Assessment Report: Biological Impairment in the Corpening Creek Watershed

Catawba River Basin
McDowell County

February 2004

North Carolina Department of Environment and Natural Resources
Division of Water Quality
Planning Branch

Collaborative Assessment of Watersheds and Streams (CAWS) Project
Funded by EPA 104(b)(3) Grant #CP984724-99

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APPENDICES

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Executive Summary

Introduction

This report presents the results of the Corpening Creek water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) and funded by the United States Environmental Protection Agency through its 104(b)(3) grant program. This project has been named 'Collaborative Assessment for Watersheds and Streams' (CAWS). It is modeled after DWQ's Watershed Assessment and Restoration Program (WARP); specifically, it follows the general approach laid out in the WARP projects, and borrows extensively from the WARP reports (NCDWQ, 2003). This report, however, is uniquely composed of observations of, and data from, the Corpening Creek watershed.

CAWS has sought to bring together numerous units from within DWQ to address biological impairments that appear on North Carolina's 303(d) list, a catalog of impaired streams. Biological impairments, as identified by assessment of the aquatic insect communities, have the highest number of listings of any impairment type on the 303(d) list. Through this project, we made an effort to address the causes of such impairments. The development of this report was possible with contributions from many units within DWQ, including: the Biological Assessment Unit (benthic macroinvertebrate and fish community surveys); Intensive Survey Unit (initial watershed reconnaissance); Aquatic Toxicology Unit (bioassays); Laboratory Section (chemical analyses of water and sediment samples); and, the Special Watersheds Project Unit (developed template for this project through the Watershed Assessment and Restoration Project, WARP).

Corpening Creek is considered impaired by DWQ because it is unable to support a balanced and diverse (i.e. not impaired) community of aquatic organisms. This means that the stream does not support its designated uses of maintenance of biological integrity and propagation of aquatic life. The goal of the assessment was to provide the foundation for future water quality restoration activities in the Corpening Creek watershed by: 1) identifying the most likely causes of the 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

Corpening Creek is a tributary of North Muddy Creek, which eventually drains to the Catawba River, and is located wholly within McDowell County in DWQ subbasin 03-08-30. Corpening Creek's watershed covers 9.15 square miles. Its headwaters include the southeastern section of the town of Marion, while its lower reaches drain the western portion of Jacktown. Streams in the watershed are designated as 'class C waters', which signifies that, among other uses, the waters shall be suitable for aquatic life propagation and maintenance of biological integrity. Sources of water pollution which preclude (this) use on either a short-term or long-term basis shall be considered to be violating a water quality standard (NCDENR, 2003).

There is one permitted point source of domestic and industrial wastewater, Marion's wastewater treatment plant (NC0031879), in the study area. Approximately 15 percent of the study area has an impervious surface, through which water does not readily infiltrate. Development is fairly extensive in the upper two-thirds of the watershed, including downtown Marion and commercial areas off of US Highway 221/NC Highway 226 (US-221/NC-226).

North Carolina's 303(d) list designates Corpening Creek's entire length as impaired. The study area stops at SR1794 (Clinch Field Road), one mile from the stream's confluence with North Muddy Creek. DWQ chose this site to be consistent with prior benthic macroinvertebrate (aquatic insects) monitoring, the basis of the impairment listing. Impairment has been apparent since 1985, when DWQ conducted its first survey of benthic macroinvertebrates. Instream habitat quality is variable, though DWQ frequently observed sedimentation in the pool sections.

Approach

The project team collected a wide range of data 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; sediment quality sampling to evaluate sediment toxicity and provide a longer term record of the pollutants the stream carries; and characterization of watershed land use, conditions and pollution sources. Data collected during the study are presented in Sections 4, 5, and 6 of this report.

Conclusions

Aquatic organisms in Corpening Creek are heavily impacted by multiple stressors associated mostly with development in the watershed. The primary cause of impairment is toxic impacts. Other cumulative causes that contribute to the impairment are habitat degradation due to lack of microhabitat, hydromodification due to scour, and nutrient enrichment.

Management Strategies

The objective of efforts to improve stream integrity is to restore water quality and habitat conditions in order to support a more diverse and functional biological community in Corpening Creek. Because of the widespread nature of biological degradation and the highly developed character of the watershed, bringing about substantial water quality improvement will be a tremendous challenge. While a return to the relatively unimpacted conditions that existed prior to urbanization is not possible, Corpening Creek can support a healthier biological community than it does today.

The following actions are necessary to address current sources of impairment in Corpening Creek, and to prevent further degradation. Actions one through five are important to restoring and sustaining aquatic communities in the watershed, with the first three recommendations being the most important.

1. **Feasible and cost-effective stormwater retrofit projects should be implemented throughout the watershed to mitigate the hydrologic effects of development** (increased stormwater volumes and increased frequency and duration of erosive and scouring flows). This should be viewed as a long term process. Although there are many uncertainties, costs in the range of $1 million per square mile can probably be anticipated.
   a) Over the short term, currently feasible retrofit projects should be identified and implemented.
   b) In the longer term, additional retrofit opportunities should be implemented in conjunction with infrastructure improvements and redevelopment of existing developed areas.
   c) Priorities should include evaluating the retrofit potential of existing in-stream impoundments (the few that exist), retrofitting areas draining directly to Corpening Creek mainstem, and Jacktown Creek, the largest unimpounded tributary and local reference stream.
   d) Grant funds for these retrofit projects may be available from EPA initiatives, such as Section 319 funds, or North Carolina programs like the Clean Water Management Trust Fund.
2. **A strategy to address toxic inputs should be developed and implemented, including a variety of source reduction and stormwater treatment methods.** As an initial framework for planning toxicity reduction efforts, the following general approach is proposed:
   a) Implementation of available BMP opportunities for control of stormwater volume and velocities. Recommended above to improve aquatic habitat potential, these BMPs will also remove toxicants from the stormwater system.
   b) Development of a stormwater and dry weather sampling strategy in order to facilitate the targeting of pollutant removal and source reduction practices.
   c) Implementation of stormwater treatment BMPs, aimed primarily at pollutant removal, at appropriate locations.
   d) 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. Suggestions for potential source reduction practices are provided.

3. **Stream channel restoration activities should be implemented in target areas, in conjunction with stormwater retrofit BMPs, in order to improve aquatic habitat.** Before beginning stream channel restoration, a geomorphologic survey should be conducted to determine the best areas for stream channel restoration. Additionally, it would probably be advantageous to implement retrofit BMPs before embarking on stream channel restoration, as restoration is probably best designed for flows exemplifying reduced stormwater runoff. Costs of approximately $1 million per mile of channel should be anticipated. Again, grant funds for these retrofit projects may be available from EPA initiatives, such as Section 319 funds, or North Carolina programs like the Clean Water Management Trust Fund.
4. Actions recommended above (e.g. stormwater quantity and quality retrofit BMPs) are likely to reduce nutrient/organic loading and its impacts to some extent. Other activities recommended to address this 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 BOD and nutrient removal at appropriate sites.
5. Prevention of further channel erosion and habitat degradation will require effective post construction stormwater management for all new development in the study area.
6. Effective enforcement of sediment and erosion control regulations on the part of Marion and McDowell County will be essential to the prevention of additional sediment inputs from construction activities. Development of improved erosion and sediment control practices may be beneficial.
7. Watershed education programs should be implemented and continued by local governments with the goal of reducing current stream damage and prevent future degradation. At a minimum, the program should include elements to address the following issues:
   a) redirecting downspouts to pervious areas rather than routing these flows to driveways or gutters;
   b) protecting existing woody riparian areas on ephemeral streams;
   c) replanting native riparian vegetation on perennial, intermittent and ephemeral channels where such vegetation is absent; and
   d) reducing and properly managing pesticide and fertilizer use.

Section 1
Introduction

This report presents the results of the Corpening Creek water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) and funded by the United States Environmental Protection Agency through its 104(b)(3) grant program. This program has been named the Collaborative Assessment for Watersheds and Streams (CAWS) project. It is modeled after DWQ's Watershed Assessment and Restoration Program (WARP); specifically, it follows the general approach laid out in the WARP projects, and borrows extensively from the WARP reports (NCDWQ, 2003). This report, however, is uniquely composed of observations of, and data from, the Corpening Creek watershed.

CAWS has sought to bring together numerous units from within DWQ to address biological impairments that appear on North Carolina's 303(d) list, a catalog of impaired streams. Biological impairments (impaired aquatic insect communities) have the highest number of listings of any impairment type on the 303(d) list. Through this project, we made an effort to address the causes of such impairments. The development of this report was possible with contributions from many units within DWQ, including: the Biological Assessment Unit (benthic macroinvertebrate and fish community surveys); Intensive Survey Unit (initial watershed reconnaissance); Aquatic Toxicology Unit (bioassays); Laboratory Section (chemical analyses of water and sediment samples); and, the Special Watersheds Project Unit (developed template for this project through the Watershed Assessment and Restoration Project, WARP).

Corpening Creek is also known as Youngs Fork Creek. The two names for the creek are used equally in the watershed and on published maps. This report will use Corpening Creek, but the reader should be aware that it may be referred to as Youngs Fork Creek in other instances.

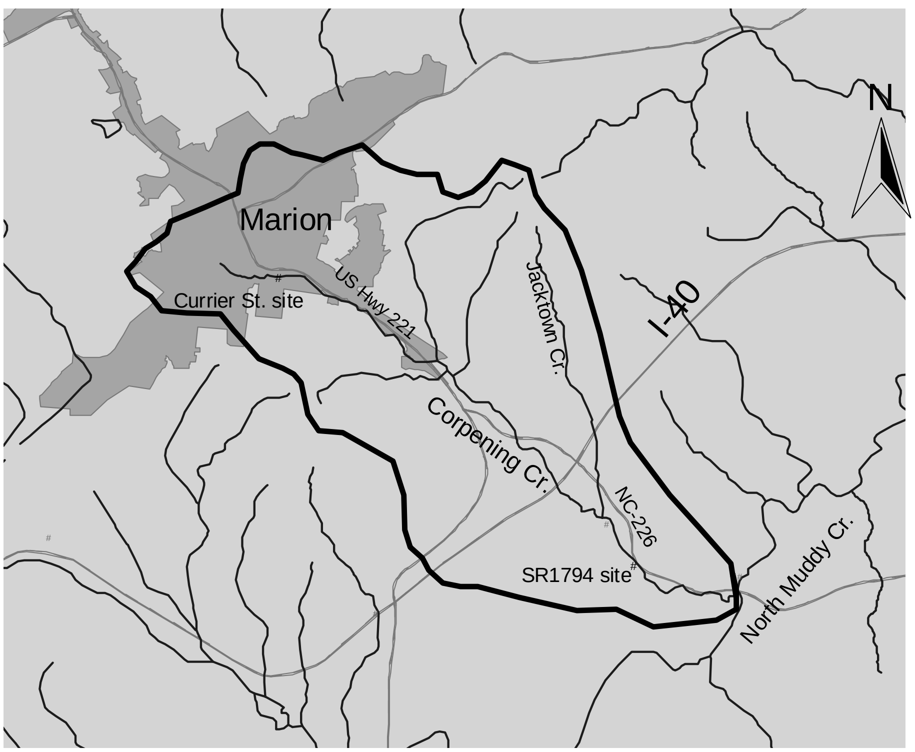
Corpening Creek is considered impaired by DWQ because it is unable to support a balanced and diverse community of aquatic organisms. The reasons for this condition have been previously unknown, inhibiting efforts to improve stream integrity in this watershed.

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. DWQ is committed to encouraging local initiatives to protect streams and to restore degraded waters. There are numerous funding sources (e.g., EPA 319 grants, North Carolina Clean Water Management Trust Fund, North Carolina Ecosystem Enhancement Program) that local initiatives may tap to implement management strategies. It is clear that local cooperation and participation are essential to achieving a lasting attainment of the stream's designated use.

1.1 Study Area Description

Corpening Creek is located in McDowell County, in the Catawba River basin (Figures 1.1 and 1.2). The stream's headwaters are within the town of Marion. The creek flows southeast for approximately 4.7 miles before emptying into North Muddy Creek. The entire watershed is 9.15 square miles, but only 8.6 square miles are included in this study; the study area stops at SR1794 (Clinch Field Road) to be consistent with prior benthic macroinvertebrate monitoring, the basis for the impairment listing. The study area contains one permitted point source of domestic and industrial wastewater, Marion's wastewater treatment plant (NC0031879). Approximately 15 percent of the study area is covered by impervious surface, through which water does not readily infiltrate.

Figure 1.1 Corpening Creek Watershed – Catawba River Basin



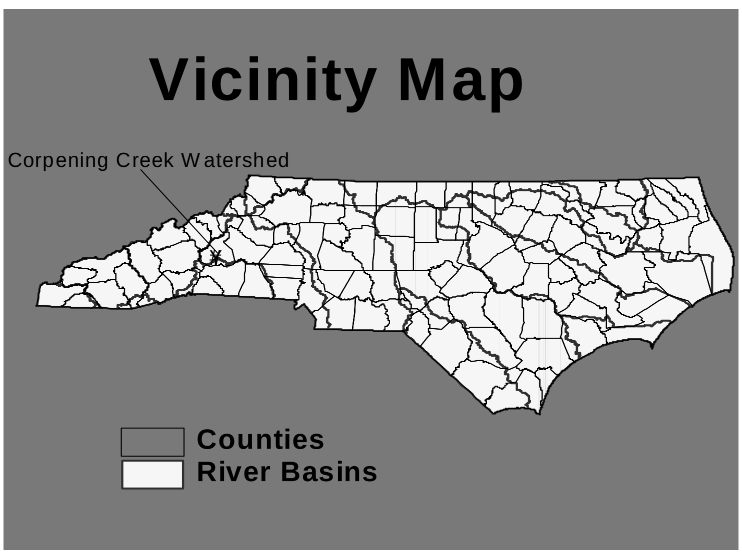
1.2 Study Purpose

The Corpening Creek assessment is part of the Collaborative Assessment of Watersheds and Streams (CAWS) project, a study of 4 watersheds across the state being conducted by DWQ between 2001 and 2003. The other three watersheds are Burnt Mill Creek in the Cape Fear Basin, Clayroot Swamp in the Neuse Basin, and West Fork French Broad

River in the French Broad River Basin. The goal of the project is to provide the foundation for future water quality restoration activities in each watershed by:

1. Identifying the most likely **causes** of biological impairment. Examples of such causes include degraded habitat or specific pollutants;
2. Identifying the **sources** of pollution contributing to those causes. Examples of sources include streambank erosion or stormwater runoff from a particular location;
3. Outlining a watershed management **strategy** that recommends restoration activities and best management practices (BMPs) to address the identified problems and improve the biological condition of the impaired streams.

Figure 1.2



1.3 Study Approach and Scope

Of the study's three objectives, identification of the likely causes of impairment is the critical building block, since addressing subsequent objectives depends on this step (Figure 1.3). Identifying causes of impairment can be done using rapid screening level approaches; however, we have taken a somewhat more detailed approach in order to more reliably and defensibly identify causes and sources of impairment.

The general conceptual approach used to determine the causes of impairment in Corpening Creek was as follows (see NCDWQ, 2003; Foran and Ferenc, 1999; USEPA, 2000).

1. Identify the most plausible potential causes of impairment in the watershed, based on existing data and initial watershed reconnaissance activities;
2. Collect a wide range of data bearing on the nature and impacts of those potential causes; and
3. 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.

This process yields the probable primary and secondary causes of impairment. Based on these results, in Section 8, we recommend general management strategies for curbing the impacts associated with a particular stressor.

1.4 Approach to Management Recommendations

The recommended management strategies are suggested for others, including local watershed stakeholders, to implement with the intention of restoring the stream's designated use. Where problems are complex and perhaps have occurred for a long time, any set of management strategies may be inadequate in the near term to restore the stream's biological integrity. In such instances an iterative process of adaptive implementation (Reckhow, 1997; USEPA, 2001) is warranted. This process involves an initial round of management actions based on this preliminary study, then continued observation to determine the effects of the initial strategy, followed by consideration of what additional measures are needed.

Protection of the drainage network from additional harm due to future development, or other activities, in the watershed is a critical consideration. Without such protection, efforts to restore water quality by mitigating existing impacts may be ineffective, or have only a temporary effect.

Management recommendations included in this document are not intended to be specifically prescriptive. Rather, they are offered to describe the types of actions that need to occur to restore Corpening Creek. It is DWQ's hope that local governments and other stakeholders in Corpening Creek watershed will work cooperatively with each other and with state agencies to implement these measures in cost-effective ways. Presently, there are many opportunities to obtain grant funds to implement management strategies that will address impaired streams. DWQ could offer technical assistance on such proposals.

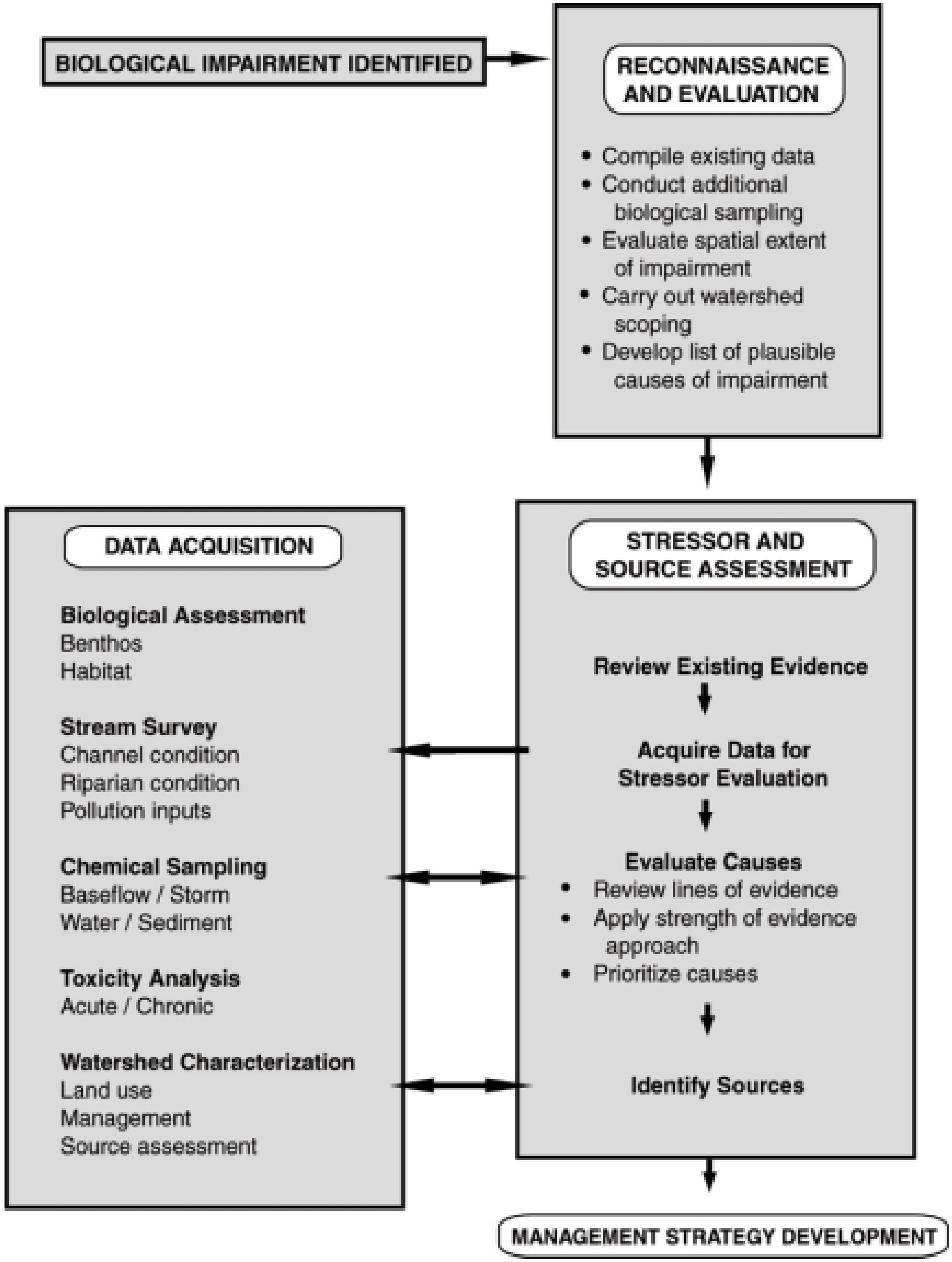
This study did not develop TMDLs (total maximum daily loads), nor establish pollutant loading targets. This task cannot be completed until a problem pollutant has been identified. Also, for many types of problems, including habitat degradation, TMDLs may not be a suitable mechanism for initiating water quality improvement. Where specific pollutants are identified as causes of impairment, TMDLs will need to be developed. Management strategies need not wait for TMDLs, however. If any organization or individual is able to address obvious problems/sources, this should be done.

1.5 Data Acquisition

While project staff made use of existing data sources during the course of the study, these were not enough to fully address the causes of the impairment. Extensive data collection was needed to develop a sufficient base of information. The types of data collected during this study included:

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

Figure 1.3 Overview of Study Activities



Background Note: Identifying Causes of Impairment (Taken from DWQ's Watershed Assessment and Restoration Project; NCDWQ, 2003).

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 reasonably well ecologically. When monitoring indicates that degradation has become severe enough to interfere significantly 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 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 the 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 enrichment, 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 macroinvertebrates or fish, identification of the causes of impairment thus involves a determination of the factors most likely leading to the unacceptable biological conditions.

All conditions that impose stress on aquatic communities may not be causes of impairment. Some stressors may occur at a frequency, duration and intensity 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 the 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.

Background Note, *continued*

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 stressor 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 on 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/index.html; *A Citizen's Guide to Water Quality Management in North Carolina* (NCDWQ, 2000); *EPA's Stressor Identification Guidance Document* (USEPA, 2000).

Section 2
Description of the Corpening Creek Watershed

2.1 Introduction

The 2002 303(d) list designates Corpening Creek as impaired for its entire length. Streams in the watershed are designated as 'class C waters', which signifies that, among other uses, the waters shall be suitable for aquatic life propagation and maintenance of biological integrity. Sources of water pollution which preclude this use on either a short-term or long-term basis shall be considered to be violating a water quality standard (NCDENR, 2003).

This section summarizes watershed hydrography and topography, describes current land use, and discusses potential pollutant sources.

2.2 Streams and Hydrology

Corpening Creek is a headwater stream in the upper Catawba River basin that flows southeast from downtown Marion (elevation 1380 ft. above mean sea level) to North Muddy Creek (elevation 1190 ft. above mean sea level), 4.7 miles from its origin.

The only named tributary of Corpening Creek is Jacktown Creek, which drains the lower, eastern portion of the watershed. Jacktown Creek's watershed includes the municipality of Jacktown, a community of lower density residences, some of which contain large vegetable gardens.

The stream network has adequate riparian buffers for the most part, particularly in the lower reaches of the watershed (just above the intersection of I-40) where they are usually greater than five meters wide and contain a variety of vegetation, including trees. The upper watershed usually has some buffer, though its width may be limited to one or two meters, and trees or woody vegetation are often absent. In downtown Marion, above Claremont St., stream buffers are noticeably absent.

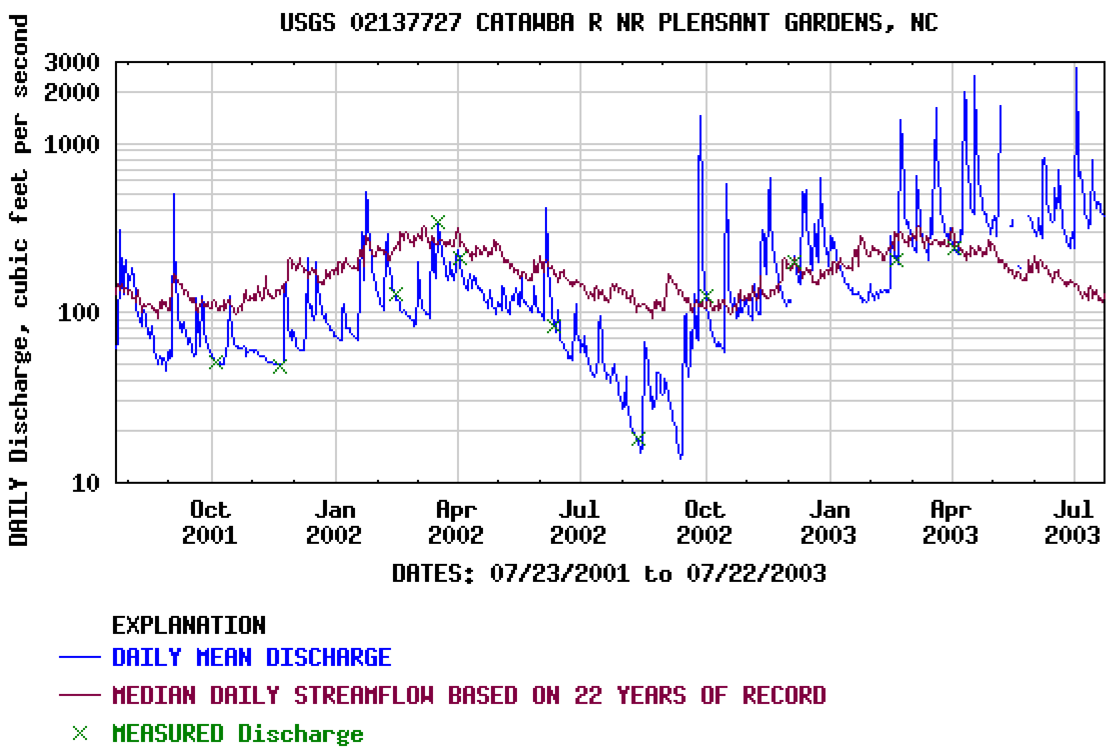
For the most part, the drainage channels are unimpeded by dams. There may be a few small impoundments on tributaries, but they do not have much effect on the watershed's function. In parts of the lower watershed, some snags/log jams slow flow. A log jam at the bridge on SR1794 was present for most of the study period, but high flows during early 2003 moved this downstream.

Estimates of annual precipitation in the watershed range from 52 to 56.5 inches.
A drought occurred beginning in the fall of 2001 and continued through 2002. The drought extended to years before the study, as well. 2003 has been a wetter than normal year.

No USGS streamflow gage exists on Corpening Creek. The closest one is on the Catawba River near Pleasant Gardens, NC. This is merely five miles from downtown Marion, so

Corpening Creek probably followed a similar pattern. As shown in Figure 2.1, from July 2001 to July 2003 the Catawba River experienced a period of below average flow until October 2002. By March 2003, however, more rain fell and the flows were well above average. This is helpful to this study because it allows us to observe the stream during a range of conditions, when different causes and sources may be more prevalent.

Figure 2.1



Notes on Figure 2.1:

- 7Q10 listed as 48 cfs (1982-1988)
- For readers without a color printout, the median daily streamflow based on 22 years of record is the less dynamic line.

The 7Q10 streamflow (lowest average 7-day flow occurring every 10 years) for Corpening Creek may be estimated from USGS predictions for low flow per square mile in this part of North Carolina. The low flow per square mile in this part of the state is 0.317 cubic feet per second per square mile (cfs/sq. mi.), and when that is multiplied by 9.15 square miles (Corpening Creek watershed at mouth), a 7Q10 estimate of 2.9 cfs results. USGS reported values at this location in 1998 were 2.5 cfs for summer 7Q10 streamflow and 3.9 cfs for winter 7Q10 streamflow.

2.3 Topography and Geology

Steep ridges, on the flanks of the watershed to the north and the south, rise from about 500 to 1000 feet above the stream elevation, clearly marking the watershed boundary in these directions. The stream loses approximately 190 feet in elevation from its origin to its mouth, a distance of 4.7 miles.

The soils in the Corpening Creek watershed are part of two series: the Hayesville-Evard and the Evard-Cowee. The Evard-Cowee covers the higher elevation areas on the flanks of the watershed. It can be found on 25-60 percent slopes and consists of well-drained, deep loamy material, formed from weathered gneiss and schist. The Hayesville-Evard covers most of the lower elevations of the watershed, intermountain uplands and foothills on 6-15 percent slopes. It also formed from weathered gneiss and schist, and consists of clayey or loamy subsoil.

2.4 Land Cover in the Watershed

The study watershed has areas that are highly developed (downtown Marion forms the headwaters, and the corridor along NC-226/US-221, especially north of I-40) and other areas that are forested (hills running along Corpening Creek below Marion, and areas lower in the watershed). Agriculture is limited to pasture and large vegetable gardens dotted about the lower half of the watershed. NC-226 runs parallel to Corpening Creek over its entire length, while US-221 joins NC-226 in the upper half of the watershed.

Below I-40, there are some industrial areas (landfill, lumber treatment and storage facility, dyed yarn factory, and Department of Transportation refueling area), institutional facilities (Department of Transportation vehicle licensing office, county prison), and the City of Marion wastewater treatment plant. Interspersed among these developed sections is forestland, and an occasional patch of pasture or vegetable garden.

Above I-40, land adjacent to NC-226/US-221 and Corpening Creek is largely developed as commercial or residential property. The commercial land includes restaurants, car washes, banks, landscaping companies and a variety of retail and repair stores. There is also industrial land use, including another lumber treatment and storage facility near Jacktown Rd.; a Chevron fuel storage facility; the City Public Works facility (mostly vehicle maintenance and storage; a recently opened air conditioning parts factory; and, two furniture manufacturing plants in Marion (Broyhill and Drexel). In the eastern portion of the watershed, behind the cemetery, is a closed textile mill, formerly known as Marion Mills. The mill is currently used for storage.

The headwaters of Corpening Creek flow under pavement and suddenly appear beneath a barbershop in Marion (Figure 2.2). From here the stream follows a fairly straight path through a kudzu-covered ravine to a more residential section (Claremont St. and Currier St.) of town.

Figure 2.2 Corpening Creek headwaters emanating from below a barber shop in downtown Marion.

The distribution of land cover in the watershed is shown in Figure 2.3 and Table 2.1. The land use/land cover characteristics of the watershed were determined using 1996 land cover data that were developed from 1993-1994 LANDSAT satellite imagery. The North Carolina Center for Geographic Information and Analysis, in cooperation with the N.C. Department of Transportation and the United States Environmental Protection Agency Region IV Wetlands Division, contracted Earth Satellite Corporation of Rockville, Maryland to generate comprehensive land cover data for the entire state of North Carolina. During the formation of this dataset, developed land was identified using the proportion of synthetic cover present; low density developed was 50-80% synthetic cover, and high density developed was 80-100% synthetic cover. Assuming that synthetic cover is impervious, and that all non-developed land cover classes have 1% impervious cover, the Corpening Creek watershed is estimated to have 12% impervious cover. This estimate is probably low, however, as subsequent development has certainly occurred since 1993-1994. Also, this dataset is known to underestimate urban land cover as trees can partially cover smaller patches of synthetic cover. Thus, considering all the factors, the impervious cover today is likely to be **at least** 15%.

Figure 2.3

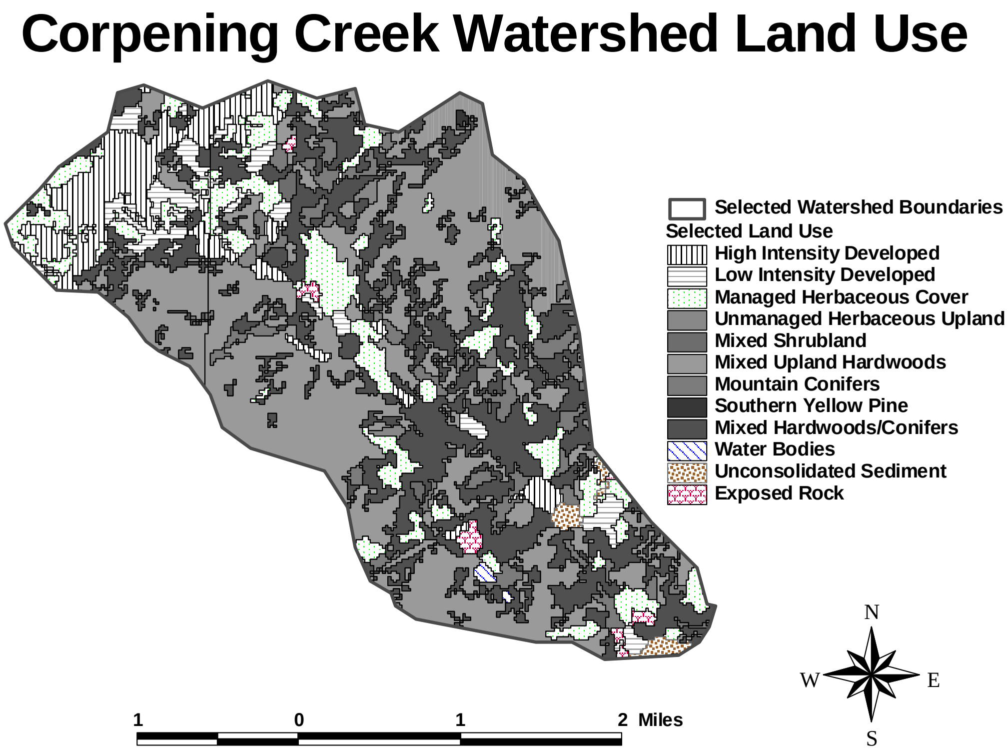


Table 2.1 1993-94 Land Cover, Corpening Creek Watershed

Category	Acres	Percent of Watershed
High density developed (80-100% impervious)	420	8
Medium density developed (50-80% impervious)	215	4
Forest	3898	75
Managed herbaceous (lawns, pasture, etc.)	604	12
Barren (exposed rock & sediment)	83	2
Water	10	0
Total	5230	100

Source: Land Use/Land Cover data developed by North Carolina Center for Geographic Information and Analysis. Based on 1993-1994 LANDSAT satellite imagery.

2.5 Sources of Pollution

2.5.1 Permitted Discharges

The City of Marion's wastewater treatment plant (NPDES permit NC0031879) is the only NPDES discharger in the Corpening Creek watershed. The plant treats both domestic and industrial wastewater. It is permitted to discharge up to 3.0 million gallons per day (MGD) of effluent into Corpening Creek. The facility is required to monitor the following parameters at sites upstream and downstream from its discharge: temperature, dissolved oxygen (DO), pH, fecal coliform bacteria, BOD5, and color. These monitoring locations are 100 feet upstream from the discharge, and downstream at SR1794 (Clinch Field Road). The facility is required to perform whole effluent toxicity testing on a quarterly basis using an instream waste concentration of 67%. The plant has passed all tests since January 1998, except for that in the second quarter of 2001 (5/24/01). It is not known what caused this bioassay failure.

Figure 2.4 shows effluent discharge from Corpening Creek WWTP from 1998 to 2003. The effluent discharge exceeded the 3.0 mgd limit twice from 1998 to 2003 (03/20/00 and 04/11/03). Concentrations of Total Phosphorus (TP), Total Nitrogen (TN) and Zinc (Zn) are shown in Figures 2.5, 2.6, and 2.7, respectively. Table 2.2 shows effluent limitations and monitoring requirements for the Corpening Creek WWTP.

The City of Marion is not required to have an NPDES stormwater permit and is currently not scheduled to receive one as part of the Phase II expansion of that program.

Table 2.2 Effluent Limitations and Monitoring Requirements for Marion's Corpening Creek WWTP

Effluent Characteristics	Limits			Monitoring Requirement	
	Monthly Average	**Weekly Average**	**Daily Maximum**	**Measurement Frequency**	**Sampling Location**
Flow	3.0 MGD			Continuous	Influent or Effluent
BOD_5	30.0 mg/l	45.0 mg/l		Daily	Influent or Effluent
Total Suspended Solids	30.0 mg/l	45.0 mg/l		Daily	Influent or Effluent
NH_3-N				3/week	Effluent
Dissolved Oxygen				Daily	Effluent, Upstream, Downstream
Fecal Coliform	200/100 ml	400/100 ml		Daily	Effluent, Upstream, Downstream
pH				Daily	
Total Residual Chlorine				Daily	
Temperature				Daily	
Total Nitrogen				Monthly	Effluent
Total Phosphorus				Monthly	Effluent
Conductivity				Daily	Effluent
Oil and Grease				2/month	Effluent
Chronic Toxicity				Quarterly	Effluent
Cadmium		3 μg/l	15 μg/l	Weekly	Effluent
Cyanide		7.5 μg/l	22 μg/l	Weekly	Effluent
Copper				2/month	Effluent
Zinc				2/month	Effluent
Silver				2/month	Effluent

Figure 2.4

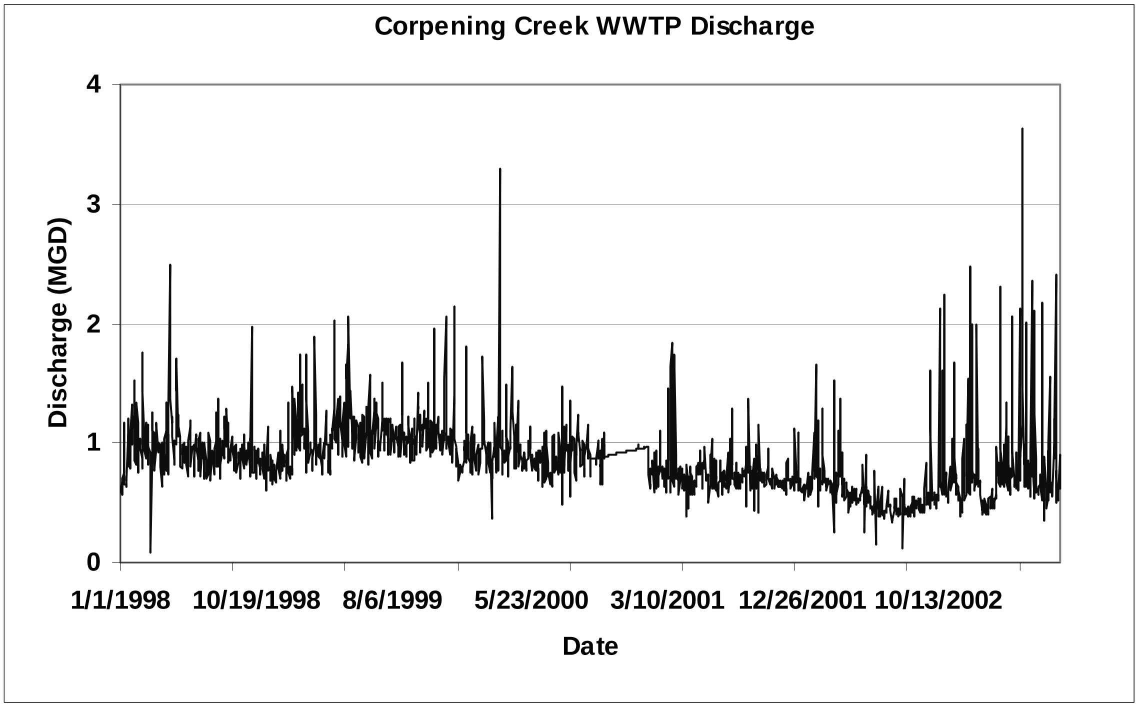


Figure 2.5

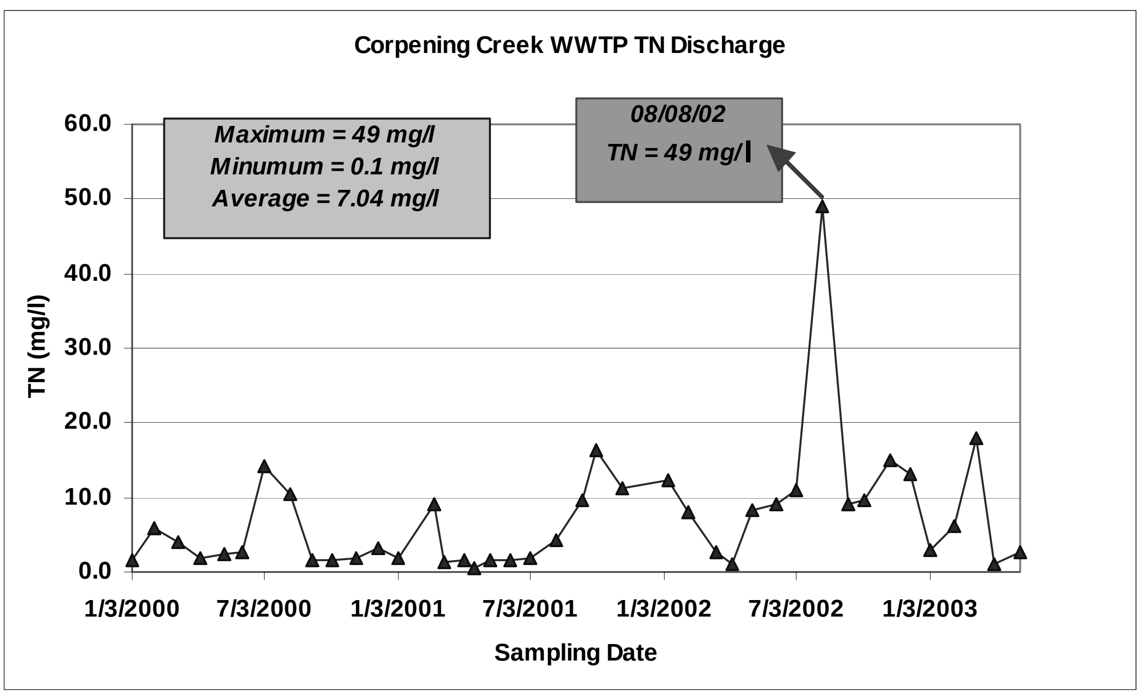


Figure 2.6

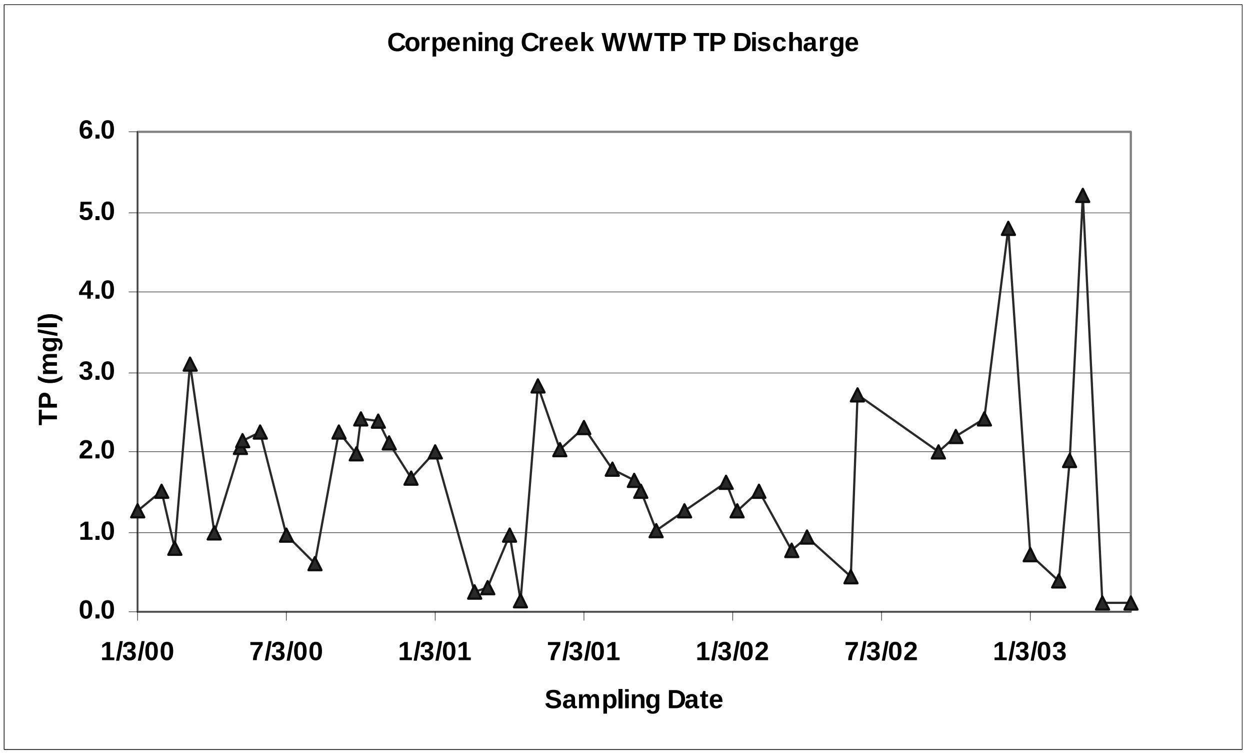
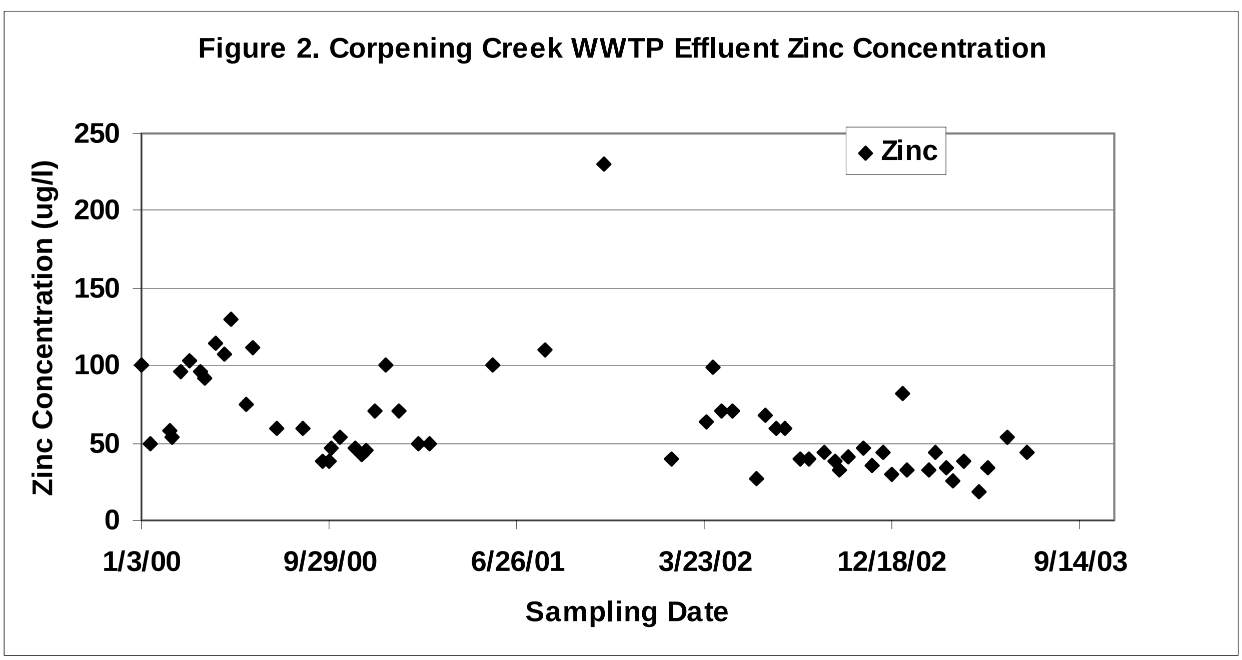


Figure 2.7



2.5.2 Nonpoint Source Inputs

A wide range of urban activities and pollution sources are of potential concern, including: roads, parking lots, rooftops, lawns, vegetable gardens, industrial areas, construction sites, etc. The list of pollutants which have been documented to increase with urbanization includes oils, antifreeze, tars, soaps, fertilizers, pesticides, solvents and salts (Bales et al., 1999; Burton and Pitt, 2001). Potential sources of pollution in the study area are discussed below.

a. Existing Developed Area.

The City of Marion zoning in the Corpening Creek watershed extends to the city limits, which roughly extend from downtown Marion to the intersection of US-221 and NC-226, though numerous smaller parcels below there have been annexed. The City's zoned land use includes a central business district in downtown Marion, and 'C2' (commercial outside of downtown Marion) and 'R2' (residential) land uses beyond downtown.

<u>Residential Development</u>. Much of the land in the City of Marion is zoned for residential uses. The density of residential areas generally decreases with distance from downtown Marion. Residential areas in the upper part of the watershed include many old mill houses, and range from medium to high density. The lower part of the watershed has single residences that may cover more than an acre, as well as medium density areas. Most of the higher density areas have traditional curb and gutter drainage. Stormwater BMPs are essentially nonexistent.

<u>Commercial and industrial development</u>. Commercial activity within the City of Marion is considerable. Industrial activity is limited, though there is some such use. Historically, industrial activity has been more prominent. See Section 2.4 for more description. As with residential areas, stormwater BMPs are absent.

Drexel Heritage (358 employees) and Broyhill Furniture (220 employees), located near downtown Marion, are two of the larger employers in the county. The largest employer in the watershed is the Marion Correctional Institution, a state correction facility in the lower part of the watershed.

The only remaining industry with a pretreatment permit to send industrial waste to the Marion WWTP is Galey & Lord Industries, a textile manufacturer. They are permitted to send 0.0250 lbs./day chromium, and 0.3500 lbs./day copper. According to DWQ's headworks analysis, this leaves 2.2122 lbs. chromium and 3.2295 lbs. copper allowable. Marion Mills, another textile manufacturer, closed in 2001. Kennedy Die Casting (aluminum and zinc die casting) ceased operation in 2000.

<u>Roads and parking areas</u>. Roads, driveways and parking lots are an integral part of an urban environment. One recent study (Cappiella and Brown, 2001) found that such "car habitat" accounted for a substantial portion of impervious cover in developed areas. Car

habitat exceeded building footprints in all urban land use categories, accounting for between 55% and 75% of total impervious area.

Storm runoff from streets, highways and parking areas has been recognized as an important contributor of metals and organic chemicals to urban streams from sources such as tire and brake pad wear, vehicle exhaust, oil and gas leaks, pavement wear, among others (Davis et al., 2001; Bannerman et al., 1993; Young et al., 1996; Lopes and Dionne, 1998; van Metre et al., 2000).

Paved areas have increased in Corpening Creek watershed in recent decades. Vehicular traffic has increased due to both an increase in watershed population (18% increase in McDowell Co. population between 1990 and 2000) and an increase in traffic originating from outside the watershed on I-40, NC-226 and US-221 (see Table 2.3).

Table 2.3 Annual Average Daily Traffic Counts at Selected Locations in Corpening Creek Watershed, 2001.

Road name	Year		
	1980	**1990**	**2001**
Interstate 40	10,600	19,800	23,000
NC-226 south of I-40	3,900	5,400	7,400
NC-226 north of I-40	7,100	9,900	15,000
US-221/NC-226 into Marion	11,700	13,100	9,700
US-221By-pass	d.n.e.	d.n.e	12,000

Source: NC Department of Transportation
d.n.e.: did not exist. US-221 By-pass takes traffic around downtown Marion, which is why US-221/NC-226 has less traffic in 2001 than earlier years.

b. Construction.
Development appears to be spreading down from Marion to the more rural areas lower in the watershed. During the study period, the main area of development was in the middle of the watershed. A big area of excavation and grading was and is located about one-quarter mile towards downtown Marion from the intersection of US-221 and NC-226. Project staff first visited the site in July 2001. At that time, an entire hillside overlooking the site had been excavated, and several terraces near the stream were recently graded. By July 2003, several businesses had opened in the area, and the excavated hillside still lacked vegetative cover. Sediment fences were erected the entire time, though maintenance of them is not evident – much of the fence is sagging or ripped. Between the excavated hillside and graded terraces, this is probably one of largest current sediment source areas in the watershed. The other current major source of sediment is likely to be streambank erosion.

c. Sanitary sewer leaks.
Marion sewage system serves the vast majority of the study area. Sanitary sewer lines run near the Corpening Creek mainstem to the treatment plant, which discharges to the creek about one-half mile downstream from I-40.

From August 1997 through July 2003, 25 spills of untreated sewage reaching surface waters of the study watershed were reported to DWQ by Marion (Table 2.3). Of note is the sharp decline in SSOs starting in March 2000. The City of Marion has done a good job of addressing problem spots in their sanitary sewer system. This is certainly a positive for the stream's restoration potential. Continued maintenance of the system will be important.

Table 2.3 Spills of Sewage to Corpening Creek and Tributaries
August 1997 through July 2003

Date	Location	Estimated Volume to SW	Receiving Stream	Cause
8/15/1997	Marion Mills	50	Corpening Cr.	dye spill
1/14/1998	Rutherford Rd.	12,000	Corpening Cr.	embankment failure
2/6/1998	W. Henderson St.	100	Corpening Cr.	line blocked by debris
2/17/1998	Glenview St.	500	Corpening Cr.	line broken by fallen tree
3/7/1998	lift station at prison	30,000	Corpening Cr.	grease
3/20/1998	between WWTP and lumber facility	NA	Corpening Cr.	excessive inflow/infiltration
4/9/1998	between WWTP and lumber facility	10,000	Corpening Cr.	excessive inflow/infiltration
4/17/1998	between WWTP and lumber facility	100,000	Corpening Cr.	excessive inflow/infiltration
6/10/1998	Drexel Furniture wood yard	200	Corpening Cr.	line broken by forklift
6/27/1998	lift station at prison	50,000	Corpening Cr.	grease
9/10/1998	influent pump at WWTP	5,000	Corpening Cr.	maintenance
10/15/1998	lift station at prison	500	Corpening Cr.	maintenance
11/18/1998	lift station at prison	9,000	Corpening Cr.	system failure
12/1/1998	Tennessee Ave.	100	UT to Corpening Cr.	roots
1/26/1999	Railroad St.	500	UT to Corpening Cr.	blockage
2/19/1999	Baldwin Ave.	500	UT to Corpening Cr.	leak from pipe shifting
6/17/1999	Morgan St.	2,000	UT to Corpening Cr.	blockage
8/18/1999	Morgan St.	1,000	UT to Corpening Cr.	line broken
11/2/1999	WWTP	300	Corpening Cr.	excessive inflow/infiltration
12/13/1999	Railroad St.and Morgan St.	500	UT to Corpening Cr.	blockage
3/20/2000	Rutherford Rd.	1500	UT to Corpening Cr.	excessive inflow/infiltration
3/27/2000	lift station at prison	3,000	Corpening Cr.	grease
4/6/2001	S. Main St.	500	UT to Corpening Cr.	blockage
6/11/2001	Rutherford Rd.	500	UT to Corpening Cr.	blockage
7/28/2003	Broyhill Furniture on W. Henderson	3,300	Corpening Cr.	blockage

2.6 Trends in Land Use and Development

The population of Marion, the county seat, in the 2000 census was 4,943 (www.mcdowellnc.org). McDowell County had 42,151 residents in 2000, an 18% increase from the 1990 census.

The City of Marion has been developed for some time. The US-221/NC-226 corridor is now developing away from the city. This will put more stress on Corpening Creek and its tributaries, especially if stormwater controls are not implemented. Stormwater controls are currently rare, if not absent.

2.7 Local Regulatory Issues and Water Quality Activities

There are few local regulations or local water quality activities in the Corpening Creek watershed. In general, the local population distrusts government and prefers to manage personal property as they wish. Often, this means very limited environmental protection. Some stream buffers are still in tact, though usually they are less than 10 feet wide and do not often include woody vegetation.

There are no rules for buffer requirements in the Corpening Creek watershed; the Catawba buffer rule, mandated by the state (Environmental Management Commission and DWQ), applies only to the mainstem of the Catawba River and its dammed lakes. The NPDES Phase II stormwater program is not scheduled to include Marion or McDowell County. Based on the results of this study, DWQ may recommend that Marion be included in the Phase II program.

Additionally, according to two City of Marion employees, there are no local stormwater regulations. The result is a mixture of curb and gutter drainage, and “random runoff”, where water goes where it wants to go (no drains). The latter may be easier to treat with retrofits than traditional curb and gutter drainage if stormwater wetlands or rain gardens can be installed in suitable locations.

The lack of local regulations, or interest in stream protection/restoration, will make the task of restoring biological integrity more difficult.

Section 3
Potential Causes of Biological Impairment

The study identified those factors that were plausible causes of biological impairment in the Corpening Creek watershed using both biological assessment and watershed-based approaches. An evaluation of the aquatic macroinvertebrate community data, and data on stream and sediment chemistry, as well as habitat and land use activities, can point to the general types of impacts that may impact the stream's biological integrity. These stressors were flagged for further investigation, which DWQ conducted in this study.

3.1 Key Stressors Evaluated in the Corpening Creek Watershed

1. *Toxicity*. An initial review of the benthic community survey for Corpening Creek indicated potential impacts from toxic inputs. Sizeable portions of the watershed are highly developed, both in residential and commercial uses. There is a significant potential for a wide variety of toxicants to enter the streams during rain events or site specific mishaps. These include metals, pesticides and a range of organic chemicals. Because of the wide range of potential toxicants and source activities in this watershed, toxicity merits further evaluation as a potential cause of impairment.

2. *Habitat degradation—sedimentation*. Sedimentation impacts habitat through loss of pools, burial or embedding of riffles, and high levels of substrate instability.

3. *Habitat degradation—lack of key microhabitat*. Preliminary watershed investigations indicated that while habitat conditions are quite variable in Corpening Creek and its tributaries, important microhabitats for benthic macroinvertebrates -such as woody debris, leaf packs and root mats- may be present in only limited amounts in some areas. The degree of, or reason for, and biological implications of habitat degradation needed further evaluation.

4. *Hydromodification—scour due to stormflows*. Highly developed watersheds, such as Corpening Creek, often experience rapid changes in streamflows during storms. Increased levels of impervious cover increase the volume and energy of streamflows, which can dislodge aquatic macroinvertebrates and some microhabitats from the stream. Two results of scouring stormflow are incised stream channels, and streambank habitat lost through erosion.

5. *Nutrient/organic enrichment*. An initial review of the benthic community data from Corpening Creek indicated potential impacts from organic loading in some portions of the stream. Organic enrichment can affect stream biota in several ways. First, it can deplete dissolved oxygen to harmful levels. Second, it can favor pollution tolerant species that filter their food from the water column.

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. Adequate dissolved oxygen is essential to aquatic communities; only certain aquatic invertebrates are able to tolerate low oxygen levels.

Excess organic levels can result in a distinct shift in community composition due to changes in food sources and lower dissolved oxygen levels. Essentially, higher particulate matter, associated with organic enrichment, can favor dominance by filter feeders, some of which are in the pollution tolerant class of macroinvertebrates.

Section 4
Biological Conditions and Stream Habitat

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

Prior to this study, DWQ's Biological Assessment Unit conducted benthic macroinvertebrate surveys at various sites in the Corpening Creek watershed in 1985, 1990 and 1997. At SR1794 (about 0.5 mile **below** the WWTP), the stream was rated Fair in 1985 and Poor in 1990. At SR1819 (about 0.5 mile **above** the WWTP), the stream was rated Fair in 1985, 1990, and 1997.

Additional surveys of the benthic community were conducted during this study for several reasons: to account for the changes in biological conditions since the watershed was last sampled in 1997; to better differentiate between portions of the watershed contributing to biological impairment and those in good ecological condition; and to collect additional information to support identification or likely stressors affecting the benthic community.

This sections describes the results of the benthic macroinvertebrate and fish community surveys completed for this project. A more detailed analysis of the condition of the aquatic macroinvertebrate communities in the Corpening Creek watershed may be found in Appendix A.

4.1 Approach to Biological and Habitat Assessment

During this study, DWQ's Biological Assessment Unit collected benthic macroinvertebrate samples at four sites in the watershed, including one site on what was considered to be a reference stream. The sites are described in Section 4.2. The reference stream does not represent undisturbed conditions; rather, it serves as a comparison site in a less impacted sub-watershed within the same ecoregion and with the same general geology. Sampling at all four sites took place in April 2001.

Additionally, the Biological Assessment Unit conducted the first and only survey of the Corpening Creek fish community at SR1794 in September 2002.

4.1.1 Benthic Community Sampling and Rating Methods

When surveying the benthic community, DWQ followed its general procedures outlined in the standard operating procedures (NCDWQ, 2001b). Reaches approximately 100 meters long were targeted, although the actual reach length sampled varied with site conditions. DWQ used standard qualitative sampling for most sites. 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 DWQ used the abbreviated Qual 4 method. This method includes only four samples: one kick, one sweep, one leaf pack and visual collections. Organisms were identified to genus, and, sometimes, to species.

Two primary indicators or metrics are derived from macroinvertebrate community data: the diversity of a more sensitive subset of the invertebrates is evaluated using EPT taxa richness counts; while the pollution tolerance of those organisms present is evaluated using a biotic index (BI). "EPT" is an acronym for Ephemeroptera + Plecoptera + Trichoptera (mayflies, stoneflies and caddisflies), which are insect groups that generally do not tolerate much or many kinds of pollution. A *higher* EPT number represents a healthier benthic macroinvertebrate community. A *lower* BI score represents a less pollution tolerant benthic community.

Biotic index ratings and EPT taxa richness rating are combined to produce a final bioclassification, such as Excellent, Good, Good-Fair, Fair or Poor. These final bioclassifications are used to determine if a stream is impaired. The cutoff for this decision is between Good-Fair and Fair, with Fair and Poor considered to be impaired. Under current DWQ policy, streams with a drainage area of less than three square miles are generally not formally rated, **but are evaluated 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'.

The use of Chironomus (midge) mentum (mouth structure) deformities is a good tool for toxicity screening (Lenat, 1993). At least 20-25 Chironomus are evaluated for deformities and a "toxic score" is computed for each site. In 2001, toxic indicator species were common or abundant at the SR1794 site, below the WWTP. These included Chironomus with mentum deformities. A midge deformity analysis found many "Class III" (most severe) type deformities, which put this site in the Poor/Toxic group.

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 piedmont streams (NCDWQ, 2001b). This subjective 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 (5);
- in-stream habitat variety and area available for colonization (20);
- bottom substrate type and embeddedness (15);
- pool variety and frequency (10);
- riffle frequency and size (16);
- bank stability and vegetation (14);

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

4.2 Findings and Discussion

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. One site, Jacktown Creek at NC-226, was too small to be given a formal rating (bioclassification). A narrative summary of conditions at each current site follows. See Table 4.1 and Appendix A for additional details.

Jacktown Creek:

Jacktown Creek at NC-226. This site is located just upstream of NC-226, near the intersection of that road and I-40. For the benthic macroinvertebrate survey, this locale was considered to be the reference site. Again, this indicates that it is **minimally impacted** for the area, rather than unimpacted. The Jacktown Creek watershed contains lower density residential land, some pasture and large vegetable gardens, and forest. I-40 intersects the stream toward its lower reaches. The Jacktown sub-watershed does not contain the commercial or industrial land uses that appear in other sub-watersheds.

The macroinvertebrate survey in April 2001 indicated that sedimentation and nonpoint sources adversely affect the benthos, but the stream did have 19 EPT taxa, which is in the Good-Fair range of ratable mountain streams. The crew also found a few pollution intolerant species (*Hexagenia, Amphinemura and Pteronacys)* that were not seen in the main stem of Corpening Creek. The Biotic Index, 4.88, was lower than elsewhere, also indicating a more pollution intolerant community. DWQ did not rate the stream because of its small size (< 4 meters); **however, based on profession judgment, these results suggest the stream is not impaired**.

The Biological Assessment Unit stated that habitat at this site is adequate to support a balanced benthic community. The substrate in the reach consists of a good mix of, in decreasing abundance, silt, sand, gravel, cobbles, bedrock and clay. The riffles are fairly frequent (at least one per 7-10 stream widths) and typically as wide as the stream. The noticeable shortcoming is, in places, unstable and severely eroding streambanks, which leads to heavy sediment deposition (more than 1 foot deep in places) in the pools. Incision may have been a problem, but it does not appear to be progressing as the stream bottom has ample bedrock to prevent this from progressing. It appears that higher and more frequent storm flows, from increasing impervious area, may have initially incised the stream channel. Subsequently, this downcutting reached bedrock, and the stream's energy was directed outwards, eroding the streambanks. The riparian zones are thickly vegetated and typically greater than 12 meters in width, though there are definitely exceptions. Finally, the instream microhabitat consists mostly of rocks, with limited sticks, leaf packs and other organic material. Periphyton growth covers less than twenty percent of the substrate.

During DWQ's habitat survey, we found crayfish and a large turtle, which suggests that toxicity is not a significant issue. Yet those are considered to be somewhat pollution tolerant organisms, so their presence does not indicate an unimpacted stream.

In sum, Jacktown Creek appears to be a good reference stream in that it has marginally adequate habitat, some pollution, an apparent lack of toxicity, and, most importantly, an unimpaired benthic community.

Corpening Creek:

Corpening Creek at Currier St./Claremont St. This is the uppermost reach surveyed on Corpening Creek. It is located in the medium to high density (2-6 dwellings per acre) residential section about one-quarter to one-half mile below downtown Marion. This site has the worst habitat in the watershed. More than eighty percent of the substrate is covered with periphyton. Aggraded sand composes forty percent of the substrate, and fills in a good portion of the pools and runs. The riparian buffers are limited to one meter of herbaceous vegetation in some locations, while they are more substantial (10-15 feet with trees and shrubs) in others. Bedrock in the stream bottom prevents the advancement of historical stream incision. Below Claremont Street, which is several blocks upstream from Currier Street, incision is less evident, perhaps 5 – 10 feet in most locations. There is evidence of very advanced incision, however, above Claremont Street; the stream flows through a kudzu-covered ravine that is 30 – 50 feet deep.

The benthos survey headwaters site was at Claremont Street. This site received a Poor bioclassification. Toxic indicator species were the dominant taxa here. The survey also noted evidence of nutrient enrichment. This observation was corroborated by an abundance of rust-colored attached algae.

At the beginning of this study, DWQ found elevated conductivity between Claremont and Currier Streets. Upon further inspection, the source of the high conductivity was identified as a leak in the sanitary sewer system. This was promptly rectified.

Corpening Creek at Youngs Creek Rd. This site is located in the middle of the watershed, off of the US-221/NC-226 corridor, approximately 0.5 miles above where NC-226 and US-221 meet. In late 2002, much of the land on the southwest side of Corpening Creek was clear-cut. This area lacked a vegetative cover for some time, but vegetation has now taken hold. The clear-cutting eliminated shade from the left (looking upstream) streambank, but tree stumps and herbaceous vegetation remain, and seem to do a decent job of maintaining bank stability.

Nevertheless, as with much of Corpening Creek's stream channel network, aggrading sand fills part of each pool; this area has less sedimentation, however, than further downstream. In fact, the habitat improves substantially from the Currier St. site. Residences sit above the right streambank, and usually provide trees/shade and a minimal riparian buffer of 10 feet or so. In-stream habitat, including sticks and leaf packs, is minimal. Some grasses grow within the channel, and periphyton covers most of the larger substrate (about forty percent of total available area). Riffles are frequent, well-defined and typically more than twice the width of the stream. Historical channel incision in this area is less than anywhere else in the watershed, probably due to shallow bedrock.

DWQ did not conduct a benthic macroinvertebrate survey at this site.

Corpening Creek at excavation site near intersection of US-221 and NC-226. This site is located about 0.25 miles towards downtown Marion from the intersection of US-221 and NC-226. Project staff first visited the site in July 2001. At that time, an entire hillside overlooking the site had been excavated, and several terraces near the stream were recently graded. Sediment fences were erected the entire time, though maintenance of them is not evident – much of the fence was sagging or ripped. By July 2003, several businesses had opened in the area and the excavated hillside still lacked vegetative cover. Some graded terraces were still undeveloped.

Between the excavated hillside and graded terraces, this is probably one of largest sediment source areas in the watershed. The other major source of sediment is streambank erosion.

The stream substrate at this site is composed of a good mix of clast sizes ranging from silt to boulders, while cobbles and gravel make up seventy percent of the material. Riffles are frequent and usually well-defined. There is evidence of historical incision as the streams banks are steep and 12 - 15 feet high, and there is little access to the floodplain for streamflow. As with all other sites in the watershed, sediment is filling the pools. The riparian cover in this area is limited to about 6 meters or less, and does not include many trees. Nevertheless, the streambanks appear to be stable for the meantime. Unlike sites in the lower part of the watershed, the stream's energy seems to be directed towards incision, rather than streambank erosion.

DWQ did not conduct a benthic macroinvertebrate survey at this site.

Corpening Creek at SR1819 (College Road). This site is a short distance (about 0.25 miles) downstream from I-40. It is also upstream from the wastewater treatment plant by about 0.5 miles.

At SR1819, DWQ surveyed the benthos in April 1985, September 1990, August 1997, April 2001, and August 2002. Each of these surveys resulted in a Fair bioclassification. Since 1985, EPT taxa richness has declined, but the EPT abundance has increased (though there was a big dip in 1997) and the Biotic Index (BI) has decreased (lower BI is better). Overall, this indicates a somewhat less pollution tolerant (better) benthic community.

In the vicinity of SR1819, there are two massive (20 feet in diameter) culverts (including one below SR1819 itself) through which the stream passes. The riparian cover ranges from good (5 meters on the right bank) to excellent (20 meters on the left bank); this provides good shading. For instream habitat, there are minimal quantities of sticks and leaf packs.

To the good, the riffles are long and frequent, and the substrate has high proportions of gravels and cobbles. However, the pools are sediment filled. The source of this sediment may be the land clearing activities in the middle watershed, or the local streambanks, some of which are severely eroded. Channel incision does not appear to be active at this site; bedrock outcrops prevent this from progressing. Historical incision, on the other hand, probably occurred.

As part of the April 2001 benthic survey, the habitat was rated as excellent despite 'a considerable amount of algae on the substrate'.

Corpening Creek at SR1794. This is the integrator site for this project, which means it serves to integrate assessment of the pollution contributions from all parts of the watershed. It also denotes the downstream extent of the biological impairment.

At SR1794, DWQ surveyed the benthos in April 1985, September 1990 and April 2001. Compared to the SR1819 site, DWQ's survey of SR1794 found a similar abundance of tolerant taxa, while it also noted the presence of toxic indicator species (*Chironomus, Conchapelopia, and Polypedilum illinoense)* that were not found upstream.
Midge deformity analysis on the *Chironomus* showed many Class III (most severe) type deformities, indicating toxic conditions sometimes occur.

Following a sharp decline in EPT richness and total taxa richness, and a corresponding increase in the Biotic Index, in the 1990 survey, when the site received a 'Poor' bioclassification, the 2001 survey reported a return of those metrics to better than 1985 levels. However, the 2001 survey still yielded a 'Fair', or impaired, bioclassification.

DWQ surveyed the fish community as part of this study in September 2002. They found both a low percentage of tolerant fish and an abundance of an herbivorous fish (particularly the central stoneroller and bluehead chub), which indicates nutrient enrichment. DWQ rated the fish community as 'Fair', based on a North Carolina Index of Biotic Integrity (NCIBI) score of 40.

The habitat at SR1794 may be summarized as suitable to sustain a viable (not impaired) aquatic community, but not without problems. The riparian buffers are relatively wide (particularly the left bank, looking upstream) and contain a diverse assemblage of vegetation, including trees. There is organic debris in the stream, but in only limited amounts. The problems begin with heavy sediment (silt and sand) accumulations in the pools and areas with slower streamflow. Additionally, there is a lower proportion of gravel and cobbles than the SR1819 site. The streambanks are typically about two meters high and are somewhat unstable. The streambank erosion at this site is not as bad as just upstream, but may be one of the sediment sources. Also, there is historical evidence of incision, as the stream does not have access to its floodplain. Shallow bedrock should prevent further down-cutting. Finally, a brownish-green attached algae (not filamentous) covers up to 30% of the substrate, or most of that which is not buried by fine sediment.

It seems that sedimentation between September 2002 and July 2003 was particularly severe, as the habitat survey's instream structure score (maximum of 20) declined from 16 to 9. Different staff conducted the surveys, but even so, the decline is remarkable. High streamflows beginning in the fall of 2002 (see Figure 2.1) may account for increased erosion or in-stream sediment transport, and subsequent channel aggradation.

4.3 Summary of Conditions and Nature of Impairment

The benthic macroinvertebrate community data collected by DWQ indicate that Corpening Creek is impaired over its entire length. The stream appears to have been impaired from its first sampling in 1985. However, Jacktown Creek, its largest tributary, meets its designated use for aquatic life.

Pollution tolerant taxa are common to all survey sites. There is evidence of at least intermittent toxicity at all Corpening Creek sites. Based on the macroinvertebrate surveys, the strongest evidence for this is at the most downstream site, SR 1794, and the most upstream site, Claremont Street.

Reach habitat tends to vary by substrate composition, degree of aggradation and incision, buffer width and vegetation, as well as the extent of streambank erosion. Common to nearly all sites is an accumulation of silt and sand in the pools, and the general paucity of instream organic debris (microhabitat).

The reference stream, Jacktown Creek, seems to have similar habitat to the Corpening Creek study sites. Its more diverse and less stressed benthic community may be attributable to less urbanized land use (essentially no commercial or industrial sites) in the catchment.

Figure 4.1 Jacktown Creek above NC-226.

Figure 4.2 Looking down Corpening Creek below College Rd. (SR1819)

Figure 4.3 Looking down Corpening Creek from Jacktown Rd.

Figure 4.4 Looking down Corpening Creek toward Youngs Fork Rd.

Table 4.1 Selected Benthic Community and Habitat Characteristics, Corpening Creek Watershed Study Sites.

	Corpening Creek														Jacktown Cr.	
Location	SR1819					SR1794					Headwaters Claremont(01) Currier(03)		Young's Cr Rd	US-221/ NC-226	NC-226	
Date	Apr-85	Sep-90	Aug-97	Apr-01	Jul-03	Apr-85	Sep-90	Apr-01	Sep-02	Jul-03	Apr-01	Jul-03	Jul-03	Jul-01	Apr-01	Jul-03
Stream Width (m)				5	5			5		5	4	4	4	4	<4	
Substrate: %sand and silt	-	-	-	20	50	-	-	30		70	20	60	35	20	40	55
Habitat Score (max of 100)	-	-	-	91	74	-	-	70	73	65.5	53	44.5	58	59	67	65
In-stream Structure Score (max of 20)	-	-	-	16	16	-	-	12	16	9	-	7	13	13	-	13
Embeddedness (max of 15) Higher score = less embedded	-	-	-	12	10	-	-	10	8	9	-	7	9	10	-	7
EPT Taxa Richness[2]	16	17	16	14	-	14	8	15	-	-	4	-	-	-	19	-
EPT Biotic Index	4.80	5.36	5.02	4.73	-	4.60	6.61	4.16	-	-	6.52	-	-	-	3.93	-
Biotic Index[3]	6.67	6.62	7.17	5.36	-	6.62	7.17	6.21	-	-	7.46	-	-	-	4.88	-
Bioclassification	Fair	Fair	Fair	Fair	-	Fair	Poor	Fair	Fair - **Fish**	-	Poor	-	-	-	NI[1]	-

[1] **Not Impaired** - based on biologists' professional judgment.
[2] Higher EPT Taxa Richness is healthier.
[3] Lower Biotic Index is healthier (same for EPT Biotic Index).

Section 5
Chemical and Toxicological Conditions

Water quality monitoring provides a basis to assess whether chemical or physical conditions negatively affect benthic communities. Specifically, this monitoring is intended to characterize the water quality conditions in the watershed, and to collect a range of chemical, physical and toxicity data to help determine the specific causes of impairment and to identify sources.

This section summarizes the sampling and data collection methods used, and discusses key monitoring results. See Appendix B for a more detailed discussion of methodology and a more comprehensive presentation of the results.

DWQ does not maintain an ambient monitoring station in the Corpening Creek watershed. Existing data come from this study.

5.1 Approach to Chemical, Physical and Toxicity Sampling

5.1.1 General Approach

General Water Quality Characterization. One station at the downstream end of the study area, Corpening Creek at SR1794, was sampled nine times. DWQ analyzed those samples for a full suite of parameters, similar to those reported at an ambient monitoring station. Grab samples were collected during baseflow and stormflow conditions. **We defined baseflow periods as those in which no measurable rain fell in the watershed during a 48-hour period preceding sampling**.

Stressor and Source Evaluation. Samples were collected at a few locations in order to identify major chemical/physical stressors to which aquatic biota are exposed, evaluate toxicity and assess major pollution sources. Station locations for stressor identification sampling were linked to areas that, through the surveys described in Section 4, showed an impairment in the benthic community. Most of the sampling occurred at two stations along the mainstem of Corpening Creek: SR1794 and Currier St. DWQ collected storm and baseflow samples from July 2001 to July 2003.

Sampling focused primarily on those physical and chemical parameters that preliminary investigation indicated merited further study as causes of biological impairment. As discussed in Section 3, these were primarily toxicants, but also included nutrients and dissolved oxygen.

We looked at a wide variety of toxic pollutants in five sites in the watershed, including:

- Metals
- Semi-volatile organics (EPA Method 625)
- PAHs (polycyclic aromatic hydrocarbons; EPA Method 610)
- Phenols (EPA Method 604)

- MBAS (methyl blue active substances, an indicator of anionic surfactants)
- Chlorinated pesticides and PCBs
- Other pesticides

Much of the sampling for these parameters focused on sediment analyses, as DWQ believes that sediment is a better long-term recorder of pollutants in the stream. Also, benthic macroinvertebrates are constantly exposed to sediment, in contrast to infrequent, potentially toxic **pulses** of stormwater. DWQ collected sediment samples at five locations in the watershed: four from the mainstem of Corpening Creek and one from Jacktown Creek. These samples were collected as a composite at each reach by combining finer grained, more organic rich material from several locations.

Ambient toxicity tests (bioassays) using *Ceriodaphnia dubia* were conducted on six occasions at two locations. Laboratory bioassays provide a method of assessing the presence of toxicity from multiple pollutants, and their cumulative effect on biota. DWQ ran both chronic and acute tests. The acute toxicity test used protocols defined in USEPA document EPA/600/4-90/027F (USEPA, 1993), which includes a 48-hour exposure and measures subject survival. The chronic toxicity test used the North Carolina *Ceriodaphnia* Chronic Effluent Toxicity Procedure (NC Division of Water Quality, 1998), which measures subject survival and reproduction during a one-week exposure. DWQ collected a grab sample on two separate days for the chronic test, and once for the acute test. DWQ favored the chronic test (four of these, compared two acute tests) as, to some degree, it better represents field conditions that the local benthic macroinvertebrates experience.

DWQ did not have the resources to conduct a forty-two day chronic toxicity sediment bioassay using *Hyallela azteca* as described in ASTM (2000) and USEPA (2000b). This test would be a useful addition to the project at a later date, as it measures longer-term exposure of organisms to a collection of pollutants that accumulated over time. This, of course, is more akin to actual field conditions.

DWQ was able to run one sediment toxicity test using Microtox®. This test uses bioluminescent marine bacteria, *Vibrio fischeri*, to detect sample toxic effects, which result in reduced light emissions by the bacteria. Serial dilutions of the sample are prepared in a sodium chloride solution, and mixed with the bacteria. The sample is exposed to the bacteria under tightly controlled conditions of temperature and time of contact. After exposure, the light intensity of the sample/bacterium mixture is measured and compared to simultaneously prepared non-toxic controls. The percent light intensity is plotted versus percent sample to determine an “EC50”, the percent of sample causing a 50% reduction (50% “effect concentration) in light intensity, as compared to control organism light emission.

The identity of the material(s) causing toxicity cannot be identified, and relative effects on other organisms cannot be confirmed on the basis of Microtox® analysis. However, *Vibrio fischeri* have been shown to have sensitivities similar to other standardized toxicity organisms (Mort, 2003). As with any species, sensitivity is contaminant-class and species specific. Any impact on native species, or induced toxicity of the sample by salinity adjustment to accommodate the test species is not known.

Water and Sediment Benchmarks.

Measured water column concentrations were compared to a suite of benchmarks to help evaluate whether observed concentrations might have an impact on aquatic life. The benchmarks for water included:

- EPA's National Ambient Water Criteria (NAWQC) for freshwater (USEPA, 1999) and Tier II benchmarks (USEPA, 1995). Metals benchmarks were adjusted for hardness where possible (USEPA, 1999).
- DWQ's standards for protection of aquatic life – 15A NCAC 2B .0100 and .0200.

The sediment benchmarks were taken from EPA's "A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems" (EPA, 2002). These benchmarks may be divided into categories for threshold effect concentrations, below which harmful effects are unlikely, and for probable effect concentrations, above which harmful effects are likely.

The threshold effect sediment quality guidelines (SQGs) include:

- TEC = Threshold effect concentration (MacDonald et al., 2000)
- TEL = Threshold effect level; dry weight (Smith et al., 1996)
- LEL = Lowest effect level, dry weight (Persaud et al., 1993)
- MET = Minimum effect threshold; dry weight (EC & MENVIQ, 1992)
- ERL = Effects range low; dry weight (Long and Morgan, 1991)
- TEL-HA28 = Threshold effect level for Hyallela azteca; 28 day test; dry weight (USEPA, 1996)
- SQAL = Sediment quality advisory levels; dry weight at 1% OC (USEPA, 1997)

The probable effect sediment quality guidelines (SQGs) include:

- PEC = Probable effect concentration (MacDonald et al., 2000)
- PEL = Threshold effect level; dry weight (Smith et al., 1996)
- SEL = Severe effect level, dry weight (Persaud et al., 1993)
- TET = Toxic effect threshold; dry weight (EC & MENVIQ, 1992)
- ERM = Effects range median; dry weight (Long and Morgan, 1991)
- PEL-HA28 = Probable effect level for Hyallela azteca; 28 day test; dry weight (USEPA, 1996)

Specific sediment benchmark levels for metals and semi-volatile organics are further discussed in Section 5.3.2, and listed in Appendix B.

Two caveats for these SQGs should be noted. First, they should be normalized for total organic carbon (TOC), and DWQ's laboratory does not have the equipment to measure that constituent. Secondly, no total metals concentration benchmarks exist, which means we cannot account for cumulative metals effects.

We used benchmarks as part of a larger screening process. All lines of evidence available, including toxicity bioassays, benthic macroinvertebrate surveys, and water quality chemistry, were used to make a decision on the likelihood of pollutants to impact the benthos.

5.1.2 Site Selection

There were only two primary chemical and toxicological stations for this project.

- *Corpening Creek at Currier St.* This site is located about 0.5 miles from downtown Marion. DWQ collected samples here for suspected stressor pollutants on numerous occasions. Additionally, six bioassays were performed using water collected at this site.

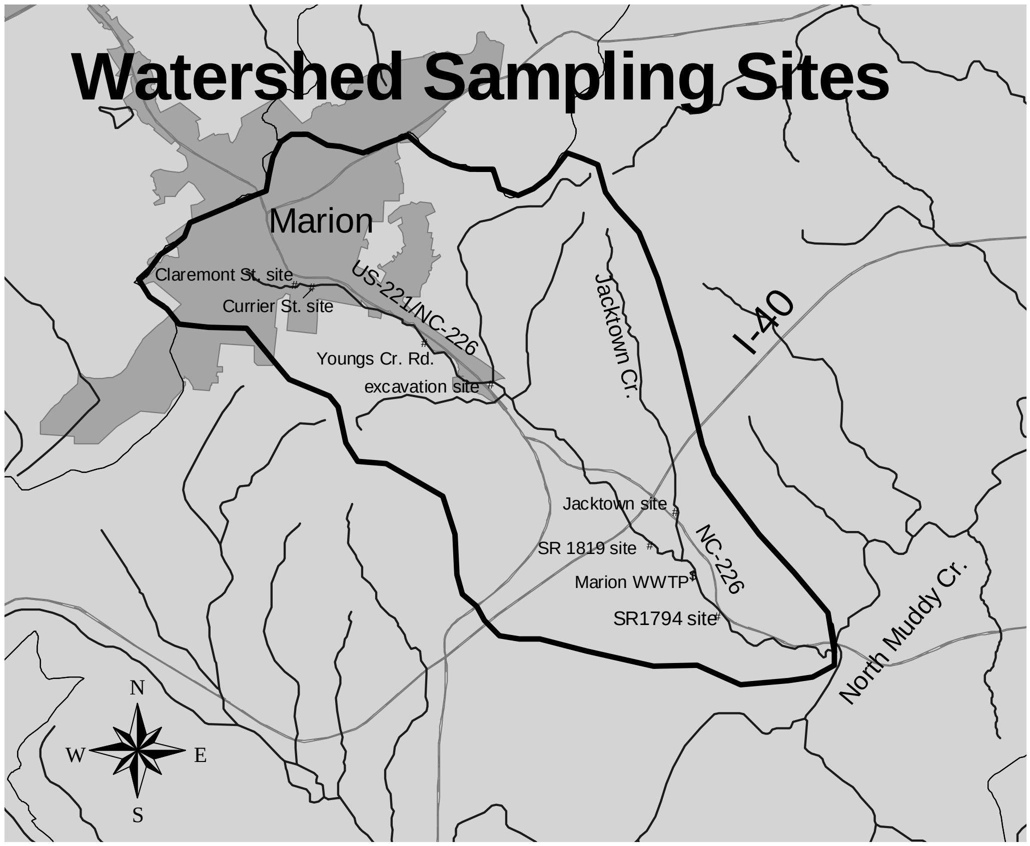
- *Corpening Creek at SR1794.* This site is the most downstream and is the aforementioned integrator site. We sampled this primarily to evaluate what caused the benthic impairment. Also, it provides indications of impacts from the wastewater treatment plant and from land applied sludge.

DWQ sampled these two sites primarily to evaluate what caused the benthic impairment.

Secondary sites, where at least one sample was collected, include:

- *Corpening Creek at Youngs Fork Rd.* DWQ analyzed one sediment sample from this site for metals, semi-volatile organics and pesticides.
- *Corpening Creek atUS-221/NC-226 (near excavation site).* DWQ collected suspended sediment and total residue samples here following a storm.
- *Jacktown Creek at NC-226.* This is the watershed reference site. DWQ analyzed one sediment sample from this site for metals, semi-volatile organics and pesticides.

Figure 5.1



5.2 Water Quality Characterization

During the two years between July 2001 and July 2003, DWQ collected four baseflow and five storm samples at the SR1794 integrator site. Results are shown in Table 5.2 and Appendix B.

Table 5.2 Means and Ranges of Selected Parameters at SR1794

	Baseflow			Stormflow		
PARAMETER	n	mean	range	n	mean	range
DO (mg/L)	4	9.9	9 - 11.3	5	10.1	8 - 13.7
pH (standard units)	3	7.2	7.1 - 7.3	5	6.8	5.9 - 7.3
Specific conductance (uS/cm)	4	153	126 - 171	5	126	80 - 156
Ammonia nitrogen (mg/L)	4	0.016	0.005 - 0.03	4	0.018	0.01 - 0.03
Total Kjedahl nitrogen (mg/L)	4	0.25	0.2 - 0.36	4	0.14	0.1 - 0.24
Nitrate+nitrite nitrogen (mg/L)	4	1.4	0.41 - 2.6	4	1.28	0.63 - 2.3
Total nitrogen (mg/L)	4	1.65	0.51 - 2.8	4	1.42	0.73 - 2.4
Total phosphorus (mg/L)	4	0.22	0.04 - 0.37	4	0.41	0.03 - 1.15

Dissolved oxygen levels were always above the state standard. Since it is a high gradient stream, one would expect adequate dissolved oxygen from aeration caused by turbulence. We cannot rule out the presence of low dissolved oxygen, however, as it may occur during the night (when DWQ did not sample) as part of diurnal fluctuation in photosynthesis and respiration by periphyton. Also, for the same reason, low dissolved oxygen could occur in the upper part of the substrate where benthic macroinvertebrates often reside.

Nitrogen and phosphorus concentrations were high compared to EPA's recommended nutrient criteria (USEPA, 2000). For the North Carolina mountain region (ecoregion 66), total nitrogen and total phosphorus criteria are 0.16 mg/L and 0.007125 mg/L, respectively. These criteria are the median values for all seasons' 25th percentiles, based on data collected at 55 streams for nitrogen and 84 streams for phosphorus between 1990 and 1999. EPA intended for these criteria to be compared to growing season average nutrient levels. Since only a limited number of samples are available for Corpening Creek, DWQ calculated the median value of all samples. These equaled 1.265 mg/L for total nitrogen and 0.235 mg/L for total phosphorus. Based on only eight samples, Corpening Creek's nutrient levels are 7.9 times the recommended level for nitrogen and 33 times the recommended level for phosphorus. Clearly, these levels would be very high on any scale, but bear in mind that the sample pool is small and may not provide good estimates of the true average nutrient concentrations.

5.3 Stressor and Source Identification

A wide range of chemical stressors could potentially impact water quality in Corpening Creek. Urban runoff constituents, particularly semi-volatile organics and metals, as well as pesticides and herbicides, could be present at levels that would stress or kill aquatic life. This possibility will be evaluated using different means in this section.

5.3.1 Water Column Toxicity

This section presents the results of bioassays performed on water samples, followed by a discussion of metals, semi-volatiles organics and other toxicants.

Bioassays.

DWQ performed two acute and four chronic bioassays using water collected from Corpening Creek at both SR1794 and Currier St. (total of twelve tests) between July 2001 and July 2003. Generally, we tried to run acute bioassays using storm samples and chronic bioassays using baseflow samples, but weather and test scheduling prevented rigorous adherence to this procedure. In fact, many chronic samples were collected following periods of rain. We preferred the more sensitive chronic test because it is considered to be more representative of the pollutant exposure (longer duration and two samples) that local benthos experience. Clearly, it does not approach constant, in-situ exposure, but it is the more telling option.

Only one bioassay showed indication of toxicity. A chronic test with samples collected on January 21 and 24, 2003 failed on the basis of reduced reproduction in the test treatment. Test treatment survival was 100 percent, but treatment mean reproduction (21.8 neonates) was significantly different than control mean reproduction (28.2 neonates). The first sample, taken on January 21, had a conductivity of 2200 uS/cm. This is very high conductance and, according to DWQ's aquatic toxicology unit, indicates an ionic imbalance that alone may have caused the toxic effects observed. Unfortunately, that does not say anything about the source of the high conductance, as we did not collect water column samples for further analysis with the January 21 sample. Also, the WWTP did not run any analyses on their effluent that day. DWQ did collect samples on January 24, but they did not show any indication of water column toxicity as no metals benchmarks were exceeded, and no semi-volatile organics were above the laboratory detection limits.

Table 5.3 Chronic and Acute Bioassays – Water Column

	SR1794		Currier St.	
Dates samples collected	**acute**	**chronic**	**acute**	**chronic**
7/24/2001	-	-	pass	-
10/23/2001 & 10/26/2001	-	pass	-	pass
9/25/2002	pass	-	pass	-
1/21/2003 & 1/24/2003	-	**fail** [1]	-	pass
4/22/2003 & 4/25/2003	-	pass	-	pass
7/15/2003 & 7/18/2003	-	pass	-	pass

[1]First sample conductivity was 2200 uS/cm, second was 231 uS/cm.
Water column samples were not collected with first sample.
Water column samples were collected with the second chronic sample, but those showed no metals above NAWQC benchmarks and all non-detects for semi-volatile organics. See Table 5.4

<u>Organic Compounds in Water Samples</u>.

DWQ performed organic chemical analyses (semi-volatile organics, PCBs, PAHs, phenols, MBAS, volatile organics) on a number of water samples collected at SR1794 and Currier St. (see Table 5.4). Sampling dates included 12/3/02 during 'dry' conditions, and 9/25/02, 1/24/03, 4/22/03 and 7/15/03 during 'storm' conditions.

With few exceptions, nothing was detected in these analyses. Three volatile organics were detected in the 9/25/03, but these were reported at less than 1 ug/L. No aquatic life criteria are available for these pollutants, as volatile organic compounds are considered to have low aquatic toxicity (Rowe et al., 1997). Except for spills, concentrations found in highway runoff and urban stormwater are too low to cause a toxic response in aquatic species (Lopes and Dionne, 1998).

One semi-volatile organic, butoxy ethanol, was reported at just over detection level in the 12/3/02 sample.

Table 5.4 Organic compounds detected in water column.

Corpening Creek at SR1794				
Date	Detected analytes	Observed Level (ug/L)	Detection Level (ug/L)	Remark
9/25/2002	sampled for semi-volatile organics (EPA Method 625), purgeable organics and MBAS			
	cis-1,2-Dichloroethene	0.27	0.25	
	Chloroform	0.70	0.25	
	Bromdichloromethane	0.54	0.30	
	(above are all purgeable organics, no semi-volatile class organics or MBAS detected)			
12/3/2002	sampled for semi-volatile organics (EPA Method 625)			
	Butoxy ethanol	11	10	N1, J4
1/24/2003	sampled for semi-volatile organics (EPA Method 625)			
	nothing above detection limits			
4/22/2003	sampled for semi-volatile organics (EPA Method 625) and MBAS			
	nothing above detection limits			
7/15/2003	sampled for semi-volatile organics (EPA Method 625) and MBAS			
	nothing above detection limits			
Corpening Creek at Currier St.				
Date	Detected analytes	Observed Level (ug/L)	Detection Level (ug/L)	Remark
12/3/2002	sampled for semi-volatile organics (EPA Method 625)			
	nothing above detection limits			J4
4/22/2003	sampled for semi-volatile organics (EPA Method 625)			
	nothing above detection limits			

J4 - Data is questionable because of improper laboratory protocols (power outage due to winter ice storm)
N1 - The componet has been tentatively identified based on mass spectral library search and has been given an estimated value.
Note: Typical detection limits are 10 ug/L or higher for semi-volatile organics, and 0.25 ug/L for purgeable organics.

Current- and Past-Use Pesticide Concentrations in Water Samples.
DWQ sampled Corpening Creek for pesticides on two occasions: 9/25/02 and 7/15/03, both of which were considered ‘storm’ conditions. On both dates, no pesticides were found above the DWQ laboratory detection limit. Additionally, the DWQ laboratory did not detect acid herbicides in a sample collected on 7/15/03.

For organochlorine pesticides, detection limit varies but is typically in the 0.015 to 0.025 or higher range (see Appendix B for reported detection levels). For organophosphate pesticides, detection limits are 0.40 ug/L or higher. For nitrogen pesticides, detection limits are usually 4.5 or 15 ug/L, depending on the target compound.

Metals in Water Samples.

Trace metals were commonly found at all sites. The most ubiquitous metals include copper, zinc, aluminum, iron and magnesium. Table 5.5 shows metals concentrations at SR1794 compared to hardness-adjusted aquatic life criteria. The only benchmark that is regularly exceeded is aluminum at chronic levels; this occurs during both baseflow and stormflow.

Two aluminum benchmark exceedances occurred during an acute and a chronic toxicity test (on 9/25/02 and 4/22/02, respectively). Both tests passed, indicating that observed concentrations of aluminum in the stream were likely not harmful on these occasions. However, we did not conduct bioassays on water column samples from 7/5/2001, when we observed the highest aluminum concentration (by far) and highest overall metals concentrations. The available bioassay data do not assess the potential toxicity of the metals concentrations occurring on this date, which may be representative of regularly occurring intermittent conditions.

Since total, rather than dissolved, concentrations were measured, metals bioavailability is difficult to determine. 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 reach may be adapted to local concentrations (NCDWQ, 2003).

Table 5.5 Corpening Creek at SR1794: Total Metals Concentrations and NAWQC Values.

Metal (ug/L)	CHRONIC BENCHMARK [1]	BASEFLOW 10/3/2001	4/3/2002	12/3/2002	6/25/2003	ACUTE BENCHMARK [1]	STORMFLOW 7/5/2001	9/25/2002	1/24/2003	4/22/2003	7/15/2003
Aluminum	87	**120**	**160**	59	**150**	750	**1600**	290	-	210	210
Arsenic	150	-	-	-	-	340	-	-	-	-	-
Cadmium	1.3	-	-	-	-	1.8	-		-	-	-
Chromium	11	-	-	-	-	16	-		-	-	-
Copper	4.6	2.1	2.1	-	2.3	6.5	4.5		3.3	2	-
Iron	1000	590	580	430	440	N/A	**2000**	930	410	560	540
Lead	1.1	-	-	-	-	28.7	-		-	-	-
Manganese	120 [2]	62	79	73	63	2300 [2]	70	74	100	94	77
Mercury	0.77		-	-	-	1.4	-	-	-	-	-
Nickel	26	-	-	-	-	234	-		-	-	-
Silver	0.36 [2]	-	-	-	-	0.99	-	-	-	-	-
Zinc	60	18	11	25	-	60	18		24	14	-

[1] Benchmark values are adjusted according to average hardness except for aluminum, iron and manganese for which no conversions are available.
[2] Tier II benchmark value; NAWQC not available.
- Metal concentration was below detection limit. Detection limits are found in Appendix B.
See Section 5.1.1 for definitions of baseflow and stormflow conditions.

5.3.2 Bed Sediment Toxicity

This section presents the results of various analyses to assess bed sediment toxicity. These analyses include: chemical samples for semi-volatile organics, metals, herbicides and pesticides, and one bioassay.

Sediment Bioassay.

DWQ does not have the capability to run the standard bed sediment bioassay, which uses the organism *Hyallela azteca* (ASTM, 2000; USEPA, 2000b). This is something that would benefit DWQ's program as it stands to reason that bed sediment is an important media to test for toxicity, since, through adsorption, it holds pollutants delivered over time. Also, benthic organisms are almost constantly exposed to stream sediment.

DWQ does have the capability to assess bed sediment toxicity using Microtox®. We ran one test using this tool. With a composite sample of organic-rich, fine-grained sediment collected on July 15, 2003 from several locations at the SR1794 site, DWQ ran serial dilutions of 846.8 to 216,800 mg/kg sediment, dry weight, suspended in a sodium chloride solution. At the highest concentration, the test sediment did not show toxic effects. However, this does not rule out toxic sediment effects on the benthos. See Section 5.1.1 for further explanation.

Organic Compounds and Pesticides in Sediment.

DWQ sampled sediments at four locations: Corpening Creek at SR1794 (3 dates), Currier St. (2 dates), and Youngs Fork Rd. (1 date), and Jacktown Creek at NC-226 (1 date). These samples were primarily analyzed for metals and semi-volatile organics, but we did analyze them for pesticides and herbicides, as well. Sediment benchmark levels for metals, semi-volatile organics are introduced in Section 5.1.1 and listed in Appendix B.

On 6/25/03, DWQ collected organic-rich, fine-grained sediment from all four sites, and had these analyzed for semi-volatile organics and pesticides. The results of all analyses are presented in the Tables 5.6 through 5.10. Polycyclic aromatic hydrocarbons (PAHs) were commonly found, some at probable toxic effect levels. The highest reported levels came from the upper end of the watershed, closer to downtown Marion (Currier St. and Youngs Fork Rd.). Because PAHs are found at higher levels in Corpening Creek sediment, it is very possible that water column concentrations at all sites in the watershed are, at times, high enough to harm the aquatic insect community. PAH sources are discussed in Section 7.2.

Pesticides were only found in the Currier St. sample at threshold effect levels (see Table 5.10). All detected pesticides are of the organochlorine family, which are largely no longer in use.

Table 5.6 Organic Pollutants Collected in Depositional Sediment, Corpening Creek at SR1794

Corpening Creek at SR1794				
Date	Detected analytes	Level (ug/Kg)	Benchmarks Exceeded	Remark
9/25/2002	fluoranthene	170	TEL, TEL-HA28	N3, A
	methyl phenol	260	none	N3, A
	alkane	1050	NA	N1, A
	hexadecenoic acid C16.H30.O2	200	NA	N1, A
	hexadecenoic acid C16.H32.O2	280	NA	N1, A
	squalene C30.H50	350	NA	N1, A
4/22/2003	hexadecenoic acid C16.H30.O2	180	NA	N1
	hexadecenoic acid C16.H32.O2	460	NA	N1
	alkane	222	NA	N1, A
	sigmastenone	740	NA	N1
	friedelin	450	NA	N1
6/25/2003	fluoranthene	220	TEL, TEL-HA28	N3
	hexadecenoic acid C16.H30.O2	290	NA	N1
	hexadecenoic acid C16.H32.O2	400	NA	N1
	alkane	610	NA	N1
	pyrene	170	TEL, TEL-HA28	N3
	benzo(b)fluoranthene	170	none	N3
	sistosterol C29.H50.O	1900	NA	N1
	methyl butanol acetate C7.H14.O2	240	NA	N1
	vitamin e C29.H50.02	440	NA	N1

Fluoranthene and Pyrene are polycyclic aromatic hydrocarbons (PAHs)
N3: estimated concentration less than the laboratory PQL limit and greater than the laboratory method detection limit.
N1: the component has been tentatively identified based on mass spectral library search and has an estimated value.
A: the reported value is the average of two or more values.
NA: no benchmark available.
Benchmark definitions are listed in Section 5.1.1.

Table 5.7 Organic Pollutants Collected in Depositional Sediment, Corpening Creek at Currier St.

Corpening Creek at Currier St.				
Date	Detected analytes	Level (ug/Kg)	Benchmarks Exceeded	Remark
9/25/2002	phenanthrene	360	TEL, ERL, TEL-HA28, TEC	N3
	fluoranthene	1100	**PEL-HA28**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	pyrene	840	**PEL-HA28**, TEL, LEL, MET, ERL, TEL-HA28, TEC	
	benzo(a)anthracene	360	**PEL-HA28**, TEL, LEL, ERL, TEL-HA28, TEC	N3
	chrysene	650	**PEL-HA28**, TEL, LEL, MET, ERL, TEL-HA28, TEC	N3
	benzo(a)pyrene	500	**PEL-HA28**, TEL, LEL, MET, ERL, TEL-HA28, TEC	N3
	bis(2-ehtylhexyl)phthalate	1900	NA	
	benzo(k)fluoranthene	310	NA	N3
	benzo(b)fluoranthene	960	NA	
	indeno(1,2,3-CD)pyrene	330	NA	N3
	benzo(g,h,l)perylene	300	NA	N3
	heptanoic acid C7.H14.O2	560	NA	N1
	phthalic anhydride C8.H4.O3	790	NA	N1
	hexadecenoic acid C16.H30.O2	710	NA	N1
6/25/2003	phenanthrene	400	TEL, MET, ERL, TEL-HA28, TEC	N3
	fluoranthene	900	TEL, LEL, MET, ERL, TEL-HA28, TEC	J2
	pyrene	780	TEL, LEL, MET, ERL, TEL-HA28, TEC	J2
	benzo(a)anthracene	350	TEL, LEL, ERL, TEL-HA28, TEC	N3
	chrysene	470	TEL, LEL, MET, ERL, TEL-HA28, TEC	N3
	benzo(a)pyrene	400	TEL, LEL, ERL, TEL-HA28, TEC	N3
	bis(2-ehtylhexyl)phthalate	760	NA	J2
	benzo(k)fluoranthene	250	NA	N3
	benzo(b)fluoranthene	680	NA	J2
	indeno(1,2,3-CD)pyrene	230	NA	N3
	benzo(g,h,l)perylene	210	NA	N3
	hexadecenoic acid C16.H30.O2	510	NA	N1
	hexadecenoic acid C16.H32.O2	690	NA	N1

N3: estimated concentration less than the laboratory PQL limit and greater than the laboratory. **N1**: the component has been tentatively identified based on mass spectral library search and has an estimated value. **J2**: the reported value failed to meet QC criteria for either precision or accuracy. **NA**: no benchmark available. Benchmark definitions are listed in Section 5.1.1

Table 5.8 Organic Pollutants Collected in Depositional Sediment, Corpening Creek at Youngs Fork Rd.

Corpening Creek at Youngs Fork Rd.				
Date	Detected analytes	Level (ug/Kg)	Benchmarks Exceeded	Remark
6/25/2003	phenanthrene	250	TEL, ERL, TEL-HA28, TEC	N3
	fluoranthene	690	**PEL-HA28**, TEL, MET, ERL, TEL-HA28, TEC	
	pyrene	490	TEL, LEL, ERL, TEL-HA28, TEC	N3
	benzo(a)anthracene	220	TEL, TEL-HA28, TEC	N3
	chrysene	330	TEL, TEL-HA28, TEC	N3
	phytol C20.H40.O	200	NA	N1
	benzo(g,h,l)perylene	150	NA	N3
	benzo(k)fluoranthene	150	NA	N3
	benzo(b)fluoranthene	460	NA	N3
	indeno(1,2,3-CD)pyrene	160	NA	N3
	sisterol C29.H50.O	420	NA	N1
	hexadecenoic acid C16.H30.O2	670	NA	N1
	hexadecenoic acid C16.H32.O2	770	NA	N1
	tetradecanoic acid C14.H28.O2	120	NA	N1

N3: estimated concentration less than the laboratory PQL limit and greater than the laboratory.
N1: the component has been tentatively identified based on mass spectral library search and has an estimated value.
NA: no benchmark available
Benchmark definitions are listed in Section 5.1.1

Table 5.9 Organics Collected in Depositional Sediment, Jacktown Creek at NC-226

Jacktown Creek at NC-226				
Date	Detected analytes	Level (ug/Kg)	Benchmarks Exceeded	Remark
6/25/2003	none			

Detection limit ranges from 0.83 to 100 ug/Kg depending on the constituent. See Appendix B for complete limit of sediment detection limits.

Table 5.10 Pesticides Collected in Depositional Sediment, Corpening Creek at Currier St.

Corpening Creek at Currier St.				
Date	Detected analytes	Level (ug/Kg)	Benchmarks Exceeded	Remark
9/25/2002	chlordane alpha	2.39	ERL	
	chlordane gamma	3.6	ERL, TEC	
	dieldrin	2.24	LEL, MET, ERL, TEC	
	trans-nonachlor	2.08	NA	
6/25/2003	chlordane alpha	7.99	TEL, LEL, MET, ERL, TEC, ***ERM***	
	dieldrin	1.79	none	J2
	trans-nonachlor	9.44	ERL	

NA: no benchmark available
Benchmark definitions are listed in Section 5.1.1

Other Notes:
- This is the only site (including Corpening Cr. at Youngs Fork Rd., and at SR1794, and Jacktown Cr. at NC-226) with any pesticides above detection.
- Only organochlorine pesticides detected* (no organophosphate pesticides, nor nitrogen pesticides detected). Organochlorine pesticides are
- largely no longer used.

Metals in Sediment.

DWQ found many types of metals in relatively fine-grained, organic-rich bed sediment of Corpening Creek and Jacktown Creek. Concentrations were usually below the benchmark levels described in Section 5.1.1; however, levels of zinc, especially, and copper and chromium exceeded some threshold SQGs. A chronic sediment bioassay is needed to determine if these levels adversely impact the benthos.

Table 5.11 Metals Collected in Depositional Sediment, Corpening Creek At SR1794

Corpening Creek at SR1794			
Date	Analyte	Level (mg/Kg)	Benchmarks Exceeded
9/25/2002	Cd	0.57	none
	Cr	32	LEL
	Cu	27	LEL
	Ni	15	none
	Pb	23	none
	Zn	150	TEL, LEL, ERL, TEC, TEL-HA28
	Al	18,000	NA
	Fe	32,000	NA
	Mg	7,100	NA
	arsenic	1.2	NA
	Hg	0.06	none
4/22/2003	Cd	0.2 U	none
	Cr	14	none
	Cu	5	none
	Ni	5.1	none
	Pb	7.2	none
	Zn	31	none
	Al	7,300	NA
	Fe	13,000	NA
	Mg	2,000	NA
	arsenic	0.28 J2	NA
	Hg	0.02 U	none
6/25/2003	Cd	0.45	none
	Cr	27	LEL
	Cu	21	LEL
	Ni	12	none
	Pb	20	none
	Zn	140	TEL, LEL, ERL, TEC, TEL-HA28
	Al	21,000	NA
	Fe	34,000	NA
	Mg	7,200	NA
	arsenic	1.1	NA
	Hg	0.05	none

NA: no benchmark available
Benchmark definitions are listed in Section 5.1.1

Table 5.12 Metals Collected in Depositional Sediment, Corpening Creek at Currier St.

Corpening Creek at Currier St.			
Date	Analyte	Level (mg/Kg)	Benchmarks Exceeded
9/25/2002	Cd	0.51	none
	Cr	18	none
	Cu	33	LEL, MET, TEL-HA28, TEC
	Ni	9.2	none
	Pb	40	TEL, LEL, ERL, TEL-HA28, TEC
	Zn	180	TEL, LEL, MET, ERL, TEL-HA28, TEC
	Al	13,000	NA
	Fe	24,000	NA
	Mg	7,900	NA
	arsenic	1.8	NA
	Hg	0.05	none
6/25/2003	Cd	0.35	none
	Cr	20	none
	Cu	15	none
	Ni	9.8	none
	Pb	25	none
	Zn	120	LEL, ERL, TEL-HA28
	Al	13,000	NA
	Fe	25,000	NA
	Mg	6,600	NA
	arsenic	1.2	NA
	Hg	0.03	none

NA: no benchmark available
Benchmark definitions are listed in Section 5.1.1

Table 5.12 Metals Collected in Depositional Sediment, Corpening Creek at Youngs Fork Rd.

Corpening Creek at Youngs Fork Rd.			
Date	Analyte	Level (mg/Kg)	Benchmarks Exceeded
6/25/2003	Cd	0.2 U	none
	Cr	11	none
	Cu	7.5	none
	Ni	4.6	none
	Pb	11	none
	Zn	65	none
	Al	6,500	NA
	Fe	13,000	NA
	Mg	2,800	NA
	arsenic	0.62	NA
	Hg	0.02 U	none

NA: no benchmark available
Benchmark definitions are listed in Section 5.1.1

Table 5.13 Metals Collected in Depositional Sediment, Jacktown Creek at NC-226.

Jacktown Creek at NC-226			
Date	Analyte	Level (mg/Kg)	Benchmarks Exceeded
6/25/2003	Cd	0.2 U	none
	Cr	32	LEL
	Cu	9.8	none
	Ni	12	none
	Pb	9.1	none
	Zn	52	none
	Al	12,000	NA
	Fe	23,000	NA
	Mg	3,600	NA
	arsenic	0.38	NA
	Hg	0.02 U	none

NA: no benchmark available
Benchmark definitions are listed in Section 5.1.1

The four metals that exceed threshold sediment benchmarks in the watershed are, in decreasing order of abundance, zinc, lead, copper and chromium. Zinc is the only metal found at high levels in the upper and lower watershed. The 9/25/02 Currier St. sample was the only one to show lead and copper threshold exceedances. Curiously, the chromium threshold was exceeded only in the 6/25/03 Jacktown Creek sediment sample. The sources of these four metals are discussed in Section 7.2.

5.3.3 Organic Enrichment and Dissolved Oxygen

DWQ measured dissolved oxygen each time it collected a water or sediment sample at a given location in the Corpening Creek watershed. This amounted to nine measurements at SR1794 and five measurements at Currier St. It also included measurements during the drought period of late 2001 to late 2002.

DWQ never measured dissolved oxygen below the state standard of 5 mg/L. That does not mean dissolved oxygen sags do not occur, as we never measured DO overnight, when it is likely to be lowest. However, frequent riffle zones and a high stream gradient make it likely that dissolved oxygen is not a problem, despite a ubiquity of periphyton (attached algae).

It appears that organic enrichment caused by excessive nutrient loading is more of a problem. Observed water column nutrient levels are shown in Table 5.14. Nitrogen and phosphorus concentrations were high compared to EPA's recommended nutrient criteria (USEPA, 2000b). For the ecoregion where Corpening Creek is located (ecoregion 66, mountain region spanning several states), total nitrogen and total phosphorus suggested criteria are 0.16 mg/L and 0.007125 mg/L, respectively. Note that these values are **not benchmarks indicating harmful levels**; rather, they are suggested levels that were purposely chosen to serve as a 'high bar' for states to consider for adoption. DWQ has plans to develop their own nutrient criteria, using just North Carolina data (EPA's levels were based on data from several states). In the meantime, EPA's recommended levels will be used in this report as a loose measure by which to compare observed nutrient levels in Corpening Creek.

These criteria are the median values for all seasons' 25th percentiles, based on data collected in the ecoregion at 55 streams for nitrogen and 84 streams for phosphorus between 1990 and 1999. EPA intended for these criteria to be compared to growing season average nutrient levels. Since only a limited number of samples are available for Corpening Creek, DWQ calculated the median value of all samples. These equaled 1.265 mg/L for total nitrogen and 0.235 mg/L for total phosphorus. Corpening Creek's nutrient levels are 7.9 times the recommended level for nitrogen and 33 times the recommended level for phosphorus. Clearly, these levels would be very high on any scale.

The impact of high nutrient levels on the biological community appears to relate more to the available food types and consequent community structure, than to low dissolved oxygen levels. Nutrients serve as food for two general types of algae: phytoplankton that float freely in the water column, and periphyton, which attaches to rocks. These algae then become the food for higher organisms on the food chain, such as benthic macroinvertebrates and fish. The types of macroinvertebrates and fish that prefer algae as their primary food source out-compete those that favor other food sources. Consequently, the assemblage of aquatic organisms in a nutrient-rich stream like Corpening Creek does not indicate a balanced community. The community surveys conducted by DWQ's Biological Assessment Unit corroborate this concept.

Table 5.14 Observed Nutrient Concentrations in Water Column, Corpening Creek at SR1794.

Parameter (mg/L)	BASEFLOW 10/3/2001	4/3/2002	12/3/2002	6/25/2003		STORMFLOW 7/5/2001	9/25/2002	4/22/2003	7/15/2003	50th percentile (all data)
Ammonia, NH3	0.01 - U	0.02	0.02 -U	0.03		0.01	0.02 - U	0.03	0.02	0.015
Total Kjedahl Nitrogen, TKN	0.2	0.2 - U	0.36	0.21		0.2 - U	0.24	0.2 - U	0.2 - U	0.15
Nitrite + Nitrate, NO2 + NO3	2.6	0.41	2.3	0.42		2.3	0.89	0.63	1.3	1.095
Total Nitrogen, TN	2.8	0.51	2.66	0.63		2.4	1.13	0.73	1.4	1.265
Total Phosphorus, TP	0.37	0.14	0.33	0.04		1.15	0.38	0.03	0.09	0.235

U: Indicates that the analyte was analyzed for but not detected above the practical quantitation limit. The number shown is equal to the laboratory's practical quantitation limit.
TKN = organic N + NH3
TN = TKN + NO2 + NO3
When TKN has U remark, we treated the value as half of detection (0.1 mg/L) to calculate TN.
Data for 12/3/02 are questionable because of improper laboratory protocols (power outage due to winter ice storm).
See Section 5.1.1 for definitions of baseflow and stormflow.

Section 6
Channel and Riparian Conditions

The characterization of stream habitat and riparian condition at benthic macroinvertebrate sampling sites provides additional information to the assessment of conditions in the Corpening Creek watershed. This section provides a more holistic look at the condition of the stream network beyond several sampling sites. This broader 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.

Project staff walked about half of the 4.7 mile mainstem of Corpening Creek, and the lower portion of Jacktown Creek. This section summarizes channel and riparian conditions, and discusses likely future changes in stream channels.

6.1 Summary of Existing Conditions

6.1.1 Overall Channel and Riparian Condition

Channel Conditions. Corpening Creek and its tributaries have been historically incised to varying degrees. The areas with the most pronounced incision are the headwaters to Claremont St., and below Youngs Creek Rd. to the confluence with the N. Muddy. For the most part, shallow bedrock prevents this erosive process from progressing further. It appears that presently the increased stream energy, from continued development and consequent impervious surface additions, is being directed towards streambank erosion. As a result, channel aggradation is widespread, with silt and fine sand accumulations up to one foot or more, in places. This produces unstable sediment habitat for the benthic macroinvertebrate community. Typically, the lower watershed (Jacktown Cr. and Corpening Creek below Youngs Creek Rd.) has the most severe sediment accumulation.

The channel network as a whole is rather unstable. It minimally maintains its natural sinuosity, and channelization, presumably from historical incision, is evident. The stream rarely has access to its flood plain. Severe streambank erosion exists in several locations (Jacktown Cr. between I-40 and NC-226, Corpening Creek below Youngs Fork Rd), which may be an indication that the stream is attempting to build a new flood plain.

Riparian Conditions. For the most part, the stream network of Corpening Creek watershed is protected by a riparian buffer. Exceptions exist between downtown Marion and the intersection of NC-226 and US-221; over this length of the creek, trees are absent in many places, and the riparian zone narrows to nothing. The most common riparian description in this reach, however, is 10-15 feet wide, with herbaceous cover and occasional trees.

Even the streambanks with good riparian buffer coverage have many places where stormwater pipes empty into the stream channel, thus negating the positive effect the buffer might have had through filtering runoff from a broader area.

Also, with no modern stormwater regulations, these discharges are likely to both carry an ample quantity of pollutants, and reach high volumes following storms.

In the past couple years, the mid-watershed, around the intersection of NC-226 and US-221, seems to be developing the fastest. The stream may have lost much of its riparian buffer during, or just before, the project in this area.

Aquatic Habitat. In-stream habitat in the Corpening Creek watershed is probably suitable to support aquatic life in most locations. Cobble and gravel covered riffles are frequent (distance between riffle sections is usually less than 2-3 times the width of the stream), but the filling of pools by fine-grained sediment (aggradation) is evident throughout the watershed. Importantly, many riffles may become embedded if sediment loading and stormwater flows are not addressed soon. This would likely have very negative effects on the benthos, because it would take away a key habitat category.

Instream organic microhabitat is surprisingly limited. One would think with decent riparian buffers, which exist along Corpening Creek, more sticks and leaf packs could be found in the stream. Perhaps storm flows flush this organic material from the stream channels. Along the banks there tends to be more organic material; however, the stream is widening in many places and this serves to remove organic material with the bank sediment.

DWQ does not know the Rosgen stream classification for Corpening Creek. A geomorphic assessment should be conducted before any stream channel restoration is initiated.

6.2 Future Changes

Corpening Creek and its tributaries appear to be responding to the altered hydrologic conditions brought about by an increase in impervious cover in the mid reaches of the watershed. Further stream widening is the most likely scenario, as shallow bedrock prevents incision. The incision may have happened in the recent past and now the stream is widening to develop a new floodplain, resulting in high stormwater flows. This widening may continue until the channel width is sufficient to allow for stabilization of eroded banks and a new geomorphic floodplain develops within the incised channel (Schumm et al., 1984; Simon, 1989; Simon and Darby, 1999). As widening occurs, bank habitat will remain unavailable to benthic organisms in many areas. Baseflow water depths will become more shallow, potentially resulting in increased water temperatures, and in lower dissolved oxygen levels, though this outcome is less likely due to the high gradient of the stream profile.

Figure 6.1 Looking up Jacktown Creek from Farview Rd. Stream is incised and lacks a riparian buffer.

Figure 6.2 Looking up Corpening Creek from Jacktown Rd. Stream has significant sedimentation.

Figure 6.3 Looking up Corpening Creek from Youngs Fork Rd. Sedimentation is significant, and riparian buffer recently cut. Riffles still have good coverage of cobbles.

Section 7
Analysis and Conclusions – Causes and Sources of Impairment

This section analyzes the likely causes of impairment in the Corpening Creek watershed, drawing on the information presented earlier in this report. The sources or origin of these key stressors are also discussed.

Admittedly, the project focused more on causes than on sources. The goal is to move Corpening Creek to the appropriate part of the 303(d) list, and then later, with more data on sources, develop a TMDL, or implement a management strategy.

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 the 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.] Acknowledgement for significant assistance on this section, as with the rest of this project, is owed to **DWQ's Watershed Assessment and Restoration Project**, which preceded this project and had the same objectives (NCDWQ, 2003).

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

A 'strength of evidence' approach 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).

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 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 that has an impact sufficient to cause biological impairment. If multiple stressors are individually capable of causing the 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.

- **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 will generally 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 the causes of or contributors to impairment.

7.1.2 Candidate Stressors

As outlined in Section 3, the primary stressors evaluated were:

- Habitat degradation—sedimentation;
- Habitat degradation—lack of microhabitat;
- Scour due to hydromodification;
- Toxicity due to nonpoint source impacts;
- Toxicity due to point source impacts;
- Nutrient enrichment.

7.1.3 Review of Evidence

Corpening Creek is impaired for its entire length in the study area, a condition that has been evident since 1985. It is not known when the last time Corpening Creek was unimpaired (had a balanced biological community).

Habitat degradation—sedimentation. Sedimentation is evident in many of the stream pools of Corpening Creek. Relevant lines of evidence include benthic macroinvertebrate community data, habitat and geomorphic evaluations, and watershed characteristics.

Stream surveys and habitat assessments indicate that sedimentation is occurring, but has probably not yet reached a point where it can be considered a primary cause of impairment. Most of the riffles are not embedded whatsoever. The pools, on the other hand, have considerable amounts of fine-grained (e.g., sand and smaller) sediment. This amounts to a loss of one type of habitat for benthos. DWQ does not sample pool habitat, however. Also, usable habitat remains, especially for organisms that prefer faster moving water (e.g. riffles) or possibly streambank areas.

The sedimentation occurring in Jacktown Creek is as severe as that in Corpening Creek. Nevertheless, the benthic community at Jacktown Creek is rated at 'Good-Fair' while Corpening Creek's benthic community remains at 'Fair'. Also, pool habitat is not sampled by DWQ for benthos, so it cannot directly contribute to an impaired rating. This leads us to conclude that sedimentation is either a potential cause or contributor.

If sedimentation is not addressed, riffles and additional habitat may be buried; if so, it seems likely that sedimentation would move from its current level of potential cause of impairment, to a more definite cause of impairment.

Habitat degradation—lack of microhabitat. Habitat degradation's role in the benthic impairment was further evaluated because preliminary assessments revealed variable habitat quality in Corpening and Jacktown Creeks, with unfavorable conditions in some areas. Relevant lines of evidence include benthic macroinvertebrate community data, habitat surveys, and watershed characteristics.

Benthic communities are impaired throughout the watershed, except in Jacktown Creek. This is the case despite variable habitat quality, which indicates that some other factor is contributing to the impairment. In-stream habitat ranges from more to less degraded throughout the watershed. Very limited to moderate amounts of organic microhabitat are present at sites throughout the watershed; this sometimes, but not always, coincides with the adequacy of the reach-specific riparian zones. That is, those reaches with woody riparian zones tend to have more organic microhabitat than those with only herbaceous riparian cover.

Streambank erosion removes habitat in one sense (removes undercut banks), while creating it in others (adds root structure as potential habitat and whole trees, at times, as well).

Local geology includes frequent bedrock outcrops, even in the stream channel. This provides a source of larger clasts, which may be broken apart by weathering processes within the stream channel.

The periphyton present on many larger clasts is the type that does not offer habitat to aquatic insects, as it is not the filamentous variety.

In sum, lack of microhabitat appears to be more of a contributing stressor than a primary, or even cumulative, cause of impairment.

Scour due to hydromodification. Scour is closely related to habitat degradation, because it relates to elevated streamflow, which also causes sedimentation and removes microhabitat. Scour will be defined as streamflow that washes aquatic insects downstream, away from their original habitat.

There is indication that scour occurs in Corpening Creek. Incised stream channels are common, though they usually are not more than a few meters below the streambanks. It appears that further incision has been impeded by bedrock in the stream bottom. In these cases, the stream's energy has been diverted to the sides, causing streambank erosion. This evidence of erosion suggests that some degree of scour occurs in the stream. It is difficult to say if this scour is sufficient to severely impact the benthos. Since some microhabitat, like leaf packs, remains in the stream, the elevated flows appear to not affect the whole channel, otherwise leafpacks might be washed away. If this were the case, the limited microhabitat would leave some locations for aquatic insects to cling during high flow events.

DWQ believes that scour is a less important stressor, perhaps in the contributing stressor class of causes of impairment.

Toxicity due to nonpoint source impacts. DWQ evaluated toxicity as a cause of impairment because the initial benthic community survey for Corpening Creek indicated toxic impacts were evident (e.g., community composition, mentum deformities). That the watershed is highly developed also raised some concern, since this translates to a wide variety of potential toxicant sources. Six lines of evidence are relevant: water and sediment chemistry data, water bioassays, one sediment bioassay, watershed characteristics and benthic community data.

All the benthic macroinvertebrate surveys conducted in the Corpening Creek watershed exhibit high BI or EPT BI values, indicating the prevalence of organisms tolerant of a variety of stressors. A mentum deformity analysis performed on midges collected at SR1794 in April 2001 indicated toxic conditions (see Section 4.1.1).

Watershed characteristics, such as a high level of development and high traffic volumes, suggest the potential for higher loading levels of many pollutants. Downtown Marion is located in the headwaters. The middle reach of Corpening Creek has been more recently developed, including an area near the intersection of NC-226 and US-221 that was developed during this study. The lower reach has some industry (lumber treatment and storage facility), a wastewater treatment plant and area for sludge application, and a large refueling station (DOT).

DWQ conducted four chronic and two acute water column bioassays. One chronic water column bioassay failed. High conductivity measured in the first sample (2200 microOhms/cm) indicates an ionic imbalance that may have caused the toxic effects observed. The source of the high conductance is difficult to determine, as no water samples were collected on the date that had the higher conductivity. On the second sampling day for this bioassay DWQ did collect a metals sample and a semi-volatile organics sample. The results indicated nothing at toxic levels.

Consideration of other factors are warranted when discussing the bioassays. First, DWQ did not conduct a bioassay when the highest pollutant levels were recorded. This leaves the possibility that observed water column pollutant levels could be toxic to local benthos and to *Ceriodapnia dubia*, the test organism. Also, the number of water column samples was limited, and it is likely that higher concentrations occur periodically. So, it cannot be ruled out that toxicity due to infrequent incidents did not occur outside of sampling events.

Another consideration is how laboratory bioassay results apply to in-stream conditions. Or probably more to the point, how can in-stream conditions be represented in bioassays? Though laboratory bioassays are useful for integrating the impacts of multiple pollutants (accounting for cumulative effects), laboratory conditions often will not reflect actual in-stream exposures 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 (such as repeated pulses of various pollutants), a situation difficult to duplicate in lab bioassays. While difficult to assess, the long-term cumulative effects of frequent exposures is likely important (Burton and Pitt, 2001). Also, volatile toxicants can escape a sample and result in bioassay conditions that are not representative of in-stream toxicant levels.

Water column chemical analyses included samples for toxic constituents such as metals, organics, MBAS and pesticides. In the metals category, aluminum was the only parameter consistently above NAWQC benchmarks (mostly chronic, though one acute exceedance). Iron was above the chronic benchmark on one occasion. North Carolina metals standards and action levels were exceeded only in one instance for iron. North Carolina does not have an action level or standard for aluminum. DWQ's laboratory detected three volatile organics and, in numerous sampling days, only one semi-volatile organic. None of the detected organic pollutants were at high levels. Finally, lab analyses found no chlorinated, organophosphate or nitrogen pesticides above detection limits on two samples dates. In sum, with the exception of aluminum, DWQ found little evidence of toxicity in water column samples.

Sediment chemistry analyses for metals, organics and pesticides were done on samples from Corpening Creek at SR1794, Youngs Fork Rd, and Currier St., and from Jacktown Creek at NC-226. There were a number of metals benchmarks exceeded. At SR794, zinc levels exceeded several threshold (toxic effects possible, not probable) benchmarks on two of three occasions. Copper and chromium exceeded one threshold benchmark in two of three samples.

The site with the most metals benchmarks exceeded was Currier St; here, zinc, lead and chromium exceeded many threshold benchmarks in one sample, while only zinc was possibly toxic in the second sample. Sediment samples for metals at Youngs Fork Rd. had no benchmark exceedances, while Jacktown Creek at NC-226 topped one chromium threshold benchmark.

The organic pollutants detected in sediment analyses mostly pointed to polycyclic aromatic hydrocarbons (PAHs). At SR1794, a total of three threshold PAH benchmarks were exceeded in two of three samples. Corpening Creek sediment from the Currier St. site had much higher levels of PAHs in two samples. The first sample included five **probable** benchmarks exceedances (with many threshold exceedances), while the second sample had many threshold exceedances. Samples from the Youngs Fork Rd. site exceeded one probable benchmark and numerous threshold benchmarks for PAHs. Importantly, sediment from Jacktown Creek showed **no** benchmark exceedances for organics.

Sediment pesticides levels did not raise a flag at SR1794, with nothing above detection levels on three sample dates. The Currier St. site, however, had three pesticides at levels beyond threshold benchmark levels and one pesticide (chlordane alpha) exceeding a probable benchmark. These higher levels of pesticides did not persist to the Youngs Fork Rd. site in the one sample taken there. Also, the Jacktown Creek sediment had no detectable pesticides.

To summarize, sediment chemistry showed toxicity according to published benchmarks for zinc, copper, chromium, PAHs and chlorinated pesticides. Toxicant levels were definitely highest, and most likely to cause impairment, closer to the city of Marion (Currier St. site). At SR1794, the integrator site and location of regular benthic macroinvertebrate surveys, aluminum and PAH levels were present at possible effect levels. Copper and chromium also exceeded a single benchmark, so their contribution to the impairment cannot be ruled out.

DWQ conducted one sediment bioassay using Microtox®. This test uses bioluminescent marine bacteria, *Vibrio fischeri*. It showed no evidence of toxic effects. A long term bioassay using *Hyallela azteca* would be preferable, but, due to resource constraints, could not be performed.

The evidence for toxicity is diverse and complicated; nevertheless, benthic community composition, midge deformity analysis, one failed bioassay, and numerous benchmark exceedances by water column and sediment samples suggest that toxic conditions contribute to the Corpening Creek benthic impairment. The specific pollutants responsible for this toxicity cannot be determined with certainty and may be variable. Leading candidates include PAHs, aluminum, copper, chromium and chlorinated pesticides.

The reach habitat is adequate enough, since the habitat in Jacktown Creek is no better than that in lower Corpening Creek, while the benthic community at Jacktown Creek has been judged as not impaired. The primary difference between the two streams is the relative prevalence of toxicity in Corpening Creek. **Thus, DWQ believes that toxicity is primary cause of the benthic macroinvertebrate impairment**.

Organic enrichment. DWQ considered organic enrichment as a cause of impairment because the initial benthic community surveys reported potential impacts from organic loading. Three lines of evidence are relevant here: benthic community data, fish community data, and water quality monitoring data.

Recent benthic community surveys included organic enrichment indicator species, particularly in the upper site at Claremont Street. Common rust colored attached algae support this assertion.

The nature of the organic enrichment seen in Corpening Creek does not seem to extend to low dissolved oxygen (DO), as that parameter was never measured below 6.0 mg/L at any of the sites. This may not be the whole story, however, as DWQ did not take DO measurements at night, or during the early morning, when the diurnal cycle of photosynthesis would produce the lowest levels of DO. In the stream's favor is a relatively high gradient, which may be adequate to maintain healthy DO levels. It may still be possible that low dissolved oxygen occurs in organic-rich, periphyton-covered sediment.

Another impact of high nutrients and subsequent algal growth is the advantage gained by aquatic insects that prefer algae as their food source. These organisms tend to be placed in the pollution tolerant class of insects.

A second metric that bears on the organic enrichment question is the fish community survey conducted by DWQ in September 2002. This study found that herbivorous fish were most abundant (60% comprised of central stoneroller and bluehead chub), while intolerant species were absent. Additionally, the total number of fish collected was very high. The biologist concluded that these observations indicated nutrient enrichment.

Nitrogen and phosphorus levels were elevated. The average concentrations exceed EPA's draft recommended nutrient criteria significantly. However, in free-flowing streams biological response to high nutrient loading is difficult to characterize, and depends on shading, stream velocity, fate of the nutrients, and other factors. The prevalence of attached algae indicates that at least some of the nutrients are absorbed locally.

The strength of evidence regarding organic/nutrient enrichment points to this as a cumulative cause of impairment.

7.1.4 Conclusion

Multiple stressors impact aquatic organisms in Corpening Creek. The watershed is highly developed, and characteristic of such urbanizing area, multiple stressors are evident. The leading stressors, in decreasing order of impact, are:

- Toxicity. Primary cause of impairment.
- Nutrient enrichment. Cumulative cause of impairment.
- Scour due to hydromodification. Contributing stressor.
- Habitat degradation-lack of microhabitat. Contributing stressor.
- Habitat degradation—sedimentation. Potential cause.

Other than toxicity, the relative contribution of each of these is difficult to differentiate based on this study.

7.2 Sources of Impairment

The primary pollutants deemed to cause the biological impairment in Corpening Creek are toxicants, sediment and nutrients. DWQ provides a brief discussion below on potential sources of these pollutants.

<u>Toxicants</u>. Based on water column and sediment chemistry data, we know that the following potentially toxic pollutants occur at elevated levels: aluminum, zinc, PAHs, copper, chromium and chlorinated pesticides. There may be other toxicants that have not been identified through this study. The observed toxicants are common to highly developed watersheds and may originate in residential, commercial and industrial areas, and vehicles. Contaminants are probably transported via a variety of pathways, including stormwater runoff, seepage from groundwater, periodic spills or unpermitted discharges to the storm sewer system.

The wastewater treatment plant has no limits for copper, zinc or chromium. Thus it appears that the treatment is only a minor contributor, at best, to the higher levels of metals observed in the SR1794 sediment and streamflow. There is not a discharge limit on aluminum; the monitoring requirements should be remedied, given the high levels of aluminum observed in numerous water column samples.

More specific information on potential sources of PAHs, copper, zinc and lead is provided below. Less specific source description is provided for pesticides.

Polycyclic Aromatic Hydrocarbons (PAHs). DWQ used a publication by Van Metre et al. (2000) as the primary source of information on PAHs. PAHs come from burning of petroleum, oil, coal and wood (fossil fuels). Automobiles, heating and power plants, industrial processes, and refuse and open burning are considered to be the principal sources. The PAHs observed in Corpening Creek are mainly the type that come from combustion; these include flouranthene, pyrene, benz(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(e)pyrene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and benzo(g,h,i)perylene. Nationally, over the past few decades there have been improvements in sediment quality caused by changes in power generation and home heating technology. These advances have been offset by increases in other stormwater PAH sources, primarily vehicle use. Specific automobile sources of PAHs are especially car emissions and crankcase oil, but also tire and roadway wear.

Two observations from the monitoring data are worth noting. First, PAHs are not in the Jacktown Creek sediment. This supports the notion that background atmospheric deposition of PAHs is not the primary issue; there must be a local source or sources (probably vehicle emissions or crankcase oil) that cause Corpening Creek sediment to contain PAHs. Secondly, PAHs are higher in the sediment near downtown Marion, than they are in the lower watershed. This indicates that the largest source is in downtown Marion, though it could be that vehicle use in the watershed is more uniform and higher flows dilute the PAHs lower in the watershed.

About 80 percent of the SVOCs in runoff are attached to suspended solids (Lopes and Dionne, 1998).

Copper. Copper originates from various urban sources. The primary source of copper in urban stormwater is deposition of abraded automobile brake linings (brake emissions) on roads (Davis et al., 2001; Malmqvist, 1983; Hewitt and Rashed, 1990). Davis et al. (2001) estimated that copper from brake wear composed at least 50% of copper in stormwater; this was from an analysis of a low density residential area that assumed residents account for all vehicle traffic, or where all travel outside the area is matched by non-resident travel inside. The Corpening Creek watershed includes downtown Marion, and several major highways, all of which have high traffic volumes. Secondary sources include building siding (possibly from wood preservative) and roofs (especially commercial buildings), and wet and dry atmospheric deposition (Davis et al., 2001).

Copper exceeded several benchmarks in a Currier St. sediment sample, and one benchmark in two SR1794 sediment samples. At these levels it may not be a problem for the benthic community. Also, given what we know about the sources of copper, it is likely that no one area is the origin of copper; major copper sources are likely to be found at crowded road intersections.

Zinc. According to Davis et al. (2001), the primary nonpoint sources of zinc are building siding (58%, particularly brick, then concrete and painted wood), and tire wear (25%).

Zinc levels in Corpening Creek sediment are high at Currier St. and SR1794, but not at Youngs Fork Rd. This may have as much to do with the organic content of the sediment as proximity to zinc sources; at any rate, it does not provide clues for more specific source identification. Zinc levels in Jacktown Creek sediment are acceptable.

Chromium. Chromium is present in potentially toxic levels only in the sediments of the lower watershed (SR1794 site and Jacktown Cr. site).

That chromium is high in the Jacktown Creek sediment, as well as the Corpening Creek sediment, suggests that the wastewater treatment plant is not a significant source. The Jacktown Creek watershed may be the best place to begin looking for a chromium source(s). It should be noted that, like copper, only one chromium benchmark is exceeded, so it is not at all certain that chromium exists at harmful levels. However, it could be a cumulative or contributing stressor.

Lead. According to Davis et al. (2001), the primary sources of lead in urban stormwater are dry deposition (42%), wet deposition (33%), building siding (12%, brick and painted wood are highest, by far), and then lesser amounts from tire wear, brake wear and roofs (total from all three is 13%).

High lead levels exist only at the Currier St. site. Thus, the source(s) of lead is somewhere in downtown Marion or its surrounding residential areas. This is surprising as the sources listed above suggest that lead primarily comes from the atmosphere. Of course, lead could be deposited on impervious surfaces and be washed into the stream network during storm events. Perhaps there are buildings in the Currier St. catchment that have high levels of lead in their siding.

Organochlorine pesticides. Pesticides were only found in the stream sediment at Currier St., which is situated among a medium density residential area, close to downtown Marion. The source of the pesticides is likely to be homeowners near Currier St. from some time ago, as organochlorines have largely been phased out of use. It is possible that the identified pesticides were used to kill termites or garden variety insects. Regardless, it seems that the pesticides entered the stream some time ago and will require time to be removed.

Sediment. Much of the sediment accumulating in the channels of Corpening Creek and Jacktown Creek appears to originate within the stream channels. This is likely a response to hydromodification of the watershed. There is no doubt, however, that other sources of sediment exist outside of the drainage network.

EPA defines hydromodification as the alteration of the hydrologic characteristics of surface waters resulting in degradation of resource conditions (USEPA, 1977). While channelization has impacted some reaches in the study area, the type of hydromodification of primary importance is the alteration of watershed hydrology by greater impervious area and the installation of a storm drainage system. These changes greatly increase the frequency and duration of peak flows, which causes greater in-stream erosion and habitat degradation. Essentially, this seems to have moved sediment from the stream banks, and to a lesser extent bottom, to accumulations of fine sediment in the stream pools.

A grading and construction zone one-quarter mile upstream from the intersection of NC-226 and US-221 appears to be the largest sediment source outside of the stream channel. Much of this area has been without a vegetative cover since this project began in July 2001; there is an excavated hillside and a number of graded terraces adjacent to Corpening Creek. Some of the area has been developed in the past two years (maybe 30%). Sediment fences have been in place, though there are places where they should be, but are not. Also, many are damaged and less than fully effective. DWQ observed sediment loading during at least two of its site visits in July 2001 and December 2002.

Nutrient enrichment. Sources of nutrients and BOD are ubiquitous in a developed watershed such as Corpening Creek. They include atmospheric deposition, and subsequent wash-off from impervious surface through the storm drainage system, or delivery to the stream via groundwater or interflow; leaking sewer lines; illegal connections to the storm sewer system; fertilizer inputs from managed turf areas; and, the wastewater treatment plant.

More specific sources of nutrients include atmospheric deposition, WWTP effluent, land applied sludge, fertilizer, animal waste (domestic and wildlife, runoff and direct deposit in stream), decaying organic matter and soil (trapped there en route to waterways).

7.3 Other Issues of Note

In its favor, the lower reaches of Corpening Creek have the potential to be recolonized by pollution intolerant benthic macroinvertebrates via downstream drift from Jacktown Creek. In April 2001, Jacktown Creek had four additional EPT taxa than Corpening Creek at SR1794, and its entire community was less impacted. Invertebrates can be carried downstream and colonize other reaches. Thus, for the benefit of Corpening Creek, it is important to maintain the more balanced aquatic community now present in Jacktown Creek. See Background Note: The Stress-Recovery Cycle, below.

Background Note: The Stress-Recovery Cycle
Taken from DWQ's WARP Project: Biological Impairment of Upper Swift Creek (NCDWQ, 2003).

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 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 creatures are "adapted" to their environment.

It is now commonly recognized that as watershed 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 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 or 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 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 recolonizing 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 Corpening Creek: Recommended Strategies

As discussed in the previous section, Corpening Creek is impaired by the cumulative impacts of toxicity, habitat degradation and nutrient enrichment. This section considers how these problems can be addressed. A summary of recommendations is included at the end of the section.

Once again it is worth noting that, in this project, DWQ closely followed the template created by the Watershed Assessment and Restoration Program (NCDWQ, 2003). The management strategies that program devised for its watersheds were general enough, and the problems were similar enough, that DWQ altered them slightly to address the problems in the Corpening Creek watershed.

8.1 Addressing Current Causes of Impairment

The objective of restoration efforts is to improve water quality and habitat to the level that they support a more diverse and functional biological community in Corpening Creek. To be sure, this will be difficult as the level of development and in-stream impacts are widespread. A return to unimpacted levels, which existed before any development, is probably not possible without a tremendous investment of resources and change in land use regulations. Restoration to unimpaired levels should be doable, however, if sufficient resources are obtained to install retrofit best management practices (BMPs) and stream channel restoration, and curb pollutant sources (NCDWQ, 2003).

As discussed in Section 7, while the key causes of impairment in Corpening Creek have been identified, how the causes interact remains unclear. Additionally, there are inherent uncertainties regarding how individual BMPs interact to affect receiving water chemistry, geomorphology and habitat (Shields et al., 1999; Urbonas, 2002), and in how aquatic organisms will respond to better conditions. Consequently, the level of management action needed to produce an unimpaired level of biological integrity cannot be determined in advance. This section describes the types of actions needed to improve biological conditions in Corpening Creek, but the combination of activities that will be necessary, and the extent of improvement that will be attainable, will only become apparent over time as adaptive management is implemented. Management actions are suggested below to address individual problems, but many of these actions are interrelated (e.g. particular BMPs or systems of BMPs can de designed to serve multiple functions).

8.1.1 Hydromodification Due to Scour

Though toxic impacts may be the harmful to the aquatic communities in Corpening Creek, DWQ will first address hydromodification, as watershed hydrology is the driver of pollutant transport.

Frequent periods of high-velocity storm flow dislodge benthic organisms and contribute to habitat degradation by removing organic microhabitat and causing bank instability. This will continue unless some of the hydrologic impacts of existing development can be abated. The vast majority of development occurred prior to any BMP requirements. Stormwater controls are necessary to partially restore watershed hydrology by reducing runoff volume and reducing the frequency and duration of erosive flows. Perhaps the best way to regulate the implementation of stormwater management would be to add Marion to the NPDES Phase II stormwater program. The City of Marion should strongly consider becoming a part of this program.

Stormwater retrofits are structural stormwater measures (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.

<u>Stormwater retrofit options</u>. Available structural and nonstructural retrofit practices to reduce hydrologic impacts and remove pollutants have been discussed widely in the literature (e.g. ASCE, 2001; Horner et al., 1994) and detailed BMP manuals (e.g. NCDWQ, 1999c; Maryland Department of the Environment, 2000). Some of these include:

- detention ponds;
- retention ponds;
- stormwater wetlands;
- bioretention;
- infiltration structures (porous pavement, infiltration trenches and basins);
- vegetative practices to promote infiltration (swales, filter strips);
- ‘run on’ approaches (regrading) to promote infiltration;
- reducing hydrologic connectivity (e.g. redirecting of downspouts);
- education to promote hydrologic awareness; and
- changes in design/construction standards.

Determining which BMPs (or which combination of practices) will be most feasible and effective for a particular catchment depends on numerous site specific and jurisdictional specific issues, including: drainage patters; 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, water quality). Considerations in the identification of retrofit sites are discussed by Schueler et al. (1991) and Claytor (1999).

A key design challenge is to maximize hydrologic mitigation and/or pollution removal potential while limiting impacts to infrastructure and existing structures.

DWQ encourages the consideration of a wide variety of practices and approaches. Ponds of various types are probably the practice most familiar to engineers and can indeed be versatile and cost effective. Detention alone, however, does not reduce stormwater volume, 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 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 (limit downstream drift of aquatic macroinvertebrates), alter the food/energy source available to downstream biota, and depending on design and operation, reduce or eliminate downstream baseflows (Maxted and Shaver, 1999; Schueler, 2000a).

Recommendation. What is feasible or cost effective in the way of retrofitting a developed watershed like Corpening 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 available options. In order to have a biologically meaningful impact on watershed hydrology, cost effective projects will likely have to be sought out and implemented over an extended time frame.

1. Short-term. Over the next decade, the city of Marion can investigate retrofit possibilities and implement those that are feasible given current infrastructure constraints.
2. Mid-term. Road realignment, sewer line, 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.

Areas draining directly to the Corpening Creek mainstem or unimpounded tributaries (nearly all of them) should be priority areas for retrofit consideration. Jacktown Creek has less urbanization than other subwatersheds (though it does show evidence of hydromodification – e.g. streambank erosion, minimal organic microhabitat and aggradation), and could provide a base for biological improvement efforts. Priority should be given to retrofits in this subwatershed.

Costs. 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 project treating 10 impervious acres. Treating a single acre costs an average of $25,000 or more.

Only gross estimates of total cost are possible. Claytor (1999) suggests that a minimum of 50% of the impervious portion of a watershed be retrofitted. Thus, for example, a two square mile watershed that is 25% impervious has approximately 320 impervious acres (2 square miles, or 1280 acres, times an imperviousness of 25%). Assuming a total 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).

8.1.2 Toxic Impacts

High levels of PAHs, zinc and other metals have been observed in Corpening Creek sediment, and aluminum has exceeded NAWQC levels in the water column. Still, the particular mix of pollutants of primary concern is less than certain. Long term impacts of repeated exposures may be important, and the most critical toxicants may vary with time, associated with specific events. Source areas likely lie throughout 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). 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 Corpening 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. Implementation of available BMP opportunities for control of stormwater volume and velocities. Recommended earlier in order to reduce scour impacts and improve aquatic habitat potential, these BMPs will also remove toxicants from the stormwater system (the extent of removal will vary depending on the specific structures and pollutants involved.).

2. Development of a stormwater and dry weather sampling strategy for the watershed. Selection of particular BMPs can be more efficient and they can be more effective if information on specific target pollutants and source areas is available. Such information would also aid in the targeting of source reduction efforts (discussed below). To address these needs, a monitoring strategy should be developed based on further watershed reconnaissance.
3. Implementation of stormwater treatment BMPs, aimed primarily at pollutant removal, at appropriate locations. Results of additional monitoring will be important in targeting these BMPs, although some likely “hot spots” (areas of intense activity or high risk) could be identified without further water quality monitoring. Proprietary treatment systems can be considered where adequate space is not available for conventional stormwater BMPs.
4. 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 pollution prevention efforts are the following:

    - Reducing nonstorm inputs of toxicity by:
        a) identification and elimination of illicit connections (actions required under pending phase II stormwater permits);
        b) review of existing information on groundwater contamination and implementation of appropriate measures as 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) outreach and technical assistance to industrial and commercial facilities regarding materials storage practices, spill prevention procedures, and spill control and cleanup procedures;
        b) encourage use of best available technology for scrubbing of automobile exhaust and industrial smokestacks;
        c) prohibit open burning of refuse or other waste in county (PAHs);
        d) provide collection facilities for proper disposal of used tires, crankcase oil and other automobile parts;
        e) encourage use of ceramic brake pads instead of traditional ones that can be primary sources of metals such as copper and zinc;
        f) encourage use of biodiesel in place on conventional diesel fuel.

Addressing vehicle related pollution will be a particular challenge. However, this will be crucial as PAHs and copper, likely the key problem parameters, primarily originate in vehicles and likely travel via stormwater runoff from roadways to the channel network. BMPs to treat parking lot runoff may often be feasible, but addressing roadway runoff will be more difficult. Sand filter systems, which are expensive and require significant maintenance but little space, are recommended and may be required at the busiest traffic intersections. Source control may have to wait for changes in vehicle or component design (e.g., scrubbing technologies for internal combustion engines).

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 is likely to be more effective if carried out by local government, agencies and stakeholders.

8.1.3 Habitat Degradation

Habitat in the study area is limited by scouring stormflows due to the hydrologic impact of historic, recent and ongoing development, and by sedimentation. These factors can be addressed by a combination of stormwater quantity retrofits and stream channel restoration.

Stormwater quantity retrofits, discussed earlier, can partially mitigate existing hydrologic impacts. This will reduce sediment inputs, allow for more rapid healing of unstable areas, and facilitate the development of better in-stream habitat. Such healing is likely to take many years, since the stream is still in the process of adjusting to recent hydrologic alteration of the watershed.

Channel restoration techniques could be used to speed the recovery process. Along some stream channels in the watershed, however, much of the riparian zone consists of areas of healthy forested vegetation, some of which lie in protected natural areas. The process of channel reconstruction could have negative impacts in these areas and from a long term perspective it is probably more prudent to confine channel restoration activities to areas where problems are particularly severe.

Specific recommendations are as follows:

1. A geomorphic survey of the stream channel network should be conducted to determine the areas that are suited to reconstruction.
2. Stream channel restoration should probably be postponed until progress has been made on stormwater retrofits/hydromodification. If not, gains in channel structure and habitat potential may be quickly eliminated by damaging stormflow.
3. The channel below Youngs Creek Dr. to NC-226 (above I-40) should be considered for restoration as incision, streambank erosion and aggradation are more apparent in this area. The most obvious area for stream restoration is at the intersection of the creek with US-221/NC-226, near the excavation site. Incision persists below NC-226, however, wider, more natural riparian areas exist here, as well.
4. Pass local regulations that prohibit all terrain vehicle (ATV) access to stream channels. ATV tracks descend into the stream channel in numerous locations in

the watershed. This destabilizes streambanks and damages in-stream habitat. See Figure 8.1.

Figure 8.1 ATV tracks down streambank, into the stream channel (just upstream from Youngs Fork Rd.).

Stream channel restoration involves re-establishing a stable channel dimension (cross-section), pattern (sinuousity and planform) and longitudinal profile. While other options exist (see NCSU, 2001 and 2002), the most feasible approach to the restoration of most channels in this watershed is probably to construct appropriate floodplain area and channel form within the existing incised channel (Rosgen priority 2 or priority 3 approach). The specific restoration strategy selected will depend on the stream corridor width available (belt width), among other factors (NSCU, 2001 and 2002; Rosgen, 1997). Based on the recent experience of the North Carolina Wetlands Restoration Program (Haupt et al., 2002) and a number of Maryland counties that have active restoration programs (Weinkam et al., 2001), cost of at least $200 per linear foot (about $1 million per mile) should be expected for the restoration of urban stream channels.

Riparian areas are poorly vegetated along much of Corpening Creek. Reestablishment of woody riparian vegetation is probably necessary to ensure an adequate supply of woody material to the stream channel. In addition, properly functioning riparian areas can also serve to reduce inputs of nutrients and other pollutants.

8.1.4 Nutrient Enrichment

Nutrient loading can be addressed in a variety of ways, including stormwater treatment. Additional BMPs constructed to address other problems (see above) are likely to reduce

BOD loading. BMPs targeted at BOD and nutrient removal may be warranted at high loading areas identified during subsequent investigation. Organic and nutrient loading can also be reduced via established practices such as: identification and elimination of illicit discharges; education of homeowners, commercial applicators, and others regarding proper fertilization use; street sweeping; and catch basin clean-out practices. Should the City of Marion be included in NPDES Phase II stormwater program (they are not currently scheduled to be included), the identification and elimination of illicit connections will be required.

8.1.5 Other Concerns

Many water quality impacts can result from the incremental and cumulative impacts of land management decisions made by individual residents and property owners throughout the watershed. Educational efforts directed at homeowners and managers of commercial and industrial areas in the watershed would be useful to promote improved riparian zone management (e.g. leave woody vegetation and keep ATVs out of stream) and the appropriate use of pesticides and fertilizers.

8.2 Addressing Future Threats

Since the upper study area is largely developed, potential threats from construction related sediment inputs and hydromodification from post-construction stormwater are likely to be less substantial than in less built-out watersheds. It is nonetheless important that effective enforcement of existing sediment and erosion control regulations occur on the part of Marion and McDowell County.

To avoid significant channel erosion, it is critical that effective stormwater management occur throughout Corpening Creek watershed. This probably means going beyond controlling the first one-inch of runoff from high density areas, as this is not likely to provide adequate channel protection.

8.3 A Framework for Improving and Protecting Stream Integrity

Watershed restoration of the type necessary to significantly improve Corpening 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 manner. The most long-standing example is probably the restoration of the Anacostia River in the Washington, D.C. area, for which planning was initiated in the 1980s (Anacostia Restoration Team, 1991; Metropolitan Washington COG, 1998; Galli, 1999; Schueler and Holland, 2000). Among the other local areas that have begun to address these issues are Austin, Texas (City of Austin, 2001); Atlanta, Georgia (CH2M-Hill, 1998); and Montgomery County, Maryland (Montgomery County DEP, 2001).

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 in order to provide oversight of project implementation, to evaluate how current restoration and protection strategies are working, and to plan for the future. While state agencies can 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 (Marion, McDowell County), as well as a broad range of other stakeholders, will be critical if conditions in Corpening Creek are to be improved. This effort must include the development of a long term vision for protecting and restoring the watershed, as well as the specific work that will be necessary to support a patient approach to planning and implementing projects to move toward that vision.

8.4 Summary of Watershed Strategies for Corpening Creek

The following actions are necessary to address current sources of impairment in Corpening Creek, and to prevent further degradation. Actions one through five are important to restoring and sustaining aquatic communities in the watershed, with the first three recommendations being the most important.

1. **Feasible and cost-effective stormwater retrofit projects should be implemented throughout the watershed to mitigate the hydrologic effects of development** (increased stormwater volumes and increased frequency and duration of erosive and scouring flows). This should be viewed as a long-term process. Although there are many uncertainties, costs in the range of $1 million per square mile can probably be anticipated.

    a) Over the short term, currently feasible retrofit projects should be identified and implemented.
    b) In the longer term, additional retrofit opportunities should be sought out in conjunction with infrastructure improvements and redevelopment of existing developed areas.
    c) Priorities should include evaluating the retrofit potential of existing in-stream impoundments (the few that exist), retrofitting areas draining directly to Corpening Creek mainsteam, and Jacktown Creek, the largest unimpounded tributary and local reference stream.
    d) Grant funds for these retrofit projects may be available from EPA initiatives, such as Section 319 funds, or North Carolina programs like the Clean Water Management Trust Fund.

2. **A strategy to address toxic inputs should be developed and implemented, including a variety of source reduction and stormwater treatment methods.** As an initial framework for planning toxicity reduction efforts, the following general approach is proposed:
   a) Implementation of available BMP opportunities for control of stormwater volume and velocities. Recommended above to improve aquatic habitat potential, these BMPs will also remove toxicants from the stormwater system.
   b) Development of a stormwater and dry weather sampling strategy in order to facilitate the targeting of pollutant removal and source reduction practices.
   c) Implementation of stormwater treatment BMPs, aimed primarily at pollutant removal, at appropriate locations.
   d) 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. Suggestions for potential source reduction practices are provided.

3. **Stream channel restoration activities should be implemented in target areas, in conjunction with stormwater retrofit BMPs, in order to improve aquatic habitat.** Before beginning stream channel restoration, a geomorphologic survey should be conducted to determined the best areas for stream channel restoration. Additionally, it would probably be advantageous to implement retrofit BMPs before embarking on stream channel restoration, as restoration is probably best designed for flows exemplifying reduced stormwater runoff. Costs of approximately $1 million per mile of channel should be anticipated. Again, grant funds for these retrofit projects may be available from EPA initiatives, such as Section 319 funds, or North Carolina programs like the Clean Water Management Trust Fund.

4. Actions recommended above (e.g. stormwater quantity and quality retrofit BMPs) are likely to reduce nutrient/organic loading and its impacts to some extent**.** Activities recommended to address this 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 BOD and nutrient removal at appropriate sites.

5. Prevention of further channel erosion and habitat degradation will require effective post construction stormwater management for all new development in the study area.

6. Effective enforcement of sediment and erosion control regulations on the part of Marion and McDowell County will be essential to the prevention of additional sediment inputs from construction activities. Development of improved erosion and sediment control practices may be beneficial.

7. Watershed education programs should be implemented and continued by local governments with the goal of reducing current stream damage and prevent future degradation. At a minimum, the program should include elements to address the following issues:

   a) redirecting downspouts to pervious areas rather than routing these flows to driveways or gutters;
   b) protecting existing woody riparian areas on ephemeral streams;
   c) replanting native riparian vegetation on perennial, intermittent and ephemeral channels where such vegetation is absent; and
   d) reducing and properly managing pesticide and fertilizer use.

Section 9
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APPENDIX A

Benthic Macroinvertebrate Sampling

Division of Water Quality
Biological Assessment Unit
18 May, 2001

MEMORANDUM

To:	Jimmie Overton
Through:	Trish Finn MacPherson
From:	Kathy Herring
Subject:	Results of Macroinvertebrate Collections from Youngs Fork Creek (McDowell County)

Background

Chris Roessler of the Modeling/TMDL Unit of the Division of Water Quality (DWQ) requested that the Biological Assessment Unit (BAU) of DWQ conduct benthic sampling in selected watersheds as part of the CAWS project (Collaborative Assessment of Watersheds and Streams). This project is funded by a 104(b)(3) grant and will emulate the WARP project (Watershed Assessment and Restoration). The CAWS project is aimed at determining the causes and sources of benthic impairments to streams. The sites surveyed are all on the impaired streams list, and were selected in a meeting between members of the BAU, Intensive Survey Unit (ISU) and CAWS on February 19, 2001. The request followed a recommendation from the ISU, based on watershed surveys in October, 2000, and from the WARP project outline, to evaluate the spatial extent of the benthic impairments. The purpose of further benthic sampling in these streams was to guide the search for sources of impairment and to determine if the impairment is limited to the previous site sampled, or indicative of a widespread problem. The question is whether the historical data that placed the site on the 303(d) impaired streams list adequately characterized conditions in the watershed.

Historical Data

Youngs Fork Creek, McDowell County – Benthos samples collected from SR 1819 and SR 1794, in 1985, 1990, and 1997 have indicated Fair to Poor water quality. This site has been referred to as Corpening Creek in earlier DWQ reports.

Methods

Habitat assessments were performed at each sampling location using DWQ's Coastal Plain or Mountain/Piedmont Habitat Evaluation Form. This evaluation is based on best professional judgment of 8 habitat metrics including analysis of channel modification, four instream habitat measurements, one streambank measurement, and two riparian zone measurements. Scores are given for each of the eight metrics (seven for coastal streams) and are then totaled (100 points possible). Streams, or monitoring stations, within major ecoregion types and size categories can be compared to one another and to reference locations.

Documentation of habitat characteristics at a sampling site can identify limiting factors that can affect biological communities. Habitat assessment provides baseline information on stream conditions so that changes resulting from natural or human causes can be identified or predicted. Habitat assessments can also determine the consequences on the biota of alteration of stream conditions, such as land use changes and channelization.

Benthic macroinvertebrates were collected at all stations in the Youngs Fork watershed using the Division of Water Quality's standard qualitative sampling procedure. This method includes 10 composite samples: two kick-net samples, three bank sweeps, two rock or log washes, one sand sample, one leafpack sample, and visual collections from large rocks and logs. The purpose of these collections is to inventory the aquatic fauna and produce an indication of relative abundance for each taxon. Organisms were classified as Rare (1-2 specimens), Common (3-9 specimens), or Abundant ($\geq$10 specimens).

Several data-analysis summaries (metrics) can be produced from standard qualitative samples to detect water quality problems. These metrics are based on the idea that unstressed streams and rivers have many invertebrate taxa and are dominated by intolerant species. Conversely, polluted streams have fewer numbers of invertebrate taxa and are dominated by tolerant species. The diversity of the invertebrate fauna is evaluated using taxa richness counts; the tolerance of the stream community is evaluated using a biotic index.

EPT taxa richness (EPT S) is used with DWQ criteria to assign water quality ratings (bioclassifications). "EPT" is an abbreviation for Ephemeroptera + Plecoptera + Trichoptera, insect groups that are generally intolerant of many kinds of pollution. Higher EPT taxa richness values usually indicate better water quality. Water quality ratings also are based on the relative tolerance of the macroinvertebrate community as summarized by the North Carolina Biotic Index (NCBI). Both tolerance values for individual species and the final biotic index values have a range of 0-10, with higher numbers indicating more tolerant species or more polluted conditions. Water quality ratings assigned with the biotic index numbers were combined with EPT taxa richness ratings to produce a final bioclassification, using criteria for Mountain streams.
EPT abundance (EPT N) and total taxa richness calculations also are used to help examine between-site differences in water quality. When the EPT taxa richness rating

and the biotic index differ by one bioclassification, the EPT abundance value was used to produce the final site rating.

Both EPT taxa richness and biotic index values can be affected by seasonal changes. DWQ criteria for assigning bioclassification are based on summer sampling: June-September. For samples collected in April, the biotic index values were seasonally adjusted by adding 0.5.

Youngs Fork Creek off US 226, 2 blocks downstream of Claremont St. in Marion, McDowell County, Catawba subbasin 30, 4/09/01. This site was very near the headwaters, near an industrial/commercial area near Broyhill Industries.

Young Fork Creek off US 226 near Claremont St.

Youngs Fork Creek SR 1819, McDowell County, CTB 30, 4/9/01. This site, upstream of the WWTP has been sampled 3 times previously.

Youngs Fork Creek SR 1819

Youngs Fork Creek SR 1794, McDowell County, CTB 30, 4/9/01. This site, downstream of the WWTP, has been sampled twice previously.

Youngs Fork Cr SR 1794

Jacktown Creek US 226, McDowell County, CTB 30, 4/9/01. This site was chosen as a reference, similar in character, with a more normal conductivity reading for the area. Staff from the ISU recorded higher conductivity values from all sites on Youngs Fork Creek than measured from other drainages in the area during the initial survey in October.

Jacktown Creek US 226

Table 3. Site Locations and Descriptions for Youngs Fork Creek watershed, McDowell County, 4/9/01.

Stream	**Youngs Fork**			**Jacktown Creek**
Collection Date	4/9/01	4/9/01	4/9/01	4/9/01
Location	headwaters	SR 1819	SR 1794	US 226
Width (m)	4	5	5	3-4
Average Depth (m)	0.5	0.1	0.2	0.1
Canopy	40	70	70	80
Aufwuchs	Abundant	Abundant	Abundant	Abundant
Bank Erosion	Severe	Moderate	Moderate	Severe
Substrate (%)				
Boulder	10	20	10	0
Rubble	30	30	20	30
Gravel	40	30	40	30
Sand	20	20	30	40
Habitat Score	53	91	70	67
Conductivity (μmhos/cm)*	150	91	150.3	70
Temperature (^{o}C)	18	18.9	21	22
Do (mg/l)	15.2	12.3	11.1	9.6

*corrected to 25^{0}C

Youngs Fork Creek, also referred to as Corpening Creek in other DWQ memos, originates in downtown Marion in McDowell County. The headwaters are near an industrial/commercial area in Marion and flows from a culvert near Broyhill Industries. From this point Youngs Fork Creek immediately enters a residential area.

The first of three Youngs Creek sites sampled for macroinvertebrates in April, 2001, was located 2 blocks downstream from Claremont Street. This collection resulted in a bioclassification of Poor using DWQ's criteria for mountain streams (Table 6). Youngs Fork at this location was 4m wide and shallow with an abundance of rust colored algae attached to the rocky substrate. The habitat score of 53 reflected the effects of urbanization on a stream: no riparian zone, little canopy and eroding, unstable banks. The conductivity here was 150μmhos/cm, much higher than the range of 50μmhos/cm to 60μmhos/cm range typical of mountain streams.

Youngs Fork Creek at SR 1819 is 5m wide with a rocky, gravely substrate. This mid-reach site on Youngs Fork had an excellent habitat score of 91. However, there was still a considerable amount of algae on the substrate and the conductivity was elevated (91μmhos).

The most downstream site on Youngs Fork Creek, at SR 1794, is located approximately 0.5 miles downstream of the Marion WWTP outfall. This site is also located below the plant's sludge field. The habitat score of 71 reflected a less rocky, more sandy substrate, less instream habitat such as snags, logs and root mats, and fewer riffles than the other Young Fork Creek sites. Conductivity here measured 155 μmhos.

Jacktown Creek entering Youngs Fork Creek near the WWTP, had conductivity values (70μmhos) much lower than any found in Youngs Fork Creek. Jacktown Creek at US 221 averaged 4m wide. The substrate here was a mixture of rubble, gravel and sand. The habitat score of 67 reflects an eroding bank, a limited riparian zone, and sedimentation.

RESULTS

Table 6. Taxa Richness and Summary Values for Youngs Fork Watershed.

Stream	**Youngs Fork Creek**								**Jacktown Cr**
Date	4/85	4/85	9/90	9/90	8/97	4/01	4/01	4/01	4/01
Location	SR1819	SR1794	SR1819	SR1794	SR1819	hdwtrs	SR1819	SR1794	US226
Ephemeroptera	8	8	10	4	8	3	6	8	8
Plecoptera	5	5	2	2	4	0	2	2	7
Trichoptera	6	4	5	2	4	2	7	6	4
Coleoptera	0	2	4	2	0	0	4	3	3
Odonata	7	7	5	5	-	3	5	8	1
Megaloptera	2	3	3	3	-	0	2	1	1
Diptera: Chironomidae	23	19	15	18	-	11	16	26	20
Misc. Diptera	3	3	5	4	-	4	5	4	5
Oligochaeta	7	5	3	3	-	4	2	1	3
Crustacea	1	1	2	1	-	1	0	1	1
Mollusca	1	1	1	0	-	2	1	2	1
Other	1	0	0	0	-	0	1	0	0
Total Taxa Richness	**64**	**58**	**55**	**44**	**-**	**30**	**51**	**62**	**54**
EPT Richness*	**16**	**14**	**17**	**8**	**16**	**4**	**14**	**15**	**19**
EPT Abundance	**65**	**63**	**70**	**17**	**46**	**27**	**88**	**46**	**81**
Biotic Index	**6.67**	**6.62**	**6.11**	**7.17**	**-**	**7.46**	**5.36**	**6.21**	**4.88**
BI Seasonally corrected	**7.17**	**7.12**	**-**	**-**	**-**	**7.96**	**5.86**	**6.71**	**5.38**
EPT Biotic Index	**4.80**	**4.60**	**5.36**	**6.61**	**5.02**	**6.52**	**4.73**	**4.16**	**3.93**
Bioclassification	**Fair**	**Fair**	**Fair**	**Poor**	**Fair**	**Poor**	**Fair**	**Fair**	**NR**

*Seasonally adjusted by subtracting winter stoneflies

The headwaters site off US 226 near Claremont Street received a bioclassification of Poor. An over-abundance of rust colored attached algae was present in this reach. Enrichment and toxic indicator species were the dominant taxa here: *Cheumatopsyche, Hydropsyche betteni, Cricotopus bicinctus, Cricotopus infuscatus,* and *Nais.*

The mid-reach of Youngs Fork Creek has been sampled for benthic macroinvertebrates 4 times since 1985, always resulting in a bioclassification of Fair. EPT taxa richness has declined, but the EPT abundance has increased and the Biotic Index has decreased since 1985, indicating a somewhat less tolerant macroinvertebrate community (Table 6).

The benthic community downstream of the Marion WWTP discharge (SR 1794) has been sampled three times since 1985. Many of the same tolerant taxa were found common or abundant above and below the plant: *Ephemerella catawba*, *Hydropsyche betteni*, *Tipula*, and *Nais*. However, in 2001, there was a sharp decline in EPT abundance and an increase in the Biotic Index below the WWTP. Toxic indicator species were also found common or abundant at the SR 1794 site that were not found above the WWTP. These include *Chironomus*, many with mentum deformities, *Conchapelopia* grp, and *Polypedilum illinoense.* A midge deformity analysis was performed on the *Chironomus* from this site. Many "Class III" (the most severe) type deformities were found, putting this site into the Poor/Toxic group (Lenat 1993).

Jacktown Creek, also seems to be adversely affected by sedimentation and nonpoint sources of pollutants. However, this stream did support a few intolerant taxa not found in Youngs Fork Creek, *Hexagenia, Amphinemura, Pteronarcys*; the Biotic Index was lower, and the conductivity measurements were lower.

SUMMARY

Based on the results of the latest sampling events the previous bioclassification assigned to the streams in this study are valid and applicable to the entire stream. The historical data that placed these sites on the 303(d) impaired streams list adequately characterized conditions in the watershed.

The severe sparcity of the benthic community at the headwaters site on Youngs Fork Creek and the abundance of two toxic indicator species (*Cricotopus bicinctus* and *Cricotopus infuscatus*) may suggest some toxic input. This stream seems to be adversely affected by some pollutant near its source. The difference in the benthic communities, and the results of the midge deformity test, above and below the Marion WWTP also indicate some toxic pollutant source. A possible source of this toxicity could be the sludge field above the SR 1794 site

As earlier indicated by the ISU group, water quality in Youngs Fork Creek could be improved by isolating the source of the elevated conductivities in the system and determining what pollutant is causing the abundance of algae and absence of benthic invertebrates in the headwaters section, and the toxic source at SR 1794.

References:

Lenat, D.R. 1993. Using mentum deformities of *Chironomus* larvae to evaluate the effects of toxicity and organic loading in streams. Journal of the North American Benthological Society 12(3):265-269.

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APPENDIX B

Water Quality Conditions

A wide range of chemical, physical and toxicological analyses were conducted in the Corpening Creek watershed over the course of this study. This appendix describes the general approach and methods used, and summarized monitoring results.

Appendix B is largely taken from DWQ's Watershed Assessment and Restoration Project, which had identical goals to this project (NCDWQ, 2003).

Section 1
Approach and Methodology

Chemical-physical and toxicity monitoring conducted during this study had two broad goals:

1. General water quality characterization. This goal involved developing a synoptic picture of the chemical and physical water quality characteristics of the study area, using a standard set of parameters.
2. Stressor-source area identification. Identifying the causes of biological impairment and the sources of these causal factors were primary goals of the project. Related to chemical-physical and toxicity monitoring, this goal included:
   - identifying the major chemical-physical stressors to which benthic macroinvertebrates in the stream are exposed;
   - providing information on the nature of exposure to these stressors (e.g. concentration, timing);
   - evaluating the toxicity of waters of concern and determining the pollutants causing any toxicity identified; and
   - determining major sources or source areas.

The nature of stressor-source identification demands a monitoring approach that is dynamic and flexible, changing over time as new information regarding biological condition, stream chemistry and watershed activities becomes available.

1.1 General Water Quality Characterization

Routine sampling was conducted at two integrator stations located on the mainstem of Corpening Creek, towards the lower end of the study area. The integrator station was located at SR1794, upstream from the bridge. DWQ collected surface grab samples (depth of 0.1 meter, or 3 inches) during both baseflow and storm conditions. We defined baseflow periods as those in which no measurable rain fell in the watershed during the 48-hour period preceding the sampling, based on staff judgment using available information (www.intellicast.com was the primary source). Integrator sampling included a standard set of parameters similar to those collected by DWQ at ambient stations (Table B.1).

Table B.1 Parameters for Water Quality Characterization, Corpening Creek at SR1794.

Field Parameters	*Laboratory Parameters*	
Dissolved Oxygen	Turbidity	*Metals:*
Air Temperature	Total Dissolved Solids	Aluminum
Water Temperature	Total Suspended Solids	Arsenic
Specific Conductance	Hardness	Cadmium
pH	Fecal Coliform	Chromium
	Total Phosphorus	Copper
	Ammonia-N	Iron
	Nitrate/Nitrite-N	Lead
	Total Kjeldahl Nitrogen	Manganese
	Calcium	Mercury
	Magnesium	Nickel
	Sodium	Silver
		Zinc

1.2 Stressor-Source Identification

1.2.1 Chemical-Physical Monitoring

DWQ collected several types of water column samples, reflecting the needs for both stressor and source identification. Stressor identification sites were selected to identify chemical stressors present in the study waters and to provide information for evaluating whether those stressors contribute to biological impairment. Source identification sites were chosen to identify or evaluate source areas or individual pollutant sources. While stressor and source identification can be separated conceptually, in practice stressor and source determination were often carried out jointly.

The sampling effort was intended to provide information relevant to the evaluation of causal relationships by tying selection of sampling sites, parameter and timing of sampling to available information on stressors and sources (e.g. macroinvertebrate surveys and watershed activities). This approach differed from many commonly used sampling frameworks, because the goal was not to characterize typical conditions or estimate pollutant loads, but to provide information to help evaluate whether particular stressors are likely contributors to biological impairment. The timing and location of sampling were selected to identify critical conditions such as periods of high levels of toxins.

<u>Station location</u>. The number and location of sites was determined based on the size of the watershed, the location and degree of the biological impairment, the nature and distribution of watershed activities, and existing chemical data. Station locations for stressor identification purposes were generally linked closely to areas of known biological impairment (benthic macroinvertebrate sampling stations) and to specific watershed activities believed to represent potential sources of impairment. Sampling stations in the Corpening Creek watershed were listed in Section 5 of this document.

Parameter selection. Monitoring focused primarily on candidate stressors initially identified based on watershed reconnaissance and a review of existing information. We added additional parameters, as necessary.

For purposes of toxicity assessment, DWQ analyzed for the following analytes and parameter groups:

- metals;
- organochlorine pesticides and PCBs (polychlorinated biphenyls; EPA Method 608);
- select current use pesticides (EPA Method 614 and 619);
- PAHs (polycyclic aromatic hydrocarbons; EPA Method 625);
- phenols (EPA Method 625);
- semi-volatile organics (EPA Method 625); and
- MBAS (methylene blue active substances, an indicator of anionic surfactants);

Type and number of samples. Manual grab sampling was used for nonstorm and storm sampling. Manual grab samples were collected at the surface (depth of 0.1 meters, or approximately 3 inches). The number of samples collected was variable, depending on analytical results to date, and the outcome of other components of the study. Because of resource constraints (e.g limited number of trips due to the long trip from Raleigh to Marion), DWQ often targeted more general source areas, rather than specific watershed activities.

1.2.2 Toxicity Assessment

DWQ conducted six ambient toxicity tests at SR1794 and at Currier St. The benthic surveys had indicated toxic conditions, so we tried to learn more about the nature of the toxicity. Laboratory 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 stressors. DWQ preferred chronic tests to acute tests (4 chronic tests per site versus 2 acute tests per site), because chronic tests are more sensitive. The following specific tests were used:

- Ambient tests for acute toxicity using protocols defined as definitive in USEPA document EPA/600/4-90/027F (USEPA, 1993) using *Ceriodaphnia dubia* with a 48-hour exposure.
- Ambient tests for chronic toxicity using the North Carolina Ceriodaphnia Chronic Effluent Toxicity Procedure (NC Division of Water Quality, 1998).

1.3 Stressor-Source Identification: Bed Sediment

Sediment toxicity was evaluated to determine if it was a likely contributor to degradation of the benthic macroinvertebrate community in Corpening Creek at SR1794 where benthic community composition and midge deformity analysis indicated likely toxic impacts.

DWQ conducted analysis on a composite of multiple grab samples collected from the top 5 cm of stream substrate. In general, we tried to collect more fine-grained, organic-rich substrate as pollutants are most likely to adhere to that sediment type. In the target reach, we collected sediment from both mid-channel depositional areas and from the channel margins, where organic material is most abundant.

Sediment toxicity was evaluated using Microtox®. We ran one test using this tool. With a composite sample collected on July 15, 2003 from several locations at the SR1794 site, DWQ ran serial dilutions of 846.8 to 216,800 mg/kg sediment, dry weight, suspended in a sodium chloride solution. At the highest concentration, the test sediment did not show toxic effects. However, this does not rule out toxic sediment effects on the benthos. See Section 5.1.1 for further explanation.

DWQ does not have the capability to run the standard bed sediment bioassay, which uses the organism *Hyallela azteca* (USEPA, 2000). This is something that would benefit DWQ's program, as it stands to reason that bed sediment is an important media to test for toxicity as, through adsorption, it holds pollutants that have been delivered over time. Also, benthic organisms are almost constantly exposed to stream sediment.

Chemical analyses conducted on sediment included pesticides (EPA Methods 8000B, 8081A, 8082, 8141), herbicides (EPA Method 8151A), PCBs, PAHs (modified EPA Method 8270C), semi-volatile organics (EPA Method 8270C), and metals. Unfortunately, DWQ does not have to equipment to measure total organic carbon (TOC) and particle size distribution. These are important parameters for normalizing toxicant results. The ability to measure TOC and particle size should be added to the DWQ program in the near future.

1.4 Toxicity Benchmarks

When performing ecological risk assessments and water quality evaluations, contaminants are often compared to screening benchmarks to determine if the reported concentrations of those contaminants are high enough to warrant further consideration. In this study, toxicological benchmarks derived for the protection of aquatic life were used to screen observed contaminant concentrations for potential aquatic ecological effects. Laboratory detection limits were also compared to benchmark values.

Benchmark screening values denote thresholds of elevated risk, but not predict actual impacts in particular situations. Actual site-specific and event-specific impacts depend on the interaction of numerous factors, including the level, timing and duration of exposure; the form and bioavailability of the particular chemicals (often dependent on pH or other variables); and simultaneous exposure to other stressors (NCDWQ, 2003).

Water. Many different sources of screening benchmarks exist, with differing levels of conservatism. A detailed discussion of these can be found in Suter and Tsao (1996). The primary screening benchmarks used in the Corpening Creek watershed assessment were:

1) EPA's acute and chronic National Ambient Water Quality Criteria (NAWQC) for freshwater (USEPA, 1999);
2) EPA's Tier II values (USEPA, 1995).

The acute NAWQC were established by EPA to correspond to concentrations that would cause less than 50% mortality in 5% of the exposed populations in a brief exposure. EPA established the chronic NAWQC by dividing acute values by the geometric mean of at least three median lethal concentrations (LC50). Tier II values were developed as part of the Great Lakes Program (USEPA, 1995) for use with chemicals for which NAWQC are not available. They are based on fewer data than are required to establish NAWQC.

For the WARP study (and hence, this study), DWQ took NAWQC for priority pollutants from EPA's online Water Quality Standards Database (http://www.epa.gov/wqsdatabase/). NAWQC for nonpriority pollutants, which are not included in the online database, were taken from USEPA (1999). DWQ obtained Tier II values and other benchmarks from the ecological benchmark listing available through the Risk Assessment Information System operated by the Oak Ridge National Laboratory (http://risklsd.ornl.gov/homepage/eco_tool.shtml).

NAWQC for many metals (cadmium, chromium III, copper, lead, nickel, silver and zinc) are a function of water hardness. NAWQC are reported by EPA for a hardness of 100 mg/L and must be adjusted for site specific hardness levels. In this study benchmarks for all of the above metals, except chromium, were adjusted for hardness using the formulas recommended in USEPA (1999). The NAWQC for chromium VI, which does not require hardness adjustment, was used instead of chromium III, since the former provides a more conservative screening level. For cadmium the chronic benchmark was used instead of the acute value because hardness adjustment reduced the acute value below the chronic level.

NAWQC for many metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver and zinc) are calculated as the concentration of dissolved metals in the water column. Comparison of the ambient total metals concentrations measured in this study to dissolved metals criteria is a conservative approach in that less than 100% of a metal in any particular ambient sample may be in dissolved form. This approach is appropriate for screening purposes. Final evaluation of the likely potential for metals and other analytes to negatively impact aquatic biota considered all lines of evidence available, including toxicity bioassays, sediment toxicant levels and benthic macroinvertebrate data, in addition to data on analyte concentrations in the water column.

Observed pollutant concentrations can also be compared to the North Carolina's Water Quality Standards (NCWQS) for freshwater aquatic life, which serve as important regulatory benchmarks. The present study, however, is concerned not with regulatory compliance but with assessing the risks of site-specific, and sometimes event-specific impacts. The NAWQC are more appropriate for this purpose. NAWQC were based solely on data and scientific judgments on the relationships between pollutant concentrations and environmental and human health effects, and do not reflect considerations of technological feasibility or economic impact (USEPA, 1999). They allow for the specific evaluation of either chronic or acute concerns and for the consideration of site specific conditions (e.g. by adjusting metals criteria for local hardness levels).

Sediment. Sediment data were compared to a set of sediment benchmarks published by EPA (2002). These benchmarks were grouped into conservative (threshold) and non-conservative (probable) effect ranges. Conservative levels are threshold values, below which there is a low probability of toxicity. Non-conservative levels are probable effect values, above which there is a high probability of toxicity. If a measured value falls between the threshold and probable effect levels, toxicity is possible and the probability of toxicity increases with concentration.

Section 2
Sampling results

Parameter (mg/L)	BASEFLOW 10/3/2001	4/3/2002	12/3/2002	6/25/2003		STORMFLOW 7/5/2001	9/25/2002	4/22/2003	7/15/2003	25th percentile (all data)
Ammonia, NH3	0.01 - U	0.02	0.02 -U	0.03		0.01	0.02 - U	0.03	0.02	0.01
Total Kjedahl Nitrogen, TKN	0.2	0.2 - U	0.36	0.21		0.2 - U	0.24	0.2 - U	0.2 - U	0.1
Nitrite + Nitrate, NO2 + NO3	2.6	0.41	2.3	0.42		2.3	0.89	0.63	1.3	0.5775
Total Nitrogen, TN	2.8	0.51	2.66	0.63		2.4	1.13	0.73	1.4	0.705
Total Phosphorus, TP	0.37	0.14	0.33	0.04		1.15	0.38	0.03	0.09	0.0775

Notes:
U: Indicates that the analyte was analyzed for but not detected above the practical quantitation limit. The number value is equal to the laboratory's practical quantitation limit.
TKN = organic N + NH3
TN = TKN + NO2 + NO3
When TKN has U remark, we treated the value as half of detection (0.1 mg/L) to calculate TN.
Samples on 12/3/02 may be off, as data are questionable because of improper laboratory protocols (power outage due to winter ice storm)
25th percentile calculated using Excel PERCENTILE function.

Section 3
Detection limits

WATER COLUMN DETECTION LIMITS

Metals
PQL = Practical Quantitation Limit

Metal	PQL (ug/L)	Metal	PQL (ugL)
Cadmium	2	Calcium	
Chromium	25	Iron	
Copper	2	Magnesium	
Nickel	10	Manganese	
Lead	10	Arsenic	10
Zinc	10	Selenium	5
Silver	5	Mercury	0.2
Cobalt	50		

Chlorinated Pesticides in water by Electron Capture Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/L)	Pesticide – Target Compound	PQL (ug/L)
ALACHLOR	0.15	ENDRIN	0.025
ALDRIN	0.025	ENDRIN ANDEHYDE	0.025
ATRAZINE	3.0	ENDRIN KETONE	0.030
BHC-ALPHA	0.025	ETHAZOLE	0.060
BHC-BETA	0.025	HEPTACHLOR	0.025
BHC-DELTA	0.025	HEPTACHLOR EPOXIDE	0.025
BHC-GAMME (LINDANE)	0.025	HEXACHLOROBENZENE	0.015
CHLORDANE, Technical	0.50	MALATHION	0.20
CHLORDANE-ALPHA	0.020	METHOXYCHLOR, PP	0.10
CHLORDANE-GAMMA	0.020	MIREX	0.030
CHLORDENE	0.025	TRANS-NONACHLOR	0.020
CHLORNEB	0.20	OXYCHLORDANE	0.050
CLOROBENZILATE	0.60	MIXED-PERMETHRIN	1.20
CHLORPYRIFOS	0.050	PROPACHLOR	0.30
CLOROTHALONIL	0.025	TECNAZENE	0.010
DCPA	0.025	TRIFLURALIN	0.035
DDD, OP	0.050	AROCLOR 1016	1.0
DDD, PP	0.025	AROCLOR 1221	1.0
DDE, OP	0.040	AROCLOR 1232	1.0
DDE, PP	0.025	AROCLOR 1242	1.0
DDT, OP	0.030	AROCLOR 1248	1.0
DDT,PP	0.025	AROCLOR 1254	1.0
DIELDRIN	0.025	AROCLOR 1260	1.0
ENDOSULFAN I	0.025	AROCLOR 1262	1.0
ENDOSULFAN II	0.025	TOXAPHENE	3.0
ENDOSULFAN SULFATE	0.025		

Organophosphate Pesticides in water by Flame Photometric Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/L)	Pesticide – Target Compound	PQL (ug/L)
CARBOPHENOTHION	0.80	FENTHION	0.40
CHLORPYRIFOS	0.40	FENSULFOTHION	2.2
DEF (OXIDIZED MERPHOS)	0.40	MEVINPHOS	0.40
DEMETON	0.80	MONOCROTOPHOS	1.0
DIAZINON	0.40	NALED	2.7
DICHLORVOS	2.1	ETHYL PARATHION	0.40
DIMETHOATE	0.40	METHYL PARATHION	0.40
DISULFOTON	0.80	PHORATE	0.40
DISULFOTON SULFONE	1.0	RONNEL	0.40
DISULFOTON SULFOXIDE	NE	SULFOTEPP	0.40
EPN	0.40	TERBUFOS	0.40
ETHION	0.40		
ETHOPROP	0.40		

NE – NO ESTABLISHED PQL

Nitrogen Pesticides in water by NP Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/L)	Pesticide – Target Compound	PQL (ug/L)
ALACHLOR	15	METRIBUZIN	15
AMETRYN	4.5	MGK 264	150
ATRAZINE	4.5	MOLINATE	4.5
BROMACIL	4.5	NAPROPAMIDE	15
BUTACHLOR	15	NORFLURAZON	15
BUTYLATE	4.5	PEBULATE	4.5
CARBOXIN	15	PROMETON	4.5
CHLORPROPHAM	15	PROMETRYN	4.5
CHLORPYRIFOS	1.5	PRONAMIDE	15
CYNANAZINE	15	PROPAZINE	4.5
CYCLOATE	4.5	SIMAZINE	4.5
DIAZINON	15	SIMETRYN	4.5
DIPHENAMID	15	TREBUTHIURON	15
EPTC (EPTAM)	4.5	TERBACIL	90
FENAMIPHOS	15	TERBUFOS	15
HEXAZINONE	15	TERBUTRYN	4.5
METOLACHLOR	15	VERNOLATE	4.5

Semi-volatile Organics in water detected by Gas Chromatography/Mass Spectrometry
PQL = Practical Quantitation Limit

Semivolatiles - Target Compound	PQL (ug/L)	Semivolatiles – Target Compound	PQL (ug/L)
ANILINE	10	2,6-DINITROTOLUENE	10
PHENOL	10	3-NITROANILINE	50
BIS(2-CHLOROETHYL)ETHER	10	ACENAPHTHENE	10
2-CHLOROPHENOL	10	2,4-DINITRO PHENOL	50
1,3-DICHLOROBENZENE	10	4-NITRO PHENOL	50
1,4-DICHLOROBENZENE	10	DIBENZOFURAN	10
BENZYL ALCOHOL	20	2,4-DINITROTOLUENE	10
1,2-DICHLOROBENZENE	10	DIETHYL PHTHALATE	10
2-METHYL PHENOL	10	4-CHLOROPHENYL PHENYL ETHER	10
BIS(2-CHLOROISOPROPYL) ETHER	10	FLOURENE	10
4-METHYL PHENOL	10	4-NITROANILINE	50
N-NITROSO-DI-N-PROPYLAMINE	10	4,6-DINITRO-2-METHYL PHENOL	50
HEXACHLOROETHANE	10	N-NITROSODIPHENYLAMINE	10
NITROBENZENE	10	4-BROMOPHENYL PHENYL ETHER	10
ISOPHORONE	10	HEXACHLOROBENZENE	10
2-NITRO PHENOL	10	PENTACHLORO PHENOL	50
2,4-DIMETHYL PHENOL	10	PHENANTHRENE	10
BENZOIC ACID	50	ANTHRACENE	10
BIS(2-CHLOROETHOXY) METHANE	10	DI-N-BUTYL PHTHALATE	10
2,4-DICHLORO PHENOL	10	FLUORANTHENE	10
1,2,4-TRICHLOROBENZENE	10	PYRENE	10
NATHTHANLENE	10	BUTYLBENZYL PHTHALATE	10
4-CHLOROANILINE	20	3,3'-DICHLOROBENZIDINE	20
HEXACHLOROBUTADIENE	10	BENZO(A)ANTHRACENE	10
4-CHLORO-3-METHYL PHENOL	20	CHRYSENE	10
2-METHYL NAPHTHALENE	10	BIS(2-ETHYLHEXYL) PHTHALATE	10
HEXACHLOROCYCLOPENTADIENE	10	DI-N-OCTYL PHTHALATE	10
2,4,6-TRICHLORO PHENOL	10	BENZO(B)FLUORANTHENE	10
2,4,5-TRICHLORO PHENOL	10	BENZO(K)FLUORANTHENE	10
2-CHLORO NAPHTHALENE	10	BENZO(A)PYRENE	10
2-NITROANILINE	50	INDENO(1,2,3-CD)PYRENE	10
DIMETHYL PHTHALATE	10	DIBENZO(A,H)ANTHRACENE	10
ACENAPHTHYLENE	10	BENZOPERYLENE	10

The GC/MS Method also detects other semi-volatile compounds (up to 30 highest peaks).

Purgeable Organics measured in water by Photo Ionization Detector (PID), Electrolytic Conductivity Detector (ELCD) and Mass Spectrometer (MS).
PQL = Practical Quantitation Limit

VOA Target Compound	PQL (ug/L)	**VOA Target Compound**	PQL (ug/L)
1,1-DICHLOROETHENE	0.25	1,2,3-TRICHLOROPROPANE	0.30
METHYLENE CHLORIDE	10	BROMOBENZENE	0.25
TRANS-1,2-DICHLOROETHENE	0.25	2-CHLOROTOLUENE	0.25
1,1-DICHLOROETHANE	0.25	4-CHLOROTOLUENE	0.25
2,2-DICHLOROPROPANE	0.25	1,3-DICHLOROBENZENE	0.25
CIS-1,2-DICHLOROETHENE	0.25	1,4-DICHLOROBENZENE	0.25
CHLOROFORM	0.25	1,2-DICHLOROBENZENE	0.25
BROMOCHLOROMETHANE	0.25	1,2-DIBROMO-3-CHLOROPROPANE	0.30
1,1,1-TRICHLOROETHANE	0.25	1,2,4-TRICHLOROBENZENE	0.30
1,1-DICHLOROPROPENE	0.25	HEXACHLOROBUTADIENE	0.30
CARBON TETRACHLORIDE	0.25	1,2,3-TRICHLOROBENZENE	0.30
1,2-DECHLOROETHANE	0.25	METHYL-TERT-BUTYL ETHER	5
TRICHLOROETHENE	0.25	BENZENE	1
1,2-DICHLOROPROPANE	0.25	TOULENE	1
BROMODICHLOROMETHANE	0.30	ETHYL BENZENE	1
DIBROMOMETHANE	0.25	M,P-XYLENES	2
CIS-1,3-DICHLOROPROPENE	0.25	O-XYLENE	1
TRANS-1,3-DICHLOROPROPENE	0.25	STYRENE	1
1,1,2-TRICHLOROETHANE	0.25	ISOPROPYLBENZENE	1
TETRACHLOROETHANE	0.25	N-PROPYLBENZENE	1
1,3-DICHLOROPROPANE	0.25	1,3,5-TRIMETHYLBENZENE	1
DIBROMOCHLOROMETHANE	0.30	TERT-BUTYLBENZENE	1
1,2-DIBROMOETHANE	0.25	1,2,4-TRIMETHYLBENZENE	1
CHLOROBENZENE	0.25	SEC-BUTYLBENZENE	1
1,1,1,2-TETRACHLOROETHANE	0.25	P-ISOPROPYLTOLUENE	1
BROMOFORM	0.30	N-BUTYLBENZENE	1
1,1,2,2-TETRACHLOROETHANE	0.30	NAPHTHALENE	2

The PID Method also detects other volatile compounds (up to 10 highest peaks).

SEDIMENT DETECTION LIMITS

Chlorinated Pesticides in sediment by Electron Capture Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/Kg)	Pesticide – Target Compound	PQL (ug/Kg)
ALACHLOR	5.0	ENDRIN	0.83
ALDRIN	0.83	ENDRIN ANDEHYDE	0.83
ATRAZINE	100	ENDRIN KETONE	1.0
BHC-ALPHA	0.83	ETHAZOLE	2.0
BHC-BETA	0.83	HEPTACHLOR	0.83
BHC-DELTA	0.83	HEPTACHLOR EPOXIDE	0.83
BHC-GAMME (LINDANE)	0.83	HEXACHLOROBENZENE	0.50
CHLORDANE, Technical	17	MALATHION	6.7
CHLORDANE-ALPHA	0.50	METHOXYCHLOR, PP	3.3
CHLORDANE-GAMMA	0.50	MIREX	1.0
CHLORDENE	0.83	TRANS-NONACHLOR	0.50
CHLORNEB	6.7	OXYCHLORDANE	1.70
CLOROBENZILATE	20	MIXED-PERMETHRIN	40
CHLORPYRIFOS	1.7	PROPACHLOR	10.0
CLOROTHALONIL	0.83	TECNAZENE	0.33
DCPA	0.83	TRIFLURALIN	1.2
DDD, OP	1.7	AROCLOR 1016	33
DDD, PP	0.83	AROCLOR 1221	33
DDE, OP	1.3	AROCLOR 1232	33
DDE, PP	0.83	AROCLOR 1242	33
DDT, OP	1.0	AROCLOR 1248	33
DDT,PP	0.83	AROCLOR 1254	33
DIELDRIN	0.83	AROCLOR 1260	33
ENDOSULFAN I	0.83	AROCLOR 1262	33
ENDOSULFAN II	0.83	TOXAPHENE	100
ENDOSULFAN SULFATE	0.83		

Acid Herbicides in sediment by Electron Capture Method
PQL = Practical Quantitation Limit

Herbicide – Target Compound	PQL (ug/Kg)	Herbicide – Target Compound	PQL (ug/Kg)
ACIFUORFEN (BLAZER)	3.3	DICHLORPROP	20
BENTAZON	13	DINOSEB	6.7
CHLORABEN	3.3	4-NITROPHENOL	13.0
2,4-D	6.7	PENTACHLOROPHENOL (PCP)	3.3
2,4-DB	27	PICLORAM	6.7
DCPA (MONOACID METABOLITE)	NE	2,4,5-T	3.3
DICAMBA	3.3	2,4,5-TP (SILVEX)	3.3
3,5 DICHLOROBENZOIC ACID	3.3		

Organophosphate Pesticides in sediment by Flame Photometric Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/Kg)	Pesticide – Target Compound	PQL (ug/Kg)
CARBOPHENOTHION	27	FENTHION	13
CHLORPYRIFOS	13	FENSULFOTHION	16
DEF (OXIDIZED MERPHOS)	13	MEVINPHOS	13
DEMETON	27	MONOCROTOPHOS	33
DIAZINON	13	NALED	NE
DICHLORVOS	13	ETHYL PARATHION	13
DIMETHOATE	13	METHYL PARATHION	13
DISULFOTON	27	PHORATE	13
DISULFOTON SULFONE	33	RONNEL	13
DISULFOTON SULFOXIDE	NE	SULFOTEPP	13
EPN	13	TERBUFOS	13
ETHION	13		
ETHOPROP	13		

NE – NO ESTABLISHED PQL

Nitrogen Pesticides in sediment by NP Detection
PQL = Practical Quantitation Limit

Pesticide – Target Compound	PQL (ug/Kg)	Pesticide – Target Compound	PQL (ug/Kg)
ALACHLOR	500	METRIBUZIN	500
AMETRYN	150	MGK 264	3000
ATRAZINE	150	MOLINATE	150
BROMACIL	500	NAPROPAMIDE	500
BUTACHLOR	500	NORFLURAZON	500
BUTYLATE	150	PEBULATE	150
CARBOXIN	500	PROMETON	150
CHLORPROPHAM	500	PROMETRYN	150
CHLORPYRIFOS	50	PRONAMIDE	500
CYNANAZINE	500	PROPAZINE	150
CYCLOATE	150	SIMAZINE	150
DIAZINON	500	SIMETRYN	150
DIPHENAMID	500	TREBUTHIURON	500
EPTC (EPTAM)	150	TERBUFOS	500
FENAMIPHOS	500	TERBUTRYN	150
HEXAZINONE	500	VERNOLATE	150
METOLACHLOR	500		

Semi-volatile Organics in sediment detected by Gas Chromatography/Mass Spectrometry
PQL = Practical Quantitation Limit

Semivolatiles - Target Compound	PQL (ug/Kg)	Semivolatiles – Target Compound	PQL (ug/Kg)
ANILINE	660	2,6-DINITROTOLUENE	660
PHENOL	660	3-NITROANILINE	3300
BIS(2-CHLOROETHYL)ETHER	660	2,4-DINITRO PHENOL	660
2-CHLOROPHENOL	660	4-NITRO PHENOL	3300
1,3-DICHLOROBENZENE	660	DIBENZOFURAN	3300
1,4-DICHLOROBENZENE	660	2,4-DINITROTOLUENE	660
BENZYL ALCOHOL	1300	DIETHYL PHTHALATE	660
1,2-DICHLOROBENZENE	660	4-CHLOROPHENYL PHENYL ETHER	660
2-METHYL PHENOL	660	FLOURENE	660
BIS(2-CHLOROISOPROPYL) ETHER	660	4-NITROANILINE	3300
4-METHYL PHENOL	660	4,6-DINITRO-2-METHYL PHENOL	3300
N-NITROSO-DI-N-PROPYLAMINE	660	N-NITROSODIPHENYLAMINE	660
HEXACHLOROETHANE	660	4-BROMOPHENYL PHENYL ETHER	660
NITROBENZENE	660	HEXACHLOROBENZENE	660
ISOPHORONE	660	PENTACHLORO PHENOL	3300
2-NITRO PHENOL	660	PHENANTHRENE	660
2,4-DIMETHYL PHENOL	660	ANTHRACENE	660
BENZOIC ACID	3300	DI-N-BUTYL PHTHALATE	660
BIS(2-CHLOROETHOXY) METHANE	660	FLUORANTHENE	660
2,4-DICHLORO PHENOL	660	PYRENE	660
1,2,4-TRICHLOROBENZENE	660	BUTYLBENZYL PHTHALATE	660
NATHTHANLENE	660	3,3'-DICHLOROBENZIDINE	1300
4-CHLOROANILINE	1300	BENZO(A)ANTHRACENE	660
HEXACHLOROBUTADIENE	660	CHRYSENE	660
4-CHLORO-3-METHYL PHENOL	1300	BIS(2-ETHYLHEXYL) PHTHALATE	660
2-METHYL NAPHTHALENE	660	DI-N-OCTYL PHTHALATE	660
HEXACHLOROCYCLOPENTADIENE	660	BENZO(B)FLUORANTHENE	660
2,4,6-TRICHLORO PHENOL	660	BENZO(K)FLUORANTHENE	660
2,4,5-TRICHLORO PHENOL	660	BENZO(A)PYRENE	660
2-CHLORO NAPHTHALENE	660	INDENO(1,2,3-CD)PYRENE	660
2-NITROANILINE	3300	DIBENZO(A,H)ANTHRACENE	660
DIMETHYL PHTHALATE	660	BENZOPERYLENE	660
ACENAPHTHYLENE	660		

The GC/MS Method also detects other semi-volatile compounds (up to 30 highest peaks). Other compounds seen in Corpening Creek samples include: methyl butanol acetate C7.H14.O2, hexadecanoic acid, alkane, sistosterol.

Metals in sediment
PQL = Practical Quantitation Limit

Metal	PQL (mg/Kg)	Metal	PQL (mg/Kg)
Cadmium	0.2	Calcium	
Chromium		Iron	
Copper		Magnesium	
Nickel		Manganese	
Lead		Arsenic	
Zinc		Selenium	
Silver		Mercury	0.02
Aluminum			

Section 4
Sediment Benchmarks

Substance	Unit	Threshold Effect Concentations						
		TEL	**LEL**	**MET**	**ERL**	**TEL-HA28**	**SQAL**	**TEC**
METALS	mg/kg DW							
Arsenic		5.9	6	7	33	11	NG	9.79
Cadmium		0.596	0.6	0.9	5	0.58	NG	0.99
Chromium		37.3	26	55	80	36	NG	43.4
Copper		35.7	16	28	70	28	NG	31.6
Lead		35	31	42	35	37	NG	35.8
Mercury		0.174	0.2	0.2	0.15	NG	NG	0.18
Nickel		18	16	35	30	20	NG	22.7
Zinc		123	120	150	120	98	NG	121
PAHs	ug/kg DW							
Anthracene		NG	220	NG	85	10	NG	57.2
Fluorene		NG	190	NG	35	10	540	77.4
Naphthalene		NG	NG	400	340	15	470	176
Phenanthrene		41.9	560	400	225	19	1800	204
Benz(a)anthracene		31.7	320	400	230	16	NG	108
Benzo(a)pyrene		31.9	370	500	400	32	NG	150
Chrysene		57.1	340	600	400	27	NG	166
Dibenz(a,h)anthracene		NG	60	NG	60	10	NG	33
Fluoranthene		111	750	600	600	31	6200	423
Pyrene		53	490	700	350	44	NG	195
Total PAHs		NG	4000	NG	4000	260	NG	1610
PCBs	ug/kg DW							
Total PCBs		34.1	70	200	50	32	NG	59.8
Organochlorine Pesticides	ug/kg DW							
Chlordane		4.5	7	7	0.5	NG	NG	3.24
Dieldrin		2.85	2	2	0.02	NG	110	1.90
Sum DDD		3.54	8	10	2	NG	NG	4.88
Sum DDE		1.42	5	7	2	NG	NG	3.16
Sum DDT		NG	8	9	1	NG	NG	4.16
Total DDTs		7	7	NG	3	NG	NG	5.28
Endrin		2.67	3	8	0.02	NG	42	2.22
Heptachlor epoxide		0.6	5	5	NG	NG	NG	2.47
Lindane (gamma-BHC)		0.94	3	3	NG	NG	3.7	2.37

The threshold effect sediment quality guidelines (SQGs) include:

- TEC = Threshold effect concentration (MacDonald et al., 2000)
- TEL = Threshold effect level; dry weight (Smith et al., 1996)
- LEL = Lowest effect level, dry weight (Persaud et al., 1993)
- MET = Minimum effect threshold; dry weight (EC & MENVIQ, 1992)
- ERL = Effects range low; dry weight (Long and Morgan, 1991)
- TEL-HA28 = Threshold effect level for Hyallela azteca; 28 day test; dry weight (USEPA, 1996)
- SQAL = Sediment quality advisory levels; dry weight at 1% OC (USEPA, 1997)

Sediment Benchmarks from USEPA, 2002.

Substance		Probable Effect Concentations					
		PEL	**SEL**	**TET**	**ERM**	**PEL-HA28**	**PEC**
METALS	mg/kg DW						
Arsenic		17	33	17	85	48	33
Cadmium		3.53	10	3	9	3.2	4.98
Chromium		90	110	100	145	120	111
Copper		197	110	86	390	100	149
Lead		91.3	250	170	110	82	128
Mercury		0.486	2	1	1.3	NG	1.06
Nickel		36	75	61	50	33	48.6
Zinc		315	820	540	270	540	459
PAHs	ug/kg DW						
Anthracene		NG	3700	NG	960	170	845
Fluorene		NG	1600	NG	640	150	536
Naphthalene		NG	NG	600	2100	140	561
Phenanthrene		515	9500	800	1380	410	1170
Benz(a)anthracene		385	14800	500	1600	280	1050
Benzo(a)pyrene		782	14400	700	2500	320	1450
Chrysene		862	4600	800	2800	410	1290
Fluoranthene		2355	10200	2000	3600	320	2230
Pyrene		875	8500	1000	2200	490	1520
Total PAHs		NG	100000	NG	35000	3400	22800
PCBs	ug/kg DW						
Total PCBs		277	5300	1000	400	240	676
Organochlorine Pesticides	ug/kg DW						
Chlordane		8.9	60	30	6	NG	17.6
Dieldrin		6.67	910	300	8	NG	61.8
Sum DDD		8.51	60	60	20	NG	28
Sum DDE		6.75	190	50	15	NG	31.3
Sum DDT		NG	710	50	7	NG	62.9
Total DDTs		4450	120	NG	350	NG	572
Endrin		62.4	1300	500	45	NG	207
Heptachlor epoxide		2.74	50	30	NG	NG	16
Lindane (gamma-BHC)		1.38	10	9	NG	NG	4.99

The probable effect sediment quality guidelines (SQGs) include:

- PEC = Probable effect concentration (MacDonald et al., 2000)
- PEL = Threshold effect level; dry weight (Smith et al., 1996)
- SEL = Severe effect level, dry weight (Persaud et al., 1993)
- TET = Toxic effect threshold; dry weight (EC & MENVIQ, 1992)
- ERM = Effects range median; dry weight (Long and Morgan, 1991)
- PEL-HA28 = Probable effect level for Hyallela azteca; 28 day test; dry weight (USEPA, 1996)

APPENDIX B. REFERENCES

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