Assessment Report: Biological Impairment in the Stoney Creek Watershed

Neuse River Basin
Wayne County, N.C.

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Executive Summary

Introduction

This report presents the results of the Stoney Creek water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) with financing from the Clean Water Management Trust Fund (CWMTF). Stoney Creek is considered impaired by the DWQ because it is unable to sustain an acceptable community of aquatic organisms, indicating that the stream does not fully support its designated uses. The goal of the assessment is to provide the foundation for future water quality restoration activities in the Stoney Creek watershed by: 1) identifying the most likely causes of biological impairment; 2) identifying the major watershed activities and pollution sources contributing to those causes; and 3) outlining a general watershed strategy that recommends restoration activities and best management practices (BMPs) to address the identified problems.

Study Area and Stream Description

Stoney Creek is located in Wayne County, in subbasin 03-04-05 of the Neuse River basin (see Figure in Section 1). From its headwaters north of Goldsboro, the stream flows southward for 10.7 miles joining the Neuse River near Seymour Johnson Air Force Base (SJAFB). The current study area includes Stoney Creek and its tributaries upstream of Slocumb Street in Goldsboro, encompassing approximately 27.6 square miles of the 29.5 square mile watershed.

The upper portion of the watershed (north of New Hope Road) is primarily agricultural (37 percent in row crops), although development activity is increasing. The majority of the lower watershed lies within the City of Goldsboro, where a mixture of residential, military (SJAFB), commercial and light industrial land uses predominates. As of 1998, impervious areas (e.g., roads and buildings) covered approximately 20 percent of the study area, with higher levels (29 percent) evident in the lower study area below New Hope Road. There are no permitted wastewater discharges in the study area.

Streams in the watershed are classified as C-NSW (nutrient sensitive waters). North Carolina's 303(d) list designates Stoney Creek as impaired for its entire length in the study area. Stoney Creek is located in North Carolina's inner coastal plain, an area characterized by low velocity streams and extensive swamp areas. These characteristics are particularly evident in the upper portion of the watershed, where swamp-like conditions predominate and there is often little observable streamflow. Visual assessment suggests that significant portions of the mainstem and major tributaries were channelized (dredged and straightened) at some point. The study area is described in more detail in Section 2.

Approach

A wide range of data was collected to evaluate potential causes and sources of impairment. Data collection activities included: benthic macroinvertebrate sampling; assessment of stream habitat, morphology, and riparian zone condition; water quality sampling to evaluate stream chemistry and toxicity; and characterization of watershed land use, conditions and pollution sources. Precipitation levels were below normal in 2001 and the first half of 2002, when most field work for the study was conducted. Data collected during the study are presented in Sections 2, 4, 5, and 6 of the report.

Conclusions

Benthic communities in Stoney Creek are impaired downstream of East Ash Street in Goldsboro. Impairment has been evident at Slocumb Street since the site was first sampled in 1995. The stream could not be rated upstream of East Ash Street due to stream size and swamp conditions.

Aquatic organisms in the watershed are impacted by multiple stressors (see Section 7 for additional discussion):

- Habitat degradation is most severe upstream of East Ash Street, especially in the area of Wayne Memorial Drive, where channel morphology is uniform and organic habitats are lacking. Some habitat degradation is evident further downstream, but in general the impaired portion of Stoney Creek appears to contain habitat adequate to support more diverse and abundant aquatic communities than those currently present. Riparian areas along lower Stoney Creek (below New Hope Road) are sometimes sparsely vegetated and are often dominated by non-native invasive species that provide limited bank protection.
- Toxicity is considered a primary cause of impairment. The most important toxicants cannot be identified definitively and may be variable, although the insecticide diazinon and several metals appear to be the most likely causes during one period of toxicity. Existing water quality data point to the urban lower half of the watershed as the most important source of toxicants. However, agricultural pesticides could not be completely characterized during the study and potential impacts from these chemicals cannot be ruled out.
- Low dissolved oxygen (DO) also contributes to biological degradation. Low DO conditions are due, at least in part, to natural swamp drainage from the upper watershed, although inputs of nutrients and oxygen-consuming wastes from developed and agricultural areas probably worsen the situation. Low DO stress declines substantially in the lower study area, where streams are free-flowing.
- Impairment in lower Stoney Creek is likely also impacted by a lack of benthic colonization sources due to low DO stress in the headwaters as well as the degraded nature of many urban tributaries.
- Scour (excessive removal of organisms and microhabitat during storms) is also a contributing factor. While the smaller tributaries draining developed areas of Goldsboro were not evaluated in detail, scour and resulting habitat degradation is likely in these streams given the high level of impervious cover in tributary watersheds and the incised nature of some of these small streams.

Recommendations

The most important factors leading to impairment in the study area are systemic in nature. Addressing these problems will require actions that are similarly broad in scope. Mitigating the potential impacts of future watershed development on watershed hydrology and pollutant loading is also critical, or improvements resulting from efforts to control current sources of impairment may be short lived.

The following actions are necessary to address sources of impairment in Stoney Creek (see Section 8 for further discussion). The intent of these recommendations is to describe the types of actions necessary to improve conditions in the Stoney Creek watershed, not to specify particular administrative or institutional mechanisms for implementing remedial practices. Actions one

through five are all important to the restoration of aquatic communities throughout the study area. Of these, actions one, three and four are considered most critical. Actions six through eight are important in order to protect streams in the watershed from the impacts of new development.

1. **A strategy to address toxic inputs from the urban portions of the watershed should be developed and implemented, including a variety of source reduction and stormwater treatment methods**. These measures should be applicable both to municipal areas and to the Seymour Johnson Air Force Base (SJAFB). As an initial framework for planning toxicity reduction efforts, the following general approach is proposed:
   a) Development and implementation of a broad set of source reduction activities focused on: reducing nonstorm inputs of toxicants; reducing pollutants available for washoff during storms; and managing water to reduce storm runoff.
   b) Implementation of stormwater treatment Best Management Practices, aimed primarily at pollutant removal, at appropriate locations.
   c) Development of a stormwater and dry weather sampling strategy in order to facilitate the targeting of pollutant removal and source reduction practices.
2. **Given the extensive crop acreage in the upper watershed, agricultural pesticides must be considered a potential risk that merits further evaluation**, although existing data provide no clear evidence of agricultural pesticide impacts. A review of current pesticide usage and application practices by appropriate agricultural agencies would provide more information on potential risks and pathways. Relevant agencies include the NC Department of Agriculture and Consumer Services (NCDACS), the NC Division of Soil and Water Conservation, local Soil and Water Conservation Districts, the NC Cooperative Extension Service and the US Department of Agriculture Natural Resources Conservation Service.
3. **Native woody riparian vegetation along Stoney Creek and its tributaries should be reestablished where it has been removed to provide an adequate supply of woody material to the stream and improve bank stability**. Where riparian vegetation is of poor quality due to dominance by non-native species, invasive species should be replaced with native riparian vegetation.
4. **In order to reduce stormflow scour and bank erosion, especially in tributaries draining developed areas, feasible and cost-effective stormwater retrofit projects should be implemented in the urban portions of the watershed to mitigate the hydrologic effects of development**. Over the short-term, currently feasible retrofit projects should be identified and implemented in both the municipal areas of the watershed and in SJAFB. In the longer term, additional retrofit opportunities should be sought out in conjunction with infrastructure improvements and redevelopment of existing developed areas. Projects already implemented through the efforts of the Mid-Neuse Nonpoint Source Team provide examples of retrofit activities.
5. **While low DO levels in the watershed are likely due in part to natural swamp drainage, nutrient reduction efforts should be implemented so that human inputs do not significantly worsen the situation.** Nutrient reduction activities currently underway as part of the Neuse River basin efforts could well have an impact, and actions recommended above (e.g., retrofit BMPs to address toxicity and stormwater quantity) are likely to reduce organic and nutrient loading to some extent. Additional efforts may be necessary, however. Activities recommended to address organic loading include the identification and elimination of illicit discharges; education of homeowners, commercial applicators, and others regarding proper fertilizer use; street sweeping; catch basin clean-out practices; and the installation of

additional BMPs targeting removal of biochemical oxygen demand and nutrients at appropriate sites.

6. Prevention of further channel erosion and habitat degradation will require effective post-construction stormwater management for new development in the study area, whether accomplished through the Neuse stormwater rules, Phase II requirements or voluntary local action. A proactive approach to reduce the risks to Stoney Creek from future development impacts would include: promotion of development design approaches that minimize the generation of storm runoff; active promotion of infiltration practices; requiring post-construction stormwater control for all but the lowest density development; exploration of retrofit opportunities for existing developed areas; limited use of the allowed exemption to the Neuse stormwater rules for development activities which are projected to increase peak flows by 10 percent or less.
7. Effective enforcement of sediment and erosion control regulations on the part of the NC Division of Land Resources will be essential to the prevention of additional sediment inputs from construction activities. Development of improved erosion and sediment control practices may be beneficial.
8. It is important to protect existing wetlands and forested riparian buffers along all waterbodies, including ephemeral streams. The protection of these areas is critical to limiting the hydrologic impacts of development and to the attenuation of pollutant inputs. Education of landowners regarding the functions of riparian areas and discouraging removal of additional riparian vegetation would be useful both in newer development constructed under the Neuse buffer regulations and in older developments. Existing swamps and other wetland areas in the upper portion of the watershed should be protected from both direct modification and the indirect impacts of encroaching development.

Section 1
Introduction

This report presents the results of the Stoney Creek water quality assessment, conducted by the North Carolina Division of Water Quality (NCDWQ) with financing from the Clean Water Management Trust Fund (CWMTF). Stoney Creek is considered impaired by the DWQ because it is unable to support an acceptable community of aquatic organisms. The reasons for this condition have been previously unknown, inhibiting efforts to improve stream integrity in this watershed.

Part of a larger effort to assess impaired streams across North Carolina, this study was intended to evaluate the causes of biological impairment and to suggest appropriate actions to improve stream conditions. The CWMTF, which allocates grants to support voluntary efforts to address water quality problems, is seeking DWQ's recommendations regarding the types of activities it could fund in these watersheds to improve water quality. Both the DWQ and the CWMTF are committed to encouraging local initiatives to protect streams and to restore degraded waters.

1.1 Study Area Description

Stoney Creek is located in Wayne County, in subbasin 03-04-05 of the Neuse River basin (Figure 1.1). From its headwaters, just east of the intersection of US 117 and SR 1537, the stream flows southward for 10.7 miles, joining the Neuse River approximately one mile south of Slocumb Street (SR 1920) in Goldsboro. Stoney Creek is listed as impaired for its entire length (NCDENR, 2000). The current study area includes Stoney Creek and its tributaries upstream of Slocumb Street, including approximately 27.6 square miles of the 29.5 square mile watershed.

Stoney Creek is located in North Carolina's inner coastal plain, an area characterized by low velocity streams and extensive swamp areas. These characteristics are particularly evident in the upper portion of the study area (north of New Hope Road) where swamp-like conditions predominate and there is often little observable streamflow. Land use in this portion of the watershed is primarily agricultural. The lower portion of the study area is primarily urban and contains portions of the City of Goldsboro and Seymour Johnson Air Force Base (SJAFB).

1.2 Study Purpose

The Stoney Creek assessment is part of the Watershed Assessment and Restoration Project (WARP), a study of eleven watersheds across the state being conducted during the period from 2000 to 2002 with funding from the CWMTF (Table 1.1). The goal of the project is to provide the foundation for future water quality restoration activities in the eleven watersheds by:

1. Identifying the most likely *causes* of biological impairment (such as degraded habitat or specific pollutants).
2. Identifying the major watershed activities and *sources* of pollution contributing to those causes (such as stream bank erosion or stormwater runoff from particular urban or rural areas).

3. Outlining a watershed *strategy* that recommends restoration activities and best management practices (BMPs) to address the identified problems and improve the biological condition of the impaired streams.

This investigation focused primarily on aquatic life use support issues. It was intended to assess the major issues related to biological impairment as comprehensively as possible within the time frame of the study. While not designed to address other important issues in the Stoney Creek watershed, such as bacterial contamination or flooding, the report discusses those concerns where existing information allows.

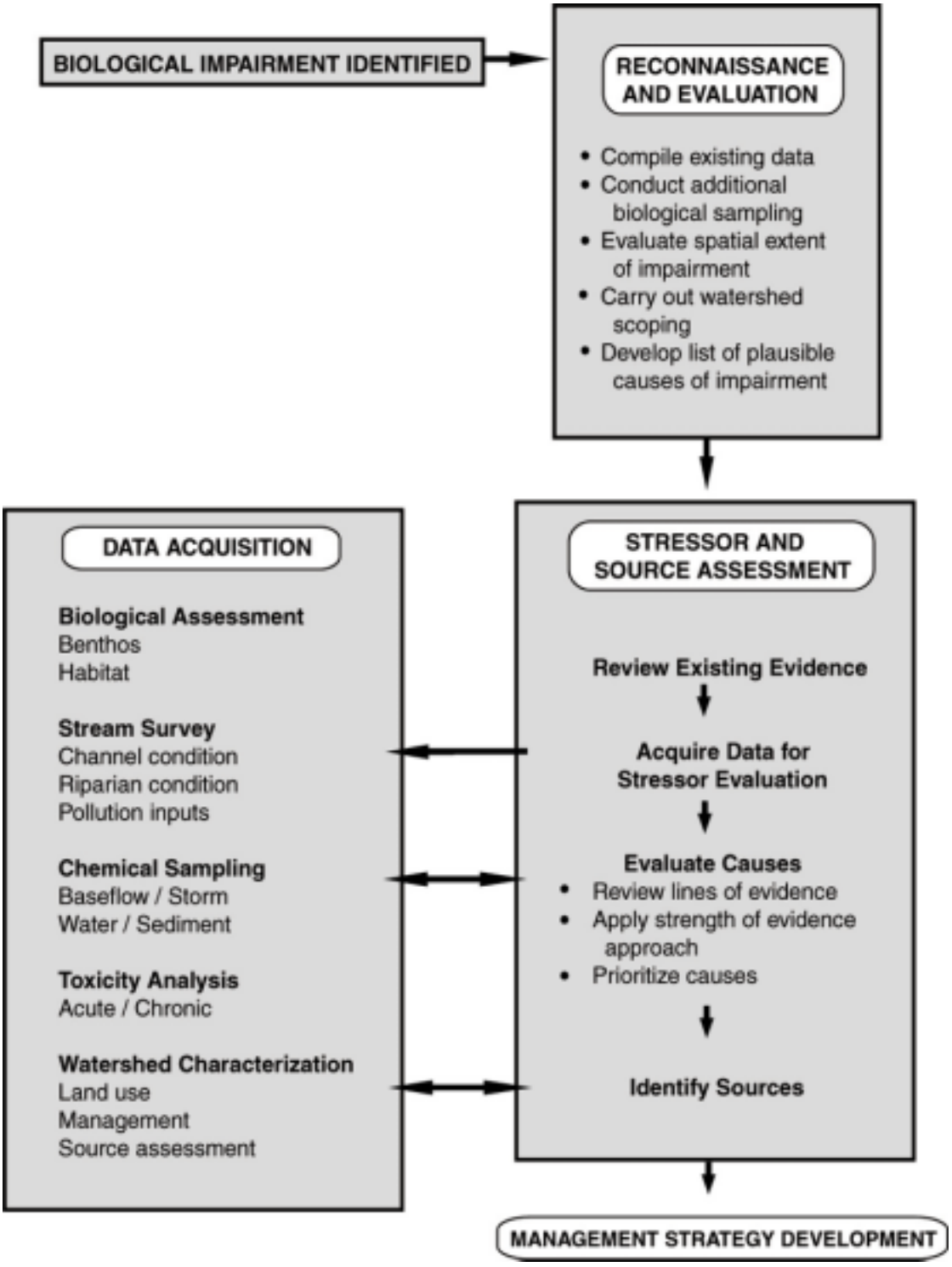
Table 1.1 Study Areas Included in the Watershed Assessment and Restoration Project

Watershed	River Basin	County
Toms Creek	Neuse	Wake
Upper Swift Creek	Neuse	Wake
Little Creek	Cape Fear	Orange, Durham
Horsepen Creek	Cape Fear	Guilford
Little Troublesome Creek	Cape Fear	Rockingham
Upper Clark Creek	Catawba	Catawba
Upper Cullasaja River/Mill Creek	Little Tennessee	Macon
Morgan Mill/Peter Weaver Creeks	French Broad	Transylvania
Mud Creek	French Broad	Henderson
Upper Conetoe Creek	Tar-Pamlico	Edgecombe, Pitt, Martin
Stoney Creek	Neuse	Wayne

1.3 Study Approach and Scope

Of the study's three objectives, identification of the likely causes of impairment is a critical building block, since addressing subsequent objectives depends on this step (Figure 1.2). Determining the primary factors causing biological impairment is a significant undertaking that must address a variety of issues (see the Background Note "Identifying Causes of Impairment"). While identifying causes of impairment can be attempted using rapid screening level assessments, this study has taken a more detailed approach in order to maximize the opportunity to reliably and defensibly identify causes and sources of impairment within the time and resource framework of the project. This provides a firmer scientific foundation for the collection and evaluation of evidence, facilitates the prioritization of problems for management, and offers a more robust basis for the commitment of resources. EPA's recently published guidance for stressor identification envisions that causes of impairment be evaluated in as rigorous a fashion as is practicable (USEPA, 2000).

Figure 1.2 Overview of Study Activities



☞ **Background Note: Identifying Causes of Impairment**

Degradation and impairment are not synonymous. Many streams and other waterbodies exhibit some degree of degradation, that is, a decline from unimpacted conditions. Streams that are no longer pristine may still support good water quality conditions and function well ecologically. When monitoring indicates that degradation has become severe enough to significantly interfere with one of a waterbody's designated uses (such as aquatic life propagation or water supply), the Division of Water Quality formally designates that stream segment as impaired. It is then included on the state's 303(d) list, the list of impaired waters in North Carolina.

Many impaired streams, including those that are the subject of this study, are so rated because they do not support a healthy population of fish or benthic macroinvertebrates (aquatic insects visible to the naked eye). While standard biological sampling can determine whether a stream is supporting aquatic life or is impaired, the cause of impairment can only be determined with additional investigation. In some cases, a potential cause of impairment is noted when a stream is placed on the 303(d) list, using the best information available at that time. These noted potential causes are generally uncertain, especially when nonpoint source pollution issues are involved.

A cause of impairment can be viewed most simply as a stressor or agent that actually impairs aquatic life. These causes may fall into one of two broad classes: 1) chemical or physical pollutants (e.g., toxic chemicals, nutrient inputs, oxygen-consuming wastes); and 2) habitat degradation (e.g., loss of in-stream structure such as riffles and pools due to sedimentation; loss of bank and root mass habitat due to channel erosion or incision). Sources of impairment are the origins of such stressors. Examples include urban and agricultural runoff.

The US Environmental Protection Agency defines causes of impairment more specifically as "those pollutants and other stressors that contribute to the impairment of designated uses in a waterbody" (USEPA, 1997, pp. 1-10). When a stream or other waterbody is unable to support an adequate population of fish or macroinvertebrates, identification of the causes of impairment thus involves a determination of the factors most likely leading to the unacceptable biological conditions.

All conditions, which impose stress on aquatic communities, may not be causes of impairment. Some stressors may occur at an intensity, frequency and duration that are not severe enough to result in significant degradation of biological or water quality conditions to result in impairment. In some cases, a single factor may have such a substantial impact that it is the only cause of impairment, or clearly predominates over other causes. In other situations, several major causes of impairment may be present, each with a clearly significant effect. In many cases, individual factors with predominant impacts on aquatic life may not be identifiable and the impairment may be due to the cumulative impact of multiple stressors, none of which is severe enough to cause impairment on its own.

The difficulty of developing linkages between cause and effect in water quality assessments is widely recognized (Fox, 1991; USEPA, 2000). Identifying the magnitude of a particular stressor is often complex. Storm-driven pollutant inputs, for instance, are both episodic and highly variable, depending upon precipitation timing and intensity, seasonal factors and specific watershed activities. It is even more challenging to distinguish between those stressors which are present, but not of primary importance, and those which appear to be the underlying causes of impairment. Following are examples of issues which must often be addressed.

- Layered impacts (Yoder and Rankin, 1995) may occur, with the severity of one agent masking other problems that cannot be identified until the first one is addressed.
- Cumulative impacts, which are increasingly likely as the variety and intensity of human activity increase in a watershed, are widely acknowledged to be very difficult to evaluate given the current state of scientific knowledge (Burton and Pitt, 2001; Foran and Ferenc, 1999).
- In addition to imposing specific stresses upon aquatic communities, watershed activities can also inhibit the recovery mechanisms normally used by organisms to 'bounce back' from disturbances.

For further information on use support and stream impairment issues, see the website of DWQ's Basinwide Planning Program at http://h2o.enr.state.nc.us/basinwide/; A *Citizen's Guide to Water Quality Management in North Carolina* (NCDWQ, 2000); EPA's *Stressor Identification Guidance Document* (USEPA, 2000).

1.3.1 Study Approach

The general conceptual approach used to determine causes of impairment in Stoney Creek was as follows (see Foran and Ferenc, 1999; USEPA, 2000).

- *Identify the most plausible potential (candidate) causes* of impairment in the watershed, based upon existing data and initial watershed reconnaissance activities.
- *Collect data* bearing on the nature and impacts of those potential causes.
- *Characterize the causes of impairment* by evaluating all available information using a *strength of evidence approach*. The strength of evidence approach, discussed in more detail in Section 7, involves a logical evaluation of multiple lines (types) of evidence to assess what information supports or does not support the likelihood that each candidate stressor is actually a contributor to impairment.

Project goals extended beyond identifying causes of impairment, however, and included the evaluation of source activities and the development of recommendations to mitigate the problems identified. In order to address all three objectives, activities conducted in the Stoney Creek watershed during this study were divided into three broad stages (Figure 1.2):

1. An initial *reconnaissance stage*, in which existing information was compiled and watershed reconnaissance conducted. At the conclusion of this stage the most plausible candidate causes of impairment were identified for further evaluation.
2. A *stressor-source evaluation stage* that included: collection of information regarding candidate causes of impairment; evaluation of all available information using a strength of evidence approach; investigation of likely sources (origins) of the critical stressors.
3. The *development of strategies* to address the identified causes of impairment.

1.3.2 Approach to Management Recommendations

One of the goals of this assessment was to outline a course of action to address the key problems identified during the investigation, providing local stakeholders, the CWMTF and others with the information needed to move forward with water quality improvement efforts in this watershed. It is DWQ's intent that the recommendations included in this document provide guidance that is as specific as possible given available information and the nature of the issues to be addressed. Where problems are multifaceted and have occurred over a long period of time, the state of scientific understanding may not permit all actions necessary to mitigate those impacts to be identified in advance. In such situations, an iterative process of 'adaptive management' (Reckhow, 1997; USEPA, 2001) is required, in which those committed to stream improvement efforts begin with implementation of an initial round of management actions, followed by monitoring to determine what additional measures are needed.

Protection of streams from additional damage due to future watershed development or other planned activities is a critical consideration. In the absence of such protection, efforts to restore water quality by mitigating existing impacts will often be ineffective or have only a temporary impact. These issues were examined during the course of the study and addressed in the management recommendations.

It is not the objective of this study to specify particular administrative or institutional mechanisms for implementing remedial practices, but only to describe the types of actions that must occur to place Stoney Creek on the road to improvement. It is DWQ's hope that local governments and other stakeholders in the Stoney Creek watershed will work cooperatively with each other and with state agencies to implement these measures in cost-effective ways.

The study did not develop TMDLs (total maximum daily loads) or establish pollutant loading targets. For many types of problems (e.g., most types of habitat degradation), TMDLs may not be an appropriate mechanism for initiating water quality improvement. Where specific pollutants are identified as causes of impairment, TMDLs may be appropriate and necessary if the problem is not otherwise addressed expeditiously.

1.3.3 Data Acquisition

While project staff made use of existing data sources during the course of the study, these were not adequate to fully address the goals of the investigation. Extensive data collection was necessary to develop a more adequate base of information. The types of data collected during the study included:

1. Macroinvertebrate sampling;
2. Assessment of stream habitat, morphology, and riparian zone condition;
3. Stream surveys--walking stream channels to identify potential pollution inputs and obtain a broad scale perspective on channel condition;
4. Chemical sampling of stream water quality;
5. Bioassays to assess water column toxicity; and
6. Watershed characterization--evaluation of watershed hydrologic conditions, land use, land management activities, and potential pollution sources.

Section 2
Description of the Stoney Creek Watershed

2.1 Introduction

The study area is comprised of Stoney Creek and its tributaries upstream of Slocumb Street (SR 1920) in Goldsboro, NC. Stoney Creek has a length of 10.7 miles, 9.6 miles of which are within the study area, and a drainage area of 29.5 square miles, 27.6 square miles of which are within the study area. Approximately 40 percent of the study area lies within the city limits of Goldsboro (2000 population 40,709), with much of the remainder of the watershed within the City of Goldsboro's planning jurisdiction. This section summarizes watershed hydrography and topography, describes current and historical land use, and discusses potential pollutant sources.

2.2 Upper and Lower Study Area Delineation

For purposes of this study, the study area was divided into upper and lower areas as described below.

1. Upper study area (13.4 square miles). This portion of the study area (Figure 2.1), located north of New Hope Road, is primarily agricultural (Exhibit 2.1), with development concentrated in areas east of NC 117 and draining to Howell Branch. Streams in this portion of the study area have little observable flow, and many reaches are contiguous with swamps.

2. Lower study area (14.1-square miles). The lower study area includes portion of Stoney Creek, Howell Branch, Reedy Branch and Billy Branch located south of New Hope Road. Land use in this portion of the study area is primarily urban (Exhibit 2.2). Although swamp-like conditions continue to characterize streams between New Hope Road and Wayne Memorial Drive, stream velocity gradually increases below Wayne Memorial Drive.

2.3 Streams

The mainstem of Stoney Creek is joined by the following major tributaries, in order from upstream to downstream: Stoney Run, Howell Creek, Reedy Branch and Billy Branch (Figure 2.1). Typical coastal plain features such as slow flowing, blackwater streams and low lying swamplands with bottomland forests and marsh floodplains characterize the upper study area. Streams in this portion of the watershed are often contiguous with larger swamp areas.

The upper portion of the study area contains numerous small agricultural impoundments, and beaver impoundments are also common. The only artificial impoundment in the lower watershed is pond in a housing development on a small tributary. Beaver impoundments are less common in the lower portion of the study area.

There is no stream gage in the watershed. Observations following moderate storm events indicate that stream stage and velocity can increase rapidly in the lower portion of the study area.

The State of North Carolina classifies Stoney Creek as C-NSW (Class C, nutrient sensitive waters). The NSW (nutrient sensitive waters) classification applies to all streams in the Neuse River basin. North Carolina's 2000 303(d) List records Stoney Creek as biologically impaired for its entire length. Although urban runoff and storm sewers are listed as potential sources on the 303(d) List, the reasons for biological impairment had not been determined prior to the study.

Visual assessments suggest that much of Stoney Creek, Stoney Creek Run, Howell Branch downstream of Tommy's Road (SR 1571) and many first and second order tributaries were channelized (dredged and straightened) at some point (Exhibits 2.3 and 2.4). Wayne County Natural Resources Conservation Service (NRCS) staff are not aware of any widespread channelization that occurred in the lower study area within the past 50 years or in the upper study area within the past 100 years.

Exhibit 2.1 Agricultural land in the upper study area.

Exhibit 2.2 Urban land use in Goldsboro, lower study area

Exhibit 2.3 Channelized reach, upper portion of the study area

Exhibit 2.4 Channelized reach, lower portion of the study area

2.4 Topography and Geology

The headwaters of Stoney Creek are located just east of the intersection of NC 117 and Stoney Creek Church Road, near the Goldsboro Municipal Airport, at an elevation of approximately 131 feet above mean sea level (msl). From the headwaters the watershed slopes gently southward, dropping to an elevation of 72 feet msl near the terminus of the watershed. The stream gradient is relatively uniform throughout the study area (approximately four to six feet per mile). Run-off on the nearly flat divides and level flood plains is slow and the area is prone to flooding.

Precipitation averages approximately 50 inches (2054 millimeters) per year at Seymour Johnson Air Force Base (SJAFB). Rainfall is typically highest from June through September (1971-2000 period of record) (Southeast Regional Climate Center at http://cirrus.dnr.state.sc.us). Because thunderstorms account for a large portion of rainfall during these months, some locations may be without significant rainfall for five to 20 days.

In September 1999, Tropical Storm Dennis and Hurricane Floyd brought some of the largest amounts of precipitation and most severe flooding on record. Precipitation at SJAFB during September 1999 was 26.9 inches compared with a historic average of 4.8 (Southeast Regional Climate Center at http://cirrus.dnr.state.sc.us). More recently, drought conditions have prevailed with precipitation below normal during the entire study period (Table 2.1).

Table 2.1 Study Period Precipitation and Departure from Normal at Seymour Johnson Air Force Base

Year	Precipitation (inches)	Departure from Normal
2000	42.5	-15.0 %*
2001	44.8	-10.4 %*
2002 (January-September)	33.0	-18.4 %**

* Compared to 1971-2000 annual average of 50.0 inches.

** Compared to 1971-2000 average for Jan.-Sept. of 40.4 inches.

Source: Southeast Regional Climate Center, 2002 (http://water.dnr.state.sc.us/climate).

Watershed soils are typically acid and strongly leached with very low to low natural fertility. Floodplain areas contain the poorly drained to very poorly drained soils of the Johnston-Chewacla-Kinston association. Many upland areas contain well drained to moderately well drained soils of the Norfolk-Goldsboro-Aycock association. Both these soil associations have a friable sandy loam to clay loam subsoil and are underlain by unconsolidated layers of sand, silt, and clay (USDA Soil Conservation Service, 1974). Some upland soils, especially in the upper watershed, are of the Rains-Torhunta-Liddell association, which are poorly drained to very poorly drained.

2.5 Land Cover in the Watershed

Land cover data for the Stoney Creek study area (Figure 2.2 and Table 2.2), based on satellite imagery from 1998 and 1999, were taken from a database developed by the US Environmental Protection Agency as part of a landscape characterization study of the Neuse River basin (see Appendix C). Approximately 41 percent of the study area is developed, with 29 percent in cropland and only 23 percent in forest. Land cover differs greatly in the upper and lower study areas, however. The area downstream of New Hope Road is 60 percent developed, while only 22 percent of the upper area is developed and 37 percent is in row crops.

Table 2.2 Land Cover Distribution in the Stoney Creek Study Area, 1998-1999

Land Cover Category	Entire Study Area (27.56 sq miles)	Upper Study Area (13.42 sq miles)	Lower Study Area (14.14 sq miles)
	% of Total	% of Total	% of Total
Urban -- Total	**41.30**	**22.84**	**59.77**
High Density	6.38	1.78	10.75
Medium Density	16.70	7.49	25.44
Low Density	18.22	12.57	23.58
Agriculture -- Total	**28.89**	**44.99**	**13.60**
Row crops	23.07	36.72	10.11
Pasture/Hay	5.82	8.27	3.49
Forest	**23.08**	**28.06**	**18.35**
Open Water	**0.22**	**0.27**	**0.18**
Wetlands	**5.99**	**4.35**	**7.56**
Barren Land	**0.53**	**0.50**	**0.55**
Total	**100.00**	**100.00**	**100.00**

Source: Land use and land cover data developed by the USEPA for the Neuse River basin. Based on 1998-1999. Spot 4 and Landsat 7 Imagery. Land use database described in Appendix C.

As of 1998, impervious areas (areas such as rooftops, roads, and parking lots that prevent infiltration of precipitation into the soil) covered approximately 20 percent of the watershed (see Appendix C). Imperviousness for the upper and lower study areas is approximately 10 percent and 29 percent, respectively. Research indicates that stream ecosystems begin to show evidence of degradation when the total impervious area in a watershed reaches approximately 10 percent. Ecological effects can generally be expected to become severe when total impervious area reaches about 25 percent (Arnold and Gibbons, 1996; Booth and Jackson, 1994; Schueler, 1994). Severe impacts to stream biota are likely in the lower watershed, where the majority of impervious cover is concentrated (Exhibit 2.5).

Exhibit 2.5 Impervious areas near Wayne Memorial Drive

Specific effects associated with increased impervious area include: increased stream temperature; increased stormwater volume and flooding, declines in infiltration and baseflow; increased bank erosion and habitat degradation; and increased pollutant loading (Lopez-Collado and Doley, 1997).

Stormwater management practices (e.g., detention ponds or infiltration practices) which could reduce pollutant inputs and slow the rate of runoff from developed areas have not historically been widely used in the study area. Such practices are required for new development under the Neuse River Basin Stormwater Management Rules and NPDES Phase II stormwater regulations (see Section 2.8).

Except for the construction of Seymour Johnson Air Force Base (SJAFB) in the 1940s, development historically has spread from downstream to upstream portions of the watershed. From its headwaters to New Hope Road, the mainstem and tributaries of Stoney Creek drain an area still dominated by agricultural land use. Land use in areas between New Hope Road and Wayne Memorial Drive is mixed agricultural, residential and commercial. Within the past decade, this part of the watershed has undergone a significant shift from agricultural to commercial and residential land use. Recent development has included Wayne Community College, a large medical park, a hospice care facility, several subdivisions, and numerous commercial establishments. Several major construction projects were underway in this area during the current study.

Land use is almost entirely urban in areas draining to Stoney Creek downstream of Wayne Memorial Drive. The upstream portions of this area contain substantial recent development including newer roads, subdivisions, apartments, and commercial establishments. Residential areas predominate west of Stoney Creek. Development to the east is more diverse, with large scale commercial development, industrial and residential areas and portions of the SJAFB. The

densest activity lies in the US 70 Bypass corridor near Berkeley Boulevard and Royall Avenue, where Berkeley Mall and a number of other large retail centers (e.g., Wal-Mart, Target, Lowes) are located.

2.6 Sources of Pollution

2.6.1 Point Sources

The study area contains no NPDES (National Pollution Discharge Elimination System) wastewater dischargers or permitted animal operations. There are two facilities in the study area that operate under NPDES stormwater permits.

Seymour Johnson Air Force Base. The SJAFB (Figure 2.1) occupies a total of approximately 3200 acres, less than half of which drains to the Stoney Creek watershed (SJAFB, 1994). The base includes a variety of residential and industrial areas. Subcatchments of the base within the Stoney Creek watershed range from 20 percent to 50 percent impervious, and drain either directly to Stoney Creek through a number of outfalls or to the Goldsboro storm sewer system near Berkeley Boulevard (SJAFB, 1994). Among the activities with potential relevance to water quality are fuel storage and handling, and the storage of pesticides, hazardous waste and other materials.

For many years, SJAFB operated under an individual wastewater permit (NC0063177) which regulated discharge from oil/water separators operated by the facility primarily to treat fuel spills. The facility was required to perform quarterly whole effluent toxicity tests (seven-day chronic toxicity tests utilizing *Ceriodaphnia dubia*) under this permit, using an in-stream waste concentration of 100 percent. A single toxicity test failure occurred in October 1999. In May of 2002, SJAFB began operating under an individual stormwater permit (NCS000335), which also encompasses the discharge from the oil/water separators (see Section 2.8).

Fuel spills are not uncommon at the base, though most are small and do not reach surface waters (SJAFB, 1994). Occasionally, however, more significant events do occur. A spill in November 2002 resulted in the discharge of jet fuel to the Neuse River, and a spill reaching Stoney Creek occurred in the mid 1990s.

Standard Products. Standard Products, a rubber production facility, holds a general stormwater permit (NCG050206) for discharges to Howell Creek. The facility is not required to perform water chemistry monitoring.

2.6.2 Nonpoint Sources

In the lower drainage, the full range of urban activities and pollution sources are of potential concern: roads, parking lots, rooftops, lawns, industrial areas, construction sites, *et cetera*. Given the overall level of imperviousness in the lower watershed, increased inputs of these pollutants are likely, particularly during storm events.

a. Existing and Ongoing Development

Construction. Considerable commercial, institutional and residential development has occurred in the watershed over the past decade, particularly in areas east of Hwy 70 Business and along Wayne Memorial Drive and Berkeley Boulevard (Exhibit 2.6). Major active construction sites during the study period included the following.

- A residential subdivision and an assisted care facility on Country Day Road;
- Construction to raise manholes along sewer lines parallel to Stoney Creek between Wayne Memorial Drive and Rose Street, and between Elm Street and Harris Street;
- Construction to install new sewer lines along NC 111 adjacent to Howell Branch.
- A multi-building medical park on Wayne Memorial Drive;
- A large medical office building on the corner of Wayne Memorial Drive and Country Day Road; and
- A residential development along Stoney Creek Parkway.

Erosion and sediment control measures are commonly observed at construction sites throughout the watershed. While these structures and practices, where appropriately constructed and maintained, can significantly reduce the amount of sediment that would otherwise reach nearby streams, actual practices often are not adequate to prevent stream impacts. During the current study, project staff observed improperly installed sediment control devices at several sites. During 2000-2002, the NC Division of Land Resources issued 19 notices of violation (NOVs) in this watershed for violations of sediment and erosion control regulations. Thirteen of these involved the off-site movement of sediment, although there is no record of how frequently this sediment reached streams or other waterbodies.

Exhibit 2.6 Aerial view of new construction

Industrial Stormwater. There are 29 manufacturing facilities in the study area, representing a variety of products and services: steel tanks, wastewater treatment chemicals, furniture and

cabinets, signs, sandwiches, rubber products, paint and printing (North Carolina Manufacturers Register, 2001). Although Standard Products (see above) is the only facility required by EPA regulations to operate under a stormwater permit, roof areas, parking lots, and other impervious surfaces at these sites add to surface runoff during storms. There is also the potential for substances associated with these facilities to be carried from parking lots and other areas during storm events.

Commercial and Residential Stormwater. Combined low, medium and high-density urban land use, including residential and commercial areas, comprise 41 percent of land use in the study area (see Table 2.2). A full range of urban pollutants, including excess nutrients, pesticides, lawn, garden and cleaning products, petroleum products, and solvents, may be present in stormwater runoff from these types of areas.

The Mid-Neuse Nonpoint Source Team, one of three teams established in the Neuse River basin to identify, prioritize, and address nonpoint source problems (see Section 2.8), surveyed households about residential lawn care and pesticide application in Goldsboro and four other communities in the Neuse River basin. Results for Goldsboro can be summarized as follows: 20 percent of households surveyed had soils tested; 66 percent used fertilizer; and 46 percent used pesticides. These results were generally comparable to averages for the five communities surveyed (26 percent soils testing, 69 percent fertilizer use, and 59 percent pesticide use), indicating that usage of nutrients, pesticides, and other lawn products from residential areas in Goldsboro were unremarkable relative to the other Neuse basin communities surveyed.

Leaking Underground Storage Tanks (LUSTs). A review of the NC Division of Waste Management database for the period 2000 through 2002 indicated entries relating to 14 separate LUST incidents in the study area during this period. Nine of these involved contamination of groundwater with petroleum products and five involved soil contamination. No incidents involving surface water contamination were documented. Four of the nine groundwater contamination sites were classified as "Close Out" indicating that remediation goals had been met. The risk for further contamination posed by active LUST sites is rated as High, Intermediate, Low or Unknown. According to staff at the Division of Waste Management, there is the potential for surface water contamination from High and Intermediate risk sites. Of the five active sites in the study area, one is rated Intermediate and two are rated High. All three sites drain to the mainstem of Stoney Creek.

Sanitary Sewer Lines. Sanitary sewers maintained by the City of Goldsboro serve areas within the city limits, including most of the lower study area. Within the city limits, most of Stoney Creek, Howell Branch, Reedy Branch, Billy Branch, and several unnamed tributaries are paralleled by sewer rights-of-way. Spills of raw sewage (bypasses) can occur at manholes due to blockages of these sewer lines or to overflows caused by stormwater infiltration or mechanical malfunction. For the period January 2000 through September 2002, four spills in the study area were reported to DWQ, one of which was due to a break in a private line not maintained by the City of Goldsboro (Table 2.3).

Most of the upper study area is served by septic systems, though water is provided by several sanitary districts. The precise number of residences served by septic systems is unknown, though development is significant in some areas, especially along major roads.

Table 2.3 Sewage Spills to Stoney Creek and Tributaries January 2000—September 2002

Date	Receiving Stream	Volume (gallons)	Cause
03/06/01	Stoney Creek	500	Blockage in sanitary sewer line.
10/26/01	Howell Branch	500	Grease and rags.
04/04/02	Stoney Creek	500	Grease and debris.
06/24/02	Howell Branch	65,000*	Vehicle hit tie line.

* Break in sewer line in private development. Line not maintained by City of Goldsboro.
Source: DWQ Non-Discharge Compliance and Enforcement Unit records and City of Goldsboro.

b. Agriculture

Commercial fertilizer and pesticide applications to row crops (23 percent of land use in the study area as a whole and 37 percent in the upper study area) are a potential source of nonpoint source pollutants. There are no permitted confined animal operations in the Stoney Creek watershed and, according to Wayne County NRCS staff, manure is not typically applied to fields. Routes by which these substances may enter surface waters include runoff from field applications, improper handling, accidental spills and discharges, illegal dumping and contaminated groundwater. Potential impacts of agricultural activities are discussed by National Research Council (1993); Nolan et al. (1998); and USGS (1999).

The potential for agricultural impacts in this part of North Carolina is underscored by a number of recent USGS studies in various streams in the Neuse, Chowan, Roanoke and Tar-Pamlico River basins. Spruill et al. (1998) found that streams in all four river basins had excess nitrogen and phosphorus levels, with the highest concentrations found in the Neuse River basin. Agricultural fertilizer and livestock were cited as the major source of nutrients.

Major crops grown in the Stoney Creek watershed include soybeans and cotton, with a small amount of tobacco and other crops. Typical nitrogen and phosphorus application rates are presented in Table 2.4. A wide range of pesticides can be used on these crops, including various herbicides, insecticides, growth regulators, and defoliants. Cotton is associated with a particularly diverse range of chemicals. Pesticides which may typically be used in the study area are listed in Table 2.5. This list is not all-inclusive. Only a few of the listed pesticides are likely to be in use in a given field during a particular season. Some substances listed represent alternative pesticides which could be used in similar situations, but which would not all be used (e.g., insecticides used on cotton, such as lambda-cyhalothrin, cyfluthrin and deltamethrin). The most common application method is spraying by ground rig. Other methods in use include soil application and injection and aerial spraying.

Table 2.4 Primary Crops and Typical Nitrogen and Phosphorus Application Rates, Stoney Creek Watershed

Crop	% of Total Crop Acreage*	Typical Nitrogen Application (lbs/acre)	Typical Phosphorus Application (lbs/acre)
Soybeans	60	0	20
Cotton	30	70	40
Tobacco	5	75	40
Other crops	5	-	-

* Estimated acreage. Precise acreage not readily available.

Source: North Carolina Cooperative Extension Service, Wayne County.

Table 2.5 Major Crops and Typical Pesticides, Stoney Creek Watershed*

Crop	Pesticide	Use	Application Method	Time of Application
Soybeans	pendimethalin	Herbicide	Ground rig	May - mid June
	glyphosate	Herbicide	Ground rig	May - early July
	sulfosate	Herbicide	Ground rig	May - early July
	thiodicarb	Insecticide	Aerial or ground rig	Late July - early August
	carbaryl	Insecticide	Ground rig	August
Cotton	dicrotophos	Insecticide	Ground rig	May - early July
	aldicarb	Insecticide	Soil application	Late April - May
	fluometuron	Herbicide	Soil application	Late April - May
	glyphosate	Herbicide	Ground rig	Late May - late June
	prometryn	Herbicide	Applied to plant base	June
	sulfosate	Herbicide	Ground rig	May - June
	mepiquat chloride	Growth regulator	Ground rig	Early June - late July.
	acephate	Insecticide	Ground rig	Late May - June
	lambda -cyhalothrin	Insecticide	Aerial or ground rig	Late July - early Aug.
	cyfluthrin	Insecticide	Aerial or ground rig	Late July - early Aug.
	deltamethrin	Insecticide	Aerial or ground rig	Late July - early Aug.
	ethephon	Growth regulator, defoliant	Aerial or ground rig	Late Sept. - early Oct.
	thidiazuron	Defoliant	Aerial or ground rig	Late Sept. - early Oct.
	ethephon+cyclanilide	Defoliant	Aerial or ground rig	Late Sept. - early Oct.
	carfentrazone	Defoliant, herbicide	Aerial or ground rig	Late Sept. - early Oct.
Tobacco	metalaxyl	Fungicide	Soil application	April
	acephate	Insecticide	Aerial or ground rig	Mid May - September
	spinosad	Insecticide	Ground rig	May - June
	fatty alcohols	Plant growth regulator	Applied to whole plant	June - July
	maleic hydrazide	Plant growth regulator	Applied to whole plant	July

* This list includes pesticides which may typically be used on crops in the watershed. Only a few would generally be used on a given field during a particular season.

Source: North Carolina Cooperative Extension Service, Wayne County.

Wayne County NRCS staff estimate that nitrogen management plans are used by 90 percent of farmers in the watershed. Conservation tillage, which requires retaining a minimum of 30 percent of residue cover, is used on approximately 60 percent of soybeans and 20 percent of cotton. Conservation tillage is not used on fields planted in tobacco. Field borders are estimated to be in use on approximately 10 percent of cropland. Water control structures are not used in the study area, as these structures are generally suitable only in areas with limited variation in elevation. According to NRCS staff, most farmers in the watershed practice some form of integrated pest management (IPM) including field inspections to target insecticides to particular pests.

2.6.3 Historical Issues

Although no written records could be located, visual appearances suggest that channelization has occurred along portions of the mainstem and tributaries in the upper study area (see Section 2.2). Although portions of the mainstem appear to be regaining some sinuosity, most reaches retain a characteristically straight channel. The indirect effects of channelization can be considerable and are discussed in Section 6.

As mentioned in Section 2.4, some of the most severe flooding on record occurred in September 1999 as the result of Tropical Storm Dennis and Hurricane Floyd. Although snagging was performed after these events, a significant amount of debris (e.g., a full size garbage dumpster and numerous tires) remains in the stream channel. Dredging to remove large debris was performed in several stream reaches. While efforts were made to remove only large debris, it is difficult to know how these activities may have impacted habitat. In coastal plain streams, sticks, leaf packs, root mats, snags and debris jams provide critical in-stream habitat for macroinvertebrates.

2.7 Trends in Land Use and Development

Population in Wayne County increased by 8.3 percent between 1990 and 2000, a moderate growth rate compared to the 21.4 percent increase experienced by the state as a whole. During this same period, housing units in the City of Goldsboro increased by 12.6 percent (Social Science Data Analysis Network at http://pbis.state.nc.us/pls/linc). Population growth for Wayne County between 2000 and 2010 is projected at 7.6 percent, compared to 17.9 percent for the state as a whole (US Census Bureau at http://quickfacts.census.gov).

Agriculture, the historically dominant land use in the watershed, is increasingly being replaced by residential and commercial land use. Personnel at the NC Cooperative Extension Service, Wayne County Center estimate that approximately 2,000 acres of farmland in the study area were lost to development between 1990 and 1998. Future development can be expected to spread from Wayne Memorial Drive and the Howell Creek drainage area to upper portions of the watershed.

2.8 Regulatory Issues and Local Water Quality Activities

Neuse River Nutrient Sensitive Waters Rules. The Stoney Creek watershed is covered under the Neuse River Basin Nutrient Sensitive Waters (NSW) Management Strategy, adopted by the NC Environmental Management Commission in December 1997. The strategy was designed to reduce the average annual nitrogen load to the Neuse River Estuary by a minimum of 30 percent of the annual average load for the period 1991-1995 by the year 2003. The rules include provisions for controlling nutrients from agriculture, wastewater treatment plants, and urban areas.

Neuse buffer rules apply throughout the watershed to intermittent and perennial waterbodies shown on the most recent county soil survey maps or USGS 1:24,000 scale topographic maps. A minimum 50-foot vegetated buffer is required on each side of a waterbody, the first 30 feet of which must remain essentially undisturbed. Exemptions are allowed for various activities. The rules apply to the preservation of existing buffers and do not require the establishment of new buffers unless existing use of the buffer area changes. Stormwater flows cannot be routed thorough the buffer in channelized form, but must be converted to sheet flow before entering the buffer, providing an opportunity for infiltration and pollutant removal.

Wayne County and the City of Goldsboro are among ten cities and five counties subject to the Neuse River Basin Stormwater Rules, which became effective in 1998. The rules require local governments to review and approve stormwater plans for all new development. Nitrogen loading from new development must be held to 3.6 pounds/acre per year, and no net increase in peak flows leaving the site from predevelopment conditions are allowed for the one-year, 24-hour storm. The vast majority of development in the study area predates these requirements. Among the other requirements of this rule are: implementation of public education programs; identification and removal of illegal discharges to the stormwater system; and identification of suitable locations for potential stormwater retrofits.

Neuse agricultural rules also apply throughout the watershed. Under these rules, each farmer has the option of participating in a collective local strategy for implementing BMPs or implementing standard BMPs as stipulated in the rule. A Basin Oversight Committee and 17 Local Advisory Committees assist farmers in complying with the rule. Members of each Local Advisory Committee include representatives from DWQ, County Soil and Water Conservation District, Natural Resources Conservation Service, NC Department of Agriculture and Consumer Services, Division of Soil and Water Conservation and at least two local farmers.

Phase II Stormwater Regulations. EPA's Phase II stormwater program has mandated that small communities, not previously covered by federal stormwater requirements, apply to state agencies for permit coverage by March 2003. This requirement is applicable to Goldsboro and Wayne County. In October 2002, the NC Environmental Management commission passed a temporary rule governing implementation of the Phase II program in the state. Communities covered by Phase II requirements are required to develop and implement a comprehensive stormwater management program that includes the following six measures: 1) public education and outreach on stormwater impacts; 2) public involvement/participation; 3) illicit discharge detection and elimination; 4) construction site stormwater runoff control; 5) post-construction stormwater

management for new development and redevelopment; and 6) pollution prevention/good housekeeping for municipal operations.

Sediment and Erosion Control. The NC Division of Land Resources regulates erosion and sediment from construction activities in the watershed under North Carolina's Sedimentation Pollution Control Act.

Goldsboro Regulations. Over the last several years, Goldsboro and Wayne County have implemented a stormwater program (including measures to control post-construction stormwater runoff from new development) to comply with the Neuse stormwater rule. Neither jurisdiction previously had stormwater requirements.

Seymour Johnson Air Force Base. The base developed a stormwater pollution prevention plan in 1994 (SJAFB, 1994) and has been operating under an individual stormwater permit since 2002. The permit requires the base to implement a comprehensive stormwater management program, including implementation of the 1994 plan, the identification and removal of illicit discharges to the storm drain system, educational programs and other measures.

Mid-Neuse Nonpoint Source Team. In 1997, representatives of the NC Division of Water Quality established the Mid-Neuse Nonpoint Source Team (MNNPST), one of three teams established in the Neuse River basin to identify, prioritize, and address nonpoint source problems. Team participants include representatives from local government, interest groups, agencies, industries, and concerned citizens.

In October 1997, the MNNPST selected the Stoney Creek watershed as a priority waterbody. The Stoney Creek watershed was selected based on the size of the watershed, the need for water quality restoration, the value of the watershed to the community, the range of activities within the watershed, and the interest and commitment of local agencies, government, industry and citizens.

MNNPST activities have included a household lawn care survey, development of a site master plan for Wayne County Industrial Park, and a BMP educational program for citizens and stakeholders. BMP demonstrations installed in the Stoney Creek watershed include the following:

- A water control structure located in the upper study area;
- Installation of a "green roof", an alternative roof designed to replace impervious surface with living plant material, at Wayne Community College;
- Installation of a pervious parking area near Berkeley Boulevard in the lower study area; and
- A stormwater infiltration area at the Industrial Park in Goldsboro (currently inoperative due to early construction and design flaws).

Citizen Initiatives. The Neuse River Foundation (NRF) is a non-profit grassroots environmental organization dedicated to protecting the Neuse River. The NRF currently employees two Riverkeepers, one for downstream portions of the basin and one for upstream areas. The Riverkeepers monitor the river for problems or violations, report problems to appropriate agencies and the press, and educate the public about threats to the Neuse River. They also

oversee volunteer Stream Keeper programs through which citizens are trained to monitor tributaries to the Neuse River.

Section 3
Potential Causes of Biological Impairment

The study identified those factors that were plausible causes of biological impairment in the Stoney Creek watershed using both biological assessment and watershed-based approaches. An evaluation of benthic community data and other biological and habitat indicators can point toward general types of impacts that may likely impact aquatic biota. These stressors were flagged for further investigation. Land uses and activities in the Stoney Creek watershed were also examined to identify potential stressors for further evaluation.

3.1 Key Stressors to be Evaluated in the Stoney Creek Watershed

Previous biological sampling in the lower half of Stoney Creek indicated widespread water quality degradation. Factors including extensive existing development, ongoing development, and upper watershed agricultural activities suggest that Stoney Creek is subject to multiple stressors. Based on available information, the following stressors merited additional research.

1. Habitat degradation-sedimentation and lack of key microhabitats.
Preliminary watershed investigations indicated that while habitat conditions are quite variable in Stoney Creek, important microhabitats for benthic macroinvertebrates -- such as woody debris, leaf packs, and root mats -- may be present in only limited amounts in some areas.

2. Toxicity.
The high percentage of urban land use in the lower study area indicates a significant potential for a variety of toxicant inputs, including metals, pesticides, and organic chemicals, to enter streams during rain events or site-specific mishaps (see Section 2.6). Agricultural chemicals including herbicides and insecticides are potential contaminants in the upper watershed. Because of the wide range of potential toxicants and source activities in this watershed, toxicity merited further evaluation as a potential cause of impairment.

3. Low dissolved oxygen/organic and nutrient enrichment.
Dissolved oxygen (DO) is critical to aquatic communities. DO concentrations in streams are influenced by numerous factors, including the rate of reaeration and inputs of organic matter and inorganic nutrients from both natural and anthropogenic sources. Organic matter in the form of leaves, sticks, and other materials provides a food source for aquatic microbes and serves as the base of the food web for many small streams. When microbes feed on organic matter, they consume oxygen in the process and make nutrients available to primary producers, especially periphyton. Macroinvertebrates feed on the microbial community and are, in turn, consumed by fish.

These processes are natural and essential to the health of small streams. However, excessive amounts of organic matter (oxygen-consuming wastes and nutrients) from human or animal waste can increase the microbial activity to levels that significantly reduce the amount of oxygen in a stream. Excessive inorganic nutrient inputs can also impact stream biology. Adequate dissolved oxygen is essential to aquatic communities; only certain aquatic invertebrates are able to tolerate low oxygen levels. These excessive organic materials also serve as food for certain

aquatic invertebrate groups that can dominate the invertebrate community. Excess organic and inorganic nutrient loading can thus result in a distinct change in community composition due to both a change in food source and low dissolved oxygen levels.

Early observations and an initial review of benthic macroinvertebrate data found that taxa indicative of low dissolved oxygen were common in some parts of the watershed. Both the substantial urban and agricultural activities in the watershed suggest the possibility for nutrient impacts. Surface algal blooms were observed in the upper watershed during early reconnaissance activities. These factors suggested that low DO/enrichment should be further evaluated.

Section 4
Biological Conditions and Stream Habitat

Biological assessment (bioassessment) involves the collection of stream organisms and the evaluation of community diversity and composition to assess water quality and ecological conditions. Evaluation of habitat conditions at sampling locations is an important component of bioassessment.

DWQ's Biological Assessment Unit first collected benthic macroinvertebrate samples from Stoney Creek in 1995, when the site at Slocumb Street was sampled. The macroinvertebrate community at that time was rated Poor. A fish community assessment, discussed in Section 4.2.1, was conducted at Slocumb Street in 1995 and 2000.

Additional benthic community sampling was conducted during the present study to serve several purposes:

- To account for any changes in biological condition since the watershed was last sampled;
- To obtain more specific information on the actual spatial extent of impairment;
- To better differentiate between portions of the watershed contributing to biological impairment and those in good ecological condition;
- To collect additional information to support identification of likely stressors affecting the biological community.

This section describes the approach to bioassessment used during the study and summarizes the results of this work. Additional photographs of the sampling sites and a more detailed analysis of the condition of aquatic macroinvertebrate communities in the Stoney Creek watershed may be found in Appendix A.

4.1 Approach to Biological and Habitat Assessment

Biologists surveyed macroinvertebrate communities and aquatic habitat at three locations on the mainstem of Stoney Creek and two locations on reference streams outside of the study area (Figure 4.1). Sites are described in Section 4.2. The reference streams do not necessarily represent undisturbed conditions, but serve as comparison sites in less impacted watersheds within the same ecoregion and general geology as Stoney Creek. Sampling occurred in June and August 2000 and February 2001.

Ideally sites would be located both upstream and downstream of all major sources of potential stress to aquatic organisms. This was not feasible due to the widespread nature of potential nonpoint source inputs. Benthic sampling was further limited by low stream velocities and swamp characteristics in upstream areas. As a consequence, those portions of Stoney Creek upstream of Wayne Memorial Drive were not sampled for benthic fauna. The uppermost sample site, at Wayne Memorial Drive, was not ratable due to its small size.

4.1.1 Benthic Community Sampling and Rating Methods

Macroinvertebrate sampling was carried out using the general procedures outlined in the Division's standard operating procedures (NCDWQ, 2001a). Reaches approximately 100 meters (328 feet) long were targeted, although the actual stream length sampled varied with site conditions. Standard qualitative methods were used for most samples. This method included ten samples: two kick-net samples, three bank sweeps, two rock or log washes, one sand sample, one leaf pack sample, and visual collections from large rocks and logs. At smaller stream sites, the abbreviated Qual 4 method was used. The Qual 4, which has been used by DWQ to sample small streams for some time, involved four samples: one kick, one sweep, one leaf pack and visual collections. Organisms were identified to genus and/or species.

Two primary indicators or metrics are derived from macroinvertebrate community data: the diversity of a more sensitive subset of invertebrate fauna is evaluated using EPT taxa richness counts; and the pollution tolerance of those organisms present is evaluated using a biotic index (BI). "EPT" is an abbreviation for Ephemeroptera + Plecoptera + Trichoptera (mayflies, stoneflies and caddisflies), insect groups that are generally intolerant of many kinds of pollution. *Generally, the higher the EPT number, the more healthy the benthic community*. A low biotic index value indicates a community dominated by taxa that are relatively sensitive (or intolerant) to pollution and other disturbances. *Thus, the lower the BI number, the more healthy the benthic community.*

Biotic index values are combined with EPT taxa richness ratings to produce a final bioclassification (Excellent, Good, Good-Fair, Fair or Poor). Final bioclassifications are used to determine if a stream is impaired. Streams with bioclassifications of Excellent, Good, and Good-Fair are all considered unimpaired. Those with Fair and Poor ratings are considered impaired. *Under current DWQ policy, streams less than four meters in width are generally not formally rated but are evaluated qualitatively based on professional judgment*. Small streams sampled using the Qual 4 method that have scores consistent with a Good-Fair or better rating are labeled as "not impaired". Historical sampling sometimes used methods other than those described above. At one site a modified Qual 4 (termed EPT method) was used in which Qual 4 sampling procedures were used but only EPT taxa were identified.

4.1.2 Habitat Assessment Methods

At the time benthic community sampling was carried out, stream habitat and riparian area conditions were evaluated for each reach using DWQ's standard habitat assessment protocol for coastal plain streams (NCDWQ, 2001a). This protocol rates the aquatic habitat of the sampled reach by adding the scores of a suite of local (reach scale) habitat factors relevant to fish and/or macroinvertebrates. Total scores range from zero (worst) to 100 (best). Individual factors include (maximum factor score in parenthesis):

- channel modification (15);
- in-stream habitat variety and area available for colonization (20);
- bottom substrate type and embeddedness (15);
- pool variety and frequency (10);
- bank stability and vegetation (20);

- light penetration/canopy coverage (10); and
- riparian zone width and integrity (10).

4.2 Results

4.2.1 Description

Selected habitat and biological characteristics for each site sampled during the study are shown in Table 4.1, which also includes information on historical sampling. Some sites were too small to be given a formal rating (bioclassification). A narrative summary of conditions at each current site follows. See Appendix A for additional details.

Stoney Creek:
Stoney Creek at Wayne Memorial Drive (STST10). Because low stream velocities and swamp-like conditions limited upstream sampling options, this site became the most upstream benthic sampling location in the study area. Though much of the drainage area is undeveloped, the immediate area contains a significant amount of urban land use, including professional offices, residential housing, and retail establishments. Observable flow was minimal, and this portion of Stoney Creek appears to have been channelized (Exhibit 4.1). There is a significant lack of in-stream habitat. Root mats, leaf packs, sticks, snags, and other organic habitat are extremely rare. The extremely sparse riparian vegetation contributes limited woody debris to the stream and provides minimal in-stream shading. Substrates are primarily sand and silt. Stream width was approximately three meters, and the riparian vegetation was poor on both sides. Overall habitat, with a total score of 24, was quite poor. Although this site was too small to rate, EPT richness and abundance were low and the biotic index was the highest of all sites sampled. Benthic community composition indicated a degraded community that was limited by low dissolved oxygen.

Stoney Creek at East Ash Street (Business US 70) in Stoney Creek Park (STST04). This site, located two miles downstream of Wayne Memorial Drive, is located in Stoney Creek Park in Goldsboro (Exhibit 4.2). The stream appears to have been channelized in this location as well. The vegetated riparian zone is greater than 18 meters wide along the west bank and less than six meters wide along the east bank. Stream width is six meters and substrates are primarily sand and gravel. Although some large hardwoods are present, much of the bank vegetation consists of weeds and grass.

This site received a bioclassification of Fair (although it barely missed a Poor classification). While some taxonomic indicators of low dissolved oxygen were identified, more flow-dependant midge taxa were present than at the upstream site, indicating increased velocity and probably higher dissolved oxygen levels than at Wayne Memorial Drive. Habitat at this site is significantly better than at Wayne Memorial Drive. A small amount of gravel substrate was present. Root mats, leaf packs, and sticks are more common. Larger woody debris is intermittently present in the channel, in-stream shading is considerable, and a moderate number of pools of varying depth are present. Although habitat at this site is much better than at the upstream site and appears capable of supporting a more diverse community, EPT richness and total taxa richness were no higher here than at Wayne Memorial Drive.

Exhibit 4.1 Stoney Creek at Wayne Memorial Drive.

Exhibit 4.2 Stoney Creek at East Ash Street.

Stoney Creek at Slocumb Street / SR 1920 (STST01). This is the historic benthic community sampling site and the most downstream sampling location in the study area. This site had the most favorable habitat of all locations sampled in the watershed (Exhibit 4.3). Woody debris, root mats and undercut banks were plentiful and the riparian area was wide and wooded on both sides of the stream.

Despite the quality of the habitat (total scores of 70 and 71), relatively few macroinvertebrates were collected at this location. Samples collected at this site in 1995 received a bioclassification of Poor. Samples collected in August 2000, June 2000 and February 2001, received a bioclassification of Fair (barely missing a Poor bioclassification in June 2000), a slight improvement over 1995 samples.

Species collected in 2000 and 2001 were mostly tolerant taxa. The midge assemblage indicated potential toxicity in the February 2001 sample (see Appendix A). Although EPT richness increased slightly relative to upstream sites, no more than eight EPT taxa were collected in any sample.

Fish community assemblages were surveyed at this site in 1995 and 2000 (see NCDWQ, 2001b). The fish community improved somewhat from 1995 to 2000, with total species at 13 in 1995 and 15 in 2000. The numbers of individuals caught were 112 in 1995 and 259 in 2000. No intolerant species were collected in either year. No formal rating was assigned on either occasion.

Exhibit 4.3 Stoney Creek at Slocumb Street

Reference Streams:

Button Branch at SR 1556. This site, a tributary of Nahunta Swamp located in Wayne County (see map in Appendix A), was chosen as a reference site for portions of Stoney Creek draining the upper agricultural portion of the study area. Button Branch drains no urban areas and shows no evidence of recent channelization. Button Branch was not swampy and, at the time of sampling, there was observable flow. Habitat is much better than at Wayne Memorial Drive. Sticks, leaf packs, and some larger woody debris are available for macroinvertebrate colonization, the riparian area is wide and well vegetated and in-stream shading is plentiful.

Benthic macroinvertebrate sampling indicated that, despite a smaller drainage area, Button Branch supports a more diverse benthic community than Stoney Creek at Wayne Memorial Drive.

The Slough at SR 1535. The Slough, also a tributary to the Nahunta Swamp (see map in Appendix A), was used as a reference site for the lower study area. The stream, though channelized many years ago, has good in-stream habitat and riparian areas (see NCDWQ, 2001b). Pools of various sizes are frequent and, although substrate is comprised primarily of sand, habitat for macroinvertebrate colonization is provided by root mats, leaf packs, and woody debris. Stream width is approximately four and a half meters, and the vegetated riparian zone is greater than 18 meters on both sides of the stream. The watershed of The Slough is largely agricultural and contains no significant development.

Although some taxa considered indicators of low DO were abundant in The Slough, this stream had much higher EPT richness (18 taxa) and abundance (82 individuals) than any site sampled in Stoney Creek and received a rating of Good-Fair. The Slough clearly supports a benthic community with much higher biological integrity than the benthic fauna found in Stoney Creek.

The Slough fish community was sampled in 1995 and in 2000. Though not formally rated, the community was one of the most diverse in the Neuse River basin with 26 species present in 2000 (NCDWQ, 2001b).

4.2.2 Summary of Conditions and Nature of Impairment

Current benthic macroinvertebrate data indicate that benthic communities in Stoney Creek are impaired downstream of East Ash Street and are generally in Fair condition. Although samples collected at Slocumb Street improved from Poor in 1995 to Fair in 2000 and 2001, Stoney Creek continues to demonstrate a tolerant biological community with low EPT richness, low EPT abundance, and low total taxa richness. No more than one stonefly taxa was collected at any location, compared with five stonefly taxa collected from The Slough, a comparison stream.

While there were taxonomic indicators of low DO at all sites, these indicators decreased progressively downstream. At the most upstream sample location at Wayne Memorial Drive, the community was particularly tolerant of low dissolved oxygen and indicative of low flow conditions. In general, the high Biotic Index values indicate a tolerant benthic community subject to a variety of stressors. Specific taxonomic indicators of toxicity were found in one sample at the Slocumb Street site, providing some evidence of toxic impacts on this occasion.

The substrate was largely sand, as would be expected for a coastal plain stream. Habitat was poor at the most upstream site (Wayne Memorial Drive), where the negative impacts of channelization were evident. Though areas of bank erosion were not uncommon, habitat improved substantially downstream, where it was adequate to support a more diverse benthic community than currently exists.

Sites on two comparison streams, The Slough and Button Branch, have habitat only slightly better than the lower Stoney Creek locations, yet support a much more diverse benthic community. Some taxonomic indicators of low DO and low stream velocity are also evident in

these two streams (though not as strongly manifested as at the upper Stoney Creek site), but do not prevent these sites from supporting communities with much higher biological integrity than Stoney Creek.

Table 4.1 Selected Benthic Community and Habitat Characteristics, Stoney Creek Study Sites

Location	Date	Stream Width[1] (m)	Substrate: (% sand and silt)[2]	Habitat Score (max 100)[3]	EPT[4] Abundance	EPT[4] Taxa Richness	EPT[4] Biotic Index	Biotic Index[4]	Bioclassification[4]
Stoney Creek at Slocumb Street (SR 1920)	8/8/95	6	90	--	22	4	5.97		Poor**
	8/22/00	5	75	70	46	8	5.61		Fair**
	6/15/00	7	90	71	18	5	5.73	6.99	Fair
	2/19/01	4.5	75	70	27	7	5.41	6.96	Fair
Stoney Creek at E. Ash Street	6/15/01	6	90	67	25	5	6.00	7.19	Fair
Stoney Creek at Wayne Memorial Drive	2/16/01	3	100	24	14	5	6.89	8.10	Not Rated*
Button Branch at SR 1556	2/16/01	3	95	72	58	10	5.00	6.63	Not Rated*
The Slough at SR 1535	2/20/01	4.5	100	75	82	18	4.78	6.76	Good-Fair

1 Wetted channel width at time of sampling.
2 Based on visual estimate of substrate size distribution.
3 Habitat data available for 2000 and 2001 samples only. See text for list of component factors.
4 See text for description. BI is seasonally adjusted where applicable.
* Qual 4 sampling method, see text for explanation.
** EPT method, see text for explanation.

Section 5
Chemical and Toxicological Conditions

Water quality assessment provides information to evaluate whether chemical and physical conditions negatively affect benthic communities. Two broad purposes of this monitoring are:

1. To characterize water quality conditions in the watershed.
2. To collect a range of chemical, physical, and toxicity data to help evaluate the specific causes of impairment and to identify sources.

This section summarizes the data collection methods and discusses key monitoring results. See Appendix B for additional discussion of methodology and results.

5.1 Chemical, Physical, and Toxicity Sampling Methods

5.1.1 General Methodology

Water Quality Characterization. An overall picture of physical and chemical conditions in the Stoney Creek watershed was obtained by assessing water quality at an integrator station (Stoney Creek at Slocumb Street). An integrator station is the monitoring station located the furthest downstream, providing an indication of upstream pollutant loading as well as the water quality leaving the study area. This site was monitored regularly for field parameters, nutrients, and potential toxicants. Sampling at sites upstream of the integrator station provides information on pollutant sources.

Water samples were collected and field parameters were measured at baseflow and during storms. Baseflow is defined as a period in which no measurable rain fell in the watershed during the 48 hours preceding sampling. Baseflow samples provide an indication of water conditions to which organisms may potentially be exposed for an extended period. Storms, however, bring a large influx of runoff that may carry toxicants or nutrients. Storm samples were typically collected during the rising stage of the hydrograph, while water levels were still increasing.

Seven baseflow and two storm samples were collected at the integrator station between August 2001 and June 2002. Grab samples (static samples) were collected during both baseflow and storm conditions.

Stressor and Source Evaluation. Samples were collected at a variety of locations to identify the major chemical and physical stressors to which the aquatic biota are exposed, evaluate toxicity, and assess major pollution sources. Station locations for stressor identification were linked to areas of known biological impairment (benthic macroinvertebrate sampling stations) and to specific watershed activities thought to represent potential sources of impairment. Samples were collected at the integrator station and from three other stations further upstream on the mainstem of Stoney Creek. Additionally, samples were taken in Reedy Branch and Howell Creek. Both storm and baseflow samples were collected between August 2001 and June 2002.

Sampling focused primarily on those physical and chemical parameters that preliminary investigations indicated merited investigation as plausible causes of biological impairment. Land use in the Stoney Creek watershed is divided between agriculture in the upper reaches and urban areas in the lower watershed. Thus, sampling of potential pollutants included those typically found both in agricultural and urban environments:

- Metals;
- Organochlorine pesticides and polychlorinated biphenyls (PCBs; EPA Method 608);
- Selected current use pesticides (GC/MS-gas chromatography/mass spectroscopy);
- PAHs (polycyclic aromatic hydrocarbons; EPA Method 610);
- Phenols (EPA Method 604);
- Semi-volatile organics (EPA Method 625);
- MBAS (methylene blue active substances, an indicator of anionic surfactants);
- TPH (total petroleum hydrocarbons); and
- MTBE (methyl tert-butyl ether, a gasoline additive).

Laboratory toxicity bioassays provide a method of assessing the presence of toxicity from either single or multiple pollutants and can be useful for assessing the cumulative effect of multiple chemical stressors. Acute toxicity tests were conducted on water samples collected during storms, while chronic tests were conducted on baseflow samples. The water flea, *Ceriodaphnia dubia*, was the indicator organism used for both the acute tests, which last for 48 hours and measure mortality, and the chronic tests, which last for seven days and examine reproductive rates. Acute toxicity tests used the protocols described in the USEPA document EPA/600/4-90/027F (USEPA, 1993). Chronic toxicity tests used the North Carolina *Ceriodaphnia* Chronic Effluent Toxicity Procedure (North Carolina Division of Water Quality, 1998). Toxicity was assessed four times during baseflow (chronic) and once during a storm (acute).

Physical parameters, such as pH, dissolved oxygen, specific conductance (standardized to 25° C) and temperature, were measured in the field on numerous occasions throughout the watershed. Additionally, multiparameter probes with a data logging capacity (data sondes) were deployed on three dates for seven days. On each date, they were simultaneously deployed at three or more sites in the watershed. These probes were programmed to record the above parameters every 15 minutes, providing information on diurnal fluctuations.

Extended in-stream monitoring to evaluate long-term exposure to pollutants was conducted using semi-permeable membrane devices (SPMDs). These are passive sampling devices that accumulate hydrophobic organic pollutants to which the devices are exposed during deployment (see Appendix B for additional details). SPMDs were deployed twice, in August and October 2002, for fourteen and twelve days, respectively. Samples were collected from three locations in August and from five locations in October.

<u>Screening Benchmarks</u>. To evaluate whether observed concentrations may have a negative impact on aquatic life, measured water column concentrations were compared to EPA's National Ambient Water Quality Criteria (NAWQC) for freshwater (USEPA, 1999) and Tier II benchmarks (USEPA, 1995). Metals benchmarks were adjusted for hardness where appropriate (USEPA, 1999). For chromium, the NAWQC for Cr VI was used. The use of NAWQC and other benchmarks is discussed in more detail in Appendix B.

Benchmarks were used for initial screening of potential impacts. Final evaluation of the potential for pollutants to negatively impact aquatic biota considered all evidence, including toxicity bioassays and benthic macroinvertebrate data, in addition to data on analyte concentrations.

5.1.2 Site Selection

Samples were obtained primarily from six sites; four sites on Stoney Creek and one site each on the Reedy Branch and Howell Creek tributaries (Figure 4.1 and Table 5.1). Sampling sites were chosen for accessibility, proximity to benthic invertebrate sampling sites, and proximity to potential stressor sources. Three of the six primary sites were in the upper portion of the watershed that drains primarily agricultural areas. Three additional primary sampling sites were located in the lower urban portion of the watershed. These sites are briefly described below. Those sites that were monitored for benthic invertebrates were also described in Section 4.

Table 5.1 Summary of Monitoring Approaches Used at Sampling Sites

		Monitoring Approach				
Station Code	**Location**	**Benthic Invertebrates**	**Water Chemistry**	**Toxicity Bioassay**	**SPMD[1]**	**Data Sonde[2]**
STST01	Stoney Creek at Slocumb Street / SR 1920	√	√ +	√	√	√
STST04	Stoney Creek at E. Ash Street / US Hwy 70 Bus.	√	√	√	√	√
STST07	Stoney Creek at Royall Avenue					√
STST09	Stoney Creek at US Hwy 70 Byp		√	√	√	√
STST10	Stoney Creek at Wayne Memorial Drive	√				
STST11	Stoney Creek at New Hope Road / SR 1003		√		√	
STST12	Stoney Creek at Stoney Creek Church Rd. / SR 1547				√	
STHC03	Howell Creek at Patetown Road / SR 1523		√		√	
STRB03	Reedy Branch at New Hope Road / SR 1003		√			
STBB01	Billy Branch at Harding Drive					√
STUN01	Unnamed tributary at Royall Avenue					√
STUN02	Unnamed tributary at Glen Oak Drive			√		

1 SPMD is a semi-permeable membrane device used to detect hydrophobic organic pollutants in a long-term study (14 days).
2 Data sonde is a multi-probe data recorder that recorded field parameters at 15-minute intervals for seven days.
\+ Integrator station.

Lower Study Area:
Stoney Creek at Slocumb Street / SR 1920 (STST01). This site was located at the downstream end of the study area near the Seymour Johnson Air Force Base and served as the integrator station. This site was sampled extensively for the potential chemical stressors described in Section 5.1.1. A data sonde was also used to obtain data from this site. It was also a benthic invertebrate monitoring station.

Stoney Creek at East Ash Street / US Highway 70 Business (STST04). This urban site was located in Stoney Creek Park, approximately 2.3 miles upstream of the integrator station (STST01). Grab samples from this site were analyzed for the potential chemical stressors listed in Section 5.1.1. A data sonde was also used to obtain data from this site. It was also a biological monitoring site.

Stoney Creek at Royall Avenue (STST07). This site was approximately 3.1 miles upstream of the integrator station and was a data sonde deployment site.

Stoney Creek at US Highway 70 Bypass (STST09). This sampling site was located approximately 4.0 miles upstream from the integrator station (STST01). It is downstream of both Reedy Branch and Howell Creek, but upstream of the confluence of Stoney Creek with Billy Branch. It is the uppermost urban site from which chemical stressors were routinely analyzed. A data sonde was also used to collect data at this site.

Stoney Creek at Wayne Memorial Drive (STST10). This biological monitoring station was located approximately 4.7 miles upstream of the integrator station (STST01). It is in an urbanized area near Wayne Memorial Hospital upstream of both Howell Creek and Reedy Branch.

Billy Branch at Harding Drive (STBB01). This sampling site on Billy Branch, a tributary of Stoney Creek, drains a highly developed commercial area including some of the most extensive impervious areas in the watershed. This data sonde deployment site was approximately 3.8 miles upstream of the integrator station (STST01).

Unnamed Tributary at Royall Avenue (STUN01). This urban site on an unnamed tributary of Stoney Creek is approximately 3.2 miles upstream of the integrator station. This station also drains a highly developed commercial area. It was used for data sonde deployment.

Unnamed Tributary at Glen Oak Drive (STUN02). This urban site on an unnamed tributary of Stoney Creek was sampled for toxicity testing. The water was highly odiferous and discolored at the time of sampling.

Upper Study Area:
Stoney Creek at New Hope Road / SR 1003 (STST11). This site, draining a largely agricultural area, was located approximately 5.7 miles from the integrator station. Several grab samples from this site were analyzed for potential chemical stressors.

Stoney Creek at Stoney Creek Church Road / SR 1547 (STST12). This site, located upstream of STST11, 8.7 miles from the integrator station, was used for data sonde deployment.

Howell Creek at Patetown Road / SR 1523 (STHC03). This sampling site was located on Howell Creek approximately 6.0 miles upstream from the integrator station (STST01). This was one of the three monitoring sites at the lower edge of the largely agricultural upper study area. Several grab samples from this site were analyzed for potential chemical stressors.

Reedy Branch at New Hope Road / SR 1003 (STRB03). This sampling site was located approximately 5.5 miles upstream of the integrator station (STST01). It was one of the three monitoring sites draining the predominately agricultural portion of the watershed. Several grab samples from this site were analyzed for potential chemical stressors.

5.2 Water Quality Characterization

To provide an overall indication of the water quality in the Stoney Creek watershed, the integrator station was sampled seven times during baseflow and twice during stormflow. The integrator station gives an indication of the water quality of the water leaving the watershed. Selected results are shown in Table 5.2 and are presented in more detail in Appendix B.

Table 5.2 Mean Values and Standard Errors for Field Parameters and Nutrients in Stoney Creek at Slocumb Street (STST01) [1]

Parameter	Baseflow	Storm
Dissolved Oxygen (mg/L)	8.76 ± 0.75 (6)	5.90 ± 0.20 (2)
pH (Standard Units)	6.73 ± 0.16 (6)	6.51 ± 0.45 (2)
Specific Conductance (µS/cm)	114.5 ± 2.4 (7)	99.6 ± 20.8 (2)
Turbidity (NTU)	16.2 ± 12.1 (7)	67.0 ± 61.0 (2)
Total Phosphorus (mg/L)	0.07 ± 0.01 (7)	0.32 ± 0.26 (2)
Ammonia Nitrogen (mg/L)	0.15 ± 0.03 (7)	0.25 ± 0.15 (2)
Total Kjeldahl Nitrogen (mg/L)	0.96 ± 0.14 (7)	3.90 ± 3.00 (2)
Nitrate + Nitrite Nitrogen (mg/L)	0.43 ± 0.09 (7)	0.42 ± 0.12 (2)
Total Nitrogen (mg/L)	1.38 + 0.18 (7)	4.33 + 2.88 (2)

1 Number of samples in parentheses.

The pH at Slocumb Street was typically near neutral and specific conductance was typical of coastal plains streams. Dissolved oxygen (DO) concentrations were generally adequate at this location. Nitrogen and phosphorus concentrations were well above background levels (Caldwell, 1992). Observed storm concentrations of total nitrogen, Kjeldahl nitrogen, ammonia and total phosphorus were much higher than baseflow levels, although the number of storm samples was limited and variability was considerable.

5.3 Stressor and Source Identification

Toxicity was evaluated by bioassays (acute and chronic), chemical pollutant monitoring (including metals, pesticides, and other organic pollutants), and the deployment of SPMDs to sample organic contaminants. Results of this sampling are discussed in Section 5.3.1. Nutrient and dissolved oxygen (DO) data are discussed in Section 5.3.2.

5.3.1 Water Column Toxicity

This section presents the results of bioassays conducted on water column samples, followed by a discussion of organic pollutants, metals, and other toxicants.

a. Bioassays

Ten long-term bioassays (chronic) for toxicity were conducted on baseflow samples (Table 5.3). Three acute bioassays for toxicity were conducted on storm samples collected at these same sites.

Table 5.3 Chronic and Acute Toxicity Bioassay of Water Column Samples*

Sampling Date	Stoney Creek at Slocumb Street / SR 1920 (STST01)		Stoney Creek at East Ash Street / US Hwy 70 Bus. (STST04)		Stoney Creek at US Hwy 70 Bypass (STST09)		Unnamed Tributary at Glen Oak Drive (STUN02)	
	Chronic Bioassay Baseflow	Acute Bioassay Storm	Chronic Bioassay Baseflow	Acute Bioassay Storm	Chronic Bioassay Baseflow	Acute Bioassay Storm	Chronic Bioassay Baseflow	Acute Bioassay Storm
March 7, 2002	PASS							
April 17, 2002	PASS		PASS				PASS	
May 13, 2002		PASS		PASS		**LC_{50} = 38.4%**		
May 21, 2002	PASS		PASS		PASS			
June 18, 2002	PASS		PASS		PASS			

* Blanks indicate that no samples were collected. See Appendix B for additional test data.
For chronic tests, a 'pass' indicates that the reproduction rate in the test sample was not significantly different than the reproduction rate in the controls. For acute tests, a 'pass' indicates that significant mortality was not observed.

While all chronic toxicity bioassays passed (Table 5.3), one of the three acute bioassays indicated the presence of toxic conditions. This test failure was from a storm sample collected from Stoney Creek at US Highway 70 Bypass (STST09) on May 13, 2002 (Table 5.3). The estimated LC_{50} for *C. dubia* was 38.4 percent (95 percent confidence interval is 35.2 – 41.9). The insecticide diazinon (trade name Spectracide) was detected in this sample at a concentration of 1.3 μg/L (Table 5.4), 7.6 times greater than the Tier II acute criterion of 0.17 μg/L (hazard quotient of 7.6). Hazard quotients are the ratio of the measured pollutant to the benchmark concentration. Atrazine, deethylatrazine, and simazine were also detected in this sample but were either below toxicity benchmarks or no benchmarks were available (see below). Several

metals -- including aluminum, cadmium, copper, lead, and zinc -- exceeded the acute National Ambient Water Quality Criteria (see Section 5.3.1). The sum of acute hazard quotients (HQs) for quantified metals was 19.9. The magnitude of the HQ for metals and diazinon indicates that these compounds have a strong potential to be the cause of the observed acute toxicity.

Confounding factors exist, however. Comparable metals levels downstream at STST01 on the same date (see below) did not result in a toxicity test failure. Other pesticides that could not be analyzed for may have been present. Laboratory analysis was not available during the study for many pesticides potentially used on crops in the watershed (Table 5.5) or for most pesticide breakdown products. While surfactants (methylene blue active substances) were not tested for at this site, they were detected further downstream at a concentration of 0.075 mg/L. The low pH (6.3) may also have contributed to toxicity directly or by increasing the bioavailability of other potential toxicants such as metals.

b. Pesticides

The upper portion of the Stoney Creek watershed is composed primarily of agricultural lands, while urban sources are a potential concern in the lower study area. At least one pesticide was detected in four of the eight baseflow grab samples for which pesticide analysis was conducted and in the only storm event evaluated (Table 5.4). Six pesticides were detected in all, five during baseflow and four during the one storm sampled. Atrazine and metolachlor were the most commonly detected pesticides. Additionally, one of the breakdown products of atrazine, deethylatrazine, was frequently detected. A complete listing of pesticides that were tested for is shown in Appendix B. Laboratory analysis was not available during the study for many of the pesticides potentially used on the major crops grown in the watershed (Table 5.5). Organochlorine pesticides and polychlorinated biphenyls (PCBs) were not detected in grab samples.

Atrazine concentrations are below EPA draft chronic and acute criteria levels of 12.35 μg/L and 351.2 μg/L, respectively (Great Lakes Environmental Center and University of Wisconsin, 2001). However, the atrazine concentration of 11.2 μg/L approached the draft chronic criteria on May 21, 2002 in Howell Creek (baseflow). A toxicity bioassay was not conducted on this occasion. As discussed previously, diazinon exceeded the Tier II benchmark during a storm on May 13, 2002.

No published freshwater ecological screening benchmarks are available for alachlor, deethylatrazine, metolachlor, or simazine. However, concentrations of each of these pesticides in the Stoney Creek watershed are several orders of magnitude below the concentrations reported in the literature to cause detrimental effects (see discussion in Appendix B).

Long-term monitoring with semi-permeable membrane devices (SPMDs) was conducted in the late summer and fall of 2002 at the integrator station (STST01) and several upstream sites. Semi-permeable membrane devices were placed in the field for twelve to fourteen days. Organic contaminants detected included, organochlorine pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and the current use pesticide chlorpyrifos (Table 5.6). None of these contaminants exceeded available screening values; concentrations detected were often ten to one hundred times lower than the screening value.

Table 5.4 Current Use Pesticides Detected in Water Samples from Stoney Creek Watershed*

Pesticide[1] (µg/L)	August 23, 2001 (Baseflow)			April 17, 2002 (Baseflow)			May 13, 2002 (Storm)		
	STST01	STST04	STST09	STST01	STST04	STST09	STST01	STST04	STST09
alachlor	-	-	-	-	-	-	-	-	-
atrazine	-	-	-	1.200	0.650	3.200	-	2.400	1.800
deethylatrazine	-	-	-	0.036	0.046	0.190	-	0.160	0.086
diazinon	-	-	-	-	-	-	-	-	1.300
metolachlor	-	-	-	-	-	-	-	-	-
simazine	0.650	-	0.820	-	-	-	-	-	2.100

Pesticide[1] (µg/L)	May 21, 2002 (Baseflow)					June 18, 2002 (Baseflow)						
	STST01	STST04	STST09	STHC03	STRB03	STST01	STST04	STST09	STST11	STHC03	STRB03	STSL01
alachlor	-	-	-	1.800	-	-	-	-	-	-	-	-
atrazine	-	-	-	11.200	-	0.074	0.036	0.084	0.030	3.900	-	-
deethylatrazine	-	-	-	0.870	-	-	-	-	-	-	-	-
diazinon	-	-	-	-	-	-	-	-	-	-	-	-
metolachlor	-	0.440	-	6.300	-	0.085	0.025	0.029	0.008	2.400	-	-
simazine	-	-	-	-	-	-	-	-	-	-	-	-

* This table includes only sampling events in which at least one pesticide was detected. Samples were also collected at baseflow on 9/24/2001, 1/17/2002, 2/13/2002, and 3/7/2002, at STST01 and STST09; all pesticides tested for on those dates and sites were below the detection limit of 0.005 µg/L.

A dash (-) indicates concentrations were below the detection limit of 0.005 µg/L. Explanations of site codes are given in Table 5.1.

1 EPA draft chronic criteria for atrazine is 351.2 µg/L, and the acute criteria are 12.35 µg/L (Great Lakes Environmental Center and University of Wisconsin, 2001). The acute Tier II benchmarks for diazinon is 0.17 µg/L. Benchmarks are not available for the other pesticides detected. See Appendix B for a complete listing of pesticide concentrations that have been shown to cause detrimental effects.

Table 5.5 Commonly Used Agricultural Pesticides for Which Laboratory Analysis of Water Samples Was Not Available During the Study*

aldicarb	deltamethrin	lambda-cyhalothrin	spinosad
carfentrazone	ethephon	maleic hydrazide	sulfosate
cyclanilide	fatty alcohols	mepiquat chloride	thidiazuron
cyfluthrin	glyphosate	metalaxyl	thiodicarb

* Based on list of agricultural pesticides potentially used in the Stoney Creek watershed. See Section 2.

Table 5.6 Selected Pesticides and PCBs Captured on Semi-Permeable Membrane Devices*

Pesticides and PCBs (ng/L)		SPMD Deployment 8/7/2002 - 8/21/2002			SPMD Deployment 10/18/2002 – 10/30/2002						NAWQC Chronic Screening Value (ng/L)	NAWQC Acute Screening Value (ng/L)
		STST01	STST04	STST09	STST01	STST04	STST09	STST11	STST12	STHC03		
Organo-chlorine Pesticides	hexachlorobenzene	0.07	0.02	0.04	bdl	bdl	bdl	bdl	bdl	bdl	-	-
	heptachlor	0.29	0.13	0.18	bdl	bdl	bdl	bdl	bdl	bdl	3.8	520
	heptachlor epoxide	bdl	bdl	bdl	0.35	0.29	0.10	bdl	bdl	bdl		
	alpha-chlordane	0.68	0.40	0.64	0.73	0.23	0.20	bdl	0.83	0.12	4.3[1]	2400[1]
	gamma-chlordane	0.50	0.32	0.42	0.33	0.11	0.14	bdl	0.50	0.06	4.3[1]	2400[1]
	trans-nonachlor	0.04	0.02	0.05	0.57	0.20	0.20	bdl	0.66	0.09	-	-
	dieldrin	0.05	0.11	0.11	bdl	bdl	bdl	bdl	bdl	bdl	56	240
	Sum of DDTs	0.67	1.00	0.88	1.07	0.15	0.24	bdl	0.11	0.35	-	-
Current Use Pesticides	chlorpyrifos	0.16	0.07	0.28	bdl	bdl	bdl	bdl	0.297	0.54	41	83
PCBs	Sum of PCBs	0.07	0.06	0.04	0.16		0.13				14	-

* NAWQC is National Ambient Water Quality Criteria. Dashes (-) indicate that screening values were not available.
Blanks indicate that screening was not conducted. Bdl is below the detection limit of 0.005 ng/L.
1 Chronic and acute screening values are for chlordane.

SPMDs are an excellent indicator of the hydrophobic organic contaminants to which the sampling site was exposed. However, the concentrations obtained from the SPMDs represent the average concentration over the entire deployment period; and thus, they do not provide information regarding specific pulse events, such as storms. Therefore, there may be transient elevated concentrations that could have ecological impacts. Rainfall occurred on at least six days during each of the two deployments.

c. Other Organic Compounds

Analysis of grab samples for the following additional organic contaminants was conducted in the lower watershed on six dates: phenols, total petroleum hydrocarbons, MTBE, PAHs, and base/neutral and acid organics. Only PAHs were detected.

The polycyclic aromatic hydrocarbons fluoranthene and benzanthracene were detected in a storm sample obtained on May 13, 2002. NAWQC benchmarks are not available for either of these compounds, although Tier II and EPA Region IV acute benchmarks are available for benz[a]anthracene and fluoranthene, respectively. The concentrations of fluoranthene detected in Stoney Creek (12.6 μg/L at Slocumb Street and 6.52 μg/L at E. Ash Street) were much lower than the EPA Region IV acute benchmark of 398 μg/L. However, observed concentrations of benz[a]anthracene (6.37 μg/L at Slocumb Street and 7.34 μg/L at E. Ash Street) were an order of magnitude greater than the Tier II acute benchmark of 0.49 μg/L. Toxicity bioassays conducted at these sites during this storm did not indicate that acute toxicity (test organism mortality) was present.

Long-term sampling with SPMDs detected a variety of polycyclic aromatic hydrocarbons (see Appendix B). Total PAH concentrations ranged from 242 ng/L at STST04 to 747 ng/L at STST01 during the August deployment.

Methylene blue active substances (MBAS), an indicator of anionic surfactants, were detected frequently in the Stoney Creek watershed (Table 5.7). They were detected at the highest concentrations and most frequently at the East Ash Street site (STST04). Concentrations were higher at East Ash Street than downstream at Slocumb Street, indicating that either there was a dilution effect or the surfactants were breaking down before they reached the integrator station. The source of these surfactants is unknown, but potential source activities include car washing (including home washing) and pavement degreasing. A toxicity bioassay conducted at the time of the highest observed MBAS concentration (0.619 mg/L at STST04 on June 18, 2002) passed.

A screening benchmark is not available for MBAS. The toxicity of specific surfactants varies, and the laboratory test for MBAS does not identify which anionic surfactants are present or their individual concentrations. The common anionic surfactant linear alkylbenzene sulfonate (LAS) can be toxic at concentrations as low as 0.025 mg/L (Kimerle, 1989). The lack of toxic effect at the MBAS concentrations observed in Stoney Creek may be explained by the nature of the specific surfactants present (e.g., predominant substances may be less toxic than LAS), by the loss of surfactants during laboratory bioassay procedures, or by analytical interferences.

Table 5.7 Methylene Blue Active Substances (MBAS) in Stoney Creek*

Date	STST01 (mg/L)	STST04 (mg/L)	STST09 (mg/L)
8/23/01	< 0.025	< 0.025	
1/17/02	< 0.025	< 0.025	
2/13/02	0.061	0.091	
3/7/02	< 0.025	0.133	
4/17/02	< 0.025	< 0.025	
5/13/02	< 0.025	0.075	
5/21/02	< 0.025	0.037	
6/18/02	0.025	0.619	0.170

* The 5/13/02 sample was collected during a storm. All others were collected during baseflow. Blanks indicate that samples were not collected.

d. Metals

Metals were commonly found at sites draining the urban portion of the Stoney Creek watershed. Metals were not sampled in the agricultural area of the watershed. Baseflow and storm data are shown in Tables 5.8 and 5.9, respectively.

Aluminum concentrations often exceeded chronic National Ambient Water Quality Criteria (NAWQC) during baseflow. The data suggest a trend of increasing aluminum concentrations in a downstream direction, with median values of 89 µg/L, 157 µg/L, and 196 µg/L at US Highway 70 bypass (STST09), East Ash Street (STST04) and Slocumb Street (STST01), respectively. Conversely, copper and iron were measured at the highest concentrations at the most upstream site tested (STST09) and decreased in concentration downstream. Iron frequently exceeded its NAWQC benchmarks, while copper only exceeded its benchmark once at station STST09. Lead was found occasionally throughout the watershed with the highest concentrations at the two upper sampling sites (STST09 and STST04). It exceeded its benchmark in five out of fourteen baseflow samples.

Manganese and cadmium were also detected in baseflow samples, but did not exceed their NAWQC benchmarks. However, manganese decreases in concentration from upstream to downstream. Zinc is found throughout the watershed, but did not exceed its NAWQC benchmarks during baseflow. Arsenic, chromium, mercury, nickel, and silver were not detected in any baseflow samples. Chronic toxicity tests conducted on several baseflow samples passed (see Table 5.3) indicating that observed concentrations on these occasions were not sufficient to cause short-term toxic impacts.

Storm sampling was limited by below normal rainfall during the study period. While it is not possible to draw definitive conclusions from the limited data available, it appears that concentrations of some metals (e.g., aluminum, iron, and zinc) were higher during storms than during baseflow. Aluminum, cadmium, copper, lead, and zinc exceeded their respective

NAWQC acute benchmarks during the May 13, 2002 storm, but not in the one sample taken during the September 24, 2001 storm.

A toxicity test failed from samples taken at US Highway 70 bypass (STST09) during a storm on May 13, 2002. Several metals, including aluminum, cadmium, copper, lead, and zinc, exceeded the NAWQC during this event. However, toxicity was not observed concurrently downstream at Slocumb Street (STST01) where concentrations of most of these metals (except copper and zinc) were higher.

Metals data must be interpreted cautiously. Since total rather than dissolved concentrations of metals were measured, bioavailability is difficult to fully assess. Adjusting benchmarks for hardness only partially addresses this issue. Metals such as aluminum, iron, manganese, copper, and zinc are widespread in North Carolina's waters. Potential effects on benthic macroinvertebrates are uncertain, since organisms in a given locality may be adapted to local concentrations. Comparison data on unimpaired coastal plain streams are limited, since many sites for which ambient data are available are either biologically impaired or are swamp waters that have not received a bioclassification. However, Contentnea Creek near SR 1800 (ambient station J7810000, in Pitt County) and Middle Creek at NC 50 (ambient station J5000000, in Johnston County) have metals concentrations similar to Stoney Creek (Table 5.10) and support adequate benthic communities (bioclassification of 'Good-Fair').

Table 5.8 Total Metal Concentrations at Baseflow and NAWQC Chronic Values

a. Stoney Creek Integrator Station at Slocomb Street / SR 1920 (STST01)

Metal	**NAWQC[1] Chronic Values (µg/L)**	8/23/01 (µg/L)	1/17/02 (µg/L)	2/13/02 (µg/L)	3/7/02 (µg/L)	4/17/02 (µg/L)	5/21/02 (µg/L)	6/18/02 (µg/L)
Aluminum	87	**216**	**255**	**214**	**196**	**166**	**114**	**125**
Arsenic	150	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Cadmium	0.88 - 0.98	< 0.1	0.1	< 0.1	< 0.1	< 0.1	0.2	< 0.1
Chromium	11	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Copper	3.05 - 3.43	< 1	1	< 1	< 1	< 1	< 1	2
Iron	1000	**1620**	757	593	677	**1550**	**1320**	**985**
Lead	0.60 - 0.72	< 1	**1**	< 1	< 1	**1**	< 1	**1**
Manganese	120	38	46	33	37	37	27	17
Mercury	0.77	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Nickel	17.23 - 19.37	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Silver	0.36	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Zinc	39.51 - 44.42	15	16	16.6	12.1	10	11.1	< 0.1
Hardness		30 mg/L	30 mg/L	32 mg/L	30 mg/L	31 mg/L	29 mg/L	27 mg/L

1 Manganese benchmark is Tier II, others are NAWQC. Bold type indicates values exceeding benchmark. NAWQC values varied according to water hardness for cadmium, copper, lead, nickel, and zinc. The range of values for the NAWQC is given for the hardness values measured.

Table 5.8 Total Metal Concentrations at Baseflow and NAWQC Chronic Values (con't)

b. Stoney Creek at East Ash Street / Highway 70 Business (STST04)

Metal	**NAWQC[1] Chronic Values (µg/L)**	2/13/02 (µg/L)	3/7/02 (µg/L)	4/17/02 (µg/L)	5/21/02 (µg/L)	6/18/02 (µg/L)
Aluminum	87	**199**	**217**	**157**	**112**	**139**
Arsenic	150	< 5	< 5	< 5	< 5	< 5
Cadmium	0.93	< 0.1	0.1	< 0.1	< 0.1	< 0.1
Chromium	11	< 1	< 1	< 1	< 1	< 1
Copper	3.24	< 1	< 1	< 1	< 1	2
Iron	1000	525	695	**1690**	**1570**	**2000**
Lead	0.66	< 1	< 1	< 1	< 1	**2**
Manganese	120	30	36	50	47	58
Mercury	0.77	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Nickel	18.30	< 1	< 1	< 1	< 1	1
Silver	0.36	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Zinc	41.98	8.5	14.5	10	6.8	1.3
Hardness		no data	no data	no data	29 mg/L	29 mg/L

1 Manganese benchmark is Tier II, others are NAWQC. Bold type indicates values exceeding benchmark. NAWQC values varied according to water hardness for cadmium, copper, lead, nickel, and zinc. The range of values for the NAWQC is given for the hardness values measured.

c. Stoney Creek at Highway 70 Bypass (STST09)

Metal	**NAWQC[1] Chronic Values (µg/L)**	5/21/02 (µg/L)	6/18/02 (µg/L)
Aluminum	87	**98**	79
Arsenic	150	< 5	< 5
Cadmium	0.96 – 1.01	0.1	< 0.1
Chromium	11	< 1	< 1
Copper	3.33 - 3.52	**4**	2
Iron	1000	**1950**	**3640**
Lead	0.69 - 0.75	< 1	**2**
Manganese	120	51	113
Mercury	0.77	< 0.2	< 0.2
Nickel	18.84 – 19.89	< 1	1
Silver	0.36	< 0.5	< 0.5
Zinc	43.20 – 45.63	25.8	< 0.1
Hardness		32 mg/L	30 mg/L

1 Manganese benchmark is Tier II, others are NAWQC. Bold type indicates values exceeding benchmark. NAWQC values varied according to water hardness for cadmium, copper, lead, nickel, and zinc. The range of values for the NAWQC is given for the hardness values measured.

Table 5.9 Total Metal Concentrations in Stormflows and NAWQC Acute Values at Three Sites on Stoney Creek

Metal	9/24/01		5/13/02			
	NAWQC[1] Acute Values (µg/L)	STST01 (µg/L)	**NAWQC[1] Acute Values (µg/L)**	STST01 (µg/L)	STST04 (µg/L)	STST09 (µg/L)
Aluminum	750	190	750	**2350**	653	**1440**
Arsenic	340	< 5	340	< 5	< 5	< 5
Cadmium	1.03	< 0.1	0.41 – 0.78	**0.6**	0.3	**0.5**
Chromium	16	< 1	16	2	-1	2
Copper	4.08	< 1	1.90 – 3.22	**10**	**5**	**13**
Iron	N/A	1190	N/A	6030	3000	5720
Lead	15.42	< 1	5.49 – 11.2	**24**	7[2]	**21**
Manganese	2300	27	2300	194	175	322
Mercury	1.40	< 0.2	1.40	< 0.2	< 0.2	< 0.2
Nickel	154.98	< 1	78.04 – 125.29	2	< 1	2
Silver	0.43	< 0.5	0.11 - 0.28	< 0.5	< 0.5	< 0.5
Zinc	39.51	8.7	19.87 – 31.93	**72.1**	**34.5**	**95.6**
Hardness		27 mg/L		18 mg/L	21 mg/L	12 mg/L

1 Manganese benchmark is Tier II, others are NAWQC. Bold type indicates values exceeding benchmark. NAWQC values varied according to water hardness for cadmium, copper, lead, nickel, and zinc. The range of values for the NAWQC is given for the hardness values measured.

2 The NAWQC acute value for lead in water with a hardness of 21 mg/L is 11.2 µg/L.

Table 5.10 Median Metal Concentrations in this Study and at DWQ Ambient Stations

Metal[1] (µg/L)	**Study Sites[2]**			**Ambient Stations, 1996-2000[3]**	
	STST01	**STST04**	**STST09**	**Middle Creek at NC 50 (J5000000)**	**Contentnea Creek near SR 1800 (J7810000)**
Aluminum	196	157	89	300	370
Copper	< 1	< 1	3	2.5	2
Iron	985	1570	2755	1300	1900
Zinc	12.1	8.5	13	14	19
Bioclassification	Fair	Fair	Not Rated	Good-Fair	Good-Fair

1 The detection limits for cadmium, lead, and manganese at the ambient stations were too high for comparison with samples from this study.

2 See Table 5.1 for descriptions of site codes. Data from study sites were obtained during baseflow.

3 Source: NCDWQ (2001b). Ambient Station data include measurement taken at baseflow and during storms.

5.3.2 Dissolved Oxygen, Nutrients, and Biochemical Oxygen Demand

a. Dissolved Oxygen

Dissolved oxygen (DO) concentrations during the study period were monitored using two approaches: instantaneous field measurements that provided static data, and multiparameter probes with a data logging capability (data sondes) that provided data on daily DO cycles. Data were collected from both the upper study area that is agriculture-intensive and the lower study area that is more urban. Results are shown in Table 5.11.

North Carolina's DO standard for these waters is 4.0 mg/L for instantaneous measurements and 5.0 mg/L as a daily average. DO concentrations at all locations sampled dropped below 5 mg/L during the night. However, at the lower two sites (STST01 and STST04), DO concentrations were generally adequate most of the time and concentrations below 4 mg/L were not recorded. Further upstream at STST09, lower DO concentrations were evident. At sites in the upper watershed, DO concentrations low enough to impact biota occurred frequently.

The agricultural areas in the upper watershed are very different hydrologically than the lower, urban portions. The streams in the upper watershed are stagnant and swamp-like, which is reflected in the exceptionally low DO concentrations (minimum DO recorded is 0.13 mg/L in Stoney Creek at STST11 during the October 18, 2002 data sonde deployment). The range of DO measured by static in-stream samples was 1.15 mg/L at STST11 to 9.75 mg/L at STHC03. This anoxic and nutrient laden water from the upper reaches drains into the lower watershed, potentially causing DO problems downstream.

Most of the lower watershed experiences observable water movement during baseflow periods, with concomitant higher DO concentrations. DO concentrations from static in-stream samples ranged from 4.09 mg/L at STST09 to 10.55 mg/L at STST01. Continuous sampling recorded a minimum DO concentration of 2.16 mg/L (at Stoney Creek on Highway 70 bypass – STST09 from the August 16, 2001 deployment).

Continuous sampling with data sonde recorders showed only small daily fluctuations in DO concentrations (for example, see Figure 5.2). Diurnal fluctuations did not exceed 1.0 mg/L in any of the deployments. This was unexpected since several of the sites, particularly in the upper area, had heavy algal growth.

On two occasions, comparisons were made between DO concentrations in the Stoney Creek watershed and a nearby reference stream, The Slough (Table 5.12). The Slough received a 'Good-Fair' rating for benthos, despite the presence of some species adapted to of low DO concentrations. While all sites had comparable DO levels during April 2002, DO concentrations were much lower in the upstream portion of the Stoney Creek watershed than in The Slough during June 2002. During this period, the lower portion of Stoney Creek had DO concentrations similar to those of the reference stream.

Table 5.11 Dissolved Oxygen Concentrations (mg/L) from Static Sampling and Continuous Sampling

Site Code[1]	Flow or Date	Mean ± s.e.	Minimum	Maximum	N
Static In-stream Sampling					
Lower Study Area					
STST01	Baseflow	8.76 ± 0.75	6.41	10.55	6
	Stormflow	5.90 ± 0.30	5.59	6.20	2
STST04	Baseflow	8.14 ± 0.87	4.97	10.01	6
	Stormflow	5.55 ± 0.00			1
STST09	Baseflow	8.12 ± 1.12	4.09	10.23	6
	Stormflow	5.35 ± 0.85	4.50	6.20	2
Upper Study Area					
STST11	Baseflow	5.39 ± 4.24	1.15	9.63	2
STRB03	Baseflow	5.94 ± 3.07	2.87	9.01	2
STHC03	Baseflow	6.64 ± 3.11	3.53	9.75	2
Continuous Sampling with Data Sonde[2]					
Lower Study Area					
STST01	8/16/01 – 8/23/01	5.92 ± 0.01	4.83	7.28	672
	10/18/02 – 10/25/02	6.90 ± 0.02	6.18	8.00	648
STST04	8/16/01 – 8/23/01	5.40 ± 0.01	4.69	6.82	686
	10/18/02 – 10/25/02	5.53 + 0.04	4.46	7.25	638
STST09	8/16/01 – 8/23/01	3.18 ± 0.02	2.16	4.86	669
	10/18/02 – 10/25/02	5.35 + 0.01	4.75	5.86	639
STBB01	10/23/01 – 10/30/01	3.59 ± 0.01	2.65	4.21	683
STST07	10/23/01 – 10/30/01	3.89 ± 0.02	2.78	4.81	680
STUN01	10/23/01 – 10/30/01	3.77 ± 0.02	2.95	4.33	633
Upper Study Area					
STST11	10/18/02 – 10/25/02	0.21 + 0.01	0.13	0.55	656

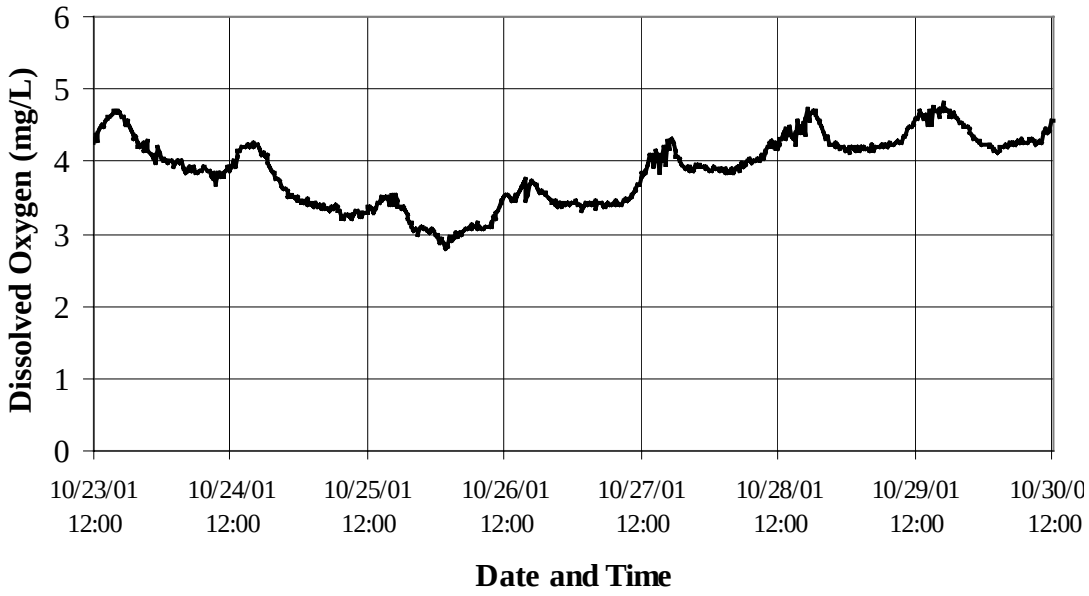
1 See Table 5.1 for explanations of the site codes.
2 Rain occurred sporadically during every deployment.

Table 5.12 Dissolved Oxygen Concentrations (mg/L) in the Stoney Creek Watershed and a Reference Stream*

Date	Lower Study Area[1]			Upper Study Area[1]			Reference Stream
	STST01	STST04	STST09	STST11	STHC03	STRB03	The Slough at SR 1535
4/17/02	9.94	9.03	9.75	9.63	9.75	9.01	9.90
6/18/02	6.44	4.97	5.13	1.15	3.53	2.87	6.15

* Samples were single static samples taken in the stream.
1 See Table 5.1 for explanations of the site codes.

Figure 5.2 Continuous Sampling of Dissolved Oxygen at Stoney Creek on Royall Avenue (STST07) from October 23, 2001 to October 30, 2001[1]



1 Rain occurred on October 25, 2001.

b. Nutrients

Mean concentrations of total phosphorus and total nitrogen at all sites in the study area (Table 5.13) exceeded the 25th percentile values calculated by EPA for total phosphorus (0.023 mg/L) and total nitrogen (0.62 mg/L) in the inner coastal plain (Ecoregion 65) (USEPA, 2000b). Mean total nitrogen concentrations exceeded 1.0 mg/L at all sites. The highest concentrations were observed in the upper study area and during storms.

Though concentrations of total nitrogen in the upper study area were high, the percentage of inorganic nitrogen was lower in this largely agricultural area than in the lower watershed (Table 5.14), even though the sampling period in the upper watershed encompassed much of the spring planting season (April through June, 2002). This implies that in the upper study area much of the nitrogen is in organic material, such as algae or detritus. The percentages of inorganic nitrogen at baseflow were the highest at STST01 and STST04 (Table 5.14). High levels of inorganic nitrogen in streams may be associated with fertilizer additions to crops and turf areas.

A single day comparison of Stoney Creek to the nearby reference stream, The Slough, indicated that high nutrient concentrations were not confined to Stoney Creek (Table 5.15). The Slough, which drains an agricultural area, had higher levels of total nitrogen, TKN, and nitrate + nitrite. Ammonia concentrations were higher in Stoney Creek, except at the integrator station. Concentrations of total phosphorus were elevated in both Stoney Creek and The Slough.

Table 5.13 Mean Nutrient Concentrations and Standard Errors in the Stoney Creek Watershed at Baseflow and Stormflow

Nutrient (mg/L)	Sampling Location							
	Lower Study Area					Upper Study Area		
	STST01		STST04	STST09		STHC03	STRB03	STST11
	Baseflow	Stormflow	Baseflow	Baseflow	Stormflow	Baseflow	Baseflow	Baseflow
Total Phosphorus	0.07 ± 0.01 (7)	0.33 ± 0.26 (2)	0.11 ± 0.00 (1)	0.12 ± 0.02 (7)	0.39 ± 0.12 (2)	0.20 ± 0.05 (3)	0.20 ± 0.05 (3)	0.17 ± 0.00 (1)
Ammonia Nitrogen	0.15 ± 0.03 (7)	0.25 ± 0.15 (2)	0.20 ± 0.00 (1)	0.16 ± 0.03 (7)	0.35 ± 0.05 (2)	0.20 ± 0.10 (3)	0.30 ± 0.12 (3)	0.20 ± 0.00 (1)
Total Kjeldahl Nitrogen	0.96 ± 0.14 (7)	3.90 ± 3.00 (2)	0.90 ± 0.00 (1)	1.06 ± 0.14 (7)	2.40 ± 0.90 (2)	1.53 ± 0.23 (3)	1.73 ± 0.40 (3)	1.50 ± 0.00 (1)
Nitrate + Nitrite Nitrogen	0.43 ± 0.09 (7)	0.43 ± 0.12 (2)	0.30 ± 0.00 (1)	0.18 ± 0.06 (7)	0.24 ± 0.01 (2)	0.10 ± 0.06 (3)	0.18 ± 0.14 (3)	0.22 ± 0.00 (1)
Total Nitrogen	1.38 ± 0.18 (7)	4.33 ± 2.87 (2)	1.20 ± 0.00 (1)	1.24 ± 0.14 (7)	2.64 ± 0.91 (2)	1.63 ± 0.28 (3)	1.92 ± 0.52 (3)	1.72 ± 0.00 (1)

Table 5.14 Inorganic Nitrogen as a Percentage of Total Nitrogen in the Stoney Creek Watershed

	Sampling Location							
	Lower Study Area					Upper Study Area		
	STST01		STST04	STST09		STHC03	STRB03	STST11
	Baseflow	Stormflow	Baseflow	Baseflow	Stormflow	Baseflow	Baseflow	Baseflow
% Inorganic Nitrogen*	41.5 (7)	27.3 (2)	41.7 (1)	28.0 (7)	24.5 (2)	16.6 (3)	22.3 (3)	24.4 (1)

* Ammonia + Nitrite/Nitrate

Table 5.15 Nutrient Concentrations Comparing Urban and Agricultural Areas in the Stoney Creek Watershed to a Reference Stream on June 18, 2002

Nutrients (mg/L)	Sampling Location						
	Lower Study Area			Upper Study Area			Reference Stream
	STST01	STST04	STST09	STST11	STHC03	STRB03	The Slough at SR 1535
Total Phosphorus	0.05	0.11	0.13	0.17	0.30	0.15	0.21
Ammonia Nitrogen	0.1	0.2	0.3	0.2	0.4	0.5	0.2
Total Kjeldahl Nitrogen	0.6	0.9	1.3	1.5	1.9	2.4	1.6
Nitrate + Nitrite Nitrogen	0.35	0.30	0.23	0.22	0.22	0.47	1.66
Total Nitrogen	0.95	1.2	1.53	1.72	2.12	2.87	3.26

c. *Biochemical Oxygen Demand*

Five-day biochemical oxygen demand (BOD_5) was measured on three occasions in both the upper and lower study areas. The Slough was also analyzed for comparative purposes (Table 5.16). In the upper agricultural portion of the watershed, the BOD_5 ranged from 1.0 to 3.9 mg/L and was typically higher than the reference stream. In contrast, the urban integrator station (STST01) had the lowest BOD_5 values (0.5 mg/L and 0.7 mg/L) and was slightly lower than the reference stream. The other urban site, Stoney Creek at Wayne Memorial Drive (STST10), had the highest BOD measured (5.2 mg/L) on the single occasion it was sampled.

Table 5.16 Five-Day Biochemical Oxygen Demand (mg/L) in the Stoney Creek Watershed

Date	Sampling Site[1]				
	Lower Study Area	Upper Study Area			Reference Stream
	STST01	STST11	STHC03	STRB03	The Slough at SR 1535
April 17, 2002[2]		1.7	2.3	3.6	1.4
May 21, 2002[3]	0.7	1.0	1.0	1.8	0.8
June 18, 2002[4]	0.5	5.2	2.9	3.9	1.3

Blanks indicate that samples were not collected.

1 Descriptions of site codes are given in Table 5.1

2 DO depletion of dilution water blank exceeded 0.2 mg/L.

3 DO depletion of dilution water blank exceeded 0.2 mg/L. The calculated seed correction exceeded the range of 0.6 to 1.0 mg/L.

4 DO depletion of the dilution water blank produced a negative value.

Section 6
Channel and Riparian Conditions

The characterization of stream habitat and riparian area condition at benthic macroinvertebrate sampling sites, described earlier, provides information essential to the assessment of conditions in the Stoney Creek study area. However, a perspective limited to a small number of locations in a watershed may not provide an accurate picture of overall channel conditions, nor result in the identification of pollutant sources and specific problem areas. This study therefore undertook a broader characterization of stream condition by examining large sections of the Stoney Creek channel network. This characterization is critical to an evaluation of the contribution of local and regional habitat conditions to stream impairment and to the identification of source areas and activities.

During the course of this study, project staff walked approximately nine miles (14.5 km) of channel including: the mainstem of Stoney Creek from SR 1920 to Wayne Memorial Drive, the lower reaches of Billy Branch and Reedy Branch and several unnamed tributaries. Although assessment of upstream channel reaches was limited by swamp conditions, staff surveyed and observed selected upstream reaches of Stoney Creek, Howell Branch, Reedy Branch, and Stoney Run. Several of these reaches were surveyed on numerous occasions.

Project staff walked the identified sections of channel while carrying out the following tasks:

- Observing overall channel stability, noting specific areas of sediment deposition, severe bank erosion, evidence of channelization and similar attributes;
- Observing overall riparian area condition and the nature of surrounding land use;
- Identifying wastewater discharge pipes, stormwater outfalls, other piped inputs or withdrawals, and tributary inflows;
- Observing visual water quality conditions (odors, surface films, *et cetera*);
- Noting specific areas where pollutants are or may be entering the stream (dump sites, land clearing adjacent to the stream, *et cetera*);
- Identifying specific areas that may be candidates for channel restoration or BMPs;
- Providing digital photo documentation of key features;
- Conducting formal habitat assessments at representative reaches, as appropriate.

This section summarizes channel and riparian conditions and discusses likely future changes in stream channels. Results of several geomorphic assessments conducted by North Carolina State University (NCSU) as a part of this study are also summarized.

6.1 Summary of Existing Conditions

6.1.1 Overall Channel and Riparian Condition

<u>Channel Conditions: Upper Study Area</u>. Key features of the hydrology of North Carolina's coastal plain include low stream velocity, broad floodplains and large wetland tracts (Kuenzler et al., 1977). Unchannelized stream reaches in the upper watershed (above New Hope Road)

display many of these characteristics (Exhibit 6.1). Although not as large as in undisturbed coastal plain watersheds, floodplain and wetland areas bordering streams range from 75 to several hundred feet in width. In numerous locations, particularly during periods of higher flow, it can be difficult to distinguish stream channels from adjoining wetland areas. Beaver impoundments are common, particularly on Reedy Branch.

Stoney Creek, Stoney Run, Howell Creek upstream of New Hope Road, and most first and second order tributaries in the upper study area show evidence of historic channelization (see Section 2 for details). Land bordering channelized reaches in the upper study area is generally less swampy than areas adjacent to unchannelized reaches as channelization tends to draw down the water table and drain nearby low-lying areas (Kuenzler et al., 1977). It has been at least a century since widespread channelization of major streams has occurred in this area, and streams have regained some of their natural morphological characteristics. Although channelized reaches have remained relatively straight, they are minimally incised and often retain a connection with adjacent wetland areas (Exhibit 6.2). Just upstream of Stoney Creek Church Road, Stoney Run is dammed to create several small impoundments in a residential area.

Channel Conditions: Lower Stoney Creek Mainstem. Stoney Creek is approximately nine feet wide at Wayne Memorial Drive, widening gradually to approximately 20 feet at East Ash Street and retaining that approximate width for several miles before narrowing slightly upstream of Slocumb Street. Stream bank height, which ranges from one to four feet, tends to increase as the stream nears East Ash Street, and then fluctuates between approximately two and five feet in the downstream areas.

A sewer right-of-way borders the entire length of the mainstem in the lower study area. The Stoney Creek Greenway, a component of the Mountains-to-Sea Trail, borders Stoney Creek from Jefferson Quail Park to Slocumb Street.

The majority of the mainstem below Wayne Memorial Drive shows some evidence of past channelization and exhibits varying degrees of incision. However, Stoney Creek retains access to its floodplain in most areas and incision is typically only slight to moderate (Exhibit 6.3). Factors related to increased incision in the lower watershed may include more recent channelization (see Section 2.2 for details) and increased discharge volumes and velocities associated with the higher levels of watershed imperviousness in the lower half of the study area.

Stoney Creek's channel is largely straight between Wayne Memorial Drive and Elm Street. Sinuosity becomes evident downstream of Elm Street and increases gradually as Stoney Creek flows towards Slocumb Street (Exhibit 6.4).

Although stream bank erosion is generally moderate and does not appear to be a significant limiting factor overall, between US 70 Bypass and Elm Street Stoney Creek exhibits more frequent bank instability and more pronounced sediment deposition (Exhibits 6.5 and 6.6). Banks failures were noted in this area during the period of study.

Exhibit 6.1 Unchannelized reach, upper study area.

Exhibit 6.2 Channelized reach and adjacent floodplain, upper study area.

Exhibit 6.3 Moderately incised channel, lower Stoney Creek watershed.

Exhibit 6.4 Developing sinuosity downstream of East Ash Street.

Exhibit 6.5 Sediment deposition in Stoney Creek upstream of East Ash Street.

Exhibit 6.6 Unstable stream banks, Stoney Creek below Elm Street.

Channel Conditions: Lower Study Area Tributaries. First and second order tributaries in the lower study area vary in condition. Some show evidence of historic channelization or are incised. Even in locations with a more natural morphology (e.g., the tributary to Stoney Creek draining the Berkeley Mall area) bank erosion is evident.

Riparian Conditions: Upper Study Area. Riparian areas adjacent to unchannelized stream reaches in the upper study area are generally bottomland hardwood swamps or other wetlands (Exhibit 6.7). Most swamp areas are bordered by forested areas ranging from 25 to several hundred feet in width, although there are locations (e.g., Howell Creek at Patetown Road and portions of Reedy Branch at New Hope Road) where swamp areas are adjacent to buildings or lawns.

Exhibit 6.7 Riparian area, upper study area.

Riparian Conditions: Lower Stoney Creek Mainstem. Riparian conditions in the lower half of Stoney Creek are varied, with the highest quality conditions found toward the downstream end of the study area. Riparian conditions at Wayne Memorial Drive, where the west bank is bordered by a single line of trees and the east bank is bordered by lawn, are particularly poor. With notable exceptions, riparian vegetation is generally more extensive downstream of Wayne Memorial Drive. One of these exceptions is located immediately upstream of East Ash Street where, for approximately 50 yards, the east bank borders a parking lot which is crumbling into the stream, and the left bank is bordered by a turf area.

Immediately downstream of East Ash Street, Stoney Creek flows through Stoney Creek Park, a public park belonging to the City of Goldsboro. A single line of one to two-foot diameter hardwoods lines the top of the stream bank along approximately 30 percent of this reach. The east bank riparian area is less than 20 feet wide. The west bank riparian area, where the park is located, is over 50 feet wide and contains widely spaced hardwoods (Exhibit 6.8). The site is prone to flooding and overbank sediment deposition is often visible in the riparian area.

Exhibit 6.8 West bank riparian area, Stoney Creek Park at East Ash Street.

The riparian area downstream of East Ash Street is generally wide and well vegetated. Exceptions to these conditions appear intermittently, particularly upstream of Elm Street, where vegetation is sparse and comprised primarily of woody shrubs. Even where the riparian zone is vegetated, non-native invasive species are common, providing limited bank protection. Riparian vegetation quality increases downstream, with mature hardwoods dominant approximately one mile upstream of Slocumb Street.

Riparian Conditions: Lower Watershed Tributaries. Riparian conditions along Billy Branch, a tributary entering Stoney Creek immediately upstream of US 70 Bypass, are generally poor. The riparian area near the mouth of Billy Branch consists of a wide marshy field adjacent to US 70 Bypass. Further upstream, Billy Branch drains extensive developed areas and the vegetated riparian area ranges in width from five to fifteen feet, comprised primarily of grass and shrubs. An unnamed tributary joins Stoney Creek immediately downstream of Royall Avenue. This tributary drains areas similar to Billy Branch and has a similarly degraded riparian area.

Aquatic Habitat: Upper Study Area. The upper watershed is primarily a swamp system lacking visible water movement. Access to streams in this area was limited and detailed habitat analyses were not conducted. However, it appears that streams in this area, though channelized many years ago, have not generally been subject to recent disturbance. Surface algal blooms were frequently observed during the warmer months, and in many swamp areas floating macrophytic vegetation was abundant through most of the year (Exhibit 6.9).

Aquatic Habitat: Lower Study Area. Access to streams between New Hope Road and Wayne Memorial Drive continued to be limited by swamp conditions. Limited portions of Stoney Creek and Howell Branch become accessible approximately 300 yards upstream of Wayne Memorial

Drive. Portions of Stoney Creek and Howell Branch located in this area have been channelized and offer little habitat value. Both channels are uniform and lack any sinuosity or depth variation. Root mats, leaf packs, snags and other organic habitat are rare. Riparian vegetation bordering Stoney Creek is extremely sparse, providing limited stream canopy and woody debris to the stream. Although vegetation bordering Howell Branch is somewhat more plentiful, it is intermittent and comprised largely of non-native understory species that provide limited bank stabilization or large woody debris to the stream. Substrates are comprised of almost entirely sand and silt, and streamflow is slow to not visible.

Exhibit 6.9 Macrophyte growth, upper Stoney Creek watershed.

For the most part, habitat gradually improves downstream of Wayne Memorial Drive with the highest quality habitat found near the terminus of the study area (Exhibit 6.10). Favorable habitat factors, increasingly present in most downstream reaches, include adequate stream canopy, root mats, leaf packs, snags and other woody debris. A good variety of depths and velocities are present in many areas. Stream banks are generally only moderately eroded. Although the substrate is primarily sand, this is expected in coastal plain streams where habitat is typically provided by in-stream woody debris, root mats and leaf packs. Snags and debris jams typically have higher species richness and productivity than other habitat types in coastal plain streams (Smock and Gilinsky, 1992).

NCSU Assessments. As a part of this study, DWQ contracted with the Stream Restoration Institute at NCSU to conduct a morphological evaluation and restoration feasibility study of two reaches (Figure 6.1):

- Stoney Creek at US 70 Business (East Ash Street). A benthic sampling site is located in this reach. This site was typical of the upper reaches of the Goldsboro portion of Stoney Creek in that bank condition was moderately degraded with more severely degraded areas sometimes present.

- Stoney Creek between Royall Avenue and Jefferson Quail Park. This reach, located three quarters of a mile upstream of the first reach and just downstream of the US 70 Bypass, was chosen because it represents of some of the more severe channel degradation problems in the study area.

The NCSU assessments (NCSU, 2002a and 2002b) noted that both reaches appeared channelized, but were not incised for the most part and remain hydrologically connected to floodplain areas. Both reaches were classified as Rosgen E type channels (Rosgen, 1996), although width/depth ratios were high for stable channels of this type. These reaches lacked appropriate pattern (sinuosity) and dimension (cross-sectional shape). The East Ash Avenue site was characterized by alternating channel bars, and the upstream reach was characterized by poor riparian vegetation on one bank. The restoration implications of this work are addressed in Section 8.

Table 6.1 Selected Geomorphic Characteristics of Two Reaches Evaluated by NCSU

	Stoney Creek at East Ash Street/US 70 Business	**Stoney Creek from Royall Ave. to Jefferson Quail Park**
Width/Depth Ratio [1]	7.9	9.5
Entrenchment Ratio [2]	>2.2	>2.2
D_{50} (mm) [3]	1.3 (sand)	4.2 (gravel)
Slope (%)	0.053	0.15
Sinuosity [4]	1.0	1.0
Rosgen Stream Type [5]	E5	E4
Bank Height Ratio [6] (range)	1.0-1.8	1.0-1.2

Source: NCSU 2002a & NCSU 2002b

1. Bankfull width/mean bankfull depth
2. Floodprone area width/bankfull channel width
3. Median diameter of channel material (size class based on visual estimate)
4. Valley slope/channel slope
5. Rosgen (1996)
6. Low bank height/ max bankfull depth

Exhibit 6.10 In-stream woody debris lower Stoney Creek mainstem.

6.1.2 Other Field Observations

On a number of occasions, project staff observed unusual water appearance and odors in the developed portions of the watershed during baseflow periods. Several of these events are described below. Although specific sources could not be located, the fact that these events were discovered by chance underscores the likelihood of similar episodic inputs.

In April 2001, staff noticed a sewage-like odor coming from an unnamed tributary to Stoney Creek below the confluence of Stoney Creek and Howell Branch. Over the next several months, staff visited the site several additional times but did not encounter the odor. Field measurements and downstream water chemistry analyses on these subsequent occasions were not noteworthy. Personnel at the Goldsboro Planning and Sewer Departments were unfamiliar with problems at the site and had no records of problems along nearby sanitary sewer lines. Staff later met with a property owner who had noticed the odor at intermittent intervals. The property owner indicated that she addressed the problem by spraying bleach along the stream bank.

In March 2002, staff noticed an acrid odor coming from a tributary upstream of US Highway 70 Bypass. The water had an atypical opaque white, cloudy appearance (Exhibit 6.11). Staff followed the tributary as far as possible, but no identifiable source was found. Analysis of water samples from the site was not noteworthy. Laboratory toxicity bioassays conducted with water samples from the site did not indicate toxicity. Staff returned to observe the site and collect field parameters on several occasions, but failed to detect the odor and cloudy appearance again. On another occasion staff spoke with a nearby property owner who had noticed the smell on previous occasions. The property owner offered to contact staff if the smell returned but has failed to notice the odor since that time.

Exhibit 6.11 Discolored water, unnamed tributary to Stoney Creek (pipe on left of photo was not discharging).

In February 2001, an unusual opaque, cloudy appearance was seen in the unnamed tributary upstream of Slocumb Street. Although Seymour Johnson Air Force Base was permitted to discharge up to one million gallons per day (MGD) of stormwater and groundwater remediation water into the tributary, staff from the Environmental Safety Department at SJAFB have indicated that groundwater remediation discharges were no longer occurring at that time. Staff were unable to follow the tributary upstream because SJAFB had restricted access to the area. The same appearance was not present on subsequent visits to the site.

6.1.3 Channelization and Hydrologic Impacts

During channelization the natural stream channel is straightened, deepened, and widened. This increases water velocity, allows the channel to contain floodwaters, drains the former floodplain, and lowers the water table on either side of the channel (Kuenzler et al., 1977). With the modification of sinuosity and slope, channelization often sets in motion an extended period of systemic instability characterized by channel incision and subsequent widening as the stream attempts to regain a stable morphology (Schumm et al., 1984; Brooks, 1998; Darby and Simon, 1999). These long-term processes can generate large amounts of sediment due to bed and bank erosion, result in highly unstable stream habitat, and increase the vulnerability of the stream to changes in watershed hydrology.

No information is available on past physical changes in Stoney Creek during the period of channelization and subsequent channel adjustment. In the upper watershed, where channelization occurred many decades ago, most reaches have regained a stable form, though they have not necessarily returned to their previous morphology. Active morphological adjustment is ongoing in the lower portion of the study area, likely due to more recent channel modification and to the hydrologic alterations resulting from urban development.

6.2 Future Changes

Streams in the upper study area (above New Hope Road) appear to be relatively stable and able to effectively dissipate stormflows by spreading into adjacent swamp and floodplain areas. These streams are likely to remain stable as long as land use is unchanged and riparian areas remain intact. If increased development occurs in the upper watershed without effective stormwater controls, destabilization of these streams is likely. This process would also increase stormwater volume and velocity into the lower watershed.

Channels in the lower watershed are not grossly unstable, but the stream is in transition. As straightened and channelized streams attempt to reestablish stable channel form, they generally regain at least some of their former sinuosity. Bank erosion inevitably occurs as part of this process. This adjustment is currently taking place in the lower half of Stoney Creek (below Wayne Memorial Drive). In addition, Stoney Creek is responding to the altered watershed hydrology brought about by past and ongoing development. The hydrologic changes caused by increases in the extent of impervious surfaces and resulting stormwater inputs generally lead to channel enlargement and prolonged stream instability. Areas in which the banks are already relatively unstable, such as those between US 70 Bypass and Elm Street, would be particularly vulnerable to these impacts.

Given the sandy substrate and the lack of grade control, further incision is a distinct possibility in this stream. If this occurs, the resulting increase in bank heights is likely to foster further bank instability, channel widening, and increased sediment loads. This would prolong the adjustment process in Stoney Creek and negatively impact aquatic organisms by eliminating bank habitat and washing away organic material. Additional development will further exacerbate the situation if stormwater impacts are not effectively managed.

Pollutant inputs from the upper study area likely undergo significant processing in the swamp and marsh areas adjacent to many streams in this portion of the watershed. These wetland areas serve an important role in protecting downstream water quality. Alteration of these wetland areas by future development (whether direct modification or indirect alteration such as changes to hydrologic loading) is likely to have negative downstream water quality impacts.

Section 7
Analysis and Conclusions:
Causes and Sources of Impairment

Stoney Creek is considered impaired below East Ash Street. This section analyzes the likely causes of this impairment, drawing upon the information presented earlier in this report. The sources or origin of these key stressors are also discussed.

7.1 Analyzing Causes of Impairment

The following analysis summarizes and evaluates the available information related to candidate causes of impairment in order to determine whether that information provides evidence that each particular stressor plays a substantial role in causing observed biological impacts. A strength of evidence approach is used to assess the evidence for or against each stressor and draw conclusions regarding the most likely causes of impairment. Causes of impairment may be single or multiple. All stressors present may not be significant contributors to impairment. [See the Background Note "Identifying Causes of Impairment", presented in Section 1, for additional discussion.]

7.1.1 A Framework for Causal Evaluation—the Strength of Evidence Approach

A ‘strength of evidence’ or ‘lines of evidence’ approach involves the logical evaluation of all available types (lines) of evidence to assess the strengths and weaknesses of that evidence in order to determine which of the options being assessed has the highest degree of support (USEPA, 1998; USEPA, 2000). The term ‘weight of evidence’ is sometimes used to describe this approach (Burton and Pitt, 2001), though this terminology has gone out of favor among many in the field because it can be interpreted as requiring a mathematical weighting of evidence.

This section considers all lines of evidence developed during the course of the study using a logical process that incorporates existing scientific knowledge and best professional judgment in order to consider the strengths and limitations of each source of information. Lines of evidence considered include benthic macroinvertebrate community data, habitat and riparian area assessment, chemistry and toxicity data, and information on watershed history, current watershed activities and land uses and pollutant sources. The ecoepidemiological approach described by Fox (1991) and USEPA (2000) provides a useful set of concepts to help structure the review of evidence. The endpoint of this process is a decision regarding the most probable causes of the observed biological impairment and identification of those stressors that appear to be most important. Stressors are categorized as follows:

- **Primary cause of impairment.** A stressor having an impact sufficient to cause biological impairment. If multiple stressors are individually capable of causing impairment, the primary cause is the one that is most critical or limiting. Impairment is likely to continue if the stressor is not addressed. All streams will not have a primary cause of impairment. In some cases, a stream may have more than one primary cause of impairment where several

stressors are individually capable of causing impairment but no single stressor can be clearly identified as most important.

- **Secondary cause of impairment.** A stressor that is having an impact sufficient to cause biological impairment but that is not the most critical or limiting cause. Impairment is likely to continue if the stressor is not addressed.
- **Cumulative cause of impairment.** A stressor that is not sufficient to cause impairment acting singly, but that is one of several stressors that cumulatively cause impairment. A primary cause of impairment generally will not exist. Impairment is likely to continue if the various cumulative stressors are not addressed. Impairment may potentially be addressed by mitigating some but not all of the cumulative stressors. Since this cannot be determined in advance, addressing each of the stressors is recommended initially. The actual extent to which each cause should be mitigated must be determined in the course of an adaptive management process.
- **Contributing stressor**. A stressor that contributes to biological degradation and may exacerbate impairment but is not itself a cause of impairment. Mitigating contributing stressors is not necessary to address impairment, but should result in further improvements in aquatic communities if accomplished in conjunction with addressing causes of impairment.
- **Potential cause or contributor**. A stressor that has been documented to be present or is likely to be present, but for which existing information is inadequate to characterize its potential contribution to impairment.
- **Unlikely cause or contributor.** A stressor that is likely not present at a level sufficient to make a notable contribution to impairment. Such stressors are likely to impact stream biota in some fashion but are not important enough to be considered causes of or contributors to impairment.

7.1.2 Candidate Stressors

As outlined in Section 3, the primary candidate causes of impairment evaluated were:

- habitat degradation--lack of microhabitat, sedimentation;
- toxicity due to nonpoint source impacts; and
- low dissolved oxygen (DO) due to swamp drainage and organic/nutrient enrichment.

Stormflow scour was added as a potential cause of impairment during the course of the study.

7.1.3 Review of Evidence

Benthic communities in Stoney Creek are impaired below East Ash Street. The Wayne Memorial Drive site did not receive a formal rating due to its narrow width (3 meters). Impairment has been evident at Slocumb Street since the site was first sampled in 1995 (Section 4). Suitable benthic sampling locations could not be identified above Wayne Memorial Drive, so the status of upstream biological communities could not be directly assessed.

a. Habitat degradation--lack of microhabitat and sedimentation

Since initial reconnaissance indicated some locations where habitat was noticeably degraded, the contribution of habitat degradation to biological impairment was further evaluated. Relevant

lines of evidence include benthic macroinvertebrate community data, habitat and geomorphic evaluation, and watershed history and characteristics.

The substrate was largely sand at all locations, as would be expected for a coastal plain stream. Habitat was extremely poor (overall score of 24 out of 100) at the most upstream site (Wayne Memorial Drive), where the negative impacts of channelization were evident (Section 4). In-stream habitat was lacking at this location, uniform channel conditions provided little diversity in depth or velocity, and riparian vegetation was poor. Habitat improved substantially downstream, where it was clearly adequate to support a more diverse benthic community than currently exists, especially toward the end of the study area near Slocumb Street. Downstream areas had more intact riparian areas, more varied depths and velocities, and more adequate supplies of large woody debris and other organic microhabitat.

Stream surveys and habitat assessments conducted in conjunction with biological sampling indicated that excessive in-channel sediment accumulation occurred intermittently in some portions of the mainstem, most notably between US 70 Bypass and East Ash Street. Variable amounts of bank erosion are also evident, with the worst conditions between Royall Avenue and Jefferson Quail Park. Even in these areas, however, overall in-stream habitat, though somewhat degraded, was probably adequate.

Benthos were impaired throughout the portion of the watershed studied, despite wide variability in reach scale habitat. This implies that factors other than or in addition to habitat condition are likely impacting the benthic community. Sites on two comparison sites, the Slough and Button Branch, have habitat only slightly better than the lower Stoney Creek locations, yet support a much more diverse benthic community.

Synopsis of Habitat Degradation. Although areas of bank erosion are evident in the impaired section of Stoney Creek, and there are localized areas of accelerated sediment deposition, habitat is probably not a primary limiting factor for benthos in most reaches downstream of East Ash Street. While sedimentation contributes to habitat degradation to some degree, there is little evidence that sedimentation *per se* is severe enough to be considered a cause of impairment in this watershed. Based on the condition of channel bars and stream banks, it appears likely that Stoney Creek carries a substantial sediment load. For the most part, however, the creek appears to have the transport capacity to carry this load without resulting in widespread severe depositional problems. Habitat is much poorer in the Wayne Memorial Drive area, where the effects of channelization were obvious, and likely contributes to biological degradation.

b. Toxicity due to nonpoint source impacts

Toxicity was evaluated as a cause of impairment. The highly developed nature of the lower study area indicated the potential for a wide variety of toxicant sources, while significant agricultural activity in the upper study area is also a potential source of toxicants. Four lines of evidence are relevant: water chemistry data, in-stream bioassay data, watershed characteristics and benthic community data.

Macroinvertebrate richness throughout Stoney Creek was very low (Section 4). Some taxonomic indicators of toxicity (midge assemblage) were found at the Slocumb Street sampling location (Appendix A). Such indicators were lacking at other locations, although communities at all sites

were dominated by stress tolerant organisms, and low DO impacts at the uppermost benthic sampling site may mask potential toxic impacts at this location. Sufficient *Chironomus* were not collected to conduct midge deformity analyses for toxicity (Lenat, 1993). At the two downstream sample sites, habitat was adequate to support a more diverse benthic community than was present, implying that water quality factors are likely important.

Row crop agriculture is an important activity in the upper study area, comprising 37 percent of land cover above New Hope Road (Section 2). Soybeans (60 percent) and cotton (30 percent) account for most of the crop acreage. Developed areas comprise 60 percent of the lower study area (below New Hope Road), and include a mix of residential, commercial and industrial activity. These activities are potential sources of pesticides, metals, and other toxicants.

A toxicity bioassay indicated the presence of acute toxicity in Stoney Creek at US 70 Bypass during the only storm for which toxicity was evaluated. The cause of this toxicity could not be determined definitively, although the pesticide diazinon was detected in this sample at a concentration more than seven times higher than the Tier II criteria for acute exposures (Section 5). Several metals (including aluminum, cadmium, copper, lead, and zinc) exceeded the acute National Ambient Water Quality Criteria. The magnitude of the hazard quotients for metals and diazinon (see Section 5) indicates that these compounds have a strong potential to be the cause of the observed acute toxicity, although a bioassay failure did not occur at a downstream location that experienced similar metals concentrations during the same storm.

Grab samples and passive sampling devices detected numerous toxicants in the water column, many at relatively low concentrations. Seven current use pesticides (chlorpyrifos, alachlor, atrazine, deethylatrazine, diazinon, metolachlor, simazine) and several organochlorine pesticides no longer in current use were detected during the study (Section 5). Diazinon was well above benchmark levels on the one occasion that it was detected (see above). The concentration of atrazine in Howell Creek (11.2 μg/L) approached EPA's draft chronic criteria (12.35 μg/L) in one of two baseflow samples collected at that location, suggesting the potential for occasional toxic impacts; however, bioassays were not conducted with that sample. Concentrations of chlorpyrifos and several organochlorine pesticides were below ecological benchmark levels (Section 5). During one storm, benz[a]anthracene exceeded Tier II acute criteria at several stations, but bioassays did not indicate the presence of acute effects (mortality). Screening benchmarks were not available for the other analytes, but observed concentrations did not appear to exceed levels suggested by the literature as toxic (Section 5 and Appendix B). Aluminum commonly exceeded NAWQC throughout the watershed, and other metals exceeded NAWQC on occasion (Section 5). As discussed above, on one occasion the cumulative impacts of several metals has a substantial potential to be toxic. Only total metals concentrations were analyzed and bioavailability could not be evaluated analytically.

It is unlikely that the limited number of samples collected during the study captured the full variability in pollutant concentrations, and higher concentrations of pollutants may occur. The low levels of precipitation during the study period (Section 2) impeded storm sampling. In addition, it was not possible to completely characterize pesticides and their metabolites during the investigation. Of the 25 pesticides potentially used on crops in the watershed (Section 2), laboratory analysis was available during the study for only nine (Section 5). For some analytes (see Appendix B) screening values were lower than laboratory detection limits. Whether these analytes were present in concentrations likely to be toxic is thus unknown. Analysis was also not

available for most breakdown products. The presence of pesticide breakdown products in surface waters has not been widely studied and, in most cases, little is known regarding their toxicity (Larson et al., 1997). These chemicals can be present at high levels, however. One study conducted by the USGS found that herbicide breakdown products were commonly present in surface waters at concentrations an order of magnitude higher than the concentrations of parent compounds (Hamilton, 2002).

Toxic impacts, especially if caused by storm inputs, can be very episodic and difficult to identify. One cannot rule out toxicity due to the occurrence of spills or infrequent incidents that occurred between sampling events. Additionally, determining how laboratory toxicity bioassays apply to the in-stream context is sometimes not straightforward. While laboratory toxicity bioassays are useful in integrating the impacts of multiple pollutants (accounting for cumulative effects), laboratory conditions often will not reflect actual in-stream exposures (or other conditions) or account for the full range of biological responses (Burton and Pitt, 2001; Herricks, 2002). For example, stream organisms may experience multiple stresses over an extended period of time (such as repeated pulse exposures to various pollutants), a situation difficult to duplicate in laboratory bioassays. While difficult to assess, the long-term cumulative effects of frequent exposures is likely important (Burton and Pitt, 2001).

Synopsis of toxicity due to nonpoint source impacts. Data collected during this study support a conclusion that toxic conditions occur at least periodically in much of Stoney Creek. A toxicity bioassay failure occurred upstream at US 70 Bypass, and taxonomic indicators of toxicity were found downstream at Slocumb Street, where in-stream habitat is good. The most important toxicants cannot be identified definitively and may be variable, although diazinon and several metals appear to be the most likely causes of toxicity on one occasion, and high levels of benz[a]anthracene were also documented.

c. Low dissolved oxygen/enrichment

An initial review of DWQ benthic macroinvertebrate data revealed that benthic community assemblages were indicative of low DO conditions. Primary watershed land uses (including extensive row crop production and developed areas) also suggested the potential for organic and nutrient enrichment. Relevant lines of evidence are benthic community data and water quality monitoring data.

Benthic community indicator assemblages point to impacts from low dissolved oxygen near Wayne Memorial Drive (Section 4 and Appendix A). Low flow/intermittent stream indicators were common at this uppermost benthic sampling location, became less prevalent at Ash Street, and declined further downstream at Slocumb Street. Taxa specifically indicative of enrichment were not found at any of the sites.

Swamp-like conditions with little visible flow predominate in the upper portion of the watershed, especially at and above New Hope Road. Low lying swamplands with bordering bottomland forests are common. Given the high levels of macrophyte growth and algal activity observed, and the low reaeration rates likely in these areas, low DO levels would not be unexpected. DO concentrations low enough to stress aquatic biota can occur naturally in unimpacted coastal plain streams (Caldwell, 1992; Kuenzler et al., 1977), due in part to the swampy, low gradient nature of these systems.

Monitoring of dissolved oxygen levels in Stoney Creek provided evidence of low concentrations at the most upstream sites (Stoney Creek and Reedy Branch at New Hope Road, Howell Creek at Patetown Road). Concentrations below 3 mg/L were observed at a number of sites in the upper watershed, and a concentration below 1 mg/l was recorded in Stoney Creek at New Hope Road (Section 5). Consistent with the benthic community data, observed DO concentrations increased at the more downstream locations. Though monitoring was limited, DO levels in The Slough, a comparison stream with more diverse benthic and fish populations, appeared to be higher than in upper Stoney Creek and comparable to concentrations in lower Stoney Creek.

Nitrogen and phosphorus levels were clearly elevated in the watershed (Section 5), although the biological response of streams to inorganic and organic nutrient loading is highly variable. It is difficult to use in-stream nutrient concentrations alone to determine whether nutrients are a cause of benthic impairment.

Conditions observed during the study were probably influenced to some extent by the ongoing drought, but cannot be attributed primarily to drought conditions (see Section 7.3).

Synopsis of low dissolved oxygen/enrichment. It can be difficult to differentiate between the impacts of organic and inorganic nutrient enrichment due to human activity, the potential contribution of naturally low DO levels, and the influence of the drought that occurred during 2001 and the first half of 2002, when most field work for the study was conducted. Low DO was a significant stressor in the upper half of Stoney Creek, including the uppermost benthic community station (Wayne Memorial Drive). Low DO at this site is likely due to the low DO waters draining from upstream swamps. To some extent this probably reflects natural conditions for these waters. Low DO stress declines substantially in the lower study area where Stoney Creek is free-flowing. Drought conditions likely exacerbated the situation during the study. However, given the high nutrient levels and other factors noted above, it seems unlikely that observed dissolved oxygen concentrations and biological impacts are due primarily to drought. Taxonomic nutrient enrichment indicators were not found among the benthos, but high nutrient levels probably exacerbate natural stresses.

d. Stormflow scour

Scour (excessive removal of organisms and microhabitat during storms) was considered a potential cause of impairment in Stoney Creek due to the highly developed nature of the lower watershed. Dislodging of organisms may occur with increased frequency and severity in urban watersheds in which hydrology has been extensively modified. In addition to its direct impact on biota, scour can also result in the loss of habitat such as leaf packs and twigs.

Given the level of impervious cover in the lower study area (29 percent), some impacts from scour would not be unexpected in downstream reaches of Stoney Creek. Evidence of such impacts was not readily apparent, however. Bank erosion was less extensive in lower reaches of the stream (e.g., near Slocumb Street) than further upstream, and organic habitat, often flushed from streams subject to high degree of scour, was abundant. Scour impacts in this system may be limited by the fact that much of the lower mainstem is not substantially incised, and the stream has ready access to a broad floodplain during storms.

It is also possible that decreased storm frequency due to drought conditions contributed to the retention of higher levels of organic material in lower Stoney Creek than would normally be present. While the smaller tributaries draining developed areas of Goldsboro were not evaluated in detail, scour and resulting habitat degradation were evident at a number of sites observed during reconnaissance and assessment activities.

7.1.4 Conclusion

Toxicity is considered a primary cause of the impaired conditions below East Ash Street. Habitat degradation, low DO, and scour are additional stressors that also contribute to biological degradation. Habitat degradation in Stoney Creek is most severe further upstream in the Wayne Memorial Drive area, and in some locations between Wayne Memorial Drive and East Ash Street. Those sections of Stoney Creek could not be given a formal bioclassification. Impairment in lower Stoney Creek is likely also impacted by a lack of benthic colonization sources due to low DO stress in the headwaters, and the degraded nature of many urban tributaries (see Section 7.3).

7.2 Sources of Impairment

Toxicants. The particular toxicants of primary importance have not been clearly identified, though it is likely that a variety of toxicants impact the stream at various times and that the cumulative impact of these contaminants is important. Potentially important sources exist throughout the watershed.

Existing water quality data point to the urban lower half of the watershed as the most important source of toxicants. Diazinon was measured at likely toxic levels on one occasion. This pesticide is widely used for insect control in turf applications, and its presence was most likely from non-agricultural use. Diazinon is among the pesticides frequently used by homeowners and found with increasing frequency in urban and suburban streams in North Carolina (Oblinger and Treece, 1996; Bales et al., 1999) and throughout the nation (Schueler, 1995; Hoffman et al., 2000). High levels of diazinon and metals, as well as an acute bioassay failure, were documented in Stoney Creek at US 70 Bypass. This is the most upstream site at which toxicity was evaluated, and current use pesticides were detected most frequently at this location. While substantial cropland lies upstream of this site, the drainage also includes significant development, notably commercial and institutional (e.g., Wayne County Memorial Hospital) development along Wayne Memorial Drive, and industrial activity west of Howell Creek along US 117.

The lower half of the watershed (below US 70 Bypass) contains diverse sources of many toxicants. The area west of Stoney Creek is primarily residential, with some pockets of commercial activity. The area east of Stoney Creek is more mixed, containing extensive commercial development (especially in the Berkeley Boulevard-Royall Avenue area) and SJAFB in addition to residential areas. Staff observations of pulses of discolored or odoriferous streamflows in urban tributaries during baseflow periods (Section 6) indicates the high potential for pollutant inputs from these areas. Occasional jet fuel spills at SJAFB, including one in November 2002 (Section 2) indicate the potential for this facility to impact the lower portion of the watershed.

The study did not document toxicity that was clearly of agricultural origin, although atrazine approached levels of concern on one occasion. The extent of sampling was limited, especially during storms, and it was not possible to fully characterize agricultural pesticides during the study.

There are many pathways by which pesticides and other pollutants may potentially reach stream channels (National Research Council, 1993). Data collected during this study are not sufficient to evaluate which pathways are most important in the Stoney Creek drainage.

Habitat degradation. Habitat degradation in Stoney Creek stems primarily from hydromodification and the removal of riparian vegetation. EPA defines hydromodification as the alteration of the hydrologic characteristics of surface waters resulting in degradation of resource conditions (USEPA, 1997). Two types of hydromodification contribute to habitat degradation in the study watershed: 1) channelization (alteration of channel morphology, dredging); and 2) increased stormflows due to the increase in impervious surfaces associated with development. While channelization has historically occurred in much of the study area, the impacts are seen most acutely in the Wayne Memorial Drive area. Increased stormflows contribute to habitat degradation in the highly developed lower study area, most notably in tributaries. Woody riparian vegetation is lacking or highly modified along much of Stoney Creek, from above Wayne Memorial Drive to downstream of Elm Street. Non-native understory species are often prevalent, providing limited bank protection.

Low dissolved oxygen/enrichment. Low DO conditions are probably due in large part to natural swamp drainage, although pollutant inputs from residential and agricultural activity may worsen the situation. Potential sources of biochemical oxygen demand (BOD) and nutrients are ubiquitous in developed areas, such as the lower half of the Stoney Creek watershed, and include leaking sewer lines, illegal connections to the storm drain system, fertilizer inputs from managed turf areas, atmospheric nitrogen sources and a variety of organic debris (both trash and natural material). Specific contributors of nutrient inputs were not evaluated, and it is likely that nutrient loading to Stoney Creek is the result of many smaller sources rather than large isolated inputs.

7.3 Other Issues of Concern

Drought. As discussed in Section 2, precipitation in the area was below normal during much of the study period, although this drought was generally less severe in the coastal plain than in the piedmont (see Southeast Regional Climate Center at http://water.dnr.state.sc.us/climate/sercc/). While it is likely that lower than normal streamflows had some impact on the conditions of the biological community observed during this study, it is not likely that the impoverished state of stream biota can be attributed entirely or primarily to drought. The Slough, a comparison stream sampled during this study, had a much more diverse benthic community despite experiencing similar drought conditions. Other biological sampling conducted by DWQ in eastern North Carolina over the past several years found numerous locations where the benthic community is considerably more diverse than in Stoney Creek (DWQ Biological Assessment Unit data). Low summer streamflows are not unusual in upper Stoney Creek, even at more normal precipitation levels. While below normal precipitation may negatively impact dissolved oxygen levels, it would also be expected to lessen storm-driven loading of nutrients and pesticides to the channel system.

Recolonization sources. Limited recolonization potential from within the watershed is a concern. Downstream drift of benthic organisms is an important mechanism for the maintenance of benthic macroinvertebrate populations, allowing for more rapid recovery from disturbance than other mechanisms such as aerial recolonization. The lack of sources of benthic colonization due to the nature of upstream swamp communities, and the highly impacted nature of urban tributaries thus contributes to biological degradation in lower Stoney Creek by altering the balance between disturbance and recovery (see the Background Note "The Stress-Recovery Cycle").

Thermal impacts. This study did not investigate the potential thermal impacts of watershed development on stream organisms. Stream biota can be subject to stress from the increased heating characteristic of the urban environment (warmer ambient water temperatures due to a generally warmer landscape), or to rapid increases in temperature (especially during summer storms) as rainfall hitting hot paved surfaces is heated and rapidly transported to streams. Discharges from shallow wet ponds can also contribute water with elevated temperatures, if there is sufficient time for heating before discharge (Horner et al., 1994; Burton and Pitt, 2001). It is likely that these factors serve as an additional stressor to aquatic organisms in urban watersheds in North Carolina, but the importance of thermal impacts was not specifically evaluated in Stoney Creek.

Broader impacts. The sediment, nutrients and toxicants carried by Stoney Creek may have negative resource impacts after they leave the study area. These materials are transported to the Neuse River. Though at under 30 square miles the Stoney Creek watershed constitutes only a small portion of the Neuse drainage, nutrient inputs from this and other small watersheds cumulatively impact the river.

☞ Background Note: The Stress-Recovery Cycle

Even in relatively pristine streams, aquatic organisms are exposed to periods of stress. Natural stresses due to high flows during storms, low flows during hot dry summer periods or episodic large sediment inputs (e.g., from slope failures in mountain areas or breaching of beaver dams) can have significant impacts on stream communities. Although aquatic communities in high quality streams may be impacted by such disturbances, and some species may be temporarily lost from particular sites, populations are able to reestablish themselves--often very quickly--by recolonization from less impacted areas or refugia (see Yount and Niemi, 1990; Niemi et al., 1990). This process can involve recolonization from backwater areas, interstitial zones (spaces between the cobble and gravel substrate), the hyporheic zone (underground habitats just below the stream bed surface layer) or other available microhabitats. Repopulation from headwaters or tributary streams not impacted by the disturbance can also occur. For insects aerial recolonization is important as well.

Without robust mechanisms of recovery, even streams subjected to relatively modest levels of disturbance would be unable to support the diversity of aquatic organisms that they often do (Sedell et al., 1990; Frissell, 1997). This balance between local elimination followed by repopulation is critical to the persistence of fish, macroinvertebrates and other organisms in aquatic ecosystems, and is part of what we mean when we say that these organisms are "adapted" to their environment.

It is now commonly recognized that as watersheds experience increased human activity, stream biota are subjected to higher levels of stress. This can include both an increased frequency, duration or intensity of 'natural' types of disturbance, such as high flows, as well as completely new stresses, such as exposure to chlorinated organic chemicals. We less often realize, however, that many of these same activities often serve to inhibit those mechanisms that allow streams to recover from disturbances--in particular movement and recolonization (Frissell, 1997). For example, as watersheds develop:

- channel margin and backwater refugia may be eliminated as bank erosion or direct channel modification (channelization) make channel conditions more uniform and habitat less diverse;
- edge habitat, such as root mats, may be unavailable to biota due to lowered baseflows;
- access to interstitial and hyporheic areas may be limited by sediment deposition;
- impoundments may limit or eliminate drift of organisms from upstream;
- small headwater and tributary streams may be eliminated (culverted or replaced with storm drain systems);
- remaining headwater and tributary streams may be highly degraded (e.g., via channelization, removal of riparian vegetation, incision and widening due to increased stormflows, or decreased baseflows);
- aerial recolonization of macroinvertebrates may be diminished by the concomitant or subsequent degradation of streams in adjacent watersheds; and
- fish migration is often limited by culverts or other barriers.

As human activity intensifies, aquatic organisms are thus subjected to more frequent and more intense periods of stress, while at the same time their ability to recover from these stresses is severely compromised. It is the interaction between these two processes that results in the failure of many streams to support an acceptable population of fish or macroinvertebrates.

Efforts to restore better functioning aquatic communities in degraded streams must consider strategies to both reduce the stresses affecting stream biota and to protect and restore potential refugia and other sources of colonizing organisms. Under some conditions, the lack of adequate recolonization sources may delay or impede recovery. Protecting existing refugia and those relatively healthy areas that remain in impacted watersheds should be an important component of watershed restoration efforts (McGurrin and Forsgren, 1997; Frissell, 1997).

Section 8
Improving Stream Integrity in Stoney Creek: Recommended Strategies

As discussed in the previous section, Stoney Creek is impaired by the impacts of toxicity and localized habitat degradation. Low dissolved oxygen and stormflow scour are also contributing factors. Future development will also pose a threat to the Stoney Creek watershed due to the potential for additional pollutant inputs and modification of watershed hydrology that will yield increased stormflows. This section discusses how these problems can be addressed. A summary of recommendations is included at the end of the section.

8.1 Addressing Current Causes of Impairment

The objective of efforts to improve stream integrity is to restore water chemistry and habitat conditions to support a more diverse and functional biological community in Stoney Creek. Because of the widespread nature of biological degradation and the intensity of urban and agricultural activity in the watershed, bringing about substantial water quality improvement will be a challenge. Yet the watershed has not been so highly modified as to preclude improvements in stream integrity. A return to the relatively unimpacted conditions is unlikely, but Stoney Creek can potentially support a healthier biological community than it does today. Additionally, the quantities of nutrients and other pollutants transported to the Neuse River can be reduced.

As discussed in Section 7, while the key factors causing impairment in Stoney Creek have been identified, their interrelationship remains unclear. Additionally, there are inherent uncertainties regarding how individual BMPs cumulatively impact receiving water chemistry, geomorphology, and habitat (Shields et al., 1999; Urbonas, 2002), and in how aquatic organisms will respond to improved conditions. For these reasons, the intensity of management action necessary to bring about a particular degree of biological improvement cannot be established in advance. This section describes the types of actions needed to improve biological conditions in Stoney Creek, but the mix of activities that will be necessary – and the extent of improvement that will be attainable – will only become apparent over time as an adaptive management approach is implemented (see Section 8.3).

8.1.1 Toxic Impacts

While impacts from agricultural pesticides cannot be ruled out, available data indicate that inputs of toxicants from the developed areas of the watershed are the most likely cause of toxic impacts in this watershed. Long-term repeated exposures are probably important, and the most critical toxicants may vary with time, associated with specific events or seasonal activities. Source areas are found throughout the developed portion of the watershed.

Two broad approaches can be used to address toxic impacts: structural BMPs to remove pollutants from stormwater and primarily nonstructural source reduction methods to prevent pollution inputs (NVPDC, 1996; Heaney et al., 1999; USEPA, 2002). These approaches are not mutually exclusive and a multifaceted strategy drawing on both approaches will be more

effective than a more narrowly focused effort. A general conceptual strategy to address toxicity in the lower half of Stoney Creek is outlined below. This should be viewed only as an initial framework for planning and implementing toxicity reduction efforts. Ongoing planning and strategy reassessment will be necessary to refine the scope and nature of management efforts.

1. Development and implementation of a broad set of source reduction activities. Since removing pollutants from stormwater can be difficult and expensive, pollution prevention activities are crucial. Among activities that should be considered for inclusion in a pollution prevention efforts are the following:

- Reducing nonstorm inputs of toxicants by:
    a) identification and elimination of illicit connections (actions required under the Neuse Stormwater Rule and the new Phase II stormwater program);
    b) review of existing information on groundwater contamination and implementation of appropriate remediation measures if warranted;
    c) verification that industrial and commercial floor drains empty to the sanitary sewer system or appropriate treatment facilities; and
    d) education of industrial and commercial operation and maintenance staff regarding proper use of storm drains and the implications of dumping.
- Reducing pollutants available for washoff during storms by:
    a) education of homeowners, grounds staff, and commercial applicators regarding appropriate pesticide use; and
    b) outreach and technical assistance to industrial and commercial facilities regarding materials storage practices; spill prevention procedures; and spill control and cleanup procedures.
- Managing water to reduce storm runoff by:
    a) routing roof drains and pavement to available pervious areas where feasible (may require some regrading); and
    b) proper maintenance of existing BMPs.

2. Implementation of stormwater treatment BMPs at appropriate locations, aimed primarily at pollutant removal. Results of additional monitoring (see below) could help to target these BMPs, although some likely "hot spots" (areas of intense activity or high risk) could be identified without water quality sampling. Proprietary treatment systems can be considered where adequate space is not available for conventional stormwater BMPs.

Conventional structural and nonstructural retrofit practices to remove pollutants and reduce hydrologic impacts have been discussed widely in the literature (e.g., ASCE, 2001; Horner et al., 1994; USEPA, 2002) and detailed in state BMP manuals (e.g., NCDWQ, 1999; Maryland Department of the Environment, 2000). Some of these include:

- bioretention;
- infiltration structures (porous pavement, infiltration trenches and basins);
- vegetative practices to promote infiltration (swales, filter strips);
- reducing hydrologic connectivity (e.g., redirecting of downspouts to pervious areas);
- education to promote hydrologic awareness;
- detention ponds;
- retention ponds; and

- stormwater wetlands.

Determining which combination of practices will be most feasible and effective for a particular catchment depends on numerous site and jurisdictional issues, including: the size of potential BMP locations; treatment volume needed considering catchment size and imperviousness; soils; location of existing infrastructure; and other goals (e.g., flood control, pollutant removal). Considerations in the identification of retrofit sites are discussed by Schueler et al. (1991) and Claytor (1999). Stormwater wetlands deserve particular consideration in this watershed, since it likely contained substantially more wetland area than is currently present, especially within the Goldsboro limits.

3. Development of a stormwater and dry weather sampling strategy for the lower watershed. A wide range of conventional BMPs can be used to remove pollutants from stormwater runoff (see ASCE, 2001). For example, constructed wetlands, vegetated swales, and various types of ponds can remove a substantial percentage of metals. Selection of particular BMPs can proceed more efficiently; however, if better information on specific target pollutants and source areas is available. Such information would also aid in the targeting of source reduction efforts. To address these needs, a monitoring strategy should be developed based upon further watershed reconnaissance.

The recommendations made above are applicable to Seymour Johnson Air Force Base (SJAFB) as well as to municipal areas of the watershed. By virtue of its size, activities, and extensive impervious areas (see Section 2), SJAFB has the potential to negatively impact Stoney Creek without careful attention to appropriate management. SJAFB should continue to seek to improve its water quality management practices and explore opportunities for innovative control strategies.

Development of a specific pollution prevention strategy is beyond the scope of this study. Some elements of a strategy could probably be implemented by enhancing or redirecting existing program activities. In other cases, new initiatives may be necessary. While state agencies such as DWQ and the Division of Pollution Prevention and Environmental Assistance (DPPEA) can play a role, planning and implementation of a strategy are likely to be more effective if carried out by local government, agencies and stakeholders.

Existing data provide no clear evidence of agricultural pesticides present at toxic levels, though atrazine is a potential concern. For a variety of reasons (Sections 5 and 7), however, the presence of pesticides and their metabolites in the surface waters of this watershed remains incompletely characterized, and impacts from these substances cannot be ruled out. Given the high level of row crops in the upper part of the watershed, pesticides must be considered a potential risk, although agricultural activity is likely to decline as development expands northward from Goldsboro. A review of current pesticide usage and application practices by appropriate agricultural agencies would serve to provide more information on potential risks and pathways. Relevant agencies include the NC Department of Agriculture and Consumer Services (NCDACS), the NC Division of Soil and Water Conservation, local Soil and Water Conservation Districts, the NC Cooperative Extension Service and the US Department of Agriculture Natural Resources Conservation Service.

8.1.2 Low Dissolved Oxygen

While the low DO conditions in the upper watershed are due in part to natural processes and the low reaeration rates in this swamp system, actions to reduce nutrient and biochemical oxygen demand (BOD) sources throughout the watershed will help to minimize these impacts and limit their effects downstream.

Nutrient and organic loading can be addressed in a variety of ways, including stormwater treatment. BMPs constructed to address other problems (see above) are likely to reduce nutrient and BOD inputs. BMPs targeted at these pollutants may be warranted at high loading areas identified during subsequent investigation. Organic and inorganic nutrient loading can also be reduced via established practices such as: the identification and elimination of illicit discharges; education of homeowners, commercial applicators, and others regarding proper fertilizer use; street sweeping; and catch basin clean-out practices.

Activities currently underway or planned by Goldsboro and Wayne County to reduce nutrient inputs to comply with the Neuse River basin stormwater rule could reduce nutrient levels significantly if effectively implemented. The identification and elimination of illicit connections is required under the Neuse Stormwater Rule and the Phase II stormwater program. The raising of manholes above flood level on the main sewer line along Stoney Creek, recently completed by Goldsboro, should help reduce waste inputs to the stream during storms. Some types of problems, e.g., replacing old sanitary sewer lines may take years to fully address. Periodic biological monitoring would also serve to document the degree of stress from low dissolved oxygen after streamflows return to normal and initial management actions have been taken to address sources.

Specific projects (e.g., stormwater retrofits to remove nutrients) resulting from efforts implemented under the Neuse rules or Phase II stormwater programs may be appropriate for CWMTF consideration.

Many measures under the Neuse agriculture rule have already been implemented in Wayne County. The goal for Wayne County was a 30 percent reduction in annual nitrogen loading from a 1991-1995 baseline level (as estimated by the Nitrogen Loss Evaluation Worksheet, or NLEW, a field-based procedure to estimate nitrogen loading from agricultural fields). As of 2001, agricultural nitrogen loading had been reduced by an estimated 25 percent from baseline levels. A variety of practices are used, of which nutrient management plans are most common. Many of these practices were being implemented during the period of the study, and any in-stream improvements resulting from these measures may not have been realized.

The extent of nutrient reduction that will be necessary to reduce stress to aquatic organisms in Stoney Creek is unknown. The creek should be monitored as implementation continues under the Neuse basin agriculture and stormwater rules to determine if additional actions are necessary. The LAC should examine agricultural practices in the Stoney Creek watershed to determine if additional opportunities exist to implement nutrient reduction measures.

8.1.3 Habitat Degradation

Habitat degradation in the study area is manifested in the lack of organic habitat, especially snags and large woody debris, and the lack of diversity in channel planform and cross-sectional dimensions. Problems are most evident upstream of East Ash Street, especially near Wayne Memorial Drive, but intermittent habitat degradation is evident in many downstream reaches as well.

Stream channel restoration could improve these conditions by reestablishing a stable channel dimension (cross-section), pattern (sinuosity and planform) and longitudinal profile (slope), and by reestablishing appropriate riparian vegetation. The specific restoration strategy selected would depend upon the stream corridor width available (belt width), among other factors (NCSU, 2002a and 2002b; Rosgen, 1997). Based on the recent experience of the North Carolina Wetlands Restoration Program (Haupt et al., 2002) and NCSU estimates (NCSU, 2002a and 2002b) of at least $200 per linear foot (about $1 million per mile) should be expected for the restoration of urban stream channels.

Aside from the area directly upstream of Wayne Memorial Drive, where channel diversity is largely lacking, it is not clear that channel restoration is necessary or cost-effective at this time. Though areas of excessive bank erosion exist, the stream is not grossly unstable. A more cost-effective approach would be to promote habitat improvement through other means and allow the stream to heal eroded areas over time.

Three important measures should be taken. First stormwater retrofits should be implemented to reduce erosive stormflows from tributary watersheds (see below) in order to reduce stress on stream banks. Secondly, woody riparian vegetation along Stoney Creek should be reestablished where it has been removed. This would help ensure an adequate supply of woody material to the stream and improve bank stability. Riparian zones along many tributaries in the developed portion of the watershed have poor riparian zones and unstable banks. Property owners should be encouraged to reestablish woody vegetation and avoid modification of streams. Third, riparian vegetation is often of poor quality, even in wooded areas due to dominance by non-native species. Non-native species should be replaced with native woody vegetation in order to promote bank stability and enhance nutrient removal. This could qualify for the program established to provide compensatory mitigation for riparian buffer impacts in the Neuse River basin. Major portions of the riparian area of Stoney Creek below US 70 Bypass are in public ownership, with Goldsboro's sewer right of way, the greenway and several city parks comprising much of the land on the west bank.

8.1.4 Stormflow Scour

Frequent periods of high-velocity stormflow can dislodge benthic organisms and contribute to habitat degradation by removing organic microhabitat and causing bank instability. Scour impacts are likely in the urban tributaries of Stoney Creek (e.g., Billy Branch and the tributary draining the densely developed Royall Avenue/Berkeley Boulevard area), though perhaps not in the mainstem itself. This will continue unless some of the hydrologic impacts of existing development, which largely occurred prior to any stormwater BMP requirements, can be abated.

Additional stormwater controls are necessary to partially restore watershed hydrology by reducing runoff volume and reducing the frequency and duration of erosive flows.

Stormwater retrofits are structural stormwater measures (best management practices or BMPs) for urban watersheds intended to lessen accelerated channel erosion, promote conditions for improved aquatic habitat and reduce pollutant loads (Claytor, 1999). A range of practices, including a variety of ponds and infiltration approaches, may be appropriate depending on specific local needs and conditions. Practices installed to reduce hydrologic impacts will also provide varying degrees of pollutant removal. The Mid-Neuse Nonpoint Source Team has already implemented several projects in the watershed (see Section 2).

DWQ encourages the consideration of a wide range of practices and approaches, with an emphasis on low impact development (LID) techniques. LID focuses on integrating stormwater management into site and building design, rather than relying primarily on the collection and storage of storm runoff (Prince George's County DEP, 2000). Ponds of various types are probably the practice most familiar to engineers. Detention alone does not reduce stormwater volume; however, though the rate and timing of discharge can be controlled. It is important to carefully examine infiltration practices, including both structures and 'behavioral' changes such as redirecting downspouts to pervious areas. While there are clearly limits to the usefulness of infiltration, based on soils, water table levels and other factors (Livingston, 2000) these practices are often underused. Design approaches to minimize runoff volume are also important tools (Caraco et al., 1998; Prince George's County DEP, 2000). Some retrofit methods may have negative side effects that must be carefully considered. For example, regional wet detention facilities, though they may remain a viable alternative in some situations, can disrupt recolonization, alter the food/energy source available to downstream biota and, depending upon design and operation, reduce or eliminate downstream baseflows (Maxted and Shaver, 1999; Schueler, 2000a).

What is feasible or cost-effective in the way of retrofitting a developed watershed like Stoney Creek is constrained by existing conditions. Conditions change, however, and a long-term commitment to partially restoring watershed hydrology will be necessary to create opportunities and take advantage of the available options.

1. Short-term. Over the next decade, local agencies can investigate retrofit possibilities and implement those that are feasible given current infrastructure and financial constraints.
2. Mid-term. Road realignment, sewer line and bridge replacement and other infrastructure projects will likely make feasible other retrofit opportunities over the next 10-20 years. Such projects can be pursued and the search for retrofit opportunities can be integrated into the capital improvement planning process.
3. Long-term. Over a more extended period, cost-effective restoration opportunities are likely as portions of the watershed are redeveloped incrementally (Ferguson et al., 1999). An ongoing awareness of retrofit needs and changes in development regulations may be necessary to help create and take advantage of these opportunities.

<u>Costs</u>. Stormwater retrofit costs are difficult to estimate until specific practices and locations have been selected. Unit costs vary greatly with the size of the area treated. Using data from the mid 1990s, Schueler (2000b) reported that typical costs for stormwater ponds were about $5,000 per impervious acre treated for projects covering 100 impervious acres but $10,000 per

impervious acre treated for projects treating 10 impervious acres. Treating a single acre costs an average of $25,000 or more.

Only gross estimates of total costs are possible. Claytor (1999) suggests that a minimum of 50 percent of a watershed be retrofitted. Thus, for example, a two square mile watershed that is 25 percent impervious has approximately 320 impervious acres (2 square miles, or 1280 acres, times an imperviousness of 25 percent). Assuming a typical cost of $10,000 per impervious acre, it would take approximately $1.6 million to retrofit 160 impervious acres. This approaches $1 million per square mile of total watershed area. This estimate should be used only as a general indication of the likely scale of effort that may be necessary, assuming a sufficient number of viable retrofit projects can be identified. Actual total costs may be higher or lower depending on many factors, including the types of BMPs used and the scale of each project. Some cost reduction may be possible if retrofits are planned and implemented in conjunction with anticipated capital improvements and infrastructure enhancements. The potential connection between watershed restoration and infrastructure issues has been increasingly recognized by local governments (e.g., City of Austin, 2001; Montgomery County DEP, 2001).

8.2 Addressing Future Threats

Much of the upper watershed is relatively undeveloped at the present time. Considerable development is likely in these areas over the next several decades. Without an effort to mitigate the hydrologic impacts of this development or improve sediment and erosion control practices for construction, additional stream degradation in the Stoney Creek watershed is likely. Addressing these future threats is essential, or improvements resulting from efforts to control current sources of impairment may be short-lived or may never materialize. Recently implemented regulations will help to assure that future development occurs in a less environmentally damaging fashion than recent growth.

8.2.1 Sediment from New Construction

Significant future sediment inputs would contribute to habitat degradation in Stoney Creek. Sediment inputs from construction activities can be substantial, particularly in the case of large projects, and existing practices often do not protect streams from sediment impacts.

Effective enforcement of sediment and erosion control regulations on the part of the Division of Land Resources will be essential to the prevention of additional sediment inputs from construction activities. While a complete evaluation of current sediment and erosion control practices is beyond the scope of this study, development of improved erosion and sediment control practices may be beneficial. The CWMTF could consider working cooperatively with regulatory agencies and willing developers to install and monitor innovative approaches that could supplement or serve as alternatives to current practices and requirements. The Neuse buffer regulations should also help prevent sediment inputs if they are properly enforced, though the regulations do not apply to ephemeral channels.

8.2.2 Hydromodification Due to Increased Stormflows

As new development occurs in the Stoney Creek watershed, it is likely that stormflows will increase with the expansion of associated impervious areas. Both peak discharges as well as the frequency and duration of high velocity flows can be expected to increase and to negatively affect channel stability. Existing conditions in a watershed can greatly affect a stream's vulnerability to these hydrologic changes (Bledsoe and Watson, 2001). As discussed previously, stream banks in portions of the lower watershed are in poor condition and the stream bed consists of unconsolidated material. Given these conditions, increased bank erosion and/or incision is likely if significant hydrologic change occurs in the watershed.

Stormwater management approaches targeted specifically at flood control may not address other concerns. Smaller, more frequent storms, especially those in the range of the 1.5-year recurrence interval, are the most critical for sediment transport processes and channel stability (Wolman and Miller, 1960; Federal Interagency Stream Restoration Working Group, 1998).

New development will be subject to a number of recently implemented regulatory efforts, including the buffer and stormwater rules now in force in the Neuse River basin. The buffer rule (see Section 2), which applies throughout the Stoney Creek watershed, requires a minimum 50-foot vegetated buffer on each side of all perennial and intermittent streams and the maintenance of diffuse flow for any stormwater routed into the buffer. The Neuse stormwater rule requires that nitrogen loading from new development be held to 3.6 pounds/acre/year, and that there be no net increase in peak flows leaving the site from predevelopment conditions for the 1-year 24-hour storm. The flow control provision applies only to new development with imperviousness of at least 15 percent. Goldsboro and Wayne County are also subject to the new Phase II stormwater requirements, which require control of the 1-year 24-hour storm for new development with imperviousness or 24 percent or more.

Given the current physical condition of Stoney Creek and its tributaries, it is unlikely that adherence to these requirements will be sufficient to prevent further degradation without additional proactive measures. Whether accomplished through the Neuse stormwater rules, Phase II requirements or voluntary local action, it is important that comprehensive practices for the management of post-construction runoff be implemented as soon as possible to avoid additional channel instability and avoid costly corrective actions in the future. A proactive approach to reduce the risks to Stoney Creek from future development impacts would include: promotion of development design approaches that minimize the generation of storm runoff; active promotion of infiltration practices; requiring post-construction stormwater control for all but the lowest density development (built-upon area of 10 percent or less); exploration of retrofit opportunities for existing developed areas; limited use of the allowed exemption to the Neuse stormwater rules for development activities which are projected to increase in peak flows by 10 percent or less. Both regulatory and voluntary incentive-based approaches should be explored. Whatever actions are taken, their effectiveness in preventing channel degradation should be monitored.

8.2.3 Riparian Area and Wetland Protection

The protection of riparian buffers is critical to limiting the hydrologic impacts of development and to the attenuation of pollutant inputs. Neuse buffer rules cover permanent and intermittent streams. However, ephemeral channels are also very important to the integrity of the channel system. Whether accomplished through incentives or regulatory measures, it is important to protect existing forested riparian buffers along all waterbodies, including ephemeral streams. Education of landowners regarding the benefits of riparian vegetation and discouraging removal of additional riparian vegetation would be useful both in newer development constructed under the Neuse buffer regulations and in older developments.

Existing swamps and other wetland areas in the upper portion of the watershed serve an important function in protecting downstream areas from hydrologic and pollutant inputs. As the upper watershed develops, it will be important to protect these areas from both direct modification (e.g., draining or channelization) and the indirect impacts of encroaching development.

8.3 A Framework for Improving and Protecting Stream Integrity

Watershed restoration of the type necessary to significantly improve Stoney Creek is clearly ambitious, but has become more common over the past decade. Local governments and watershed-based organizations have increasingly sought to plan and implement long-term restoration and management strategies that integrate channel, riparian and watershed measures to address stream issues in an integrated fashion. Restoration projects of this scale require an iterative process of 'adaptive management' (Reckhow, 1997; USEPA, 2001). Considering the scope of activities, logistical complexities and scientific uncertainties, it is not possible to anticipate all necessary actions in advance. An initial round of management actions must be planned and implemented, the results of those activities monitored over time, and the resulting information used as the basis for planning subsequent efforts. Additional measures should be implemented as appropriate. Improvement in stream condition is likely to be incremental.

An organizational framework for ongoing watershed management is essential to provide oversight over project implementation, to evaluate how current restoration and protection strategies are working, and to plan for the future. While state agencies must play an important role in this undertaking, planning is often more effectively initiated and managed at the local level. A coordinated planning effort involving local governments in the watershed, agricultural agencies, DWQ and a broad range of other stakeholders, will be critical if conditions in Stoney Creek are to be improved. This effort must include the development of a long-term vision for protecting and restoring the watershed, and the establishment of a framework to support the planning and project implementation necessary to move toward that vision. The work of the Mid-Neuse Nonpoint Source Team can be used as an important building block in this effort.

8.4 Summary of Watershed Strategies for Stoney Creek

The most important factors leading to impairment in the study area are systemic in nature. Addressing these problems will require actions that are similarly broad in scope. Mitigating the

potential impacts of future watershed development on watershed hydrology and pollutant loading is also critical, or improvements resulting from efforts to control current sources of impairment may be short lived.

The following actions are necessary to address current sources of impairment in Stoney Creek. The intent of these recommendations is to describe the types of actions necessary to improve conditions in the Stoney Creek watershed, not to specify particular administrative or institutional mechanisms for implementing remedial practices. Actions one through five are all important to the restoration of aquatic communities throughout the study area. Of these, actions one, three and four are considered most critical. Actions six through eight are important in order to protect streams in the watershed from the impacts of new development.

1. **A strategy to address toxic inputs from the urban portions of the watershed should be developed and implemented, including a variety of source reduction and stormwater treatment methods**. These measures should be applicable both to municipal areas and to the Seymour Johnson Air Force Base. As an initial framework for planning toxicity reduction efforts, the following general approach is proposed:
   a) Development and implementation of a broad set of source reduction activities focused on: reducing nonstorm inputs of toxicants; reducing pollutants available for washoff during storms; and managing water to reduce storm runoff.
   b) Implementation of stormwater treatment BMPs, aimed primarily at pollutant removal, at appropriate locations.
   c) Development of a stormwater and dry weather sampling strategy to facilitate the targeting of pollutant removal and source reduction practices.
2. **Given the extensive crop acreage in the upper watershed, agricultural pesticides must be considered a potential risk that merits further evaluation**, although existing data provide no clear evidence of agricultural pesticide impacts. A review of current pesticide usage and application practices by appropriate agricultural agencies would serve to provide more information on potential risks and pathways. Relevant agencies include the NC Department of Agriculture and Consumer Services (NCDACS), the NC Division of Soil and Water Conservation, local Soil and Water Conservation Districts, the NC Cooperative Extension Service and the US Department of Agriculture Natural Resources Conservation Service.
3. **Native woody riparian vegetation along Stoney Creek and its tributaries should be reestablished where it has been removed to provide an adequate supply of woody material to the stream and improve bank stability**. Where riparian vegetation is of poor quality due to dominance by non-native species, invasive species should be replaced with native riparian vegetation. Much of the land along the lower half of Stoney Creek is already in public ownership.
4. **To reduce stormflow scour and bank erosion, especially in tributaries draining developed areas, feasible and cost-effective stormwater retrofit projects should be implemented in the urban portions of the watershed to mitigate the hydrologic effects of development** (increased stormwater volumes and increased frequency and duration of erosive and scouring flows). Over the short-term, currently feasible retrofit projects should be identified and implemented in both the municipal areas of the watershed and in SJAFB. In the longer term, additional retrofit opportunities should be sought out in conjunction with infrastructure improvements and redevelopment of existing developed areas. Projects

already implemented through the efforts of the Mid-Neuse Nonpoint Source Team provide examples of retrofit activities.

5. **While low DO levels in the watershed are likely due primarily to natural swamp drainage, nutrient reduction efforts should be implemented so that human inputs do not significantly worsen the situation.** Nutrient reduction activities currently underway as part of the Neuse River basin efforts could well have an impact, and actions recommended above (e.g., retrofit BMPs to address toxicity and stormwater quantity) are likely to reduce organic and nutrient loading to some extent. Additional efforts may be necessary, however. Activities recommended to address organic loading include the identification and elimination of illicit discharges; education of homeowners, commercial applicators, and others regarding proper fertilizer use; street sweeping; catch basin clean-out practices; and the installation of additional BMPs targeting removal of biochemical oxygen demand and nutrients at appropriate sites.
6. Prevention of further channel erosion and habitat degradation will require effective post-construction stormwater management for new development in the study area, whether accomplished through the Neuse stormwater rules, Phase II requirements or voluntary local action. A proactive approach to reduce the risks to Stoney Creek from future development impacts would include: promotion of development design approaches that minimize the generation of storm runoff; active promotion of infiltration practices; requiring post-construction stormwater control for all but the lowest density development; exploration of retrofit opportunities for existing developed areas; limited use of the allowed exemption to the Neuse stormwater rules for development activities which are projected to increase peak flows by 10 percent or less.
7. Effective enforcement of sediment and erosion control regulations on the part of the NC Division of Land Resources will be essential to prevent additional sediment inputs from construction activities. Development of improved erosion and sediment control practices may be beneficial.
8. It is important to protect existing wetlands and forested riparian buffers along all waterbodies, including ephemeral streams. The protection of these areas is critical to limiting the hydrologic impacts of development and to the attenuation of pollutant inputs. Education of landowners regarding the functions of riparian areas and discouraging removal of additional riparian vegetation would be useful both in newer development constructed under the Neuse buffer regulations and in older developments. Existing swamps and other wetland areas in the upper portion of the watershed should be protected from both direct modification and the indirect impacts of encroaching development.

Section 9
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