock wastes. Pollutant sources affect hydrology by contributing excess water to stream channels. Higher and flashier flows may lead to additional channel incision. Pollutant sources contribute excess nutrients (primarily nitrogen and phosphorus) and/or toxic pollutants to stream channels, thus interfering with normal biogeochemical cycling.

Habitat is also adversely affected by nutrient or chemical additions. Excess nutrients in the presence of sufficient sunlight can create algal accumulations that may lead to nighttime anoxia. Toxic chemicals can directly poison stream organisms.

Pollutant sources affect stream channels both by entering a reach from upstream and by entering within a reach itself. We assume that sources within the reach are generally more detrimental than sources upstream from a reach. Regardless, distance upstream and type of source should be taken into consideration. However, beaver impoundments trap sediment and increase the residence time of water, thus allowing time for nutrient processing and removal. Therefore, some pollutant sources may be disregarded if a beaver impoundment occurs between pollutant sources and the assessed reach. However, more egregious inputs such as toxic chemicals, domestic sewage, and animal waste are expected to alter stream water chemistry even if partially processed through a beaver impoundment before entering reach.

5. *Factors affecting the riparian zone.*
This indicator is related to all three functions, but for riparian zone condition only. The rationale is the same as provided above for stream channels. The difference is that sources of degradation are limited to those within or directly adjacent to a reach. (It is assumed that alterations to upstream riparian zones do not directly affect the riparian zone of the assessed reach or that such alterations are taken into account by the previous indicator).

Alterations to the riparian zone, but not to channels directly, include grading, filling, excavation, cultivation, and other non-forest land uses. Variations in scoring of factors affecting riparian condition reflect the degree to which they are believed to alter condition. For example, discharges to the riparian zone from septic or sewer systems are considered potentially more detrimental than livestock access, which in turn may be considered more detrimental than minor pollutant sources.

Channelization drains adjacent floodplains and increases the capacity of the channel to convey water. This typically eliminates overbank flow onto the floodplain, thus degrading the riparian zone. However, the loss in functioning of a former floodplain of a deeply channelized stream would be ameliorated somewhat if water that would otherwise bypass the former floodplain via ditches and culverts is instead diverted to a forested riparian zone. Forested riparian zones are capable of trapping sediment and removing nutrients before they reach the channel. Especially egregious pollutant inputs, such as toxic chemicals and sewage, would likely overwhelm the capacity of a forested riparian zone to remove them and are still treated as a severe alteration.

Beaver impoundments trap sediment and increase the residence time of water, thus allowing time to remove nitrate and suspended sediments. Therefore, if a beaver impoundment occurs between pollutant sources and the assessed riparian zone, such pollutant sources may be disregarded. However, egregious pollutant inputs described in the "extremely altered" category would not be expected to be ameliorated much by a beaver impoundment.

6. *Habitat quality of riparian zone.*
This indicator is related only to the habitat function of the riparian zone. Vegetation composition (evaluated relative to native forest) is a direct measure of plant habitat, which in turn affects animal habitat. It is assumed that mature to old forests represent

the least altered condition that is conducive to supporting native communities. The footnote provides a list of canopy species characteristic of native forests. If at least four of the listed species are present in the canopy and the understory is intact with minimal cover of invasive species (Table 3), then the remaining composition and structure of the forest is assumed to be relatively unaltered.

When forest cover is less than 50%, it is assumed that habitat quality is severely degraded for forest-dependent species. Invasive and ecotone-dependent species displace those that require contiguous canopy of intact forest as cover becomes more fragmented.

7. Stream bank stability.
This indicator is related to the biogeochemistry and habitat functions of free-flowing streams. (It cannot be used to assess channels backed up by impoundments. In such cases, indicators either fail to develop adequately or are not readily observed.) As stream discharge increases, hydraulic energy is first dissipated along stream banks and on LDW and roots residing in the channel. Some of this energy results in bank erosion, exposes roots, and causes bank slumping and tree fall, when excessive. If the stream channel is not incised, even higher flows associated with overbank flow transfer total stream energy to the floodplain where it is dissipated without erosion over a large surface area, thus protecting the channel itself from excessive scouring. While some bank erosion and sediment redistribution are natural processes, they are minor in low gradient streams in the coastal plain. Alteration of riparian condition is assumed if erosion, slumping, and undercutting are excessive (especially in places other than at cutbanks) and herbaceous vegetation is unable to re-establish on banks after extreme events. Alterations in bank stability lead to excessive introduction of sediment to the channel, which is ultimately transported to downstream ecosystems.

Table 3. Invasive, non-native species found in riparian ecosystems.

Species	Common name	Prevalence
Trees		
none to rare		
Shrubs		
Ligustrum sinense	Chinese privet	common
Elaeagnus angustrifolia	Russian olive	uncommon[1]
Herbs		
Lonicera japonica	Japanese honeysuckle	common
Microstegium virmineum	Japanese stiltgrass	common
Rosa multiflora	multiflora rose	uncommon[1]
Murdania keisak	Asian dayflower	common
Polygonum cuspidatum	Japanese knotweed	common
Vines		
Lonicera japonica	Japanese honeysuckle	common
Pueraria lobata	kudzu	uncommon[1]

[1]Uncommon invasive in riparian ecosystems, but may be abundant elsewhere.

2.4. Office and Field Criteria for Differentiating Urban from Rural Reaches

This guidance is used to determine which protocol should be used to assess a randomly assigned reach. Presence of any one indicator below is sufficient for confirming urban status (either in the office or in the field).

Office Determinations (made using USGS 7.5 minute series topographic maps and USGS digital orthophoto quarter quads or higher resolution orthogonalized aerial photographs)

1. >10% impervious surface within a circle centered on random point (low order 600 ft (200 yd) radius; high order 1,500 ft (500 yd) radius; see template of aerial photographs, in Appendix).
2. Area denoted as urban on USGS topo (brown, purple, or pink color).
3. Housing density >2.37 units/acre[1] (for low order, >62 units in 600 ft radius circle; for high order >384 units in 1,500 ft radius circle). (Units are dwelling units: single family home = 1 unit, duplex = 2 units, each apartment with in a complex = 1 unit.)

Field Determinations

1. Stormwater treatment unit (wet or dry detention/retention, or infiltration basin, etc.) is located in assessment reach or upstream (low order within 600 ft (200 yd); high order within 1,500 ft (500 yd) or within watershed.
2. Stormwater input to stream or floodplain from urban stormwater sources, such as curb-and-gutter street or parking lot, is located in assessment reach or upstream (low order within 600 ft; high order within 1,500 ft). Here, "stormwater input" does not refer to road ditches or grassed swales. (Grassed swales and ditches in agricultural settings indicate that the rural riparian assessments should be used.)
3. Sewer line right-of-way is in riparian zone within 50 ft of stream channel.
4. Three or more dwelling units are located within 90 ft of the stream (either side) along 300 ft assessment reach[2].

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[1] The rural-urban threshold housing density (2.37 units/acre) is the mean of the lowest density urban zoning classification for Greenville, NC (R-15S, 3 units/acre) and the rural residential zoning classification for Pitt County, NC (minimum lot size 25,000 ft^2, which equals 0.57 acre or 1.74 units/acre).

[2] Based on the rural-urban threshold housing density (2.37 units/acre) and the size of the assessment area (300 ft x 180 ft = 54,000 ft^2, or 1.24 acre; 1.24 acre x 2.37 units/acre = 2.94 units, or ~3 units within the assessment area).

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[ ] Site #   Date ____________

[ ] Watershed   Field Crew ____________________

[RHO] Stream type

A. Reasons for Rejecting or Moving a Randomly Assigned Reach (Enter 1 for Yes, 0 for No)

[ ] Reach rejected (check one): ( ) both channel and riparian zone flooded by beaver impoundment; ( ) flooded by other impoundment type; ( ) inaccessible. **If rejected, do not assess reach.**

[ ] Reach moved upstream or downstream ( ) feet due to ( ) beaver or ( ) other impoundment in <50% of reach. (Enter 1 for yes, 0 for no in box, enter distance moved, and check impoundment type in parentheses.)

B. Upstream and Downstream Influences on Reach. (Enter 1 for Yes, 0 for No)

[ ] Only the channel is backed up by downstream impoundment; the riparian zone is not inundated, except after a heavy rainfall event. ***If so, conduct assessment, but do not assess SRC #2, #3, and #7 (pp. 4 & 5).***

[ ] Reach formerly and recently impounded by beaver or man-made dam, but dam now abandoned and recovering.

C. General Channel Condition. (Enter 1 for Yes, 0 for No)

[ ] Unincised, free-flowing stream with large downed wood (LDW) and/or litter and tree roots in channel.

[ ] Unincised, free-flowing stream with little or no LDW, litter, and tree roots in channel.

[ ] Channelized or incised stream with trees growing in and along channel and LDW or leaf litter in channel.

[ ] Channelized or incised stream with trees growing in and along channel, but lacking much LDW or leaf litter in channel. (Look for evidence of desnagging as possible reason.)

[ ] Channelized or incised stream with mostly shrubs and/or herbaceous vegetation growing in and along channel; few or no trees.

[ ] Relic channel located on former floodplain

Notes:

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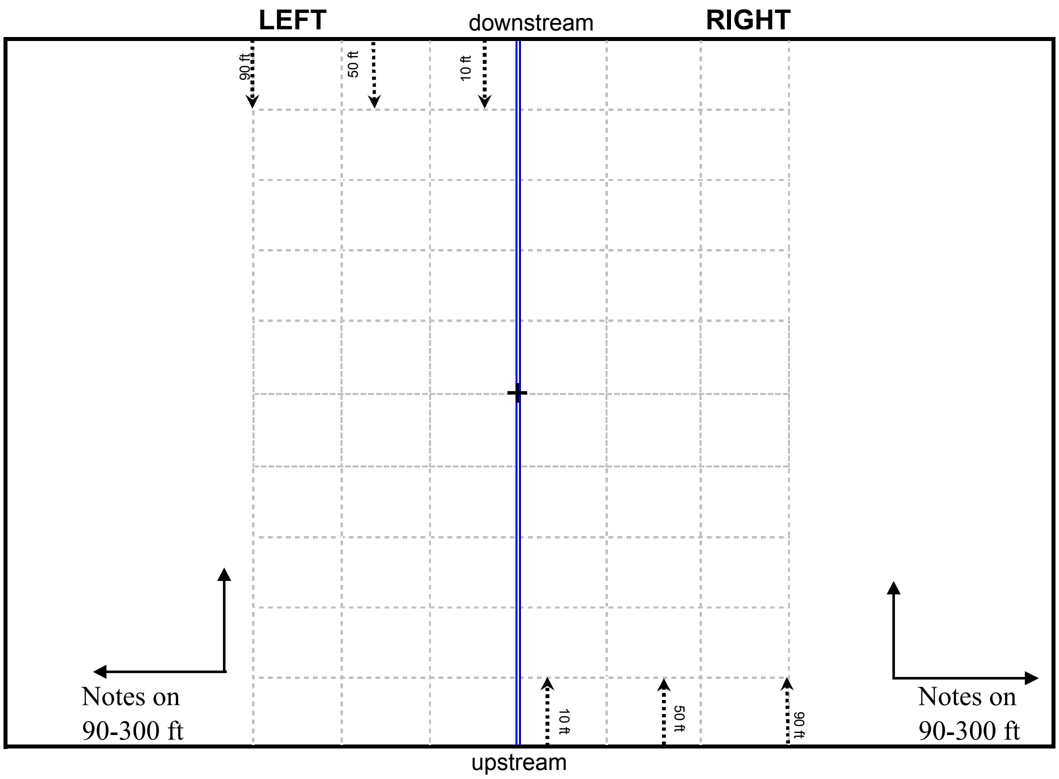
Site # _______ Watershed ___________________________________ Date ____________

Site Sketch *Reach is 300 ft in upstream-downstream direction by 180 ft wide. Each square is 30 x 30 ft. Identify and label cover types to 90 ft using abbrevations in Part D below. Portray stream as straight. Add north arrow.*



Draw stream's meander

Draw channel x-section

D. Riparian Zone Cover (RZC) and Near Stream Cover (NSC) - *In the blank boxes, record the % cover for each cover type by zone (0-10 ft, 10-50 ft, 50-90 ft). For example, if a zone is equally represented by two cover types, record 50 in the boxes adjacent to the cover types. Insert abbreviations (OF, MF, etc.) on the sketch map above. (Age ranges in parentheses.) For Mature Forest that has been selectively cut or high-graded, record as Young Forest. These data should be transferred to the "RZC Calculator" file to calculate RZC and NSC scores. (Make sure that total % = 100 for each column.) The NSC score is 2.5 times the total score for the 0-10-ft zone.*

Land use by cover type	LEFT SIDE ZONE (distance from stream)							RIGHT SIDE ZONE (distance from stream)					
	0-10 ft	%	10-50 ft	%	50-90 ft	%		0-10 ft	%	10-50 ft	%	50-90 ft	%
Old Forest (>75 yr)	20		25		5		OF	20		25		5	
Mature Forest (50-75 yr)	17		22		4		MF	17		22		4	
Young Forest (5-25 yr)	13		16		3		YF	13		16		3	
Successional Forest (25-50 yr)	7		9		2		SF	7		9		2	
Recently Harvested (0-5 yr)	3		4		1		RH	3		4		1	
Shrubs/Saplings	3		3		1		SS	3		3		1	
Perennial Herb (incl. residential lawns)	2		2		0		PH	2		2		0	
Annual Rowcrop	1		1		0		AR	1		1		0	
Impervious	0		0		0		IP	0		0		0	
Total % (If >100, correct data entry)													
	NRC=				RCZ=			NRC=				RCZ=	

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Site # ___________ Watershed ____________________ Date _______

C. Riparian Zone and Near Stream Cover, p. 2

☐ RZC (total of possible 100% derived from both sides)

☐ NSC (total of possible 100% derived from both sides of "0-10 ft" zone, multiplied by 2.5)

D. Stream and Riparian Condition (SRC) indicator scores (pp. 4 & 5)

☐ 1. Instream woody structure

☐ Sub-condition "a or b."

☐ 2. Sediment regime ***(If channel is backed up by beaver, enter Bv.)***

☐ Sub-condition "a, b, c, or d." **(*If channel is backed up by beaver, enter Bv.)***

☐ 3. (LEFT) Channel-riparian zone connection ***(If channel is backed up by beaver, enter Bv.)***

☐ Sub-condition "a, b, c, or d." (***If channel is backed up by beaver, enter Bv.)***

☐ 3. (RIGHT) Channel-riparian zone connection ***(If channel is backed up by beaver, enter Bv.)***

☐ Sub-condition "a, b, c, or d." (***If channel is backed up by beaver, enter Bv.)***

☐ If relic channel of former floodplain is observed, record '1"; otherwise record "0" here.

☐ 4. Pollution affecting the stream

☐ Sub-condition "a, b, c, or d."

☐ 5. (LEFT) Factors affecting the riparian zone

☐ Sub-condition "a, b, or c."

☐ 5. (RIGHT) Factors affecting the riparian zone

☐ Sub-condition "a, b, or c."

☐ 6. (LEFT) Habitat quality of riparian zone

☐ Sub-condition "a, b, or c," if appropriate

☐ 6. (RIGHT) Habitat quality of riparian zone

☐ Sub-condition "a, b, or c."

☐ 7. (LEFT) Stream bank stability ***(If channel is backed up by beaver, enter "Bv")***

☐ Sub-condition "a, b, c, or d." (***If channel is backed up by beaver, enter Bv.)***

☐ 7. (RIGHT) Stream bank stability ***(If channel is backed up by beaver, enter "Bv")***

☐ Sub-condition "a, b, c, or d." (***If channel is backed up by beaver, enter Bv.)***

Notes:

E. Stream and Riparian Condition (SRC). *For each SRC indicator, record on page 3 the SRC indicator score and one or more letters (a-d) that apply. (If a condition is encountered that is not provided, choose a score, and explain alteration and rationale for scoring in notes on p. 3.) Verbiage in brackets ([ ]) provide guidance on scoring.*

	Condition Category			
SRC Indicator	**Relatively Unaltered**	**Somewhat Altered**	**Altered**	**Severely Altered**
1. Instream woody structure	Much large down wood (LDW) in channel and along banks. (Recent treefalls from extreme weather events or erosion not applicable.) **(a)** LDW represents a variety of decay classes[1]. **(b)** LDW in channel and along banks represents a mix of sizes >4 inch dia. Some LDW >8 inch dia.	Some LDW in channel and along banks. Some may be partially buried in channel bottom. **(a)** LDW in channel and along banks represents a variety of decay classes[1]. **(b)** Few or no LDW >8 inch dia. [If large >4 inch dbh trees grow along both banks, score 80, if only along one side, score 70, if streamside trees are <4-inch dbh, score 60.]	Few or no LDW in channel and on banks[2] but potential supply is present. **(a)** LDW represents only one decay class[2]. [If large >4 inch dbh trees grow along both banks, score 50, if only along one side, score 40, if streamside trees are <4-inch dbh, score 30.]	No LDW in channel **(a)** Stream is channelized and periodically cleared of debris to maintain drainage **(b)** No large trees (>4 inch dbh) grow along channel banks. [Lowest score should be given to channels that are partially in culvert or lined with rocks or concrete.]
Score =	100 90	80 70 60	50 40 30	20 10 0
2. Sediment regime[3]	Little or no silt or sand carried by stream. Water runs fairly clear even during periods of high flow. **(a)** Stream is not channelized. **(b)** Channel bottom is mostly sandy with little or no silt on channel bottom or on floodplain. [If sand deposition in channel bottom is due to upstream activities, then see "severely altered" category.]	Some silt carried by stream. **(a)** At high flows, suspended sediment evident in water. **(b)** When water runs clear during base flow, sediment can be re-suspended by shuffling feet in channel. **(c)** Thin layer (<1 inch thick) of silt deposited on channel bars or on floodplain surface. [Thickest deposits score lower.] **(d)** Sediment >1 inch thick due to recent abandonment of impoundment[4].	Silt and sand carried by stream. **(a)** Water is silt laden, esp. after heavy rains. **(b)** Thick (1-2 inches) silt or sand deposited on channel bars, bank edge, or on floodplain (if present).	Heavy sediment load carried by stream. **(a)** Sediment suspended in water even during low flow. **(b)** Thick (>2 inches) sand or silt layers recently deposited on channel bars, bank edge, or on floodplain (if present). **(c)** Evidence that sand or silt deposits in reach are being generated by upstream activities.
Score =	100 90	80 70 60	50 40 30	20 10 0
3. Channel-riparian zone connection[3]	Strong evidence of overbank flow on floodplain. **(a)** No apparent channelization or incision. **(b)** Wrack, sediment, and/or trash on floodplain. [Sparse wrack scores 45.] **(c)** High water marks on trees apparent. **(d)** No spoil berm alongside channel, but perhaps a natural levee.	Evidence of occasional overbank flow on floodplain. **(a)** Some wrack, sediment, trash on floodplain, but sparse and/or old. **(b)** Stream channelized within historic channel with low spoil berms or breaks in them along channel. (Channel may have been channelized in past, but is filled sufficiently with sediments that overbank flow now is common.) **(c)** Channel slightly channelized or incised.	Evidence of overbank flow only after extreme (rare) flood events[4]. **(a)** No or little wrack on floodplain. **(b)** Channelization (i.e., spoil berms present and high). **(c)** Channel deeply incised (not channelized).	Overbank flow eliminated[4]. **(a)** Deep channelization with spoil berms present. **(b)** Deeply incised (not channelized). **(c)** Filling and/or leveling of floodplain, some or all of fill may have been derived from spoil from channelization. **(d)** Presence of high artificial levee or other channel-containment structure.
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0
4. Pollution affecting the stream	No on-site or off-site pollution[5] affecting stream. **(a)** There is no pollution entering directly into the stream within the reach or within 1,500 ft (500 yd) upstream from reach. **(b)** No livestock access to channel or waste dumping from confined animal operations (CAO) located upstream from reach. **(c)** Stream is not channelized.	Only off-site pollution[5] affects stream. **(a)** Pollution feeds directly into stream channel within 1,500 ft (500 yd) upstream from reach (not within reach). **(b)** Pollution from stormwater or other drainage is discharged (or diverted) to riparian zone where it is detained and processed before entering stream. [More sources or more proximate pollution sources should score lower.]	On-site pollution[5] affects stream. **(a)** Water from roadside ditch directly empties into reach. **(b)** Overland-flow from agricultural field directly enters reach. **(c)** Nearstream livestock activity appears to pollute channel [Field edges closer than 10 ft scores 30, 10-50 ft scores 40, >50 ft or depressed, grassy swale (BMP) scores 50.	Especially egregious pollution affects stream. **(a)** Pollution from confined animal operations entering directly into channel. **(b)** Pollution from septic or sewage treatment systems entering directly into channel. **(c)** Livestock have access to stream within reach. **(d)** Sediment input from construction activities entering directly into channel.
Score =	100 90	80 70 60	50 40 30	20 10 0

[1] Decay classes: (1) bark intact, leaves attached, no evidence of decay, (2) loose bark, no leaves, (3) peeling bark, fungi present, (4) advanced stages of decay, no bark or soft enough for a prod to be easily poked through, and (5) bole decayed into ground.

[2] If few or no LDW occurs within channel, check stream banks for sawed-off pieces in floodplain. This indicates de-snagging. LDW from severe bank erosion not applicable.

[3] Do not assess SRC #2, #3, & #7 if stream is backed up by downstream beaver impoundment. Do assess relic beaver impoundments. For relic impoundments, sediment layer may be deep at upstream end of unmaintained impoundment and reduced in depth closer to former dam site.

[4] On higher order streams, an historic channel may occur on former floodplain. On data sheet, p. 3, record if relic channel is observed.

[5] Pollutant sources include runoff from roadside ditches, channelized tributaries originating in agricultural fields or nurseries, and drainage from impervious surfaces. Note, beaver impoundments largely negate the effects of most pollutant sources, except inputs described in the "altered" and "severely altered" categories. Therefore, other upstream pollutant sources may be disregarded if a beaver impoundment occurs between the pollutant sources and assessed reach.

E. Stream and Riparian Condition (cont.)

SRC Indicator	Condition Category: Relatively Unaltered	Somewhat Altered	Altered	Severely Altered
5. Factors affecting the riparian zone[1] (0-90 ft)	No factors affecting riparian zone condition within reach. **(a)** Stream is not channelized. **(b)** No pollution[2] empties into riparian zone. **(c) Livestock do not have access to riparian zone.** [Presence of trash or organic waste (clippings. etc.) score 45.]	Factors somewhat affecting riparian zone. **(a)** Stream is not channelized and water from properly designed and maintained detention facilities empties into riparian zone. **(b)** Stream is channelized and drainage or stormwater is discharged (or diverted) to riparian zone where it is detained and processed before entering stream. **(c)** Herbicides are applied to maintain a utility right of way that traverses riparian zone. [Forested riparian zone scores higher than other cover types.]	Factors affecting riparian zone. **(a)** Stream not channeled and ditches or tributaries from spray fields of CAO diverted onto riparian zone. **(b)** Stream is channelized with low spoil berms alongside channel, such that overbank flow sometimes occurs, but is rare. **(c)** Water from tributary streams and roadside ditches is diverted directly to channel, thus bypassing riparian zone. [Forested riparian zone scores higher than other cover types.]	Especially egregious pollution or other factors affecting riparian zone. **(a)** More than 25% of riparian zone of reach filled, excavated, graded, or converted to other non-forested land covers. **(b)** Stream so incised or deeply channelized (with high spoil berms) that overbank flow to floodplain is extremely unlikely even during major storm events AND no stormwater is diverted to former floodplain. **(c)** Evidence of sewage or discharge from confined animal operations (COA) into riparian zone. [Excessive amount of sewage and/or lack of forest on former floodplain score lower.]
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0
6. Habitat quality[3] of riparian zone (0-90 ft)	Habitat quality intact. Riparian zone dominated by old or mature intact[4] forest (>95% of area). No or low cover of exotic or invasive species. No grazing, mowing, or selective harvesting within riparian zone. [Old or Mature forest (>50 yr. old) scores 50; slightly younger forest scores 45. Exotics in 5-25% in any stratum scores 45.]	Habitat quality somewhat degraded. **(a)** Intact[4] forest covers 75-95% of riparian zone with remainder of area representing other cover types. **(b)** Intact forest covers >95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers >95% of riparian zone with at least one understory stratum of native vegetation asent or not well represented (due to understory removal or timber harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests.]	Habitat quality degraded. **(a)** Intact[4] forest covers 50-75% of riparian zone with remainder of area representing other cover types. **(b)** Intact forest covers 75-95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers 75-95% of riparian zone with at least one understory stratum of native vegetation absent or not well represented (due to understory removal, timber harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests in all cases.]	Habitat quality extremely degraded. **(a)** Forest covers <50% of riparian zone with remainder of area representing other cover types. **(b)** Intact[4] forest covers 50-75% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers 50-75% of riparian zone with at least one understory stratum of native vegetation absent or not well represented (due to understory removal, timber harvesting, etc.). [Old or Mature forest (>50 yr. old) covering more than 25% of riparian zone should be scored 10; younger forest or lower forest cover scores 5, lack of trees scores 0.]
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0
7. Stream bank stability[5]	Stream bank relatively stable. **(a)** Evidence of erosion or bank failure absent or minimal (<10%) of length. **(b)** Streamside vegetation tightly binds soil along banks, although exposed roots may occur at cut-banks of stream channel. [Slight erosion or bank undercutting scores 45.]	Stream bank moderately stable. **(a)** 10-25% of bank eroded or slumping. **(b)** If trees present along bank, a few large (>1 inch dia.) roots exposed. **(c)** Most eroded areas recovering.	Stream banks unstable. **(a)** 25-50% of bank eroded. **(b)** Erosion, slumping, and undercutting prevalent, especially at places other than cutbanks. **(c)** If trees present along bank, many large (>1 inch in dia.) roots exposed with some trees toppled into stream due to undercutting.	Stream bank extremely unstable. **(a)** >50% of bank eroded **(b)** Erosion, slumping, and undercutting prevalent, esp. at places other than cutbanks. **(c)** If trees present along bank, many toppled into stream due to undercutting. **(d)** Banks hardened with rocks, gabions, concrete, or bulkheading.
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0

[1] Riparian zone is from the stream bank to the floodplain or former floodplain edge. If former floodplain is not discernible, use 90-ft RZC boundary as edge.

[2] Pollutant sources include runoff from roadside ditches, channelized tributaries originating in agricultural fields, drainage from impervious surfaces, and flows containing seqage and livestock wastes. Note, beaver impoundments largely negate the effects of most pollution, except types of pollution described in the "altered" and "severely altered" categories. Therefore, other upstream pollutant sources may be disregarded if a beaver impoundment occurs between the sources and the assessed reach.

[3] Habitat quality encompasses both plant and animal habitat and includes both quality and area. Quality assumes that mature or old forest with appropriate quality and quantity of LDW, snags, and characteristic 3-D structure.

[4] Intact forest is one with all strata present, including canopy, midstory, understory, and herb layers. Canopy must be comprised of trees >6 in (15 cm) dbh, including at least 4 of the following species: red maple, bald cypress, sycamore, sweetgum, water tupelo, swamp blackgum, tulip poplar, elm, and wetland oaks. A pine plantation does not count as native forest. Forest cover could be linearly arranged along channel or in blocks scattered within the riparian zone.

[5] Do not assess SRC #2, #3, & #7 if channel is backed up by downstream beaver impoundment.

Rural Low Order Riparian Assessment Protocol, V. 2.0

1. Background

This assessment protocol was designed for assessing the condition of headwater riparian ecosystems (1st – 2nd order) that originate in the coastal plain of North Carolina, with emphasis on landscapes dominated by forest or rowcrop agriculture. It was prepared to aid in filling out the field sheets for the Rural Low Order Riparian Assessment Version 2.0. It was not explicitly developed for landscapes dominated by urban development or affected by other types of development activities.

This assessment method was also not designed for evaluating beaver impoundments that have flooded *both* the channel and floodplain. However, it can be used to assess beaver-modified reaches where *only* the channel has been backed up by a downstream impoundment, i.e., where water has not inundated the adjacent floodplain except following a heavy rainfall event. In such cases, Stream and Riparian Condition (SRC) indicators Sediment Regime (#1) and Channel-Riparian Zone Connection (#3) (page 4) should not be assessed either because fluvial features are underwater or channel processes have been modified.

This assessment method is also not appropriate for higher order riparian systems or for riparian ecosystems in other physiographic provinces. Although initially developed in the Little Contentnea Creek drainage basin, it has been field tested in other coastal plain drainage basins in North Carolina. Therefore, this method would be appropriate for use in other coastal plain drainage basins in North Carolina and probably other coastal plain regions in the Southeast.

Headwater streams in the coastal plain include all streams that are fed by ground water for some portion of the year and usually flow from fall to late spring during years of normal rainfall. They tend to stop flowing (surface flow) during summer months when weather is warm and evapotranspiration is high. However, even these intermittent reaches sometimes flow year-round during particularly wet years. In agricultural landscapes, headwater riparian ecosystems range in condition from natural, un-channelized reaches buffered by forest to channelized reaches with only herbaceous vegetation or rowcrop in their riparian zones. Relatively unaltered riparian ecosystems are rare in the coastal plain, particularly the intermittent ones located at the top of drainages. They are (and were) easily converted to ditches in agricultural fields.

2. Office and Field Methods

Reasons for conducting an assessment should be clearly established. They may include the following:

- documenting baseline conditions along a given reach
- determining types and degree of alteration in a drainage basin by assessing multiple sites
- determining how a proposed project will alter riparian condition
- comparing several reaches as part of an alternatives analysis
- identifying specific actions that could be taken to minimize project impacts

- determining the effects of specific manipulations following restoration or other management practices.

Defining objectives of an assessment may reduce misunderstanding among stakeholders and other interested parties. It will also focus the interpretation of assessment results on the specific requirements of a project.

For some assessment parameters, we used field data to validate relationships between riparian condition and water quality (biogeochemical and biotic). In other cases, relationships are based on information published in scientific literature. Finally, best professional judgment was employed where there are as yet no data to validate relationships. However, all parameters are calibrated and field tested against reference sites that range between relatively unaltered to severely altered.

2.1. Office preparation.

Maps and photographs are useful in characterizing a reach for assessment. They provide such information as project boundaries, location of jurisdictional wetlands, and location of proposed alterations or restoration. Geographic features are needed in evaluating some of the indicators such as the presence of roads, ditches, buildings, tributary streams, land use, land cover, and other pertinent features. Some useful sources are (a) high-resolution aerial photographs, such as DOQQs, (b) county soil surveys, (c) topographic maps (USGS 1:24,000), and (d) drainage maps. While the field assessment may be completed without these sources during the field visit, field time can be shortened considerably by having access to remotely acquired information. For areas that may contain both rural and urban drainages, criteria for choosing the right set of field sheets is provided on the last page of this protocol (2.4).

Equipment should be assembled before the field visit. Essential items are a GPS unit, shovel or trowel, hand-held laser level, stiff tape measure or meter stick, and 300 ft tape.

2.2. Guidelines for recognizing low order riparian zones and channels

First, the reach should be evaluated to determine if it is a true stream of low order. Nearly all low order streams in the coastal plain have intermittent rather than perennial flow. Many channels in the area are not streams, but rather are ephemeral draws or field ditches where there never was a true stream. Ephemeral draws are flow paths that carry surface runoff only during precipitation events, and do not flow as a result of connection with the water table. Ephemeral draws should not be assessed with this method.

Sometimes it is difficult to determine whether a reach is a true stream (a channelized former stream) or a field ditch. Typically, a true stream will have one or more of the following attributes: (1) it will occur in the proper topographic position (along a linear depression rather than running parallel to contours or across a flat); (2) it will have a hydric soil type; (3) it may have a high-organic soil layer at the level of the former floodplain (which may be buried under fill from channelization or field grading). Channelized streams may also retain some of the original stream sinuosity, depending on the topography, while field ditches are usually straight. Field ditches that were never true streams are most difficult to discern where a channel has been excavated upslope beyond the stream's headward limit. The field assessor should use his or her judgment based on these criteria and observation of similar reaches in the same area, rejecting or avoiding the assessment of sites that fall on field ditches.

Differentiating ephemeral flow paths from intermittent streams can also be challenging. By definition the distinction between the two is hydrologic: ephemeral flow paths do not have a groundwater flow component (their flow is all surface runoff), while flow in intermittent streams is driven by groundwater with additional flow from surface runoff. Intermittent streams are therefore able to develop, but don't always develop, fluvial geomorphologic features similar to those found in perennial streams (such as channels, stream beds, banks, sinuosity, point bars, and so on). These features, when present, are usually far less evident than in perennial streams, and are typically discontinuous or sporadic, especially upslope where they transition to ephemeral. Intermittent streams usually have a floodplain (although it may be very narrow), and there is usually evidence of overbank flow on the floodplain (sediment deposits or silt-covered leaves, wrack, and so on). The channel of intermittent streams also typically supports hydric soils and sometimes wetland biota (hydrophytic plants and animals such as crayfish), at least in some places, while ephemeral flow paths have neither. These indicators are intentionally qualitative, although they could be quantified and calibrated against reference sites with known hydrology to form the basis for classification (as in NC DWQ's Stream Classification Method). The field assessor should use his or her judgment based on these criteria and observations of similar sites in the same area. The assessment procedure should not be used for ephemeral reaches.

2.3 Guidelines for rejecting or moving sites

A watershed can be characterized by assessing a statistically robust number of reaches and using the data from the assessed watershed to make inferences about riparian areas in the watershed as a whole. Various random and stratified random approaches could be used depending on the questions being posed. Regardless of the method applied for randomly selecting reaches for sampling, in some cases, a randomly assigned reach will occur at a place that the assessment procedure was not designed to assess (e.g., along an ephemeral flow path) and so it must be moved or rejected.

If a reach is rejected or moved, the reason for rejection should be noted on the data sheet in the space provided on page 1 (Part A). The following guidelines for moving or rejecting reaches should be followed in the sequence in which they appear. These criteria will probably only be applied in cases where one is assessing randomly-selected reaches. Items 1 and 2 are mapping exercises for the office. The remainder are conducted in the field.

1. If a random point marking the center of a reach is located within 300 ft of another random point, it should be rejected and another random point should be substituted.

2. If the random center point falls less than150 ft from the end of a mapped first order stream, the point should be moved downstream until a full 300 ft reach is encompassed.

3. If a stream junction occurs less than 150 ft downstream of the randomly selected point, the reach should be moved upstream until the entire 300-ft reach is above

the junction. If a junction occurs less than 150 ft upstream from the random point, then the 300-ft reach should encompass the main stem (the same stem on which the random point falls).

4. If the mapped point lands on an ephemeral channel or ditch located more than 150 ft above where the channel becomes intermittent the site should be rejected and the next alternate random point should be chosen. If the point is located less than 150 ft from the beginning of an intermittent channel, then the point should be moved downstream until all 300 ft of the assessment reach encompasses an intermittent reach.

5. If the randomly selected 300-ft reach falls entirely within beaver impoundment (where both channel and floodplain are impounded) or other type of impoundment, the site should be rejected and no substitution should be made for the point.

6. If the random center point is <150 ft from the upstream or downstream boundary of a beaver or other impoundment, the point should be moved upstream or downstream in the un-impounded reach to allow assessment of an un-impounded 300 ft reach. (If moved upstream, the channel may be backed-up, thus requiring that Stream and Riparian Condition indicators #2 and #3 on page 4 of the Field Sheets be omitted.) In many cases, beaver impoundments show a stepwise pattern in which the upper end of one impoundment is adjacent to the dam of the next impoundment upstream. In such cases, moving the reach upstream or downstream will still place it in an impoundment and so the site should be rejected. If rejected, no substitution should be made for the point.

2.4. Data collection and observations on-site

If none of the above-described rejection criteria are met, then rural low order reaches should be assessed as outlined below. Field sheets are referred to by page number below.

Page 1, Reasons for rejecting or moving a randomly assigned reach (Part A). The top section provides boxes for recording whether a randomly assigned reach has to be rejected or moved for occurring at a place that the assessment procedure was not designed to assess. A reach that is specifically chosen for assessment would presumably not be rejected and a "0" would be recorded in each box. However, for reaches randomly chosen from maps that that must be rejected or moved (see above listed criteria), Part A provides a format for recording the reason for rejection or distance and reason moved (if the reach should be moved).

Page 1, Upstream and Downstream Influences on Reach (Part B). This category provides information on whether the reach is hydrologically affected by an impoundment or by roadside ditches. Roadside ditches are a conduit for excess water, sediment, and nutrients, and thus are expected to adversely affect hydrologic regime and nutrient input and cycling. DOQQs are useful for locating roadside ditches. The flow and connection of the ditches with the assessed reach can be verified in the field.

In conducting the assessment, first record if the reach is downstream from any street crossings, stormwater outfalls, or ditches. Next, record if the channel is backed up by a beaver or other impoundment. Standing, non-flowing water in the channel suggests that there is an impoundment downstream from reach. A channel can be affected by an impoundment without a dam occurring within the assessed reach or even if there is no impounded water on the floodplain. (Note: even an impounded reach may begin to flow during high rainfall events). Although this assessment method was not developed for assessing the condition of impoundments (see above rejection criteria), a channel that is backed up should be assessed if its riparian zone is not impounded, but SRC indicators #2 and #3 (page 4) should not be assessed. Instead, “Bv” should be recorded in the appropriate data boxes on page 3. Care should be taken to make sure that standing, non-flowing water is not simply a result of channel bed scour that creates an elongated pool of stagnant water.

Next, record if the reach was formerly and recently impounded by beaver, but has been abandoned (or dam removed). An abandoned beaver impoundment should be assessed as un-impounded.

Page 1, General Channel Condition (Part C). Part of characterizing channel condition requires determining the general condition of the stream channel: channelization, incision, presence of large downed wood (LDW), and degree to which the near-channel zone is vegetated. Record these conditions in the boxes in Part C.

Channel incision can be recognized by a deep channel (deeper than expected for the size of the drainage basin) that lacks adjacent spoil piles. Incision is often caused by an increase in the volume of peak flows due to a decrease in infiltration resulting from the expansion of facilitated drainage and compaction of soils. Channelization can usually be identified by the presence of spoil piles or berms along one or both sides of the channel, and by the level of the adjacent historic floodplain being positioned below that of the berm.

Both incision and channelization tend to reduce or eliminate the frequency of overbank flow, thus eliminating contact between floodwater and the floodplain. In some 2nd - 4th order systems, the original stream channel can still be found on the floodplain, but it is much more narrow and shallow than the channelized section and usually has little or no flow.

Another factor in characterizing channel condition requires determining if there is large downed wood (LDW) in the stream channel. If there is none, search the stream banks for sawed-off pieces of logs in the floodplain. Sawed-off large wood indicates that LDW has been removed from the stream (“de-snagged”) to facilitate flow.

Page 2, Site Sketch. The sketch provides a grid on which to map the relative area of cover types within 90 ft of each side of the stream and for less-detailed information or notes about conditions from 90-300 ft. Sixty 30 x 30 ft grids have been pre-drawn on the page to facilitate sketching a 90-ft riparian zone on each side of the stream channel.

The sketch map is to be drawn facing downstream with the center of the reach positioned at the midpoint (+) in the center of the map. Marks are also provided for the 10 ft, 50 ft, and 90 ft riparian zones. Sixty 30 x 30 ft grids have been pre-drawn on the page to facilitate sketching a 90-ft riparian zone on each side of the stream channel. Notes on the condition of the 90 – 300 ft zone should be made to the left and right of the grids.

Cover types should be marked with abbreviations provided in Part D, page 2 (OF, MF, YF, etc.), along with a north arrow. If a stream meanders or curves along the 300 ft reach, the sketch should be adjusted so that it is shown as straight. The meander can be drawn in the box located on the right side of the sketch map. Likewise, the channel cross-section can be drawn in the other box. Rough estimates of dimensions can be made (depth from bank top to channel bottom, width of channel, height of berm above floodplain, etc.).

Page 2, Riparian Zone Cover (Part D). This indicator provides information on the general structure of vegetation in zones adjacent to the stream channel. Information needed for recording attributes can be obtained from the Site Sketch grid (above) on page 2. Riparian Zone Cover influences the condition of all aspects of riparian zone. For hydrology, infiltration in the riparian zone is greater under forested conditions than for other land covers. Also, evapotranspiration rates tend to be higher than some of the other cover types that have lower biomass and especially those that have impervious surfaces. Overland flow from adjacent land uses may be more effectively intercepted, dispersed, and absorbed by forest cover as long as gullying does not occur. (Gullying is not as great a problem in most areas of the coastal plain as it is in piedmont riparian zones.) Impervious surfaces disrupt groundwater flow paths by preventing infiltration and by shunting water to streams via surface flows. This also contributes to increased flashiness and potentially to channel incision.

Biogeochemistry is similarly affected by riparian zone condition because forested riparian zones are well known for their capacity to trap sediments and to intercept nutrients transported by surface and ground water through the riparian zone. In addition, microbial processes are maintained by organic matter produced above and belowground, both of which are greater under forested conditions than other cover types.

For habitat maintenance, mature riparian forests provide the structure for riparian-dependent animals. In addition to the canopy trees and other strata, snags and downed wood are essential for maintaining a suite of vertebrates and invertebrates that depend upon large detritus for food and cover. Both vertical and horizontal structural complexity is higher in forests than in other cover types.

Calibration of cover types within a column was based on our study data for live aboveground biomass and for detrital biomass (both aboveground detritus and shallow soil organic matter) with differences among cover types related to variations in total biomass. Calibrations across rows (distances from stream) are scaled to indicate reduced influences with distance from the stream. An assumption is made here that variations in total biomass and distance from stream channel together combine to affect hydrology, water quality, and habitat quality.

The 90 ft riparian zone outer boundary was chosen for RZC because the riparian zone would likely be influenced by surrounding forest, which in this region, can generally reach 90-100 ft in height. Therefore, if growing within the 90-ft riparian zone, a 90-ft tree would have more than a 50% chance of falling into the riparian zone. Of those that fall into the riparian zone, some would be capable of contributing wood to the stream channel. The 50-ft inner zone was chosen to correspond with the NC buffer rules and the 10-ft zone was chosen to correspond to the zone that would most likely affect channel processes (see Near-stream Cover, below).

Because property boundaries often occur along streams, management activities may differ on each side of the stream. Therefore, riparian cover is assessed for each side separately, with a maximum score of 50 for each side and 100 for both sides. A score of 100 means that riparian zone cover is similar to relatively unaltered reference standard sites.

To evaluate riparian zone cover, the site sketch should be filled out first. From this, the percent cover of the condition (rows) of each zone (columns) should be identified and entered in the adjacent blank cell for each condition identified. One or more cover types could occur in any given zone. By entering the percent cover for each type within a zone, the calculated RZC score is based on a weighted average of all cover types present. The assessor should verify that multiple cover types add up to 100 percent for each column.

An example of scoring is as follows: Suppose that on the left side of the stream bank, Mature Forest (MF) occurs from the bank edge to 20 ft, Young Forest (YF) from 20-30 ft, and Perennial Herb (PH) extends from 30-60 ft, and Annual Rowcrop (AR) extends from 60-90 ft (Table 1). In this scenario, MF covers 100% of the 0-10 ft zone and 25% of the 10-50 ft zone (10-20 ft). YF covers 25% and PH covers 50% of the remainder of the 10-50 ft zone (20-30 ft and 30-50 ft, respectively). PH also covers 25% of the 50-90 ft zone (50-60 ft) while AR covers 75% of the zone (60-90 ft). The percent cover of each cover type is multiplied by the appropriate RZC score and summed across all cover types within a zone. Therefore, the column total for each zone must always equal 100%. In the example, the LEFT side RZC score would be 27.5 (17+10.5). For the 10-50 ft zone, 10.5 is derived by summing: (0.25*22)=5.5, (0.25*16)=4.0, and (0.50*2)=1.0. The sum of zone scores for LEFT and RIGHT is used to assign the total riparian zone cover score when computing functioning. In the example below, the total RZC score fro the LEFT and RIGHT sides would be 66.0 (27.5+38.5). These calculation may be conducted in the office.

Page 2, Near-stream Cover (Part D). This indicator provides information on the structure of vegetation nearest the stream channel (within 10 ft). Both biogeochemistry and habitat of the stream channel are more greatly influenced by the proximity of the near-stream cover than the riparian zone as a whole. Vegetation nearest to the stream channel affects in-stream habitat by contributing leaves for shredder biota, a source of LDW to the channel for instream structural habitat complexity, and by providing shade that ameliorates stream water temperature for stream biota. Near-stream vegetation also provides litterfall to the channel as a relatively labile source or organic matter for microbial and other food webs. Streamside vegetation is important in stabilizing stream banks, thus reducing erosion and preventing nutrient–laden sediment from entering streams. In addition, vegetation nearest a stream provides the best opportunity for nutrient uptake and transformation because it is often closest to the areas of groundwater discharge into streams. In low order streams, tree roots extend into the stream channel, creating small pools that trap leaf litter.

Table 1. Calculation of Near Stream Cover (NSC) and Riparian Zone Cover (RZC) indicators. Total reach score for each is the sum of the LEFT and RIGHT sides.

Land use by cover type	LEFT SIDE ZONE (distance from stream)							RIGHT SIDE ZONE (distance from stream)					
	0-10 ft	%	10-50 ft	%	50-90 ft	%		0-10 ft	%	10-50 ft	%	50-90 ft	%
Old Forest (>75 yr)	20		25		5		OF	20	*100*	25	*50*	5	
Mature Forest (50-75 yr)	17	*100*	22	*25*	4		MF	17		22		4	
Young Forest (25-50 yr)	13		16	*25*	3		YF	13		16	*25*	3	
Successional Forest (5-25 yr)	7		9		2		SF	7		9		2	
Recently Harvested (0-5 yr)	3		4		1		RH	3		4	*25*	1	*100*
Shrubs/Saplings	3		3		1		SS	3		3		1	
Perennial Herb, incl. residential lawns	2		2	*50*	0	*25*	PH	2		2		0	
Annual Rowcrop	1		1		0	*75*	AR	1		1		0	
Impervious	0		0		0		IP	0		0		0	
Total % (If < 100, correct data entry)		*100*		*100*		*100*			*100*		*100*		*100*
	NSC=	42.5			RZC=	27.5		NSC=	50.0			RZC=	38.5

Scoring for Near-stream Cover (NSC) is derived from the RZC scores for the LEFT and RIGHT 0-10 ft zones. The score for the 0-10-ft zone must be multiplied by 2.5 to covert the NSC total score to a 0 to 100 scale. Scores for each side range from 50 (Old Forest) to 0 (Impervious). Applying the RZC scenario presented above, the LEFT NSC score would be 42.5 (i.e., 17*2.5) and the RIGHT NSC score would be 50 (i.e., 20*2.5). Again, these calculations can be performed in the office.

Page 3, Summary Sheet. This page provides space for recording RZC and NSC scores and information from Part E, Stream and Riparian Condition. This allows pages 4 and 5 to be used repeatedly. All summary data, except RZC and NSC scores, should be filled in before leaving the site to make sure nothing is missed.

Pages 4 and 5, Stream and Riparian Condition (SRC) Scores (Part E). The six indicators in this section are scored to determine the condition of the stream channel and its riparian zone. Scores should be entered on page 3, Summary Sheet.

Stream and Riparian Condition (SRC) scores, along with RZC and NSC scores, can be used to estimate condition. Each column describes four discrete categories from relatively unaltered to severely altered. Each category can be further assigned a condition from high to low within a category. In some cases, a slightly different set of criteria is applied to intermittent streams that dry for long periods than are used for streams with longer periods of flow.

At the top of each indicator category from unaltered to severely altered is a general description of the indicator's condition. Below each general description are more specific descriptions of field indicators, each proceeded by a letter (a-d). On the Summary Sheet (p. 3), space is provided to record one or more of the letters (each which corresponds to a specific indicator) that best describes the site's condition. Verbiage in brackets ([ ]) provide some guidance on scoring.

Each stream riparian condition indicator is related to slightly different aspects of the three categories of function: hydrology, biogeochemistry, and habitat. Some are related only to stream channel condition, some only to riparian zone condition, and some to both. A general outline of the rationale for the six indicators is provided below. Together with the Near Stream Condition and the Riparian Zone Condition, the indicators are assembled in Table 2 into the function categories.

1. *Instream woody structure.*
This indicator is related to all three functions, but for stream channel condition only. Wood in the stream channel affects hydrology by creating pool and riffle sequences that dissipate energy of flowing water and stores water in pools during low flows. In small, unchannelized streams, live tree roots may play this role. Woody structure affects biogeochemistry by providing a surface for microbial activity and a potential source of dissolved organic carbon (DOC), that is released into the water slowly over long periods of time. DOC can be used as an energy source for denitrification and other microbial processes. Instream wood also provides structural habitat complexity for epifauna and epiphytes. In larger streams, fish and invertebrates may use woody structure for resting during high flows.

2. *Sediment regime.*
This indicator is related only to the biogeochemistry of free-flowing stream channels. It should not be used to assess channels that have been backed up by an impoundment. In such cases, indicators either fail to develop adequately or are not readily observed. Excess sediment in free-flowing headwater reaches may come from roadside ditches that enter streams at road crossings, from field ditches that connect directly to channels, and from overland flows that transport surface water from sparsely vegetated agricultural fields through poorly vegetated riparian zones to stream channels. Thus, excess sediment indicates erosional problems within a reach and upstream from the assessed reach. Suspended sediments influence channel biogeochemistry by acting as a carrier of sediment-bound phosphorus, the major mechanism by which phosphorus (and heavy metals) are transport by fluvial systems. Phosphorus enrichment may change the N/P ratio of the stream and enrichment with heavy metals may harm intolerant aquatic biota. Stream channel habitat is normally compromised when excess sediments lower water transparency, suppress primary production of epiphytic algae, and bury the habitat of benthic and epiphytic organisms. We have not incorporated this indicator into habitat of the stream channel function, however, because "4. Pollution affecting the stream" addresses many of the same stream habitat conditions. Further, the sediment regime indicator is not indicated for the hydrology function in the stream channel. We acknowledge that excessive sediment deposits in channels reduce bankfull channel flow capacity. For channelized streams, filling contributes positively to channel-riparian zone connection indicator, described next.

Table 2. Example of how indicator scores are averaged to obtain various function, channel condition, and riparian zone condition scores. Indicator scores are averaged by function (columns) to obtain Hydrologic, Biogeochemical, and Habitat mean function

	STREAM CHANNEL			RIPARIAN ZONE		
INDICATORS	**Hydrology**	**Biogeo-chemistry**	**Habitat**	**Hydrology**	**Biogeo-chemistry**	**Habitat**
Riparian zone cover				44	44	44
Near-stream cover		45	45			
Instream woody structure	10	10	10			
Sediment regime		10				
Channel-riparian zone connection	30	30	30	30	30	30
Pollution affecting stream	40	40	40			
Factors affecting riparian zone				10	10	10
Habitat quality of riparian zone						10
Function Score: Mean of all appropriate indicator scores for each function and whether for stream or riparian zone.	27	27	31	28	28	24
	Mean Function Score for Channel = 28			Mean Function Score for Riparian Zone = 27		
	Composite Function Score = 28					

3. Channel-riparian zone connection.

This indicator is based on the degree to which a free-flowing stream channel is incised. It is related to all functions for both stream channels and riparian zones. (The indicator should not be used to assess channels that have been backed up by an impoundment for reasons stated above.) The indicator's application to all functions reflects the fact that the connection between channel and riparian zone is fundamental to the characteristic functioning of riparian ecosystems. The degree of channel incision determines the degree to which functioning is impaired in both the stream channel and riparian zone. Channelized streams and channels incised by high flow velocities affect hydrology by transporting water more rapidly through the system during high flows and by increasing the groundwater slope toward the channel during low flows. Both types of alterations reduce the residence time of water in the system by increasing water flows and reducing storage.

Greater channel capacity of channelized and incised streams, compared to natural channels, requires greater flow volumes to reach a stage at which overbank flow is initiated. This can greatly reduce the duration and frequency of flooding or eliminate it altogether. Overbank flow is the major mechanism by which the channel and riparian zone are hydrologically connected. This in turn affects biogeochemistry in at least two ways: the lowered water table may eliminate contact of surficial groundwater with the organic rich surface horizons of the soil, thus reducing the potential for denitrification in both the channel and riparian zone. A lowered water table also exposes the soil column to greater aeration, thus suppressing anaerobic processes that are common in the floodplains of headwater streams. For biogeochemical processes as a whole, the system becomes more oxidized, which reduces the capacity to accumulate organic matter.

Hydrologic alterations caused by channelization or incision also adversely affect habitat for aquatic and wetland-dependent species. In the riparian zone, hydrophytes are less likely to occur. Within the stream, greater flow velocities, especially during storm flows, increase sediment concentrations through re-suspension and scour, thus degrading habitat.

4. Pollution affecting the stream.
This indicator is related to all three functions, but for channel condition only. A pollutant source for assessment purposes is herein defined as runoff from roadside ditches, channelized tributaries originating in agricultural fields, drainage from impervious surfaces, and flows containing sewage and livestock wastes. Pollutant sources affect hydrology by contributing excess water to stream channels. Higher and flashier flows may lead to additional channel incision. Pollutant sources contribute excess nutrients (primarily nitrogen and phosphorus) and/or toxic pollutants to stream channels, thus interfering with normal biogeochemical cycling. Habitat is also adversely affected by nutrient or chemical additions. Excess nutrients in the presence of sufficient sunlight can create algal accumulations that may lead to nighttime anoxia. Toxic chemicals can directly poison stream organisms.

Pollutant sources affect stream channels both by entering a reach from upstream and by entering within a reach itself. We assume that sources within the reach are generally more detrimental than sources upstream from a reach. Regardless, distance upstream and type of source should be taken into consideration. However, beaver impoundments trap sediment and increase the residence time of water, thus allowing time for nutrient processing and removal. Therefore, some pollutant sources may be disregarded if a beaver impoundment occurs between pollutant sources and the assessed reach. However, more egregious inputs such as toxic chemicals, domestic sewage, and animal waste are expected to alter stream water chemistry even if partially processed through a beaver impoundment before entering reach.

5. Factors affecting the riparian zone.
This indicator is related to all three functions, but for riparian zone condition only. The rationale is the same as provided above for stream channels. The difference is that sources of degradation are limited to those within or directly adjacent to a reach. (It is assumed that alterations to upstream riparian zones do not directly affect the riparian zone of the assessed reach, but that such alterations are taken into account by the previous indicator).

Alterations to the riparian zone, but not to channels directly, include grading, filling, excavation, cultivation, and other non-forest land uses. Variations in scoring of factors affecting riparian condition reflect the degree to which they are believed to alter condition. For example, discharges to the riparian zone from septic or sewer systems are considered potentially more detrimental than livestock access, which in turn may be considered more detrimental than minor pollutant sources.

Channelization drains adjacent floodplains and increases the capacity of the channel to convey water. This typically eliminates overbank flow onto the floodplain, thus degrading the riparian zone. However, the loss in functioning of a former floodplain of a deeply channelized stream would be ameliorated somewhat if water that would otherwise bypass the former floodplain via ditches and culverts is instead diverted to a forested riparian zone. Forested riparian zones are capable of trapping sediment and removing nutrients before they reach the channel. Especially egregious pollutant inputs, such as toxic chemicals and sewage, would likely overwhelm the capacity of a forested riparian zone to remove them and are treated as a severe alteration.

Beaver impoundments trap sediment and increase the residence time of water, thus allowing time to remove nitrate and suspended sediments. Therefore, if a beaver impoundment occurs between pollutant sources and the assessed riparian zone, such pollutant sources may be disregarded. However, egregious pollutant inputs described in the "extremely altered" category would not be expected to be ameliorated much by a beaver impoundment.

6. Habitat quality of riparian zone.

This indicator is related only to the habitat function of the riparian zone. Vegetation composition (evaluated relative to native forest) is a direct measure of plant habitat, which in turn affects animal habitat. It is assumed that mature to old forests represent the least altered condition that is conducive to supporting native communities. The footnote provides a list of canopy species characteristic of native forests. If at least four of the listed species are present in the canopy and the understory is intact with minimal cover of invasive species (Table 3), then the remaining composition and structure of the forest is assumed to be relatively unaltered.

When forest cover is less than 50%, it is assumed that habitat quality is severely degraded for forest-dependent species. Invasive and ecotone-dependent species displace those that require contiguous canopy of intact forest as cover becomes more fragmented.

Table 3. Invasive, non-native species found in riparian ecosystems.

Species	Common name	Prevalence
Trees		
none to rare		
Shrubs		
Ligustrum sinense	Chinese privet	common
Elaeagnus angustrifolia	Russian olive	uncommon[1]
Herbs		
Lonicera japonica	Japanese honeysuckle	common
Microstegium virmineum	Japanese stiltgrass	common
Rosa multiflora	multiflora rose	uncommon[1]
Murdania keisak	Asian dayflower	Common
Polygonum cuspidatum	Japanese knotweed	Common
Vines		
Lonicera japonica	Japanese honeysuckle	common
Pueraria lobata	kudzu	uncommon[1]

[1]Uncommon invasive in riparian ecosystems, but may be abundant elsewhere.

2.5. Office and Field Criteria for Differentiating Urban from Rural Reaches

This guidance is used to determine which protocol should be used to assess a randomly assigned reach. Presence of any one indicator below is sufficient for confirming urban status (either in the office or in the field).

Office Determinations (made using USGS 7.5 minute series topographic maps and USGS digital orthophoto quarter quads or higher resolution orthogonalized aerial photographs)

1. >10% impervious surface within a circle centered on random point (low order 600 ft (200 yd) radius; high order 1,500 ft (500 yd) radius; see template of aerial photographs, in Appendix).
2. Area denoted as urban on USGS topo (brown, purple, or pink color).
3. Housing density >2.37 units/acre[1] (for low order, >62 units in 600 ft radius circle; for high order >384 units in 1,500 ft radius circle). (Units are dwelling units: single family home = 1 unit, duplex = 2 units, each apartment with in a complex = 1 unit.)

Field Determinations

1. Stormwater treatment unit (wet or dry detention/retention, or infiltration basin, etc.) is located in assessment reach or upstream (low order within 600 ft (200 yd); high order within 1,500 ft (500 yd) or within watershed.
2. Stormwater input to stream or floodplain from urban stormwater sources, such as curb-and-gutter street or parking lot, is located in assessment reach or upstream (low order within 600 ft; high order within 1,500 ft). Here, "stormwater input" does not refer to road ditches or grassed swales. (Grassed swales and ditches in agricultural settings indicate that the rural riparian assessments should be used.)
3. Sewer line right-of-way is in riparian zone within 50 ft of stream channel.
4. Three or more dwelling units are located within 90 ft of the stream (either side) along 300 ft assessment reach[2].

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[1] The rural-urban threshold housing density (2.37 units/acre) is the mean of the lowest density urban zoning classification for Greenville, NC (R-15S, 3 units/acre) and the rural residential zoning classification for Pitt County, NC (minimum lot size 25,000 ft^2, which equals 0.57 acre or 1.74 units/acre).

[2] Based on the rural-urban threshold housing density (2.37 units/acre) and the size of the assessment area (300 ft x 180 ft = 54,000 ft^2, or 1.24 acre; 1.24 acre x 2.37 units/acre = 2.94 units, or ~3 units within the assessment area).

Rural Low Order Riparian Assessment, V. 2.0

[ ] Site # Date ________________

[ ] Watershed Field Crew ________________________________

[RLO] Stream type

A. Reasons for Rejecting or Moving a Randomly Assigned Reach (Enter 1 for Yes, 0 for No)

[ ] Reach rejected (check one): ( ) ditch; ( ) ephemeral, no stream present; ( ) piped, culverted;
( ) both channel and riparian zone flooded by beaver impoundment; ( ) flooded by other impoundment types;
( ) inaccessible. ***If rejected, do not assess reach.***

[ ] Reach moved upstream or downstream ( ) feet due to ( ) beaver or ( ) other impoundment in <50% of reach.
(Enter 1 for yes, 0 for no in box, enter distance moved, and check impoundment type in parentheses.)

[ ] Reach moved downstream ( ) feet due to ( ) ephemeral channel, or ( ) ditch.
(Enter 1 for yes, 0 for no in box, enter distance moved, and check channel type in parentheses.)

B. Upstream and Downstream Influences on Reach. (Enter 1 for Yes, 0 for No)

[ ] Stream reach is downgradient from at least one roadside ditch or stormwater outfall without an associated detention basin.

[ ] Only the channel is backed up by downstream impoundment; the riparian zone is not inundated, except after a heavy rainfall event. ***If so, conduct assessment, but do not assess SRC #2 and #3 (p. 4).***

[ ] Reach formerly and recently impounded by beaver or man-made dam, but dam now abandoned and flooplain vegetation is recovering.

C. General Channel Condition. (Enter 1 for Yes, 0 for No)

[ ] Unincised, free-flowing stream with large downed wood (LDW) and/or litter and tree roots in channel.

[ ] Unincised, free-flowing stream with little or no LDW, litter, and tree roots in channel.

[ ] Channelized or incised stream with trees growing in and along channel and LDW or leaf litter in channel.

[ ] Channelized or incised stream with trees growing in and along channel, but lacking much LDW or leaf litter in channel. (Look for evidence of desnagging as possible reason.)

[ ] Channelized or incised stream with mostly shrubs and/or herbaceous vegetation growing in and along channel; few or no trees.

[ ] Unvegetated ditch (recently cleared) or ditch lined with rocks.

Notes:

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Site # _______ Watershed ________________________________ Date ___________

Site Sketch *Reach is 300 ft in upstream-downstream direction by 180 ft wide. Each square is 30 x 30 ft. Identify and label cover types to 90 ft using abbrevations in Part D below. Portray stream as straight. Add north arrow. Draw meander and cross-section in boxes to right.*

LEFT **RIGHT**

Notes on 90-300 ft

Notes on 90-300 ft

upstream

Draw stream's meander

Draw channel x-section

D. Riparian Zone Cover (RZC) and Near Stream Cover (NSC) -- *In the blank boxes, record the % cover for each cover type by zone (0-10 ft, 10-50 ft, 50-90 ft). For example, if a zone is equally represented by two cover types, record 50 in the boxes adjacent to the cover types. Insert abbreviations (OF, MF, etc.) on the sketch map above. (Age ranges in parentheses.) For Mature Forest that has been selectively cut or high-graded, record as Young Forest. These data should be transferred to the "RZC Calculator" file to calculate RZC and NSC scores. (Make sure that total % = 100 for each column.) The NSC score is 2.5 times the total score for the 0-10-ft zone.*

	LEFT SIDE ZONE (distance from stream)						RIGHT SIDE ZONE (distance from stream)						
Land use by cover type	**0-10 ft**	**%**	**10-50 ft**	**%**	**50-90 ft**	**%**		**0-10 ft**	**%**	**10-50 ft**	**%**	**50-90 ft**	**%**
Old Forest (>75 yr)	20		25		5		OF	20		25		5	
Mature Forest (50-75 yr)	17		22		4		MF	17		22		4	
Young Forest (25-50 yr)	13		16		3		YF	13		16		3	
Successional Forest (5-25 yr)	7		9		2		SF	7		9		2	
Recently Harvested (0-5 yr)	3		4		1		RH	3		4		1	
Shrubs/Saplings	3		3		1		SS	3		3		1	
Perennial Herb, incl. residential lawns	2		2		0		PH	2		2		0	
Annual Rowcrop	1		1		0		AR	1		1		0	
Impervious	0		0		0		IP	0		0		0	
Total % (If <100, correct data entry)													
	NSC=				**RZC=**			**NSC=**				**RZC=**	

Rural Low Order Riparian Assessment, V. 2.0

Site # ____________ Watershed ______________________ Date ____________________

D. Riparian Zone and Near Stream Cover, p. 2

☐ RZC (total of possible 100% derived from both sides)

☐ NSC (total of possible 100% derived from both sides of "0-10 ft" zone, multiplied by 2.5)

E. Stream and Riparian Condition (SRC) indicator scores (pp. 4 & 5)

☐ 1. Instream woody structure

☐ Sub-condition "a, b, c, or d."

☐ 2. Sediment regime ***(If channel is backed up by beaver, enter "Bv.")***

☐ Sub-condition "a, b, c, or d." ***(If channel is backed up by beaver, enter "Bv.")***

☐ 3. (LEFT) Channel-riparian zone connection ***(If channel is backed up by beaver, enter "Bv.")***

☐ Sub-condition "a, b, c, or d." ***(If channel is backed up by beaver, enter "Bv.")***

☐ 3. (RIGHT) Channel-riparian zone connection ***(If channel is backed up by beaver, enter "Bv.")***

☐ Sub-condition "a, b, c, or d." ***(If channel is backed up by beaver, enter "Bv.")***

☐ 4. Pollution affecting the stream

☐ Sub-condition "a, b, c, or d."

☐ 5. (LEFT) Factors affecting the riparian zone

☐ Sub-condition "a, b, c, or d."

☐ 5. (RIGHT) Factors affecting the riparian zone

☐ Sub-condition "a, b, c, or d."

☐ 6. (LEFT) Habitat quality of riparian zone

☐ Sub-condition "a, b, or c."

☐ 6. (RIGHT) Habitat quality of riparian zone

☐ Sub-condition "a, b, or c."

Notes:

Rural Low Order Riparian Assessment, V. 2.0

E. Stream and Riparian Condition (SRC). *For each SRC indicator, record on page 3 the SRC indicator score and one or more letters (a-d) that apply. (If a condition is encountered that is not provided, choose a score, and explain alteration and rationale for scoring in notes on p. 3.) Verbiage in brackets ([ ]) provides guidance on scoring.*

	Condition Category			
SRC Indicator	**Relatively Unaltered**	**Somewhat Altered**	**Altered**	**Severely Altered**
1. Instream woody structure	Much large down wood (LDW) in channel and along banks. (Recent treefalls from extreme weather events or erosion not applicable.) **(a)** LDW represents a variety of decay classes[1]. **(b)** LDW in channel and along banks represents a mix of sizes >4 inch dia[2]. Some LDW > 8 inch dia. **(c)** For stream channels that are dry for long periods, tree roots with hypertrophied lenticels are located *in stream bottom.* **(d)** Large (>1 inch) tree roots in channel create small pools that trap leaf litter, when available.	Some LDW in channel and along banks. Some may be partially buried in channel bottom. **(a)** LDW in channel and along banks represents a variety of decay classes[1]. **(b)** Few or no LDW >8 inch dia. [If large >4 inch dbh trees grow along both banks, score 80, if only along one side, score 70, if streamside trees are <4-inch dbh, score 60.] **(c)** For streams channels that are dry for long periods, tree roots located in stream bottom lack hypertrophied lenticels.	Few or no LDW in channel and on banks[2] but potential supply is present. **(a)** LDW represents only one decay class[1]. **(b)** For channelized or deeply incised stream channels that are dry for long periods, channel is maintained so infrequently that small trees or shrubs grow along channel banks. [If large >4 inch dbh trees grow along both banks, score 50, if only along one side, score 40, if streamside trees are <4-inch dbh, score 30.]	No LDW in channel **(a)** Stream is channelized or deeply incised and periodically cleared of debris to maintain drainage. **(b)** No large trees (>4 inch dbh) grow along channel banks. **(c)** Stream is lined with rocks, rip-rap or concrete. [Assign lowest score to trapezoidal channels with concrete bottoms.]
Score =	100 90	80 70 60	50 40 30	20 10 0
2. Sediment regime[3]	Little or no silt or sand carried by stream. Water runs fairly clear even during periods of high flow. (If originating in flats, water is may be dark (tea colored) due to tannins.) **(a)** Stream is not channelized. **(b)** Channel bottom is mostly sandy or clayey with little or no silt on channel bottom or on floodplain [If sand deposition in channel bottom is due to upstream activities, then see "severely altered" category.]	Some silt carried by stream. **(a)** At high flows, suspended sediment evident in water. **(b)** When water runs clear during base flow, sediment[4] can be re-suspended by shuffling feet in channel. **(c)** Thin layer (<1 inch thick) of silt deposited on channel bars or on floodplain surface. [Thickest deposits score lower.] **(d)** Sediment >1 inch thick due to recent abandonment of impoundment.	Silt and sand carried by stream. **(a)** Water is silt laden, esp. after heavy rains. **(b)** Thick (1-2 inches) silt or sand deposited on channel bars, bank edge, or on floodplain (if present). **(c)** For streams that are dry for long periods, sand or silt may collect behind root dams and be deposited on floodplain (if stream not channelized or incised).	Heavy sediment load carried by stream. **(a)** Sediment suspended in water even during low flow. **(b)** Thick (>2 inch) sand or silt layers recently deposited on channel bars, bank edge, or on floodplain (if present). **(c)** Evidence that sand or silt deposits in reach are being generated by upstream activities. [Sand or silt on an artificial stone bottom scores lowest.]
Score =	100 90	80 70 60	50 40 30	20 10 0
3. Channel-riparian zone connection[3,5]	Strong evidence of overbank flow on floodplain. **(a)** No apparent channelization or incision. **(b)** Wrack, sediment, and/or trash on floodplain. [Sparse wrack scores 45.] **(c)** High water marks on trees apparent. **(d)** No spoil berm alongside channel.	Evidence of occasional overbank flow on floodplain. **(a)** Some wrack, sediment, trash on floodplain, but sparse and/or old. **(b)** Stream channelized within historic channel with low spoil berms or breaks in them along channel. (Channel may have been channelized in past, but filled sufficiently with sediments that overbank flow is now common.) **(c)** Channel slightly channelized or incised.	Evidence of overbank flow only after extreme (rare) flood events. **(a)** No or little wrack on floodplain. **(b)** Channelization (i.e., spoil berms present and high)[5]. **(c)** Channel deeply incised (not channelized).	Overbank flow eliminated. **(a)** Deep channelization with spoil berms present[5]. **(b)** Filling and/or leveling of floodplain, some or all of fill may have been derived from spoil from channelization. **(c)** On low order streams in agricultural fields, spoil and other material spread over the historic floodplain, entirely covering it. **(d)** Presence of high artificial levee or other channel-containment structure.
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0

[1] Decay classes: (1) bark intact, leaves attached, no evidence of decay, (2) loose bark, no leaves, (3) peeling bark, fungi present, (4) advanced stages of decay, no bark or soft enough for a prod to be easily poked through, and (5) bole decayed into ground.

[2] If few or no LDW occurs within channel, check stream banks for sawed-off pieces in floodplain. This indicates de-snagging. LDW from severe bank erosion not applicable.

[3] Do not assess SRC #2 and #3 if stream is backed up by downstream beaver impoundment. Do assess relic beaver impoundments. For relic impoundments, sediment layer may be deep at upstream end of unmaintained impoundment and reduced in depth closer to former dam site.

[4] Make sure that particulate organic matter (POM) is not confused with excess sediment. POM is very dark in color.

[5] On 2nd order streams, an historic channel may occur on former floodplain.

E. Stream and Riparian Condition (cont.)

SRC Indicator	Condition Category			
	Relatively Unaltered	**Somewhat Altered**	**Altered**	**Severely Altered**
4. Pollution affecting the stream	No on-site or off-site pollution[1] affecting stream. **(a)** There is no pollution entering directly into the stream within the reach or within 600 ft (200 yd) located upstream from reach. **(b)** No livestock access to channel or waste dumping from confined animal operations (CAO) located upstream from reach. **(c)** Stream is not channelized.	Only off-site pollution[1] affects stream. **(a)** Pollution feeds directly into stream channel within 600 ft (200 yd) upstream from reach (not within reach). **(b)** Water from roadside ditches enters stream within 600 ft (200 yd) above reach. [More sources or more proximate pollution sources should be scored lower.]	On-site pollution[1] affects stream. **(a)** Water from roadside ditch directly empties into reach. **(b)** Overland-flow from agricultural field directly enters reach. **(c)** Nearstream livestock activity appears to pollute channel. [Field edges closer than 10 ft scores 30, 10-50 ft scores 40, >50 ft or depressed, grassy swale (BMP) scores 50.	Especially egregious pollution affects stream. **(a)** Pollution from confined animal operations entering directly into channel. **(b)** Pollution from septic or sewage treatment systems entering directly into channel. **(c)** Livestock have access to stream within reach. **(d)** Sediment input from construction activities entering directly into channel.
Score =	100 90	80 70 60	50 40 30	20 10 0
5. Factors affecting the riparian zone (0-50 ft zone)	No factors affecting riparian zone condition within reach. **(a)** Stream is not channelized. **(b)** No pollution[1] empties into riparian zone. **(c)** Livestock do not have access to riparian zone. [Presence of trash or organic waste (clippings. etc.) score 45.]	Factors somewhat affecting riparian zone. **(a)** Stream is not channelized. **(b)** Some pollution[1] empties into riparian zone, but only at outer fringes (furthest from channel). **(c) EXCEPT** If stream is channelized, drainage from pollutant source is discharged (or diverted) to riparian zone where it is detained and processed before entering stream. **(d)** If livestock are present, trampling and browsing are evident over <5% of riparian zone.	Factors affecting riparian zone. **(a)** Stream not channelized and pollution[1] enters directly into riparian zone of reach. **(b)** Stream is channelized, but no stormwater is diverted to riparian zone. **(c)** 5-25% of riparian zone (0-50 ft) of reach filled, graded, cultivated, or covered with impervious surface. **(d)** Livestock have access to riparian zone. [5-25% grazed and trampled scores 25, 25-75% scores 20, 75-100% scores 15.] [Presence of more categories or greater intensities score lower.]	Especially egregious factors affecting riparian zone. **(a)** More than 25% of riparian zone of reach graded, filled, excavated, cultivated, or converted to other non-forested land covers. **(b)** Septic or sewer system leaking into riparian zone. **(c)** Discharge from lagoons of confined animal operations discharge directly into riparian zone. [Lack of forest in riparian zone scores lower.]
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0
6. Habitat quality of riparian zone (0-50 ft)	Habitat quality intact. Riparian zone dominated by old or mature native forest (>95% of area) with all strata[2] intact. No or low cover of exotic or invasive species. No grazing, mowing, or selective harvesting within riparian zone. [Old or Mature forest (>50 yr. old) scores 50; slightly younger forest scores 45. Exotics in 5-25% in any stratum scores 45.]	Habitat quality somewhat degraded. **(a)** Forest (with all strata[2] intact) covers 75-95% of riparian zone with remainder of area representing other cover types. **(b)** Forest (all strata intact) covers >95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers >95% of riparian zone with at least one understory stratum of native vegetation asent or not well represented (due to understory removal or timber harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests.]	Habitat quality degraded. **(a)** Forest (with all strata[2] intact) covers 50-75% of riparian zone with remainder of area representing other cover types. **(b)** Forest (all strata intact) covers 75-95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers 75-95% of riparian zone with at least one understory stratum of native vegetation absent or not well represented (due to understory removal or timber harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests in all cases.]	Habitat quality extremely degraded. **(a)** Forest covers <50% of riparian zone with remainder of area representing other cover types. **(b)** Forest (all strata intact[2]) covers 50-75% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers 50-75% of riparian zone with at least one understory stratum of native vegetation absent or not well represented (due to understory removal or timber harvesting, etc.). [Old or Mature forest (>50 yr. old) covering more than 25% of riparian zone should be scored 10; younger forest or lower forest cover scores 5, lack of trees scores 0.]
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0

[1] Pollutant sources include runoff from roadside ditches, channelized tributaries originating in agricultural fields, drainage from impervious surfaces, and flows containing sewage and livestock wastes. Note, beaver impoundments largely negate the effects of most pollution, except types of pollution described in the "altered" and "severely altered" categories. Therefore, other upstream pollutant sources may be disregarded if a beaver impoundment occurs between the sources and the assessed reach.

[2] Intact strata include canopy, midstory, understory, and herb layers. Canopy must be comprised of trees >6 in (15 cm) dbh, including at least 5 of the following species: red maple, sweetgum, blackgum, tulip poplar, elm, oak, loblolly pine, and sweetbay. A pine plantation does not count as native forest. Forest cover could be linearly arranged along channel or in blocks scattered within the riparian zone.

Urban High Order Riparian Assessment Protocol, V. 2.0

1.0 Background

This assessment manual is designed for assessing the condition of 3rd to 4th order riparian ecosystems that originate in the coastal plain of North Carolina, and are influenced by urban land uses. It was prepared to aid in filling out the field sheets for the Urban High Order Riparian Assessment Version 2.0. It was modified from the one developed for rural landscapes by adjusting indicators and thresholds to better represent reference sites occurring in urban environments. This assessment method was not designed for evaluating active beaver impoundments. However, it can be used to assess beaver-impounded reaches where *only* the channel has been backed up by a downstream impoundment. In this case the water does not inundate the adjacent floodplain except following heavy rainfall events. In such cases, Stream and Riparian Condition indicators Sediment Regime (#1), Channel-Riparian Zone Connection (#3), and Stream Bank Stability (#7) (pages 4 and 5) should not be assessed because channel features are underwater or channel processes have been modified.

High order streams in the coastal plain include 3rd to 4th order intermittent and perennial streams. This assessment method is not appropriate for riparian ecosystems in other physiographic provinces, low order (1st – 2nd order) riparian systems, or larger river systems such as the Tar or Neuse Rivers. Although developed in coastal plain drainage basins in North Carolina, it would probably be applicable to some other coastal plain regions in the Southeast. Further use of this method will allow evaluation to see how well it works in other urban areas of the coastal plain.

High order riparian areas in the coastal plain include those with both intermittent and perennial flow. Intermittent streams tend to cease flow in late summer and early fall when evapotranspiration during the growing season has depressed water tables throughout their drainages, thus reducing surface flows from upstream tributaries and disconnecting the source of local groundwater discharge to the surface. Precipitation from tropical depressions, hurricanes, and convective storms can interrupt periods of low discharge.

In comparison with low-order riparian ecosystems, those of unaltered 3rd and 4th order streams have larger floodplains and are wetter. In their unmodified condition, they receive proportionally more water from overbank flow during floods and receive groundwater discharge from larger aquifers than their low-order counterparts. Consequently, they support vegetation adapted to longer periods of saturation and flooding, such as bald cypress and water tupelo in the canopy and lizard's tail and water willow in the ground layer. In urban locations where channelization has created spoil piles and drained floodplains, Chinese privet is often prevalent. Riparian ecosystems range in condition from relatively natural, un-channelized reaches buffered by forest to channelized reaches with bank and bed hardened with concrete or other artificial substrate.

The presence of stormwater outfalls as a water source is one of the signature properties of higher order urban streams. This is partly a consequence of the conversion of low order streams to stormwater drainages that now feed directly to high order riparian floodplains and stream channels. Stormwater drainages may shunt runoff directly from impervious surfaces or from detention ponds. In either case, there is little opportunity for infiltration in the drainage basin. This results in higher peak flows and lower base flows than occurred prior to urbanization. Where the construction of storm detention basins is required, faulty design, construction, and maintenance can render them ineffective in moderating peak flows and removing sediments, nutrients, and other pollutants. In urban areas there is a general pattern of truncated low-order drainages and channelization in the high order streams that remain. The purpose of all of these modifications is to transport water away from urban areas to reduce potential damages due to flooding. Consequently, the drainage network offers little opportunity for ameliorating water quality and reducing peak discharge. The additional hydraulic loading downstream can alter channel morphology. Therefore, riparian ecosystems in urban areas are highly degraded.

2.0 Office and Field Methods

Reasons for conducting an assessment should be clearly established. They may include the following:

- documenting baseline conditions along a given reach
- determining types and degree of alteration in a drainage basin by assessing multiple sites
- determining how a proposed project will alter riparian condition
- comparing several reaches as part of an alternatives analysis
- identifying specific actions that could be taken to minimize project impacts
- determining the effects of specific manipulations following restoration or other management practices.

Defining objectives of an assessment may reduce misunderstanding among stakeholders and other interested parties. It will also focus the interpretation of assessment results on the specific requirements of a project.

For some assessment parameters, we used field data to validate relationships between riparian condition and water quality (biogeochemical and biotic). In other cases, relationships are based on information published in scientific literature. Finally, best professional judgment was employed where there are as yet no data to validate relationships. However, all parameters are calibrated and field tested against reference sites that range between relatively unaltered to severely altered.

2.1 Office preparation.

Maps and photographs are useful in characterizing a reach for assessment. They provide such information as project boundaries, location of jurisdictional wetlands, and location of proposed alterations or restoration. Geographic features are needed in evaluating some of the indicators such as the presence of roads, ditches, buildings, tributary streams, land use, land cover, and other pertinent features. Some useful sources are (a) high-resolution aerial photographs, such as DOQQs, (b) county soil surveys, (c) topographic maps (USGS 1:24,000), and (d) drainage maps. While the field assessment may be completed without these sources during the field visit, field time can be shortened considerably by having access to remotely acquired information. For areas that may contain both rural and urban drainages, criteria for choosing the right set of field sheets is provided on the last page of this protocol (2.5).

Equipment should be assembled before the field visit. Essential items are a GPS unit, shovel or trowel, hand-held laser level, stiff tape measure or meter stick, and 300 ft tape.

2.2 Guidelines for rejecting or moving sites

A watershed can be characterized by assessing a statistically robust number of reaches and using the data from the assessed watershed to make inferences about riparian areas in the watershed as a whole. Various random and stratified random approaches could be used depending on the questions being posed. Regardless of the method applied for randomly selecting reaches for sampling, in some cases, a randomly assigned reach will occur at a place that the assessment procedure was not designed to assess(e.g., in a beaver impoundment) and so must be moved or rejected.

If a reach is rejected or moved, the reason for rejection should be noted on the data sheet in the space provided on page 1 (Part A). The following guidelines for moving or rejecting reaches should be followed in the sequence in which they appear. These criteria will probably only be applied in cases where one is assessing randomly-selected reaches. Items 1 and 2 are mapping exercises for the office. The remainder are conducted in the field.

1. If a random point marking the center of a reach is located within 300 ft of another random point, it should be rejected and another point should be substituted.

2. If a stream junction occurs less than 150 ft downstream of the randomly selected point, the reach should be moved upstream until the entire 300-ft reach is above the junction. If a junction occurs less than 150 ft upstream from the random point, then the 300-ft reach should encompass the main stem (the same stem on which the random point falls).

3. If the randomly selected 300-ft reach falls entirely with in beaver impoundment (where both channel and floodplain are impounded) or other type of impoundment, the site should be rejected. If the random center point is <150 ft from the upstream or downstream boundary of a beaver or other impoundment, the point should be moved upstream or downstream in the un-impounded reach to allow assessment of an un-impounded 300 ft reach. (If moved upstream, the channel may be backed-up, thus requiring that Stream Riparian Condition indicators Sediment Regime, Channel-Riparian Zone Connection, and Stream Bank Stability be omitted.) In many cases, beaver impoundments show a stepwise pattern in which the upper end of one impoundment is adjacent to the dam of the next impoundment upstream. In such cases, moving the reach upstream or downstream will still place it in an impoundment and so the site should be rejected. If rejected, no substitution should be made for the point.

2.3 Data collection and observations on-site

Page 1. If none of the above-described rejection criteria are met, then urban high order reaches should be assessed as outlined below. Field sheets are referred to by page number below:

Page 1, Reasons for rejecting or moving a randomly assigned reach (Part A). The top section provides boxes for recording whether a randomly assigned reach has to be rejected or moved for occurring at a place that the assessment procedure was not designed to assess. A reach that is specifically chosen for assessment would presumably not be rejected and a “0” would be recorded in each box. However, for randomly chosen reaches that that must be rejected or moved, Part A provides a format for recording the reason for rejection or distance and reason moved (if the reach should be moved).

Page 1, Upstream and Downstream Influences on Reach (Part B). This category provides information on whether the reach is hydrologically affected by an impoundment. First, record if the channel is backed up by a beaver or other impoundment. Standing, non-flowing water in the channel suggests that there is an impoundment downstream from reach. A channel can be affected by an impoundment without a dam occurring within the assessed reach or even if there is no impounded water on the floodplain. (Note: even an impounded reach may begin to flow during high rainfall events). Although this assessment method was not developed for assessing the condition of impoundments, a channel that is backed up should be assessed if its riparian zone is not impounded, but indicators Sediment Regime, Channel-Riparian Zone Connection, and Stream Bank Stability (pp. 4 and 5) should not be assessed. Instead, “Bv” should be recorded in the appropriate data boxes on page 3. Care should be taken to make sure standing, non-flowing water is not simply a result of channel bed scour that creates an elongated pool of stagnant water.

Next, record if the reach was formerly and recently impounded by beaver, but has been abandoned (or dam removed). An abandoned beaver impoundment should be assessed as un-impounded.

Page 1, General Channel Condition (Part C). Part of characterizing channel condition requires determining the general condition of the stream channel: channelization, incision, presence of large downed wood (LDW), and degree to which the near-channel zone is vegetated. Record these conditions in the boxes in Part C.

Channel incision can be recognized by a deep channel (deeper than expected for the size of the drainage basin) that lacks adjacent spoil piles. Incision is often caused by an increase in the volume of peak flows due to an increase in the area of impervious surfaces and compaction of soils in the drainage basin. In contrast, channelization can usually be identified by the presence of spoil piles or berms along one or both sides of the channel, and by the level of the adjacent historic floodplain being positioned below that of the berm.

Both incision and channelization tend to reduce or eliminate the frequency of overbank flow, thus eliminating contact between floodwater and the floodplain. In some 2nd - 4th order systems, the original stream channel can still be found on the floodplain, but it is much more narrow and shallow than the channelized section and usually has little or no flow.

Another factor in characterizing channel condition requires determining if there is large downed wood (LDW) in the stream channel. If there is none, search the stream banks for sawed-off pieces of logs in the floodplain. Sawed-off large wood indicates that LDW has been removed from the stream (“de-snagged”) to facilitate flow.

Page 2, Site Sketch. The sketch provides a grid on which to map the relative area of cover types within 90 ft of each side of the stream and for less-detailed information or notes about conditions from 90-300 ft. Sixty 30 x 30 ft grids have been pre-drawn on the page to facilitate sketching a 90-ft riparian zone on each side of the stream channel.

The sketch map is to be drawn facing downstream with the center of the reach positioned at the midpoint (+) in the center of the map. Marks are also provided for the 10 ft, 50 ft, and 90 ft riparian zones. Sixty 30 x 30 ft grids have been pre-drawn on the page to facilitate sketching a 90-ft riparian zone on each side of the stream channel. Notes on the condition of the 90 – 300 ft zone should be made to the left and right of the grids.

Cover types should be marked with abbreviations provided in Part D, page 2 (OF, MF, LDR, etc.), along with a north arrow. If a stream meanders or curves along the 300 ft reach, the sketch should be adjusted so that it is shown as straight. The meander can be drawn in the box located on the right side of the sketch map. Likewise, the channel cross-section can be drawn in the other box. Rough estimates of dimensions can be made (depth from bank top to channel bottom, width of channel, height of berm above floodplain, etc.).

Page 2, Riparian Zone Cover (Part D). This indicator provides information on the general structure of vegetation in zones adjacent to the stream channel. Information needed for recording attributes can be obtained from the Site Sketch grid on page 2. Riparian Zone Cover influences the condition of all aspects of riparian zone. For hydrology, infiltration in the riparian zone is greater under forested conditions than for other land covers. Also, evapotranspiration rates tend to be higher than some of the other cover types that have lower biomass and especially those that have impervious surfaces. Overland flow from adjacent land uses may be more effectively intercepted, dispersed, and absorbed by forest cover as long as gullying does not occur. (Gullying is not as great a problem in most areas of the coastal plain as it is in piedmont riparian zones.) Impervious surfaces disrupt groundwater flow paths by preventing infiltration and by shunting water to streams via surface flows. This also contributes to increased flashiness and potentially to channel incision.

Biogeochemistry is similarly affected by riparian zone condition because forested riparian zones are well known for their capacity to trap sediments and to intercept nutrients transported by surface and ground water through the riparian zone. In addition, microbial processes are maintained by organic matter produced above and belowground, both of which are greater under forested conditions than other cover types.

For habitat maintenance, mature riparian forests provide the structure for riparian-dependent animals. In addition to the canopy trees and other strata, snags and downed wood are essential for maintaining a suite of vertebrates and invertebrates that depend upon large detritus for food and cover. Both vertical and horizontal structural complexity is higher in forests than in other cover types.

Calibration of land-use cover types relies upon both field data and the literature. For urban riparian zones, scores for cover types were derived by adapting components of the Land Development Intensity (LDI) index developed in Florida.[1] The Florida index is based on embodied energy (also called "emergy") analysis[2] and incorporates total energy flow, corrected for quality that occurs in a unit area of land use. It represents the intensity of human use and encompasses such factors as air and water pollutants, alteration of physical structure, hydrologic changes, etc. Some of the land uses in Florida (e.g., orange groves, etc.) do not occur our study area. Others were adapted or combined based on our best judgment. For example, golf courses may include multiple cover types such intensively managed lawns and rooftops. When only portions of golf courses are present in an assessed riparian zone, alternative land uses were chosen, such as intensively managed lawns or golf courses.

As yet, there are no data to validate these adaptations of the Florida LDI index. However, we have conducted preliminary assessments in the field along a range of reference sites (relatively unaltered to severely altered) in developing the description of conditions for each of the indicators. We chose to set reference standard conditions for urban areas as high as those for rural areas (e.g., old and mature forest) because timber harvesting is unlikely in built-out suburban areas. However, the most degraded urban conditions are lower than those of rural areas. The net result expands the rural scale to include more degraded conditions commonly found in urban but not rural areas. This allows differentiation between varieties of urban land uses that are absent or rare in rural areas.

The 90 ft riparian zone outer boundary was chosen for RZC because the riparian zone would likely be influenced by surrounding forest, which in this region, can generally reach 90-100 ft in height. Therefore, if growing within the 90-ft riparian zone, a 90-ft tree would have more than a 50% chance of falling into the riparian zone. Of those that fall into the riparian zone, some would be capable of contributing wood to the stream channel. The 50-ft inner zone was chosen to correspond with the NC buffer rules and the 10-ft zone was chosen to correspond to the zone that would most likely affect channel processes (see Near-stream Cover, below).

To evaluate riparian zone cover, the site sketch should be filled out first. From this, the percent cover of the condition (rows) of each zone (columns) should be identified and entered in the adjacent blank cell for each condition identified. One or more cover types could occur in any given zone. By entering the percent cover for each type within a zone, the calculated RZC score is based on a weighted average of all cover types present. The assessor should verify that multiple cover types add up to 100 percent for each column.

Because property boundaries often occur along streams, management activities may differ on each side of the stream. Therefore, riparian cover is assessed for each side

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[1] Brown, M.T. and M.B. Vivas. 2005. Landscape development intensity index. Environmental Monitoring and Assessment 101:289-309.
[2] Odum, H.T. and E.C. Odum 2001. A Prosperous Way Down. Univ. Press of Colorado, Boulder, CO.

separately, with a maximum score of 50 for each side and 100 for both sides. A score of 100 means that riparian zone cover is similar to relatively unaltered reference sites.

An example of scoring is as follows: Suppose that the left side of the stream bank has low density residential (LDR), but the 0-10 ft buffer is Old Forest with lawns and houses in the 10-90 ft zone (Table 1). In this case, 100% Old Forest (OF) would be entered for the 0-10 ft zone (since low density residential would not adequately characterize the zone). However, 100% LDR would be recorded for the outer two zones (10-90 ft).

In this scenario, the percent cover of each cover type is multiplied by the appropriate RZC score and summed across all cover types within a zone. Therefore, the column total for each zone must always equal 100%. In the example below, the LEFT side RZC score would be 38 (20+15+3). The sum of zone scores for LEFT and RIGHT is used to assign the total riparian zone cover score when computing functioning. In the example below, the total RZC score for the LEFT and RIGHT sides would be 61.3 (38.0+23.6). These calculation may be conducted in the office.

Table 1. Calculation of Near Stream Cover (NSC) and Riparian Zone Cover (RZC) indicators. Total reach score for each is the sum of the LEFT and RIGHT sides.

Land use by cover type	LEFT SIDE ZONE (distance from stream)						RIGHT SIDE ZONE (distance from stream)						
	0-10 ft	%	10-50 ft	%	50-90 ft	%		0-10 ft	%	10-50 ft	%	50-90 ft	%
Old Forest	20	100	25		5		OF	20		25		5	
Mature Forest	20		25		5		MF	20		25		5	
Young Forest	19		24		5		YF	19		24		5	
Successional Forest	19		23		5		SF	19		23		5	
Recently Harvested	18		22		5		RH	18		22		5	
Shrubs/Saplings	17		21		4		SS	17	100	21	30	4	
Perennial Herb	16		2		4		PH	16		2		4	
Low intensity pasture	15		20		4		LIP	15		20		4	
Annual rowcrop	14		18		3		AR	14		18		3	
Low density residential			15	100	3	100	LDR			15		3	
Intensely managed lawns	9		11		2		IML	9		11		2	
Medium density residential			7		1		MDR			7		1	
High density residential			7		1		HDR			7		1	
Medium density mobile homes			6		1		MDM			6		1	
High density mobile homes			5		1		HMD			5		1	
High density buildings			0		0		HDM			0		0	
Impervious	0		0		0		IP	0		0	70	0	100
Total %		100		100		100			100		100		100
RZC Scores		20.0		15.0		3.0			17.0		6.3		0.0

Housing unit density and number of housing units per side of stream (used in Table 1) were calculated as follows:

Land use by cover type (Brown and Vivas 2005)	Density (units/ha)	Density (units/acre)[3]	# units/side of 300 ft reach[4]
Low density residential (LDR)	<10	<4	<3
Medium density residential (MDR)	10-20	4-8	3-5
High density residential (HDR)	>20	>8	>5

Medium density mobile home (MDM) and high density mobile home (HDM) cover types have the same densities and number of units per side as medium density residential (MDR) and high density residential (HDR), respectively.

Page 2, Near-stream Cover (Part D). This indicator provides information on the structure of vegetation nearest the stream channel (within 10 ft). Both biogeochemistry and habitat of the stream channel are more greatly influenced by the proximity of the near-stream cover than the riparian zone as a whole. Vegetation nearest to the stream channel affects in-stream habitat by contributing leaves for shredder biota, a source of LDW to the channel for instream structural habitat complexity, and by providing shade that ameliorates stream water temperature for stream biota. Streamside vegetation is important in stabilizing stream banks, thus reducing erosion and preventing nutrient–laden sediment from entering streams. In addition, vegetation nearest a stream provides the best opportunity for nutrient uptake because it is often closest to the areas of groundwater discharge to the channel. In addition, tree roots extend into the stream channel, creating small pools that trap leaf litter. Therefore, both biogeochemistry and habitat of the stream channel are more greatly influenced by the proximity of the near-stream cover than the riparian zone as a whole.

Scoring for Near-stream Cover (NSC) is derived from the RZC scores for the LEFT and RIGHT 0-10 ft zones. The score for the 0-10-ft zone must be multiplied by 2.5 to covert the NSC total score to a 0 to 100 scale. Scores for each side range from 50 (Old Forest) to 0 (Impervious). Applying the RZC scenario presented above, the LEFT NSC score would be 50 (i.e., 20*2.5) and the RIGHT NSC score would be 42.5 (i.e., 17*2.5). Again, these calculations can be performed in the office.

Page 3, Summary Sheet. This page provides space for recording RZC and NSC scores and information from Part E, Stream and Riparian Condition. This allows pages 4 and 5 to be used repeatedly. All summary data, except RZC and NSC scores, should be filled in before leaving the site to make sure nothing is missed.

Pages 4 and 5, Stream and Riparian Condition (SRC) Scores (Part E). The seven indicators in this section are scored to determine the condition of the stream channel and its riparian zone. Scores should be entered on page 3, Summary Sheet.

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[3] Conversion factor 2.47 acre/ha (results rounded to nearest integer)

[4] "# units/side of 300 ft reach" means the number of units on one side of the assessed reach, within 90 ft of the stream (based on the size of the assessment area and the Brown and Vivas (2005) density criteria; results rounded to the nearest integer). Each side of the assessment area is 300 ft long x 90 ft wide = 27,000 ft^2, or 0.62 acre; 0.62 acre x 4 units/acre = 2.48 units; 0.62 acres x 8 units/acre = 4.96 units

Stream and Riparian Condition indicator scores, along with RZC and NSC scores, can be used to estimate condition. Each column describes four discrete categories from relatively unaltered to severely altered. Each category can be further assigned a condition from high to low within a category.

At the top of each indicator category from unaltered to severely altered is a general description of the indicator's condition. Below each general description are more specific descriptions of field indicators, each proceeded by a letter (a-d). On the Summary Sheet (p. 3), space is provided to record one or more of the letters (each which corresponds to specific indicator) that best describes the site's condition. Verbiage in brackets ([ ]) provide some guidance on scoring.

Each stream riparian condition indicator is related to slightly different aspects of the three categories of function: hydrology, biogeochemistry, and habitat. Some are related only to stream channel condition, some only to riparian zone condition, and some to both. A general outline of the rationale for the seven indicators is provided below. Together with the Near Stream Condition and the Riparian Zone Condition, the indicators are assembled in Table 2 into the function categories.

1. *Instream woody structure.*
This indicator is related to all three functions, but for channel condition only. Wood in the stream channel affects hydrology by creating pool and riffle sequences that dissipate energy of flowing water and stores water in pools during low flows. In small, unchannelized streams, live tree roots may play this role. Woody structure affects biogeochemistry by providing a surface for microbial activity and a potential source of dissolved organic carbon (DOC), which is released into the water slowly over long periods of time. DOC can be used as an energy source for denitrification and other microbial processes. Instream wood also provides structural habitat complexity for epifauna and epiphytes. In larger streams, fish and invertebrates may use woody structure for resting during high flows and for hiding (shelter).

2. *Sediment regime.*
This indicator is related only to the biogeochemistry of free-flowing stream channels. It should not be used to assess channels that have been backed up by an impoundment. In such cases, indicators either fail to develop adequately or are not readily observed. Excess sediment in free-flowing headwater reaches may come from storm drainages that enter streams at road crossings, from construction sites, from excessive bank erosion upstream, and from other land disturbance activities. Thus, excess sediment indicates erosional problems within a reach and upstream from the assessed reach. Sediments influence channel biogeochemistry by acting as a carrier of sediment-bound phosphorus, the major mechanism by which phosphorus (and heavy metals) are transport by fluvial systems. Phosphorus enrichment may change the N/P ratio of the stream and enrichment with heavy metals may harm intolerant aquatic biota. Stream channel habitat is normally compromised when excess sediments lower water transparency, suppress primary production of epiphytic algae, and bury the habitat of benthic and epiphytic organisms. We have not incorporated this indicator into habitat of the stream channel function, however, because "4. Pollution affecting the stream" addresses many of the same stream habitat conditions. Further, the sediment regime indicator is not indicated for the

Table 2. Example of how indicator scores are averaged to obtain various function, channel condition, and riparian zone condition scores. Indicator scores are averaged by function (columns) to obtain Hydrologic, Biogeochemical, and Habitat mean functions.

	STREAM CHANNEL			RIPARIAN ZONE		
INDICATORS	**Hydrology**	**Biogeo-chemistry**	**Habitat**	**Hydrology**	**Biogeo-chemistry**	**Habitat**
Riparian zone cover				44	44	44
Near-stream cover		45	45			
Instream woody structure	10	10	10			
Sediment regime		10				
Channel-riparian zone connection	30	30	30	30	30	30
Pollution affecting stream	40	40	40			
Factors affecting riparian zone				10	10	10
Habitat quality of riparian zone						10
Stream bank stability		50	50			
Function Score: Mean of all appropriate indicator scores for each function and whether for stream or riparian zone.	27	31	35	28	28	24
	Mean Function Score for Channel = 31			Mean Function Score for Riparian Zone = 27		
	Composite Function Score = 29					

hydrology function in the stream channel. We acknowledge that excessive sediment deposits in channels reduce bankfull channel flow capacity. For channelized streams, filling contributes positively to channel-riparian zone connection indicator, described next.

Often, channels of channelized streams begin to fill over time, especially those in urbanizing areas that are subject to erosional problems upstream. The filling may seem to indicate that the channel is restoring its morphology, but excess sedimentation will still continue to cause problems for biota if not prevented.

3. Channel-riparian zone connection.

This indicator is based on the degree to which a free-flowing stream channel is incised. It is related to all functions for both stream channels and riparian zones. (The indicator should not be used to assess channels that have been backed up by an impoundment for reasons stated above.) The indicator's application to all functions reflects the fact that the connection between channel and riparian zone is fundamental to the characteristic functioning of riparian ecosystems. The degree of channel incision determines the degree to which functioning is impaired in both the stream channel and riparian zone. Channelized streams and channels incised by high flow velocities affect hydrology by transporting water more rapidly through the system during high flows and by increasing the groundwater slope toward the channel during low flows. Both types of alterations reduce the residence time of water in the system by increasing water flows and reducing storage.

Greater channel capacity of channelized and incised streams, compared to natural channels, requires greater flow volumes to reach a stage at which overbank flow is initiated. This can greatly reduce the duration and frequency of flooding or eliminate it altogether. Overbank flow is the major mechanism by which the channel and riparian zone are hydrologically connected. This in turn affects biogeochemistry in at least two ways: the lowered water table may eliminate contact of surficial groundwater with the organic rich surface horizons of the soil, thus reducing the potential for denitrification in both the channel and riparian zone. A lowered water table also exposes the soil column to greater aeration, thus suppressing anaerobic processes that are common in the floodplains of headwater streams. For biogeochemical processes as a whole, the system becomes more oxidized, which reduces the capacity to accumulate organic matter.

Hydrologic alterations caused by channelization or incision also adversely affect habitat for aquatic and wetland-dependent species. In the riparian zone, hydrophytes are less likely to occur. Within the stream, greater flow velocities, especially during storm flows, increase sediment concentrations through re-suspension and scour, thus degrading habitat.

4. Pollution affecting the stream.
This indicator is related to all three functions, but for channel condition only. Pollutant source for assessment purposes is herein defined as drains from streets and detention ponds, roadside ditches, channelized tributaries, and drainage from impervious surfaces. Pollutant sources affect hydrology by contributing excess water to stream channels. Higher and flashier flows may lead to additional channel incision and headward erosion. Pollution sources, by definition, contribute excess nutrients (primarily nitrogen and phosphorus) and/or toxic pollutants to stream channels, thus interfering with normal biogeochemical cycling. Habitat is also adversely affected by nutrient or chemical additions. Excess nutrients in the presence of sufficient sunlight can create algal accumulations that may lead to nighttime anoxia. Toxic chemicals can directly poison stream organisms.

Pollutant sources affect stream channels both by entering a reach from upstream and by entering within a reach itself. We assume that sources within the reach are generally more detrimental than sources upstream from a reach. Regardless, distance upstream and type of source should be taken into consideration. However, beaver impoundments trap sediment and increase the residence time of water, thus allowing time for nutrient processing and removal. Therefore, some pollutant sources may be disregarded if a beaver impoundment occurs between pollutant sources and the assessed reach. However, more egregious inputs such as toxic chemicals, domestic sewage, and animal waste are expected to alter stream water chemistry even if partially processed through a beaver impoundment before entering reach.

Stormwater detention ponds are meant to moderate peak flows from impervious surfaces and trap sediment and toxic chemicals. Consequently, some pollutant sources may be disregarded if a detention pond occurs between the sources of pollution and the assessed reach. However, in some cases storm detention basins are improperly planned, designed, constructed, or maintained, thus rendering them ineffective in moderating flows and/or trapping sediments and pollutants. Therefore, where detention basins occur within 1,500 ft above an assessed reach (or along a contributing tributary), the detention pond(s) should be examined to determine if they are properly designed or managed. If the detention basins are determined to be ineffective, then they should be treated as a source of pollution rather than as a sink (trap).

Storm water treatment systems are often sophisticated engineered systems. While there are criteria to determine whether they have been properly designed and constructed, and whether they are being properly operated, evaluation of their effectiveness is beyond the scope of this assessment method. The reader is referred to EPA regulatory[5] and non-regulatory[6] information, NC Division of Water Quality guidelines and regulations[7], and the Center for Watershed Protection[8] for further information.

5. Factors affecting the riparian zone.

This indicator is related to all three functions, but for riparian zone condition only. The rationale is the same as provided above for stream channels. The difference is that sources of degradation are limited to those within or directly adjacent to a reach. (It is assumed that alterations to upstream riparian zones do not directly affect the riparian zone of the assessed reach, but that such alterations are taken into account by the previous indicator).

Alterations to the riparian zone, but not to channels directly, include grading, filling, excavation, cultivation, impervious surfaces, and other activities in non-forest land uses. Variations in scoring reflect the degree to which they are believed to alter condition. For example, discharges to the riparian zone from septic or sewer systems are considered potentially more detrimental than intensively managed lawns.

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[5] for US EPA stormwater regulatory information see http://www.epa.gov/ebtpages/watestormwater.html; federal stormwater regulations and requirements are included in NPDES regulations 40 CFR Part 122; portions of other regulations are also relevant (see EPA web page for more detail); EPA publishes numerous documents related to stormwater management, including a series of Stormwater Technology Fact Sheets (eg, Wet detention ponds EPA 832-F-99-048, Vegetated swales EPA 832-F-99-027, Stormwater wetlands EPA 832-F-02-020, Bioretention EPA 832-F-99-012, etc.)

[6] US EPA Office of Research and Development's Urban Watershed Management Branch provides non-regulatory information about urban stormwater risks and management (see http://www.epa.gov/ednnrmrl); EPA ORD UWMB publishes numerous documents, journal articles and books related to urban stormwater; a CD compilation of UWMB reports is available from this web page; also available is an electronic copy of Burton, G. Allen, Jr. and Robert E. Pitt. 2001. Stormwater effects manual: A toolbox for watershed managers, scientists and engineers. Lewis Publishers (CRC Press), Boca Raton, FL, USA.

[7] see NC DWQ stormwater permitting units web page (http://h2o.enr.state.nc.us/su/stormwater.html); pertinent documents include: NC DENR. 1999. Stormwater best management practices.; state stormwater management program (SSWMP) supplement sheets; stormwater management regulations 15A NCAC 2H .0100 (especially 2H .1008 "Design of stormwater management measures"); and stormwater fact sheets prepared by the Land-of-Sky Regional Council

[8] see Center for Watershed Protection web page (http://www.cwp.org); CWP has recently released the Urban Subwatershed Restoration Manual series, an 11-part series of manuals written for a broad audience including planners, engineers and consultants (Schueler, Tom. 2004. An integrated framework to restore small urban watersheds. Urban Subwatershed Restoration Manual No. 1. Center for Watershed Protection, Ellicott City, MD.

Channelization drains adjacent floodplains and increases the capacity of the channel to convey water. This typically eliminates overbank flow onto the floodplain, thus degrading the riparian zone. However, the loss in functioning of a former floodplain of a deeply channelized stream would be ameliorated somewhat if water that would otherwise bypass the former floodplain via ditches and culverts is instead diverted to a forested riparian zone. Forested riparian zones are capable of trapping sediment and removing nutrients before they reach the channel. Especially egregious pollutant inputs, such as toxic chemicals and sewage, would likely overwhelm the capacity of a forested riparian zone to remove them and are still treated as a severe alteration.

Beaver impoundments trap sediment and increase the residence time of water, thus allowing time to remove nitrate. Therefore, if a beaver impoundment occurs between pollutant sources and the assessed riparian zone, such pollutant sources may be disregarded. However, egregious pollutant inputs described in the "extremely altered" category would not be expected to be ameliorated much by a beaver impoundment.

6. *Habitat quality of riparian zone.*
This indicator is related only to the habitat function of the riparian zone. Vegetation composition (evaluated relative to native forest) is a direct measure of plant habitat, which in turn affects animal habitat. It is assumed that mature to old forests represent the least altered condition that is conducive to supporting native communities. The footnote provides a list of canopy species characteristic of native forests. If at least four of the listed species are present in the canopy and the understory is intact with minimal cover of invasive species (Table 3), then the remaining composition and structure of the forest is assumed to be relatively unaltered.

When forest cover is less than 50%, it is assumed that habitat quality is severely degraded for forest-dependent species. Invasive and ecotone-dependent species displace those that require contiguous canopy of intact forest as cover becomes more fragmented.

7. Stream bank stability.
This indicator is related to the biogeochemistry and habitat functions of free-flowing streams. (It cannot be used to assess channels backed up by impoundments. In such cases, indicators either fail to develop adequately or are not readily observed.) As stream discharge increases, hydraulic energy is first dissipated along stream banks and on LDW and roots residing in the channel. Some of this energy results in bank erosion, exposes roots, and causes bank slumping and tree fall, when excessive. If the stream channel is not incised, even higher flows associated with overbank flow transfer total stream energy to the floodplain where it is dissipated without erosion over a large surface area, thus protecting the channel itself from excessive scouring. While some bank erosion and sediment redistribution are natural processes, they are minor in low gradient headwater streams in the coastal plain. Alteration of riparian condition is assumed if erosion, slumping, and undercutting are excessive (especially in places other than at cutbanks) and herbaceous vegetation is unable to re-establish on banks after extreme events. Alterations in bank stability lead to excessive introduction of sediment to the channel and is ultimately transported to downstream ecosystems.

Table 3. Invasive, non-native species found in riparian ecosystems.

Species	Common name	Prevalence
Trees		
none to rare		
Shrubs		
Ligustrum sinense	Chinese privet	common
Elaeagnus angustrifolia	Russian olive	uncommon[1]
Herbs		
Lonicera japonica	Japanese honeysuckle	common
Microstegium virmineum	Japanese stiltgrass	common
Rosa multiflora	multiflora rose	uncommon[1]
Murdania keisak	Asian dayflower	common
Polygonum cuspidatum	Japanese knotweed	common
Vines		
Lonicera japonica	Japanese honeysuckle	common
Pueraria lobata	kudzu	uncommon[1]

[1]Uncommon invasive in riparian ecosystems, but may be abundant elsewhere.

2.5. Office and Field Criteria for Differentiating Urban from Rural Reaches

This guidance is used to determine which protocol should be used to assess a randomly assigned reach. Presence of any one indicator below is sufficient for confirming urban status (either in the office or in the field).

Office Determinations (made using USGS 7.5 minute series topographic maps and USGS digital orthophoto quarter quads or higher resolution orthogonalized aerial photographs)

1. >10% impervious surface within a circle centered on random point (low order 600 ft radius; high order 1,500 ft radius; see template of aerial photographs, in Appendix).
2. Area denoted as urban on USGS topo (brown, purple, or pink color).
3. Housing density >2.37 units/acre[9] (for low order, >62 units in 600 ft radius circle; for high order >384 units in 1,500 ft radius circle). (Units are dwelling units: single family home = 1 unit, duplex = 2 units, each apartment with in a complex = 1 unit.)

Field Determinations

1. Stormwater treatment unit (wet or dry detention/retention, or infiltration basin, etc.) is located in assessment reach or upstream (low order within 600 ft; high order within 1,500 ft) or within watershed.
2. Stormwater input to stream or floodplain from urban stormwater sources, such as curb-and-gutter street or parking lot, is located in assessment reach or upstream (low order within 600 ft; high order within 1,500 ft). Here, "stormwater input" does not refer to road ditches or grassed swales. (Grassed swales and ditches in agricultural settings indicate that the rural riparian assessments should be used.)
3. Sewer line right-of-way is in riparian zone within 50 ft of stream channel.
4. Three or more dwelling units are located within 90 ft of the stream (either side) along 300 ft assessment reach[10].

[9] The rural-urban threshold housing density (2.37 units/acre) is the mean of the lowest density urban zoning classification for Greenville, NC (R-15S, 3 units/acre) and the rural residential zoning classification for Pitt County, NC (minimum lot size 25,000 ft^2, which equals 0.57 acre or 1.74 units/acre).

[10] Based on the rural-urban threshold housing density (2.37 units/acre) and the size of the assessment area (300 ft x 180 ft = 54,000 ft^2, or 1.24 acre; 1.24 acre x 2.37 units/acre = 2.94 units, or ~3 units within the assessment area).

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[ ] Site # Date ______________

[ ] Watershed Field Crew ______________________________

[UHO] Stream type

A. Reasons for Rejecting or Moving a Randomly Assigned Reach. (Enter 1 for Yes, 0 for No)

[ ] Reach rejected (check one): ( ) both channel and riparian zone flooded by beaver impoundment; ( ) channel and riparian zone flooded by other impoundment type; ( ) inaccessible. **If rejected, do not assess.**

[ ] Reach moved upstream or downstream ( ) feet due to ( ) beaver impoundment in <50% of reach; ( ) other impoundment type, or ( ) overlap of previous reach. Enter 1 for yes, 0 for no in box, enter distance moved, and check reason.

B. Upstream and Downstream Influences on Reach. (Enter 1 for Yes, 0 for No)

[ ] Only the channel is backed up by downstream impoundment; the riparian zone is not inundated, except after a heavy rainfall event. ***If so, conduct assessment, but do not assess SRC #2, #3, and #7 (pp. 4 & 5).***

[ ] Reach formerly and recently impounded by beaver or man-made dam, but now abandoned and recovering.

C. General Channel Condition. (Enter 1 for Yes, 0 for No)

[ ] Unincised, free-flowing stream with large downed wood (LDW) and/or litter and tree roots in channel.

[ ] Unincised, free-flowing stream with little or no LDW, litter, and tree roots in channel.

[ ] Channelized or incised stream with trees growing in and along channel and LDW or leaf litter in channel.

[ ] Channelized or incised stream with trees growing in and along channel, but lacking much LDW or leaf litter in channel. (Look for evidence of desnagging as possible reason.)

[ ] Channelized or incised stream with mostly shrubs and/or herbaceous vegetation growing in and along channel; few or no trees.

[ ] Stream channel rip-rapped, bulkheaded, or lined with concrete bottom.

[ ] Relic stream channel present on former floodplain.

Notes:

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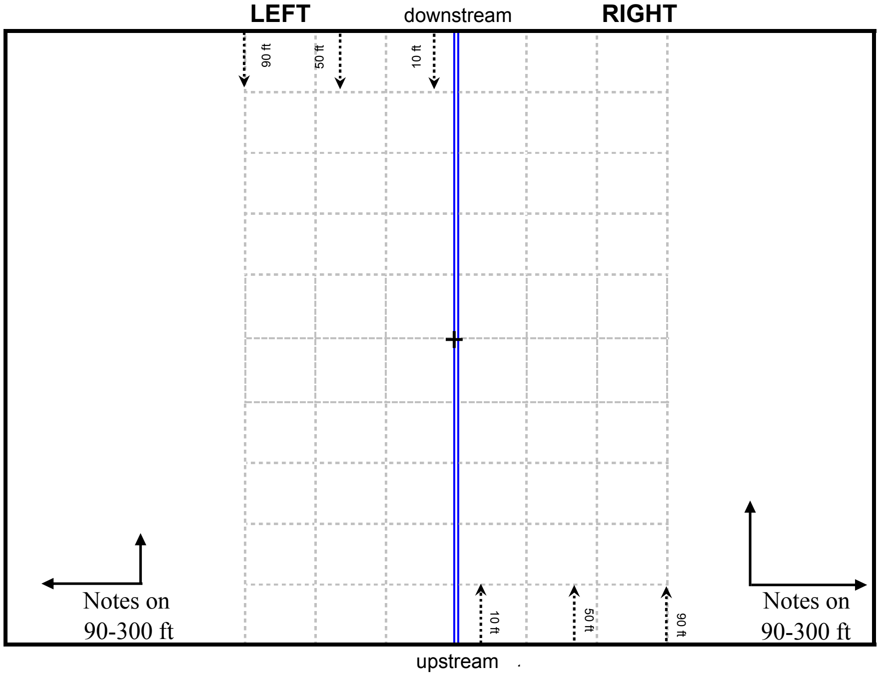
Site # _______ Watershed ________________________________ Date ________________

Site Sketch *Reach is 300 ft in upstream-downstream direction by 180 ft wide. Each square is 30 ft x 30 ft. Identify and label cover types to 90 ft using abbrevations in Part D below. Portray stream as straight. Add north arrow.*



Draw stream's meander

Draw channel x-section

D. Riparian Zone Cover - *In the blank boxes, record the % cover for each cover type by zone (0-10 ft, 10-50 ft, 50-90 ft). For example, if a zone is equally represented by two cover types, record 50 in the boxes adjacent to the cover types. Insert abbreviations (OF, MF, etc.) for cover types on sketch map above. (Age ranges in parentheses. For Mature Forest that has been selectively cut or high graded, record as Young Forest. These data should be transferred to the "RZC Calculator" file to calculate RZC and NSC scores. (Appendix C). (Make sure that total % = 100 for each column.) The NSC score is 2.5 times the total score for the 0-10-ft zone.*

Land use by cover type	LEFT SIDE ZONE (distance from stream)							RIGHT SIDE ZONE (distance from stream)					
	0-10 ft	%	10-50 ft	%	50-90 ft	%		0-10 ft	%	10-50 ft	%	50-90 ft	%
Old Forest (OF), >75 y old	20		25		5		OF	20		25		5	
Mature Forest (MF), 50-75 y old	20		25		5		MF	20		25		5	
Young Forest (YF), 25-50 y old	19		24		5		YF	19		24		5	
Successional Forest (SF), 5-25 y old	19		23		5		SF	19		23		5	
Recently Harvested (RH), 0-5 y old	18		22		5		RH	18		22		5	
Shrubs/Saplings (SS)	17		21		4		SS	17		21		4	
Perennial Herb (PH) (incl. residential lawns)	16		20		4		PH	16		20		4	
Low intensity pasture with livestock (grazing intensity <3 animals/acre) (LIP)	15		18		4		LIP	15		18		4	
Annual crop agriculture (AR)	14		17		3		AR	14		17		3	
Low density residential, single family (<3 houses per side, within 90 ft of channel); minimally managed lawns (LDR)			15		3		LDR			15		3	
Intensely managed lawns, golf course, recreation field, etc. (IML)	9		11		2		IML	9		11		2	
Medium density residential, single family (3-5 houses per side, 10-90 ft from channel) (MDR)			7		1		MDR			7		1	
High density residential, single family (>5 houses per side, 10-90 ft from channel) (HDR)			7		1		HDR			7		1	
Medium density mobile home (3-5 units per one side of 100 yd reach within 90 ft of channel) (MDM)			6		1		MDM			6		1	
High density mobile home (more than 5 units per one side of 100 yd reach within 90 ft of channel) (HDM)			5		1		HMD			5		1	
High density building, multi-unit: strip mall, commercial mall, condos, manufacturing, motels, institutions, etc. (HDB)			0		0		HDM			0		0	
Impervious (IP)	0		0		0		IP	0		0		0	
Total % (If <100%, correct data entry													
	NSC=				RZC=			NSC=				RZC=	

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Site # ___________ Watershed ____________________ Date _______

C. Riparian Zone and Near Stream Cover (p. 2)

☐ RZC (total of possible 100%, both sides)

☐ NSC (total of possible 100% derived from both sides of "0-10 ft" zone, multiplied by 2.5)

D. Stream and Riparian Condition (SRC) indicator scores (pp. 4 & 5)

☐ 1. Instream woody structure

☐ Sub -condition "a, b, or c." ***(If channel is backed up by beaver, enter Bv.)***

☐ 2. Sediment regime

☐ Sub-condition "a, b, c, or d." ***(If channel is backed up by beaver, enter Bv.)***

☐ 3. (LEFT) Channel-riparian zone connection ***(If channel is backed up by beaver, enter Bv.)***

☐ Sub-condition "a, b, c, or d." **(If channel is backed up by beaver, enter Bv.)**

☐ 3. (RIGHT) Channel-riparian zone connection ***(If channel is backed up by beaver, enter Bv.)***

☐ Sub-condition "a, b, c, or d." **(If channel is backed up by beaver, enter Bv.)**

☐ If relic channel of former floodplain is observed, record '1"; otherwise record "0" here.

☐ 4. Pollution affecting the stream

☐ Sub-condition "a, b, c, or d."

☐ 5. (LEFT) Factors affecting the riparian zone

☐ Sub-condition "a, b, c, or d."

☐ 5. (RIGHT) Factors affecting the riparian zone

☐ Sub-condition "a, b, c, or d."

☐ 6. (LEFT) Habitat quality of riparian zone

☐ Sub-condition "a, b, or c."

☐ 6. (RIGHT) Habitat quality of riparian zone

☐ Sub-condition "a, b, or c."

☐ 7. (LEFT) Stream bank stability ***(If channel is backed up by beaver, enter "Bv")***

☐ Sub-condition "a, b, c, or d." ***(If channel is backed up by beaver, enter Bv.)***

☐ 7. (RIGHT) Stream bank stability ***(If channel is backed up by beaver, enter "Bv")***

☐ Sub-condition "a, b, c, or d." ***(If channel is backed up by beaver, enter Bv.)***

Notes:

E. Stream and Riparian Condition (SRC). *For each SRC indicator, record on page 3 the SRC indicator score and one or more letters (a-d) that apply. (If a condition is encountered that is not provided, choose a score, and explain the alteration and rationale for scoring in notes on p. 3.) Verbiage in brackets ([ ]) provides guidance on scoring.*

	Condition Category			
SRC Indicator	**Relatively Unaltered**	**Somewhat Altered**	**Altered**	**Severely Altered**
1. Instream woody structure	Much large down wood (LDW) in channel and along banks. (Recent treefalls from extreme weather events or erosion not applicable.) **(a)** LDW represents a variety of decay classes[1]. **(b)** LDW in channel and along banks represents a mix of sizes >4 inch dia. Some LDW >8 inch dia.	Some LDW in channel and along banks. Some may be partially buried in bottom. **(a)** LDW in channel and along banks represents a variety of decay classes[1]. **(b)** Few or no LDW >8 inch dia. [If large >4 inch dbh trees grow along both banks, score 80, if only along one side, score 70, if streamside trees are <4-inch dbh, score 60.]	Few or no LDW in channel and on banks[2] but potential supply is present. **(a)** LDW represents only one decay class[1]. [If large >4 inch dbh trees grow along both banks, score 50, if only along one side, score 40, if streamside trees are <4-inch dbh, score 30.]	No LDW in channel **(a)** Stream is channelized and periodically cleared of debris to maintain drainage **(b)** No large trees (>4 inch dbh) grow along channel banks. **(c)** Stream is lined with rocks, rip-rap, or concrete. [Assign lowest score to channels partially in culvert or lined with rocks, etc.]
Score =	100 90	80 70 60	50 40 30	20 10 0
2. Sediment regime[3, 4]	Little or no silt or sand carried by stream. Water runs fairly clear even during periods of high flow. **(a)** Stream is not channelized. **(b)** Channel bottom is mostly sandy with little or no silt on channel bottom or on floodplain. [If sand deposition in channel bottom is due to upstream activities, then see "severely altered" category.]	Some silt carried by stream. **(a)** At high flows, suspended sediment evident in water. **(b)** When water runs clear during base flow, sediment can be re-suspended by shuffling feet in channel. **(c)** Thin layer (<1 inch thick) of silt deposited on channel bars or on floodplain surface. [Thickest deposits score lower.] **(d)** Sediment >1 inch thick due to recent abandonment of impoundment[4].	Silt and sand carried by stream. **(a)** Water is silt laden, esp. after heavy rains. **(b)** Thick (1-2 inches) silt or sand deposited on channel bars, bank edge, or on floodplain (if present).	Heavy sediment load carried by stream. **(a)** Sediment suspended in water even during low flow. **(b)** Thick (>2 inches) sand or silt layers recently deposited on channel bars, bank edge, or on floodplain (if present). **(c)** Evidence that sand or silt deposits in reach are being generated by upstream activities.
Score =	100 90	80 70 60	50 40 30	20 10 0
3. Channel-riparian zone connection[3, 4]	Strong evidence of overbank flow on floodplain. **(a)** No apparent channelization or incision. **(b)** Wrack, sediment, and/or trash on floodplain. [Sparse wrack scores 45.] **(c)** High water marks on trees apparent. **(d)** No spoil berm alongside channel, but perhaps a natural levee.	Evidence of occasional overbank flow on floodplain. **(a)** Some wrack, sediment, trash on floodplain, but sparse and/or old. **(b)** Stream channelized within historic channel with low spoil berms or breaks in them along channel. (Channel may have been channelized in past, but filled sufficiently with sediments that overbank flow now is common.) **(c)** Channel slightly channelized or incised.	Evidence of overbank flow only after extreme (rare) flood events. **(a)** No or little wrack on floodplain. **(b)** Channelization (i.e., spoil berms present and high). **(c)** Channel deeply incised (not channelized).	Overbank flow eliminated. **(a)** Deep channelization with spoil berms present. **(b)** Deeply incised (not channelized). **(c)** Filling and/or leveling of floodplain, some or all of fill may have been derived from spoil from channelization. **(d)** Presence of high artificial levee or other channel-containment structure.
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0
4. Pollution affecting the stream[5]	No on-site or off-site pollution affecting stream. **(a)** There is no pollution entering directly into the stream within the reach or within 1,500 ft (500 yd) located upstream from reach. **(b)** All stormwater detention basins and ponds within 1,500 ft (500 yd), if present, are adequately designed and maintained to reduce peak flows and trap sediment and nutrients. [Condition scores 90.] **(c)** Stream is not channelized. [If stream is channelized, score 90.]	Only off-site pollution affecting stream. **(a)** Pollution feeds directly into stream channel within 1,500 ft (500 yd) upstream from reach (not within reach). **(b)** Water from inadequately designed or maintained detention basin enters stream within 1,500 ft (500 yd) above reach. [More sources or more proximate pollution sources should be scored lower.]	On-site pollution affects stream. **(a)** Pollution from stormwater directly enters stream reach. **(b)** Water from inadequately designed or maintained detention basin directly empties into reach. **(c)** Overland-flow from impervious surfaces, gardens, and lawns directly enters reach. **(d)** Stream culverted for 5-20% of length. [Presence of several pollution sources should be scored lower than fewer sources.]	Especially egregious pollution affects stream. **(a)** Sediment input from construction activities entering channel directly. **(b)** >20% of reach passes through culvert. **(c)** Evidence of sewer line or septic source leaking into stream (note evidence). **(d)** Hydrocarbons or other toxic chemicals leaking directly into stream (note evidence).
Score =	100 90	80 70 60	50 40 30	20 10 0

[1] Decay classes: (1) bark intact, leaves attached, no evidence of decay, (2) loose bark, no leaves, (3) peeling bark, fungi present, (4) advanced stages of decay, no bark or soft enough for a prod to be easily poked through, and (5) bole decayed into ground.

[2] If few or no LDW occurs within channel, check banks for sawed-off pieces in floodplain, which indicates de-snagging. LDW from severe bank erosion not applicable. If impossible to determine presence of LDW due to high flow, score 55.

[3] Do not assess SRC #2, #3, & #7 if stream is backed up by downstream beaver impoundment. Do assess relic beaver impoundments.

[4] Sediment layer of relic beaver impoundment may be deep at upstream end of former impoundment and reduced in depth closer to former dam site.

[5] Pollutant sources include runoff from roadside ditches, stormwater drainage, leakage from septic drainfields, runoff from intensely managed lawns or kennels, direct drainage from impervious surfaces including roof tops, and discharge from inadequate detention facilities. Note, beaver impoundments and *adequately designed and maintained* detention basins largely negate the effects of most pollution, except those described in the "severely altered" category. Therefore, other upstream pollutant sources may be disregarded if an impoundment or properly operating detention basin occurs between the pollutant source(s) and the assessed reach.

E. Stream and Riparian Condition (cont.)

SRC Indicator	Condition Category: Relatively Unaltered	Condition Category: Somewhat Altered	Condition Category: Altered	Condition Category: Severely Altered
5. Factors affecting riparian zone[1]	No pollution[2] or other factors affecting riparian zone condition within reach. **(a)** Stream is not channelized and no pollution empties into riparian zone. **(b)** All stormwater detention basins and ponds, if present, are adequately designed and maintained to reduce peak flows and trap sediment and nutrients. [Presence of clippings or organic waste in floodplain scores 45.]	Pollution[2] or other factors somewhat affecting riparian zone. **(a)** Stream is not channelized and water from properly designed and maintained detention facilities empties into riparian zone. **(b)** Stream is channelized and drainage or stormwater is discharged (or diverted) to riparian zone where it is detained and processed before entering stream. [Forested riparian zone scores higher than other cover types.]	Pollution[2] or other factors affecting riparian zone. **(a)** Stream not channelized and pollution empties directly into riparian zone. [More than one pollutant source should be scored lower than only one source within reach.] **(b)** Water from tributary streams and roadside ditches is diverted directly to channel, thus bypassing riparian zone. **(c)** 5-25% of riparian zone (0-50 ft) of reach filled, graded, cultivated, or covered with impervious surface. **(d)** Sewer and storm drain system or power line right of way are within riparian zone. [Forested riparian zone scores higher than other cover types.]	Especially egregious pollution or factors affecting riparian zone. **(a)** More than 25% of riparian zone of reach filled, graded, excavated, cultivated, or converted to other non-forested land covers. **(b)** Stream so incised or deeply channelized (with high spoil berms) that overbank flow to floodplain is extremely unlikely even during major storm events AND no stormwater is diverted to former floodplain. **(c)** Evidence of sewage or toxic chemicals entering riparian zone (note evidence). [Lack of forest on former floodplain scores lower.]
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0
6. Habitat quality[3] of riparian zone (0-90 ft)	Habitat quality intact. (a) Riparian zone dominated by old or mature intact[4] forest (>95% of area). No or low cover of exotic or invasive species. No grazing, mowing, or selective harvesting within riparian zone. [Old or Mature forest (>50 yr. old) scores 50; slightly younger forest scores 45. Exotics in 5-25% in any stratum scores 45.]	Habitat quality somewhat degraded. **(a)** Intact[4] forest covers 75-95% of riparian zone with remainder of area representing other cover types. **(b)** Intact forest covers >95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers >95% of riparian zone with at least one understory stratum of native vegetation asent or not well represented (due to understory removal or timber harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests.]	Habitat quality degraded. **(a)** Intact[4] forest covers 50-75% of riparian zone with remainder of area representing other cover types. **(b)** Intact forest covers 75-95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers 75-95% of riparian zone with at least one understory stratum of native vegetation absent or not well represented (due to understory removal, timber harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests in all cases.]	Habitat quality extremely degraded. **(a)** Forest covers <50% of riparian zone with remainder of area representing other cover types. **(b)** Intact[4] forest covers 50-75% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers 50-75% of riparian zone with at least one understory stratum of native vegetation absent or not well represented (due to understory removal, timber harvesting, etc.). [Old or Mature forest (>50 yr. old) covering more than 25% of riparian zone should be scored 10; younger forest or lower forest cover scores 5, lack of trees scores 0.]
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0
7. Stream bank stability[5]	Stream bank relatively stable. **(a)** Evidence of erosion or bank failure absent or minimal (<10%) of length. **(b)** Streamside vegetation tightly binds soil along banks, although exposed roots may occur at cut banks of stream channel. [Slight erosion or bank undercutting scores 45.]	Stream bank moderately stable. **(a)** 10-25% of bank eroded or slumping. **(b)** If trees present along bank, a few large (>1 inch dia.) roots exposed. **(c)** Most eroded areas recovering.	Stream banks unstable. **(a)** 25-50% of bank eroded. **(b)** Erosion, slumping, and undercutting prevalent, especially at places other than cutbanks. **(c)** If trees present along bank, many large (>1 inch in dia.) roots exposed with some trees toppled into stream due to undercutting.	Stream bank extremely unstable. **(a)** >50% of bank eroded **(b)** Erosion, slumping, and undercutting prevalent, esp. at places other than cut banks. **(c)** If trees present along bank, many toppled into stream due to undercutting. **(d)** Banks hardened with rocks, gabions, concrete, or bulkheading.
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0

[1] Riparian zone is from the stream bank to the floodplain or former floodplain edge if >90 ft. If former floodplain is not discernible, use 90-ft RZC boundary.

[2] See page 4, footnote 5, for definition of pollution.

[3] Habitat quality encompasses both plant and animal habitat and includes both quality and area. Quality assumes that mature or old forest with appropriate quality and quantity of LDW, snags, and characteristic 3-D structure.

[4] Intact forest is one with all strata present, including canopy, midstory, understory, and herb layers. Canopy must be comprised of trees >6 inch (>15 cm) dbh, including at least 4 of the following species: red maple, bald cypress, sycamore, sweetgum, water tupelo, swamp blackgum, elm, and wetland oaks. Forest cover could be linearly arranged along channel or in blocks scattered within the riparian zone.

[5] Do not assess SRC #2, #3, & #7 if stream is backed up by downstream beaver impoundment. Assess relic beaver impounments. For relic impoundments, sediment layer may be deep at upstream end of unmaintained impoundment and reduced in depth closer to former dam site.

Urban Low Order Riparian Assessment Protocol, V 2.0

1. Background

This assessment protocol was designed for assessing the condition of low-order riparian ecosystems (1st – 2nd order streams) that originate in urban areas of the coastal plain of North Carolina. It was prepared to aid in filling out the field sheets for the Urban Low Order Riparian Assessment Version 2.0. It was modified from the one developed for rural landscapes by adjusting indicators and thresholds to better represent reference sites occurring in urban environments. This assessment method was not designed for evaluating portions of beaver impoundments that have flooded *both* the channel and floodplain. However, it can be used to assess beaver-impounded reaches where *only* the channel has been backed up by a downstream dam. In this case the water has not inundated the adjacent floodplain except following a heavy rainfall event. In such cases, Stream and Riparian Condition indicators Sediment Regime (#1), Channel-Riparian Zone Connection (#3), and Stream Bank Stability (#7) (pages 4 and 5) should not be assessed either because fluvial features are underwater or channel processes have been modified.

This assessment method is also not appropriate for higher order riparian systems or for riparian ecosystems in other physiographic provinces. It has been field tested principally in the Greenville area, but has not been tested nearly as much as the rural methods developed for agriculturally dominated landscapes. Further use of this method will allow evaluation to see how well it works in other urban areas of the coastal plain.

Headwater streams in the coastal plain include all streams that are fed by ground water for some portion of the year and usually flow from fall to late spring during years of normal rainfall. They tend to stop flowing (except for stormwater runoff) during summer months when weather is warm and evapotranspiration is high. However, even these intermittent reaches sometimes flow year-round during particularly wet years.

In urban areas, low-order riparian ecosystems range in condition from relatively natural, un-channelized reaches buffered by forest to incised or channelized reaches with stream bank and bed hardened with concrete or other artificial substrate. In fact, many headwater streams in urban areas have been replaced by underground conduits that are connected to stormwater drainages. Moreover, urbanization fundamentally changes stream hydrology from groundwater flows to surface flows. The proliferation of impervious surfaces during urbanization is responsible for this change. Ephemeral overland flows that once fed the upper reaches of intermittent streams during storm events have been obliterated entirely and replaced by rooftops, parking lots, streets, and other impervious surfaces. Many first order intermittent streams have been converted to underground storm drains that convey higher peak flows than they did originally because impervious surfaces cannot effectively detain rainfall nor allow groundwater recharge. Where the construction of stormwater detention basins is required, faulty design, construction, and maintenance can render them ineffective in moderating peak flows and removing sediments, nutrients, and other pollutants. Low order riparian ecosystems are sparse in urban areas, and those that remain are often highly degraded.

2.0 Office and Field Methods

Reasons for conducting an assessment should be clearly established. They may include the following:

- documenting baseline conditions along a given reach
- determining types and degree of alteration in a drainage basin by assessing multiple sites
- determining how a proposed project will alter riparian condition
- comparing several reaches as part of an alternatives analysis
- identifying specific actions that could be taken to minimize project impacts
- determining the effects of specific manipulations following restoration or other management practices.

Defining objectives of an assessment may reduce misunderstanding among stakeholders and other interested parties. It will also focus the interpretation of assessment results on the specific requirements of a project.

For some assessment parameters, we used field data to validate relationships between riparian condition and water quality (biogeochemical and biotic). In other cases, relationships are based on information published in scientific literature. Finally, best professional judgment was employed where there are as yet no data to validate relationships. However, all parameters are calibrated and field tested against reference sites that range between relatively unaltered to severely altered.

2.1 Office preparation.

Maps and photographs are useful in characterizing a reach for assessment. They provide such information as project boundaries, location of jurisdictional wetlands, and location of proposed alterations or restoration. Geographic features are needed in evaluating some of the indicators such as the presence of roads, ditches, buildings, tributary streams, land use, land cover, and other pertinent features. Some useful sources are (a) high-resolution aerial photographs, such as DOQQs, (b) county soil surveys, (c) topographic maps (USGS 1:24,000), and (d) drainage maps. While the field assessment may be completed without these sources during the field visit, field time can be shortened considerably by having access to remotely acquired information. For areas that may contain both rural and urban drainages, criteria for choosing the right set of field sheets is provided on the last page of this protocol (2.5).

Equipment should be assembled before the field visit. Essential items are a GPS unit, shovel or trowel, hand-held laser level, stiff tape measure or meter stick, and 300 ft tape.

2.2 Guidelines for recognizing low order riparian zones and channels

First, the reach should be evaluated to determine if it is a true stream of low order. Nearly all low order streams in the basin have intermittent rather than perennial flow. Many channels in the area are not streams, but rather are ephemeral draws that never were a true stream. Ephemeral draws are flow paths that carry surface runoff only during precipitation events, and do not flow as a result of connection with the water table. Ephemeral draws should not be assessed with this method.

Sometimes it is difficult to determine whether a reach is a true stream (a channelized former stream) or a field ditch. Typically, a true stream will have one or more of the following attributes: (1) it will occur in the proper topographic position (along a linear depression rather than running parallel to contours or across a flat); (2) it will have a hydric soil type; (3) it may have a high-organic soil layer at the level of the former floodplain (which may be buried under fill from channelization or field grading). Channelized streams may also retain some of the original stream sinuosity, depending on the topography, while field ditches are usually straight. Field ditches that were never true streams are most difficult to discern where a channel has been excavated upslope beyond the stream's headward limit. The field assessor should use his or her judgment based on these criteria and observation of similar points in the same area, rejecting or avoiding the assessment of sites that fall on field ditches.

Differentiating ephemeral flow paths from intermittent streams can also be challenging. By definition the distinction between the two is hydrologic: ephemeral flow paths do not have a groundwater flow component (their flow is all surface runoff), while flow in intermittent streams is driven by groundwater with additional flow from surface runoff. Intermittent streams are therefore able to develop, but don't always develop, fluvial geomorphologic features similar to those found in perennial streams (such as channels, stream beds, banks, sinuosity, point bars, and so on). Such features, when present, are usually far less evident than in perennial streams, and are typically discontinuous or sporadic, especially upslope where they transition to ephemeral. Intermittent streams usually have a floodplain (although it may be very narrow), and there is usually evidence of overbank flow on the floodplain (sediment deposits or silt-covered leaves, wrack, and so on). The channel of intermittent streams also typically supports hydric soils and sometimes wetland biota (hydrophytic plants and animals such as crayfish), at least in some places, while ephemeral flow paths have neither. These indicators are intentionally qualitative, although they could be quantified and calibrated against reference sites with known hydrology to form the basis for classification (as in NC DWQ's Stream Classification Method). The field assessor should use his or her judgment based on these criteria and observations of similar sites in the same area. The assessment procedure should not be used for ephemeral reaches.

The user should make a preliminary decision of whether to use the urban assessment described here, or the rural assessment. Criteria for determination should be used in the office and during the field visit. Office determinations should be verified in the field, especially in the periphery of urban areas where housing and other development activities can change in a matter of a few months. Below is a list of office and field criteria for differentiating urban reaches from rural ones. If a reach is determined to be urban in the office, it is unlikely that the determination will be changed in the field. The converse is not as likely.

Office Determinations made using USGS 7.5 minute series topographic maps and USGS digital orthophoto quarter quads or higher resolution orthogonalized aerial photographs:

1. >10% impervious surface within a circle centered on random point (low order 600 ft radius; high order 1,500 fr radius; see template of aerial photographs, in Appendix).

2. Area denoted as urban on USGS topo (brown, purple, or pink color).

3. Housing density >2.37 units/acre[1] (for low order, >62 units in 600 ft radius circle; for high order >384 units in 1,500 ft radius circle). (Units are dwelling units: single family home = 1 unit, duplex = 2 units, each apartment within a complex = 1 unit.)

Field Determinations:

1. Stormwater treatment unit (wet or dry detention/retention, or infiltration basin, etc.) is located in assessment reach or upstream (low order within 600 ft; high order within 1,500 ft) or within watershed.

2. Stormwater input to stream or floodplain from urban stormwater sources, such as curb-and-gutter street or parking lot, is located in assessment reach or upstream (low order within 600 ft; high order within 1,500 ft). Here, "stormwater input" does not refer to road ditches or grassed swales. (Grassed swales and ditches in agricultural settings indicate that the rural riparian assessments should be used.)
3. Sewer line right-of-way is in riparian zone within 50 ft of stream channel.

4. Three or more dwelling units are located within 90 ft of the stream (either side) along 300 ft assessment reach[2].

After determining which field sheets to use (rural or urban), the following items should be used in the field: topographic maps (USGS 1:24,000), county soil surveys, and DOQQs (or equivalent high-resolution photography), a GPS, a shovel or trowel, a hand-held laser level, a stiff tape measure or meter stick, and a 100-300 ft tape.

2.3 Guidelines for rejecting or moving sites

A watershed can be characterized by assessing a statistically robust number of reaches and using the data from the assessed watershed to make inferences about riparian areas in the watershed as a whole. Various random and stratified random approaches could be used depending on the questions being posed. Regardless of the method applied for randomly selecting reaches for sampling, in some cases, a randomly assigned reach will occur at a place that the assessment procedure was not designed to assess (e.g., along an ephemeral flow path) and so it must be moved or rejected.

If a reach is rejected or moved, the reason for rejection should be noted on the data sheet in the space provided on page 1 (Part A). The following guidelines for moving or

[1] The rural-urban threshold housing density (2.37 units/acre) is the mean of the lowest density urban zoning classification for Greenville, NC (R-15S, 3 units/acre) and the rural residential zoning classification for Pitt County, NC (minimum lot size 25,000 ft^2, which equals 0.57 acre or 1.74 units/acre).
[2] Based on the rural-urban threshold housing density (2.37 units/acre) and the size of the assessment area (300 ft x 180 ft = 54,000 ft^2, or 1.24 acre; 1.24 acre x 2.37 units/acre = 2.94 units, or ~3 units within the assessment area).

rejecting reaches should be followed in the sequence in which they appear. These criteria will probably only be applied in cases where one is assessing randomly-selected reaches. Items 1 and 2 are mapping exercises for the office. The remainder are conducted in the field.

1. If a random point marking the center of a reach is located within 300 ft of another random point, it should be rejected and another point should be substituted.

2. If the random center point falls less than 150 ft from the end of a mapped first order stream, the point should be moved downstream until a full 300 ft reach is encompassed.

3. If a stream junction occurs less than 150 ft downstream of the randomly selected point, the reach should be moved upstream until the entire 300-ft reach is above the junction. If a junction occurs less than 150 ft upstream from the random point, then the 300-ft reach should encompass the main stem (the same stem on which the random point falls).

4. If the mapped point lands on an ephemeral channel or ditch located more than 150 ft above where the channel becomes intermittent the site should be rejected and the next alternate random point should be chosen. If the point is located less than 150 ft from the beginning of an intermittent channel, then the point should be moved downstream until all 300 ft of the assessment reach encompasses an intermittent reach.

5. If the randomly selected 300-ft reach falls entirely with in beaver impoundment (where both channel and floodplain are impounded) or other type of impoundment, the site should be rejected and no substitution should be made for the point.

6. If the random center point is <150 ft from the upstream or downstream boundary of a beaver or other impoundment, the point should be moved upstream or downstream in the un-impounded reach to allow assessment of an un-impounded 300 ft reach. (If moved upstream, the channel may be backed-up, thus requiring that Stream Riparian Condition indicators Sediment Regime, Channel-Riparian Zone Connection, and Stream Bank Stability be omitted.) In many cases, beaver impoundments show a stepwise pattern in which the upper end of one impoundment is adjacent to the dam of the next impoundment upstream. In such cases, moving the reach upstream or downstream will still place it in an impoundment and so the site should be rejected. If rejected, no substitution should be made for the point.

7. If the reach is culverted over one-half of its length (>150 ft), the point should be rejected and the next alternate random point should be chosen. If culverted less than 150 ft, the reach should be assessed.

2.4 Data collection and observations on-site

If none of the above-described rejection criteria are met, then a urban low order reaches should be assessed as outlined below. Field sheets are referred to by page number below.

Page 1, Reasons for rejecting or moving a randomly assigned reach (Part A). The top section provides boxes for recording whether a randomly assigned reach has to be rejected or moved for occurring at a place that the assessment procedure was not designed to assess. A reach that is specifically chosen for assessment would presumably not be rejected and a "0" would be recorded in each box. However, for reaches randomly chosen from maps that that must be rejected or moved (see above listed criteria), Part A provides a format for recording the reason for rejection or distance and reason moved (if the reach should be moved).

Page 1, Upstream and Downstream Influences on Reach (Part B). This category provides information on whether the reach is hydrologically affected by stormwater outfalls, streetside ditches, an impoundment, or other inputs that alter hydrology. Roadside ditches are a conduit for excess water, sediment, and nutrients, and thus are expected to adversely affect hydrologic regime and nutrient input and cycling. DOQQs are useful for locating roadside ditches. The flow and connection of the ditches with the assessed reach can be verified in the field.

In conducting the assessment, first record if the reach is downstream from any street crossings, stormwater outfalls, or ditches. Next, record if the channel is backed up by a beaver or other impoundment. Standing, non-flowing water in the channel suggests that there is an impoundment downstream from reach. A channel can be affected by an impoundment without a dam occurring within the assessed reach or even if there is no impounded water on the floodplain. (Note: even an impounded reach may begin to flow during high rainfall events). Although this assessment method was not developed for assessing the condition of impoundments, a channel that is backed up should be assessed if its riparian zone is not impounded, but indicators Sediment Regime, Channel-riparian Zone Connection, and Stream Bank Stability (pp. 4 and 5) should not be assessed. Instead, "Bv" should be recorded in the appropriate data boxes on page 3. Care should be taken to make sure standing, non-flowing water is not simply a result of channel bed scour that creates an elongated pool of stagnant water.

Next, record if the reach was formerly and recently impounded by beaver, but has been abandoned (or dam removed). An abandoned beaver impoundment should be assessed as un-impounded.

Page 1, General Channel Condition (Part C). Part of characterizing channel condition requires determining the general condition of the stream channel: presence of large downed wood (LDW), channelization, incision, or degree to which the near-channel zone is vegetated. Record these conditions in the boxes in Part C.

Channel incision can be recognized by a deep channel (deeper than expected for the size of the drainage basin) that lacks adjacent spoil piles. Incision is often caused by an increase in the volume of peak flows due to an increase in the area of impervious surfaces and compaction of soils in the drainage basin. In contrast, channelization can usually be identified by the presence of spoil piles or berms along one or both sides of the channel, and by the level of the adjacent historic floodplain being positioned below that of the berm.

Both incision and channelization tend to reduce or eliminate the frequency of overbank flow, thus eliminating contact between floodwater and the floodplain. In some 2nd - 4th order systems, the original stream channel can still be found on the floodplain, but it is much more narrow and shallow than the channelized section and usually has little or no flow.

Another factor in characterizing channel condition requires determining if there is large downed wood (LDW) in the stream channel. If there is none, search the stream banks for sawed-off pieces of logs in the floodplain. Sawed-off large wood indicates that LDW has been removed from the stream ("de-snagged") to facilitate flow.

Page 2, Site Sketch. The sketch provides a grid on which to map the relative area of cover types within 90 ft of each side of the stream and for less-detailed information or notes about conditions from 90-300 ft. Sixty 30 x 30 ft grids have been pre-drawn on the page to facilitate sketching a 90-ft riparian zone on each side of the stream channel.

The sketch map is to be drawn facing downstream with the center of the reach positioned at the midpoint (+) in the center of the map. Marks are also provided for the 10 ft, 50 ft, and 90 ft riparian zones. Sixty 30 x 30 ft grids have been pre-drawn on the page to facilitate sketching a 90-ft riparian zone on each side of the stream channel. Notes on the condition of the 90 – 300 ft zone should be made to the left and right of the grids.

Cover types should be marked with abbreviations provided in Part D, page 2 (OF, MF, LDR, etc.), along with a north arrow. If a stream meanders or curves along the 300 ft reach, the sketch should be adjusted so that it is shown as straight. The meander can be drawn in the box located on the right side of the sketch map. Likewise, the channel cross-section can be drawn in the other box. Rough estimates of dimensions can be made (depth from bank top to channel bottom, width of channel, height of berm above floodplain, etc.).

Page 2, Riparian Zone Cover (Part D). This indicator provides information on the general structure of vegetation in zones adjacent to the stream channel. Information needed for recording attributes can be obtained from the Site Sketch grid (above) on page 2. Riparian Zone Cover influences the condition of all aspects of riparian zone. For hydrology, infiltration in the riparian zone is greater under forested conditions than for other land covers. Also, evapotranspiration rates tend to be higher than some of the other cover types that have lower biomass and especially those that have impervious surfaces. Overland flow from adjacent land uses may be more effectively intercepted, dispersed, and absorbed by forest cover as long as gullying does not occur. (Gullying is not as great a problem in most areas of the coastal plain as it is in piedmont riparian zones.) Impervious surfaces disrupt groundwater flow paths by preventing infiltration and by shunting water to streams via surface flows. This also contributes to increased flashiness and potentially to channel incision.

Biogeochemistry is similarly affected by riparian zone condition because forested riparian zones are well known for their capacity to trap sediments and to intercept nutrients transported by surface and ground water through the riparian zone. In addition, microbial processes are maintained by organic matter produced above and belowground, both of which are greater under forested conditions than other cover types.

For habitat maintenance, mature riparian forests provide the structure for riparian-dependent animals. In addition to the canopy trees and other strata, snags and downed wood are essential for maintaining a suite of vertebrates and invertebrates that depend upon large detritus for food and cover. Both vertical and horizontal structural complexity is higher in forests than in other cover types.

Calibration of land-use cover types relies upon both field data and the literature. For urban riparian zones, scores for cover types were derived by adapting components of the Land Development Intensity (LCI) index developed for Florida[1]. The Florida index is based on embodied energy (also called “emergy”) analysis[2] and incorporates total energy flow, corrected for quality that occurs in a unit area of land use. It represents the intensity of human use and encompasses such factors as air and water pollutants, alteration of physical structure, hydrologic changes, etc. Some of the land uses in Florida (e.g., orange groves, etc.) do not occur our study area. Others were adapted or combined based on our best judgment. For example, golf courses may include multiple cover types such intensively managed lawns and rooftops. When only portions of golf courses are present in an assessed riparian zone, alternative land uses were chosen, such as intensively managed lawns or golf courses.

As yet, there are no data to validate these adaptations of the Florida LDI index. However, we have conducted preliminary assessments in the field along a range of reference sites (relatively unaltered to severely altered) in developing the description of conditions for each of the indicators. We chose to set reference standard conditions for urban areas as high as those for rural areas (e.g., old and mature forest) because timber harvesting is unlikely in built-out suburban areas. However, the most degraded urban conditions are lower than those of rural areas. The net result expands the rural scale to include more degraded conditions commonly found in urban but not rural areas. This allows differentiation between varieties of urban land uses that are absent or rare in rural areas.

The 90 ft riparian zone outer boundary was chosen for RZC because the riparian zone would likely be influenced by surrounding forest, which in this region, can generally reach 90-100 ft in height. Therefore, if growing within the 90-ft riparian zone, a 90-ft tree would have more than a 50% chance of falling into the riparian zone. Of those that fall into the riparian zone, some would be capable of contributing wood to the stream channel. The 50-ft inner zone was chosen to correspond with the NC buffer rules and the 10-ft zone was chosen to correspond to the zone that would most likely affect channel processes (see Near-stream Cover, below).

To evaluate riparian zone cover, the site sketch should be filled out first. From this, the percent cover of the condition (rows) of each zone (columns) should be identified and entered in the adjacent blank cell for each condition identified. One or more cover types could occur in any given zone. By entering the percent cover for each type within a zone, the calculated RZC score is based on a weighted average of all cover types present. The assessor should verify that multiple cover types add up to 100 percent for each column.

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[1] Brown, M.T. and M.B. Vivas. 2005. Landscape development intensity index. Environmental Monitoring and Assessment 101:289-309.
[2] Odum, H.T. and E.C. Odum 2001. A Prosperous Way Down. Univ. Press of Colorado, Boulder, CO.

Because property boundaries often occur along streams, management activities may differ on each side of the stream. Therefore, riparian cover is assessed for each side separately, with a maximum score of 50 for each side and 100 for both sides. A score of 100 means that riparian zone cover is similar to relatively unaltered reference sites.

An example of scoring is as follows: Suppose that the left side of the stream bank has low density residential (LDR), but the 0-10 ft buffer is Old Forest with lawns and houses in the 10-90 ft zone (Table 1). In this case, 100% Old Forest (OF) would be entered for the 0-10 ft zone (since low density residential would not adequately characterize the zone). However, 100% LDR would be recorded for the outer two zones (10-90 ft).

In this scenario, the percent cover of each cover type is multiplied by the appropriate RZC score and summed across all cover types within a zone. Therefore, the column total for each zone must always equal 100%. In the example below, the LEFT side RZC score would be 38 (20+15+3). The sum of zone scores for LEFT and RIGHT is used to assign the total riparian zone cover score when computing functioning. In the example below, the total RZC score for the LEFT and RIGHT sides would be 61.3 (38.0+23.3). These calculations may be conducted in the office.

Table 1. Calculation of Near Stream Cover (NSC) and Riparian Zone Cover (RZC) indicators. Total reach score for each is the sum of the LEFT and RIGHT sides.

Land use by cover type	LEFT SIDE ZONE (distance from stream)						RIGHT SIDE ZONE (distance from stream)						
	0-10 ft	%	10-50 ft	%	50-90 ft	%		0-10 ft	%	10-50 ft	%	50-90 ft	%
Old Forest	20	100	25		5		OF	20		25		5	
Mature Forest	20		25		5		MF	20		25		5	
Young Forest	19		24		5		YF	19		24		5	
Successional Forest	19		23		5		SF	19		23		5	
Recently Harvested	18		22		5		RH	18		22		5	
Shrubs/Saplings	17		21		4		SS	17	100	21	30	4	
Perennial Herb	16		2		4		PH	16		2		4	
Low intensity pasture	15		20		4		LIP	15		20		4	
Annual rowcrop	14		18		3		AR	14		18		3	
Low density residential			15	100	3	100	LDR			15		3	
Intensely managed lawns	9		11		2		IML	9		11		2	
Medium density residential			7		1		MDR			7		1	
High density residential			7		1		HDR			7		1	
Medium density mobile homes			6		1		MDM			6		1	
High density mobile homes			5		1		HMD			5		1	
High density buildings			0		0		HDM			0		0	
Impervious	0		0		0		IP	0		0	70	0	100
Total %		100		100		100			100		100		100
RZC Scores		20.0		15.0		3.0			17.0		6.3		0.0

Housing unit density and number of housing units per side of stream (used in Table 1) were calculated as follows:

Land use by cover type (Brown and Vivas 2005)	Density (units/ha)	Density (units/acre)[3]	# units/side of 300 ft reach[4]
Low density residential (LDR)	<10	<4	<3
Medium density residential (MDR)	10-20	4-8	3-5
High density residential (HDR)	>20	>8	>5

Medium density mobile home (MDM) and high density mobile home (HDM) cover types have the same densities and number of units per side as medium density residential (MDR) and high density residential (HDR), respectively.

Page 2, Near-stream Cover (Part D). This indicator provides information on the structure of vegetation nearest the stream channel (within 10 ft). Both biogeochemistry and habitat of the stream channel are more greatly influenced by the proximity of the near-stream cover than the riparian zone as a whole. Vegetation nearest to the stream channel affects in-stream habitat by contributing leaves for shredder biota, a source of LDW to the channel for instream structural habitat complexity, and by providing shade that ameliorates stream water temperature for stream biota. Streamside vegetation is important in stabilizing stream banks, thus reducing erosion and preventing nutrient–laden sediment from entering streams. In addition, vegetation nearest a stream provides the best opportunity for nutrient uptake because it is often closest to the areas of groundwater discharge to the channel. In addition, tree roots extend into the stream channel, creating small pools that trap leaf litter. Therefore, both biogeochemistry and habitat of the stream channel are more greatly influenced by the proximity of the near-stream cover than the riparian zone as a whole.

Scoring for Near-stream Cover (NSC) is derived from the RZC scores for the LEFT and RIGHT 0-10 ft zones. The score for the 0-10-ft zone must be multiplied by 2.5 to covert the NSC total score to a 0 to 100 scale. Scores for each side range from 50 (Old Forest) to 0 (Impervious). Applying the RZC scenario presented above, the LEFT NSC score would be 50 (i.e., 20*2.5) and the RIGHT NSC score would be 42.5 (i.e., 17*2.5). Again, these calculations can be performed in the office.

Page 3, Summary Sheet. This page provides space for recording RZC and NSC scores and information from Part E, Stream and Riparian Condition. This allows pages 4 and 5 to be used repeatedly. All summary data, except RZC and NSC scores, should be filled in before leaving the site to make sure nothing is missed.

Pages 4 and 5, Stream and Riparian Condition (SRC) Scores (Part E). The seven indicators in this section are scored to determine the condition of the stream channel and its riparian zone. Scores should be entered on page 3, Summary Sheet.

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[3] Conversion factor 2.47 acre/ha (results rounded to nearest integer)
[4] "# units/side of 100 yd. reach" means the number of units on one side of the assessed reach, within 90 ft of the stream (based on the size of the assessment area and the Brown and Vivas (2005) density criteria; results rounded to the nearest integer). Each side of the assessment area is 300 ft long x 90 ft wide = 27,000 ft^2, or 0.62 acre; 0.62 acre x 4 units/acre = 2.48 units; 0.62 acres x 8 units/acre = 4.96 units

Stream and Riparian Condition (SRC) scores, along with RZC and NSC scores, can be used to estimate condition. Each column describes four discrete categories from relatively unaltered to severely altered. In some cases, a slightly different set of criteria is applied to intermittent streams that dry for long periods than are used for streams with longer periods of flow.

At the top of each indicator category from unaltered to severely altered is a general description of the indicator's condition. Below each general description are more specific descriptions of field indicators, each proceeded by a letter (a-d). On the Summary Sheet (p. 3), space is provided to record one or more of the letters (each which corresponds to specific indicator) that best describes the site's condition. Verbiage in brackets ([ ]) provide some guidance on scoring.

Each stream riparian condition indicator is related to slightly different aspects of the three categories of function: hydrology, biogeochemistry, and habitat. Some are related only to stream channel condition, some only to riparian zone condition, and some to both. A general outline of the rationale for the seven indicators is provided below. Together with the Near Stream Condition and the Riparian Zone Condition, the indicators are assembled in Table 2 into the function categories.

1. Instream woody structure.
This indicator is related to all three functions, but for channel condition only. Wood in the stream channel affects hydrology by creating pool and riffle sequences that dissipate energy of flowing water and stores water in pools during low flows. In small, un-incised streams, live tree roots may play this role. Woody structure affects biogeochemistry by providing a surface for microbial activity and a potential source of dissolved organic carbon (DOC), which is released into the water slowly over long periods of time. DOC can be used as an energy source for denitrification and other microbial processes. Instream wood also provides structural habitat complexity for epifauna and epiphytes. In larger streams, fish and invertebrates may use woody structure for resting during high flows and for hiding (shelter).

2. Sediment regime.
This indicator is related only to the biogeochemistry of free-flowing stream channels. It should not be used to assess channels that have been backed up by an impoundment. In such cases, indicators either fail to develop adequately or are not readily observed. Excess sediment in free-flowing headwater reaches may come from storm drainages that enter streams at road crossings, from construction sites, from excessive bank erosion upstream, and from other land disturbance activities. Thus, excess sediment indicates erosional problems within a reach and upstream from the assessed reach. Sediments influence channel biogeochemistry by acting as a carrier of sediment-bound phosphorus, the major mechanism by which phosphorus (and heavy metals) are transport by fluvial systems. Phosphorus enrichment may change the N/P ratio of the stream and enrichment with heavy metals may harm intolerant aquatic biota. Stream channel habitat is normally compromised when excess sediments lower water transparency, suppress primary production of epiphytic algae, and bury the habitat of benthic and epiphytic organisms. We have not incorporated this indicator into habitat of the stream channel function, however, because "4. Pollution affecting the stream" addresses many of the same

Table 2. Example of how indicator scores are averaged to obtain various function, channel condition, and riparian zone condition scores. Indicator scores are averaged by function (columns) to obtain Hydrologic, Biogeochemical, and Habitat mean functions.

INDICATORS	STREAM CHANNEL			RIPARIAN ZONE		
	Hydrology	Biogeo-chemistry	Habitat	Hydrology	Biogeo-chemistry	Habitat
Riparian zone cover				44	44	44
Near-stream cover		45	45			
Instream woody structure	10	10	10			
Sediment regime		10				
Channel-riparian zone connection	30	30	30	30	30	30
Pollution affecting stream	40	40	40			
Factors affecting riparian zone				10	10	10
Habitat quality of riparian zone						10
Stream bank stability		50	50			
Function Score: Mean of all appropriate indicator scores for each function and whether for stream or riparian zone.	27	31	35	28	28	24
	Mean Function Score for Channel = 31			Mean Function Score for Riparian Zone = 27		
	Composite Function Score = 29					

stream habitat conditions. Further, the sediment regime indicator is not indicated for the hydrology function in the stream channel. We acknowledge that excessive sediment deposits in channels reduce bankfull channel flow capacity. For channelized streams, filling contributes positively to channel-riparian zone connection indicator, described next.

Often, channels of channelized streams begin to fill over time, especially those in urbanizing areas that are subject to erosional problems upstream. The filling may seem to indicate that the channel is restoring its morphology, but excess sedimentation will still continue to cause problems for biota if not prevented.

3. Channel-riparian zone connection.

This indicator is based on the degree to which a free-flowing stream channel is incised. It is related to all functions for both stream channels and riparian zones. (The indicator should not be used to assess channels that have been backed up by an impoundment for reasons stated above.) The indicator's application to all functions reflects the fact that the connection between channel and riparian zone is fundamental to the characteristic functioning of riparian ecosystems. The degree of channel incision determines the degree to which functioning is impaired in both the stream channel and riparian zone. Channelized streams and channels incised by high flow velocities affect hydrology by transporting water more rapidly through the system during high flows and by increasing the groundwater slope toward the channel during low flows. Both types of alterations reduce the residence time of water in the system by increasing water flows and reducing storage.

Greater channel capacity of channelized and incised streams, compared to natural channels, requires greater flow volumes to reach a stage at which overbank flow is initiated. This can greatly reduce the duration and frequency of flooding or eliminate it altogether. Overbank flow is the major mechanism by which the channel and riparian zone are hydrologically connected. This in turn affects biogeochemistry in at least two ways: the lowered water table may eliminate contact of surficial groundwater with the organic rich surface horizons of the soil, thus reducing the potential for denitrification in both the channel and riparian zone. A lowered water table also exposes the soil column to greater aeration, thus suppressing anaerobic processes that are common in the floodplains of headwater streams. For biogeochemical processes as a whole, the system becomes more oxidized, which reduces the capacity to accumulate organic matter.

Hydrologic alterations caused by channelization or incision also adversely affect habitat for aquatic and wetland-dependent species. In the riparian zone, hydrophytes are less likely to occur. Within the stream, greater flow velocities, especially during storm flows, increase sediment concentrations through re-suspension and scour, thus degrading habitat.

4. Pollution affecting the stream.
This indicator is related to all three functions, but for channel condition only. Pollutant source for assessment purposes is herein defined as drains from streets and detention ponds, roadside ditches, channelized tributaries, and drainage from impervious surfaces. Pollutant sources affect hydrology by contributing excess water to stream channels. Higher and flashier flows may lead to additional channel incision and headward erosion. Pollution sources, by definition, contribute excess nutrients (primarily nitrogen and phosphorus) and/or toxic pollutants to stream channels, thus interfering with normal biogeochemical cycling. Habitat is also adversely affected by nutrient or chemical additions. Excess nutrients in the presence of sufficient sunlight can create algal accumulations that may lead to nighttime anoxia. Toxic chemicals can directly poison stream organisms.

Pollutant sources affect stream channels both by entering a reach from upstream and by entering within a reach itself. We assume that sources within the reach are generally more detrimental than sources upstream from a reach. Regardless, distance upstream and type of source should be taken into consideration. However, beaver impoundments trap sediment and increase the residence time of water, thus allowing time for nutrient processing and removal. Therefore, some pollutant sources may be disregarded if a beaver impoundment occurs between pollutant sources and the assessed reach. However, more egregious inputs such as toxic chemicals, domestic sewage, and animal waste are expected to alter stream water chemistry even if partially processed through a beaver impoundment before entering reach.

Stormwater detention ponds are meant to moderate peak flows from impervious surfaces and trap sediment and toxic chemicals. Consequently, some pollutant sources may be disregarded if a detention pond occurs between the sources of pollution and the assessed reach. However, in some cases storm detention basins are improperly planned, designed, constructed, or maintained, thus rendering them ineffective in moderating flows and/or trapping sediments and pollutants. Therefore, where detention basins occur within 1,500 ft above an assessed reach (or along a contributing tributary), the detention pond(s) should be examined to determine if they are properly designed or managed. If the detention basins are determined to be ineffective, then they should be treated as a source of pollution rather than as a sink (trap).

Storm water treatment systems are often sophisticated engineered systems. While there are criteria to determine whether they have been properly designed and constructed, and whether they are being properly operated, evaluation of their effectiveness is beyond the scope of this assessment method. The reader is referred to EPA regulatory[5] and non-regulatory[6] information, NC Division of Water Quality guidelines and regulations[7], and the Center for Watershed Protection[8] for further information.

5. Factors affecting the riparian zone.
This indicator is related to all three functions, but for riparian zone condition only. The rationale is the same as provided above for stream channels. The difference is that sources of degradation are limited to those within or directly adjacent to a reach. (It is assumed that alterations to upstream riparian zones do not directly affect the riparian zone of the assessed reach, but that such alterations are taken into account by the previous indicator).

Alterations to the riparian zone, but not to channels directly, include grading, filling, excavation, cultivation, impervious surfaces, and other activities in non-forest land uses. Variations in scoring reflect the degree to which they are believed to alter

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[5] for US EPA stormwater regulatory information see http://www.epa.gov/ebtpages/watestormwater.html; federal stormwater regulations and requirements are included in NPDES regulations 40 CFR Part 122; portions of other regulations are also relevant (see EPA web page for more detail); EPA publishes numerous documents related to stormwater management, including a series of Stormwater Technology Fact Sheets (e.g., Wet detention ponds EPA 832-F-99-048, Vegetated swales EPA 832-F-99-027, Stormwater wetlands EPA 832-F-02-020, Bioretention EPA 832-F-99-012, etc.).

[6] US EPA Office of Research and Development's Urban Watershed Management Branch provides non-regulatory information about urban stormwater risks and management (see http://www.epa.gov/ednnrmrl); EPA ORD UWMB publishes numerous documents, journal articles and books related to urban stormwater; a CD compilation of UWMB reports is available from this web page; also available is an electronic copy of Burton, G. Allen, Jr. and Robert E. Pitt. 2001. Stormwater effects manual: A toolbox for watershed managers, scientists and engineers. Lewis Publishers (CRC Press), Boca Raton, FL, USA.

[7] see NC DWQ stormwater permitting units web page (http://h2o.enr.state.nc.us/su/stormwater.html); pertinent documents include: NC DENR. 1999. Stormwater best management practices.; state stormwater management program (SSWMP) supplement sheets; stormwater management regulations 15A NCAC 2H .0100 (especially 2H .1008 "Design of stormwater management measures"); and stormwater fact sheets prepared by the Land-of-Sky Regional Council.

[8] see Center for Watershed Protection web page (http://www.cwp.org); CWP has recently released the Urban Subwatershed Restoration Manual series, an 11-part series of manuals written for a broad audience including planners, engineers and consultants (Schueler, Tom. 2004. An integrated framework to restore small urban watersheds. Urban Subwatershed Restoration Manual No. 1. Center for Watershed Protection, Ellicott City, MD.

condition. For example, discharges to the riparian zone from septic or sewer systems are considered potentially more detrimental than intensively managed lawns.

Channelization drains adjacent floodplains and increases the capacity of the channel to convey water. This typically eliminates overbank flow onto the floodplain, thus degrading the riparian zone. However, the loss in functioning of a former floodplain of a deeply channelized stream would be ameliorated somewhat if water that would otherwise bypass the former floodplain via ditches and culverts is instead diverted to a forested riparian zone. Forested riparian zones are capable of trapping sediment and removing nutrients before they reach the channel. Especially egregious pollutant inputs, such as toxic chemicals and sewage, would likely overwhelm the capacity of a forested riparian zone to remove them and are still treated as a severe alteration.

Beaver impoundments trap sediment and increase the residence time of water, thus allowing time to remove nitrate. Therefore, if a beaver impoundment occurs between pollutant sources and the assessed riparian zone, such pollutant sources may be disregarded. However, egregious pollutant inputs described in the "extremely altered" category would not be expected to be ameliorated much by a beaver impoundment.

6. *Habitat quality of riparian zone*.
This indicator is related only to the habitat function of the riparian zone. Vegetation composition (evaluated relative to native forest) is a direct measure of plant habitat, which in turn affects animal habitat. It is assumed that mature to old forests represent the least altered condition that is conducive to supporting native communities. The footnote provides a list of canopy species characteristic of native forests. If at least four of the listed species are present in the canopy and the understory is intact with minimal cover of invasive species (Table 3), then the remaining composition and structure of the forest is assumed to be relatively unaltered.

When forest cover is less than 50%, it is assumed that habitat quality is severely degraded for forest-dependent species. Invasive and ecotone-dependent species displace those that require contiguous canopy of intact forest as cover becomes more fragmented.

7. Stream bank stability.
This indicator is related to the biogeochemistry and habitat functions of free-flowing streams. (It cannot be used to assess channels backed up by impoundments. In such cases, indicators either fail to develop adequately or are not readily observed.) As stream discharge increases, hydraulic energy is first dissipated along stream banks and on LDW and roots residing in the channel. Some of this energy results in bank erosion, exposes roots, and causes bank slumping and tree fall, when excessive. If the stream channel is not incised, even higher flows associated with overbank flow transfer total stream energy to the floodplain where it is dissipated without erosion over a large surface area, thus protecting the channel itself from excessive scouring. While some bank erosion and sediment redistribution are natural processes, they are minor in low gradient headwater streams in the coastal plain. Alteration of riparian condition is assumed if erosion, slumping, and undercutting are excessive (especially in places other than at cutbanks) and herbaceous vegetation is unable to re-establish on banks after extreme events. Alterations in bank stability

lead to excessive introduction of sediment to the channel and is ultimately transported to downstream ecosystems.

Table 3. Invasive, non-native species found in riparian ecosystems.

Species	Common name	Prevalence
Trees		
none to rare		
Shrubs		
Ligustrum sinense	Chinese privet	common
Elaeagnus angustrifolia	Russian olive	uncommon[1]
Herbs		
Lonicera japonica	Japanese honeysuckle	common
Microstegium virmineum	Japanese stiltgrass	common
Rosa multiflora	multiflora rose	uncommon[1]
Murdania keisak	Asian dayflower	common
Polygonum cuspidatum	Japanese knotweed	common
Vines		
Lonicera japonica	Japanese honeysuckle	common
Pueraria lobata	kudzu	uncommon[1]

[1]Uncommon invasive in riparian ecosystems, but may be abundant elsewhere.

2.3. Office and Field Criteria for Differentiating Urban from Rural Reaches

This guidance is used to determine which protocol should be used to assess a randomly assigned reach. Presence of any one indicator below is sufficient for confirming urban status (either in the office or in the field).

Office Determinations (made using USGS 7.5 minute series topographic maps and USGS digital orthophoto quarter quads or higher resolution orthogonalized aerial photographs)

4. >10% impervious surface within a circle centered on random point (low order 600 ft radius; high order 1,500 ft radius; see template of aerial photographs, in Appendix).
5. Area denoted as urban on USGS topo (brown, purple, or pink color).
6. Housing density >2.37 units/acre[9] (for low order, >62 units in 600 ft radius circle; for high order >384 units in 1,500 ft radius circle). (Units are dwelling units: single family home = 1 unit, duplex = 2 units, each apartment with in a complex = 1 unit.)

Field Determinations

7. Stormwater treatment unit (wet or dry detention/retention, or infiltration basin, etc.) is located in assessment reach or upstream (low order within 600 ft; high order within 1,500 ft) or within watershed.
8. Stormwater input to stream or floodplain from urban stormwater sources, such as curb-and-gutter street or parking lot, is located in assessment reach or upstream (low order within 600 ft; high order within 1,500 ft). Here, "stormwater input" does not refer to road ditches or grassed swales. (Grassed swales and ditches in agricultural settings indicate that the rural riparian assessments should be used.)
9. Sewer line right-of-way is in riparian zone within 50 ft of stream channel.
10. Three or more dwelling units are located within 90 ft of the stream (either side) along 300 ft assessment reach[10].

[9] The rural-urban threshold housing density (2.37 units/acre) is the mean of the lowest density urban zoning classification for Greenville, NC (R-15S, 3 units/acre) and the rural residential zoning classification for Pitt County, NC (minimum lot size 25,000 ft^2, which equals 0.57 acre or 1.74 units/acre).

[10] Based on the rural-urban threshold housing density (2.37 units/acre) and the size of the assessment area (300 ft x 180 ft = 54,000 ft^2, or 1.24 acre; 1.24 acre x 2.37 units/acre = 2.94 units, or ~3 units within the assessment area).

Urban Low Order Riparian Assessment, V. 2.0

[ ] Site # Date __________

[ ] Watershed Field Crew ______________________________

ULO Stream type

A. Reasons for Rejecting or Moving a Randomly Assigned Reach. (Enter 1 for Yes, 0 for No)

[ ] Reach rejected (check one): ( ) ditch; ( ) ephemeral, no stream present; ( ) piped, culverted; ( ) filled; ( ) both channel and riparian zone flooded by beaver impoundment; ( ) flooded by other impoundment type; ( ) inaccessible ***If rejected, do not assess reach.***

[ ] Reach moved upstream or downstream ( ) feet due to ( ) beaver or ( ) other impoundment in <50% of reach. (Enter 1 for yes, 0 for no in box, enter distance moved, and check impoundment type in parentheses

[ ] Reach moved downstream ( ) feet due to ( ) ephemeral channel, ( ) ditch, or ( ) culverted in <50% of reach. (Enter 1 for yes, 0 for no in box, enter distance moved, and check channel type in parentheses

B. Upstream and Downstream Influences on Reach. (Enter 1 for Yes, 0 for No)

[ ] Stream reach is downgradient from at least one roadside ditch or stormwater outfall without an associated detention basin

[ ] Only the channel is backed up by downstream impoundment; the riparian zone is not inundated, except after a heavy rainfall event.***If so, conduct assessment, but do not assess SRC #2, #3, and #7 (pp. 4 & 5)***

[ ] Reach formerly and recently impounded by beaver or man-made dam, but dam now abandoned and floodplain vegetation is recovering.

C. General Channel Condition (Enter 1 for Yes, 0 for No)

[ ] Unincised, free-flowing stream with large downed wood (LDW) and/or litter and tree roots in channel.

[ ] Unincised, free-flowing stream with little or no LDW, litter, and tree roots in channel.

[ ] Channelized or incised stream with trees growing in and along channel and LDW or leaf litter in channel.

[ ] Channelized or incised stream with trees growing in and along channel, but lacking much LDW or leaf litter in channel. (Look for evidence of desnagging as possible reason

[ ] Channelized or incised stream with mostly shrubs and/or herbaceous vegetation growing in and along channel; few or no trees.

[ ] Stream channel rip-rapped, bulkheaded, or lined with concrete bottom.

[ ] Stream partially or entirely culverted.

Notes:

Site # _______ Watershed ______________________________ Date ______________

Site Sketch *Reach is 300 ft in upstream-downstream direction by 180 ft wide. Each square is 30 x 30 ft. Identify and label cover types to 90 ft using abbrevations in Part D below. Portray stream as straight. Add north arrow. Draw meander and cross-section in boxes to right.*

LEFT downstream **RIGHT**

Notes on 90-300 ft

Notes on 90-300 ft

upstream

Draw stream's meander

Draw channel x-section

D. Riparian Zone Cover - *I n the blank boxes, record the % cover for each cover type by zone (0-10 ft, 10-50 ft, 50-90 ft). For example, if a zone is equally represented by two cover types, record 50 in the boxes adjacent to the cover types. Insert abbreviations (OF, MF, etc.) for cover types on sketch map above. (Ages in parentheses.) For Mature Forest that has been selectively cut or high-graded, record as Young Forest. These data should be transferred to the "RZC Calculator" file to calculate RZC and NSC scores. (Make sure that total % = 100 for each column.) The NSC score is 2.5 times the total score for the 0-10-ft zone.*

Land use by cover type	LEFT SIDE ZONE (distance from stream)							RIGHT SIDE ZONE (distance from stream)					
	0-10 ft	%	10-50 ft	%	50-90 ft	%		0-10 ft	%	10-50 ft	%	50-90 ft	%
Old Forest (OF), >75 y old	20		25		5		OF	20		25		5	
Mature Forest (MF), 50-75 y old	20		25		5		MF	20		25		5	
Young Forest (YF), 25-50 y old	19		24		5		YF	19		24		5	
Successional Forest (SF), 5-25 y old	19		23		5		SF	19		23		5	
Recently Harvested (RH), 0-5 y old	18		22		5		RH	18		22		5	
Shrubs/Saplings (SS)	17		21		4		SS	17		21		4	
Perennial Herb (PH) (incl. residential lawns)	16		20		4		PH	16		20		4	
Low intensity pasture with livestock (grazing intensity <3 animals/acre) (LIP)	15		18		4		LIP	15		18		4	
Annual crop agriculture (AR)	14		17		3		AR	14		17		3	
Low density residential, single family (<3 houses per side, within 90 ft of channel); minimally managed lawns (LDR)			15		3		LDR			15		3	
Intensely managed lawns, golf course, recreation field, etc. (IML)	9		11		2		IML	9		11		2	
Medium density residential, single family (3-5 houses per side, 10-90 ft from channel) (MDR)			7		1		MDR			7		1	
High density residential, single family (>5 houses per side, 10-90 ft from channel) (HDR)			7		1		HDR			7		1	
Medium density mobile home (3-5 units per one side of 100 yd reach within 90 ft of channel) (MDM)			6		1		MDM			6		1	
High density mobile home (more than 5 units per one side of 100 yd reach within 90 ft of channel) (HDM)			5		1		HMD			5		1	
High density building, multi-unit: strip mall, commercial mall, condos, manufacturing, motels, institutions, etc. (HDB)			0		0		HDM			0		0	
Impervious (IP)	0		0		0		IP	0		0		0	
Total % (If <100%, correct data entry)													
	NSC=				RZC=			NSC=				RZC=	

Urban Low Order Riparian Assessment, V. 2.0

Site # __________ Watershed ____________________________ Date _______

D. Riparian Zone and Near Stream Cover, p. 2

☐ RZC (total of possible 100% derived from both sides)

☐ NSC (total of possible 100% derived from both sides of "0-10 ft" zone, multiplied by 2.5)

E. Stream and Riparian Condition (SRC) indicator scores (pp. 4 & 5)

☐ 1. Instream woody structure
☐ Sub-condition "a, b, c, or d."

☐ 2. Sediment regime ***(If channel is backed up by beaver, enter "Bv")***
☐ Sub-condition "a, b, c, or d." ***(If channel is backed up by beaver, enter "Bv.")***

☐ 3. (LEFT) Channel-riparian zone connection ***(If channel is backed up by beaver, enter "Bv")***
☐ Sub-condition "a, b, c, or d." ***(If channel is backed up by beaver, enter "Bv.")***

☐ 3. (RIGHT) Channel-riparian zone connection ***(If channel is backed up by beaver, enter "Bv")***
☐ Sub-condition "a, b, c, or d." ***(If channel is backed up by beaver, enter "Bv.")***

☐ 4. Pollution affecting the stream
☐ Sub-condition "a, b, c, or d."

☐ 5. (LEFT) Factors affecting riparian zone
☐ Sub-condition "a, b, c, or d."

☐ 5. (RIGHT) Factors affecting riparian zone
☐ Sub-condition "a, b, c, or d."

☐ 6. (LEFT) Habitat quality of riparian zone
☐ Sub-condition "a, b, or c."

☐ 6. (RIGHT) Habitat quality of riparian zone
☐ Sub-condition "a, b, or c."

☐ 7. (LEFT) Stream bank stability ***(If channel is backed up by beaver, enter "Bv")***
☐ Sub-condition "a, b, c, or d."

☐ 7. (RIGHT) Stream bank stability ***(If channel is backed up by beaver, enter "Bv")***
☐ Sub-condition "a, b, c, or d."

Notes:

E. Stream and Riparian Condition (SRC). *For each SRC indicator, record on page 3 the SRC indicator score and one or more letters (a-d) that apply. (If a condition is encountered that is not provided, choose a score, and explain the alteration and rationale for scoring in notes on p. 3.) Verbiage in brackets ([ ]) provides guidance on scoring.*

SRC Indicator	Condition Category			
	Relatively Unaltered	**Somewhat Altered**	**Altered**	**Severely Altered**
1. Instream woody structure	Much large down wood (LDW) in channel and along banks. (Recent treefalls from extreme weather events or erosion not applicable.) (a) LDW represents a variety of decay classes[1]. **(b)** LDW in channel and along banks represents a mix of decay and size classes >4 inch dia[1]. Some LDW >8 inch dia. **(c)** For stream channels that are dry for long periods, tree roots with hypertrophied lenticels are located *in stream bottom.* **(d)** Large (>1 inch) tree roots in channel create small pools that trap leaf litter, when available.	Some LDW in channel and along banks. Some may be partially buried in channel bottom. **(a)** LDW in channel and along banks represents a variety of decay classes[1]. **(b)** Few or no LDW >8 inch dia. [If large >4 inch dbh trees grow along both banks, score 80, if only along one side, score 70, if streamside trees are <4-inch dbh, score 60.] **(c)** For streams channels that are dry for long periods, tree roots located *in stream bottom* lack hypertrophied lenticels. **(d)** Large (>1 inch) tree roots in channel are elevated above channel bottom due to undercutting.	Few or no LDW in channel and on banks[2] but potential supply is present. **(a)** LDW represents only one decay class[1]. **(b)** For channelized or deeply incised stream channels that are dry for long periods, channel is maintained so infrequently that small trees or shrubs grow along channel banks. [If large >4 inch dbh trees grow along both banks, score 50, if only along one side, score 40, if streamside trees are <4-inch dbh, score 30.]	No LDW in channel **(a)** Stream is channelized or deeply incised and periodically cleared of debris to maintain drainage. **(b)** No large trees (>4 inch dbh) grow along channel banks. **(c)** Stream is lined with rocks, rip-rap or concrete. [Assign lowest score to trapezoidal channels with concrete bottoms.]
Score =	100 90	80 70 60	50 40 30	20 10 0
2. Sediment regime[3, 4]	Little or no silt or sand carried by stream. Water runs fairly clear even during periods of high flow. (If originating in flats, water is may be dark (tea colored) due to tannins.) **(a)** Stream is not channelized. **(b)** Channel bottom is mostly sandy or clayey with little or no silt on channel bottom or on floodplain. [If sand deposition in channel bottom is due to upstream activities, then see "severely altered" category.]	Some silt carried by stream. **(a)** At high flows, suspended sediment evident in water. **(b)** When water runs clear during base flow, sediment[5] can be re-suspended by shuffling feet in channel. **(c)** Thin layer (<1 inch thick) of silt deposited on channel bars or on floodplain surface. [Thickest deposits score lower.] **(d)** Sediment >1 inch thick due to recent abandonment of impoundment[4].	Silt and sand carried by stream. **(a)** Water is silt laden, esp. after heavy rains. **(b)** Thick (1-2 inches) silt or sand deposited on channel bars, bank edge, or on floodplain (if present). **(c)** For streams that are dry for long periods, sand or silt may collect behind root dams and be deposited on floodplain (if stream not channelized or incised).	Heavy sediment load carried by stream. **(a)** Sediment suspended in water even during low flow. **(b)** Thick (>2 inch) sand or silt layers recently deposited on channel bars, bank edge, or on floodplain (if present). **(c)** Evidence that sand or silt deposits in reach are being generated by upstream activities. [Sand or silt on an artificial stone bottom scores lowest.]
Score =	100 90	80 70 60	50 40 30	20 10 0
3. Channel-riparian zone connection[4]	Strong evidence of overbank flow on floodplain. **(a)** No apparent channelization or incision. **(b)** Wrack, sediment, and/or trash on floodplain. [Sparse wrack scores 45.] **(c)** High water marks on trees apparent. **(d)** No spoil berm alongside channel.	Evidence of occasional overbank flow on floodplain. **(a)** Some wrack, sediment, trash on floodplain, but sparse and/or old. **(b)** Stream channelized within historic channel with low spoil berms or breaks in them along channel. (Channel may have been channelized in past, but filled sufficiently with sediments that overbank flow is common.) **(c)** Channel slightly channelized or incised.	Evidence of overbank flow only after extreme (rare) flood events. **(a)** No or little wrack on floodplain. **(b)** Channelization (i.e., spoil berms present and high). **(c)** Channel deeply incised (not channelized).	Overbank flow eliminated. **(a)** Deep channelization with spoil berms present. **(b)** Deeply incised (not channelized). **(c)** Filling and/or leveling of floodplain, some or all of fill may have been derived from spoil from channelization. **(d)** Presence of high artificial levee or other channel-containment structure.
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0
4. Pollution[6] affecting the stream	No on-site or off-site pollution affecting stream. **(a)** There is no pollution entering directly into the stream within the reach or within600 ft (200 yd) upstream from reach. **(b)** All stormwater detention basins and ponds within 600 ft (200 yd), if present, are adequately designed and maintained to reduce peak flows and trap sediment and nutrients. [Condition scores 90.] **(c)** Stream is not channelized.	Only off-site pollution affects stream. **(a)** Pollution feeds directly into stream channel within 600 ft (200 yd) upstream from reach (not within reach). **(b)** Water from inadequately designed or maintained detention basin enters stream within 600 ft (200 yd) above reach. [More sources or more proximate pollution sources should be scored lower.]	On-site pollution affects stream. **(a)** Pollution from stormwater directly enters stream reach. **(b)** Water from inadequately designed or maintained detention basin directly empties into reach. **(c)** Overland-flow from impervious surfaces, gardens, and lawns directly enters reach. **(d)** Stream culverted for 5-20% of length. [Presence of several pollution sources should be scored lower than fewer sources.]	Especially egregious pollution or culverting affects stream. **(a)** Sediment input from construction activities entering channel directly. **(b)** >20% of reach passes through culvert. **(c)** Evidence of sewer line leaking into stream (note evidence). **(d)** Hydrocarbons or other toxic chemicals leaking directly into stream (note evidence).
Score =	100 90	80 70 60	50 40 30	20 10 0

[1] Decay classes: (1) bark intact, leaves attached, no evidence of decay, (2) loose bark, no leaves, (3) peeling bark, fungi present, (4) advanced stages of decay, no bark or soft enough for a prod to be easily poked through, and (5) bole decayed into ground. If impossible to determine presence of LDW due to high flow, score 55.

[2] If few or no LDW occurs within channel, check banks for sawed-off pieces in floodplain, which indicates de-snagging. LDW from severe bank erosion not applicable.

[3] Sediment layer of relic beaver impoundments may be deep at upstream end of unmaintained impoundment and reduced in depth closer to former dam site.

[4] Do not assess SRC #2, #3, and #7 if stream is backed up by downstream beaver impoundment. <u>Do assess relic beaver impoundments</u>.

[5] Make sure that particulate organic matter (POM) is not confused with excess sediment. POM is very dark in color.

[6] See page 5, footnote 1, for definition of pollution.

E. Stream and Riparian Condition (cont.)

SRC Indicator	Condition Category: Relatively Unaltered	Somewhat Altered	Altered	Severely Altered
5. Factors affecting the riparian zone (0-50 ft zone)	No pollution[1] or other factors affecting riparian zone condition within reach. (a) Stream is not channelized and no pollution empties into riparian zone. (b) All stormwater detention basins and ponds, if present, are adequately designed and maintained to reduce peak flows and trap sediment and nutrients. [Presence of clippings or organic waste in floodplain scores 45.]	Pollution[1] or other factorssomewhat affecting riparian zone. (a) Stream is not channelized and water from properly designed and maintained detention facilities empties into riparian zone. (b) Stream is channelized and drainage or stormwater is discharged (or diverted) to riparian zone where it is detained and processed before entering stream. [Forested riparian zone scores higher than other cover types.]	Pollution[1] or other factorsaffecting riparian zone. (a) Stream not channelized and pollution enters directly into riparian zone of reach. (b) Stream is channelized, but no stormwater is diverted to riparian zone. (c) 5-25% of riparian zone (0-50 ft) of reach filled, graded, cultivated, or covered with impervious surface. (d) Combined sewer and storm drain system occurs within riparian zone. [Presence of more categories or greater intensities score lower.]	Especially egregious pollution[1] or other factors affecting riparian zone. (a) More than 25% of riparian zone of reach graded, filled, excavated, cultivated, covered with impervious surface, or converted to other non-forested land cover. (b) Septic or sewer system leaking into riparian zone. (c) Hydrocarbons or other toxic chemicals leaking into riparian zone. [Lack of forest in riparian zone scores lower.]
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0
6. Habitat quality of riparian zone[2] (0-50 ft)	Habitat quality intact. Riparian zone dominated by old or mature intact[3] forest (>95% of area). No or low cover of exotic or invasive species. No grazing, mowing, or selective harvesting within riparian zone. [Old or Mature forest (>50 yr. old) scores 50; slightly younger forest scores 45. Exotics in 5-25% in any stratum scores 45.]	Habitat quality somewhat degraded. **(a)** Intact[3] forest covers 75-95% of riparian zone with remainder of area representing other cover types. **(b)** Intact forest covers >95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers >95% of riparian zone with at least one understory stratum of native vegetation asent or not well represented (due to understory removal or timber harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests.]	Habitat quality degraded. **(a)** Intact[3] forest covers 50-75% of riparian zone with remainder of area representing other cover types. **(b)** Intact forest covers 75-95% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers 75-95% of riparian zone with at least one understory stratum of native vegetation absent or not well represented (due to understory removal, timber harvesting, etc.). [Old or Mature forest (>50 yr. old) should be scored higher than younger forests in all cases.]	Habitat quality extremely degraded. **(a)** Forest covers <50% of riparian zone with remainder of area representing other cover types. **(b)** Intact[3] forest covers 50-75% of riparian zone with exotic or aggressive species covering >25% in at least one stratum. **(c)** Forest canopy covers 50-75% of riparian zone with at least one understory stratum of native vegetation absent or not well represented (due to understory removal, timber harvesting, etc.). [Old or Mature forest (>50 yr. old) covering more than 25% of riparian zone should be scored 10; younger forest or lower forest cover scores 5, lack of trees scores 0.]
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0
7. Stream bank stability[4]	Stream bank relatively stable. **(a)** Evidence of erosion or bank failure absent or minimal (<10%) of length. **(b)** Streamside vegetation tightly binds soil along banks, although exposed roots may occur at cut banks of stream channel. [Slight erosion or bank undercutting scores 45.]	Stream bank moderately stable. **(a)** 10-25% of bank eroded or slumping **(b)** If trees present along bank, a few large (>1 inch dia.) roots exposed. **(c)** Most eroded areas recovering.	Stream banks unstable. **(a)** 25-50% of bank eroded. **(b)** Erosion, slumping, and undercutting prevalent, especially in places other than cutbanks. **(c)** If trees present along bank, many large (>1 inch in dia.) roots exposed with some trees toppled into stream due to undercutting.	Stream bank extremely unstable. **(a)** >50% of bank eroded **(b)** Erosion, slumping, and undercutting prevalent, esp. at places other than cutbanks. **(c)** If trees present along bank, many toppled into stream due to undercutting. **(d)** Banks hardened with rip-rap, rocks, gabions, concrete, or bulkheading.
Score (L) =	Left Bank: 50 45	40 35 30	25 20 15	10 5 0
Score (R) =	Right Bank: 50 45	40 35 30	25 20 15	10 5 0

[1] Pollutant sources include runoff from roadside ditches, stormwater drainage, leakage from septic drainfields, runoff from intensely managed lawns or kennels, direct drainage from impervious surfaces including roof tops, and discharge from inadequate detention facilities. Note, beaver impoundments and *adequately designed and maintained* detention basins largely negate the effects of most pollution, except those described in the "severely altered" category. Therefore, other upstream pollutant sources may be disregarded if an impoundment or properly operating detention basin occurs between the pollutant source(s) and the assessed reach.

[2]Habitat quality encompasses both plant and animal habitat and includes both quality and area. Quality assumes that mature or old forest with appropriate quality and quantity of LDW, snags, and characteristic 3-D structure.

[3] Intact forest is one with all strata present, including canopy, midstory, understory, and herb layers. Strata need not be dense to be intact, but no evidence of clearing, grazing, selective harvesting, etc. allowed. Canopy must be comprised of trees >6 inch dbh, including at least 4 of the following species: tulip poplar, red maple, sweetgum, blackgum, elm, oak, loblolly pine, and sweetbay. Forest cover could be linearly arranged along channel or in blocks scattered within the riparian zone.

[4] Do not assess SRC #2, #3, and #7 if stream is backed up by downstream beaver impoundment. Assess relic beaver impoundments. For relic impoundments, sediment layer may be deep at upstream end of unmaintained impoundment and reduced in depth closer to former dam site.

APPENDIX B

Data Summary

Table B-1. Raw Data Summary

SW	Site #	Code	Total RZC	Total NSC	IWS	SR	CRZC	PAS	FARZ	HQRZ	SBS	STREAM CHANNEL			RIPARIAN ZONE			FUNCTIONS			Channel Condition	Riparian zone Condition	Composite Function Score
												Hydrology	Biogeo-chemistry	Habitat Quality	Hydrology	Biogeochemistry	Habitat Quality	Hydrology	Biogeochemistry	Habitat			
2	44	RLO	7	10	60	Bv	Bv	30	10	0	NA	45	33	33	9	9	6	27	21	20	37	8	22
	59	RLO	64	65	80	70	30	100	100	90	NA	70	69	69	65	65	71	67	67	70	69	67	68
	70	RLO	5	7	70	Bv	Bv	30	20	0	NA	50	36	36	12	12	8	31	24	22	40	11	26
	A21	RLO	41	85	80	40	60	30	25	15	NA	57	59	64	42	42	35	49	51	50	60	40	50
2	**AVG**		**29**	**42**	**73**	**55**	**45**	**48**	**39**	**26**		**55**	**49**	**50**	**32**	**32**	**30**	**44**	**41**	**40**	**52**	**31**	**41**
4	8	RLO	42	50	100	100	10	60	55	30	NA	57	64	55	36	36	34	46	50	45	59	35	47
	11	RLO	65	63	100	90	40	60	25	55	NA	67	71	66	43	43	46	55	57	56	68	44	56
	17	RLO	86	85	100	90	10	40	45	70	NA	50	65	59	47	47	53	49	56	56	58	49	53
	46	RLO	45	50	70	40	50	70	90	55	NA	63	56	60	62	62	60	62	59	60	60	61	60
	71	RLO	51	65	70	10	40	40	45	15	NA	50	45	54	45	45	38	48	45	46	50	43	46
	73	RLO	58	59	90	90	40	40	85	90	NA	57	64	57	61	61	68	59	62	63	59	63	61
	A14	RLO	47	48	20	10	90	50	90	50	NA	53	44	52	76	76	69	65	60	61	50	74	62
	A17	RLO	61	80	70	10	50	30	10	30	NA	50	48	58	40	40	38	45	44	48	52	39	46
	A19	RLO	30	41	80	60	50	40	30	25	NA	57	54	53	37	37	34	47	45	43	55	36	45
	A20	RLO	52	61	60	50	50	40	60	50	NA	50	52	53	54	54	53	52	53	53	52	54	53
4	**AVG**		**54**	**60**	**76**	**55**	**43**	**47**	**54**	**47**		**55**	**56**	**57**	**50**	**50**	**49**	**53**	**53**	**53**	**56**	**50**	**53**
5	33	RLO	24	31	80	Bv	Bv	50	45	10	NA	65	54	54	35	35	26	50	44	40	58	32	45
	37	RLO	5	8	50	10	10	30	10	0	NA	30	22	24	8	8	6	19	15	15	25	8	16
5	**AVG**		**15**	**19**	**65**	**10**	**10**	**40**	**28**	**5**		**48**	**38**	**39**	**21**	**21**	**16**	**34**	**30**	**28**	**41**	**20**	**31**
6	9	RLO	53	68	60	20	70	70	80	35	NA	67	58	67	68	68	60	67	63	63	64	65	64
	20	RLO	8	13	40	10	10	30	50	10	NA	27	21	23	23	23	19	25	22	21	23	21	22
	21	RHO	86	85	100	50	100	80	95	100	100	93	86	93	94	94	95	94	90	94	91	94	92
	24	RLO	13	28	50	90	20	90	90	10	NA	53	56	47	41	41	33	47	48	40	52	38	45
	27	RLO	15	26	30	20	50	40	25	0	NA	40	33	37	30	30	22	35	32	29	37	27	32
	28	RHO	60	55	100	40	100	100	95	70	70	100	78	85	85	85	81	93	81	83	88	84	86
	30	RHO	86	85	100	10	100	70	90	90	90	90	76	89	92	92	92	91	84	90	85	92	88

SW	Site #	Code	Total RZC	Total NSC	IWS	SR	CRZC	PAS	FARZ	HQRZ	SBS	STREAM CHANNEL			RIPARIAN ZONE			FUNCTIONS			Channel Condition	Riparian zone Condition	Composite Function Score
												Hydrology	Biogeo-chemistry	Habitat Quality	Hydrology	Biogeochemistry	Habitat Quality	Hydrology	Biogeochemistry	Habitat			
6	35	RLO	65	85	100	90	100	50	100	60	NA	83	85	84	88	88	81	86	87	83	84	86	85
	54	RHO	79	85	100	10	100	80	85	90	100	93	79	93	88	88	89	91	84	91	89	88	88
	60	RHO	86	85	100	Bv	Bv	70	80	55	Bv	85	85	85	83	83	74	84	84	79	85	80	82
	67	RHO	86	85	100	40	100	80	100	90	100	93	84	93	95	95	94	94	90	94	90	95	93
	A10	RHO	86	85	100	90	100	70	80	90	100	90	91	91	89	89	89	89	90	90	91	89	90
	A2	RLO	48	56	60	20	20	90	50	10	NA	57	49	57	39	39	32	48	44	44	54	37	45
6	**AVG**		**59**	**65**	**80**	**41**	**73**	**71**	**78**	**55**	**93**	**75**	**68**	**73**	**70**	**70**	**66**	**73**	**69**	**69**	**72**	**69**	**70**
7	5	RLO	18	34	20	10	20	30	50	0	NA	23	23	26	29	29	22	26	26	24	24	27	25
	6	RLO	31	23	40	20	0	90	25	70	NA	43	35	38	19	19	32	31	27	35	39	23	31
	7	RLO	15	30	0	20	90	30	60	0	NA	40	34	38	55	55	41	48	45	39	37	50	44
	12	RLO	14	29	40	10	60	40	35	10	NA	47	36	42	36	36	30	42	36	36	42	34	38
	15	RLO	47	48	10	20	90	70	100	30	NA	57	48	54	79	79	67	68	63	61	53	75	64
	16	RLO	68	79	50	10	50	40	50	45	NA	47	46	55	56	56	53	51	51	54	49	55	52
	25	RLO	36	35	90	90	90	60	80	0	NA	80	73	69	69	69	52	74	71	60	74	63	68
	38	RLO	52	51	50	30	60	70	70	45	NA	60	52	58	61	61	57	60	56	57	57	59	58
	47	RLO	29	21	30	30	10	0	30	20	NA	13	18	15	23	23	22	18	21	19	16	23	19
	50	RLO	28	23	70	30	10	40	45	45	NA	40	35	36	28	28	32	34	31	34	37	29	33
	52	RHO	82	85	100	Bv	Bv	60	70	70	Bv	80	82	82	76	76	74	78	79	78	81	75	78
	56	RLO	62	85	70	30	60	30	40	45	NA	53	55	61	54	54	52	54	55	57	57	53	55
	58	RLO	85	85	90	90	100	40	85	100	NA	77	81	79	90	90	93	83	86	86	79	91	85
	68	RLO	6	9	10	30	10	30	20	0	NA	17	18	15	12	12	9	14	15	12	16	11	14
	A25	RLO	32	38	20	30	0	50	10	45	NA	23	28	27	14	14	22	19	21	24	26	17	21
	A3	ULO	94	95	90	10	60	45	85	10	60	65	60	70	80	80	62	72	70	66	65	74	69
	A3	RLO	36	35	90	10	60	40	60	10	NA	63	47	56	52	52	42	58	50	49	56	49	52
	A9	RLO	25	25	20	30	40	40	40	10	NA	33	31	31	35	35	29	34	33	30	32	33	32
7	**AVG**		**42**	**46**	**49**	**29**	**48**	**45**	**53**	**31**	**60**	**48**	**44**	**47**	**48**	**48**	**44**	**48**	**46**	**46**	**47**	**47**	**47**
9	14	RHO	34	38	40	30	0	40	10	15	75	27	37	39	15	15	15	21	26	27	34	15	24

SW	Site #	Code	Total RZC	Total NSC	IWS	SR	CRZC	PAS	FARZ	HQRZ	SBS	STREAM CHANNEL			RIPARIAN ZONE			FUNCTIONS			Channel Condition	Riparian zone Condition	Composite Function Score
												Hydrology	Biogeo-chemistry	Habitat Quality	Hydrology	Biogeochemistry	Habitat Quality	Hydrology	Biogeochemistry	Habitat			
9	18	RHO	31	38	20	10	0	40	10	0	55	20	27	31	14	14	10	17	20	20	26	12	19
	26	RHO	86	85	20	20	0	40	10	60	70	20	39	43	32	32	39	26	36	41	34	34	34
	31	RLO	25	39	20	10	10	50	25	15	NA	27	26	30	20	20	19	23	23	24	27	20	23
	32	RLO	50	38	10	10	0	40	15	50	NA	17	20	22	22	22	29	19	21	25	19	24	22
	34	RHO	40	38	40	10	0	40	10	5	50	27	30	34	17	17	14	22	23	24	30	16	23
	42	RHO	27	38	40	10	0	40	10	0	65	27	32	37	12	12	9	19	22	23	32	11	22
	45	RHO	40	38	70	50	20	60	20	5	85	50	54	55	27	27	21	38	40	38	53	25	39
	51	RLO	17	10	20	10	0	30	15	5	NA	17	14	15	11	11	9	14	12	12	15	10	13
	53	RHO	28	38	20	10	30	40	25	5	50	30	31	36	28	28	22	29	29	29	32	26	29
	55	RHO	40	38	40	10	0	60	10	0	65	33	35	41	17	17	13	25	26	27	36	15	26
	61	RLO	27	20	20	10	10	50	25	5	NA	27	22	25	21	21	17	24	21	21	25	19	22
	65	RHO	43	44	90	10	50	60	30	40	90	67	57	67	41	41	41	54	49	54	64	41	52
	66	RHO	45	45	20	10	0	40	10	0	65	20	30	34	18	18	14	19	24	24	28	17	22
	69	RLO	35	30	20	10	0	40	5	15	NA	20	20	23	13	13	14	17	17	18	21	14	17
	74	RHO	58	38	20	10	0	40	10	15	60	20	28	32	23	23	21	21	25	26	26	22	24
	A11	RHO	22	23	40	0	0	50	10	20	80	30	32	39	11	11	13	20	21	26	34	11	22
	A12	RHO	19	29	60	10	0	60	0	10	70	40	38	44	6	6	7	23	22	26	41	7	24
	A13	RLO	44	38	10	10	0	40	15	10	NA	17	20	22	20	20	17	18	20	20	19	19	19
	A16	RLO	16	23	10	10	10	40	10	10	NA	20	19	21	12	12	11	16	15	16	20	12	16
	A6	RHO	8	15	20	0	0	30	10	10	60	17	21	25	6	6	7	11	13	16	21	6	14
9	**AVG**		**35**	**35**	**31**	**12**	**6**	**44**	**14**	**14**	**67**	**27**	**30**	**34**	**18**	**18**	**17**	**23**	**24**	**25**	**30**	**18**	**24**

Table B-2. Data Summary Sorted by Composite Function Score

Site#	SW	Code	Channel Condition	Riparian Zone Condition	Composite Function Score
Relatively Unaltered (90-100)					
67	6	RHO	90	95	93
21	6	RHO	91	94	92
Somewhat Altered (60-89)					
A10	6	RHO	91	89	90 (89.9)
30	6	RHO	85	92	88
54	6	RHO	89	88	88
28	6	RHO	88	84	86
35	6	RLO	84	86	85
58	7	RLO	79	91	85
60	6	RHO	85	80	82
52	7	RHO	81	75	78
A3	7	ULO	65	74	69
25	7	RLO	74	63	68
59	2	RLO	69	67	68
9	6	RLO	64	65	64
15	7	RLO	53	75	64
A14	4	RLO	50	74	62
73	4	RLO	59	63	61
46	4	RLO	60	61	60
Altered (30-59)					
38	7	RLO	57	59	58
11	4	RLO	68	44	56
56	7	RLO	57	53	55
17	4	RLO	58	49	53
A20	4	RLO	52	54	53
65	9	RHO	64	41	52
16	7	RLO	49	55	52
A3	7	RLO	56	49	52
A21	2	RLO	60	40	50
8	4	RLO	59	35	47
71	4	RLO	50	43	46

Site#	SW	Code	Channel Condition	Riparian Zone Condition	Composite Function Score
A17	4	RLO	52	39	46
A2	6	RLO	54	37	45
24	6	RLO	52	38	45
A19	4	RLO	55	36	45
33	5	RLO	58	32	45
7	7	RLO	37	50	44
45	9	RHO	53	25	39
12	7	RLO	42	34	38
26	9	RHO	34	34	34
50	7	RLO	37	29	33
A9	7	RLO	32	33	32
27	6	RLO	37	27	32
6	7	RLO	39	23	31
Severely Altered (0-29)					
53	9	RHO	32	26	29
55	9	RHO	36	15	26
70	2	RLO	40	11	26
5	7	RLO	24	27	25
14	9	RHO	34	15	24
74	9	RHO	26	22	24
A12	9	RHO	41	7	24
31	9	RLO	27	20	23
34	9	RHO	30	16	23
20	6	RLO	23	21	22
A11	9	RHO	34	11	22
66	9	RHO	28	17	22
44	2	RLO	37	8	22
61	9	RLO	25	19	22
32	9	RLO	19	24	22
42	9	RHO	32	11	22
A25	7	RLO	26	17	21
47	7	RLO	16	23	19
18	9	RHO	26	12	19

Site#	SW	Code	Channel Condition	Riparian Zone Condition	Composite Function Score
A13	9	RLO	19	19	19
69	9	RLO	21	14	17
37	5	RLO	25	8	16
A16	9	RLO	20	12	16
A6	9	RHO	21	6	14
68	7	RLO	16	11	14
51	9	RLO	15	10	13

APPENDIX C

DWQ Monitoring Report

Division of Water Quality
Biological Assessment Unit
May 24, 2004

MEMORANDUM

To: Jimmie Overton

Through: Trish Finn MacPherson

From: Cathy Tyndall

Subject: Biological Monitoring of Bear Swamp and Mill Branch Watersheds (Lumber Subbasin 51), Environmental Enhancement Program, March 2004.

BACKGROUND

Purpose

This survey was conducted to provide biological sampling data for the Environmental Enhancement Program (EEP**)** as part of the comprehensive watershed assessment of the Bear Swamp and Mill Branch watersheds. The Special Watersheds Project Unit of the Planning Branch provided the Biological Assessment Unit (BAU) with a list of recommended monitoring sites on Bear Swamp, two tributaries to Bear Swamp (Moss Neck Swamp and Watering Hole Branch), and Mill Branch**.**

Benthic sampling was conducted in the upper reaches of the watersheds where there was adequate flow and distinct channels. EPT samples were collected since there were no known stressors.

General Watershed Description and Historical Sampling

Subbasin 51 contains the mainstem of the Lumber River from its source plus many small tributary systems. Though its headwaters are within the Sandhills ecoregion, the Lumber River flows through the Southeastern Floodplains and Low Terraces ecoregion that includes river swamp forests and blackwater floodplains. The tributary sites are swamp streams, which exhibit less relief, and usually have very little flow during summer months. A majority of the subbasin remains forested. According to the 2002 Lumber River Basin Basinwide Assessment Report, landuse in subbasin 51 is mostly forest/wetland (57%) and agriculture (41%).

All ambient water quality monitoring sites in subbasin 51 are located on the Lumber River mainstem. No sites are located on tributary streams.

Historical Data

Benthic macroinvertebrates have been sampled on Bear Swamp at SR 1339 in 1996 (winter) and 2001 (winter and summer) for basinwide sampling (Table 1. and Figure 1.). SR 1339 is located approximately ten miles downstream of NC 710, where Bear Swamp was sampled in 2004. SR 1339 is the most downstream road crossing on Bear Swamp and is located approximately 0.5 miles above the confluence with the Lumber River.

The two winter samples from 1996 and 2001 had similar fauna and BI values. The characteristics of the samples were similar to reference swamp streams in the area and indicated natural swamp conditions. Unusual taxa from winter were *Shipsa rotunda*, a stonefly, and *Rhyacophila* near *lobifera*, a caddisfly. The summer 2001 sample, which was sampled using EPT methods, could not be rated due to its small size. However, the EPT taxa richness of 11 for such a small stream did not suggest major degradation. The low dissolved oxygen (3.3 mg/L) in July 2001 was probably why only facultative taxa were abundant.

Table 1. Summary of historical BAU sampling in the Bear Swamp watershed, Robeson County, 1996 and 2001.

	Bear Swamp SR 1339 3/14/96	Bear Swamp SR 1339 2/8/01	Bear Swamp SR 1339 7/18/01
Ephemeroptera	8	8	6
Plecoptera	4	2	-
Trichoptera	8	7	5
Coleoptera	5	6	-
Odonata	6	11	-
Megaloptera	0	0	-
Diptera: Chironomidae	15	23	-
Misc. Diptera	3	3	-
Oligochaeta	2	4	-
Crustacea	3	5	-
Mollusca	4	6	-
Other	0	4	-
Total Taxa Richness	58	79	11
EPT Richness	20	17	11
EPT Abundance	100	115	64
Biotic Index	6.13	6.23	6.31
Bioclassification	Natural	Natural	Not Rated
Sample Type	Swamp	Swamp	EPT

METHODS

Benthos

On March 4, 2004, benthic macroinvertebrates were collected at four sites using the Division of Water Quality's EPT method. The EPT sampling method consists of one kick, one sweep, one leaf pack, and visuals. Only EPT taxa are collected.

EPT taxa richness (EPT S) criteria have been developed by DWQ to assign water quality ratings (bioclassifications) for EPT samples. "EPT" is an abbreviation for Ephemeroptera + Plecoptera + Trichoptera, insect groups that are generally intolerant of many kinds of pollution. Higher EPT taxa richness values usually indicate better water quality. EPT sample ratings were based only on EPT taxa richness. Criteria for Coastal A streams were used.

The purpose of these collections is to inventory the aquatic fauna and produce an indication of the relative abundance for each taxon. Organisms are classified as Rare (1-2 specimens, denoted by "R" on taxa tables), Common (3-9 specimens, "C"), or Abundant (≥10 specimens, "A").

Habitat Evaluation

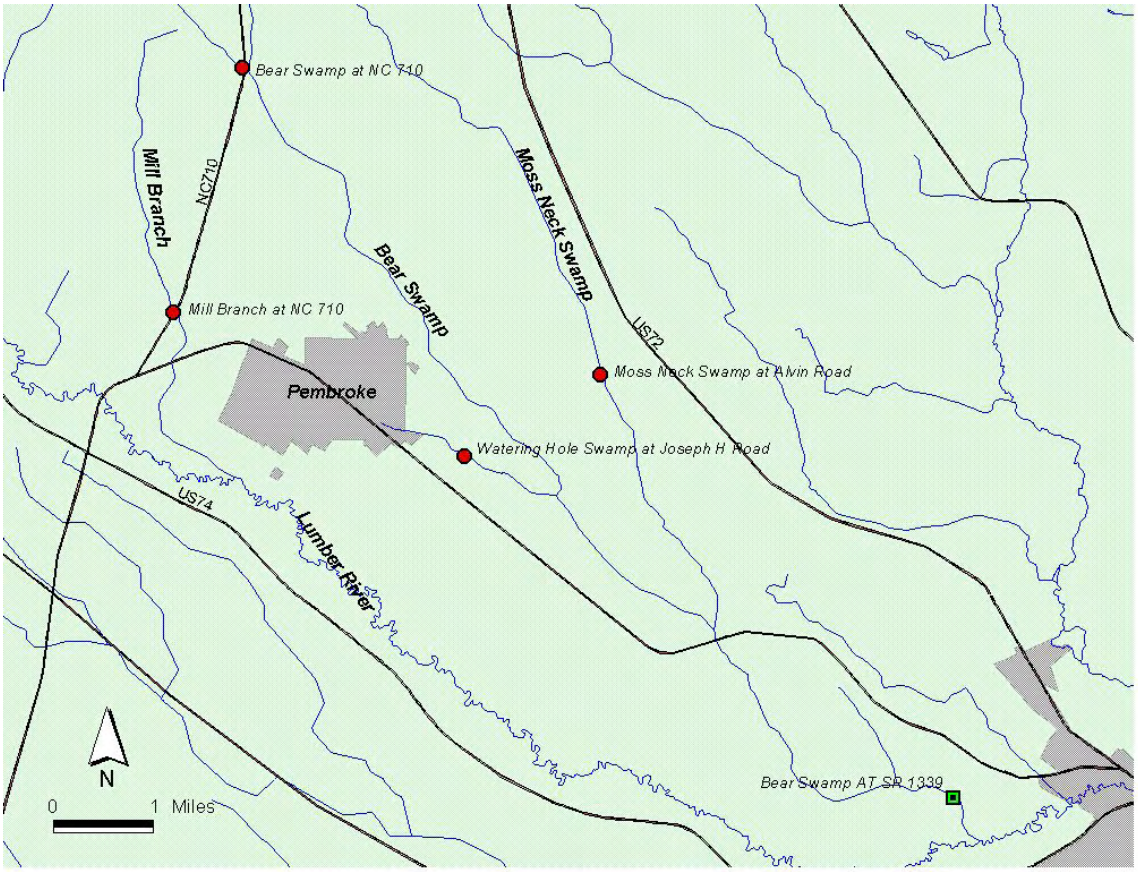
Habitat evaluations were made using the Biological Assessment Unit's Habitat Assessment Field Data Sheet for Coastal Plain Streams. This assessment assigns a numerical score from 0-100 for the reach of stream sampled, based on channel modification, instream habitat, bottom substrate, pool variety, bank stability and vegetation, light penetration, and width of the riparian zone. No criteria have been developed to rate habitat scores, but the higher the score, the better the overall habitat.

Streams within ecoregion types and size categories can be compared to one another and to reference sites. Habitat assessment also provides baseline information on stream conditions so that changes resulting from natural or human causes can be identified or predicted.

Physical-Chemical

Field measurements were taken at the time of sampling for temperature, dissolved oxygen, conductivity, and pH using a YSI 85 meter and an Accumet pH meter.

Figure 1. Benthic Macroinvertebrate Sampling Sites in the Bear Swamp and Mill Branch Watersheds.



SITE DESCRIPTIONS
Bear Swamp at NC 710

At this location, the stream was 3 meters wide and the drainage area is 4.3 square miles. The stream bordered a grassed church lawn on the right bank. The substrate was mostly sand and silt with a small amount of detritus. The riparian zone on the left bank was wide and swamp-like. The predominate habitat for benthos was snags, logs and leafpacks. Root mats and undercut banks were rare. Conductivity was 94 µmhos/cm and the habitat scored 63.

Watering Hole Swamp at Joseph H. Road

This small tributary to Bear Swamp was 1 meter wide and the drainage area is only 0.8 square miles. Though Watering Hole Swamp drains the town of Pembroke, the conductivity (71 μmhos/cm) was lower at this site than any other in the study. The average depth was .6 meters and the substrate was mainly sand with a small amount of silt. The habitat score was 61.

Moss Neck Swamp at SR 1570

This tributary to Bear Swamp drains much of the northern part of the Bear Swamp watershed. The stream width at this site was five meters and the drainage area is approximately 3.5 square miles. The Moss Neck catchment is primarily agricultural with scattered housing. Much of the stream is channelized and is maintained by a drainage district. The low habitat score (39) was due to channelization, absence of pools, steeply eroded stream banks, partial shading, and a narrow riparian zone on both banks. The conductivity was 82 μmhos/cm.

Mill Branch at NC 710

Mill Branch is a tributary to the Lumber River. This mostly rural watershed is 3.8 square miles. At this location, the stream width was five meters. The substrate was mostly sand and the remainder was silt. Undercut banks and root mats were rare; the most abundant habitats were snags and leafpacks. This reach scored 61 for habitat, reflecting moderate streambank erosion, good shading and the presence of some pools. The riparian zone was 12-18 meters in width on both banks and contained breaks. The site is directly below a railroad trestle crossing Mill Branch. The conductivity was 104 μmhos/cm, the highest value in the study.

RESULTS AND DISCUSSION
Bear Swamp at NC 710

Fourteen EPT taxa were collected including several intolerant and unusual caddisfly taxa (*Rhyacophila lobifera* (Abundant), *Oecetis* sp *E*, and *Ceraclea tarsipunctata*. *Shipsa rotunda*, an uncommon winter stonefly was also found in Bear Swamp. The site rated Good-Fair and the EPT BI was 5.74. *Stenonema modestum*, a tolerant mayfly, which is generally considered ubiquitous, was not collected. Of the four sites sampled in the study, the habitat and riparian zone of Bear Swamp appeared the most swamp-like. This would explain the absence of *S. modestum*, which is flow dependant. It is likely that Bear Swamp may stop flowing during the summer months. If this stream does stop flowing during summer months, it is likely the EPT richness would be lower than a stream that flows all year. Considering the small drainage area, 14 EPT taxa (including some unusual and relatively intolerant taxa), and the possibility that the flow is not consistent throughout the year, indicates a minimally to moderately impacted watershed.

Watering Hole Swamp At Joseph H. Road

Only one EPT taxon was collected at this site, *Ironoquia punctatissima,* a tolerant caddisfly. *I.punctatissima* is capable of living in temporary streams and pools. Since the drainage area of Watering Hole Swamp at this location is less than one square mile, it is likely than this stream experiences low or no flow during dry periods. In addition, Watering Hole Swamp receives runoff from the Town of Pembroke and the possibility of toxic input to the stream cannot be ignored. Watershed size, low flow, and possible toxic inputs could all affect the number and diversity of benthic macroinvertebrates in Watering Hole Swamp.

Table 2. Benthic Macroinvertebrate Results and Site Characteristics. Bear Swamp and Mill Branch Watersheds, March 2004. Lumber River Basin, Subbasin 51, Robeson County.

	Bear Swamp NC 710 3/4/04	**Watering Hole Swamp Joseph H Road 3/4/04**	**Moss Neck Swamp SR 1570 Alvin Rd 3/4/04**	**Mill Branch NC 710 3/4/04**
Biological Community				
Ephemeroptera	4	0	6	3
Plecoptera	2	0	1	1
Trichoptera	8	1	7	5
EPT Richness	14	1	14	9
EPT Seasonal Correction	12	1	13	8
EPT Abundance	63	3	70	24
EPT Biotic Index	5.74	7.8	4.54	5.46
Bioclassification	Good-Fair	Not Rated	Good-Fair	Fair
Sample Type	EPT	EPT	EPT	EPT
Long-lived Intolerant Stoneflies	Absent	Absent	Absent	Absent
Philopotamid Caddisflies	Absent	Absent	Present, but rare	Present, but rare
Habitat				
Stream Width (m)	3	1	5	5
Drainage Area (sq. miles)	4.3	0.8	3.5	3.8
Depth-Average (m)	0.4	0.6	0.6	0.2
Canopy %	50	50	0	70
Substrate (%)				
Boulder	0	0	0	0
Rubble	0	0	0	0
Gravel	0	0	10	0
Sand	40	90	55	70
Silt	50	10	35	30
Habitat Score (0-100)	63	61	39	61
Physical				
Temp (°C)	16	14	15	15
DO (mg/L)	6.4	7.0	7.6	4.4
Conductivity (μmhos/cm)	94	71	82	104
pH	5.8	6.2	5.9	5.9
General/Location				
Latitude	344338	344018	344060	344132
Longitude	791241	791022	790857	791324

The presence of long-lived stoneflies indicates constant good water quality and quantity.
Philopotamid caddisflies are intolerant and are collected at sites exhibiting good water quality

Moss Neck Swamp at SR 1570
Fourteen EPT taxa were collected in Moss Neck Swamp, the same number as in Bear Swamp. This site rated Good-Fair and the EPT BI (4.54) was the lowest of all sites in the survey. Notable taxa collected were the stonefly, *Shipsa rotunda,* and the caddisfly, *Chimarra* sp. *Chimarra* is considered a pollution intolerant caddisfly and is generally restricted to streams exhibiting good water quality. Moderately tolerant taxa were also collected in Moss Neck Swamp that were not found at the other sites. For example, *Eurylophella doris*, a seasonal mayfly and *Hydropsyche decalda*, a caddisfly were both abundant. *Stenonema modestum*, which was absent at Bear Swamp, was abundant. The presence and abundance of *S. modestum* indicates that this site may flow all year. Since this stream had obviously been channelized, it is likely that it continues to flow all year and would positively affect the EPT richness. Moss Neck Swamp scored the lowest in habitat due to poor riparian zone, channelization, steeply eroding streambanks and partial shading at the site. Evidently, water quality and habitat in the upper reaches of the watershed is good enough to support a Good-Fair benthic community.

Mill Branch
The sample from Mill Branch contained fewer EPT taxa (9) than Bear Swamp or Moss Neck Swamp (14) and rated Fair. However, the EPT BI was lower at this site (5.46) than in Bear Swamp ((5.74), but higher than Moss Neck (4.54). *Chimarra*, although rare in abundance, was collected in Mill Branch and not in Bear Swamp. *Isoperla transmarina*, a moderately tolerant seasonal stonefly, was collected at this site, but at no other site in the study. Most of the EPT taxa collected were moderately tolerant.

CONCLUSIONS
1. There is no indication of severely degraded water quality in Bear Swamp, Moss Neck Swamp or Mill Branch. The benthic samples were indicative of moderately impacted watersheds. Long-lived stoneflies were not collected at any of the sites, but intolerant taxa were collected in addition to moderately intolerant and tolerant taxa. The drainage areas are small (4.3 to 3.5 square miles) and this could limit the taxa richness and abundance. The EPT taxa richness would also be reduced if the streams stop flowing during the summer months.

2. EPT criteria for coastal plain streams were used to determine the ratings. If the streams are swamps, the more rigorous coastal plain rating criteria would make the streams appear worse than they really are. Therefore, it would be advisable to conduct a hydrological investigation to see if flows stop during summer months at the locations sampled in this study.

3. It is somewhat more difficult to assess Watering Hole Branch. Since the drainage area is very small (0.8 square miles), lower EPT abundance would be expected. It is highly probable that Watering Hole Branch experiences reduced or no flow during dry periods. In addition, Watering Hole Swamp receives runoff from the Town of Pembroke and the possibility of toxic input to the stream cannot be ignored. Watershed size, low or no flow, and possible toxic inputs could all affect the number and diversity of benthic macroinvertebrates in Watering Hole Swamp.

Cc: Jim Blose, Planning Branch
Rob Breeding, Planning Branch
Darlene Kucken, Planning Branch

Table 3. Benthic Macroinvertebrates Collected from the Bear Swamp and Mill Branch Watersheds, March 2004. R (Rare) = 1-2 specimens, C (Common) = 3-9 specimens, and A (Abundant) = ≥ 10 specimens.

	Bear Swamp 3/4/04 NC 710	Watering Hole Swamp 3/4/04 JOSEPH H ROAD	Moss Neck Swamp 3/4/04 SR 1570	Mill Branch 3/4/04 NC 710
EPHEMEROPTERA				
ACERPENNA PYGMAEA	C		A	C
BAETIS FRONDALIS	A		R	R
CAENIS SPP	R		R	
EURYLOPHELLA DORIS			A	
LEPTOPHLEBIA SPP			R	
STENONEMA MODESTUM			A	R
STENACRON INTERPUNCTATUM	R			
PLECOPTERA				
AMPHINEMURA SPP	A			
ISOPERLA TRANSMARINA (GR)				R
SHIPSA ROTUNDA	R		R	
TRICHOPTERA				
CERACLEA TARSIPUNCTATA	R			
CHEUMATOPSYCHE SPP	A		A	A
CHIMARRA SPP			R	R
HYDROPSYCHE DECALDA			A	
HYDROPSYCHE ROSSI			R	
IRONOQUIA PUNCTATISSIMA	A	C	R	C
OECETIS SPE	R			
PTILOSTOMIS SPP	R			
PYCNOPSYCHE SPP	C		A	C
RHYACOPHILA LOBIFERA	A			R
TRIAENODES IGNITUS	R		C	

DRAFT
18 April 2005

Water Quality Monitoring in the Bear Swamp Watershed - Lumber River 2004

Division of Water Quality
North Carolina Department of Environment and Natural Resources

March 2005

Prepared for the North Carolina Ecosystem Enhancement Program

Local watershed plans (LWP) developed by the North Carolina Ecosystem Enhancement Program (NCEEP) provide assistance to local governments and stakeholders on local watershed management issues including degradation of water quality, potential impacts of various land use practices, and the identification of opportunities for implementing best management practices and restoration efforts. The NCEEP assists stakeholders in the development of the long-term strategy to implement and evaluate the effectiveness of watershed protection recommendations proposed in the LWP. The NCEEP also assists the North Carolina Department of Transportation in meeting compensatory mitigation needs for stream, riparian buffer and wetland impacts while minimizing future adverse impacts on water quality. The Division of Water Quality assists in the development of the LWP by monitoring and evaluating the water quality in the local watersheds.

The Watershed Assessment Team (WAT) of the Division of Water Quality (DWQ) conducted ambient monitoring in the Bear Swamp watershed of the Lumber River Basin, January 2004 through September 2004 as part of the Bear Swamp/Lumber River Local Watershed Plan that the NC Ecosystem Enhancement Program (EEP) implemented in this watershed. North Carolina's 303(d) list (NCDENR 2003) classifies all of the Lumber River in this watershed as impaired due to mercury concentrations in fish tissues and the resultant fish consumption advisory. The Bear Swamp watershed lies within subbasin 03-04-51. Portions of the Bear Swamp watershed and streams flowing into it are designated as Water Supply Waters (WS-IV) and High Quality Waters (HQW). This summary documents monitoring activities and describes the major water quality patterns observed in this study.

I. DESCRIPTION OF STUDY PLAN

A. Site Locations and Characteristics.

Bear Swamp is a tributary of the Lumber River subbasin 03-04-51, cataloging unit 03040203, within the upper Lumber River Basin. The watershed (Figure 1) encompasses an area of approximately 52 square miles northwest of Lumberton and includes the 14-digit Hydrological Units (HU) 03040203050010 and 03040203030010. The drainage area lies totally within Robeson County and includes the Town of Pembroke, which lies on the border of the two hydrological units. Geologically, Bear Swamp and the other tributaries within the study area are swamp streams in the Southeastern Plains (Level III Ecoregion 65). About 60 % of the soils in the watershed are hydric, and the more well drained soils generally occur along the broad outer rims of the inter-stream divides adjacent to drainageways. Land cover is 61 to 68 % agricultural, 28 to 33 % natural, and the remaining percentage in residential and other uses (NCEEP 2004). One NPDES permit (Town of Pembroke) and two stormwater discharge General Permits (Buie Land Company and Fletwwod Homes of NC) have has been issued in the watershed.

B. Field and Laboratory Methods

The DWQ Watershed Assessment Team (WAT) conducted physicochemical monitoring at seven sites (Figure 1) during 2004 to provide water quality data in support of Phase II of the Lumber River Local Watershed Plan developed for this area by the EEP. Specific sites monitored during 2004 are shown in Table.

Sampling under base flow conditions occurred on an approximately monthly schedule at both sites from January 2004 through September 2004. Base flow conditions are defined as occurring at least 48 hours after measurable precipitation. Storm flow samples were collected from each site on August 12, 2004. Storm flow sampling occurred during the rising stage of stream flow. Additional samples were collected during storm flow on January 13, 2004, at Watering Hole Swamp and Jack's Branch for *Daphnia magna* feeding inhibition toxicity testing. Loss of the *Daphnia magna* culture prevented further feeding inhibition toxicity studies during the course of the monitoring program. Chemical and physical monitoring were followed protocols described in the Intensive Survey Unit's Standard Operating Procedures manual (NCDWQ 2003) and the DWQ Laboratory Section's sample submission guidance (NCDWQ 2002). All water samples were surface grabs collected at 0.15 meters depth.

Variables measured in the field included water temperature, dissolved oxygen concentration, percent oxygen saturation, pH, and specific conductance. Samples collected for other variables were submitted to the DWQ Laboratory for analyses. Laboratory analyses for base flow included nutrients and metals. Analyses for storm flow included residues and turbidity in addition to all of the field and laboratory variables measured for base flow. Laboratory methods and Practical Quantitation Limits (PQLs) for all analyses are provided in Table 2. All chemical analyses were conducted on unfiltered water samples and represent total concentrations within the water samples (i.e. both dissolved and suspended particulate fractions combined).

Daphnia magna feeding inhibition toxicity tests were conducted on stormwater samples by the DWQ Laboratory Section using the technique of McWilliam and Baird (2002).

C. Comparison of Data With State Water Quality Standards, EPA Benchmarks, or EPA Nutrient Ecoregion Reference Values

Field and laboratory data were compared with the North Carolina Water Quality Standards (NCWQS) for freshwater aquatic life, wherever standards existed for the specific variables examined. These are important regulatory benchmarks. The present study, however, was not concerned with regulatory compliance but with assessing the risks of site-specific impacts. Thus, we also compared our data with the more conservative NAQWC and nutrient ecoregion reference values from the EPA.

Nutrient concentrations were compared with reference values from the EPA's Aggregrate Ecoregion IX, Level 3 Ecoregion 65 for the inner coastal plain (USEPA, 2000). These reference values are calculated as the twenty-fifth percentile of all samples from the streams in the inner coastal plain ecoregion. Thus, seventy-five percent of the streams sampled in the inner coastal plains ecoregion had higher concentrations of nutrients than the reference values. This ecoregion spans the inner coastal plain regions from Maryland through North Carolina and to Mississippi. The concentrations of nutrients at the twenty-fifth percentile are used as a proxy for un-impacted streams and are considered protective of aquatic life and recreational activities by the EPA. However, these reference values do not represent the results of toxicological evaluations.

Metals concentrations were compared with the EPA's National Ambient Water Quality Criteria (NAWQC) (USEPA 2000a) and the EPA's Tier II values (USEPA, 1995). Acute NAWQC were established by the EPA to correspond to concentrations that would cause less than 50% mortality in 5% of the exposed populations in a brief exposure. Chronic NAWQC are the acute values divided by the geometric mean of at least three median lethal concentrations (LC_{50}). Tier II values were developed by EPA as part of the Great Lakes Program (USEPA, 1995) for use with chemicals for which NAWQC are not available and are based on less data. Chronic NAWQC were used to evaluate the baseflow metals concentrations measured in the Bear Swamp/Lumber River watershed.

The NAWQC for the metals cadmium, chromium III, copper, lead, nickel, and zinc are a function of water hardness. The hardness was calculated from the calcium and magnesium concentrations. In this study, Only four of thirteen metals analyzed were present above the practical quantitation limit (PQL). These included a single priority pollutant (copper) and three non-priority pollutants (aluminum, iron, and manganese). Benchmarks for copper were adjusted for site-specific hardness using the formulas recommended by the USEPA (1999). Benchmarks for the other three metals did not have hardness adjustments. The total recoverable metals concentrations of all four detectable metals were compared with published EPA benchmarks for chronic and acute toxicity to aquatic organisms (USEPA 2000b). The metals data and their relationship to the benchmarks must be interpreted cautiously. Since total rather than dissolved concentrations of metals were measured, bioavailability is difficult to assess fully. Additionally, organisms could be adapted to local concentrations of metals and be somewhat resistant to these metals. Adjusting benchmarks for hardness only partially addresses these issues.

II. SUMMARY OF OBSERVED PATTERNS

A. Comparison of Sites

1. **Field variables.** Ambient field conditions generally were relatively similar at most monitoring stations during the sampling period (Table 3). The greatest site-to-site differences observed among field variables were specific conductivity and dissolved oxygen.

    a. **Water temperature.** The observed ranges of base flow water temperatures at each site were normal for the respective times of the year in which sampling occurred. The lowest and highest summer temperatures occurred in the Lumber

River and at Watering Hole Swamp, respectively. These two sites also had the lowest and highest yearly average temperatures, respectively. Temperatures during storm flow ranged from 22.9 to 24.3 ^{o}C and averaged 23.4 ^{o}C over all five sites. Storm flow water temperatures were within approximately one degree C of the temperatures measured at the same sites during base flow on other dates during the summer.

b. **Specific conductivity.** Specific conductivity during base flow (Table 3) ranged from 69.8 µS/cm in Lower Bear Swamp to 480 µS/cm in Jack's Branch. Site means ranged from 73 µS/cm in Lower Bear Swamp to 197 at Jack's Branch. The maximum reading at Lower Bear Swamp was 79 µS/cm; this was less than the lowest readings measured at any of the other four sampling stations during base flow. Conductivity during storm flow ranged from 11.7 µS/cm at Watering Hole Swamp to 1463 µS/cm at Jack's Branch. Median and mean storm flow values over all sites were 78 and 342 µS/cm, respectively. The conductivities at three sites (Upper Bear Swamp, Moss Neck Swamp, and Watering Hole Swamp) were lower than the minimum readings observed during base flow.

c. **Dissolved oxygen.** Dissolved oxygen concentrations (Table 3) decreased at most sites with increasing water temperature. The lowest and highest dissolved oxygen concentrations as well as the lowest and highest sampling station averages occurred at Jack's Branch and Watering Hole Swamp, respectively. On four occasions, oxygen concentrations in Jack's Branch fell below the 4.0 mg/L minimum state standard for instantaneous oxygen measurements, and, on two occasions, fell below 1.0 mg/L (0.98 and 0.36 mg/L, respectively, on 7 July and 24 August). On these same dates, as well as three additional dates, dissolved oxygen was supersaturated at Watering Hole Swamp, in spite of the fact that water temperatures were higher at Watering Hole Swamp than at Jack's Branch. Water temperatures at Jack's Branch, however, were similar to those at the other sampling stations on the same dates. Oxygen concentrations during storm flow (8/12) ranged from 3.74 mg/L (Lower Bear Swamp) to 7.2 mg/L at Watering Hole Swamp and averaged 5.1 mg/L over all stations combined.

d. **pH.** The pH for all sites was slightly acidic and ranged from a low of 5.89 on one date at Jack's Branch to a high of 6.92 at Watering Hole Swamp (Table 3). Observed values were similar throughout the monitoring period at all sampling stations except Watering Hole Swamp, which exhibited a slight trend toward higher pH than the other stations. The pH values observed during storm flow all fell within the ranges of pH values for the same stations during base flow.

2. **Nutrients.** Nutrient concentrations varied substantially from site to site during both base flow and storm flow (Table 4). The greatest between-site differences observed were the concentrations of nitrate + nitrate nitrogen.

a. **Ammonia nitrogen.** Ammonia nitrogen concentrations (Table 4) during base flow varied from less than detectable (PQL = 0.02 mg/L) to a high of 0.86 mg/L

(Jack's Branch). Minimum readings at Jack's Branch (0.2 mg/L) were higher than any maximum readings for other sampling stations. Ammonia nitrogen concentrations during storm flow were below detection in three of the five sites.

b. Kjeldahl nitrogen. Kjeldahl nitrogen during base flow varied from 0.27 mg/L at Lower Bear Swamp to 1.7 mg/L at Jack's Branch (Table 4). Jack's Branch had the highest concentration measured for any sampling date or station and the highest average concentration over the entire sampling period. Kjeldahl nitrogen during storm flow ranged from 0.45 mg/L at Moss Neck Swamp to 1.4 mg/L at Watering Hole Swamp. Three of the five storm flow samples had Kjeldahl nitrogen levels higher than the maximum concentrations measured during base flow at the same stations. The storm sample from Watering Hole Swamp was more than twice the maximum measured at that site during base flow.

c. Nitrate + nitrite nitrogen. Concentrations of nitrate + nitrite nitrogen during base flow range from less than detectable (PQL = 0.02 mg/L) at the Lower Bear Swamp to 3.0 mg/L at Mill Branch and 3.3 mg/L at Moss Neck Swamp. Concentrations of nitrate + nitrite nitrogen during storm flow ranged from 0.03 to 0.51 mg/L at Lower Bear Swamp and Moss Neck Swamp, respectively. Concentrations measured during storm flow were substantially lower at all sites during storm flow than the maximum values measured during base flow at the same sites. This is should not be considered unusual, as nitrite and nitrate are common in shallow ground water, both in urban (Bruce and McMahon 1996) and agricultural areas (Gilliam *et al.* 1974; Karr *et al.*1998; Nolan 2001). Storm flow would have provided a dilution effect.

d. Total nitrogen. Highest total nitrogen (sum of TKN and nitrate + nitrite nitrogen) concentrations (Table 4) during base flow were 3.32 mg/L at Mill Branch (3/12) and Moss Neck Swamp (2/23); these two sites also had the highest average concentrations (2.46 and 2.55 mg/L, respectively). Total nitrogen during storm flow ranged from 0.84 to 1.71 mg/L, at Upper Bear Swamp and Watering Hole, respectively. Total nitrogen during storm flow was lower than the maximum base flow readings for all sites except Lower Bear Swamp.

e. Phosphorus. Total phosphorus (Table 4) during base flow ranged from less than detectable (PQL = 0.02 mg/L) at three stations to 0.14 mg/L at Jack's Branch; the highest site average was 0.087 mg/L at the Lumber River station. Average phosphorus concentrations also were high in Jack's Branch and Watering Hole Swamp (0.066 and 0.075 mg/L, respectively). Phosphorus during storm flow was substantially higher than the maximum concentrations measured for the same sites during base flow except at Moss Neck Swamp. Phosphorous is bound primarily on soil particulates and reflects the presence of soil particles in the water. High total phosphorus concentrations would therefore suggest possible upstream erosional conditions in the watershed, livestock wading in the stream, or some other disturbance that would result in increased soil particulates in runoff water.

3. **Residues and turbidity.** Residues and turbidity (Table 5), with the exception of a single turbidity measurement of 18 NTU on 1/14 at Moss Neck Swamp, were measured only during a single storm flow sampling at five sampling stations. The highest suspended, fixed, and total residue concentrations all occurred at Jack's Branch; the second highest concentrations of all of these variables occurred at Watering Hole Swamp. The two highest turbidity readings also occurred at these two sampling sites.

4. **Metals.** Analyses were conducted on unfiltered samples (total metals) for 13 metals (aluminum, arsenic, cadmium, calcium, chromium, copper, iron, lead, nickel, magnesium, manganese, mercury, and zinc). None of the more toxic metals (arsenic, cadmium, chromium, copper, lead, nickel, mercury, and zinc) except copper occurred above the detection limit (i.e., the PQL) in any samples collected during the monitoring period. Copper is discussed further below. Manganese is only moderately toxic and was above detection limits (PQL = 10 µg/L) in all but six samples, all of which were collected during base flow. Manganese and the less toxic metals (aluminum, calcium, iron, and magnesium) are discussed in more detail below and are summarized in Table 6. Copper was the only detectable metal listed by the EPA as a priority pollutant (USEPA 2000a).

   a. **Copper.** Copper was detectable (PQL = 2 µg/L) during base flow on three occasions (Moss Neck Swamp, 2.7 µg/L on 1/14/04; Watering Hole Swamp, 2.3 µg/L and Jack's Branch, 7.9 µg/L on 7/07/04) and during the August 12 storm flow sampling at two sites (4.40 µg/L at Watering Hole Swamp and 4.60 µg/L at Jack's Branch). Only the sample taken at Jack's Branch on July 7 exceeded the state water quality criterion of 7 µg/L. The copper concentration in this sample was two to three times higher than the maximum concentration observed during base flow at any of the other locations and nearly twice the maximum concentration observed during storm flow. It also was the only sample from Jack's Branch during base flow in which copper was above the detection limit. It is uncertain whether this value was real or possibly was be the result of sample contamination at some point during the sampling or analytical procedures. The presence of high specific conductivity, iron, manganese, phosphorus, ammonia nitrogen, and Kjeldahl nitrogen concentrations at Jack's Branch on this date suggests that some type of disturbance upstream may have temporarily increased the amount of suspended soil particles in the water column (turbidity was not measured). Therefore, the elevated concentrations of these variables seems to support the 7.9 µg/L copper reading on that date as being a real value rather than an artifact.

   b. **Aluminum.** Aluminum concentrations during base flow varied from 98 µg/L on January14 at Lower Bear Swamp to 2400 µg/L at Moss Neck Swamp on January 14 (Table 6). The lowest and highest average aluminum concentrations during base flow also occurred at these two stations, respectively. Aluminum concentrations during storm flow ranged from 170 to 3100 µg/L and were substantially higher than the maximum base flow concentrations, except at Lower Bear Swamp and Moss Neck Swamp. It is uncertain why the aluminum concentration was so high (about 14 times that measured during storm flow at that site) at Moss Neck Swamp on January 14. Iron and total phosphorous concentrations also were somewhat higher at that site on January 14, and turbidity (not measured during base flow at any time except on January 14 at this one site) was 18 NTU. The turbidity value was more than four times that measured at Moss Neck during storm flow. Field notes indicated that there had been activity of an all-terrain vehicle crossing the stream several times above the Moss Neck Swamp sampling station to knock out a beaver dam. Consequently, the unusual aluminum reading (as well as the high iron and phosphorus concentrations on that date) most likely reflected this disturbance and should not be considered reflective of normal ambient conditions. Elevated aluminum concentrations usually are indicators of erosion in the upper part of the watershed and usually do not pose any direct toxic threat to aquatic life.

c. **Calcium.** Calcium concentrations during base flow ranged from 3.8 mg/L at Upper Bear Swamp to 11 mg/L at Watering Hole Swamp (Table 6). Average concentrations also were lowest and highest, respectively, at these sampling stations. Calcium concentrations measured during storm flow ranged from 3.8 to 6.3 mg/L and averaged 5.26 mg/L over all sites; these values were lower than the minimum base flow concentrations at all stations except Lower Bear Swamp.

d. **Iron.** Iron measured during base flow ranged from 130 μg/L at Moss Neck Swamp and Watering Hole Swamp to 5200 μg/L at Jack's Branch (Table 6). Average concentrations were highest (2238 μg/L) at Jack's Branch. Iron concentrations during storm flow varied from approximately 50% of the maximum concentrations measured during base flow to about twice that of base flow for the respective sampling stations. High iron concentrations are indicators of soil erosion in the watershed and generally do not pose any toxic threat to aquatic life.

e. **Magnesium.** Magnesium concentrations during base flow (Table 6) ranged from 1.6 mg/L (Watering Hole Swamp) to 3.5 mg/L at Upper Bear Swamp and Mill Branch and averaged from 1.87 to 3.13 mg/L. Concentrations during storm flow ranged from 1.0 to 2.8 mg/L and exceeded the base flow minimum concentrations only slightly at two of the five stations.

f. **Manganese.** Manganese concentrations during base flow (Table 6) ranged from less than detectable (PQL = 10 μg/L) at three locations to 180 μg/L at Upper Bear Swamp. Concentrations during storm flow ranged from 24 to 170 μg/L. Manganese levels do not appear to be a threat to aquatic life at any of the sites.

B. Field and Laboratory Results Falling Outside the Accepted Range of State Water Quality Standards, EPA Benchmarks, or EPA Nutrient Ecoregion Reference Values

1. Variables lying outside state water quality standards (Table 9).

a. **Dissolved oxygen.** Dissolved oxygen concentrations fell below 5.0 mg/L (NC criterion for average daily oxygen concentrations) on three occasions each at both

Lower Bear Swamp and 2 and on four occasions at Jack's Branch. Two of the readings at Upper Bear Swamp and all four at Jack's Branch were below the 4.0-mg/L criterion for instantaneous oxygen measurement; two at Jack's Branch also were less than 1.0 mg/L. During storm flow, all three of these stations had oxygen concentrations less than 5.0 mg/L, and Lower Bear Swamp was less than 4.0 mg/L. These data suggest that oxygen impairment may be occurring at all three stations, but particularly so at Jack's Branch. None of the other stations had dissolved oxygen less than 5.0 mg/L at any time during base flow or storm flow.

b. **pH.** The pH dropped slightly below 6.0 on five occasions during base flow and three occasions during storm flow. All of these instances were borderline (5.89 to 5.96) and probably do not pose any substantial threat to aquatic life. Nitrate + nitrite was well below the standard at all sites on all occasions.

c. **Turbidity.** Turbidity did not exceed the 50 NTU state standard at any time during storm flow (not measured during base flow), but was equal to the state standard at Jack's Branch.

d. **Metals.** Copper exceeded the 7.0 μg/L state standard on only one occasion (Jack's Branch during base flow). The data suggest that copper is not a problem in any of the sites, with the possible exception of Jack's Branch. No samples exceeded the 200 μg/L state standard for manganese (for protection of water supplies) either during base flow or storm flow. Iron concentrations exceeded the 1000 μg/L (1.0 mg/L) state standard on 14 occasions during base flow and at four out of five sites during storm flow. High iron concentrations are not unusual in this part of the coastal plain because of the iron content of the soils in the watersheds. Elevated iron concentrations generally do not pose a toxicity problem, because they are associated largely with the suspended particulate fraction. All other metals fell below the PQL and, hence, could not be quantified. There is some concern that the PQL for cadmium (2.0 μg/L) is the same as the state water quality standard for that metal and, particularly, that the PQL for mercury is nearly 20 times greater than the state water quality standard. In general, metals do not appear to be a problem in these watersheds.

2. **Nutrient and turbidity levels exceeding EPA 25th percentile reference values.** The Lumber River/Bear Swamp watersheds monitored in this study fall within Ecoregion IX Level III Ecoregion 65 (Southeastern Plains). The 25th percentile values for the Level III Ecoregion 65 (Table 7) may be used for comparison as "reference values" that are somewhat representative of the streams in this ecoregion. A total of 42 samples was collected for nutrient analysis during base flow and compared with the 25th percentile reference values (Table 8). Kjeldahl nitrogen concentrations exceeded reference 30 times. Nitrite + nitrate nitrogen, total nitrogen, and total phosphorus exceeded the reference values 21, 31, and 25 times, respectively. During storm flow, these nutrients exceeded reference values at all sites, with the single exception of nitrite + nitrate nitrogen at Lower Bear Swamp. The single turbidity measurement during base flow at

Moss Neck Swamp on 1/14 and three of the five taken during storm flow exceeded reference.

3. **Metals exceeding EPA benchmarks.** Only four of the thirteen metals analyzed (see above) were present above the practical quantitation limit (PQL). These included a single priority pollutant (copper) and three non-priority pollutants (aluminum, iron, and manganese). The total recoverable metals concentrations of all four detectable metals were compared with published EPA benchmarks for chronic and acute toxicity to aquatic organisms (USEPA 2000b). Copper benchmarks were adjusted for hardness; benchmarks for the other three metals did not have hardness adjustments. Copper was detected in only three of 44 base flow samples and exceeded the hardness-adjusted benchmark values of 3.4 and 4.6 µg/L for both chronic and acute toxicity, respectively, in only the single sample from Jack's Branch (7.9 µg/L) on 7/7. Copper was detectable in all five storm flow samples but exceeded their respective hardness-adjusted chronic benchmark values only twice (Jack's Branch and Watering Hole). All 50 aluminum measurements exceeded the chronic benchmark value (87 µg/L); two base flow and three storm flow samples also exceeded the acute benchmark value (750 µg/L). Eighteen (41 %) of 44 iron analyses, including 14 during base flow and four of five storm samples (all except Moss Neck Swamp) exceeded the chronic benchmark value of 1000 µg/L. No acute benchmark value was published for iron. Only risk-based Tier II chronic and acute benchmark values were available for manganese. Three of 44 manganese analyses (one sample each during base flow from Upper Bear Swamp and Jack's Branch, both on 7/7, and one storm flow sample from Lower Bear Swamp) exceeded the 120 µg/L chronic benchmark. None exceeded the 2300 µg/L acute benchmark for manganese.

C. Ambient Toxicity Testing

The results of the feeding inhibition tests with *Daphnia magna* suggested that water quality in both Jack's Branch and Watering Hole Swamp may be impacted (Figure 2). During the 24-hour toxicant exposure (ambient water dilutions up to and including 100 % ambient water) phase, *D. magna* survival in 100% ambient water was 90% for Jack's Branch and 95 % for Watering Hole (Figure 2). Feeding (i.e., rate of ingestion of *Selenastrum capricornutum* cells by *D. magna*) at 100% ambient water was inhibited at these two sites approximately 16% and 62%, respectively. During the 4-hour feeding period following removal from the ambient dilutions, there was 100% survival of the remaining test organisms that had survived exposure to the undiluted ambient water. Feeding continued to decline precipitously in the Jack's Branch test organisms during the 4-hr feeding period following their removal from ambient water. Feeding of test organisms originally exposed to 100 % ambient water from Watering Hole Swamp was nearly equal to the controls during the 4-hr feeding period after removal from the ambient water. The poor recovery of *Daphnia magna* feeding during the 4-hur post-toxicant exposure period for Jack's Branch suggests that the overall adverse impacts on aquatic organisms may be greater at that location than at Watering Hole Swamp. This is reflected clearly in the LC50 and LC20 values calculated for each site (Table 10). The toxicology laboratory expressed some concern that low pH (5.95) and the presence of residual chlorine in the Jack's Branch ambient sample may have contributed to the effects observed at the higher sample concentration treatments. Isolation of effects due to pH or chlorine could not be determined from the data. Examination of water quality data for

1/14/04 from both sites does not suggest anything obvious that might help explain the continued feeding suppression during the 4-hour post-exposure feeding period for *Daphnia magna* previously exposed for 24 hours to the 100% ambient water from Jack's Branch.

III. CONCLUSIONS

- Water quality within the overall Bear Swamp watershed (inclusive of all sampling stations) does not appear to be particularly degraded, with the exceptions of Jack's Branch and Watering Hole Swamp.

- Jack's Branch had the poorest overall water quality and was followed by Watering Hole Swamp. This is based upon the frequencies of occurrence that nutrient and metal concentrations were highest at Jack's Branch and that dissolved oxygen and pH were lowest at Jack's Branch, compared with all of the other sampling stations on the same sampling dates.

- The primary causes of poor water quality at Jack's Branch appear to be low dissolved oxygen and, to a lesser extent, low pH (< 6.0). The low oxygen readings are a particular concern here as they occurred during mid-day through late afternoon, when dissolved oxygen should be at its maximum value. The low pH values, with one exception, also occurred during mid- to late summer and paralleled high water temperatures and extremely low dissolved oxygen readings. During these conditions, one also would expect find high dissolved carbon dioxide (not measured), which, in turn, would lower pH in the relatively unbuffered surface water in this watershed. Ammonia nitrogen was highest on all eight and total Kjeldahl nitrogen on five of eight sampling dates during base flow at this site. Specific conductivity also was highest at this location on more than half of the sampling dates. High conductivity is indicative of elevated concentrations of dissolved electrolytes. It also is possible that pesticide runoff (not measured) from a large golf course upstream from the monitoring station may have contributed to the degradation of water quality at this site. Examination of this possibility may be warranted.

- Dissolved oxygen concentrations consistently less than 5 mg/L observed on all sampling dates from July through September indicate that low dissolved oxygen may be a concern for both Bear Swamp stations.

- Nitrite + nitrate nitrogen concentrations were highest at Mill Branch (1.4 to 2.5 mg/L) and Upper Bear Swamp (0.12 to 2.2 mg/L). This raises concern as they were consistently higher throughout the study than the 0.095 mg/L EPA 25th percentile reference value, even though the North Carolina standard of 10 mg/L was not exceeded.

- The possible causes of generally poor water quality at Watering Hole Swamp are not clear from these data. Aluminum, manganese, and iron were highest at this site on 4, 3, and 2 sampling dates, respectively. Aluminum and iron are associated largely with suspended particulates, rather than the dissolved fraction. Kjeldahl nitrogen and nitrite + nitrate nitrogen were high during storm flow, but none of the nitrogen analyses (including ammonia) were elevated during base flow and probably are not a major concern here. Dissolved oxygen was supersaturated on six of the eight sampling dates and exceeded 84% saturation on the remaining two. Supersaturation of oxygen was accompanied by the highest water temperatures measured at any site during the summer. Supersaturated oxygen accompanied by high water temperatures usually is indicative of the presence of dense algal blooms. Total phosphorus also was highest at this site on five of eight sampling dates and would have been sufficient to stimulate filamentous algal blooms, even though nitrogen was not excessively high at this site. The pH in relatively unbuffered waters usually is very high (may exceed 9.0) during mid- to late afternoon when dense algal blooms are present. The pH values fell between 6.0 and 7.0 on all sampling dates at this location, however. This observation seems to contradict the hypothesis of algal blooms.

- Metals do not appear to be of significant concern in any of the Bear Swamp watersheds sampled during 2004. Calcium and magnesium are the common components contributing to water hardness and are essentially nontoxic. Manganese concentrations exceeded the EPA Tier II chronic benchmark in two base flow and a single storm flow sample, but did not exceed the state criterion for water supplies. Aluminum and iron were measured only as "total" metal. Both are common in the soils in this area and occur in the water column primarily bound to suspended soil particles and, hence, largely are not biologically available. All of the more toxic metals were below detection limits, except for copper on three occasions during base flow and twice during storm flow. Copper exceeded state water quality guidelines only on one occasion (Jack's Branch), and was below detection at that site on all other sampling occasions. This single sample also exceeded both the chronic and acute hardness-adjusted EPA benchmarks. The cause of this apparently anomalous copper reading could not be determined from the available data. Two samples during storm flow (Jack's Branch and Watering Hole Swamp) also exceed the hardness-adjusted chronic benchmark, but not the acute benchmark.

- Feeding inhibition tests with *Daphnia magna* suggested that water quality in both Jack's Branch and Watering Hole Swamp may be somewhat impacted. The toxicity data seem to support the previous conclusions about water quality at these two sites based on field and laboratory data. Dissolved organic compounds from urban runoff (not measured) into Watering Hole Swamp and possible pesticide runoff (also not measured) from the golf course into Jack's Branch may have contributed to the observed feeding inhibition. Some residual chlorine was detected in the Jack's Branch water during toxicity testing and also may have adversely impacted the *Daphnia magna* feeding. No comparison of ambient water column toxicity can be made between these and any of the other sites, however, as feeding inhibition tests were conducted only on water samples from Jack's Branch and Watering Hole Swamp.

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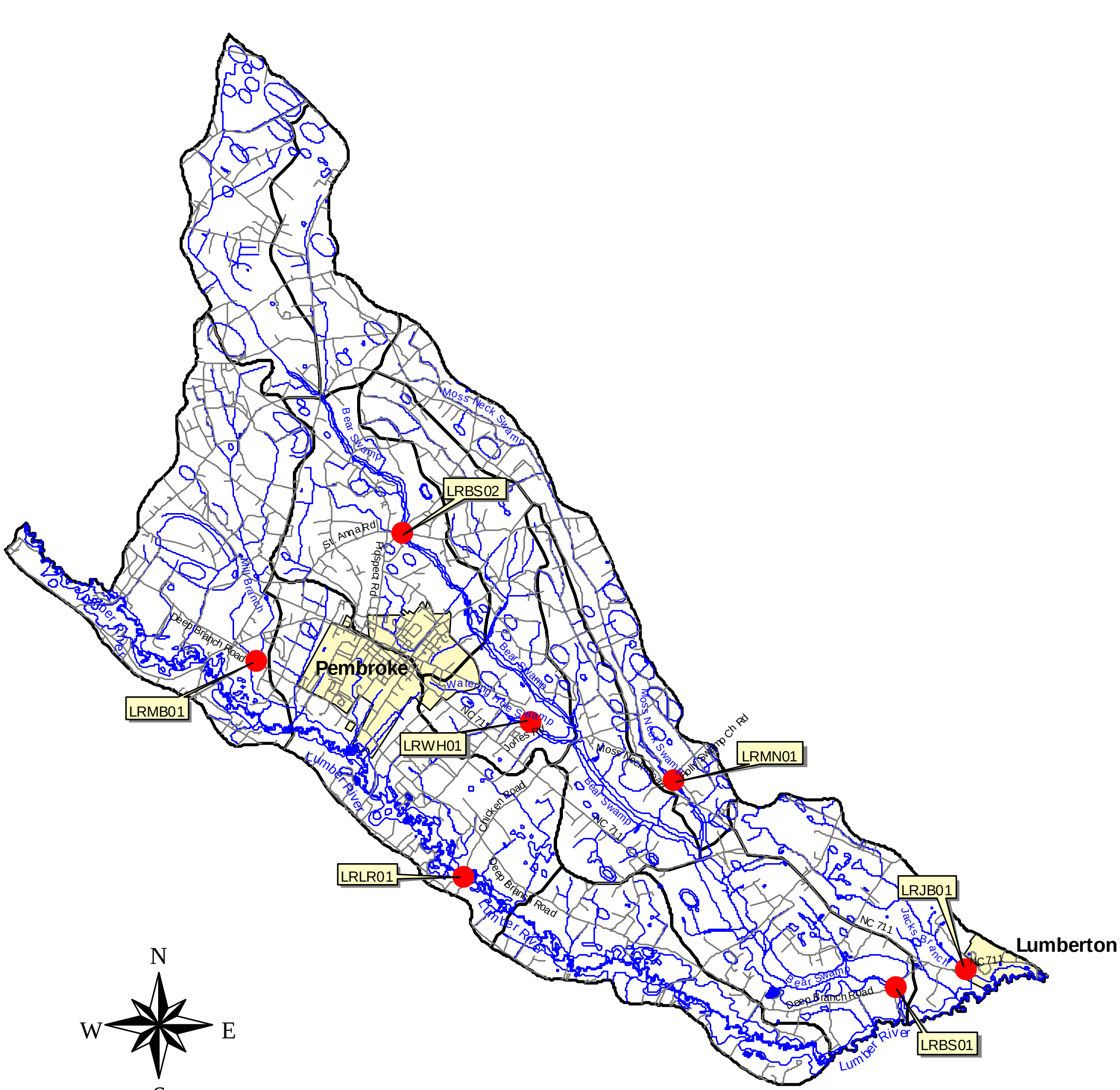


Figure 1. Lumber River watershed sampling stations for 2004.

Table 2. DWQ Laboratory Section – Methods and Practical Quantitation Limits (PQL).

Variable	EPA Method[1]	APHA Method[2]	Other Method	Practical Quantitation Limit (PQL)	Revision Date
Coliform, MF fecal	600/8-78-017	9222D		1colony/100mL	3/13/01
Total residue	160.3	2540B		10 mg/L	3/13/01
Total volatile residue	160.4			10 mg/L	3/13/01
Total fixed residue	160.4			10 mg/L	3/13/01
Turbidity	180.1	2130B		1NTU	3/13/01
NH3 as N	350.1 and 350.2		QUIK CHEM 10-107-06-1-J	0.02 mg/L	7/24/01
TKN as N	350.1 and 351.2		QUIK CHEM 10-107-06-2-H	0.20 mg/L (0.6 mg/L old value)	7/24/01
NO2+ NO3 as N	353.2		QUIK CHEM 10-107-04-1-C	0.01 mg/L (0.15 mg/L old value)	7/24/01
P total as P	365.1		QUIK CHEM 10-115-01-1-EF	0.02 mg/L (0.10 mg/L old value)	7/24/01
Cd	200.8 / 200.9 (11/16/04)			2.0µg/L	3/13/01
Cr	200.8 / 200.7			25µg/L	3/13/01
Cu	200.8 / 200.9 (11/16/04)			2.0µg/L	3/13/01
Ni	200.8 / 200.9 (11/16/04)			10µg/L	3/13/01
Pb	200.8 / 200.9 (11/16/04)			10µg/L	3/13/01
Zn	200.8 / 200.7			10µg/L	3/13/01
Al	200.7			50µg/L	3/13/01
Ca	200.7			0.10 mg/L	3/13/01
Fe	200.7			50µg/L	3/13/01
Mg	200.7			0.10 mg/L	3/13/01
Mn	200.8 / 200.7			10µg/L	3/13/01
As	200.8 / 200.9 (11/16/04)			5µg/L	11/4/04

[1]Information on EPA methods is available at http://h2o.enr.state.nc.us/lab/files/40cfr136_10_23_02.pdf.

[2]APHA methods reference: Standard Methods for the Examination of water and Wastewater, 18th Edition.

Table 3. Field variables in the Lumber River watershed during 2004.

	Base flow								Storm
Variable	Station Code	N	Min.	Max.	Median	Mean	Std.	Stderr.	(N = 1)
Water Temperature, °C	Lower Bear Swamp	8	4.6	26	17.65	16.83	7.507	2.654	22.90
	Upper Bear Swamp	8	7.3	26	18.65	17.53	6.68	2.362	23.00
	Jack's Branch	8	5.9	25.8	17.9	16.9	7.31	2.584	24.30
	Lumber River	3	4.6	22.6	13.3	13.5	9.002	5.197	
	Mill Branch	6	8	24.7	21.35	18.55	6.52	2.662	
	Moss Neck Swamp	7	5.9	24.1	16.8	16.93	6.529	2.468	23.30
	Watering Hole Swamp	8	7.5	30.5	20.2	19.36	8.01	2.832	23.60
	Storm*	5	22.9	24.3	23.300	23.420	0.563	0.252	
Specific Conductivity, μS/cm	Lower Bear Swamp	8	69.8	79	71.35	72.79	3.588	1.269	84.50
	Upper Bear Swamp	8	90.5	102.9	95.8	96.2	4.486	1.586	75.20
	Jack's Branch	8	83.2	480.4	164	197.36	130.08	45.99	1463
	Lumber River	3	133.8	137.6	135.5	135.63	1.9	0.912	
	Mill Branch	6	102	115.1	113.95	111.32	5.35	2.184	
	Moss Neck Swamp	7	85.3	97.5	87.8	89.74	4.681	1.769	78.00
	Watering Hole Swamp	8	94.9	110.8	97	99.86	6.11	2.16	11.70
	Storm*	5	11.7	1463	78.000	342.480	627.081	280.439	
Oxygen, mg/L	Lower Bear Swamp	8	4.11	9.92	6.69	6.87	2.333	0.825	3.74
	Upper Bear Swamp	8	3.49	10.45	6.02	6.34	2.732	0.966	4.26
	Jack's Branch	8	0.36	9.65	2.66	4.85	3.64	1.287	4.84
	Lumber River	3	7.76	11.41	9.35	9.51	1.83	1.057	
	Mill Branch	6	6.61	10.11	7.88	8.19	1.61	0.657	
	Moss Neck Swamp	7	6.42	11.05	9.57	9.03	1.742	0.658	5.47
	Watering Hole Swamp	8	7.00	13.42	10.77	10.42	2.38	0.841	7.20
	Storm*	5	3.74	7.2	4.84	5.10	1.339	0.599	

*Storm = average of all storm flow samples collected from all stations (collected Aug. 12, 2004).

Table 3. Field variables in the Lumber River watershed during 2004, cont'd.

	Base flow								Storm
Variable	**Station Code**	**N**	**Min.**	**Max.**	**Median**	**Mean**	**Std.**	**Stderr.**	**(N = 1)**
Oxygen, % saturation	Lower Bear Swamp	8	46.8	84.1	69	67.9	13.49	4.77	45.40
	Upper Bear Swamp	8	37.9	93.7	65.5	64.81	19.411	6.863	50.10
	Jack's Branch	8	4.4	87	45.05	45.95	30.48	10.776	58.80
	Lumber River	3	75.6	91.6	88.5	85.23	8.49	4.902	
	Mill Branch	6	85.8	98.2	82.85	86.13	8.72	3.56	
	Moss Neck Swamp	7	76.1	111.2	88.2	91.1	11.96	4.52	64.20
	Watering Hole Swamp	8	84.9	160	110.55	114.39	26.31	9.302	85.10
	Storm*	5	45.4	85.1	58.800	60.720	15.473	6.920	
pH, standard units	Lower Bear Swamp	8	5.96	6.39	6.14	6.15	0.131	0.046	6.37
	Upper Bear Swamp	8	6.06	6.44	6.3	6.29	0.123	0.043	6.16
	Jack's Branch	8	5.89	6.28	6.13	6.08	0.15	0.053	5.92
	Lumber River	3	6.25	6.74	6.35	6.45	0.26	0.15	
	Mill Branch	6	6.15	6.8	6.44	6.42	0.24	0.098	
	Moss Neck Swamp	7	5.95	6.41	6.18	6.2	0.161	0.061	6.19
	Watering Hole Swamp	8	6.28	6.92	6.46	6.55	0.23	0.081	6.43
	Storm*	5	5.92	6.43	6.190	6.210	0.201	0.090	

*Storm = average of all storm flow samples collected from all stations (collected Aug. 12, 2004).

Table. 4. Nutrients in the Lumber River watershed during 2004. (revised table)

	Base flow										Storm
Nutrient (mg/L)	**Station Code**	**N**	**N > det.**	**Min.**	**Max.**	**Median**	**Mean**	**SD**	**SE**		**(N = 1)**
Ammonia Nitrogen	Lower Bear Swamp	8	2	< 0 .02	0.02	0.01	0.013	0.005	0.003		< 0.02
(PQL = 0.02)	Upper Bear Swamp	8	5	< 0 .02	0.11	0.03	0.038	0.036	0.013		< 0.02
	Jack's Branch	8	8	0.06	0.86	0.19	0.265	0.268	0.100		0.11
	Lumber River	3	2	< 0.02	0.03	0.02	0.020	0.010	0.006		
	Mill Branch	6	5	< 0.02	0.06	0.02	0.025	0.018	0.007		
	Moss Neck Swamp	7	4	< 0.02	0.04	0.02	0.020	0.012	0.004		< 0.02
	Watering Hole Swamp	8	7	< 0 .02	0.07	0.03	0.030	0.018	0.006		0.14
	Storm*	5	2	< 0.02	0.14	0.01	0.056	0.064	0.029		
Kjeldahl Nitrogen	Lower Bear Swamp	8	8	0.27	0.83	0.67	0.591	0.231	0.082		1.0
(PQL = 0.2)	Upper Bear Swamp	8	8	0.32	0.67	0.51	0.491	0.128	0.045		0.70
	Jack's Branch	8	8	0.38	1.7	0.67	0.796	0.428	0.151		0.74
	Lumber River	3	3	0.31	0.58	0.42	0.437	0.136	0.078		
	Mill Branch	6	6	0.3	0.44	0.39	0.375	0.054	0.022		
	Moss Neck Swamp	7	7	0.3	0.68	0.37	0.404	0.137	0.052		0.45
	Watering Hole Swamp	8	8	0.28	0.6	0.41	0.413	0.098	0.035		1.40
	Storm*	5	5	0.45	1.4	0.74	0.860	0.487	0.218		
Nitrate + Nitrite Nitrogen	Lower Bear Swamp	8	1	< 0.02	0.26	0.01	0.04	0.089	0.034		0.03
(PQL = 0.02)	Upper Bear Swamp	8	8	0.12	2.2	0.565	0.844	0.703	0.274		0.14
	Jack's Branch	8	6	< 0.02	1.6	0.13	0.478	0.613	0.247		0.20
	Lumber River	3	3	0.25	0.46	0.27	0.327	0.116	0.067		
	Mill Branch	6	6	1.4	3.3	1.95	2.13	0.683	0.332		
	Moss Neck Swamp	7	7	1.5	3	1.9	2.143	0.591	0.217		0.51
	Watering Hole Swamp	8	8	0.27	1.5	0.69	0.764	0.414	0.179		0.31
	Storm*	5	5	0.03	0.51	0.230	0.250	0.210	0.094		

*Storm = average of all storm flow samples collected from all stations (collected Aug. 12, 2004).
**Total N = TKN + (Nitrate + Nitrite Nitrogen)

Table. 4. Nutrients in the Lumber River watershed during 2004, cont'd. (revised table)

	Base flow									Storm
Nutrient (mg/L)	**Station Code**	**N**	**N > det.**	**Min.**	**Max.**	**Median**	**Mean**	**Std.**	**Stderr.**	**(N = 1)**
Total N**	Lower Bear Swamp	8	8	0.28	0.84	0.675	0.631	0.196	0.069	1.03
	Upper Bear Swamp	8	8	0.58	2.61	1.175	1.335	0.637	0.238	0.84
	Jack's Branch	8	8	0.76	1.98	1.205	1.274	0.438	0.155	0.94
	Lumber River	3	3	0.67	0.85	0.770	0.763	0.090	0.052	
	Mill Branch	6	6	1.79	3.32	2.365	2.458	0.549	0.224	
	Moss Neck Swamp	7	7	1.98	3.32	2.200	2.547	0.588	0.222	0.96
	Watering Hole Swamp	8	8	0.72	1.78	1.065	1.176	0.358	0.127	1.71
	Storm*	5	5	0.84	1.71	0.960	1.096	0.350	0.156	
Total Phosphorus	Lower Bear Swamp	8	7	< 0.02	0.05	0.040	0.036	0.017	0.006	0.09
(PQL = 0.02)	Upper Bear Swamp	8	7	< 0.02	0.05	0.040	0.039	0.021	0.007	0.11
	Jack's Branch	8	8	0.03	0.14	0.060	0.066	0.041	0.015	0.27
	Lumber River	3	3	0.06	0.13	0.070	0.087	0.038	0.022	
	Mill Branch	6	6	0.02	0.06	0.040	0.040	0.018	0.007	
	Moss Neck Swamp	7	6	< 0.02	0.08	0.030	0.035	0.023	0.009	0.04
	Watering Hole Swamp	8	8	0.04	0.11	0.070	0.075	0.022	0.008	0.32
	Storm*	5	5	0.04	0.32	0.110	0.166	0.122	0.055	

*Storm = average of all storm flow samples collected from all stations (collected Aug. 12, 2004).
**Total N = TKN + (Nitrate + Nitrite Nitrogen)

Table 5. Residues and turbidity in the Lumber River watershed during 2004.* (table ok as is)

Station Code	Fixed Residue (mg/L)	Suspended Residue (mg/L)	Volatile Residue (mg/L)	Turbidity NTU
Lower Bear Swamp	4	6	< 2.5	3.6
Upper Bear Swamp	10	13	3	18
Jack's Branch	68	78	10	50
Moss Neck Swamp	3	3	< 2.5	4.0
Watering Hole Swamp	43	52	9	36
N	5	5	5	5
N > Det.	5	5	3	5
Min	3	3	< 2.5	3.6
Max	68	78	10	50
Median	10	13	3	18.0
Mean	25.6	30.4	4.9	22.3
S.D.	28.8	33.1	4.27	20.36
S.E.	12.9	14.8	1.91	9.11

*All samples were collected during storm flow.

Table 6. Concentrations of metals in the Lumber River watershed during 2004. (revised)-

Metals	Station Code	N	N > det.	Min.	Max.	Median	Mean	Std.	Stderr.	Storm (N = 1)
	Base flow									
Aluminum (μg/L)	Lower Bear Swamp	8	8	98	220	160	158.500	47.096	16.65	170
(PQL = 50 μg/L)	Upper Bear Swamp	8	8	110	210	170	166.250	39.978-	14.13	810
	Jack's Branch	8	8	140	320	285	256.250	71.101	25.14	3100
	Mill Branch	6	6	190	270	230	228.333	34.303	14.00	
	Moss Neck Swamp	7	6	230	2400**	310	638.571	785.354	296.84	170
	Watering Hole Swamp	8	8	190	920	360	395.000	228.286	80.71	2600
	Storm*	5	5	170	3100	810	1370	1387	620	
Calcium (mg/L)	Lower Bear Swamp	8	8	3.8	5.5	4.8	4.75000	0.62564	0.22120	6.30
(PQL = 0.10 mg/L)	Upper Bear Swamp	8	8	5.6	7.5	6.5	6.60000	0.61644	0.21794	5.00
	Jack's Branch	8	8	5.4	8.7	7.1	7.00000	1.25357	0.44320	3.80
	Mill Branch	6	6	7.7	9	8.45	8.36667	0.52409	0.21396	
	Moss Neck Swamp	7	7	5.7	7.1	5.9	6.08571	0.48452	0.18313	5.30
	Watering Hole Swamp	8	8	8.1	11	9.65	9.61250	0.83741	0.29607	5.90
	Storm*	5	5	5.3	6.3	5.3	5.26	0.96	0.43	
Iron (μg/L)	Lower Bear Swamp	8	8	140	1200	695	640.00	410.05	144.98	2400
(PQL = 50 μg/L)	Upper Bear Swamp	8	8	150	1700	935	855.00	555.00	196.22	1600
	Jack's Branch	8	8	490	5200	2150	2237.50	1625.82	574.81	2400
	Mill Branch	6	6	130	660	410	376.67	201.66	82.33	
	Moss Neck Swamp	7	7	130	970	430	431.43	310.24	117.26	420
	Watering Hole Swamp	8	8	580	1400	1100	1056.25	270.97	95.80	1500
	Storm*	5	5	420	2400	1600	1664	816	365	

*Storm = average of all storm flow samples collected from all stations (collected Aug. 12, 2004).
**If the 2400 μg/L reading on 1/14/04 is dropped, the Max. Median, mean, std., and stderr. are 520, 305, 345, 127, and 52, respectively.

Table 6. Concentrations of metals in the Lumber River watershed during 2004, cont'd. (revised)

	Base flow									Storm
Metals	Station Code	N	N > det.	Min.	Max.	Median	Mean	Std.	Stderr.	(N = 1)
Magnesium (mg/L)	Lower Bear Swamp	8	7	2	2.6	2.25	2.23750	0.206588	0.07304	2.80
(PQL = 0.10 mg/L)	Upper Bear Swamp	8	7	2.9	3.5	3.05	3.11250	0.210017	0.07425	2.20
	Jack's Branch	8	7	2.3	3	2.5	2.56250	0.255999	0.09051	1.20
	Mill Branch	6	5	2.9	3.5	3.1	3.13333	0.206559	0.08433	
	Moss Neck Swamp	7	6	2.5	3	2.6	2.62857	0.170434	0.06442	2.70
	Watering Hole Swamp	8	7	1.6	2.1	1.9	1.87500	0.148805	0.05261	1.00
	Storm*	5	5	1	2.8	2.2	1.98	0.84	0.38	
Manganese (µg/L)	Lower Bear Swamp	8	5	<10	30	17.5	16.5000	10.4745	3.703	170
(PQL = 10 µg/L)	Upper Bear Swamp	8	8	13	180	32.5	50.0000	55.0013	19.446	96
	Jack's Branch	8	7	<10	170	28	50.7500	52.8549	18.687	47
	Mill Branch	6	6	12	25	16.5	17.0000	4.4721	1.826	
	Moss Neck Swamp	7	5	<10	24	16	14.0000	7.1181	2.690	24
	Watering Hole Swamp	8	8	11	27	20	19.5000	6.2792	2.220	36
	Storm*	5	5	24	170	47	75	60	27	

*Storm = average of all storm flow samples collected from all stations (collected Aug. 12, 2004).

Table 7. EPA 25th percentile "reference" values for Aggregate Ecoregion IX Level III Ecoregion 45 streams.

Variable	Units	Number of streams	Range of Values for Level III Ecoregion 65 P25-all seasons	Min	Max
TKN	mg/L	554	0.3	0	4.138
NO2 + NO3	mg/L	518	0.095	0	5.077
Total N*	mg/L	65	0.618	0.33	2.938
Total P	mg/L	650	0.0225	0	1.735
Turbidity	NTU	173	6.2	0.25	100

*Reported values for total N.

Table 9. Numbers of samples exceeding or lying outside[1] of established NC water quality standards for freshwaters.[2] (revised)

Variables with established NC criteria	Criteria	Units	Sampling stations (base flow)													
			L. Bear S.		U. Bear S.		Jack's Br.		Lumber R		Mill Br.		Moss Nck.		Water. H.	
			N	N >	N	N >	N	N >	N	N >	N	N >	N	N >	N	N >
Field Measurements																
Dissolved oxygen[3]	5 (4)	mg/L	8	3 (0)	8	3 (2)	8	4 (4)	3	1 (0)	6	0 (0)	7	0 (0)	8	0 (0)
pH	6.0-9.0	std. Units	8	1	8	0	8	3	3	0	6	0	7	1	8	0
Nutrients																
Nitrate[4]	10	mg/L	8	0	8	0	8	0	3	0	6	0	7	0	8	0
Metals[5]																
Copper	7	µg/L	8	0	8	0	8	1			6	0	7	0	8	0
Iron	1000	µg/L	8	1	8	3	8	5			6	0	7	0	8	5, 1=
Manganese	200	µg/L	8	0	8	0	8	0			6	0	7	0	8	0
			Sampling stations (storm flow)													
			L. Bear S.		U. Bear S.		Jack's Br.						Moss Nck.		Water. H.	
			N	N >	N	N >	N	N >					N	N >	N	N >
Field Measurements																
Dissolved oxygen[3]	5 (4)	mg/L	1	1 (1)	1	1 (0)	1	1 (0)					1	0 (0)	1	0 (0)
pH	6.0-9.0	std. Units	1	0	1	0	1	1					1	0	1	0
Nutrients																
Nitrate[4]	10	mg/L	1	0	1	0	1	0					1	0	1	0
Miscellaneous																
Turbidity	50	NTU	1	0	1	0	1	1=					1	0	1	0
Metals[5]																
Copper	7	µg/L	1	0	1	0	1	1					1	0	1	0
Iron	1000	µg/L	1	1	1	1	1	1					1	0	1	1
Manganese	200	µg/L	1	0	1	0	1	0					1	0	1	0

[1]N > indicates the number of samples that either exceed or lie outside of the established criteria.
[2]All standards shown above are enforced by the NC Division of Water Quality. These standards are for protection of aquatic life, except where more stringent standards are listed for the water supply classification. Other variables monitored that do not have established NC standards are not listed below. Federal standards may exist for other variables monitored by the DWQ but are not enforced by the DWQ or listed above unless they also are on the NC standards list.
[3]Criterion of 5 mg/L is for daily average oxygen concentrations (not measured in this study); instantaneous oxygen readings; must be > 4 mg/L.
[4]Criterion is established for nitrate N only (analyses in current study measured nitrite + nitrate N; criterion also has been converted from 10,000 µg/L to 10 mg/L for ease of comparison with laboratory analyses.
[5]Only those metals above the detection limits (> PQL) are shown; the PQL for cadmium was = the NC criterion; the PQL for mercury was nearly 20 times greater than the criterion.

Table 1. Station locations, station codes, and brief descriptions for monitoring in the Lumber River, Bear Swamp watershed during 2004.

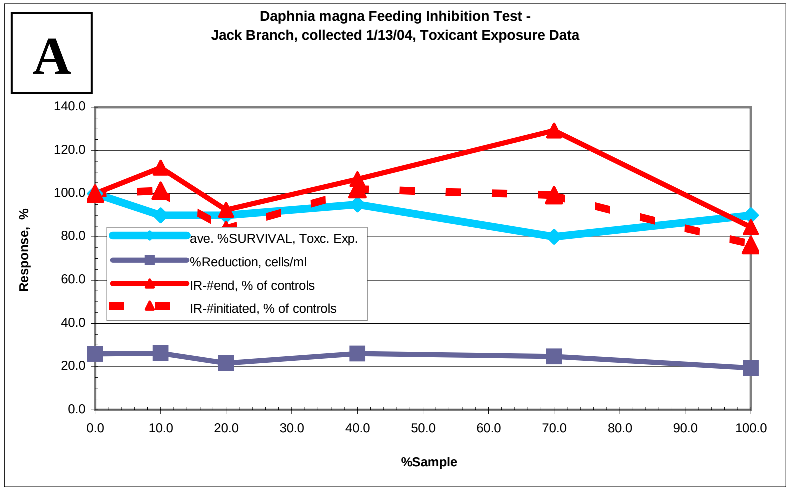
Station	Location	Station Code	Site Description
Lower Bear Swamp	SR 1339	LRBS01	Primarily rural, agricultural, drains Watering Hole Swamp
Upper Bear Swamp	Saint Anna Rd.	LRBS02	Rural, suburban development just above Pembroke
Jack's Branch	NC 711	LRJB01	Primarily rural, large golf course along creek
Lumber River	SR 1003	LRLR01	Largely rural, swamp forest, agricultural
Mill Branch	SR 1339	LRMB01	Mostly rural, agricultural, swamp forest
Moss Neck Swamp	Holly Swamp Church Rd.	LRMN01	Primarily rural, agricultural
Watering Hole Swamp	Jones Rd.	LRWH01	Urban drainage from Town of Pembroke

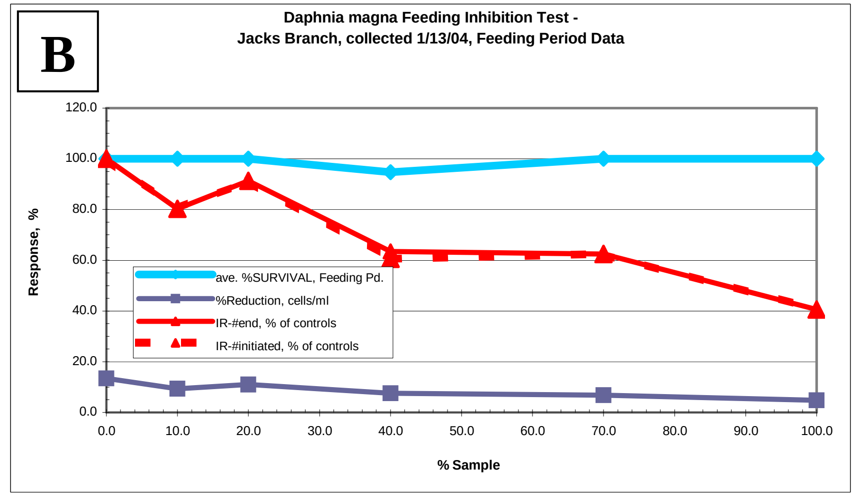
Table 8. Nutrient and turbidity values which were equal to or exceeded EPA 25th percentile "reference" values for Level III Ecoregion 65 streams. (revised)

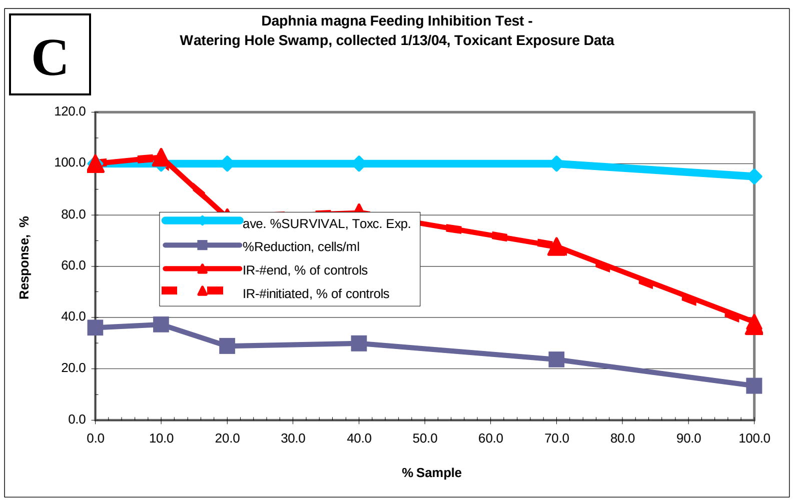
Variable	Base flow				Storm (N = 1)
	N	N = Ref.	N > Ref.	Mean > Ref.	(> Ref.)
Lower Bear Swamp					
TKN	8		6	Y	Y
NO2+NO3	8		1	N	N
Total N	8		6	Y	Y
Total P	8		5	Y	Y
Turbidity	0	-	-	-	N
Upper Bear Swamp					
TKN	8		8	Y	Y
NO2+NO3	8		8	Y	Y
Total N	8		8	Y	Y
Total P	8		5	Y	Y
Turbidity	0	-	-	-	Y
Jack's Branch					
TKN	8		8	Y	Y
NO2+NO3	8		4	Y	Y
Total N	8		8	Y	Y
Total P	8		8	Y	Y
Turbidity	1	-	-	-	Y
Lumber River					
TKN	3		3	Y	
NO2+NO3	3		3	Y	
Total N	3		3	Y	
Total P	3		3	Y	
Mill Branch					
TKN	6	1	5	Y	
NO2+NO3	6		6	Y	
Total N	6		6	Y	
Total P	6		4	Y	

Table 8, cont'd

Variable	Base flow				Storm (N = 1)
	N	N = Ref.	N > Ref.	Mean > Ref.	(> Ref.)
Moss Neck Swamp					
TKN	7	2	5	Y	Y
NO2+NO3	7		7	Y	Y
Total N	7		6	Y	Y
Total P	7		4	Y	Y
Turbidity	0	-	-	-	N
Watering Hole Swamp					
TKN	8		8	Y	Y
NO2+NO3	8		8	Y	Y
Total N	8		8	Y	Y
Total P	8		8	Y	Y
Turbidity	0	-	-	-	Y







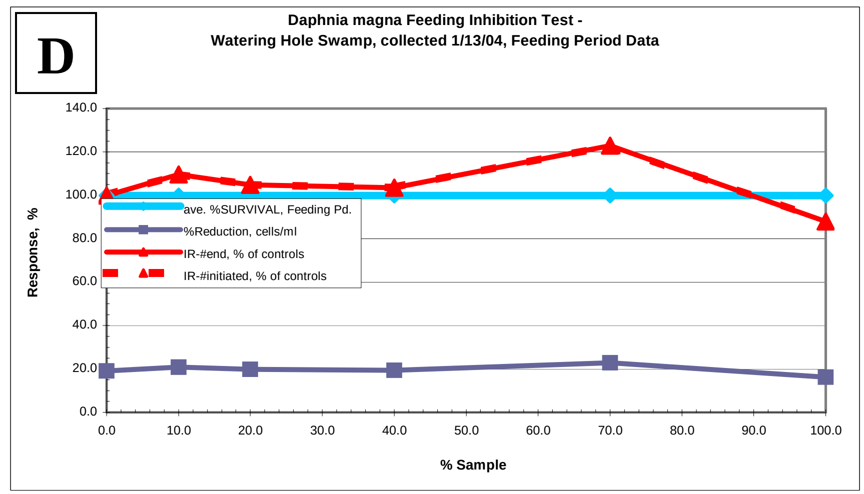


Figure 2. *Daphnia magna* feeding inhibition trials: A) Jack's Swamp toxicant exposure period; B) Jack's Swamp post-exposure feeding period; C) Watering Hole Swamp toxicant exposure period; D) Watering Hole Swamp post-exposure feeding period.

APPENDIX D

Mitigation Criteria

Stream Mitigation

The following discussion and definitions about mitigation and stream restoration are a compilation of information primarily from the April 2003 Stream Mitigation Guidelines published by the USACE Wilmington District. The guidance was prepared by a workgroup consisting of representatives from U.S. Army Corps of Engineers (USACE), Wilmington District, North Carolina Division of Water Quality (DWQ), U.S. Environmental Protection Agency, Region IV (EPA), Natural Resources Conservation Service (NRCS) and the North Carolina Wildlife Resources Commission (WRC).

At one time, compensatory mitigation for impacts to all aquatic systems was in the form of wetland mitigation. However, wetland mitigation does not provide appropriate replacement of aquatic functions lost due to impacts to stream systems. Because of this, the USACE and DWQ began to require that compensatory mitigation for impacts to stream resources should be in the form of restoration and/or enhancement of degraded stream channels. Stream restoration and enhancement is defined as follows:

Stream Restoration - The process of converting an unstable, altered, or degraded stream corridor, including adjacent riparian zone (buffers) and flood-prone areas, to its natural stable condition considering recent and future watershed conditions. This process should be based on a reference condition/reach for the valley type and includes restoring the appropriate geomorphic dimension (cross-section), pattern (sinuosity), and profile (channel slopes), as well as reestablishing the biological and chemical integrity, including transport of the water and sediment produced by the stream's watershed in order to achieve dynamic equilibrium. Examples include adding a stable pattern, dimension and profile to a channelized stream; add pools and riffles with in-stream structures.

Stream enhancement - The process of implementing certain stream rehabilitation practices in order to improve water quality and/or ecological function. These practices are typically conducted on the stream bank or in the flood prone area. Enhancement activities may also include the placement of in-stream habitat structures. Examples include fencing out livestock; planting wooded buffers without stream or stream bank modifications; install habitat structures; daylighting channel without altering pattern, dimension and profile with planted buffer and instream structures.

Stream/Buffer Preservation – Protection of ecologically important streams, generally, in perpetuity through the implementation of appropriate legal and physical mechanisms. Preservation may include the protection of upland buffer areas adjacent to streams as necessary to ensure protection or enhancement of the overall stream. Preservation must protect both sides of the channel. Generally, stream preservation should be in combination with restoration or enhancement activities. Under exceptional circumstances, preservation may stand alone where high value waters will be protected or ecologically important waters may be subject to development pressure. Stand-alone preservation may generally be most acceptable in mitigating impacts associated with nationwide and regional general permits. Preservation may be utilized for relatively undisturbed areas that require little or no enhancement activities other than protective measures.

FLEXIBLE STREAM MITIGATION

In urban areas, traditional stream mitigation may not be possible due to multiple landowners, physical constraints, or hydraulic (flooding) concerns. The regulatory agencies recognize that innovative approaches to controlling storm water and pollutant removal may provide benefits to water quality and aquatic life where traditional mitigation (as defined above) is not possible, these concepts are considered Flexible Stream Mitigation.

Where innovative approaches are approved, typically the project proponent will be required to document the benefits of the mitigation through development of a Watershed Management Plan and then monitoring. The specific mitigation credit that is generated from these innovative approaches will be determined by the regulatory agencies on a case-by-case basis. Watershed mitigation is essentially a program to provide long-term improvement and protection of an urban watershed with a variety of best management practices (BMPs), installation of aquatic habitat structures, and measures for improving public access and enjoyment.

The most important consideration for BMP selection for the watershed approach is the ability of the BMP to remedy the problem(s) identified in the watershed or sub-watershed assessment. For instance, if the problem identified is excess nutrient loading, one might consider utilizing an extended detention wetland, which is considered to be one of the better BMPs for nutrient removal. Similarly, it may be inappropriate to consider a dry detention pond, which is less effective at removing nutrients than other BMPs. In any event, BMPs must be considered on a case-by-case basis.

APPENDIX E

Potential Project Identification

Table E-1. Potential Projects

ProjNum	FigureNum	ECU_PT_1	ECU_PT_2	ECU_PT_3	ET_PT_1	ET_PT_2	STRM_STAT	PP_LENGTH	NUM_PARCEL	NUM_OWNERS	STREAM_NAM	SW_ID	TyStrmRest	TyStrmEnh	TyBuffRest	TyBuffEnh	TyAgBMP	TyLvstkBMP	TyStormBMP	TyWetRest	Group	Priority	ECU_SC_1	ECU_SC_2	ECU_SC_3
PP06	4	NS			NS		PER	1670	5	5	Bear Swamp	4				X					C	1			
PP08	5	R37			05-015		PER	1280	1	1	Little Bear Swamp	5	X		X						C	1	16		
PP19	7	R38			05-067	05-068	PER	3050	6	4	Ditch to, and Watering Hole Sw	7	X		X		X	X		X	C	1	58		
PP03	3	R44	R70		NS		INT	8000	2	1	UT to Lumber River	2	X		X		X			X	Int	2	22	26	
PP04	3	A21			03-045		INT	1510	2	2	UT Lumber River	2	X		X	X	X				Int	2	50		
PP16	7	R5			NS		INT	2610	3	3	UT to Bear Swamp	7	X		X		X	X			Int	2	25		
PP17	7	R68			NS		INT	4378	5	5	UT to Bear Swamp	7	X			X					Int	2	14		
PP14	7	R6	R50		NS		INT	4360	2	2	UT to Bear Swamp	7	X			X					DD	3	31	33	
PP15	7	A25			NS		INT	2500	5	5	UT to Bear Swamp	7	X			X					DD	3	21		
PP20	8	R32			NS		INT	4830	1	1	Moss Neck Swamp	9		X							DD	3	22		
PP21	8	R31	R61		NS		PER	1280	1	1	Moss Neck Swamp	9		X		X					DD	3	23	22	
PP22	8	NS			NS		PER	2340	5	5	Moss Neck Swamp	9		X		X					DD	3			
PP23	8	NS			NS		PER	1740	4	4	Moss Neck Swamp	9		X		X					DD	3			
PP24	9	A11			NS		PER	3890	4	4	Moss Neck Swamp	9		X		X	X				DD	3	22		
PP25	9	A12	R18	R34	NS		PER	1670	5	5	Moss Neck Swamp	9		X		X	X				DD	3	24	19	23
PP26	9	R66			NS		PER	2540	5	5	Moss Neck Swamp	9		X		X	X				DD	3	22		
PP27	9	R74			NS		PER	2530	5	5	Moss Neck Swamp	9		X		X	X				DD	3	24		
PP28	9	NS			NS		PER	1940	4	3	Moss Neck Swamp	9		X		X					DD	3			
PP01	3	NS			NS		PER	19450	>5	>5	Lumber River	2					X		X		Di	4			
PP02	3	NS			03-042		PER	16870	>5	>5	Lumber River	2					X		X		Di	4			
PP01a	3	NS			03-037		INT	10300	>5	>5	UT Lumber River	2					X		X		Di	4			
PP05	4	NS			NS		DIT	6340	>5	>5	Ditch Bear Swamp	4					X				Di	4			
PP07	5	NS			NS		INT	3190	>5	>5	Ditch Little Bear Swamp	5					X				Di	4			
PP11	6	NS			NS		INT	11960	>5	>5	Ditch to UT Bear Swamp	6					X		X		Di	4			
PP09	6	A10	R54		NS		PER	3540	>5	>5	Bear Swamp	6					X				Di	4	90	88	
PP10	6	R28	R30		NS		PER	1880	5	5	Bear Swamp	6					X				Di	4	86	88	
PP18	7	R25			05-066	05-067	PER	6398	>5	>5	Ditch to, and Watering Hole Sw	7					X				Di	4	68		
PP12	6	A2	R24	R27	05-049	05-050	INT	9800	>5	>5	Ditch and UT Bear Swamp	6							X		Sto	4	45	45	32
PP13	6	R21			NS		PER	3760	>5	>5	Ditch to, and Bear Swamp	6							X		Sto	4	92		

ABBREVIATIONS

Field lengths for attribute tables in the GIS are limited to 10 characters, so a list of abbreviations used in Tables 1 and 2 is included here.

C	Conventional Group
DD	Drainage District Group
Di	Ditch BMP group
DIT	Ditch
ECU_PT_X	Data point assessed according to ECU functional assessment protocol.
ECU_SC_X	Composite function score calculated for a data point
ET_PT_1	Point assessed for Earth Tech windshield survey
Int	Intermittent Stream Group
NS	Not sampled
NUM_OWNERS	Number of owners associated with parcels that compose a potential project site
NUM_PARCEL	Number of parcels associated with a potential project site
PP_LENGTH	Potential project length (in feet)
ProjNum	Potential project number
STREAM_NAM	Stream name
STRM_STAT	Stream status (intermittent or perennial) as classified in BasinPro
SW_ID	Sub-watershed ID number
TyAgBMP	Type of potential project-Agricultural BMPs
TyBuffEnh	Type of potential project-Buffer enhancement (increasing width of existing inadequate buffer)
TyBuffRest	Type of potential project-Buffer restoration (planting a buffer where absent)
TyLvstkBMP	Type of potential project-Livestock BMPs
TyStormBMP	Type of potential project-Stormwater BMPs
TyStrmEnh	Type of potential project-Stream enhancement
TyStrmRest	Type of potential project-Stream restoration
TyWetRest	Type of potential project-Wetland Restoration

DEFINITIONS

Some brief definitions are provided here for convenience. Stream classification, jurisdictional topics, regulatory policy, and watershed management techniques will be addressed in greater detail in the Critical Area Analysis and Solution Identification Report.

Agricultural BMPs	Best management practices applied to row crops. Includes conservation tillage, grassed waterways, field borders, fertilizer management, and cover crops. Also includes water control structures in ditches for enhanced denitrification. Where forested riparian buffers are not feasible, includes herbaceous or shrubby buffers along streams and ditches.
Buffer Enhancement	Increasing the width of an existing riparian buffer. May also include exotic species removal and management.
Buffer Restoration	Planting a forested riparian buffer where absent
Livestock BMPs	Best management practices applied to animal operations. Includes controlling livestock access to streams through fencing and alternate watering sources, maintaining buffers on streams, pasture rotation, and nutrient management.
Stormwater BMPs	Best management practices applied where concentrated areas of impervious surface are present, such as residential neighborhoods, business districts, industrial areas, and large public facilities such as schools and hospitals. Includes retention/detention ponds, rain gardens, level spreaders, constructed wetlands, rainwater collection systems, and green roofs.
Stream Enhancement	Engineered modifications to a perennial stream channel to restore two of the three characteristics of an unaltered stream-dimension, pattern, and profile. In this setting, dimension and pattern are the most likely to be restored.
Stream Restoration	Engineered modifications to a perennial stream channel to restore all three of the above characteristics. Given the long-term efforts to drain this watershed, restoration of profile is unlikely in most potential project locations.
Wetland Restoration	Where hydric soils are present, replanting of characteristic wetland vegetation and re-establishment of former wetland hydrologic regime, often by plugging drainage ditches and/or raising the bed elevation (profile) of a channelized stream.

NARRATIVE SITE DESCRIPTIONS

Potential Project 01 (PP01) is located along the Lumber River in SW02. PP01 was selected based on the presence of a ditch network that drains agricultural fields and low-density residential areas. Project possibilities include agricultural and stormwater BMPs. There were no sample sites within this project area.

Potential Project 01a (PP01a) is downstream of PP01 and was selected for the same reasons and project possibilities.

Potential Project 02 (PP02) is downstream of PP01a and also encompasses a large area of agricultural fields and low-density residential development. A ditch network drains this area and empties directly into the Lumber River. The river itself is well-buffered with a mixture of swamp forest and mixed forest approximately 25-50 years old.

Native and exotic species are found in the buffer. Native species include bald cypress (*Taxodium distichum*), red maple (*Acer rubrum*), swamp black gum (*Nyssa biflora*) and smartweeds (*Polygonum sp*.) along the wetland edges. Exotic species are present in this buffer and include Japanese honeysuckle (*Lonicera japonica*), Chinese privet (*Ligustrum sinense*), and multiflora rose (*Rosa multiflora*). Wetlands are present in some locations along the river.

Project possibilities include agricultural and stormwater BMPs.

Potential Project 03 (PP03) is immediately downstream of PP02 and includes an unnamed tributary and a ditch that run through an agricultural field, draining to the Lumber River. The ditch and UT lack adequate buffers, although a thin line of shrubs are growing in or along the channel. The UT is downstream from at least one roadside ditch lacking an associated detention basin and is backed up by a clogged culvert. The channel incision ratio is between 2.0 and 2.25 indicating the channel is severely incised.

Exotic species are present along the stream and include Chinaberry (*Melia azedarach*) and multiflora rose.

There appear to be no hydrologic constraints, so wetland restoration may be possible in this area. Other project possibilities include stream and buffer restoration for the UT and agricultural BMPs for the ditch and fields

The UT is currently mapped as intermittent, so project potential hinges on that classification.

Potential Project 04 (PP04) is a segment of an unnamed tributary to the Lumber River and is located in SW02. It is currently mapped as intermittent. The tributary passes through an agricultural field in this area. The buffer is variable and ranges from absent to greater than 50 feet along this stretch. Where forested, the buffer is generally composed of relatively young trees between 10 and 25 years of age. The channel incision ratio is approximately 1.47 indicating the channel is moderately incised. An unmapped ditch also appears to be present perpendicular to the right bank of the UT. A mapped ditch originates in the floodplain of the left bank and empties into the UT just downstream of the project area.

Native and exotic species are found in the buffer. Native species include red maple, sweetgum (*Liquidambar styraciflua*), swamp black gum, sweetbay (*Magnolia virginiana*), ti-ti (*Cyrilla racemiflora*), loblolly pine (*Pinus taeda*), and giant cane (*Arundinaria gigantea*). The primary exotic species found in the project area is Japanese honeysuckle.

Project possibilities in this area include stream restoration (if UT is found to be perennial), buffer restoration and enhancement, and agricultural BMPs.

Potential Project 05 (PP05) is located north of Bear Swamp in SW04. It contains a network of drainage ditches through agricultural fields. Project possibilities include agricultural BMPs to reduce sediment and nutrient inputs from the ditches to Bear Swamp.

Potential Project 06 (PP06) is located on Bear Swamp and is immediately south of PP05 in SW04. It was selected based on its similarities in land use to other sampled PPAs visible on aerial photography. Buffer enhancement is recommended along this reach.

Potential Project 07 (PP07) is located along an unnamed tributary of Bear Swamp in SW05. It was selected for the presence of ditches draining agricultural fields. Agricultural BMPs to reduce sediment and nutrient inputs from the ditches to the UT are recommended.

Potential Project 08 (PP08) includes a small segment of an unnamed perennial tributary to Bear Swamp in SW05. This tributary passes through an agricultural field. No buffer is present. The mean channel incision ratio is 2.5 for the tributary, indicating the channel is severely incised.

Project possibilities include buffer restoration and stream restoration, although probably not full hydrologic restoration.

Potential Project 09 (PP09) includes two ditches that empty into a high-quality segment of Bear Swamp in SW06. The ditches appear mainly to drain agricultural fields.

The riparian buffer along Bear Swamp in this area is young to mature forest extending greater than 50 feet from the stream edge. Native and exotic species are present in the buffer although native species predominate. Native species include red maple, swamp black gum, tulip poplar (*Liriodendron tulipifera*), water oak (*Quercus nigra*), willow oak (*Quercus phellos*), sweet bay, ti-ti, and Virginia willow (*Itea virginica*). The exotic species present include Chinese privet and wart-removing herb (*Murdannia keisak*). Of the two exotic species Chinese privet was by far the more common species.

Agricultural BMPs to reduce sediment and nutrient inputs from the ditches to Bear Swamp are recommended.

Potential Project 10 (PP10) adjoins PP09 on the east side of Bear Swamp. It also contains a ditch that drains an agricultural field and empties into Bear Swamp. Agricultural BMPs to reduce sediment and nutrient inputs from the ditch to Bear Swamp are recommended.

Potential Project 11 (PP11) is a large area along the western border of SW06 that drains to a long, north-south ditch network. This system crosses into SW02 and PP01, eventually emptying into the Lumber River. The ditches drain agricultural fields, small forest fragments, and scattered residential lots.

Agricultural and stormwater BMPs are recommended to reduce sediment, nutrient, and runoff inputs from the ditches to the Lumber River.

Potential Project 12 (PP12) includes an unnamed tributary to Bear Swamp in SW06 between the railroad tracks and N. Odum Dr. The tributary is currently mapped as intermittent. Land use in this area is a mixture of high and low density residential development, small agricultural fields, and forest fragments. Buffers along this tributary are primarily grass and typically 25 feet or less in width. A ditch feeding into the tributary is also present and transports pollutants and sediment to the stream.

The buffers are composed of primarily herbaceous species and exotic vegetation. Maintained grass lawns are the primary vegetation type with some native vegetation present such as rushes (*Juncus sp*.). Exotic species are present in the riparian area and include mimosa (*Albizia julibrissin*), Japanese honeysuckle, and multiflora rose.

Restoration of the tributary is not a viable option because of the high number of landowners in this area as well as physical constraints. Primarily stormwater BMPs are recommended, although some buffer enhancement may be possible.

Potential Project 13 (PP13) is on the east side of the railroad tracks and across from PP12. This project area includes a reach of Bear Swamp and a ditch feeding into Bear Swamp. Land use includes residential development and agricultural fields. The buffer along this segment of Bear Swamp is greater than 25 feet in width. It is composed of mature swamp forest and includes the following native species: bald cypress, swamp black gum, loblolly pine, red maple, tulip poplar, and swamp chestnut oak (*Quercus michauxii*). Exotics present in the buffer include Chinese privet and bamboo (*Phyllostachys* sp.).

Agricultural BMPs to reduce sediment and nutrient inputs from the ditch to Bear Swamp are recommended. Bear Swamp is in good condition in this area and is not in need of stream restoration of enhancement.

Potential Project 14 (PP14) encompasses a headwater stretch of an unnamed tributary to Bear Swamp in SW07. Streams and ditches are maintained by the Moss Neck Drainage District in this area. This site and all those in the Moss Neck drainage district were selected because of the deeply incised stream channels and lack of forested buffers along one or both sides of the selected reach. These sites also meet the criteria for length and number of landowners.

The UT, currently mapped as intermittent, flows through agricultural fields and forested stands. The riparian buffer in the forested stands is greater than 50 feet in width and is composed of predominantly young or successional forest. The buffer is primarily a mixed pine-hardwood forest composed of loblolly pine, red maple, water oak, red bay (*Persea borbonia*), sweet pepperbush (*Clethra alnifolia*), and horse sugar (*Symplocos tinctoria*). No exotic species were documented in this area.

Stream restoration opportunities in this reach are limited to experimental approaches such as the stream-within-a-stream technique, which may restore in-stream habitat and certain hydrologic functions without causing adverse impacts to adjacent farmlands. Buffer enhancement may be possible as well. Coordination with the Moss Neck Drainage District is essential to develop a solution for improving water quality in the district.

Potential Project 15 (PP15) is downstream of PP14 to the southeast on the same intermittent UT to Bear Swamp and is in the Moss Neck Drainage District. The channel has a channel incision ratio of 5.9 and is severely incised. The buffers are much narrower along this reach, and Japanese honeysuckle is present in low densities.

Project possibilities are the same as for PP14.

Potential Project 16 (PP16) is downstream of PP15 on the same UT to Bear Swamp in SW07. It is outside the Moss Neck Drainage District. This reach flows through an agricultural field and the buffer, consisting of young forest, is generally less than 10 feet wide. The channel incision ratio is approximately 2.8 indicating the channel is severely incised.

Buffer vegetation is composed of native and exotic species. Native species in the buffer include sweetgum, black willow, sweetbay, red maple, and loblolly pine. Exotic species encountered include wart-removing herb.

Although this reach is not within the drainage district, hydrologic constraints still exist because of the proximity of some structures to the stream. The project possibilities are the same as for a drainage district site, with the potential for full 50-foot buffer restoration. Agricultural and livestock BMPs are also recommended.

Potential Project 17 (PP17) is similar to PP16 and includes reaches of two unnamed tributaries to Bear Swamp in SW07. Both tributaries flow through agricultural fields. The buffer along these tributaries is extremely narrow to nonexistent. The channel incision ratio on the larger tributary is 4.4 indicating a severely incised channel. The small amount of buffer vegetation present is primarily grasses and other perennial herbaceous species.

Although this reach is not within the drainage district, hydrologic constraints still exist because of the proximity of some structures to the stream. The project possibilities are the same as for a drainage district site, with the potential for full 50-foot buffer restoration.

Potential Project 18 (PP18) includes two ditches that drain to Watering Hole Swamp in SW07. The ditches drain low density residential areas and agricultural areas. Watering Hole Swamp has a 25-50 foot buffer in this area. The channel incision ratio for the tributary is 2.0 indicating the channel is severely incised.

The tributary buffer is a mixture of native and non-native species. Cover type is primarily shrubs or herbaceous/grassy areas. Native species observed along the tributary include black willow and bald cypress. Non-native species were common in the riparian zone and include Japanese honeysuckle, Chinese privet, and kudzu (*Pueraria lobata*).

Although Watering Hole Swamp is obviously channelized in this area, the number of landowners is high. Project possibilities are most likely limited to agricultural BMPs to lessen the impact of the ditches.

Potential Project 19 (PP19) is downstream of PP18 on Watering Hole Swamp, and includes a ditch. This reach of Watering Hole Swamp runs through a cow pasture. Cattle have complete access and there is no buffer along the channel except at the far downstream end where Watering Hole joins

Bear Swamp. The channel incision ratio was estimated to be 1.5 in this area. There is one agricultural ditch that drains into the tributary

This site appears to have excellent stream and wetland restoration potential. It lies in a wide, shallow valley that appears to allow for full restoration of stream dimension, pattern, and profile as well as wetland hydrology. Wetland restoration may be possible within the full width of the valley. If the cattle operation is maintained, livestock BMPs and 50-foot forested buffers would be recommended. Agricultural BMPs implemented along the ditch would also be recommended.

Potential Projects 20-28

These sites all occur along Moss Neck Swamp in the Moss Neck Swamp Drainage District. The stream has been deeply channelized and widened and is regularly cleared of woody debris. The left bank is regularly mowed and devoid of trees. Buffer width varies along the right bank. A dirt access road parallels the swamp along the top of the left bank for its entire length. All sites in the Moss Neck Drainage District were selected because of the deeply incised stream channels and lack of forested buffers along one or both sides of the selected reach. These sites also meet the criteria for length and number of landowners. Coordination with the Moss Neck Drainage District is essential to develop a solution for improving habitat and water quality in the district.

Potential Project 20 (PP20) includes two unnamed tributaries that merge in this project area to form the headwaters of Moss Neck Swamp in SW09. They are currently mapped as intermittent.

The buffer is narrow to nonexistent at the beginnings of each stream. A dirt road parallels the channel for the entire length of Moss Neck Swamp right at the top of the left bank. Where intact, the buffer of the northernmost channel is typically young forest that is extremely variable in width, ranging from 10 to 90 feet wide. The southernmost channel has riparian buffers that are primarily a mixture of successional forest and residential or agricultural plantings. The northern most channel has a channel incision ratio of 4 and the southernmost channel has a ratio of 2.77. These ratios indicate that both channels are severely incised.

This project area is adjacent to a portion of the Moss Neck Savanna Significant Natural Heritage Area (Moss Neck SNHA). Moss Neck SNHA is an upland pine savanna and is potential habitat for red-cockaded woodpecker (*Picoides borealis*) and Michaux's sumac (*Rhus michauxii*).

Because of the drainage district, stream restoration opportunities in this reach are probably limited to experimental approaches such as the stream-within-a-stream technique, which may restore in-stream habitat and certain hydrologic functions without causing adverse impacts to adjacent farmlands. Buffer enhancement may be possible as well.

Potential Project 21 (PP21) is located along Moss Neck Swamp immediately downstream and adjacent to Moss Neck Savanna SNHA. Moss Neck Swamp has a narrow buffer in this area and is surrounded by low density residential and agricultural areas. The riparian buffer typically ranges from 10 feet to approximately 100 feet in width. The buffer, where intact is primarily young forest. The channel incision ratio is variable and ranges from 2.15 to 4.9 indicating a severely incised channel. Exotic vegetation is present in the riparian buffers and includes wart-removing herb, Chinese privet, Japanese honeysuckle, and tree-of-heaven (*Ailanthus altissima*).

Because of the drainage district, stream restoration opportunities in this reach are probably limited to experimental approaches such as the stream-within-a-stream technique, which may restore in-stream habitat and certain hydrologic functions without causing adverse impacts to adjacent farmlands. Buffer enhancement may be possible as well.

Potential Project 22 (PP22) is located on Moss Neck Swamp and was selected based on its similarities on aerial photography to other sampled PPAs. Project possibilities are the same as for all sites in the Moss Neck Drainage District.

Potential Project 23 (PP23) is located on Moss Neck Swamp and was selected based on its similarities on aerial photography to other sampled PPAs. Project possibilities are assumed to be the same as for all sites in the Moss Neck Drainage District.

Potential Project 24 (PP24) is along Moss Neck Swamp downstream of PP23. A segment of Moss Neck Swamp and a drainage ditch are included in this project area. The eastern side of Moss Neck Swamp has a sizeable buffer (over 50 feet) while the buffer along the western side has been reduced significantly to less than 50 feet in some cases.

Riparian buffers in this area are a mixture of native and non-native vegetation. Native species include loblolly pine, sweetgum, black cherry, red maple, water oak, and red bay. Exotic species are also present in this project area and include wart-removing herb and wisteria (*Wisteria floribunda*).

Because of the drainage district, stream restoration opportunities in this reach are probably limited to experimental approaches such as the stream-within-a-stream technique, which may restore in-stream habitat and certain hydrologic functions without causing adverse impacts to adjacent farmlands. Buffer enhancement may be possible as well. Agricultural BMPs are also recommended for the ditch.

Potential Project 25 (PP25) is located along Moss Neck Swamp downstream of PP24. It includes a segment of Moss Neck Swamp and a drainage ditch feeding into Moss Neck Swamp. Buffers along Moss Neck Swamp are very narrow or nonexistent in this area. Buffer types are generally young or successional forest where present and usually less than 100 feet in width and in many cases under 50 feet. There is no buffer between the drainage ditch and the agricultural fields it drains.

Vegetation in the riparian buffer is a mixture of native and non-native species. Native species include black willow, black cherry, sweetgum, ti-ti, and red maple. Non-native species include tree-of-heaven, Chinese privet, multiflora rose, and wart-removing herb.

Because of the drainage district, stream restoration opportunities in this reach are probably limited to experimental approaches such as the stream-within-a-stream technique, which may restore in-stream habitat and certain hydrologic functions without causing adverse impacts to adjacent farmlands. Buffer enhancement may be possible as well. Agricultural BMPs are also recommended for the ditch.

Potential Project 26 (PP26) is located along Moss Neck Swamp downstream of PP25. It includes a segment of Moss Neck Swamp and a drainage ditch feeding into Moss Neck Swamp. Buffers along Moss Neck Swamp are somewhat narrow in this area. Buffer types are generally mature forest where present and usually no more than 10 feet in width and in many cases less. Vegetation in the riparian buffer is a mixture of native species. These include white oak, sweetgum, and red maple. There is no buffer between the drainage ditch and the agricultural fields it drains.

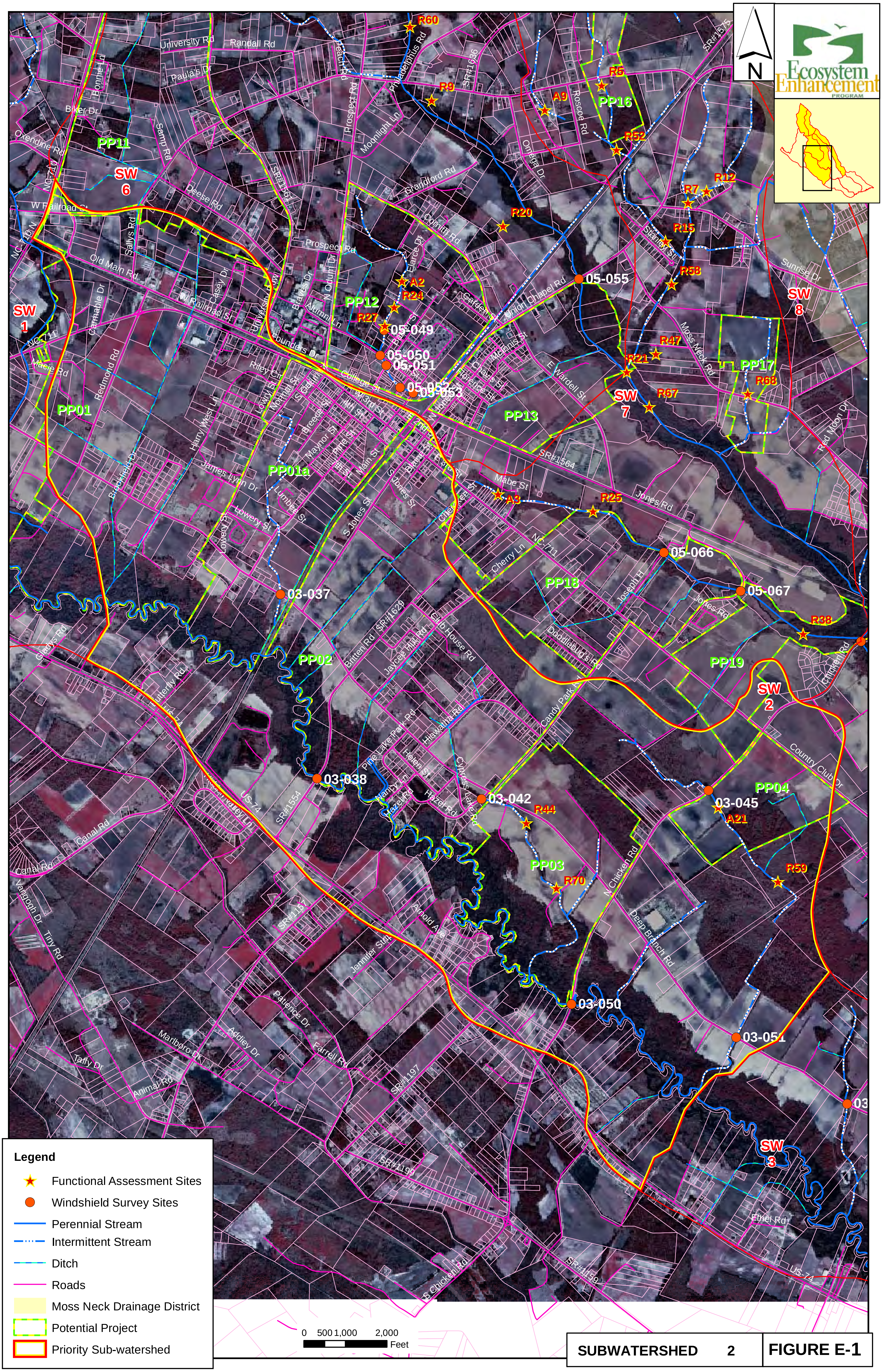
Because of the drainage district, stream restoration opportunities in this reach are probably limited to experimental approaches such as the stream-within-a-stream technique, which may restore in-stream habitat and certain hydrologic functions without causing adverse impacts to adjacent farmlands. Buffer enhancement may be possible as well. Agricultural BMPs are also recommended for the ditch.

Potential Project 27 (PP27) is located on Moss Neck Swamp downstream of PP26 and was selected based on its similarities on aerial photography to other sampled PPAs. Project possibilities are assumed to be the same as for all sites in the Moss Neck Drainage District.

Potential Project 28 (PP28) is located on Moss Neck Swamp downstream from PP27. This segment of Moss Neck Swamp has buffers typically greater than 75 feet in width in most places. In some areas the buffer is in excess of 200 feet or more.

The buffer along Moss Neck Swamp is a mixture of native and non-native species. Native species include sweetgum, tulip poplar, willow oak, red maple, American holly (*Ilex opaca*), and horse sugar. Japanese privet is an exotic that has been found in the riparian buffer in this area.

Because of the drainage district, stream restoration opportunities in this reach are probably limited to experimental approaches such as the stream-within-a-stream technique, which may restore in-stream habitat and certain hydrologic functions without causing adverse impacts to adjacent farmlands. Buffer enhancement may be possible as well.



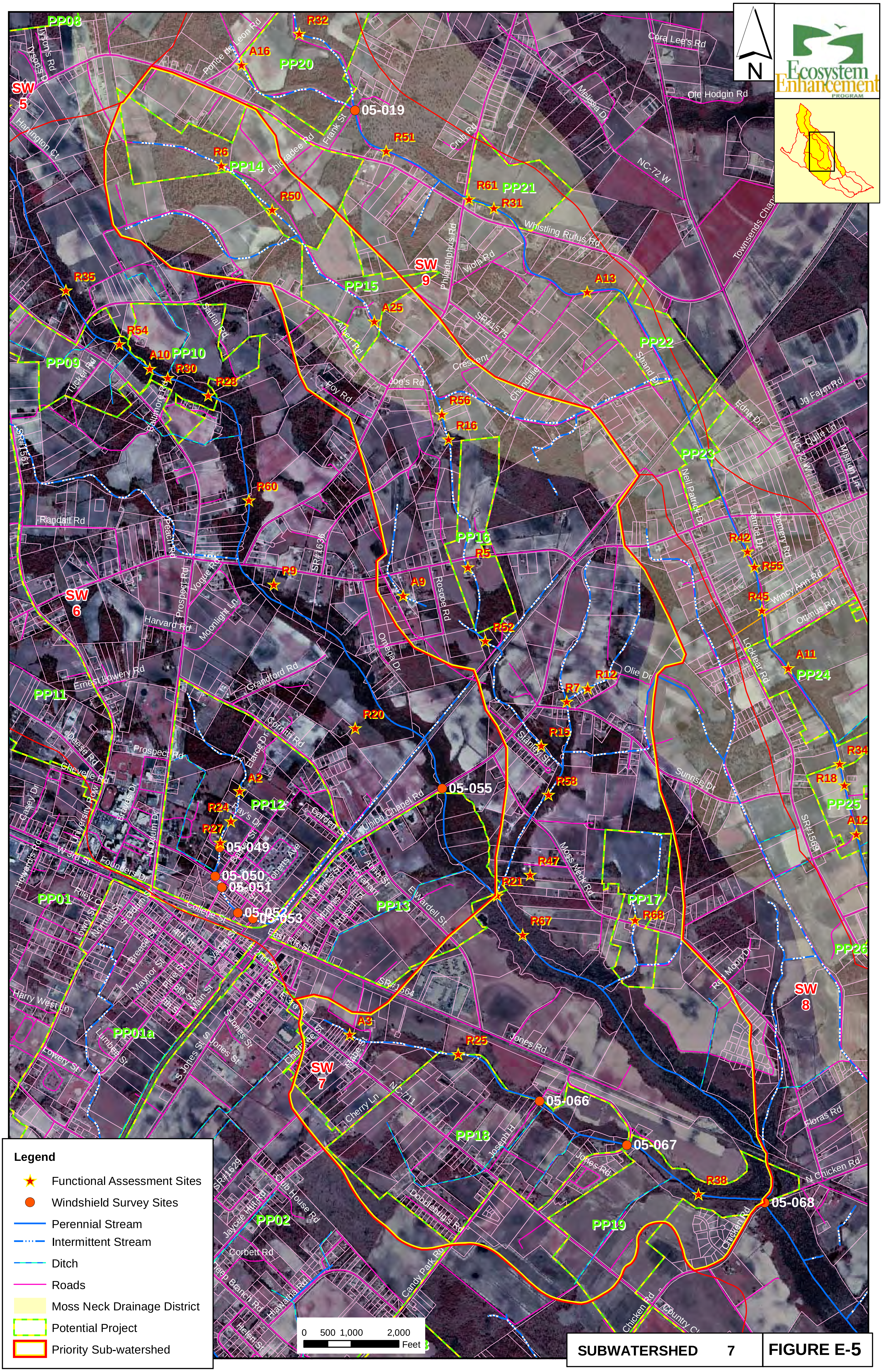
N
Ecosystem Enhancement Program
Legend
Functional Assessment Sites
Windshield Survey Sites
Perennial Stream
Intermittent Stream
Ditch
Roads
Moss Neck Drainage District
Potential Project
Priority Sub-watershed
0 500 1,000 2,000
Feet
SUBWATERSHED 2
FIGURE E-1
SW 1
SW 2
SW 3
SW 6
SW 7
SW 8
PP01
PP01a
PP02
PP03
PP04
PP11
PP12
PP13
PP16
PP17
PP18
PP19
R60
R9
A9
R5
R52
R7
R12
R20
R15
R58
A2
R24
R27
R47
R21
R67
R68
A3
R25
R38
R44
A21
R59
R70
05-049
05-050
05-051
05-052
05-053
05-055
05-066
05-067
03-037
03-038
03-042
03-045
03-050
03-051
University Rd
Randall Rd
Paulas Dr
Bonnie Ln
Biker Dr
Oxendine Rd
Samp Rd
Prospect Rd
Philadelphus Rd
Moonlight Ln
Standford Rd
Prospect Rd
W Railroad St
Old Main Rd
Railroad St
Sallys Rd
Deese Rd
Casey Dr
Braves Dr
Union Chapel Rd
Gardenia St
Moss Neck Rd
Sunrise Dr
Saunders Dr
College St
Riley Cir
Redmond Rd
Constable Dr
Charlie Rd
Harry West Ln
James Lynn Dr
Brookfield Dr
Lowery St
Main St
S Jones St
E Wardell St
SR#1564
Mabe St
Jones Rd
Cherry Ln
NC-711
Joseph Ln
Red Moon Dr
Chicken Rd
Britten Rd
SR#1620
Jaycee Hut Rd
Club House Rd
Candy Park Ln
Hiawatha Rd
Pine Lake Park Rd
Country Club Dr
Canal Rd
Vantooth Dr
Tiny Rd
SR#1554
US-74
N Chicken Rd
Deep Branch Rd
Arnold Ave
Jennifer Shol
Patience Dr
Marlboro Dr
Taffy Dr
Animal Rd
Addley Dr
Farrell Rd
SR#1197
SR#1199
S Chicken Rd
Ethel Rd
SR#1575
Roscoe Rd
Oxford Dr


Ecosystem Enhancement PROGRAM
N
Arthur Rd
Preston Rd
Chavis Rd
Rosadia Dr
Old Red Springs Rd
Mt Zion Church Rd
Leonardo Blvd
NC-710
Tonya L Rd
Buie - Philadelphus Rd
St Clifford Rd
Brewer Rd
Delia Dr
Charlotte Rd
Grey Eagle
McArthur Rd
Keever Rd
Prospect Rd
Carter Rd
Brydoc Rd
Vonnie's Dr
Sanborn Ln
Island Grove Rd
J I Rd
Elias Rd
Melinda Rd
Goins Rd
Cameron Ln
Crepe Myrtle Dr
Lowe Rd
W L Moore Woods Rd
Gurney Rd
Greely Rd
Susie's Dr
W L Moore Rd
Whistling Rufus Rd
Annes Dr
Red Bank Rd
Harrington Ct
Onnie Joe Rd
Sherrill Rd
R8
R17
R11
A19
R73
R71
A17
A20
R46
A14
R37
R33
05-015
05-021
SW 4
SW 5
SW 1
SW 6
SW 7
SW 9
PP05
PP06
PP07
PP08
PP14
Legend
Functional Assessment Sites
Windshield Survey Sites
Perennial Stream
Intermittent Stream
Ditch
Roads
Moss Neck Drainage District
Potential Project
Priority Sub-watershed
0 500 1,000 2,000 Feet
SUBWATERSHED 4
FIGURE E-2

SUBWATERSHED 5 FIGURE E-3

SUBWATERSHED 6

FIGURE E-4

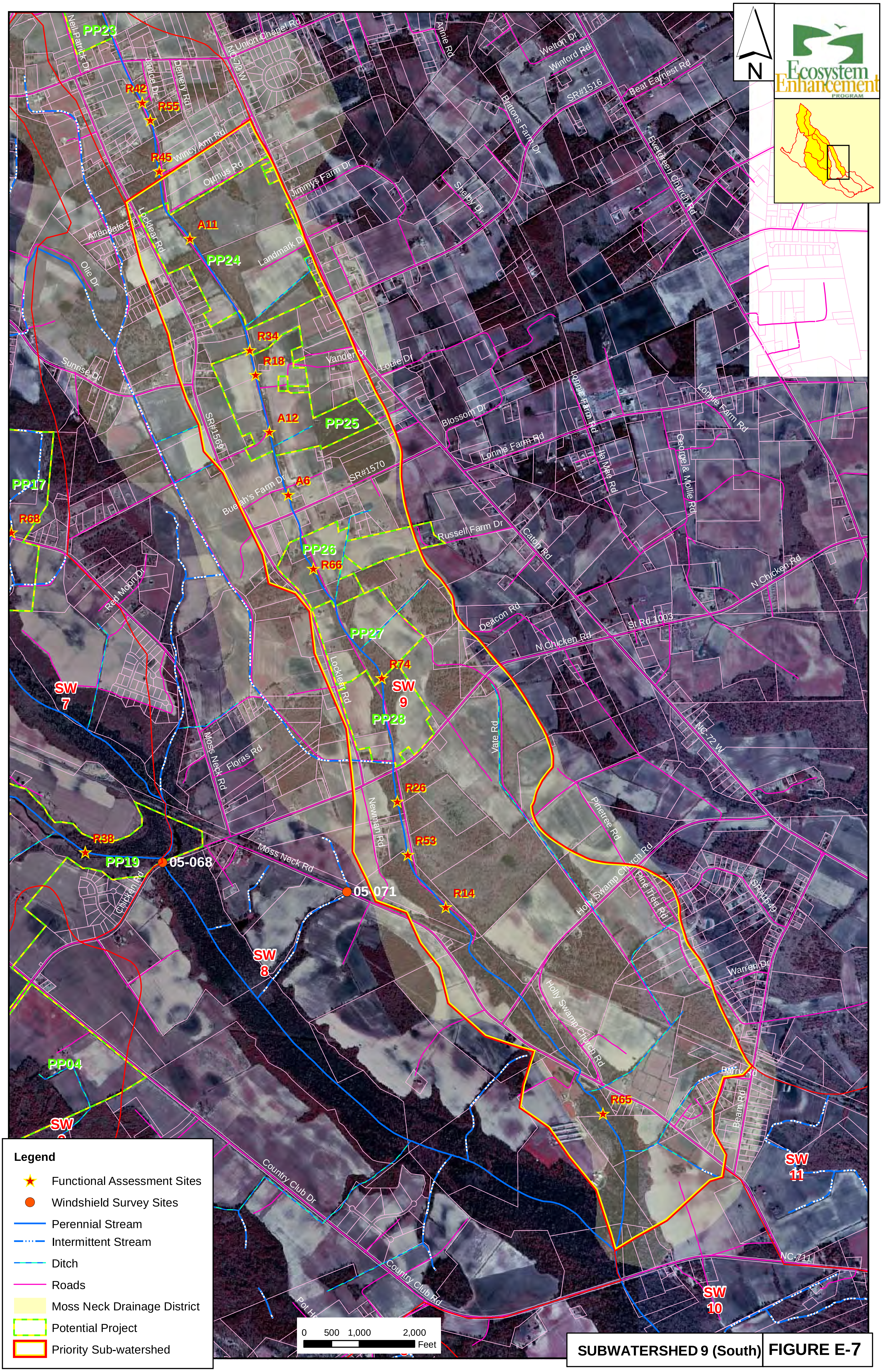


SUBWATERSHED 7

FIGURE E-5

SUBWATERSHED 9 (North)

FIGURE E-6



SUBWATERSHED 9 (South)

FIGURE E-7