Crisp Creek
Local Watershed Plan

Tar-Pamlico CU 03020103 Phase 2

Rehabilitation Plan

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Environmental Consulting Geomatics Consulting
Land Planning Landscape Design

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1. INTRODUCTION

This report is for the Phase 2 and Phase 3 components of the Local Watershed Plan (LWP) for Cataloging Unit 03020103 of the Tar Pamlico River Basin. This Cataloging Unit (CU) was chosen by the North Carolina Ecosystem Enhancement Program (NCEEP) as an area to focus watershed planning efforts. Phase 1 of this LWP included watershed characterization and targeting of areas for further study. The planning area is comprised of four watersheds located within portions of Edgecombe, Martin, and Pitt Counties in North Carolina. The Phase 1 report showed that all study areas had been significantly impacted by development and agricultural practices, resulting in a loss of wetlands and buffers, increased runoff and a general degradation in water quality. The Phase 1 report is available at http://www.nceep.net/services/lwps/Tar-Pamlico/tarpam.htm.

The current and expected future land use in the four watersheds under this study (Hendricks Creek, Crisp Creek, Green Mill Run, Cow Swamp) will not allow for complete restoration of the once natural systems. Improvement of specific watershed functions, however, is possible. The goal of this plan is to provide a framework for watershed functional rehabilitation and to provide primary supporting information for implementation of the rehabilitation system while taking into consideration development and agriculture. To achieve this, efforts were focused on three investigative methods: 1) land use / land cover (LULC) trending analysis; 2) watershed system modeling; and 3) riparian reach field investigation. The findings and results from these tasks were tabulated and compared with the concerns of the stakeholder groups. The end result being the location of potential restoration, enhancement, preservation and BMP (best management practices) sites that are best suited to meet the goals of the study.

The potential recommended actions were formed based on the stakeholder meetings and the findings from this study. The investigative methods were used to find indicators of key stressors in the watershed. If these stressors can be removed or alleviated the goals and objectives (Table 1-1) can be achieved.

The Crisp Creek watershed was divided into five catchments (Map 1-1 Crisp Creek Watershed). Crisp Creek itself is divided into two sections near Ralston Road. The Upper Crisp Creek catchment is the upstream area, while the Lower Crisp Creek catchment is the downstream area. Three other tributary catchments were created due to their respective size and/or land use. The unnamed tributary that flows through the large managed pine stand in the northern portion of the watershed is called the Pine Plantation catchment in this study. The unnamed tributary that makes up the drainage network in the mid-east portion of the watershed is called the Council catchment due to its proximity to Council Road. The last unnamed tributary is a small catchment that flows to Crisp Creek from the southern side of the highway, and is therefore named the US 64 catchment.

Map 1-1 Crisp Creek Watershed

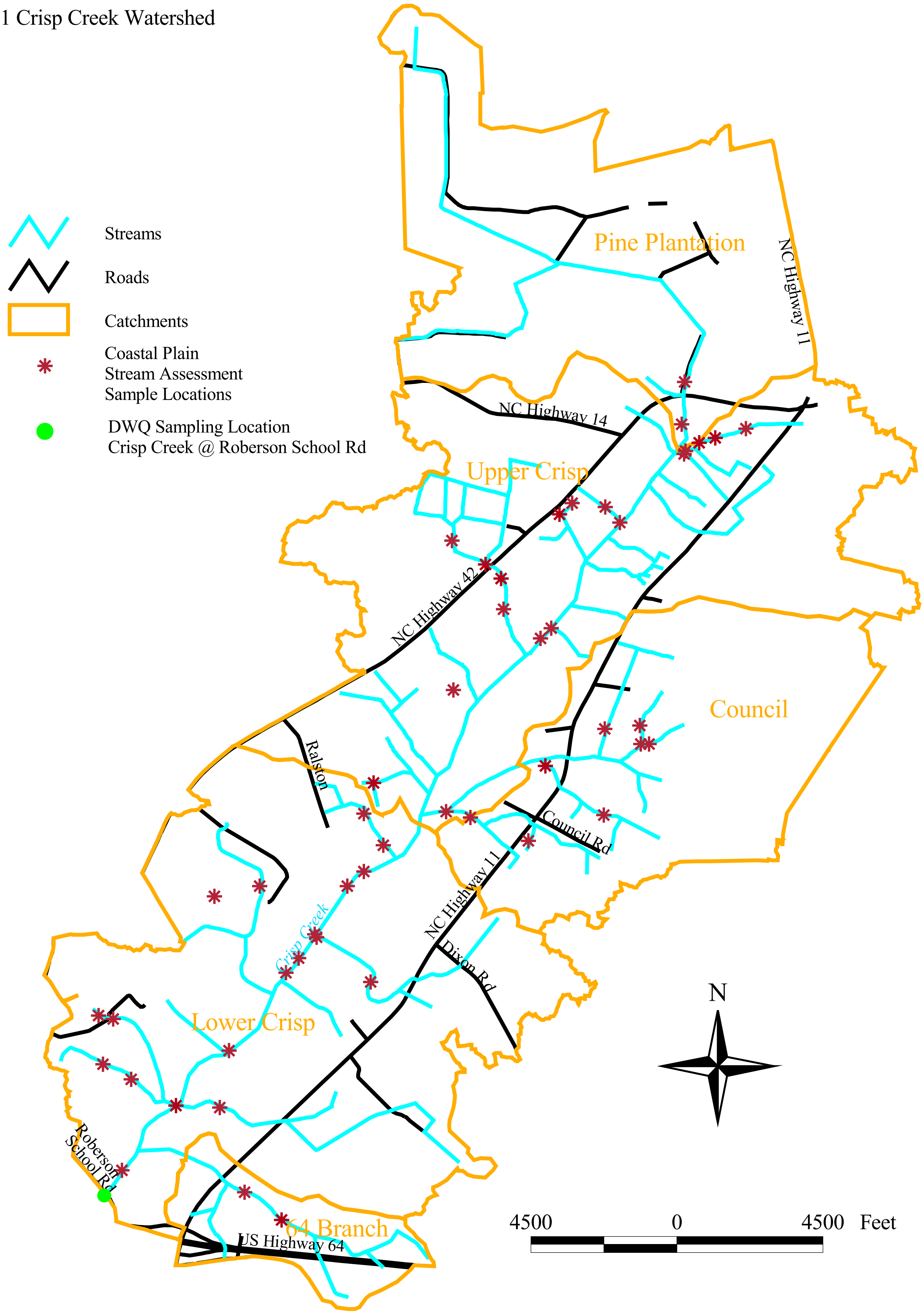

Table 1-1 Tar-Pamlico Local Watershed Plan: Goals, Objectives, Assessment Elements, Potential Actions and Stakeholder Concerns 2-14-05

Goal: Improve the functions of the watershed while considering development and agriculture

Watershed Function Goals	Objectives	Key stressors	Indicators of Stressors	Investigative Methods	Potential Recommended Actions	May address the following stakeholder concerns
Protect/Improve Water Quality	Prevent or alleviate functional losses to the TarPam River and other surface waters from poor water quality	contaminated runoff	-lack of riparian zone cover -high percentage of impervious surfaces -unstable banks	-Coastal Plain Stream Assessment -% impervious cover -outfall investigation -MUSIC water quality model	-buffers -preservation -stream restoration -BMPS	-improve water quality -nutrient removal -sediment control -improve bank stability -natural filter system
Protect/Improve Aquatic Habitat (physical)	Prevent or alleviate functional losses due to stream erosion/ instability and the associated sediment loading	poor instream habitat	-lack of large woody debris habitat -unstable banks -lack of stream shading -lack of riffle/pool sequence	-Coastal Plain Stream Assessment	-buffers -stream restoration	-aquatic species diversity -sediment control -stream stability
Protect/Improve Aquatic Habitat (chemical)	Prevent or alleviate functional losses due to poor instream water quality conditions	poor water quality (low DO, toxicity, turbidity)	-excess sediment -excess nutrients -presence of pesticides/ herbicides	-Coastal Plain Stream Assessment -outfall investigation	-BMPs -buffers	-clean water/improve/protect water quality -nutrient removal
Protect/Improve Terrestrial Habitat	Prevent or alleviate functional losses due to degradation of terrestrial wildlife habitat[	-poor wildlife habitat -loss of habitat	-lack of diverse composition and structure in riparian zone vegetation -lack of forest connectivity -dominance of invasive species	-Coastal Plain Stream Assessment -land use investigation	-preservation -buffers	-diversity of terrestrial species -habitat for bird species -open space -public recreation -wildlife corridors
Protect/Improve Baseflow and Prevent Flooding	Prevent or alleviate functional losses due to disruption or modification of floodplain hydrology	-flooding -reduced baseflow	-incised channels -lack of channel - riparian zone connection -high % of impervious surface	-Coastal Plain Stream Assessment -land use investigation -outfall investigation	-BMPs -wetland restoration -stream restoration -preservation	-groundwater recharge -greenways -stormwater retention -stormwater treatment -retain runoff to decrease downstream flooding
Protect/Improve Aquatic and Terrestrial Habitat and Baseflow, Prevent Flooding	Prevent or alleviate functional losses due to disruption or loss of riparian wetlands	wetland loss	wetland acreage drained, cleared or cutover	DCM NCREWS analysis	-wetland restoration	-education -greenspace -stormwater retention -stormwater treatment

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2. STAKEHOLDER PARTICIPATION

The local public was involved in order to get feedback on the assessment process and findings. They will be integral to the successful implementation of the watershed plan. NCEEP contracted with Watershed Education for Communities and Local Officials (WECO) to facilitate stakeholder meetings. Prior to the session of stakeholder meetings, WECO conducted an issue assessment for the four watersheds. Issues brought up included drainage districts and their legal jurisdiction over many streams, flooding, open space, potential of rare mussels, nuisance of beavers, growth and economic development, land use planning, and agricultural efforts. All issues may not apply to the Crisp Creek watershed as the assessment included the three additional watersheds in the area where plans are being prepared, as mentioned in the introduction.

WECO formed an advisory committee made up of resource professionals and local government staff. The committee included stakeholders for this watershed and the three other watersheds included in the overall study. The committee was made up of representatives from the City of Greenville, East Carolina University, Edgecombe County Soil and Water Conservation District (SWCD), Edgecombe County Planning, Edgecombe Cooperative Extension, Clean Water Management Trust Fund, NC Wildlife Resources Commission, Pitt County SWCD, Pitt County, Martin County SWCD, Southeastern Drainage District, Town of Tarboro, Upper Coastal Plain Council of Government, and the Pamlico-Tar River Foundation.

Tasks established for the committee include the following:

- Assist with landowner contacts and education
- Assist in selection of priority subwatersheds, stream segments and specific watershed improvement project sites
- Help identify optimal sites for traditional (stream, wetlands and buffers) restoration projects, nontraditional restoration strategies and preservation
- Help identify additional funding sources
- Fit projects into the development of an overall watershed restoration/protection strategy
- Introduce and promote recommended watershed solutions to local governments and the community

During meetings, stakeholders were given an overview of the Coastal Plain Stream Assessment Protocol and a review of the initial findings from the first phase of the LWP. Participants in the meetings were asked to identify areas of concern or interest within the watersheds. This information aided in selecting project sites and in describing overall watershed conditions as described in the **Findings and Proposed Improvement Projects** section of this report. Stakeholders also provided a list of concerns that should be addressed by this watershed plan. These concerns were taken into consideration when forming the goals and objectives of the watershed plan. This list can be found in *Table 1-1. Tar-Pamlico Local Watershed Plan: Goals, Objectives, Assessment Elements, Potential Actions and Stakeholder Concerns*. When field work and office analysis were complete, the findings were presented to the stakeholders along with an explanation of the proposed projects. Stakeholders gave comments and helped identify additional projects. After each stakeholder meeting, WECO produced a newsletter. A copy of each newsletter can be found in Appendix A. Towards the end of this phase of planning, the need arose to form an agricultural subcommittee to help work with the drainage districts. There are unique constraints in areas with drainage districts and most projects will require additional landowner cooperation.

3. PREVIOUS AND CONCURRENT STUDIES

NCDWQ Water Quality Sampling
DWQ performed sampling in Crisp Creek at Roberson School Rd (SR 1627) nine times between December 2003 and October 2004. Results can be found in Appendix B.

NCDWQ also completed the 'Assessment Report: Biological Impairment in the Upper Conetoe Creek Watershed.' This can be found on the web at http://h2o.enr.state.nc.us/swpu/ and was discussed in the Tar Pamlico Phase I Characterization Report.

4. LAND USE TRENDING

Land use / land cover (LULC) has a major influence on watershed function. Areas with static land use have steady inputs into the watershed system, whereas areas of land use change alter the riparian equilibrium and can cause watershed function degradation. One of the goals of this section of the project is to establish a growth pattern to predict future growth areas so that steps can be taken now to alleviate future growth-related impacts to watershed health. A second goal is to quantify the amount of impervious surface in the watershed. As the percent impervious increases in a watershed, the level of stream quality decreases (Schueler 2000).

Four sets of high resolution imagery were utilized for the trending analysis. The four sets cover a twenty year time span from 1982 to 2003. March 1982 color infrared images were obtained from the USDA/FSA Aerial Photography Field Office. BLWI staff georeferenced and orthorectified the images using Global Mapper. The black and white 1993 images and the 1998 color infrared images are USGS digital orthophoto quadrangles obtained from NCCGIA. The September 2003 images are black and white and were taken following Hurricane Isabel. They are available on the web at http://www.nconemap.com.

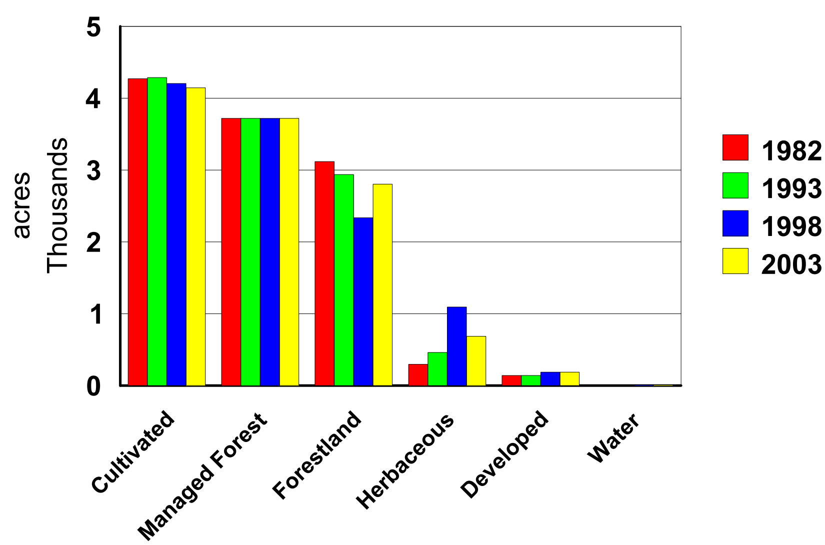
Land use on each set of images was digitized to produce a LULC map for each of the four years. LULC classes were based on the publication 'A Standard Classification System for the Mapping of Land Use and Land Cover' produced by the State of North Carolina Governor's Office of State Planning Center for Geographic Information and Analysis in January 1994. This publication has separate classes for land use and land cover. For this watershed analysis, a modified version of the land cover classes was used to better incorporate land uses. For example, according to the previously mentioned standard classification system, the 'developed' land cover class does not include low density residential areas and isolated farmsteads. For this analysis, all built upon land is considered developed whether or not it is isolated as these buildings add to the amount of impervious area in the watershed. Developed areas were divided into two classes, 'high-density developed' and 'low-density developed' because developed areas such as shopping malls contain more impervious surface than developed areas with single-family homes. All of the LULC classes are described in Table 4-1.

Table 4-1. LULC Classes

Developed	All areas where the land is covered predominantly by human structures, including buildings and pavement with minimal vegetation
Cultivated Land	Land used principally for row and root crops
Herbaceous Cover (and recent harvest)	Land predominantly covered by communities of grasses, grasslike plants, and forbs, including small flowering and non-flowering plants, and mixtures thereof, including golf courses and cemeteries; in addition recently harvested land was included
Forest Land (forest and successional)	Covered with deciduous or coniferous woody vegetation about 3 meters or more in height
Forest Management and Harvesting	Active timber harvesting or managed plantation of trees used for lumber or pulp production, includes passive management
Water	All areas of surface water with no, or minimal, emergent vegetation

Modified classes from: A Standard Classification System for the Mapping of Land Use and Land Cover, State of North Carolina Governor's Office of State Planning Center for Geographic Information and Analysis January 1994.

Figure 4-1 Crisp Creek LULC



The land in Crisp Creek is primarily used for agriculture and managed forest. Table 4-2. shows LULC for the four points in time covering the 20-year time span. In 1982, almost 37% (4,273 acres) of the watershed was used for cultivated land, over 32% (3,720) was managed pine, and approximately 27% (3,130 acres) was forest land. Over the 20-year time period studied, cultivated land decreased, managed forests remained constant, and forest land decreased (see Table 4-3. Percent Change of Land Use / Land Cover).

Table 4-2. LULC 1982-2003 (acres)

	1982	1993	1998	2003
Cultivated	4,273	4,289	4,206	4,145
Managed Forest (managed pine)	3,720	3,720	3,720	3,720
Forestland	3,118	2,938	2,337	2,806
Herbaceous	298	461	1,094	686
Developed	141	141	189	188
Water	7	7	13	13

Table 4-3. Percent Change of Land Use / Land Cover (per decade and for 20-year period)

	Percent change		
	1982 - 1993	1993 - 2003	*1982 - 2003*
Cultivated	0.38	-3	*-3*
Forest Land	-6	-5	*-11*
Managed Forest (managed pine)	0	0	*0*
Developed	-0.06	25	*25*
Herbaceous	35	33	*57*
Water	0	45	*45*

In addition to the quantitative calculation, LULC trending was analyzed spatially. To spatially analyze where LULC change has been occurring, each of the vector layers was converted to raster format with a pixel size of one square meter. The raster layers were combined such that each pixel contained the LULC data for each the four time periods. The new raster layer enabled spatial analysis of the data to show exactly what the cover types were being converted to in the twenty year time period. This is a better reflection of trends in a given area when compared to simple watershed totals of LULC acreages.

Over the 20-year study period, forest land declined 11% and most of the former forested areas remained as herbaceous land, accounting for its 57% increase. It is likely this herbaceous land will be left to grow and the trees will be harvested in another 30 years. The decline in forest occurred on large tracts and was not cleared for development reasons. Only 6 acres of forest land were paved, built upon or used for agriculture. Cultivated land has also decreased over the 20-year period by 3%. Developed land increased by over 57%, however this only represents 41 acres. The increase of water was due to the construction of a 5.7 acre swine waste lagoon.

Between 1982 and 1993, LULC changed on 750 acres, or 6.5% of the watershed. The main source of change the fluctuation of herbaceous to forest land and vice versa. There was a slight increase in cultivated land on previously forested land. Development only occurred on 3 acres, almost all of which was previously cultivated land.

The change in LULC was similar between 1993 and 1998 occurring on approximately 930 acres, or 8% of the watershed. Development occurred on 55 acres. Approximately 45 acres of the newly developed area was US Highway 64 and associated entrance and exit ramps. The buildings associated with the new swine facility take up 5 acres. The swine facility also includes a 5.7 acre lagoon that accounts for the increase in water. The majority of the change is once again associated with the rotation between forest and herbaceous. In this time period over 700 acres of forest were harvested (and then classified as herbaceous) and 115 acres of previously classified herbaceous land became forest land.

The amount of acreage that experienced a land use change between 1998 and 2003 was 1,211 acres. In this period over 800 acres became forest land from herbaceous and 370 acres became herbaceous. Less than 2 acres were developed.

Over the two decade study period it is clear that the rotation of cutting mature stands of forest and leaving them to regenerate is common. Harvesting also occurs on the pine plantations located in the headwaters.

The population has declined in the Crisp Creek watershed as reported in Phase I of this project. The population in the area between the Town of Tarboro and the Crisp Creek subwatershed (block group 2, census tract 208, Edgecombe County) has increased slightly from 827 persons in 1990 to 847 persons in 2000. On the other hand, the area to the west of Crisp Creek in Martin County (block group 3, census tract 9706, Martin County) has seen a population decline from 982 persons in 1990 to 813 persons in 2000. In the mid 1990s, US Highway 64 was constructed along the eastern edge of the Crisp Creek watershed. To date, the new highway has not resulted in population growth. A few new houses have been built along the two principal roads that run through the watershed. Yet the number of abandoned houses is equal to or greater than the number of new ones. Based on this information and the spatial analysis, it is unlikely the population of Crisp Creek will increase significantly in the future.

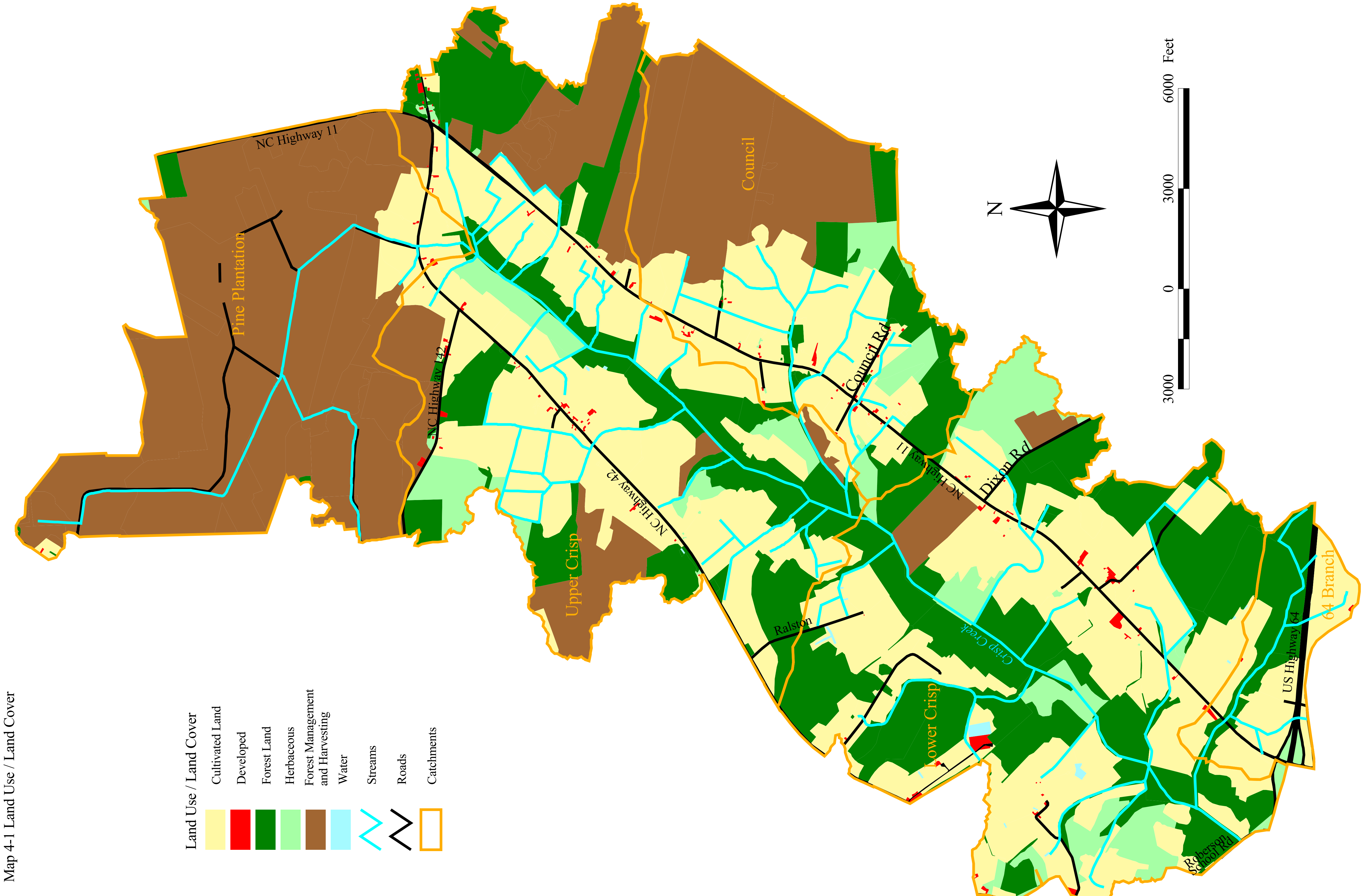
Developed and Impervious Area

As described in the introduction, the Crisp Creek watershed was divided into five catchments. These catchments are Upper and Lower Crisp Creek; the US 64 catchment; the Council catchment; and the Pine Plantation catchment. The developed land and impervious acreage was calculated for each catchment for 2003. Roads were considered 100 percent impervious and built areas were considered 50 percent impervious. Currently the built area in the catchments is residential with the exception of a few churches, a community building, and the swine facility. The majority of the developed land, over 75%, is roadways.

As mentioned above, high levels of impervious surfaces result in a low level of stream quality. Schueler (2000) has devised management categories according to the relationship between impervious cover and stream quality. The category describes the level of quality that can be achieved. Impervious cover <10% is categorized as a sensitive stream. Impacted streams have 11-25% impervious cover and non-supporting streams have >25% impervious cover. Streams that fall into the sensitive category can be protected by "strict zoning, site impervious restrictions, stream buffers and stormwater practices." Streams in the impacted category should be relieved with stormwater management practices. Finally, non-supporting streams are those where the primary objective is to remove pollutants as it is very difficult to achieve predevelopment channel stability and biodiversity. Some level of stream quality can be accomplished by using stream restoration techniques. According to this categorization system, streams in the Crisp Creek watershed are sensitive. It is unlikely that any of the catchments will exceed 10% with the exception of the 64 branch catchment (Table 4-4). If a gas station or other commercial building is built along the highway, impervious levels will likely exceed 10%. Measures should be taken to control stormwater runoff from additional development in this catchment.

Table 4-4. Developed and Impervious Areas by Catchment

Catchment	Developed acres	Impervious acres	% Impervious
64 branch	42.5	41.7	8.9
Upper Crisp	60.2	53	1.5
Lower Crisp	49.3	38.8	1.1
Council	19.4	15.6	0.8
Pine Plantation	16.4	15.7	0.7



Map 4-1 Land Use / Land Cover

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5. COASTAL PLAIN STREAM ASSESSMENT

In prior research, East Carolina University (ECU) researchers developed a rapid assessment procedure for assessing functions of intermittent to second order (headwater) riparian reaches in agricultural landscapes in the coastal plain. Due to the inadequacies of other stream assessment methods for use in the coastal plain, the North Carolina Ecosystem Enhancement Program (NCEEP) contracted ECU to further develop their methodology for use in this and other local watershed planning efforts. As part of this project, the Coastal Plain Stream Assessment was expanded such that it could be applied to higher (third and fourth) order streams as well as urban stream reaches. ECU staff also conducted comprehensive training of this new assessment methodology for NCEEP staff, other state and federal agency staff, as well as the consultants involved in the local watershed planning process (including BLWI staff).

The base layer used for this assessment was the USGS hydrography GIS data layer. USGS 'blueline' streams in eastern North Carolina tend to include many agricultural ditches that were likely never natural streams, but instead wet flats. Based on topography from the USGS topographic quadrangles as well as soil survey information, ECU researchers removed a number of headwater agricultural ditches from the assessment. They also added a few small first order streams to the data layer using the topography and soils information. In general, first and second order streams were considered low order streams while third and fourth order streams were considered high order streams. There are no fifth order streams in the watershed. The resulting stream layer contains 78% (33 miles) low order streams and 22% high order streams. This assessment method was not meant to evaluate areas ponded by beaver or other impoundments.

To create statistically valid results ECU developed a stratified-random sampling scheme based on abundance (stream order and drainage area). This approximated 2.5 samples sites/mi^2 (1 site/km^2). In Crisp Creek 45 reaches were assessed, with each reach constituting 300 feet of stream length and 90 feet of riparian area on either side. To ensure that a complete sample set could be achieved, a list of alternate sites was also provided by ECU in the event that one or more of the original sample sites was rejected. Rejection occurred whenever any of the random reaches overlaid each other, the sample site was not a stream, the sample site landed on a stream that was piped underground, or the landowners were not willing to permit access. No sites were rejected due to access issues. The approximate locations of the points that were assessed are shown on Map 1-1 Crisp Creek Watershed.

The Coastal Plain Stream Assessment is a reference-based assessment of riparian functions. The condition of each reach is evaluated relative to unaltered reaches of the same type. Four types of reaches were used in this assessment: urban low order, rural low order, urban high order and rural high order. Sampling forms and assessment protocols can be found in Appendix C. The purpose of the assessment is to provide data to evaluate the ecosystem (stream channel and riparian zone) in order to diagnose problems and identify potential solutions. Riparian ecosystem functioning depends upon the condition of the stream itself, which incorporates onsite and upstream influences, and upon the condition of its adjacent riparian zone (Rheinhardt 2005). The condition of the riparian zone and the stream channel were evaluated using a number of indicators (Table 5-1). There are 8 or 9 condition indicators of riparian condition evaluated for each reach, depending on if it is high or low order and urban or rural.

The riparian zone cover (RZC), near stream cover (NSC), and composition and structure of vegetation in the riparian zone (SRC 7) indicator scores were all determined by the type and age of riparian zone vegetation. The instream woody structure indicator (SRC 1) evaluated the presence of large (>4 inch diameter) downed wood within the channel and along the banks. Sediment regime (SRC 2) was determined by observing turbidity levels as well as the amount of silt and sand deposits along the floodplain and within the channel. Channel-riparian zone connection (SRC 3) measures the level of channel incision and overbank flooding. The on/off site factors affecting stream and riparian zone indicators (SRC 4 and 5) were determined by evaluating the presence of pollution sources and the ability for those contaminants to access the surface water. Bank stability (SRC 6) was assessed by evaluating the prevalence of bank erosion and is only determined for high order and urban streams. SRC 2, SRC 3, and SRC 7 are not evaluated if the channel is impounded. Each of these indicators was used to determine the condition of the watershed, causes and sources of degradation, and the range of restoration opportunities in the watershed.

Table 5-1. Function Score Determinations

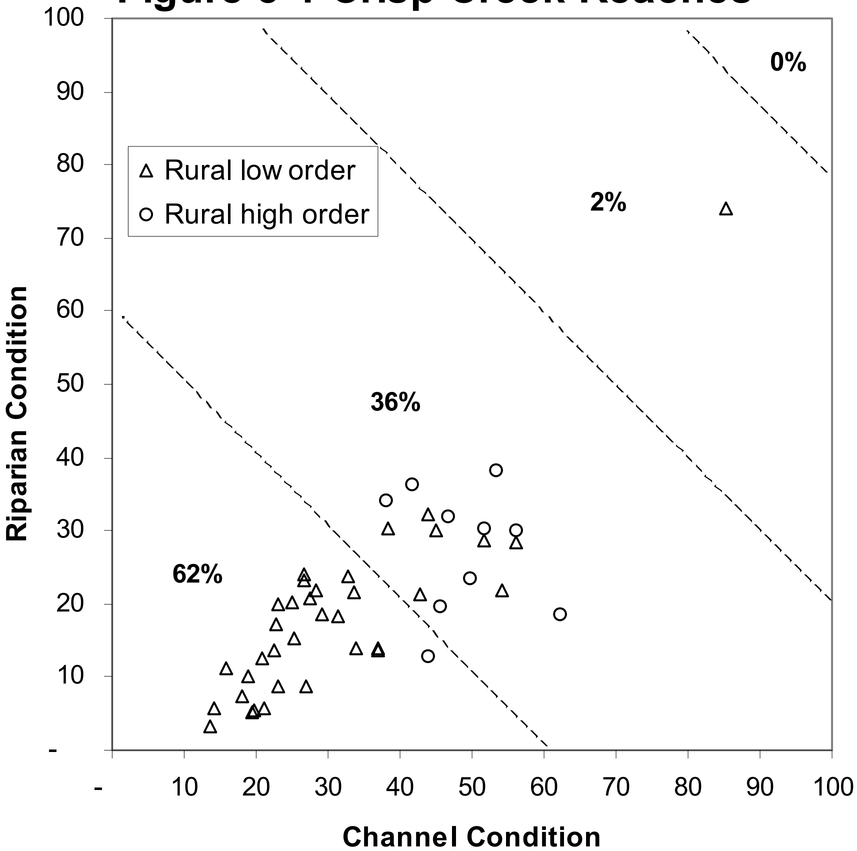
	Hydrology		Biogeochemistry		Habitat	
Indicators	Stream Channel	Riparian Zone	Stream Channel	Riparian Zone	Stream Channel	Riparian Zone
Riparian zone cover (RZC)		X		X		X
Near stream cover (NSC)			X		X	
Instream woody structure (SRC 1)	X		X		X	
Sediment regime (SRC 2)			X			
Channel-riparian zone connection (SRC 3)	X	X	X	X	X	X
On/off site factors affecting stream (SRC 4)	X		X		X	
On/off site factors affecting riparian zone (SRC 5)		X		X		X
Bank stability (SRC 6)			X		X	
Composition and structure of vegetation in riparian zone (SRC 7)						X
Function Score (mean of marked indicators)						

<u>Results</u>

Specific indicators are combined and averaged according to Table 5-1 to determine the level of function for hydrology, biogeochemistry and habitat for the stream channel and the riparian zone. The watersheds were evaluated relative to the condition of the channel and riparian zone by averaging the hydrology, biogeochemistry, and habitat of each component and then graphing these scores for 45 of the reaches. The reaches are clustered along a line with a slope of 1 because alterations to the channel affect the riparian zone and visa versa (Figure 5-1) (Rheinhardt 2005).

A Composite Function Score is calculated by averaging the six function scores (bottom row of Table 5-1). The condition of the stream is based on the Composite Function Score. The possible conditions are, from best to worst, relatively unaltered (100-85) followed by somewhat altered (84-55), altered (54-25), and finally severely altered (24-0). The relatively unaltered condition is not found in any of the streams in Crisp Creek, 2.2% are somewhat altered, 35.6% are altered, and 62.2% are severely altered. If 62.2% of the assessed reaches are severely altered it can be inferred that 62.2% of all of the streams in the watershed are severely altered based on the Composite Function Scores (Rheinhardt 2005). The Mean Composite Function Score is the average of the Composite Score for each of the 40 reaches (5 reaches are not graphed as they were impounded by beaver and the assessment was not completed). This score reflects 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 (Rheinhardt 2005). Crisp Creek has a Mean Composite Score of 28 with a range of 8-80.

Figure 5-1 Crisp Creek Reaches



In addition to watershed level analysis, the data was analyzed by stream order. The following table outlines the conditions for the six functions based on stream order (Table 5-2). The conditions are the same as outlined in the previous paragraph. The stream channel functions in the low order streams are also altered while the riparian zone functions are severely altered. Five high order samples and two low order samples were not included due to beaver activity. All flooding at beaver affected areas was contained within the deep channels. Almost all of the low order streams have been channelized through agricultural areas, contain virtually no natural riparian zone and therefore score very low.

Table 5-2. Crisp Creek Function Scores

Function	Low Order		High Order	
Hydrology - Stream	31	Altered	49	Altered
Hydrology - Riparian Zone	18	Sev Altered	26	Altered
Biogeochemistry - Stream	31	Altered	46	Altered
Biogeochemistry - Rip. Zone	18	Sev Altered	26	Altered
Habitat - Stream	30	Altered	51	Altered
Habitat - Riparian Zone	18	Sev Altered	29	Altered

Function Index ranges from 0 - 100; Low Order n=33; High Order n=5; Sev Altered = Severely Altered

The Crisp Creek watershed was divided into five catchments as described in the introduction. The catchments are Upper and Lower Crisp, the US 64 catchment, the Council catchment, and the Pine Plantation catchment. Function scores were tabulated for each catchment (Table 5-3). The following table gives an indication of what conditions are like in each area of the watershed. These catchments are discussed in further detail below.

Table 5-3. Crisp Creek Low Order Function Score by Catchment

Function	Catchment				
	Upper Crisp	Lower Crisp	Pine Plant.	Council	US 64 Branch
Hydrology - Stream	27	40	13	22	45
Hydrology - Riparian Zone	15	27	0	10	34
Biogeochemistry - Stream	3	41	16	22	45
Biogeochemistry - Rip. Zone	15	27	4	10	34
Habitat - Stream	27	41	12	19	46
Habitat - Riparian Zone	15	29	3	7	36

Function Index ranges from 0 - 100

The RZC, NSC and SRC 6 were low for low order streams since much of the surrounding land has been converted to crops. High order streams scored better for these indicators as one side of the channel was almost always forested although the opposite side was maintained as herbaceous cover to allow access. Low order streams throughout the watershed have been channelized leading to a low indicator score for the channel-riparian zone connections (SRC 3). The high order streams, including the main stem of Crisp Creek, were deeply channelized in the past leading to a very low score for channel riparian zone connection (Table 5-4) (Rheinhardt 2005).

Table 5-4. Mean indicator scores, by stream order, for Crisp Creek watershed

	Riparian zone cover (RZC)	Near-stream cover (NSC)	Instream woody structure (SRC-1)	Sediment regime (SRC-2)	Channel-riparian zone connection (SRC-3)	Factors affecting stream (SRC-4)	Factors affecting riparian zone (SRC-5)	Habitat quality of riparian zone (SRC-6)	Bank stability (SRC-7)
Rural Low Order	25	30	37	34	11	43	19	20	NA
Rural High Order	51	62	65	24	6	51	14	31	44
Mean	31	37	44	32	10	45	17	22	44

Rural Low Order n=35; Rural High Order n=10

6. HABITAT ANALYSIS

The majority of the land area in Crisp Creek is used for agriculture and managed pine plantations. The natural communities and habitats in these areas have been destroyed or are degraded. The "natural" forests provide a less altered habitat, although even these areas are subject to harvesting. Only 1,698 acres of forest were untouched during the 20 year LULC study period. Wetlands are found throughout the watershed in forests and the managed pine areas. The best habitat in the Crisp Creek watershed is likely found in these wetlands areas, especially those that are unaltered and have not been converted into pine plantations.

The wetland habitat was analyzed using NCCREWS (North Carolina Coastal Region Evaluation of Wetland Significance). The evaluation is based on functions including water quality, hydrology, and habitat. The habitat functions are divided into terrestrial and aquatic categories. According to the data, the wetlands in the Crisp Creek watershed are divided between flats (2,424 acres) and riverine/headwater wetlands (663 acres). Overall habitat in the riverine/headwater wetlands is rated high for 580 acres and medium for 83 acres. None of the area was rated low. The high ratings are attributed to terrestrial habitat, although the majority of those wetlands rated medium for aquatic habitat. The riverine/headwater wetlands are found in areas where the forests have not yet been converted to pine plantation, although many have been harvested in the past. Overall habitat in the flats is rated high for 2,323 acres, medium for 35 acres and low for 66 acres. The high rating is attributed to the terrestrial habitat as the majority of the area rated low for aquatic habitat. Yet when the NCCREWS data was compared to the current LULC layer, it was found that only 87 acres of the flats are not in pine plantation or drained areas. Although drained wetlands and pine plantations may provide shelter and some food for fauna they are not considered high quality habitat. It is our opinion that the NCCREWS data layer had an error and pine plantations and drained areas were given a higher rating than appropriate according to the parameter description in the NCCREWS literature (DCM 1999).

The Natural Heritage Program has not identified any areas of significance in the Crisp Creek watershed. There is no documented the presence of endangered, threatened or rare species or species of concern. The Wildlife Resources Commission is interested in the presence of mussel species on streams in this area. One species was found in the section of Crisp Creek just upstream of Roberson School Rd. The species was not identified.

7. WATERSHED SYSTEM RESPONSE SIMULATION (MUSIC)

In the first phase of the Tar-Pamlico watershed assessment, BLWI completed a pollutant loading analysis for catchments within the targeted subwatersheds. This analysis was based on average annual constituent export by land use. In other words, a given area of a particular land use / land cover was determined to generate a specific amount of pollutant per year. This analysis was valuable to assess the distribution and relative magnitudes of pollutant loading in the subwatersheds.

In this phase of the Tar-Pamlico watershed assessment, one of the goals is to assess the relative pollutant removal performance of proposed structural stormwater Best Management Practices (BMPs) and restoration projects. Various estimates of BMP pollutant removal efficiencies are available. One manner in which the performance analysis could be undertaken is to apply average pollutant removal rates to each proposed BMP. This analysis does not, however, take into account hydrologic and hydraulic parameters, nor spatial and temporal variations of such. Hydrologic parameters include precipitation, evapotranspiration, infiltration, runoff, and others. Hydraulic parameters include velocity, flow, depth, width, area, and others.

Pollutant loading is directly affected, and largely controlled, by hydrologic and hydraulic processes. Likewise, pollutant removal by structural stormwater BMPs is directly affected, and largely controlled, by hydrologic and hydraulic processes.

To address these important parameters, a simulation method was required. A Monte Carlo (or similar) simulation method could have been undertaken that accounted for the range of possible efficiencies for each proposed BMP and restoration project. Given the project scope, the effort required to undertake this type of analysis was determined to be equal to or greater than that required to undertake a planning-level hydrologic, hydraulic, and water quality simulation model analysis. As such the software application MUSIC (Model for Urban Stormwater Improvement Conceptualization) was employed for such an analysis.

MUSIC is a tool that helps us understand stormwater runoff and associated pollutants in a given watershed and was developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH) in Victoria, Australia. The underlying mathematical representation of physical processes within the MUSIC system allows the application to be applied in a wide range of climatic conditions. The primary limitations determined are freezing precipitation events and occult precipitation inputs. Neither of these are significant in the project area. The model has been used in various locations within Australia, New Zealand, and other areas. The MUSIC system is directly applicable to the project area.

MUSIC provides the ability to simulate both the quantity and quality of stormwater runoff from catchments (watersheds). These watersheds can range from a single house block up to about 40 square miles. The modeling system simulates how this stormwater runoff passes through and interacts with a wide range of natural and constructed management measures. The system simulates this by performing calculations using the model equations and taking into account how the system changes over periods of time. By doing this, the modeling system can provide information on the downstream quantity and quality of the runoff.

The formal name of the MUSIC software application implies that it is limited to urban watershed analysis: Model for Urban Stormwater Improvement Conceptualization. The model is actually intended for analysis of forested, agricultural, and urban watersheds, with each of these being represented as the fundamental watershed types in the model. Analysis of urban systems is generally more complex than analysis of agricultural and forested systems at equivalent detail. The term “Urban” in the formal name indicates that it is suitable to undertake the more complicated urban watershed analysis in addition to - not exclusive of - agricultural and forested systems.

Background

Many organizations, including government and nonprofit entities, have initiated watershed analysis, assessment, and planning efforts. These efforts are being undertaken in rural, suburban, urban, and mixed character watersheds. Often these initiatives have focused on point source pollution, such as sewage discharge and industrial effluent. Building on the success of these efforts, organizations are now turning their attention to non-point source (NPS) pollution, such as agricultural and urban stormwater runoff. Associated with these efforts may be goals such as economic, aesthetic, recreation, and flooding improvements. It is difficult to prevent stormwater from polluting creeks as runoff can be contaminated almost anywhere rain falls. Consequently, successful initiatives to manage stormwater will adopt a watershed approach. The diffuse sources of stormwater pollution also demand a multidisciplinary approach. Successful initiatives may need to integrate a range of analysis, design, and planning disciplines.

Unfortunately, progress has often been hampered because organizations have insufficient knowledge or expertise in relevant disciplines or are unable to fully integrate the various disciplines. To provide support for entities undertaking watershed analysis, assessment, and planning efforts, the Cooperative Research Centre for Catchment Hydrology (CRCCH) is addressing these deficiencies through its Urban Stormwater Quality Research Program. The program's research has culminated in MUSIC. As an aid to decision-making, MUSIC predicts the performance of stormwater quality management systems. It is intended to help organizations plan and design (at a conceptual level) appropriate stormwater management systems for their watersheds.

A pilot version of MUSIC was released in March 2001 for testing in Australia by Melbourne Water, Brisbane City Council, and associated consultants. Following the eight-month testing period, MUSIC Version 1 was released to the public at large. MUSIC Version 2 now extends the capabilities of the original program through additional calculation and presentation features, greater ability to export data for external analysis, and substantially smaller saved files.

The model's algorithms are based on the known performance characteristics of common stormwater quality improvement measures. These data, derived from research undertaken by CRCCH and other organizations, represent the most reliable information currently available in the field. Nonetheless, knowledge gaps remain. MUSIC will develop as the CRCCH, and the stormwater field generally, conducts further research into: the watershed factors influencing the generation of stormwater pollutants and the characteristics of these pollutants; various physical, chemical, and biological processes influencing the performance of stormwater quality improvement facilities; and how aquatic ecosystems respond to stormwater-based pollutants.

<u>Approach</u>
MUSIC is an aid to decision-making. It enables evaluation of conceptual stormwater management system designs to determine which are appropriate for specific watersheds. By simulating the performance of stormwater quality improvement measures, MUSIC provides information as to whether proposed systems can meet specified water quality objectives.

MUSIC runs on an event (single storm) or continuous (many storms) basis, allowing rigorous analysis of the merit of proposed strategies over the short-term and long-term. The adoption of a continuous simulation approach is recommended in water quality modeling. This stems from the fact that impacts of poor stormwater quality on aquatic ecosystem health are associated with cumulative pollutant loads and frequency of aquatic ecosystem “exposure” to poor water quality. Pollutant loads delivered to receiving waters from many of the small storm events can make up in excess of 90% of the annual loads discharged from the watershed.

To effectively utilize the capabilities of the MUSIC system or another hydrologic simulation model employed for water quality analysis, long term meteorological data must be employed. As calibration and verification of the model was beyond the scope of the watershed assessment, such meteorological data did not need to be from within the project area but rather representative of the area. Additionally, the longer the span of the data record, the more valuable such data is for analysis as it provides a better representation of temporal parameter variability. The best meteorological data record available for such application was obtained from the National Weather Service weather station in Elizabeth City. This data record was employed for the analysis. A continuous 10-year, 1-hour time step simulation was used for this study. Data include rainfall and potential evapotranspiration for the past ten years on a one hour time step. In addition to climate data, the subwatershed size, the percent of impervious surface, the land cover/land use and the soil properties were utilized. Nitrogen, phosphorous, and total suspended solids loads were entered for baseflow and stormflow conditions.

MUSIC then simulates the performance of a group of stormwater management measures, configured in series (one after another) or in parallel (side by side) to form a “treatment train.” The stormwater management measures available in MUSIC are listed in Table 7-1. MUSIC Treatment Options. The evaluation of the effectiveness of the stormwater management system is based on a risk-based approach associated with examination of (i) the long-term frequency in which the receiving aquatic ecosystem is subjected to exposure of pollutant concentrations above a pre-specified threshold level and/or (ii) the long-term mean annual pollutant load delivered to the receiving waters.

The general model response to various parameters (including precipitation, soil permeability, channel travel time, soil depth, and others) was observed during model development. As would be expected, precipitation and infiltration parameters produced the most significant effects on model response. A formal sensitivity analysis is beyond the scope of this assessment. Such is suggested prior to any subsequent model calibration and verification.

MUSIC is a powerful tool. It is not, however, a detailed design tool: as complex as some of the mathematical models are within the model, MUSIC does not employ the degree of mathematical equations necessary for detailed design of structural stormwater quantity and/or quality facilities. MUSIC is a conceptual design tool: a planning level tool. As such, MUSIC was employed as one of several tools in the watershed analysis. Factors other than stormwater quality also influence such efforts. MUSIC does not currently incorporate all aspects of stormwater management that decision-makers must consider.

MUSIC was used in this project to help assess how individual components and groups of components in the watershed will function. This analysis can then be used to aid engineers, planners, and others when making decisions as which project to implement.

Results

From the MUSIC simulation results, two primary output components were utilized to analyze the treatment removal benefit of each project: 1) the relative mass reduction of pollutants by the project; and 2) the relative pollutant removal efficiency of the project. This can be thought of as follows: A removal rate of 90% is great, but is not that significant if there was very little loading to begin with relative to other areas in the watershed. A removal rate of 5% may seem bad, but if it removes 5 times the pollutant mass as another project in the watershed then it might be worthwhile to implement. This was quantitatively assessed in relative terms by normalizing the mass reduction and percent removal of each project to the maximum mass reduction and percent removal of any project within a watershed. Each of the pollutants were equally weighted as was the mass reduction and percent removal for each pollutant. From this, a score was generated for each project relative to all other projects within a watershed.

The model assumes implementation of all projects therefore the results show which projects are the most effective in the treatment train. The most important links (projects) in the treatment train are discussed in section 8. No one type of project consistently outperformed others. The realized removal rates are highly dependent upon the design, construction, and long term condition of the proposed measures. Sediment from unstable streambanks is a source of water quality degradation and stabilizing these banks can improve water quality. The model does not evaluate stream stability, therefore some projects may appear to do little to improve water quality but may be important to overall watershed health.

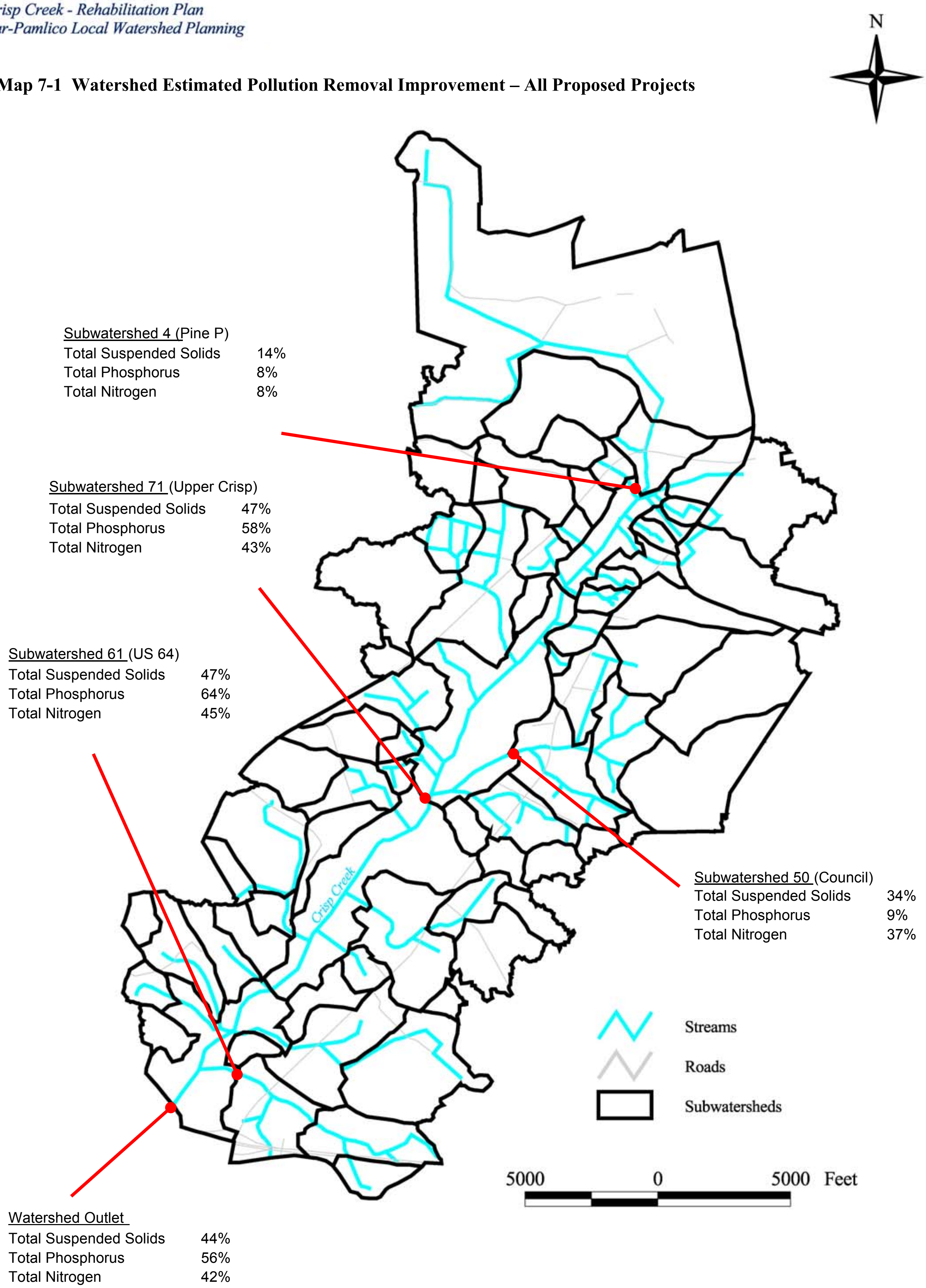
In addition to comparing specific projects in the treatment train, model results were analyzed to determine the improvement over existing conditions in each catchment when all projects are implemented (Map 7-1). The improvement is noted at the outlet of each catchment except for Council. Those removal numbers represent most of the Council catchment. Each set of removal numbers is cumulative. For example, the numbers at Upper Crisp represent not only the pollutant removal in that catchment but also the pollutant removal from all other waters entering from the Pine Plantation and Council catchments. Downstream pollutant removal efficiencies may be lower than upstream efficiencies due to cumulative pollutant inputs.

Table 7-1. MUSIC Treatment Options

Treatment	Description
Buffer Strips	Buffer Strips are commonly used as a source control measure, particularly for management of road runoff. They are effective in the removal of coarse to medium-size sediments and can be used as an effective pretreatment measure for bioretention systems.
Vegetated Swales	Vegetated Swales are open channel systems which utilize vegetation to aid the removal of sediment and suspended solids. These systems are subjected to fairly high hydraulic loading and the removal efficiency is dependent on the density and height of the vegetation in the channel.
Wetlands	Wetlands are an effective stormwater treatment measure for the removal of fine suspended solids and associated contaminants, as well as soluble contaminants. These systems utilize a combination of physical, chemical and biological processes in removing stormwater pollutants. They are commonly used as "end-of-pipe" stormwater treatment systems, but recent research has shown that they are scalable for application as near-source control measures. The model also has the capability to model the reuse of treated stormwater stored in wetland systems.
Bioretention Systems	Bioretention Systems promote the removal of particulate and soluble contaminants by passing stormwater water through a filter medium. The type of filter medium determines the effectiveness of the pollutant removal, with material of lower hydraulic conductivity providing the most efficient pollutant removal (owing to longer detention time). Typical filter material ranges from gravel (~ 10 mm) to fine sand (~0.1 mm).
Ponds	Ponds are stormwater treatment measures such as open water bodies (without significant shallow vegetated areas in the predominant flow paths) and ornamental ponds. The treatment of stormwater is predominantly associated with the temporary detention of stormwater to facilitate settling of suspended solids. Other treatment processes promoted in pond systems include phytoplankton assimilation of soluble nutrients and ultra-violet disinfection. These processes are currently not explicitly included in the modeling algorithm. The model also has the capability to model the reuse of treated stormwater stored in ponds.
Sedimentation Basins	Sedimentation Basins are open water bodies aimed predominantly at the removal of coarse and medium particles. Typically they operate at high hydraulic loading rates, and have fairly short detention times. The treatment of stormwater in detention basins is achieved almost entirely by the temporary detention of stormwater to facilitate settling of suspended solids. No other biological or biochemical processes are simulated within the Sedimentation Basin node.
Gross Pollutant Traps	Gross Pollutant Traps are devices for effective removal of solids conveyed by stormwater which are typically larger than 5 mm. Often, they are used as the first treatment element in a stormwater treatment train. There are many proprietary gross pollutant traps currently suitable for use in urban catchments and information on their performance is becoming available.
Generic Treatment Nodes	Generic Treatment Nodes are used to enable the user to define “transfer functions” for flows and water quality for stormwater quality treatment measures which are not explicitly modeled in MUSIC. Generic nodes can also be used to model such situations as flow diversion, flow dilution, contamination by sewer overflow, etc.

Table from the MUSIC v. 2.0 Help file

Map 7-1 Watershed Estimated Pollution Removal Improvement – All Proposed Projects



8. FINDINGS AND PROPOSED IMPROVEMENT PROJECTS

The previous sections explained the investigative methods used in this study and the results found. The results were analyzed to determine the projects that would help rehabilitate each catchment. The projects are summarized in Table 8-1. Map 8-1 Existing Watershed Conditions and Proposed Improvement Projects illustrates the locations of the projects. The NC Ecosystem Enhancement Program provides an excellent resource for landowners and other groups interested in undertaking restoration and water quality improvement projects. The publication, *A Guide for North Carolina Landowners; Financial Incentives and Technical Assistance Programs Which Apply to Wetlands, Streams and Streamside (Riparian Areas),* was developed in 1999 and can be found at: http://www.nceep.net/business/landowner/landowng.pdf.

US 64 Catchment

The US 64 catchment contains an unnamed tributary that flows to Crisp Creek from the southern side of the highway. This catchment is mostly agricultural with some managed pine in the headwaters that could contribute nutrients to the surface water. Stormwater runoff from the highway flows into this catchment. Even though the primary channel does have a riparian buffer, it is channelized and maintained by the drainage district. The side channels are channelized and some are unbuffered. All of these factors led to this catchment receiving a score of altered. However, there is little opportunity for traditional restoration projects within the primary channel in this catchment due to drainage district limitations. Riparian buffers are proposed for the unbuffered side streams and ditches. Model results indicate buffer project 2 is the most beneficial in this catchment in terms of pollutant removal. The only potential for development within the catchment could be highway exit-related development such as a gas station and/or fast food restaurant.

Lower Crisp Catchment

The Lower Crisp catchment contains the lower portion of Crisp Creek from Roberson School Road up to the Upper Crisp catchment near Ralston Road. Crisp Creek as well as a couple of side tributaries are maintained by the drainage district. Various sections of the main channel of Crisp Creek throughout this catchment are backed up by beaver dams. The water is backed up in the channel but not into the floodplain due to the deep channelized nature of the stream. As previously mentioned, freshwater mussels were found in the lower section of Crisp Creek. As of this report, the species of the mussels had not been identified.

As mentioned in previous sections, the stream assessment method could not be applied to sample locations that were flooded by beaver ponds. Since the beaver ponded areas are restricted to the channels, water quality and habitat are not improved as much as if the water was allowed to access the floodplain. Even though the sample points in the flooded areas were not evaluated using the ECU method, BLWI staff did visit a number of locations along this section of stream. Crisp Creek's riparian zone, excluding the drainage district road, is well buffered with hardwoods and managed pine although tracts are periodically harvested. The side channels flow from forested areas, are unbuffered through intense agriculture, then circumvent Crisp Creek's buffer by flowing directly into the creek or through pipes under the drainage district road. According to the stream assessment, the low order streams and the stream channel of Crisp Creek is altered, while the riparian zone of Crisp Creek is severely altered. There is little opportunity for traditional restoration projects within the primary channel in this catchment due to drainage district limitations. Buffers are proposed for the tributaries in this catchment. Wetland restoration is proposed along a number of side streams that originate near NC 42. These streams are not maintained by the drainage district. Model results show a few highly beneficial projects. These are buffer project 4 off of NC 11 and wetland projects 6 and 7.

Council Catchment

Council catchment contains the unnamed tributaries that make up the drainage network near Council Road. This drainage network is one of the lowest functioning catchments; it garnered a severely altered score in the stream assessment. Other than the managed pine headwaters, the unbuffered drainage network flows through intensively farmed areas. A large portion of the large channels are maintained by the drainage district. Buffers are proposed for the tributaries in northern branch of this catchment. A stream and wetland restoration is proposed for the southernmost branch. Both of these projects scored well in the model. However, the buffer project has fewer constraints than the stream and wetland restoration project. These projects are not in series therefore implementation of both projects is necessary for maximum water quality improvement.

Upper Crisp Catchment

The Upper Crisp catchment contains the upper portion of Crisp Creek from the Lower Crisp catchment to the headwaters east of NC Highway 11. Crisp Creek as well as a couple of side tributaries are maintained by the drainage district. Beaver activity is not as prevalent in this catchment as in Lower Crisp. The main channel is deep and channelized. As in Lower Crisp, Upper Crisp Creek's riparian zone, excluding the drainage district road, is well buffered with hardwoods and managed pine, although periodically harvested. The side channels flow from forested areas, are unbuffered through intense agriculture, then circumvent Crisp Creek's buffer by flowing directly into the creek. According to the stream assessment, the majority of the low order stream functions are severely altered, while the one sample location on Crisp Creek itself is altered. There is little opportunity for traditional restoration projects within the primary channel in this catchment due to drainage district limitations. Buffers are proposed for the tributaries in this catchment. Wetland restoration is proposed along a number of side streams. Model results show projects 16 and 17, a combination of wetland and stream restoration and buffers, are the most efficient projects in terms of pollutant removal. Other projects worth noting for water quality improvement are buffer project 24 and wetland project 13.

Pine Plantation Catchment

The Pine Plantation catchment contains the managed pine areas in the northern portion of the watershed. Local resource professionals stated that this catchment contributes significant sediment to Crisp Creek. The stream assessment sample locations are located on the primary channel in the agricultural area at the lower portion of the catchment; both samples score in the severely altered category. This section of stream is maintained by the drainage district. There is little opportunity for traditional restoration projects due to drainage district and pine plantation limitations. A forestry BMP should be implemented on/near the stream to alleviate the sediment load before it enters Crisp Creek. The model results indicate this project ranked eleventh of all of the projects in Crisp Creek in terms of pollutant removal efficiency in the treatment train.

Overall Watershed Findings

Crisp Creek is a part of the watershed controlled by the Edgecombe County Drainage District #2. NC General Statute 156-54 provides for the establishment of drainage districts in North Carolina. A board of drainage commissioners is responsible for the activities within each drainage district. This provision addresses the activities of maintaining a drainage canal. Activities such as access, maintaining a road along the canal for maintenance, removal of sediment and desnagging of fallen trees/limbs do not allow for the typical stream or wetland restoration approach.

Models results show stream and wetland restoration would improve water quality, however the presence of the drainage district constrains traditional restoration methods. Improvements within the watershed regarding water quality and habitat must come from alternative techniques. It is suggested that these methods be applied along the field ditches, side drainages that flow into the district canal and their associated fields. Techniques to be employed are the addition of buffers, the placement of best management practices (BMPs), and controlled drainage.

Vegetated buffers will help reduce sediment and nutrient loading into the waters of Crisp Creek. Vegetation can be either grass, herbaceous, forested (woody) or a combination of the choices, depending on the location along the corridor. Field ditches offer the best placement of either grass or herbaceous buffers. Forested (woody) riparian plantings are best located on either intermittent or perennial streams. The buffer type which would provide the best treatment/removal is location dependent and all factors should be considered. For example, the planting of a forested buffer may seem to be the best choice in terms of habitat and nutrient removal, but if the associated stream is deeply incised, it is possible that the roots would never grow deep enough to be effective in nutrient removal. Incised or deeply excavated streams are frequent within the Crisp watershed.

The use of BMPs and controlled drainage are most effective in nutrient and to some extent toxin removal. Proper placement and use of these practices are critical for its success. The farmer/landowner should work with local, state and federal agencies in understanding the placement and sequencing associated with BMP methods. There are a few landowners already participating in the NRCS CREP program.

Table 8-1. Proposed Improvement Projects

No.	Location	Type	Size*
1	Blount Farms LLC	woody buffer	241,500 sqft
2	Carson Property south of US Highway 64	woody buffer	140,000 sqft
3	Smith/Roberson Farms Properties - NC Highway 11	wetland restoration	16 acres
4	Smith Property - NC Highway 11	woody buffer	300,000 sqft
5	Mayo Property - Roberson School Rd	wetland restoration	40 sqft
6	Mayo/Roberson Properties - Roberson School Rd	wetland restoration	14 sqft
7	Roberson Property - Roberson School Rd	wetland restoration	30 sqft
8	Doughtie Property - Roberson School Rd	grass buffer	480 linear feet
9	Flanagan Property - NC Highway 11	woody buffer	170,000 sqft
10	NC Highway 11 between Dixon Rd and Council Rd	wetland restoration/buffer	24 acres (wetland) 610,000 sqft (buffer)
11	Ralston Rd	wetland restoration	31 acres
12	NC Highway 42 north of Ralston Rd	woody buffer	478,500 sqft
13	NC Highway 42 north of Ralston Rd	wetland restoration	60 acres

Table 8-1. (continued)

14	Council Rd and NC Highway 11	stream and wetland restoration/woody buffer	1,400 linear feet (stream) 11 acres (wetland) 560,000 sqft (buffer)
15	North of Council Rd	woody and grass buffers	2,000,000 sqft (woody buffer) 115,300 sqft (grass buffer)
16	Between Ralston Rd and NC Highway 142	stream and wetland restoration	2,600 linear feet (stream) 15 acres (wetland)
17	South of NC Highway 142	wetland restoration/woody buffer	88 acres (wetland) 645,000 sqft (buffer)
18	West of NC Highway 11	grass buffer	106,500 sqft
19	West of NC Highway 11	woody buffer	270,000 sqft
20	West of NC Highway 11	woody buffer	313,000 sqft
21	East of NC Highway 42	woody buffer	343,000 sqft
22	West of NC Highway 11	woody buffer	200,000 sqft
23	East of NC Highway 42	grass buffer	104,300 sqft
24	West of NC Highway 11	woody buffer	551,500 sqft
25	West of NC Highway 11	woody buffer	137,100 sqft
26	West of NC Highway 11	woody buffer	148,900 sqft
27	West of NC Highway 11	woody buffer	191,500 sqft
28	East of NC Highway 42	grass buffer	88,800 sqft
29	East of NC Highway 42	woody buffer	180,800 sqft
30	On either side of NC Highway 42 at top of watershed	grass buffer	463,700 sqft
31	West of NC Highway 11	stream restoration/woody buffer	2,658 linear feet (stream) 113,500 sqft (buffer)
32	East of NC Highway 11	wetland restoration	9.55 acres

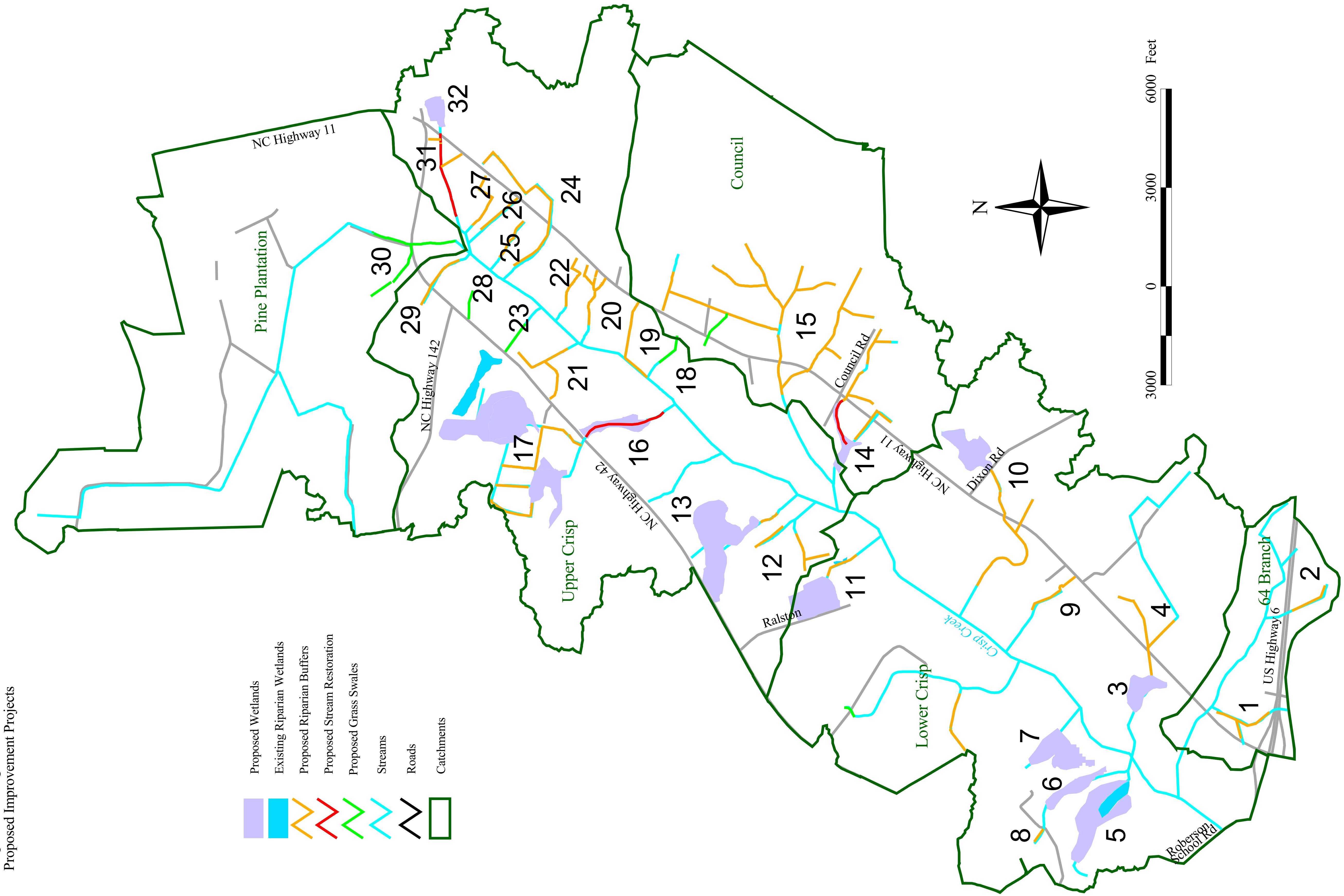
**Riparian buffers sizes are given in square feet, a buffer width of 50 feet on each side of the stream was assumed for all projects.*

9. CONCLUSION

Crisp Creek is an agricultural watershed with an immense network of unbuffered ditches and channels. Other than runoff from US Highway 64, imperviousness and development is not an issue in the Crisp Creek watershed due to a declining trend in population. Watershed functions have been severely impacted with the removal of native forest, the draining of wetlands, and the straightening of channels. As mentioned above, there is limited opportunity for traditional restoration projects on larger channels. The proposed traditional projects will be difficult to implement unless an agreement is reached with the drainage district and landowners. Alternative ways to improve water quality and hydrology should be evaluated. Buffers have been recommended for all of the unbuffered streams. Streams were determined to be unbuffered using aerial imagery, the land cover analysis, and stream assessments in the field. This was primarily confined to USGS streams and those drainages added for the Coastal Plain stream assessment (see section 5 for an explanation). It was not within the scope of this study to visit all of the unbuffered streams. Therefore it is likely that grass buffers will be more beneficial in some of the reaches where woody buffers are suggested. Any stream reach should be analyzed before installing buffers to determine if a grass or woody buffer is more appropriate.

The drainage network in Crisp is very extensive and many ditches were not included in this assessment. To improve water quality, buffers and other BMPs should also be installed along these secondary ditches. Potentially, projects in the headwaters, where many of the secondary ditches are found, will treat the water before it gets to Crisp Creek and lessen the downstream inputs to the 303-d listed Conetoe Creek.

Map 8-1 Existing Watershed Conditions and Proposed Improvement Projects



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