Summary of Monitoring Results in Lower Creek Watershed and Tributaries Catawba River Basin: February 2004--April 2005

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

Prepared for the
North Carolina Ecosystem Enhancement Program

September 1, 2005
(Revised January 30, 2006)

Executive Summary

Four different approaches were used to characterize water and habitat quality issues and patterns in the Lower Creek watershed. These included the collection of physical and chemical parameters, biological sampling using benthic macroinvertebrates, five separate toxicological assessments, and detailed assessments of stream habitat and riparian condition. The North Carolina Division of Water Quality (DWQ) conducted these four assessment techniques in support of the North Carolina Ecosystem Enhancement Program's watershed planning efforts,. Efforts were focused on bodies of water that have been previously identified as having impacted communities of aquatic insects. These water bodies include Lower Creek, Greasy Creek, Spainhour Creek, and Zacks Fork.

Results show a variety of conditions ranging from relatively unimpacted streams, such as Abington Creek, to an unnamed tributary to Blair Fork that had high levels of nutrients, high conductivity, and water that produced toxic responses in three out of five toxicity tests. Water quality at this site is influenced by a closed landfill. Causes of impairment in the Lower Creek watershed include both rural and urban impacts, such as habitat degradation, stormwater scour, and toxicity. The most likely causes and sources of impairment were identified based on available data and are listed for each subwatershed below.

Zacks Fork

Excessive sediment deposits and one of the highest biotic indices and lowest EPT taxa richness values in the Lower Creek watershed characterize Zacks Fork. Sediment deposits, along with the lack of extensive woody riparian vegetation, appear to be the major sources of instream habitat loss. Both streambank instability and a large sediment plug, which was released when a historic upstream water impoundment was eliminated, seem to be the origins of the deposits. Zacks Fork has been channelized, and channelization has led to uniform velocity and depth in the creek. High concentrations of total phosphorus and fecal coliform bacteria recorded during baseflow conditions indicate an urban point source and may be a sign of a pervasive problem within the collection system.

Blair Fork

Sites in the Blair Fork, particularly the Landfill UT to Blair Fork, had some of the highest nutrient concentrations during baseflow conditions in the Lower Creek watershed. A closed landfill on NC 90 and possible straight pipes may contribute to high nutrients in the watershed, and the closed landfill appears to be the primary source of various toxicants entering the creek. Habitat degradation in Blair Fork stems from channelization, excess sediment deposition, and the removal of riparian vegetation.

Spainhour Creek

Spainhour Creek is located in an area where wastewater collection system failures have occurred during baseflow and stormflow conditions. These problems may account for some of the high fecal coliform bacteria, nutrients, and metals within the creek. Runoff from plant nurseries may also be adding to the nutrient levels. Excess sediment deposits, the primary type of habitat degradation in this creek, result from stormwater scour and streambank instability.

UT to Spainhour Creek

The UT to Spainhour Creek, a headwater tributary to Spainhour Creek, showed signs of degradation due to habitat degradation, though habitat degradation was not as severe on the UT to Spainhour Creek as it was in the other two subwatersheds. Sedimentation due to bank erosion appeared to be the main type of habitat degradation in this creek. Breaks in the riparian buffer also allow sediment to enter the stream during stormflow events. Inadequate instream habitat was also noted as a type of habitat degradation in the stream.

Greasy Creek

Upper Greasy Creek received the highest habitat rating in the Lower Creek watershed among streams included in this report. Based on benthic macroinvertebrate sampling, this site is not impaired. In contrast, lower Greasy Creek suffers from habitat degradation that may be attributed to cattle access to the stream, the removal of riparian vegetation, and runoff from an ornamental shrub nursery. These impacts are most evident during stormflow conditions when the stream experiences high levels of suspended residue, nutrients, and metals (especially copper and lead). High levels of fecal coliform bacteria during baseflow may result from cattle access to the stream.

UT to Lower Creek

The UT to Lower Creek is an extremely urbanized stream in the City of Lenoir, where commercial, industrial, and residential development are abundant. Several semivolatile organic pollutants were tentatively identified at the UT to Lower Creek at NC 18. High concentrations of TKN and nitrate+nitrite were recorded during baseflow and stormflow conditions, suggesting a potential direct discharge into the creek or ground water contamination in the area. Metals (zinc, manganese, copper, and lead) were higher than any of the other sites in the Lower Creek watershed during baseflow.

Lower Creek

Sediment deposition appears to be the primary type of habitat degradation in Lower Creek. The main causes of habitat degradation in Lower Creek were stormwater scour, bank erosion, and channelization. Steep, eroding banks were observed throughout Lower Creek and are a likely source of sediment, especially during storms when increased water velocity and energy speed erosive processes. Riparian buffer areas along Lower Creek were generally thin and sparsely vegetated resulting in poorly bound soils along the stream banks. Lower Creek had high levels of fecal coliform bacteria during baseflow conditions, suggesting either an urban point source or impacts from livestock.

Table of Contents

Section 1: Introduction

The North Carolina Division of Water Quality (DWQ) conducted benthic macroinvertebrate sampling, physical-chemical water quality monitoring, habitat assessments, toxicity testing, and stream walks in Lower Creek and several of its tributaries (DWQ Subbasin 03-08-31) between February 2004 and April 2005 in support of the North Carolina Ecosystem Enhancement Program (EEP) watershed planning in this area. Local watershed plans (LWP) developed by the EEP provide assistance to local governments and stakeholders on local watershed management issues including degradation of water quality, potential impacts of various land use practices, and the identification of opportunities for implementing best management practices and restoration efforts. The EEP assists stakeholders in the development of the long-term strategy to implement and evaluate the effectiveness of watershed protection recommendations proposed in the LWP. The EEP also assists the North Carolina Department of Transportation (NCDOT) in meeting compensatory mitigation needs for stream, riparian buffer and wetland impacts while minimizing future adverse impacts on water quality. The DWQ assists in the development of the LWP by monitoring and evaluating the water quality in the local watersheds.

1.1 Description

This water quality report is part of the LWP for Lower Creek (Hydrological Units 03050101080010 and 03050101080020), a tributary of the Catawba River. The planning area for Lower Creek is 99 square miles in the upper Piedmont foothills of North Carolina and is located within Caldwell and Burke Counties, including the towns of Lenoir and Gamewell. This creek flows into Lake Rhodhiss, an impoundment of the Catawba River. The Lower Creek watershed is classified as C except from Caldwell County SR 1143 to a point 0.7 miles downstream Bristol Creek where it has a Water Supply (WS)-IV classification. From 0.7 miles downstream Bristol Creek to Lake Rhodhiss, Lower Creek has a classification of WS-IV Critical Area (CA). The entire length of Lower Creek below the junction of Zacks Fork (approximately 12.7 miles) is listed on North Carolina’s 2004 draft 303(d) list as having impaired biological integrity and elevated turbidity (NCDWQ Draft 2004a). The Division of Water Quality completed a Total Maximum Daily Load (TMDL) study in November 2004 that identified turbidity as a critical condition within the Lower Creek subbasin (NCDWQ 2005a). Several major tributaries to Lower Creek (Zacks Fork, Spainhour Creek, Greasy Creek, and Bristol Creek) are also listed on the 2004 draft 303(d) list as biologically impaired. All other tributaries have C and WS-IV classifications.

The Lower Creek watershed is almost completely located within in North Carolina's Northern Inner Piedmont ecoregion. This ecoregion has higher elevations and more rugged topography than other Piedmont ecoregions, and monadnocks, or mountain outliers, are found in this ecoregion. The soils tend to be mesic rather than the more typical thermic Piedmont soils. The predominant soils are characterized as having severe erosion potential when inadequately protected (NCDWQ 2005a). A small portion of the Lower Creek mainstem headwaters is located in the Eastern Blue Ridge Foothills ecoregion. These areas are lower in elevation than most of the Blue Ridge and have Piedmont influences.

There is one major National Pollutant Discharge Elimination System (NPDES) permitted wastewater treatment plant (WWTP) and two minor NPDES permitted WWTP facilities within the Lower Creek watershed. There are also approximately 27 NPDES general permits which include, but are not limited to, construction sites, cooling water, storm water from industrial sites, sand mining, and instream sand dredging. The instream sand dredging occurs seasonally (February and March) within the Lower Creek mainstem downstream of SR 1143 (Permit No. NCG520071).

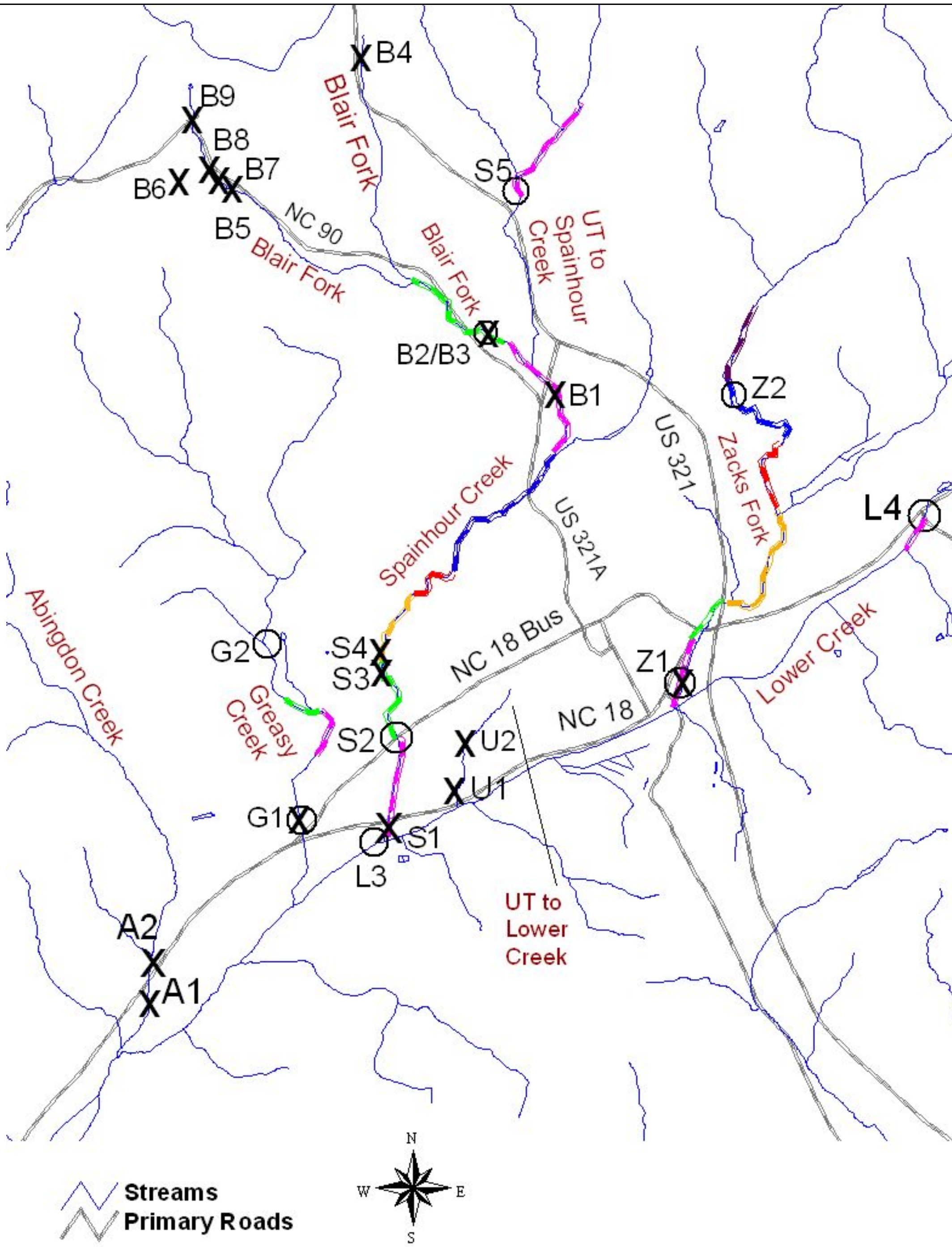
The central portion of the watershed is urban and industrial (primarily furniture finishing plants). The remaining areas consist of forest, agriculture (predominately shrub/tree nursery operations and cattle) and residential land.

1.2 Water Sampling and Data Collection

To support the Local Watershed Plan being developed for this area by EEP, DWQ conducted chemical-physical monitoring on the mainstem of Lower Creek and six tributaries (Greasy Creek, Spainhour Creek, Blair Fork, Unnamed tributary (UT) to Lower Creek, Zacks Fork and Abingdon Creek). See Tables 1.1 and 1.2 and Figures 1.1 and Figure 1.2 for detailed information on sampling sites and their locations in the watershed. Periodic sampling was conducted under both baseflow (defined as at least 48 hours after measurable precipitation) and stormflow conditions on the Lower Creek mainstem from February 2004 through April 2005. Only stormflow samples were collected at five tributaries (Greasy Creek, Spainhour Creek, Blair Fork, UT to Lower Creek and Zacks Fork) from February 2004 until June 2004. It became evident that baseflow samples were needed from these tributaries to better identify possible contaminant sources within Lower Creek. Beginning June 30, 2004, baseflow sampling was initiated for these five tributaries. In addition, Abingdon Creek was added in July 2004 to represent a less urban influenced stream for comparison with the urban tributaries. Stormflow samples were collected during rising stream stage. All samples were collected at the surface (0.15 m in depth; “grab samples”). Chemical and physical monitoring were conducted according to the procedures described in the Division of Water Quality’s Intensive Survey Unit’s Standard Operating Procedures (SOP) (NCDWQ, 2003a) and the DWQ Laboratory Section’s sample submission guidance (NCDWQ, 2002a).

Water quality monitoring included field measurements and water chemistry (suspended residue, turbidity, fecal coliform bacteria, nutrients and metals). Water samples were collected at several sites in order to identify any semivolatile organic compounds. Locations of the sampling sites are provided in Figure 1.1 and 1.2 and in Table 1.1. A summary of the types of monitoring conducted at each site is provided in Table 1.2.

Field measurements included percent saturation of oxygen, concentration of dissolved oxygen, specific conductance, pH, air and water temperature. All metal and nutrient water samples were sent to the DWQ Laboratory Section for analysis. Water samples for nutrient analysis were analyzed for total phosphorus, ammonia nitrogen, nitrate plus nitrite nitrogen (NO2+NO3), and total Kjeldahl nitrogen (TKN). Metals measured included mercury {starting in July 2004}, aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, silver, zinc and major cations (sodium {starting in March 2004}, calcium, and magnesium). Residue (suspended, fixed, and volatile), turbidity, and fecal coliform bacteria were also analyzed by the DWQ Laboratory Section, except between February 2004 and June 3, 2004, when the Asheville Regional Laboratory was in the process of changing locations. During this time, Environmental Testing Solutions, Inc. in Asheville, North Carolina analyzed these water samples. Sample preservation requirements are available at the DWQ Laboratory Section web site:



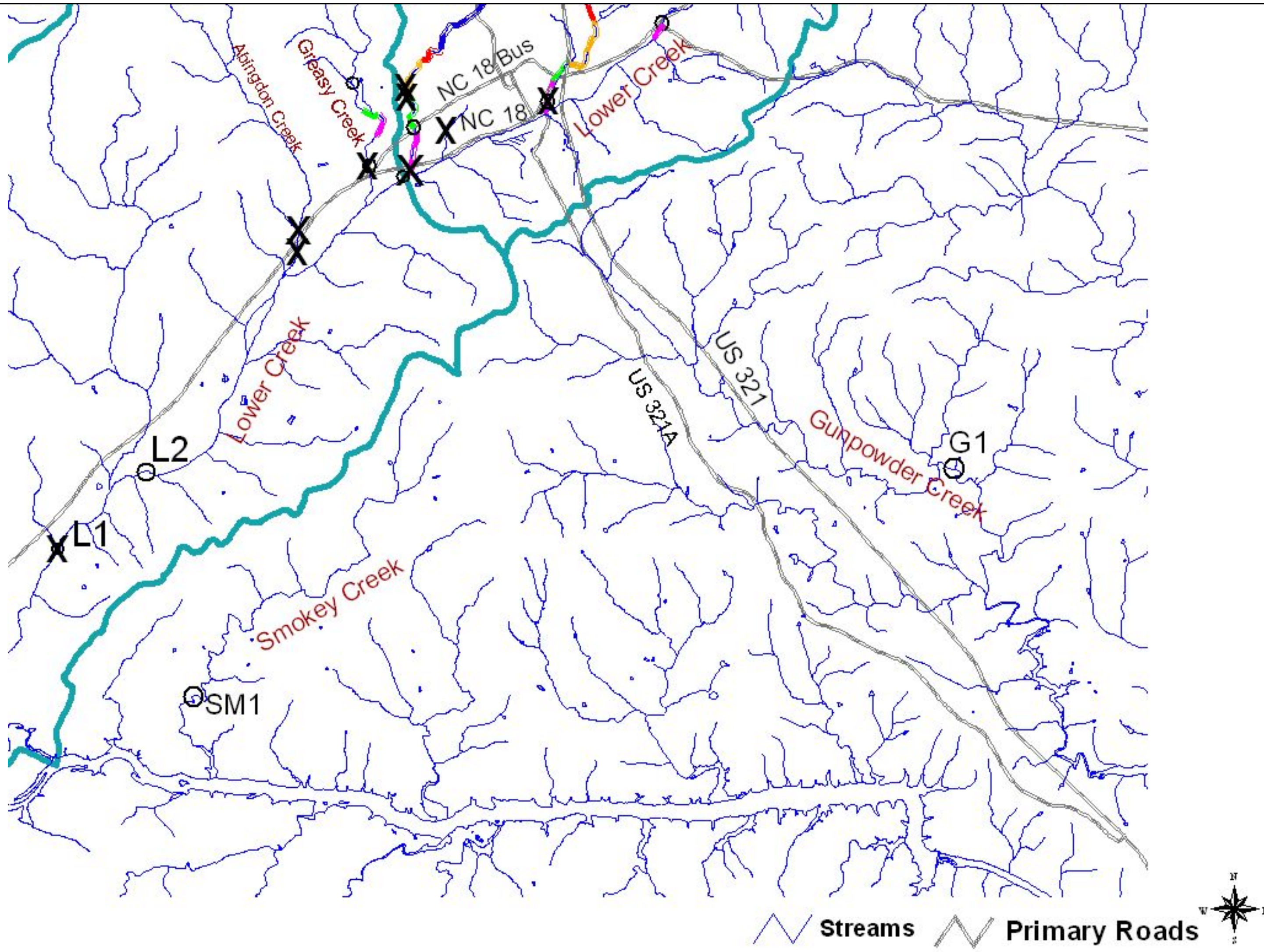
Map of benthic macroinvertebrate and physical/chemical monitoring sites and habitat assessment reaches in the Lower Creek watershed. The two downstream sites on Lower Creek and the benthic comparison sites are not shown.

X Physical/chemical monitoring
O Benthic macroinvertebrate monitoring

Reach 1 **Reach 4**
Reach 2 **Reach 5**
Reach 3 **Reach 6**

Reaches are color-coded. The most downstream reach of each stream is **pink**, the next most downstream reach is **green**, etc.

Figure 1.1. Monitoring sites and reaches in the Lower Creek watershed.



X Physical/chemical monitoring **O** Benthic macroinvertebrate monitoring Hydrological unit boundaries for the Lower Creek watershed

Figure 1.2. Lower Creek Watershed Monitoring Site Map. Map of the two downstream study sites on Lower Creek and the benthic comparison sites on Smoky and Gunpowder Creeks in relation to other sites and reaches in the Lower Creek watershed. See Table 1.1 and 1.2 and Figure 1.1 for specific locations of monitoring sites and reaches.

Table 1.1. Lower Creek watershed sample site locations, North Carolina stream classifications, and status on the 303(d) impaired list.

Map Code	Description	Latitude (N)	Longitude (W)	Stream Classification	303(d) impaired list
L1	Lower Creek at SR 1501	35.82531	81.63573	Water Supply - IV	X
L2	Lower Creek at SR 1142	.	.	Water Supply - IV	X
L3	Lower Creek at SR 1303	.	.	C	X
L4	Lower Creek at NC 90	.	.	C	.
G1	Greasy Cr at SR 1425	35.89575	81.56855	C	X
G2	Greasy Creek at SR 1305/Powell Brickyard Road	.	.	C	X
S1	Spainhour Creek below NC 18	35.89595	81.55994	C	X
S2	Spainhour Creek at NC 18 Business	.	.	C	X
S3	Plant nursery runoff to Spainhour	.	.	C	.
S4	Plant nursery pond UT to Spainhour	35.91226	81.56122	C	
S5	UT to Spainhour Creek at SR 1513	.	.	C	
B1	Blair Fork at SR 1525	35.93564	81.54538	C	
B2	Blair Fork at 1944 Valway / NC 90	35.93807	81.5493	C	
B3	Blair Fork spring across 1944 Valway	35.93779	81.54878	C	.
B4	Unnamed Tributary (UT) to Blair Fork at US 321	35.96368	81.56462	C	
B5	Blair Fork downstream of landfill at NC 90	.	.	C	
B6	Landfill pond to Blair Fork above NC 90	35.95045	81.58346	C	.
B7	Landfill UT to Blair Fork at NC 90	35.95135	81.57911	C	
B8	Blair Fork at NC 90 upstream of UT	35.95154	81.57945	C	
B9	Blair Fork at NC 90 above landfill	35.95579	81.58209	C	
U1	UT to Lower Creek at NC 18	35.89865	81.55232	C	
U2	UT to Lower Creek at Underdown Road	35.90909	81.54689	C	
Z1	Zacks Fork at US 321A	35.90828	81.52933	C	X
Z2	Zacks Fork at SR 1531	.	.	C	X
A1	Abingdon Creek at SR 1927/Old Morganton Road	35.8815	81.58431	C	.
A2	Abingdon Creek at NC 18 Bypass	.	.	C	.
G1	Gunpowder Creek at Mason Road	.	.	Water Supply - IV	.
SM1	Smoky Creek at SR 1515	.	.	Water Supply - IV	.

Table 1.2. Type of monitoring conducted at each sampling site within the Lower Creek watershed. An “X” signifies that monitoring was conducted.

Site Number	Site location	Benthos 1997	Benthos 2002	Benthos 2004	Habitat 2004-2005	Toxicity 2005	Physical/ Chemical 2004-2005
L1	Lower Creek at SR 1501	X	X	.	.	.	X
L2	Lower Creek at SR 1142	X	X	.	.	.	.
L3	Lower Creek at SR 1303	X	X	.	.	.	.
L4	Lower Creek at NC 90	X	X	X	X	.	.
G1	Greasy Cr at SR 1425	X	X	X	.	X	X
G2	Greasy Creek at SR 1305/Powell Brickyard Road	.	X	X	.	.	.
S1	Spainhour Creek below NC 18	.	.	.	X	X	X
S2	Spainhour Creek at NC 18 Business	.	X	.	X	.	.
S3	Plant nursery runoff to Spainhour	.	.	.	X	.	.
S4	Plant nursery pond UT to Spainhour	.	.	.	X	.	.
S5	UT to Spainhour Creek at SR 1513	.	X	.	X	.	.
B1	Blair Fork at SR 1525	.	.	.	X		X
B2	Blair Fork at 1944 Valway / NC 90	.	X	.	X	X	X
B3	Blair Fork spring across 1944 Valway	.	.	.	X	.	.
B4	Unnamed Tributary (UT) to Blair Fork at US 321	.	.	.	.	.	.
B5	Blair Fork downstream of landfill at NC 90	.	.	.	.	X	.
B6	Landfill pond to Blair Fork above NC 90	.	.	.	.	.	.
B7	Landfill UT to Blair Fork at NC 90	.	.	.	.	X	.
B8	Blair Fork at NC 90 upstream of UT	.	.	.	.	.	.
B9	Blair Fork at NC 90 above landfill	.	.	.	.	X	
U1	UT to Lower Creek at NC 18	.	.	.	.	X	X
U1	UT to Lower Creek at Underdown Road	.	.	.	.	.	.
Z1	Zacks Fork at US 321A	.	X	.	X	X	X
Z2	Zacks Fork at SR 1531	.	X	.	X	.	.
A1	Abingdon Creek at SR 1927/Old Morganton Road	.	.	.	.	.	X
A2	Abingdon Creek at NC 18 Bypass	.	X	.	.	.	.
G1	Gunpowder Creek at Mason Road	.	X	.	.	.	.
SM1	Smoky Creek at SR 1515	.	X	.	.	.	.

http://h2o.enr.state.nc.us/lab/ (NCDWQ 2002a). DWQ Lab Methods and Practical Quantitation Limits (PQLs) for all parameters, except semivolatile organics, are provided in Table 1.3. The semivolatile DWQ Lab Methods and PQLs are available at the website: http://h2o.enr.state.nc.us/lab/ (NCDWQ 2002a).

Table 1.3. DWQ Laboratory Section -- Methods and Practical Quantitation Limits (PQL)

Parameter	EPA Method[1]	APHA Method[2]	PQL	Revision Date
Bacteria				
Coliform, MF fecal	600/8-78-017	9222D	1 colony/100mL	3/13/2001
Residues and Turbidity				
Suspended Residue	160.2	2540D	2 mg/L	3/13/2001
Suspended Volatile residue	160.4		2 mg/L	
Suspended Fixed residue	160.4		2 mg/L	
Turbidity	180.1	2130B	1 NTU	
Nutrients				
NH_3 as N[3]	350.1 and 350.2		0.02 mg/L	7/24/2001
TKN as N[4]	350.1 and 351.2		0.20 mg/L	
NO_2+ NO_3 as N[5]	353.2		0.01 mg/L	
P total as P[6]	365.1		0.02 mg/L	
Metals				
Aluminum (Al)	200.7		50 µg/L	3/13/2001
Arsenic (As)	200.8/200.9 (11/16/04)[a]		5 µg/L (10 µg/L previously)	11/4/04
Cadmium (Cd)	200.8/200.9 (11/16/04)[a]		2.0 µg/L	3/13/01
Calcium (Ca)	200.7		0.10 mg/L	
Chromium (Cr)	200.8/200.7		25 µg/L	
Copper (Cu)	200.8/200.9 (11/16/04)[a]		2.0 µg/L	
Iron (Fe)	200.7		50 µg/L	
Lead (Pb)	200.8/200.9 (11/16/04)[a]		10 µg/L	
Magnesium (Mg)	200.7		0.10 mg/L	
Manganese (Mn)	200.8/200.7		10 µg/L	
Mercury (Hg)	245.1		0.2 µg/L	
Nickel (Ni)	200.8/200.9 (11/16/04)[a]		10 µg/L	
Potassium (K)	200.7		0.10 mg/L	7/24/2001
Silver (Ag)	200.8/200.9 (11/16/04)[a]		5 µg/L	
Sodium (Na)	200.7		0.10 mg/L	3/13/01
Zinc (Zn)	200.8/200.7		10 µg/L	

[1] Information on EPA methods available at
http://www.esb.enr.state.nc.us/lab/qa/epamethods/epamethods.htm
[2] APHA reference: *Standard Methods for the Examination of Water and Wastewater*, 18th ed.
Other Methods
[3] QUIK CHEM 10-107-06-1-J; [4] QUIK CHEM 10-107-06-2-H; [5] QUIK CHEM 10-107-04-1-C;
[6] QUIK CHEM 10-115-01-1-EF

[a] EPA method revision date

A special toxicological study was conducted on the following streams and their tributaries: Greasy Creek, Spainhour Creek, UT to Lower Creek, Zacks Fork, and Blair Fork. To help determine landfill discharge effects on stream quality, more intensive sampling occurred near the closed landfill located downstream of the Blair Fork headwaters. In addition to the toxicological scan, field parameters and water samples for analyses of nutrients and metals were collected. Detailed results of the toxicology study are provided in *Draft Report – Toxicity Assessment of Catawba Basin Surface Waters Collected In Caldwell County, April 2005*, by the NC DWQ Aquatic Toxicology Unit (NCDWQ 2005b). An abbreviated summary is provided in Section 3.

1.3 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, 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. A detailed description of the benchmarks used in this study as well as the sources of each benchmark can be found in Table 1.4.

Benchmark screening values denote thresholds of elevated risk, but do not predict actual impacts in particular situations. Actual site-specific and event-specific impacts depend upon 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.

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 Lower Creek assessment are toxicity based provided in: 1) EPA's acute and chronic National Ambient Water Quality Criteria (NAWQC) for freshwater (USEPA, 2002) and 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. The chronic NAWQC were derived by various formulas and are generally lower than acute values (USEPA, 2002). Tier II values were developed by EPA as part of the Great Lakes Program (USEPA, 1995) for use with chemicals for which NAWQC are not available. They are based on fewer data than are required to establish NAWQC.

In this study NAWQC for priority pollutants were taken from EPA's online Water Quality Standards Database (http://www.epa.gov/wqsdatabase/). NAWQC for non-priority pollutants, which are not included in the online database, were taken from USEPA (2002). Tier II values were obtained from the ecological benchmark listing available through the Risk Assessment Information System operated by the Oak Ridge National Laboratory (2004) (http://risk.lsd.ornl.gov/homepage/eco_tool.shtml).

Benchmark values for many of the parameters included in this study are provided in Table 1.4. For trace metals, chronic (baseflow) and acute (stormflow) benchmarks are the EPA's Acute National Ambient Water Quality Criteria (NAWQC) values. For manganese, benchmarks are the EPA's Tier II values. Benchmarks for Cd, Cu, Pb, Ni, and Zn were adjusted for the hardness of each sample. For major cations and nutrients, benchmarks are comparison ranges (25^{th} to 75^{th} quartile range) for the Piedmont physiographic province, which are compiled in Briel, 1997.

For field parameters, turbidity, and fecal coliform bacteria, benchmarks are NC Water Quality Standards for Class C waters.

Observed pollutant concentrations can also be compared to either North Carolina's Water Quality Standards (NCWQS) for specifically freshwater aquatic life (NCDENR 2004: 15A NCAC 02B.0211), which serve as important regulatory benchmarks, or to the 25 - 75^{th} quartile range comparisons complied for the Piedmont Physiographic Province in Briel (1997), which are regional references derived by comparing water quality parameters recorded in a specific physiographic province. More information on North Carolina's Water Quality Standards can be found in the NC Freshwater Standards Table on the DWQ's website:http://h2o.enr.state.nc.us/csu/#StTables.

Table 1.4. Benchmark values for many of the parameters included in this study.

Parameter	Benchmark	Parameter	Risk-based Benchmark[3]	
			Chronic	**Acute**
Field		*Metals (µg/L)*		
Dissolved Oxygen (mg/L)[1]	>5	Aluminum	87	750
pH[1]	6 - 9	Arsenic	150	340
Temperature (°C)[1]	29	Cadmium	Adjusted for sample-specific hardness[5]	
Nutrients (mg/L)		Chromium	11	16
Ammonia as N[2]	0.07 – 0.47	Copper	Adjusted for sample-specific hardness[5]	
Nitrite + Nitrate as N[2]	0.43 – 2.9	Iron	1000	N/A
Phosphorus[2]	0.06 – 0.58	Lead	Adjusted for sample-specific hardness[5]	
Other (NTU)		Mercury	0.77	1.4
Turbidity[1]	50	Manganese	120[(4)]	2300[(4)]
Major cations (mg/L)		Nickel	Adjusted for sample-specific hardness[5]	
Calcium[2]	5.7 – 20	Silver	0.36[(4)]	3.4
Magnesium[2]	2.1 – 6.7	Zinc	Adjusted for sample-specific hardness[5]	
Sodium[2]	4.7 – 14			
Bacteria (col/100 mL)				
Fecal Coliform[1]	200			

[1] NC Water Quality Standards for Freshwater Classifications, 15A NCAC 2B.0211, for Class C waters. http://h2o.enr.state.nc.us/csu/#StTables. See NC Freshwater Standards Table (NCDENR-DWQ 2004)
[2] Briel, L.I. 1997. Water quality in the Appalachian Valley and Ridge, the Blue Ridge, and the Piedmont physiographic provinces, eastern US. USGS Professional Paper 1422-D.
[3] Chronic and Acute National Ambient Water Quality Criteria (NAWQC) for freshwater (USEPA, 2002 and 2004).
[4] Tier II values (USEPA, 1995).
[5] Benchmark values were adjusted for the hardness of each sample. See section 2.4.

These benchmarks are included in this summary report to provide additional benchmark information and to use as comparisons for parameters that are not included in the NAWQC compilation of benchmarks or in the Risk Assessment Information System. However, the NAWQC, which are concerned with assessing the risks of site-specific impacts, are more appropriate for this study, as they were based solely on data and scientific judgments on the relationship between pollutant concentrations and environmental and human health effects (USEPA, 2002).

Section 2: Physical and Chemical Results

2.1 Introduction

This section provides a summary of physical and chemical water quality monitoring results. Physical and chemical samples are collected during stormflow and baseflow conditions to distinguish among the types and concentrations of substances found in streams during these two flow conditions. Baseflow samples may include substances that are indicative of local groundwater and point source discharges into the creeks. Samples collected during stormflow events have constituents from urban and overland flow. Thus aquatic organisms will be exposed to different substances or substances at varying concentrations and durations depending on flow conditions.

A series of graphs were constructed to show differences between the results observed during baseflow and stormflow conditions or among sites (Figures 2.1 to 2.9). JMP statistical software was used to develop summaries of the measured results and to construct the figures. Results on graphs representing the sample values were spread laterally ("jittered") as opposed to being plotted on top of each other, which would falsely represent one result instead of several.

The overall mean is depicted as a horizontal gray line across the graph. Shorter horizontal lines, if present, represent group averages. Parameters not found above reporting limits in the Lower Creek watershed, such as arsenic, are not shown.

2.2 Nutrients

Nitrate is highly mobile and can infiltrate ground water when derived from agricultural fertilizer, animal waste, or decaying plant material (USGS 2005). The UT to Lower Creek at NC 18 was found to have a high concentration of nitrate nitrite during both base and stormflow conditions (Figures 2.1 and 2.2). These data may indicate a potential direct discharge into the creek or ground water contamination in the area.

Ammonia tends to be relatively immobile in soils and ground water because of adsorption on soil surfaces and particulate filtering; therefore, it is more likely to originate from a point source (USGS 2005). Blair Fork at 1944 Valway had higher ammonia concentrations in two baseflow samples than in stormflow sampling. Staff had noticed possible sewage straight pipes on this stream that might account for these high ammonia results.

Higher concentrations of TKN were observed during stormflow than baseflow across all sites. This increase is likely due to surface water runoff since these nutrients are relatively immobile in soils and ground water. Sources may include the decay of organic material, such as plant material and animal wastes, and urban and industrial disposal of sewage and organic waste (USGS 2005). Specific subwatershed stormflow sources may include ornamental plant nurseries, cattle access to the creek, raw sewage inputs (e.g., a failing collection system and sewage straight pipes) and urban non-point sources (e.g., domestic pet fecal matter and lawn/garden fertilizers).

Similarly, total phosphorus generally occurred at higher concentrations during stormflows than baseflows across the entire watershed. This increase is usually caused by phosphorus attaching to suspended residue and entering the stream in surface water runoff, but there are incidences when phosphorus enters the stream through point sources, such as overflowing sewer manholes. On numerous occasions, staff observed raw sewage entering Spainhour

Creek from either overflowing manholes or failing collection system pipes. Greasy Creek, which had the highest TP concentrations, Lower Creek, and Blair Fork occasionally surpassed the upper range of the TP benchmark of 0.58 mg/L. The amount of phosphorus entering streams can be influenced by manure (which varies by animal source and type of animal feed) and the application of fertilizer. One of the probable phosphorus sources in Greasy Creek is the ornamental plant nursery. Due to the narrow riparian buffer along the creek near the nursery, nutrient inputs may not be sufficiently filtered before entering the stream. Cattle access to the creek is another potential source of nutrients on Greasy Creek. The banks along Reach 1 of Greasy Creek in particular were heavily eroded due to cattle trampling, and manure was observed in and near the stream.

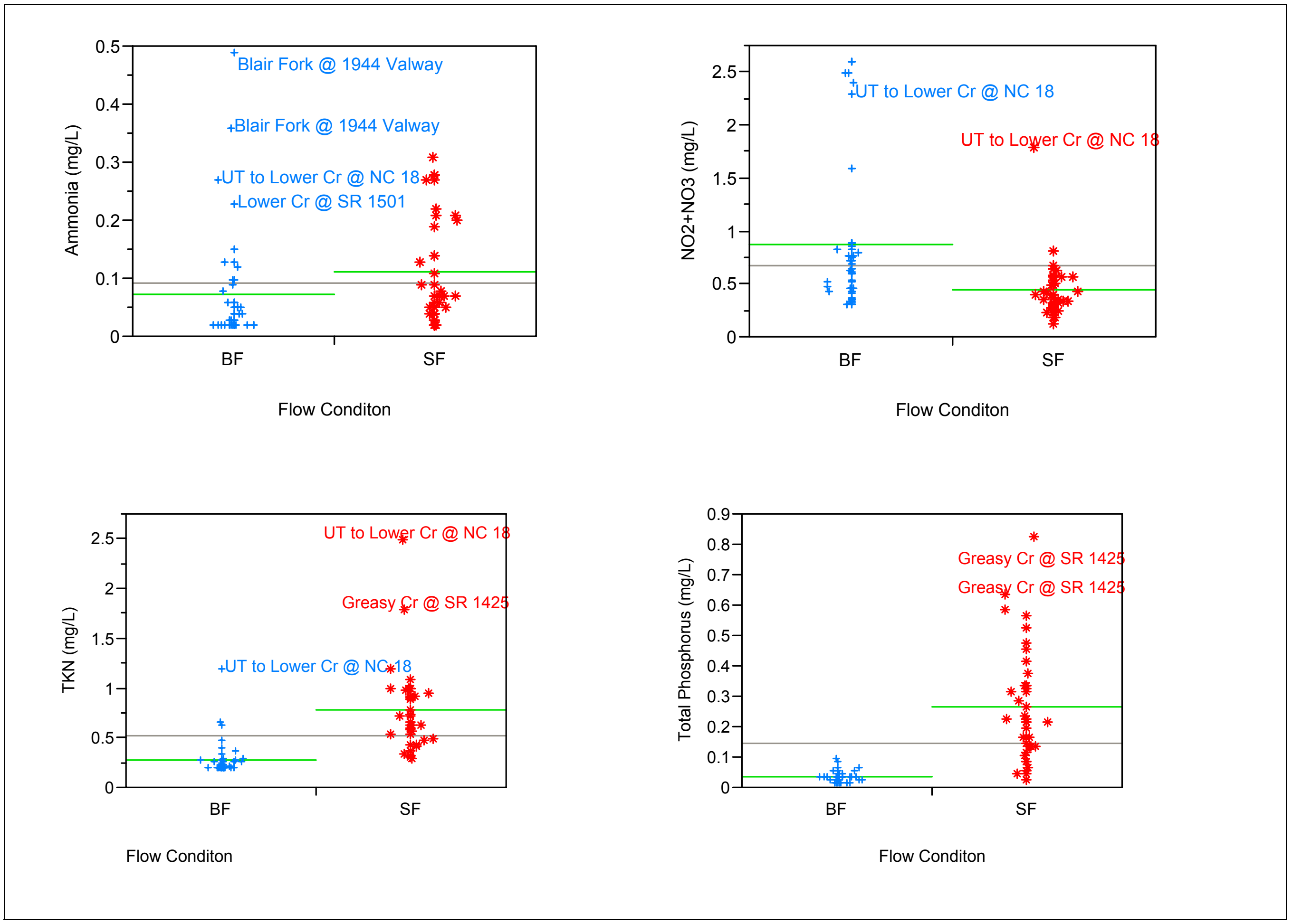


Figure 2.1. Graphs depicting differences between baseflow (BF) and stormflow (SF) for nutrients. All five of the high results for NO_2+NO_3 were observed at the UT to Lower Cr at NC 18. The horizontal line extending across the graph depicts the grand mean, shorter horizontal lines represent the averages for each flow condition.

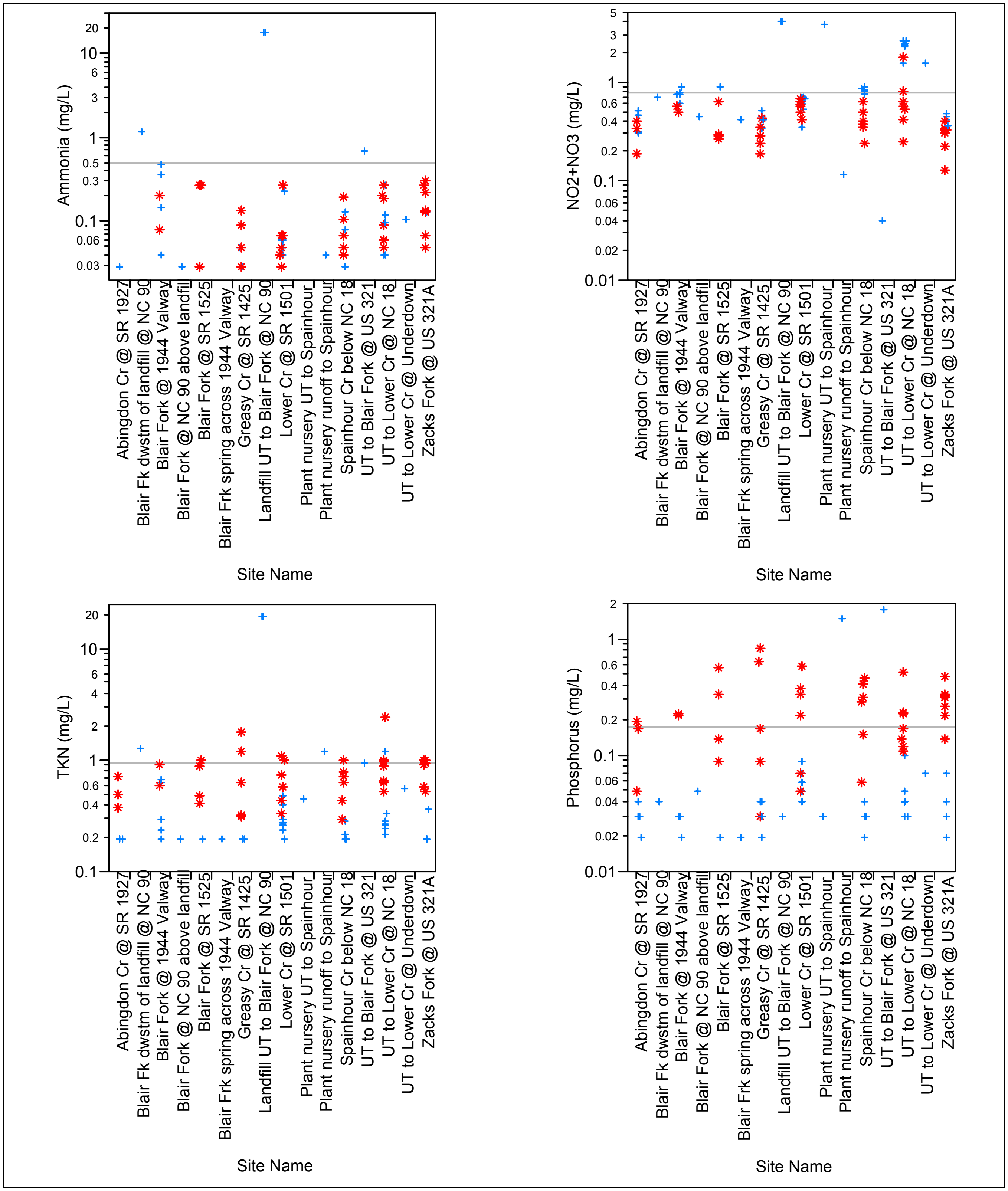


Figure 2.2. Variations among stations and baseflow (+) and stormflow (*) conditions for nutrients. Note that results are log-transformed to better show differences between low values and the highest (outlier) values. The horizontal lines across the graphs depict the grand means.

2.3 Turbidity and Suspended Residue

Turbidity and suspended residue (volatile and fixed) are higher during stormflow than baseflow (Figure 2.3). Every creek sampled during stormflow within the watershed exceeded the North Carolina freshwater water quality standard for turbidity of 50 NTU in at least one event, illustrated in Figure 2.4. High levels of suspended fixed solids may be a result of stream bank erosion and urban sediment sources (such as construction sites, road runoff, and unstable ground surfaces).

Greasy Creek had the highest turbidity and suspended solids, but these data may have been skewed by a beaver dam, first noted on January 21, 2005, located down stream of the sampling point. The ponded water may have artificially elevated these stormflow concentrations, and may not fully represent actual stream concentrations.

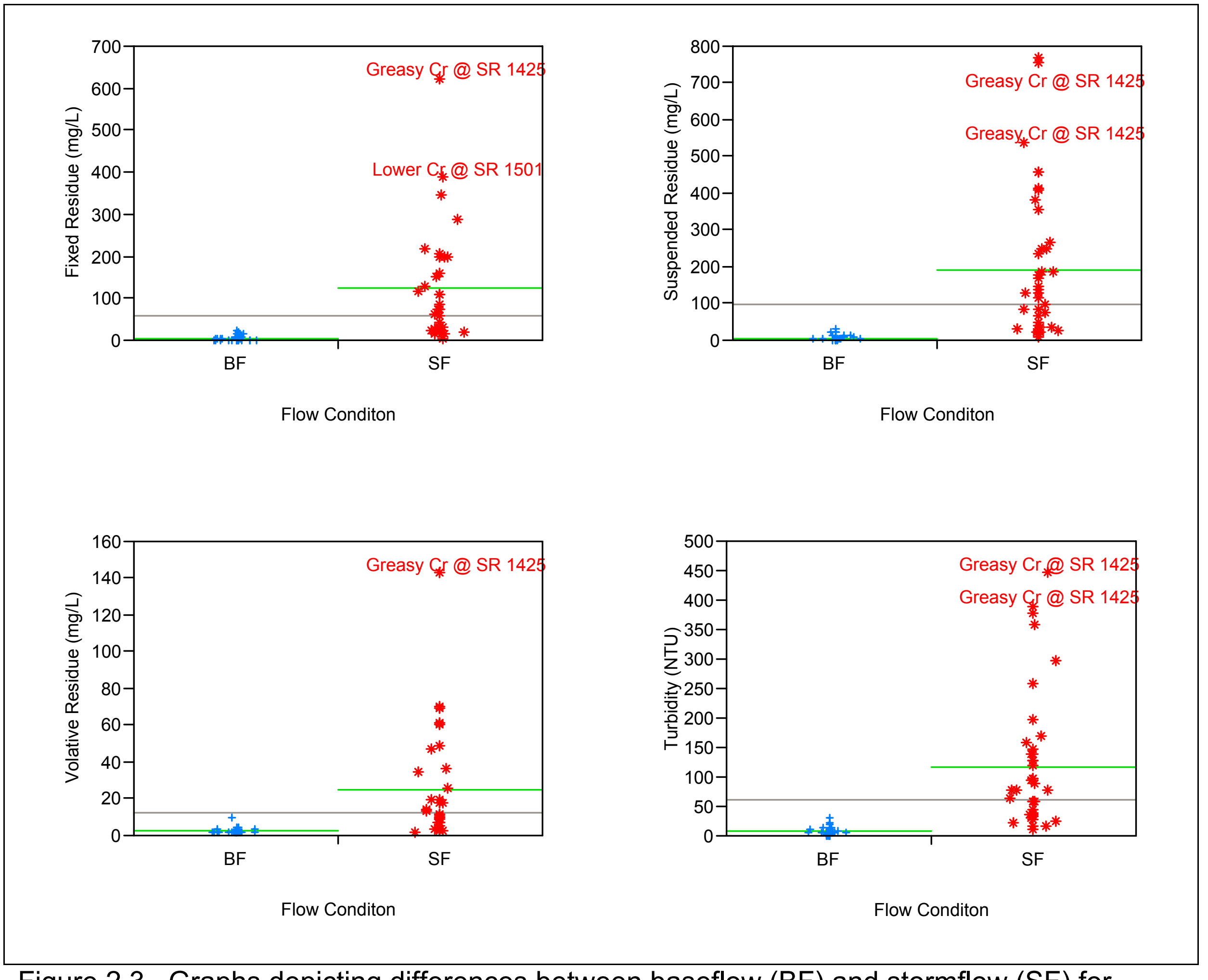


Figure 2.3. Graphs depicting differences between baseflow (BF) and stormflow (SF) for residues and turbidity. The horizontal line extending across the graph depicts the grand mean, shorter horizontal lines represent the averages for each flow condition.

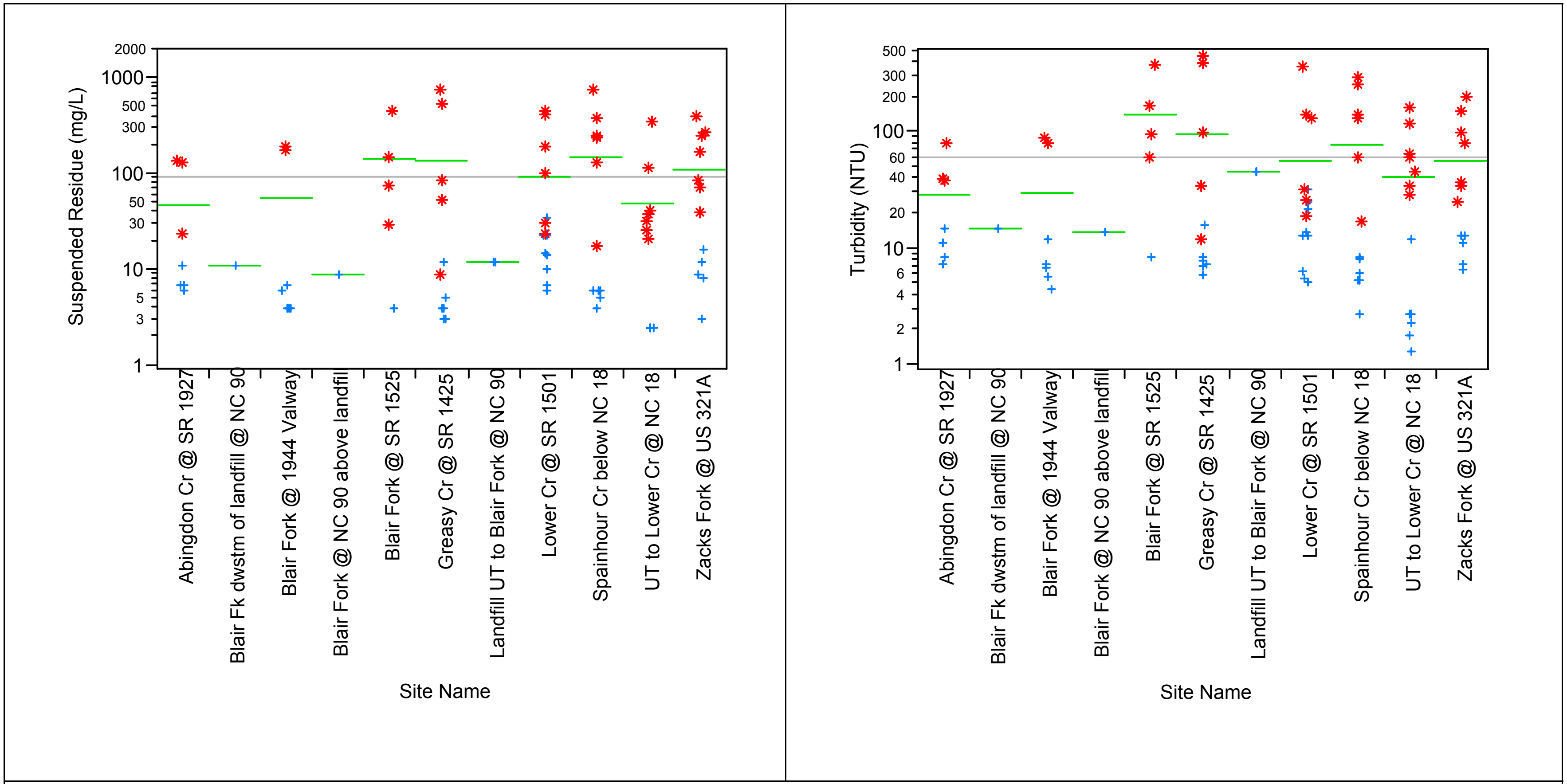


Figure 2.4. Results among stations for suspended residue and turbidity. The horizontal line crossing the graph represents the grand mean. Shorter horizontal lines represent site means. Baseflow results are depicted by a "+," stormflow by an "*."

2.4 Metals

Throughout the watershed, with the exception of the UT to Lower Creek at NC 18, the majority of aluminum concentrations at baseflow were above the chronic benchmark of 87 µg/L, and across all sites, the majority of aluminum levels at stormflow were above the acute benchmark of 750 µg/L (Figure 2.5). Similarly, iron concentrations at both baseflow and stormflow were consistently higher than the EPA benchmark for iron of 1000 µg/L (Figure 2.6). The sharp increase in aluminum and iron concentrations throughout the watershed during stormflow is most likely a result of their presence in native soils (Reid 1993). The two highest iron concentrations in the watershed, however, occurred at baseflow at the Landfill UT to Blair Fork at NC 90 and the UT to Blair Fork @ US 321 during baseflow conditions. These high levels may be attributable to sources other than the native soils. The UT to Blair Fork @ US 321 is adjacent to the expansion of US 321, and the source or type of fill material used in the expansion is unknown. Further investigation is needed to determine the source of these high baseflow iron concentrations. The Abingdon Creek watershed, which has fewer urban influences than most of the streams in the Lower Creek watershed, still had aluminum concentrations above benchmark levels during both baseflow and stormflow conditions, which may illustrate a more pervasive groundwater or soil pH condition within the watershed.

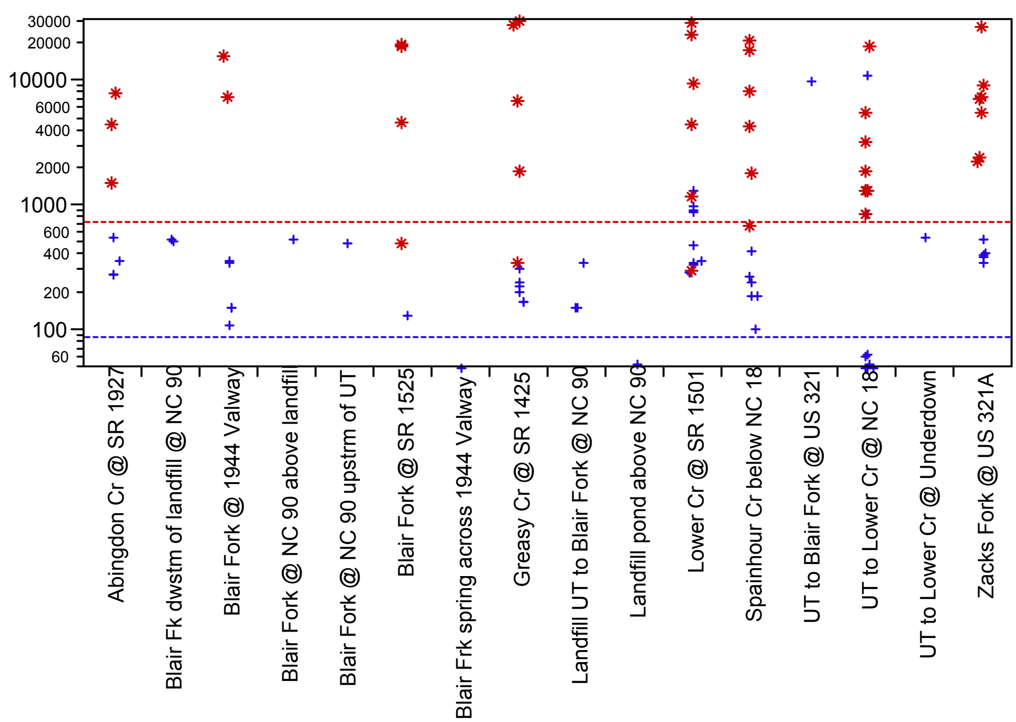


Figure 2.5. Baseflow (+) and stormflow (*) aluminum concentrations (µg/L) in the Lower Creek watershed (log scale). The blue line shows the EPA chronic benchmark of 87 µg/Land the red line indicates the EPA acute benchmark of 750 µg/l.

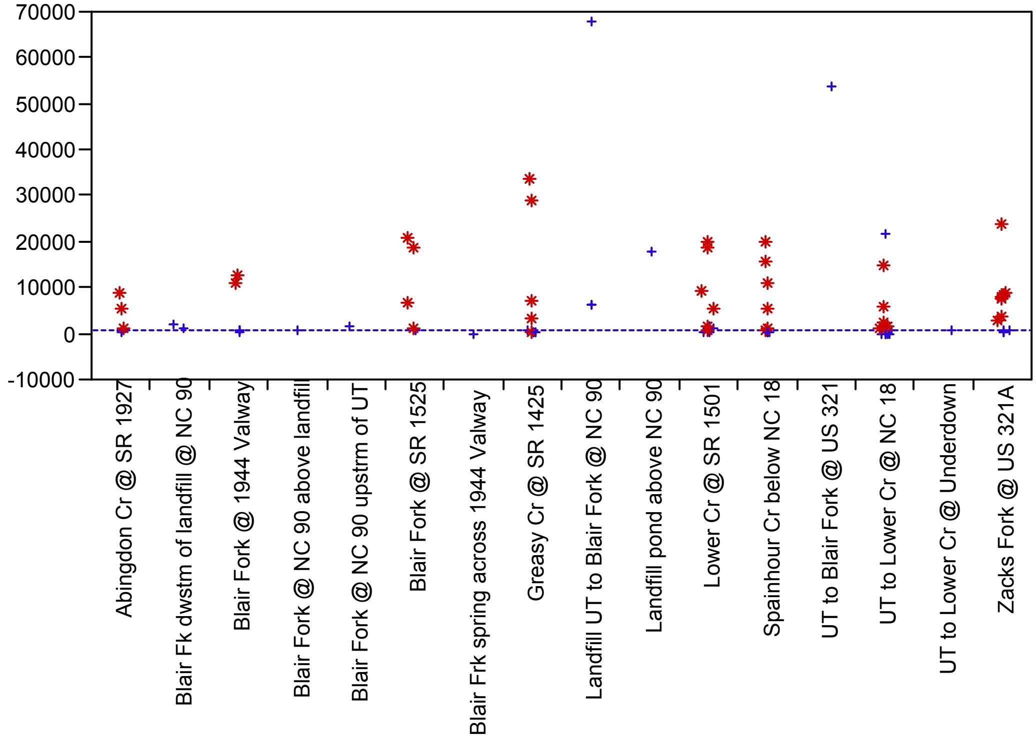
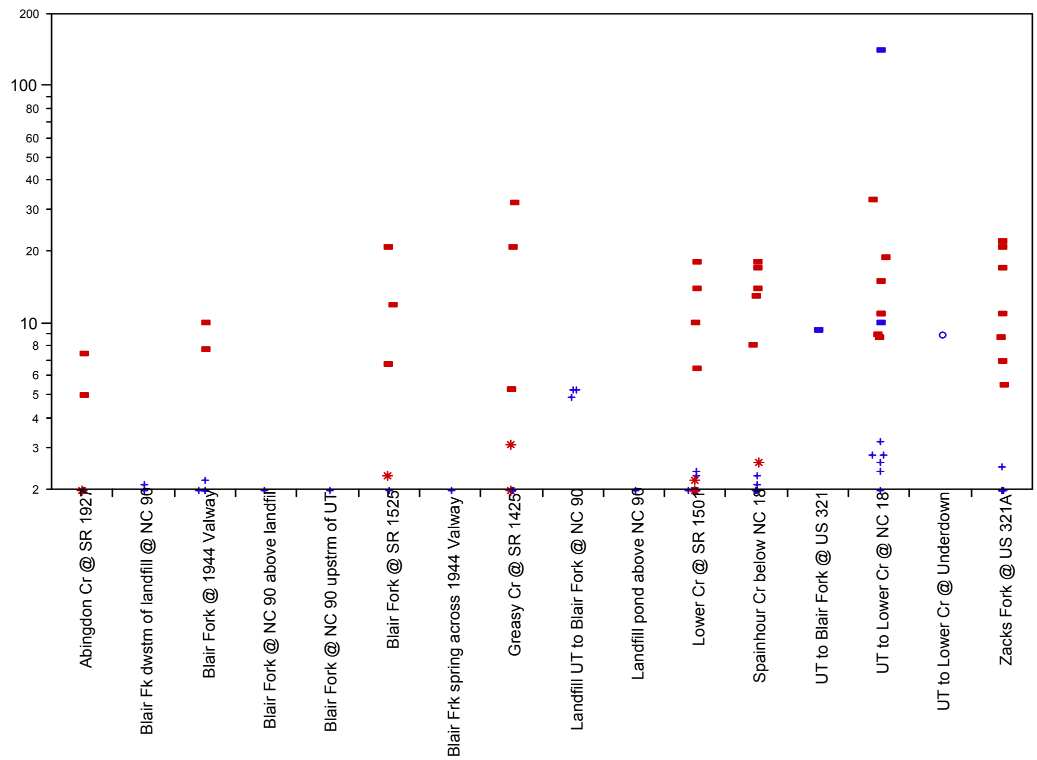


Figure 2.6. Baseflow (+) and stormflow (*) iron concentrations (µg/l) in the Lower Creek watershed. The line indicates the EPA chronic benchmark of 1000 µg/L (no acute benchmark is available for this metal).

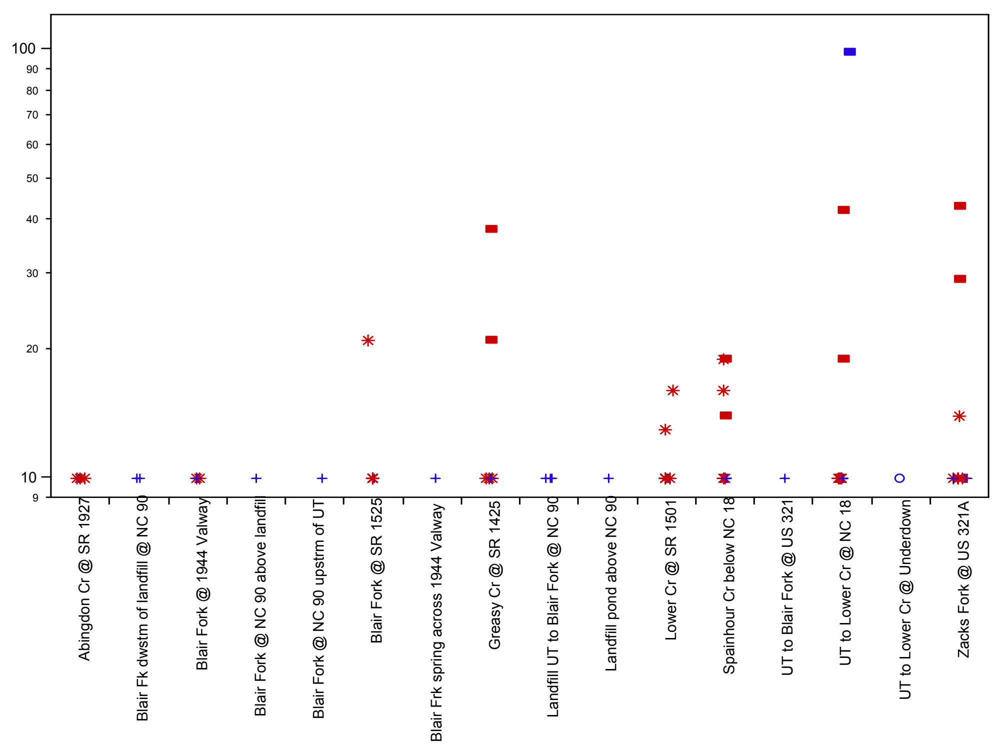
The UT to Lower Creek at NC 18 had higher levels of zinc, manganese, copper, and lead at baseflow than any of the other sites in the Lower Creek watershed (Figures 2.7 A, B, and C and Figure 2.8). Looking at the overall map of the geology of the Lower Creek watershed, geologists noted that UT to Lower Creek at NC 18 has complex geology, which may be partially responsible for metals at this site (Carl Merschat, 2005). However, this source is not certain, and the metals may also be attributed to urban influences.

The highest zinc concentration in the Lower Creek watershed (670 µg/L), which is more than four times higher than its hardness-adjusted chronic benchmark of 140 µg/L, was recorded at this site at baseflow. The only other site to have zinc concentrations above sample-specific benchmarks at baseflow was the UT to Blair Fork at US 321. At stormflow, six of seven zinc samples at the UT to Lower Creek at NC 18 were above their hardness-adjusted benchmarks, while five of six samples and four of six samples were above sample-specific benchmarks at Spainhour Creek below NC 18 and Zacks Fork at US 321, respectively (Table 2.1).

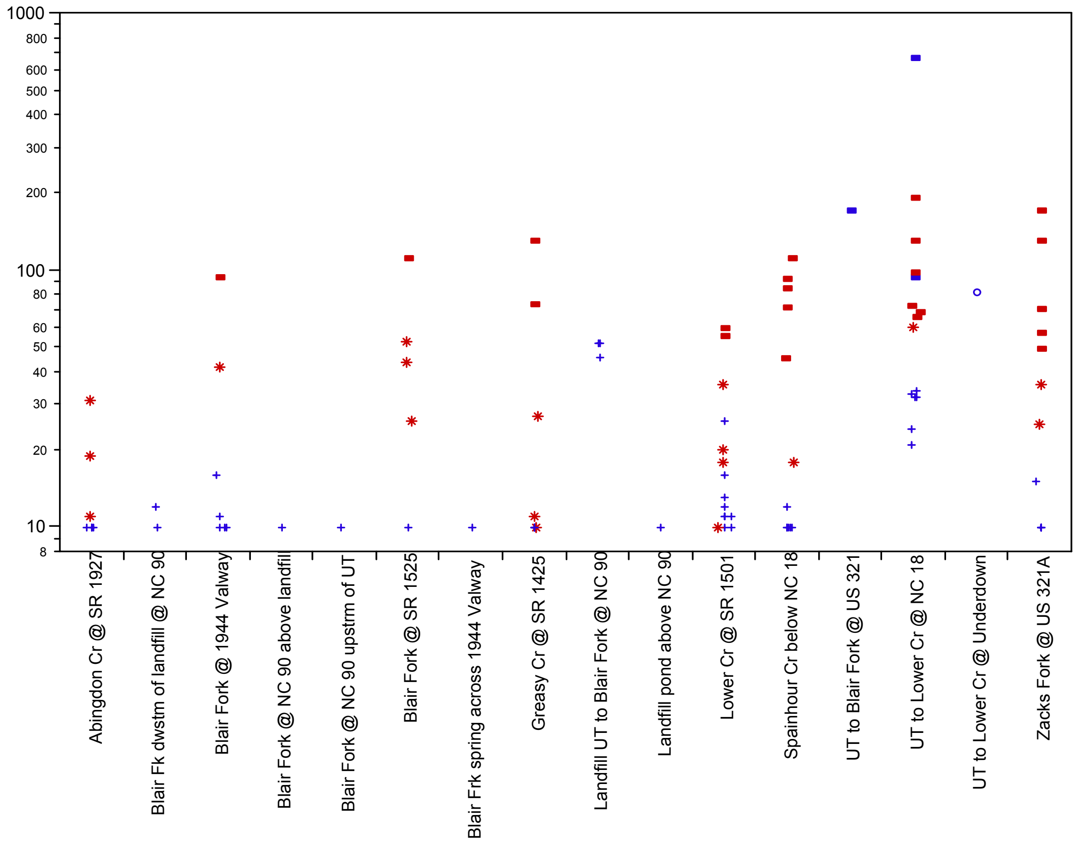
Manganese was high across the Blair Fork watershed. Seven of the nine sites in the Blair Fork watershed had manganese concentrations above the chronic benchmark of 120 µg/L during baseflow conditions. The only sites in the Blair Fork watershed that did not have samples that exceeded benchmarks were the site located upstream of the landfill (Blair Fork at NC 90 above landfill) and Blair Fork spring. In addition, the Landfill UT to Blair Fork at NC 90, the Landfill pond above NC 90, and UT to Blair Fork at US 321 had baseflow samples above the acute benchmark of 2300 µg/L. Outside of the Blair Fork watershed, only Lower Creek at SR 1501 had baseflow samples above the chronic manganese benchmark.



A



B



C

Figures 2.7 A, B, and C. Copper (A), lead (B), and zinc (C) concentrations (µg/l) at baseflow (blue) and stormflow (red) in the Lower Creek watershed. Samples represented by a “+” and a “*” indicate baseflow and stormflow samples that did not exceed sample-specific, hardness-adjusted benchmarks. Samples represented by blue (baseflow) and red (stormflow) rectangles exceeded their sample-specific, hardness-adjusted benchmarks. Circles are used to indicate samples for which no calcium or magnesium samples were available to calculate hardness.

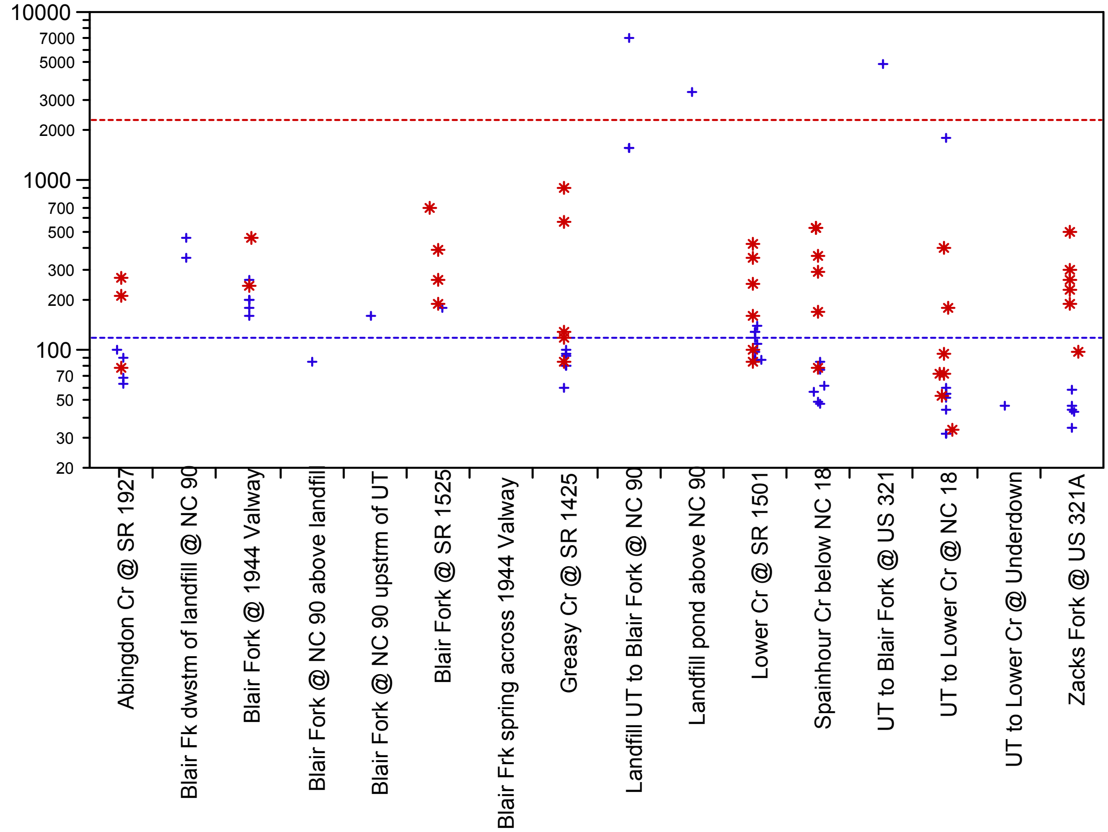


Figure 2.8. Baseflow (+) and stormflow (*) manganese concentrations (µg/L) in the Lower Creek watershed (log scale). The blue line indicates the EPA chronic benchmark of 120 µg/Land the red line illustrates the acute benchmark of 2300 µg/L.

As with zinc, only the UT to Lower Creek at NC 18 and the UT to Blair Fork at US 321 had copper concentrations above their chronic hardness-adjusted benchmarks at baseflow. During stormflow conditions, copper exceeded its hardness-adjusted benchmarks at both urban and rural sites in the watershed (Table 2.2). All of the samples taken at the UT to Lower Creek at NC 18 and at Zacks Fork at US 321A were above their hardness-adjusted acute benchmarks at stormflow, and sites in Greasy Creek, Blair Fork, Spainhour Creek, and Lower Creek also exceeded acute benchmarks in some stormflow samples. Even at Abingdon Creek, the reference site in this study, copper concentrations surpassed acute benchmarks in two of three samples. Urban sources for copper include brake linings, which also have a relatively high lead and zinc content, and leaded, unleaded and diesel fuel emissions.

Lead levels exceeded hardness-adjusted acute benchmarks during several storm events at Greasy Creek at SR 1425, Spainhour Creek below NC 18, UT to Lower Creek at NC 18 and Zacks Fork at 321A (Table 2.3). The highest lead concentration recorded in the Lower Creek watershed (98 µg/L) occurred at the UT to Lower Creek at NC 18 at baseflow and was more than 24 times higher than its hardness-adjusted chronic benchmark of 4 µg/l.

Table 2.1. Zinc concentrations at baseflow (BF) and stormflow (SF) in the Lower Creek watershed and comparison benchmark (BM) values. Sites listed are those with at least one sample above benchmark values. Concentrations ≥ benchmarks are in bold type. All benchmarks were adjusted for sample-specific hardness.

		Blair Fork @ 1944 Valway		**Blair Fork @ SR 1525**		**Greasy Cr @ SR 1425**		**Lower Cr @ SR 1501**		**Spainhour Cr below NC 18**		**UT to Blair Fork @ US321**		**UT to Lower Cr @ NC 18**		**Zacks Fork @ US 321A**	
Flow condition	Date	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM
BF	2/11/04													32	79		
	4/23/04											**170**	105				
	10/19/04	<10	53			<10	38	<10	44								
	2/14/05													**93**	63		
	4/4/05	<10	47											32	88		
	4/6/05															15	35
	3/24/04							11	37								
	4/6/04					<10	33	<10	40	<10	45						
	6/3/04							26	42								
	6/30/04			<10	51	<10	35	12	43	<10	44			24	80	<10	36
	9/15/04	16	53			<10	37	16	47	<10	47			**670**	140	<10	40
	12/14/04					<10	35	11	40	<10	46			34	91	<10	36
	12/28/04	11	50			<10	34	11	42	<10	46			33	89	<10	36
	1/5/05		50					13	41	12	45			21	88		
SF	8/12/04			53	54			36	44	**92**	35			**65**	30	**70**	38
	9/7/04			44	53	11	37	20	44	**45**	41			**68**	36	25	32
	9/28/04	42	45			27	35	**55**	42	**71**	44			60	65	36	37
	10/19/04									18	36			**97**	40	**49**	36
	2/21/05			26	47	10	33	<10	37					**72**	36		
	2/6/04			**110**	58	**73**	46	**59**	43	**110**	48			**130**	35	**57**	36
	5/20/04	**94**	57			**130**	69	18	41	**85**	44			**190**	45	**130**	41

Table 2.2. Copper concentrations at baseflow (BF) and stormflow (SF) in the Lower Creek watershed and comparison benchmark (BM) values. Sites listed are those with at least one sample above benchmark values. Concentrations ≥ acute benchmarks are in bold type. All benchmarks were adjusted for sample-specific hardness.

				Blair Fork @ SR 1525		Greasy Cr @ SR 1425		Lower Cr @ SR 1501		Spainhour Cr below NC 18		UT to Blair Fork @ US321		UT to Lower Cr @ NC 18		Zacks Fork @ US 321A		Abingdon Cr @ SR 1927	
Flow condition	Date	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM	Conc. (µg/L)	BM
BF	2/11/04	--	--	--	--	--	--	--	--	--	--	--	--	2.4	6.1	--	--		
	4/23/04	--	--	--	--	--	--	--	--	--	--	**9.3**	8.2	--	--	--	--		
	10/19/04	<2	4.1			<2	2.9	<2	3.4	--	--	--	--	--	--	--	--	<10	2.8
	2/14/05	--	--	--	--	--	--	--	--	--	--	--	--	**10.0**	4.8	--	--		
	4/4/05	2.2	3.6			--	--	--	--	--	--	--	--	3.2	6.8	--	--		
	4/6/05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<2	2.7		
	3/24/04	--	--	--	--	--	--	<2	2.9	--	--	--	--	--	--	--	--		
	4/6/04	--	--	--	--	<2	2.6	<2	3.1	<2	3.4	--	--	--	--	--	--		
	6/3/04	--	--	--	--	--	--	2.4	3.3	--	--	--	--	--	--	--	--		
	6/30/04	--	--	<2	3.9	<2	2.7	<2	3.3	<2	3.4	--	--	2.6	6.2	<2	2.8		
	9/15/04	<2	4.1	--	--	<2	2.9	<2	3.6	<2	3.7	--	--	**140.0**	11	<2	3.1	<10	2.7
	12/14/04	--	--	--	--	<2	2.7	<2	3.1	<2	3.6	--	--	<2	7.1	<2	2.8	<10	2.8
	12/28/04	<2	3.9	--	--	<2	2.6	2.3	3.2	2.1	3.5	--	--	2.8	6.9	<2	2.8	<10	2.7
	1/5/05	<2	3.9	--	--	--	--	<2	3.2	2.3	3.5	--	--	2.8	6.9				
SF	8/12/04	--	--	**12.0**	5.7	--	--	**10.0**	4.6	**17.0**	3.6	--	--	**11.0**	3.0	**17.0**	3.9		
	9/7/04	--	--	**6.7**	5.7	3.1	3.8	**6.4**	4.6	**8.1**	4.2	--	--	**11.0**	3.7	**5.5**	3.2	**19**	3.7
	9/28/04	**7.8**	4.7	--	--	**5.3**	3.5	14.0	4.3	**14.0**	4.6	--	--	**8.7**	7.1	**8.7**	3.8	**31**	3.4
	10/19/04	--	--	--	--	--	--	--	--	2.6	3.7	--	--	**15.0**	4.1	**6.9**	3.7		
	2/21/05	--	--	2.3	5.0	**5.0**	3.4	2.2	3.8	--	--	--	--	**8.9**	3.6	--	--	**11**	3.2
	2/6/04	--	--	**21.0**	6.2	**21.0**	4.8	**18.0**	4.5	**18.0**	5.1	--	--	**19.0**	3.6	**11.0**	3.7		
	5/20/04	**10.0**	6.1	--	--	**32.0**	7.5	<2	4.3	**13.0**	4.7	--	--	**33.0**	4.7	**21**	4.4		

Table 2.3. Lead results (µg/L) during stormflow in the Lower Creek watershed and comparison benchmark (BM) values. Sites listed are those with at least one sample above acute benchmarks. Values ≥ acute benchmarks are in bold type. All benchmarks were adjusted for sample-specific hardness. *Note:* At baseflow, only one lead sample in the Lower Creek watershed was above its chronic benchmark. The lead concentration of 98 µg/L, which was recorded at the UT to Lower Creek at NC 18, was more than 24 times higher than its hardness-adjusted chronic benchmark of 4.0 µg/L.

	Greasy Cr @ SR 1425		**Spainhour Cr below NC 18**		**UT to Lower Cr @ NC 18**		**Zacks Fork @ US321A**	
Date	Result	BM	Result	BM	Result	BM	Result	BM
8/12/04	--	--	**19**	13	<10	10	14	15
9/7/04	<10	14	<10	16	<10	14	<10	11
9/28/04	<10	14	14	18	<10	33	<10	14
10/19/04	<10	13	<10	19	<10	16	<10	14
2/21/05	<10	12	--	--	<10	13	<10	13
2/6/04	**31**	19	19	21	**19**	13	**29**	16
5/20/04	**38**	35	16	18	**42**	19	**43**	17

2.5 Fecal Coliform Bacteria

The North Carolina Water Quality Standard (NCWQS) states that fecal coliform bacteria shall not exceed a geometric mean of 200 colonies per 100 ml in five samples in 30 days (5/30 day) during baseflow conditions or exceed 400 colonies per 100 ml in more than 20 percent of the samples examined during such period (NCDENR-DWQ 2004). Fecal coliform sampling for this study did not include 5 samples collected within a 30 day period, however, most sites exceeded a geometric mean of 200 colonies per 100 ml (Table 2.4).

Abingdon Creek is the only site with more than one result (n=3) for baseflow conditions that had a geometric mean below the 200 colonies/100 ml threshold. All sampled sites exceeded 200 colonies/100 ml in the majority of stormflow samples (Figure 2.9). Blair Fork (at both primary sampling sites), Greasy Creek, Spainhour Creek, UT to Lower Creek, Zacks Fork and Lower Creek all exceeded the 400 colonies per 100 ml criteria in more than 20 percent of the baseflow samples. These creeks are all located within the Lenoir central sewer collection system geographic area, which has a known overflow problem. Traditionally, it was thought that most of the overflows occurred during storm events as a result of existing infiltration problems. But these findings indicate that there may be a more pervasive problem within the collection system. Additionally, Blair Fork sites exceeded 200 colonies per 100 ml in the single samples taken near its headwaters off of NC 90 outside of the wastewater collection system. These bacteria levels may be a result of an instream pond and livestock. The only sampling sites with insignificant to no fecal coliform bacteria were the ponded water on top of the closed landfill site off of NC 90 and the groundwater spring across from 1944 Valway Road.

Table 2.4. Summary of results for fecal coliform bacteria (col/100 ml).

Site Name	Baseflow samples			All Samples[1]		
	N[2]	Geometric Mean	%>400	N[2]	Geometric Mean	%>400
Abingdon Cr at SR 1927	3	124.8	.	6	566.1	33.3
Blair Fork downstream of landfill at NC 90	1	260.0	.	1	260.0	.
Blair Fork at 1944 Valway	4	268.3	50	6	948.3	66.7
Blair Fork at NC 90 above landfill	1	280.0	.	1	280.0	.
Blair Fork at SR 1525	1	700.0	100	4	2437.1	100.0
Blair Fork spring across 1944 Valway	1	1.0	.	1	1.0	.
Greasy Cr at SR 1425	5	214.1	40	9	777.0	55.6
Landfill UT to Blair Fork at NC 90	2	5.0	.	2	5.0	.
Lower Cr at SR 1501	8	438.7	37.5	13	787.1	53.8
Spainhour Cr below NC 18	5	851.1	80	10	1724.1	90.0
UT to Lower Cr at NC 18	5	348.2	40	11	1123.7	72.7
Zacks Fork at US 321A	4	353.8	25	10	1953.3	70.0

[1]All samples includes baseflow samples and stormflow samples [2]N=number of samples

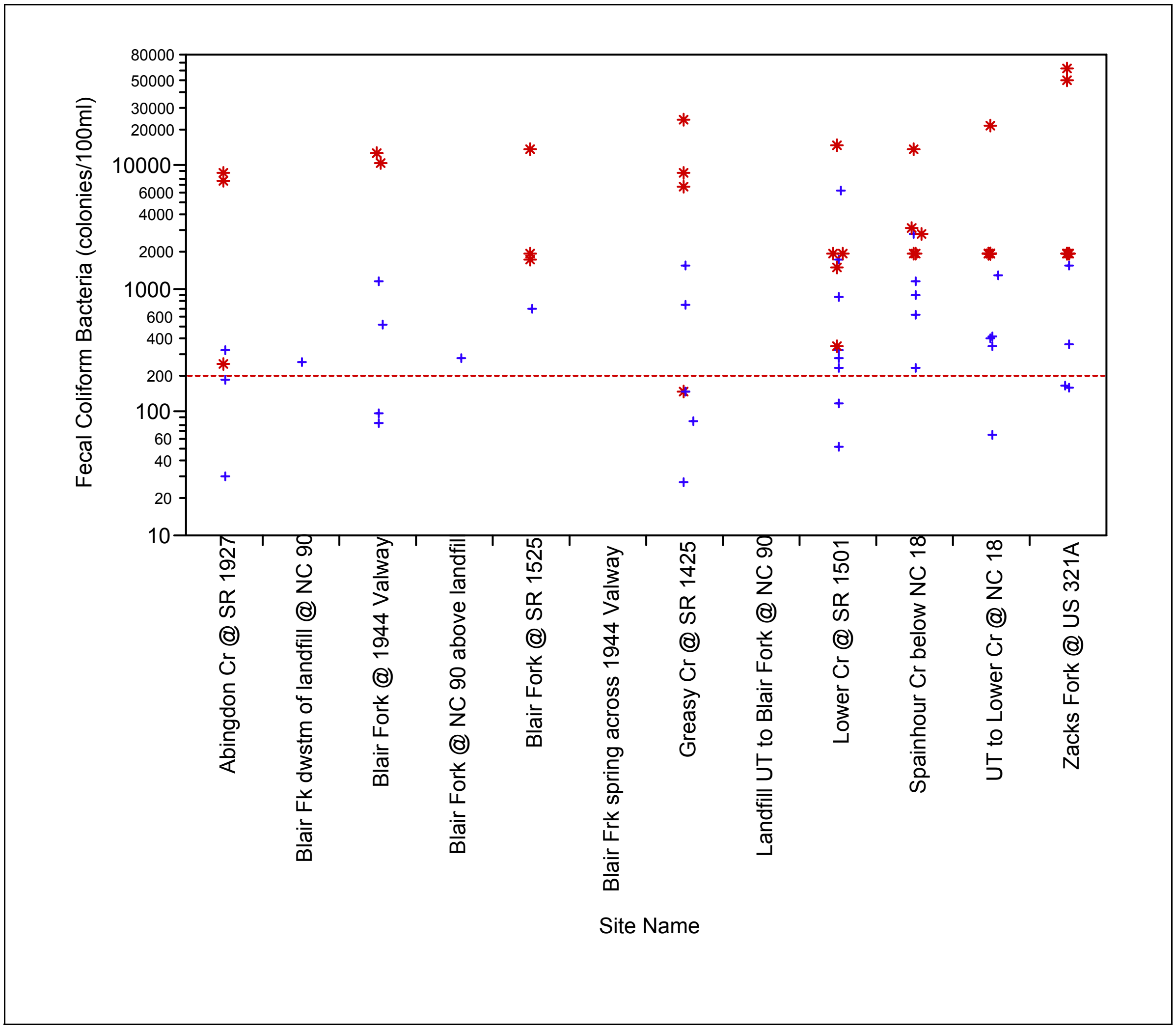


Figure 2.9. Scatterplot of the baseflow (+) and stormflow (*) samples for fecal coliform bacteria. The horizontal dashed line (red) represents the state standard of a geometric mean of 200 colonies/ml. Note that the graph is in log scale.

2.6 Field Parameters

Dissolved oxygen, water temperature, pH and specific conductance were measured in the field. Zacks Fork was the only site where low DO was found and this was during a storm event during which raw sewage may have entered the creek. Fecal coliform concentrations were greater than 64,000 colonies/100 ml on that date (May 20, 2004). During a separate streamwalk on June 23, 2005, staff found a significant sewer pipe leak upstream of US 321A, which local residents stated is a common occurrence. The City of Lenoir wastewater collection supervisor was notified and they initiated repairs that day.

Most of the creeks within the Lower Creek watershed had a pH between 6.5 and 7.5 s.u. during both stormflow and baseflow sampling. The most notable exception is at the UT to Lower Creek at NC 18. At baseflow, pH within this creek tended to always be above 7 s.u. with one sample measuring 8.2 s.u. (September 15, 2004). This particular sample also had a high specific conductivity of 188 µs/cm with correspondingly high metals, cations and nutrients.

Mountain streams may have specific conductance values of 30 µs/cm, whereas Piedmont streams can have values ranging from 150 to over 300 µs/cm. The UT to Lower Creek data show both a sharp difference between baseflow and stormflow specific conductance values and that baseflow levels are twice as high at this site than at other sampled creeks in the watershed (Figure 2.10). Staff followed the creek upstream one day after a storm event and found a range of specific conductivity from 162 µs/cm at the UT to Lower Creek at NC 18 to 103 µs/cm upstream at the corner of Prospect Street and Wheeler Street. It is unlikely that the high conductivity is from the complex geology of the area, since a seep upstream of Prospect Street was found to have specific conductivity of only 80 µs/cm.

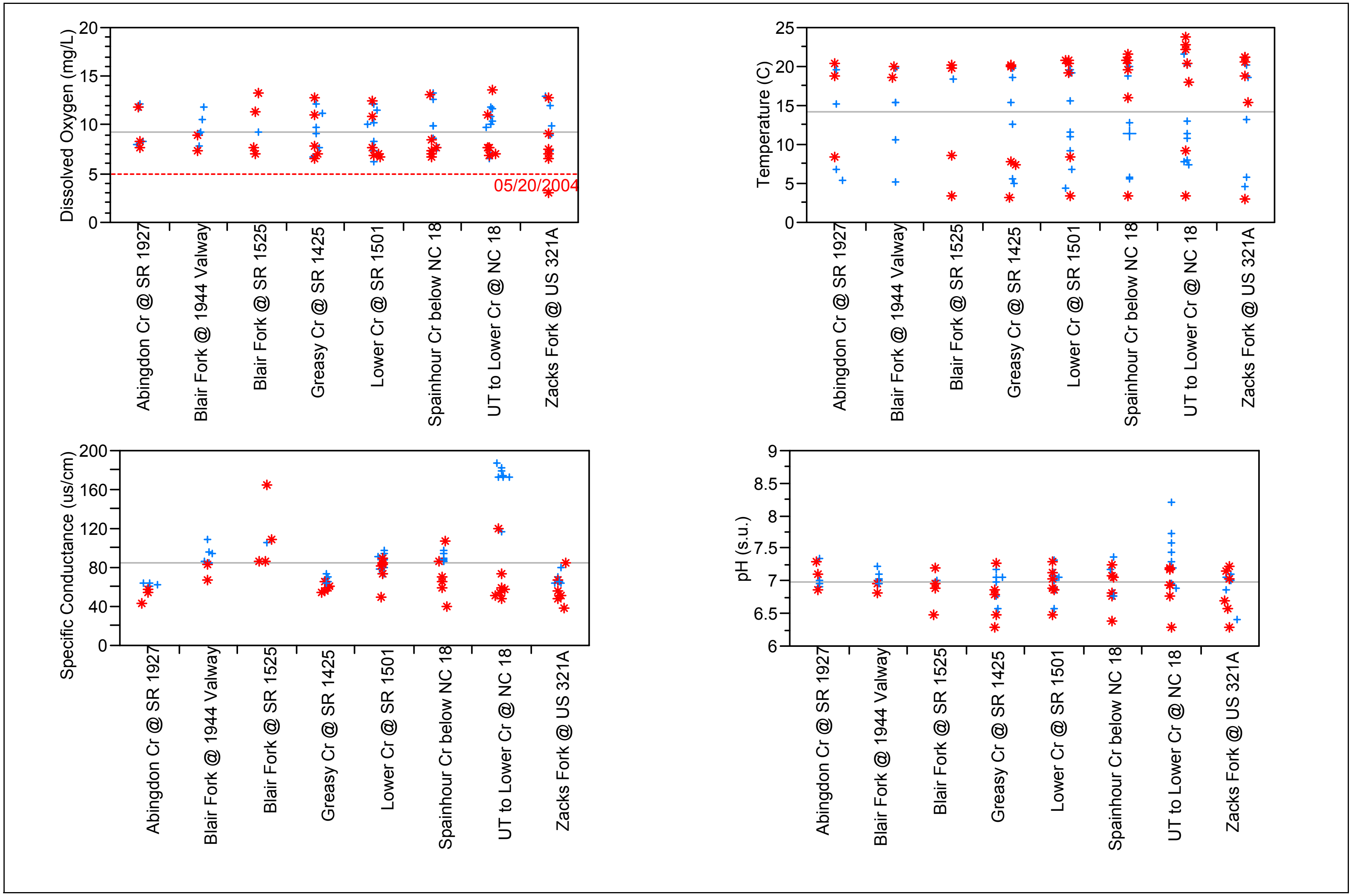


Figure 2.10. Scatterplot of the baseflow (+) and stormflow samples (*) for field parameters from sites with more than one result. The horizontal solid horizontal line across all graphs represents the grand mean. The dashed line across the graph for dissolved oxygen depicts 5 mg/L, the state standard for dissolved oxygen.

2.7 Semivolatile Organic Compounds

Water samples were collected at several sites to identify base-neutral and acid extractable organic compounds that may be present. (These compounds are commonly referred to as semivolative compounds.) Semivolatile organic compounds were detected at the UT to Lower Creek at NC 18 and Zacks Fork at US321A (Table 2.5). All numeric results included data qualification codes. These codes are part of a data validation process resulting from a series of checks and reviews that are intended to assure that the reported results are of a verifiable and acceptable quality. More information is available at: http://h2o.enr.state.nc.us/lab/qa/qualifier.htm Each code provides further information about the reported result.

Methoxy propyl acetate, heptanone C7.H14.O, and chloroform were recorded in the UT to Lower Creek at NC 18. Methoxy propyl acetate is a component of paints and lacquers. Heptanone C7.H14.O is both a solvent and ingredient in lacquers likely to be used in furniture factories and is regulated by the USEPA. Chloroform is also used in the furniture manufacturing industry (USEPA, 2005). The Department of Health and Human Services has determined that chloroform may reasonably be anticipated to be a carcinogen (US Department of Health and Human Services, 2004). These compounds may have entered the creek through release into the air, attachment to raindrops, and precipitation back into the creek, or through a possible direct discharge (Kelling, 2005).

Terpineol (Methenol) was recorded in Zacks Fork at US 321A. This compound has a wide variety of uses, which include fragrances in household products (e.g. polishes, detergents and soaps), assorted types of killing agents (e.g. fungicides, insecticides and microbiocides), textile and printing dye, and a foaming agent for the floatation of various metals. This compound has high soil mobility and may have entered the creek as either soil leachate or a possible direct discharge.

Table 2.5. Semivolatile organic pollutants detected in the Lower Creek watershed in 2004 and 2005.

Site	Semivolatile compound	Date	Concentration µg/L (Qualifier)[1]
UT to Lower Creek at NC 18	Methoxy propyl acetate	2/21/2005	3 (N1)
	Heptanone C7.H14.O	9/7/2004	7 (N1)
		2/21/2005	5 (N1)
	Chloroform	10/19/2004	0.28 (N2)
	Unidentified compound	2/14/2005	3 (J)
	Unidentified compound	2/14/2005	3 (J)
	Unidentified compound	2/14/2005	4 (J)
Zacks Fork at US 321A	Terpineol (Methenol)	9/7/2005	10 (N1)

[1] Qualifiers:
- N1. The component has been tentatively identified based on mass spectral library search;
- N2. There is an indication that the analyte is present, but quality control requirements for confirmation were not met (i.e., presence of analyte was not confirmed by alternate procedures).
- J. Estimated value; value may not be accurate.

Section 3: Aquatic Toxicity Testing

3.1 Background

Traditionally, aquatic toxicology has focused on whether treated water (effluent) from municipal or industrial plants may produce a biological effect on a test organism. These biological (toxicological) analyses are very efficient and effective at predicting aquatic effects without having to chemically characterize the solutions and make predictions of individual and/or interactions among chemicals. Tests may be conducted on samples of complex wastewater, individual chemical compounds, or on actual stream samples and can be sensitive enough to determine not only lethal responses but also responses that do not result in the death of a test organism. These sub-lethal responses may include suppression of reproduction or growth, feeding inhibitions, or other effects.

Overall, the majority of toxicological tests have been conducted on wastewater from municipal or industrial facilities, however since limited methods have been employed on surface waters from streams and rivers in North Carolina, the Division of Water Quality's Aquatic Toxicology Unit (ATU) is exploring the use of additional toxicological tests on water samples using a variety of test organisms. These tests represent an effort to identify water quality concerns that may not be apparent from more traditional water chemistry or biological sampling. These toxicity tests, which are new to DWQ, are a tool currently under consideration for use to determine toxicity in streams. Interpreting results from these aquatic toxicology tests on surface waters will improve as additional testing is performed throughout North Carolina. Sampling strategies may be modified and collaborative sampling among other water quality sampling programs (e.g. chemical and biological) will aid greatly in data interpretation.

The toxicology tests measure the response of an organism to various concentrations of surface water collected at various sites and compare these responses to a control sample. Different organisms, including fairy shrimp, the Cladoceran *Daphnia magna,* and luminescent bacterium, are used to demonstrate lethal or sub-lethal effects on different trophic levels in an aquatic ecosystem. Types of responses may vary among organisms used.

For example the Checklight test uses a luminescent bacterium. The amount of luminescence emitted by the bacterium in various concentrations of sample water is compared to the amount of luminescence emitted by the bacterium in control samples. A reduction in luminescence measured in the samples is likely to be the result of the presence of toxic substances in the sample water. The Checklight test is capable of differentiating between heavy metals or organic toxicants as potential sources of toxicity (Checklight, 2004).

Interpreting Results

In the example of the Checklight test, reductions in the amount of luminescence are related to the various concentrations of sample water used in the tests. Thus, these responses (reduction in luminescence) can be plotted against the proportions of sample water into a dose-response curve. This curve is used to determine the proportion (%) of sample water that resulted in a 20 percent (IC20) or 50 percent (IC50) inhibition in the amount of luminescence (IC refers to the inhibition concentration). For example an IC20 value of 6.9 means that solution containing 6.9% of sample water reduced the bacterium's luminescence by 20%. In other words, the lower the percentage of sample water needed to reduce the bacterium's luminescence by 20% or 50%, the more toxic the sample water.

IC50 data illustrate levels of inhibitory effects (toxicity) to aquatic biota that would likely be significant in the ecosystem, and may result in substantial long-term negative impacts. IC20 effect levels indicate lower levels of potential inhibitory effects that alone, or when combined with other negative impacts, may also lead to significant harm. A 20% negative effect level is commonly used as the nominal level of concern in ecological risk assessments, when observed at a sample concentration representing a substantial proportion of the water body. For the purposes of this assessment, ATU considered IC20 values ≤50% sample as sites of potential ecologically relevant negative impacts to the aquatic biota. Inhibitory effects observed across multiple tests (classes of organisms) may increase the potential for, and ultimately the magnitude of, impairment to the ecosystem.

3.2 Methods

Five different toxicity tests were performed on samples of surface water from eight sites collected from this watershed   Water samples were collected on April 4 and 6, 2005. Organisms used in these tests include two species of bacteria, an alga, and two crustacean species (fairy shrimp and the Cladoceran *Daphnia magna*). The samples were collected during baseflow conditions at eight sites. Details can be found in "*Draft Report – Toxicity Assessment of Catawba Basin Surface Waters Collected In Caldwell County, April 2005*" by the NC DWQ Aquatic Toxicology Unit (2005b).   A summary of these results is presented in Table 3.1 and detailed results are found in the DWQ ATU report referenced above.

Except for two sets of analyses, all assays were initiated within 72 hours of sample collection. Due to staff availability, the Microtox bacterial assay was not initiated until 5 days after sample collection for 3 samples (Greasy Creek at SR 1425, Zacks Fork at US 321A, and Spainhour Creek at NC 18). These same 3 samples were held for 5 days for the Cladoceran feeding inhibition assay, due to problems encountered with organism hatching. Effects expected for extended sample holding times prior to initiation of analyses would most likely be a biasing of the potential to observe toxic impacts, if any, due to physico-chemical or biological changes in the sample matrices.

3.3 Results

The Landfill UT to Blair Fork has positive responses to three of the toxicity tests. The responses to the organic component of the Checklight test warrant particular attention. Within this test, solutions containing only 3.5% and 19.5% of sample water resulted in toxic responses. Whereas, it took a test sample containing a considerable amount (>90%) of sample water in the fairy shrimp and Daphnia magna crustacean tests to cause a 20% reduction in effects.

Toxicity at levels that may impact aquatic populations at the test sites was observed in 6 of the 8 samples. Two sites (Landfill UT to Blair Fork at NC 90 and UT to Lower Creek at NC 18) had toxicity at a 50% effect level in the CheckLight bacterial assay. Twenty percent effect levels were also observed in the UT to Blair Fork site at sample concentrations >90% in the acute crustacean and Cladoceran feeding inhibition assays. Multiple detections of toxicity at the Landfill UT to Blair Fork may indicate the potential for toxic impacts to various trophic levels. The Blair Fork at NC 90 downstream sample was the only other site at which negative effects were observed in more than one assay (CheckLight bacteria and Cladoceran assays). The Blair Fork at NC 90 effects were both at the IC20 level.

Seven of the eight samples exhibited toxicity at a 20% negative effect level (IC20) in one or more of the assays. Five of 8 sites (Landfill UT to Blair Fork, Blair Fork at 1944 Valway, UT to Lower Creek at NC 18, Greasy Creek at SR 1425, and Spainhour Creek at NC 18) had IC20 values ≤ 50% sample, each in a single assay. At Zacks Fork at US 321A toxicity was observed at an IC20 of 91.8% sample in the Cladoceran assay, and likely would not result in significant inhibitory effects at this level.

Five of eight samples (Landfill UT to Blair Fork, Blair Fork at NC 90 downstream, Blair Fork at 1944 Valway, Greasy Creek at SR 1425, and Zacks Fork at US 321A) indicated a potential degrading nutrient enrichment in the algal growth assay test. Additionally, growth stimulation at Blair Fork at NC 90 upstream of the landfill UT was just below the level considered indicative of potentially degrading nutrient enrichment. Nutrients are strongly suspected of inducing biostimulation, however other substances may be responsible.

The only sample not indicating any inhibitory effects in any toxicity assay was Blair Fork at NC 90 upstream of the landfill UT, where none of the assay endpoints were detected at the highest tested sample concentration.

Table 3.1. Results of toxicity tests. Percentages represent the proportion of stream water necessary to produce an effect on the organism used in a toxicity test. Biostimulation is indicated by an "X" when sample response is positive and exceeds control response by 20% or more.

Toxicity Test	Site: Landfill UT to Blair Fork	Blair Fork at NC 90 downstream	Blair Fork at 1944 Valway	Blair Fork.at NC 90 upstrm of landfill	UT to Lower Cr at NC 18	Greasy Cr at SR 1450	Zacks Fork at US321A	Spainhour at NC 18
Number of assays in which a response was observed[1]	3	2	1	0	1	1	1	1
Bacterial toxicity, Checklight								
IC20, Metal	No toxicity was observed with the metals buffers							
IC50, Metal								
IC20, Organic	3.54%	65.6%	29.3%	.	18.6%	.	.	.
IC50, Organic	19.5	.	.	.	75.7%	.	.	.
Bacterial toxicity, Microtox	No toxicity was observed in these two tests. Note that a stimulatory effect was observed in the algal toxicity test.							
Algal Growth Assay, AlgalToxKit								
Biostimulation (>20%)	**X**	**X**	**X**			**X**	**X**	
Crustacean toxicity, ThamnoToxKit								
IC20	90.6%	.	.	.	.	.	.	.
IC50	.	.	.	.	.	.	.	.
Cladoceran toxicity, D. magna feeding inhibition								
lowest IC20	91.4%	68.1%	.	.	.	43.6%	91.8%	49.7%
lowest IC50	.	.	.	.	.	.	.	.

[1]A positive test is defined here as any proportion (%) of a test sample that resulted in an inhibition concentration (IC) response. A positive test does not necessary infer an ecological problem, although lower proportions of test samples producing an IC response warrant consideration.

Section 4: Benthic Community and Habitat Assessment

Bioassessments involve the collection of stream organisms and the evaluation of benthic community diversity and composition to assess water quality and ecological conditions in a stream. Benthic macroinvertebrates are useful biological monitors because they are found in all aquatic environments, are less mobile than many other groups of organisms, and are of a size which makes them easily collectable. Habitat assessment data, an important component of bioassessments, measure ecological conditions within and along streams by visually evaluating elements of instream and riparian habitat. These assessment data were collected both as part of the benthic macroinvertebrate studies conducted in 2002 and 2004, and in separate studies of portions, or reaches, of each of the impaired streams. Between one and six reaches were analyzed for each stream.

Additional information on the reaches analyzed in this study is available in the appendix.

4.1 Benthic Community Sampling and Rating Methods

Benthic macroinvertebrates have been sampled in the Lower Creek watershed since 1984. The most recent samplings were conducted in 2002 and 2004 (NCDWQ 2002b, NCDWQ 2004b) by DWQ's Biological Assessment Unit (BAU), which followed sampling procedures as outlined in DWQ's standard operating procedures (NCDWQ 2001 and 2003b). Only the EPT sampling method was used in 2004, while the standard qualitative (Full Scale) method, Qual 5 method, and EPT method were used at 5, 12, and 2 sites, respectively, in 2002.

The EPT method focuses on an assessment of mayflies (Ephmeroptera), stoneflies (Plectopterea), and caddisflies (Tricoptera) collected within four samples, including one kick, one sweep net, one leaf pack, and visuals. These EPT insects are found to be generally intolerant of many kinds of pollution and therefore are a good indicator of water quality. The ratings used for EPT samples are: Excellent, Good, Good/Fair, Fair or Poor. The Full Scale method is the most comprehensive sampling method and uses the most number of collections. (A "collection" refers to the type of method used to sample macroinvertebrates. Examples include the use of sweep nets, log washes, and leaf packs. Refer to the following website for more information: http://www.esb.enr.state.nc.us/benthicsop.htm. Qual 5 uses the same sample collection method as EPT with the addition of one rock/log wash and the collection of all macroinvertebrates, not just EPT. The Qual 5 method is only used for very small streams that will likely have few EPT taxa, but where data are needed to assess differences in benthic communities.

The results from macroinvertebrate sampling can be summarized in a variety of ways. The simplest method of data analysis is the tabulation of taxa richness, which is a summary of the number of species, summarized by taxonomic Order, found in a sample. The higher EPT taxa richness values indicate better water quality. Additional metrics include ecological information such as a species' ability to adapt to pollution or stress (tolerance values). Tolerant species can tolerate pollutants, while intolerant species cannot tolerate pollution. Biotic index (BI) values are used to indicate the presence of either tolerant or intolerant species with adjustments for regions within the state (e.g. mountains, Piedmont, and coastal plain) and the season. These index values generally range from 4 to 8, with the lower BI value representing the most intolerant (intolerant of pollution or stress) macroinvertebrate communities found in better water quality. Note that streams with higher-quality water would have both a low BI value and a high richness value. Details on sampling methods, collection techniques, and data summaries are available in *Standard Operating Procedure for Benthic Macroinvertebrates*, Biological Assessment Unit, July

2003 (http://www.esb.enr.state.nc.us/BAU.html) (NCDWQ. 2003b). Illustrations of the various collection techniques are available at the website: http://www.esb.enr.state.nc.us/benthicsop.htm.

4.2 Habitat Assessment Methods

Habitat assessments conducted in conjunction with benthic monitoring in 2002 and 2004 analyzed three parameters to determine an overall habitat score. A brief description of each parameter is provided in Table 4.1.

Table 4.1. A brief description of the three parameters analyzed in the habitat assessments conducted in conjunction with benthic monitoring in 2002 and 2004 in the Lower Creek watershed. The maximum possible scores for each parameter and for the total habitat score are also provided.

Parameter	Description
Substrate % sand + silt	Based on visual estimate of substrate size distribution. Score maximum (indicating complete coverage by sand and silt): 100.
Instream structure score	Visual quantification of the instream structures present, including leafpacks and sticks, large wood, rocks, macrophytes, and undercut banks/root mats. Score maximum: 20.
Lack of embeddedness	Estimation of riffle embeddedness, or the degree to which a riffle's larger inorganic substrate is buried by sand and silt. The higher the score, the less embedded. Score maximum: 15.
Habitat total score	Score maximum: 100.

Habitat assessments conducted as part of the separate reach-level studies conducted in 2004 and 2005 analyzed the following elements:

- Instream habitat (the diversity and abundance of habitat favorable for benthos colonization or fish cover)
- Bottom substrate
- Pool variety
- Riffle habitats
- Bank stability and vegetation
- Light penetration (evaluates canopy cover over the stream)
- Riparian buffer width
- Riparian buffer breaks (breaks in the buffer allow sediments or pollutants to directly enter the stream)

Each of these elements received a numerical score, with higher scores indicating better habitat. The total score, like the total habitat score for the habitat assessments conducted along with the benthic monitoring, had a maximum possible score of 100.

The following elements were also assessed to provide a better understanding of each reach's conditions, though they did not contribute to the overall habitat score.

- Impacted buffers
- Erosion
- Outfalls
- Structural crossings
- Utility impacts

Another protocol used was the Bank Erosion Hazard Index (BEHI), which considers the bank height to bankfull ratio, the root depth to bank height ratio, root density, bank angle and surface protection to establish a bank erosion hazard or risk rating (Rosgen, 1996). These ratings may range from low (5-9.5) to extreme (over 46) erosion potential. BEHI scores were calculated for two to four different bank conditions within each reach.

4.3 Results and Discussion by subwatershed

The 2002 and 2004 benthic macroinvertebrate sampling and habitat assessment data are provided in Table 4.2. None of the benthic communities collected in 2002 and 2004 indicated severe nutrient or organic enrichment, nor toxic conditions (NCDWQ 2004b), with the exception of Blair Fork. However, all sites are characterized by degraded benthic communities. The 2004 sampling found both Lower Creek at NC 90 and upper Greasy Creek to have slightly improved ratings, but lower Greasy Creek did not show as much improvement. There were two streams in particular (Lower Creek at NC 90 and Greasy Creek) which seemed to have degraded from Good-Fair in 1997 to Poor in 2002. Since the 2002 results could have been influenced by a long-term drought and other temporal effects, Greasy Creek and the upstream site on Lower Creek were resampled in 2004 (NCDWQ 2004b).

Biotic indices range from 4.66 (UT to Spainhour Creek) to 6.87 (Zacks Fork at US321A). The highest habitat scores were recorded in upstream sites on tributaries and catchments located southwest of Lenoir. The combination of poor habitat and urban/commercial/industrial impacts produced the most stressed benthic communities within Lower Creek, lower Zacks Fork and lower Blair Fork. The creeks draining less urban areas (Abingdon Creek and UT to Spainhour Creek) supported more diverse or intolerant benthic communities. A more detailed narrative summary of each creek follows.

Table 4.2. Results of 2002 and 2004 benthic macroinvertebrate sampling and habitat assessments (NCDWQ 2002b, NCDWQ 2004b).

Site	Date	Habitat score	EPT richness	EPT biotic index	Biotic Index	Bioclassification
Abingdon Cr at SR 1927	2002	51	20	5.11	5.6	Not impaired
Blair Fork at NC 90	2002	45	5	5.58	6.42	Not rated
Greasy Cr at SR 1305	2002	70	13	3.99	4.86	Fair
	2004	81	19	3.72	.	Good-Fair
Greasy Cr at NC 18	2002	42	14	5.19	5.7	Not rated
	2004	43	13	4.12	.	Fair
Lower Cr at NC 90	2002	29	9	5.35	6.46	Poor
	2004	35	19	5.59	.	Good-Fair
Lower Cr at SR 1303	2002	38	13	5.53	6.67	Fair

Site	Date	Habitat score	EPT richness	EPT biotic index	Biotic Index	Bioclassification
Lower Cr at SR 1142	2002	40	11	5.54	6.52	Fair
Lower Cr at SR 1501	2002	38	14	4.96	6.14	Fair
Spainhour Cr at NC 18 BUS	2002	43	15	5.82	6.46	Fair
UT to Spainhour Cr at SR 1513	2002	52	13	4.38	4.66	Not rated
Zacks Fork at SR 1531	2002	55	19	5.02	5.67	Not impaired
Zacks Fork at US 321A	2002	26	6	6.15	6.87	Not rated

4.3.1 Zacks Creek watershed

Benthic macroinvertebrate monitoring and habitat assessment data were collected at two sites on Zacks Fork on September 9 and 10, 2002 (Table 4.3). Stream walks and habitat assessments were conducted along reaches of Zacks Fork in June and July 2004. Habitat scores and bank erosion hazard indices (BEHIs), which are used to determine the potential for stream bank erosion, were calculated for the reaches during these stream walks (Table 4.4). Physical/chemical monitoring data (detailed discussion in Section 2) were collected at Zacks Fork at US 321A in 2004 and 2005.

Benthic macroinvertebrate sampling results indicate large disparities between the upstream (Zacks Fork at SR 1531) and downstream (Zacks Fork at US 321A) sites. Zacks Fork at SR 1531, which was rated Not impaired, supported a much more diverse benthic community (EPT richness of 19) than Zacks Fork at US 321A (EPT richness of 6). The upstream habitat had an overall habitat score (55) more than twice as high as the habitat score (26) calculated for the downstream site. The benthic community was also more intolerant (biotic index of 5.67) at the upstream site than at the lower site (biotic index of 6.87). The high specific conductance and low dissolved oxygen concentrations recorded at the most downstream site, which were unique in the Lower Creek watershed, may partially account for the absence of pollution intolerant benthic species, and may have been a partial consequence of an ongoing sewage leak. In addition, the benthic community may have been adversely affected by the abundant silt and sand in the creek. Large amounts of silt and sand and sand dunes that were as tall as 3 inches in height were observed moving downstream. These sand deposits account for the absence of downstream riffles and the high degree of embeddedness. One of the logical upstream sources of silt/sand is an old water retention pond/dam, which had been located between the last two upstream stream reaches. Streambank erosion may also be a source of sediment, as implied by the high to extreme bank erosion hazard index (BEHI) scores.

A narrative summary of conditions at each site follows.

Table 4.3. Benthic macroinvertebrate and habitat data collected on Zacks Fork and two comparison sites, Gunpowder Creek and Smoky Creek, in 2002.

Site	Sampling Type	Date	Substrate % sand + silt	Instream structure score	Lack of embedd-edness score	Habitat total score	EPT richness	EPT biotic index	Biotic index	Bio-Class
Zacks Fork at US 321A	Qual 5	9/02	90	8	3	26	6	6.15	6.87	Not rated
Gunpowder Cr at Mason Rd[1]	*EPT*	*8/02*	*90*	*12*	*3*	*48*	*23*	*4.68*	--	*Good-Fair*
Zacks Fork at SR 1531	Qual 5	9/02	70	12	5	55	19	5.02	5.67	Not impaire d
Smoky Cr at SR 1515[2]	*EPT*	*8/02*	*45*	*12*	*5*	*62*	*26*	*3.55*	--	*Good-Fair*

[1] Gunpowder Creek is the comparison site for the lower Zacks Fork site. Unlike Lower Creek and many of its tributaries, Gunpowder Creek drains a rural catchment.
[2] Smoky Creek at SR 1515, which also drains a rural catchment, is the comparison site for the upper Zacks Fork site.

Table 4.4 Bank erosion hazard index (BEHI) scores and classifications and Habitat total scores for reaches analyzed in the Zacks Creek watershed in 2004.

Reach	BEHI score[1]	BEHI classification[2]	Habitat total score[3]
Reach 1	36.5 – 43.5	High – very high	16
Reach 2	32.5 – 39	High	45
Reach 3	39.6 – 40.7	High – very high	36
Reach 4	NA[4]	NA	41
Reach 5	36 – 47	High – extreme	57
Reach 6	NA	NA	48

[1] Higher BEHI scores indicate higher bank erosion.
[2] BEHI classifications range from very low (score of 5-9.5) to extreme (score of 46-50).
[3] Score maximum: 100.
[4] BEHI scores are not available.

Zacks Fork at US 321A (Z1). The downstream site on Zacks Fork is located immediately downstream of a golf course and just upstream of its confluence with Lower Creek. The stream was channelized, the substrate was nearly all silt and sand (90%), and extensive bar development was observed. Riffles were absent and there was no riparian vegetation or shade on the streambanks of the golf course. The overall habitat score of 26 was the lowest in the Lower Creek watershed. Specific conductance (SC) measurements at this site were extremely high (1000 µS/cm). On June 23, 2005, DWQ and MACTEC staff discovered a sewage leak with heavy flow going into Zacks Fork upstream of the water quality sampling point. If this was as common an occurrence as suggested by locals, then this problem may help account for the high SC measurements and severely stressed benthic community at this site.

Zacks Fork at SR 1531 (Z2). This site was chosen to reflect the stream's condition upstream of potential urban influences in the City of Lenoir. Even at this location, bank erosion was severe, and the riparian zone was not intact. Sand was abundant and embeddedness was high, but two riffles were observed and the instream habitat structure was the same as that found at the comparison site (instream habitat scores of 12). The overall habitat score was 55, which is slightly lower than the score at Smoky Creek but higher than Gunpowder Creek. The benthic community at this Zacks Fork site was healthier than the downstream site. Several intolerant taxa, including *Serratella deficiens, Baetisca carolina,* and *Neophylax oligius*, were found, and three taxa of stoneflies (*Pteronarcys, Acroneuria abnormis,* and *Tallaperla*) were also collected.

4.3.2 Spainhour Creek watershed

The Spainhour Creek watershed includes the Spainhour Creek mainstem and its two primary headwater tributaries, Blair Fork and the Unnamed (UT) to Spainhour Creek. Benthic macroinvertebrate monitoring and habitat assessment data were collected at sites on Spainhour Creek, the UT to Spainhour Creek, and Blair Fork on September 9, 2002 (Table 4.5). Stream walks and habitat assessments were also conducted along reaches of Spainhour Creek, the UT to Spainhour Creek, and Blair Fork in April and May 2004 and January and March 2005. Habitat scores and bank erosion hazard indices (BEHIs), which are used to determine the potential for stream bank erosion, were calculated for the reaches (Table 4.6). Physical/chemical monitoring data, which were discussed earlier in this report, were also collected in 2004 and 2005 at eleven sites in the Spainhour Creek watershed, including Blair Fork at 1944 Valway, which was also sampled in the 2002 benthic macroinvertebrate and habitat assessment study.

Benthic macroinvertebrate sampling at Spainhour Creek, UT to Spainhour Creek, and Blair Fork showed that the two headwater streams that form Spainhour Creek are very different and support distinct benthic communities. The benthic community at UT to Spainhour Creek, which is located in a non-urban area and has the highest habitat score of the three sites, is far less impacted than the community at Blair Fork. The community at Blair Fork, which is located in an industrial watershed, is very tolerant to degradation, and had the lowest richness of EPT organisms in the entire Lower Creek watershed, but a slightly higher habitat score than Spainhour Creek and other assessed creeks. The low EPT richness could be linked to poor water quality and a lack of stable substrate/microhabitat (90% sand/silt). The high to very high BEHI classifications indicate that streambank erosion may be a source of sand and silt. Spainhour Creek's benthic community was also much more tolerant than the community at the UT to Spainhour Creek. Spainhour Creek had a similar biotic index to Blair Fork, though it supported a greater richness of EPT organisms than Blair Fork.

A narrative summary of conditions at each reach follows.

Table 4.5. Benthic macroinvertebrate and habitat data collected on Spainhour Creek, Blair Fork, the UT to Spainhour Creek, and a comparison site (Smoky Creek) in 2002.

Site	Sample Type	Date	Substrate % sand + silt	Instream structure score	Lack of embedded-ness score	Habitat total score	EPT richness	EPT biotic index	Biotic index	Bio-Class
Spainhour Cr at NC 18 Bus.	Full scale	9/02	40	8	3	43	15	5.82	6.46	Fair
Blair Fork at NC 90	Qual 5	9/02	90	8	3	45	5	5.58	6.42	Not rated
UT to Spainhour Cr at SR 1513	Qual 5	9/02	45	10	5	52	13	4.38	4.66	Not rated
Smoky Cr at SR 1515[1]	*EPT*	*8/02*	*45*	*12*	*5*	*62*	*26*	*3.55*	--	*Good-Fair*

[1] Smoky Creek at SR 1515 is the comparison site for streams in the Spainhour Creek watershed. The substrate and drainage area of Smoky Creek are similar to Spainhour Creek, however, Smoky drains a rural catchment.

Spainhour Creek at NC 18 Business (S2). The channel at this site is wide and shallow, and the substrate was a mix of boulders, gravel, and sand, with sand and silt comprising 40% of the substrate material. Riffles were infrequent and embedded. Bank erosion was severe and the riparian buffer was poor. This site received a habitat total score of 43. The benthic community at Spainhour Creek (EPT biotic index of 5.82) was much more tolerant than the community at the comparison site at Gunpowder (EPT biotic index of 3.55) and the community at UT to Spainhour Creek (EPT biotic index of 4.38). This site received a bioclassification of Fair (impaired).

Blair Fork at NC 90 (B2). Blair Fork is one of two major headwater tributaries to Spainhour Creek. Its watershed is characterized by commercial/industrial development and includes sawmills, railroad tracks, plant nurseries, a closed landfill, and salvage yards. The water was slightly turbid and 90% of the substrate was composed of sand and silt. Bank erosion was moderate to severe especially near stormwater outfall pipes and the riparian buffer zone was narrow. Periphyton growth, a sign of nutrient enrichment was seen on the limited instream substrate. Only one riffle was observed in the sampling reach, and pools were infrequent. The habitat score was 45. The benthic community at this site was severely impacted. EPT richness was very low (5) and all of the EPT taxa collected were tolerant (biotic index of 6.46). *Stenonema modestum* and *Cheumatopsyche*, ubiquitous throughout the Lower Creek watershed, were rare at this site, and no stoneflies were found. *Calopteryx*, a taxon tolerant to low dissolved oxygen conditions, was the only organism that was abundant.

UT to Spainhour Creek at SR 1513 (S5). The UT to Spainhour Creek, located on one of the two main tributaries that form Spainhour Creek, is located in a watershed outside any possible urban runoff from the City of Lenoir. The riparian buffer was moderate and had breaks, and the small size of this stream restricted the riffle-run-pool system observed in larger streams. This creek did contain some good habitat including cobble, some undercut banks, and well-defined riffles. Almost half of the substrate was silt and sand, and instream habitat was only slightly better than that found at Spainhour Creek and Blair Fork. The overall habitat score for this site was 52. This site supported the most intolerant benthic community (biotic index of 4.66) in the Spainhour Creek watershed, although the stream's small size likely limited diversity (EPT richness of 13). Several intolerant taxa, including *Baetisca Carolina, Chimarra, Acroneuria abnormis*, and *Goera*, were found only at this site in the Spainhour Creek watershed. *Elimia*, which is sensitive to organic enrichment, was also collected. This was the only site among the sampling sites included in this Lower Creek report that contained long-lived stoneflies and philopotamid caddisflies. The presence of these taxa shows that intolerant taxa are present in subwatersheds in the Lower Creek watershed that are not influenced by urban runoff. Thus downstream restoration sites would have a potential source of intolerant macroinvertebrate taxa.

Table 4.6. Bank erosion hazard index (BEHI) scores and classifications and Habitat total scores for reaches analyzed in the Spainhour Creek watershed in 2004 and 2005.

Reach	BEHI score[1]	BEHI classification[2]	Habitat total score[3]
Spainhour 1	27.2 – 40.3	Moderate-very high	30
Spainhour 2	36 – 45.8	High-very high	38
Spainhour 3	NA[4]	NA	42
Spainhour 4	NA	NA	46
Spainhour 5	NA	NA	38
Blair Fork 1	34 – 42.5	High-very high	38
Blair Fork 2	32.5 – 41.6	High-very high	42
UT to Spainhour	26.2 – 45.6	Moderate-very high	58

[1] Higher BEHI scores indicate higher bank erosion.
[2] BEHI classifications range from very low (score of 5-9.5) to extreme (score of 46-50).
[3] Score maximum: 100.
[4] BEHI scores are not available.

4.3.3 Greasy Creek watershed

Benthic macroinvertebrate monitoring and habitat assessment data were collected at two sites on Greasy Creek on September 9, 2002 and July 7, 2004 (Table 4.7). Physical/chemical monitoring data, which were discussed earlier in this report, were also collected in 2004 and 2005 at Greasy Creek at NC 18/SR 1425. A limited number of stream walks were conducted on this creek in May 2005.

Greasy Creek shows signs of increasing stress from upstream to downstream. The upstream site (G2) had a slightly more impacted benthic community than the comparison site on Smoky Creek, though habitat assessment parameters received equal or higher scores at the upper Greasy Creek site compared to Smoky Creek. However, the benthic community at the lower Greasy Creek site (G1), which was rated Fair (impaired), shows signs of stress. Several sensitive benthic taxa that were common at the upper Greasy Creek site were either absent or rare at the lower site, while taxa tolerant to organic enrichment increased in abundance at the lower site. Habitat was limited at the lower site, which was characterized by high amounts of sand and silt. Overall habitat scores were roughly twice as high at the upper Greasy Creek site and the upper reach than at the lower Greasy Creek site and the lower reach. The upstream site had a good mix of instream habitat favorable to macroinvertebrate colonization. Pools were common, and the streambed had a good mix of gravel, cobble and boulders, with only 20 – 40% embeddedness by sand/silt. The downstream site had a large increase in the amount of sand/silt and the streambed was primarily comprised of sand, with some gravel areas. There were obvious sediment input areas where stream banks were collapsing primarily from cattle access to the creek at the downstream site, but was also noted adjacent to a hayfield in the upstream site.

A narrative summary of conditions at each site follows.

Table 4.7. Benthic macroinvertebrate and habitat data collected on Greasy Creek and Smoky Creek (a comparison site) in 2002 and 2004.

Site	Date	Sample Type	Substrate % sand + silt	Instream structure score	Lack of embedded-ness score	Habitat total score	EPT richness	EPT biotic index	Biotic index	BioClass
Greasy Cr at NC 18 / SR 1425	9/02	Qual 5	80	8	3	42	14	5.19	5.7	Not rated
	7/04	EPT	78	10	3	43	13	4.12	--	Fair
Greasy Cr at SR 1305	9/02	Qual 5	55	12	10	70	13	3.99	4.86	Fair
	7/04	EPT	73	16	11	81	19	3.72	--	Good-Fair
Smoky Cr at SR 1515[1]	*8/02*	EPT	*45*	*12*	*5*	*62*	*26*	*3.55*	--	*Good-Fair*

[1] Smoky Creek at SR 1515, which drains a rural catchment, is the comparison site for Greasy Creek.

Greasy Creek at NC 18/SR 1425 (G1). The lower site on Greasy Creek runs between a fallow field and a residence, and bank vegetation consisted of a thin strip of trees and shrubs. Riffles and pools were infrequent, and embeddedness was high. The substrate was nearly all (78-80%) sand and silt. Instream habitat was fair, and this site had total habitat scores in the low 40s. EPT richness indicated a stressed benthic community, and EPT biotic index scores were moderate. The site was not rated in 2002 and received a rating of Fair, or impaired, in 2004. Several of the intolerant benthic macroinvertebrate taxa that were rare or common in the upper site were absent at the lower site. *Isonychia*, a taxon with high tolerance to pollution, was more abundant at this site than at the upper site. *Overall, the benthic community was much more tolerant at this site than at the upstream site.*

Greasy Creek at SR 1305 (G2). The site runs through a hayfield and has a thin, woody buffer on one bank and a wider forested buffer on the other. The channel was somewhat sinuous and the stream had frequent riffles and pools. Its bottom substrate was primarily a mix of gravel and sand and embeddedness was low. Instream habitat was good, and this site had the highest total habitat score in the Lower Creek watershed. EPT biotic indices were good (3.72 and 3.99), indicating the presence of more sensitive taxa. EPT richness increased from 13 in 2002 to 19 in 2004. The lower EPT richness, which seemed out of place considering this site's high habitat quality and good biotic index scores from 2002, may have been the result of the long-term drought. While many of the same taxa were collected at both sites in Greasy Creek, several intolerant taxa, including *Glossosoma*, *Leuctra*, and *Stenonema pudicum*, which are indicators of high water quality, were only found at this site. *This site received a bioclassification of Good-Fair.*

4.3.4 Lower Creek

Benthic macroinvertebrate monitoring and habitat assessment data were collected at four sites on Lower Creek between September 9 and 10, 2002, and at one site on July 7, 2004 (Table 4.8). Physical/chemical monitoring data, which were discussed earlier in this report, were also collected at Lower Creek at SR 1501 in 2004 and 2005. This creek was very difficult to access and only limited stream walks were conducted in 2005.

Benthic macroinvertebrate sampling results demonstrate that all four sites on Lower Creek have very tolerant benthic communities. Of the four sites, Lower Creek at SR 1142 (L2) and Lower Creek at SR 1303 (L3), which are the first two sites located downstream of the City of Lenoir, have the most stressed benthic communities. All four sites show much more tolerant communities than the reference site at Gunpowder Creek (EPT biotic indices of 4.46 – 5.59 compared to 4.68 at Gunpowder Creek). The collection of taxa tolerant of organic enrichment is consistant with periphyton growth observed on streambed sediment. Habitat scores are also low, and the substrate at all of the sites, except Lower Creek at SR 1142, was predominately composed of sand and silt, with sand and silt comprising almost all of the substrate at Lower Creek at NC 90 (L4) and Lower Creek at SR 1501 (L1). Sandbars and pools filling with sand were observed in these reaches.

A narrative summary of conditions at each site follows.

Table 4.8. Benthic macroinvertebrate and habitat data collected on Lower Creek and Gunpowder Creek (a comparison site) in 2002 and 2004.

Site	Date	Sample Type	Substrate % sand + silt	Instream structure score	Lack of embedded-ness score	Habitat total score	EPT richness	EPT biotic index	Biotic index	Bio-Class
Lower Cr at SR 1501	9/02	Full scale	80	11	3	38	14	4.96	6.14	Fair
Lower Cr at SR 1142	9/02	Full scale	50	12	6	40	11	5.54	6.52	Fair
Lower Cr at SR 1303	9/02	Full scale	65	11	3	38	13	5.53	6.67	Fair
Lower Cr at NC 90	9/02	Full scale	90	10	3	29	9	5.35	6.46	Poor
	7/04	EPT	98	8	3	35	19	5.59	--	Good-Fair
Gun-powder Cr at Mason Rd[1]	*8/02*	*EPT*	*90*	*12*	*3*	*48*	*23*	*4.68*	*--*	*Good-Fair*

[1] This is the monitoring site on Gunpowder Creek, the comparison site for Lower Creek. Unlike Lower Creek and many of its tributaries, Gunpowder Creek drains a rural catchment.

Lower Creek at SR 1501 (L1). This site, located 4 miles above Lake Rhodhiss, is the most downstream site sampled on Lower Creek. The channel appears to have been straightened, pools were infrequent, and riffles were absent. Bank erosion was severe, and there were breaks in the riparian zone. The riparian zone was wider at this site than at upstream sites, in part because this stream is in a rural setting at this site. The overall habitat score was 38. This was the only site on Lower Creek where stoneflies were collected, and the taxa collected, including *Paragnetina fumosa* and *Pteronarcys*, are considered long-lived and intolerant. *Brachycentrus nigrosoma*, an intolerant caddisfly, and *Dicrotendipes fumidus*, an indicator of organic enrichment, were abundant at this site. This site had the most intolerant benthic community on Lower Creek; it had the highest EPT richness score (14) and the lowest biotic index (6.14) of the four sites. The comparison site at Gunpowder Creek, however, had higher EPT richness and lower EPT biotic index scores than Lower Creek at SR 1501. Lower Creek at SR 1501 received a bioclassification of Fair (impaired).

Lower Creek at SR 1142 (L2). This site is located below the confluence of Greasy and Abingdon Creeks, and below the Lenoir WWTP discharge and an instream sand dredging operation. The channel had lots of sediment, however, the percentage of silt and sand was the lowest in Lower Creek (50% of the substrate), while the other half of the substrate was comprised of boulders, cobble, and gravel. Banks were steep and eroding, and there was extensive bar development. No riffles were observed and pools were infrequent, and the riparian buffer was minimal with frequent breaks. The habitat score was 40. The benthic community at this site was stressed; the biotic index was 6.52, indicating dominance by tolerant taxa. This site received a bioclassification of Fair (impaired).

Lower Creek at SR 1303 (L3). This site is located directly below the confluence with Spainhour Creek, which runs through the City of Lenoir for much of its length. The substrate was mostly sand, pools were infrequent, and riffles were absent. Banks were steep and incised, erosion was severe, and signs of sediment deposition, such as extensive bar development, were observed. The overall habitat score was 38. The biotic index for this site (6.67) was the highest on Lower Creek, indicating a very tolerant benthic community. Tolerant midge taxa (*Polypedilum convictum, P. illinoense,* and *Conchapelopia*) were abundant, and most sensitive taxa were absent. This site received a bioclassification of Fair (impaired).

Lower Creek at NC 90 (L4). This is the most upstream site sampled on Lower Creek and it is located in an urban/commercial setting. The substrate was nearly all sand with a small amount of gravel, and there was extensive bar development. The percentage of silt and sand in the substrate was extremely high (90% in 2002 and 98% in 2004), and embeddedness was also high. Bank erosion was severe and the riparian zone was narrow on both sides. Sections of the left bank were completely open since NC 90 is adjacent to the left bank. The overall habitat score was 29 in 2002 and 35 in 2004.

In part due to its low EPT richness of 9, this site received a rating of Poor in 2002, which differed greatly from its rating of Good-Fair in 1997. In a follow-up study in 2004, EPT richness increased to 19, and the site returned to a bioclassification of Good-Fair, although it was only one EPT taxon away from receiving a classification of Fair (impaired). The low EPT richness observed in 2002 may have been the result of the long-term drought. The site's high EPT biotic index (5.59) demonstrates dominance by impact-tolerant taxa, such as *Hydropsyche betteni, Cheumatopsyche, Baetis intercalaris*, and *Baetis armillatus*. Dominance by baetids, which are collector-gatherers, is typical of organically enriched streams, such as those located below pastures. However, some intolerant taxa, such as *Pteronarcys*, which is sensitive to toxins and is found in streams with high water quality, were also present. In 2004, this was the only site in Lower Creek that was not rated as impaired.

4.3.5 UT to Lower Creek

Formal habitat assessments were not conducted on the UT to Lower Creek. To provide a general description of conditions on this creek, the UT to Lower Creek is located in a very urbanized area of the City of Lenoir. From upstream to downstream, it follows railroad tracks through residential areas, continues through a commercial/industrial area in which the stream is channelized in a cement channel, flows underneath the Broyhill factory, a furniture factory, which was built over the stream directly above Route NC 18, and flows in a culvert under NC 18 before reaching its confluence with Lower Creek.

Section 5: Nature of impairment and degradation for 303(d) listed streams and their tributaries

In this section all available information is used to attempt to ascertain causes of impairment for 303(d) listed streams and causes of degradation for non-listed tributaries that are degraded (Table 5.1). If sufficient evidence points to a particular cause of impairment or degradation, then management strategies can be considered to remove the body of water from the 303(d) list of impaired water bodies or to improve the water quality in non-listed streams. Table 1.1 identifies the four streams listed on the impaired streams list, as well as their tributaries. These streams include all or portions of:

- Zacks Fork
- Spainhour Creek
  - Blair Fork
  - UT to Spainhour Creek
- Lower Creek
  - The unnamed tributary (UT) to Lower Creek
- Greasy Creek

Table 5.1. Probable sources and causes of impairment and degradation of 303(d) listed streams and their tributaries in the Lower Creek watershed.

Site	Probable causes	Probable sources
Zacks Fork	Habitat degradation Stormwater scour	Inadequate riparian vegetation Impervious surfaces Channelization
Blair Fork	Toxicity Habitat degradation	Runoff from closed landfill Severe bank erosion
Spainhour Creek	Habitat degradation Stormwater scour Toxicity	Impervious surfaces Channelization Inadequate riparian vegetation Plant nursery runoff
UT to Spainhour Creek	Habitat degradation	Channelization Inadequate riparian vegetation Bank erosion
Greasy Creek	Habitat degradation	Cattle access to creek Inadequate riparian vegetation Runoff from ornamental plant nursery
UT to Lower Creek	Toxicity	Commercial/industrial development
Lower Creek	Habitat degradation Stormwater scour	Eroding banks Inadequate riparian vegetation

5.1 Zacks Fork

This stream was included in the 2004 North Carolina Water Quality Assessment and Impaired Waters List for having impaired biological integrity (NCDWQ Draft, 2004a). Both habitat and water quality degradation may be responsible for the tolerant benthic community in Zacks Fork.

Habitat degradation

Several types of habitat degradation that could reduce the stream's ability to provide sufficient habitat for benthos and other aquatic life were observed.

Excess sediment deposits were observed during habitat assessments throughout the Zacks Fork watershed and are a major source of habitat loss. In addition, Zacks Fork had high levels of suspended residue and turbidity during stormflow conditions, while during baseflow conditions, turbidity did not exceed the state standard of 50 NTU. The habitat assessments combined with the water quality monitoring data point to a combination of existing instream sediment re-suspension and stormflow scour as the main sources of sedimentation. Some instream sediment originates from a large sediment plug, which was released when a historic upstream water impoundment was eliminated. This sediment plug may account for the 3 inch sand dunes seen moving downstream.

Streambank instability was observed throughout the watershed and most often in areas where riparian vegetation was either nonexistent or consisted of bamboo, turf grass, or other shallow rooted plants. The high to extreme BEHI classifications indicate streambank erosion as a current source of additional instream sand and silt. Channelization and impervious surfaces, which are common in the urbanized area that drains into lower Zacks Fork, increase water velocity and volume at stormflow. High water velocity and volume can cause streambank erosion by scouring away the soil at the bank edges and depositing it into the stream. These same forces will also re-suspend existing instream sediment. Impervious surfaces also contribute to increasing stream velocity through higher peak flow point source stormwater runoff that will both transport additional sediment into the stream and increase scouring and channel erosion at the discharge points.

Few types of organic habitat were observed in Zacks Fork. Riparian vegetation contributes the materials that create several types of instream habitat, such as leaves, sticks, and snags. In many areas, riparian vegetation was replaced by turf grass or other non-woody vegetation, resulting in the stream no longer receiving these necessary structural inputs. The most common favorable instream habitat found within Zacks Fork was root mats. Habitat diversity is also limited because the stream receives full sun, as opposed to a mixture of shade and sunlight, since turf grasses cannot provide the shade provided by trees and shrubs. The lack of habitat diversity resulted in a low biotic index, and those taxa that were collected were tolerant to pollution. The site's EPT taxa richness and biotic index showed that this site has one of the lowest benthic community qualities in the Lower Creek watershed.

Zacks Fork lacked instream velocity and depth diversity; in other words, both the velocity of water in the channel and the depth of the channel were uniform, rather than variable in different sections of the stream. Very few pools and riffles were seen and the creek appears to have been channelized. Channelization reduces riffles and minimizes stream meanders, resulting in a lack of physical and dynamic diversity. This in turn can reduce benthic diversity.

Other stressors

Other stressors, additional to those previously discussed, may also affect the ability of Zacks Fork to support aquatic life during both baseflow and stormflow conditions.

Baseflow samples are useful as an indicator of local groundwater and point source discharges into the creeks. The high concentrations of total phosphorus and fecal coliform bacteria at baseflow may be attributed to the same urban point source: overflowing sewer manholes and sewer pipe leaks as observed by DWQ staff on several occasions.

Stormflow waters will have constituents from point sources, urban sources and overland flow. Urban sources, including roads, parking lots, fuel emissions, and commercial/residential land uses, are likely responsible for high concentrations of metals, particularly zinc, lead, and copper. The high zinc, copper and lead may originate from brake linings. Unleaded and diesel fuel emissions are another possible copper source. Terpineol, a semivolatile compound, was tentatively identified at this site during a sample collected on September 7, 2005 (Table 2.5).

Higher concentrations of TKN observed during stormflow may be attributed to raw sewage inputs (e.g., a failing collection system and sewage straight pipes) and urban non-point sources (e.g., domestic pet fecal matter and lawn/garden fertilizers). Both of these sources may also explain the very high fecal coliform bacteria concentrations recorded in Zacks Fork at stormflow (geometric mean of 1954 col/100 ml), including an individual recording of 64,000 col/100 ml. And the very high specific conductance measurement of 1000 µS/cm recorded at the US321A site during the September 2002 benthos sampling. In addition, local residents near Powel St spoke of overflowing manholes as a common occurrence.

5.2 Blair Fork

Blair Fork is a tributary to Spainhour Creek, a 303(d) listed stream. Both Blair Fork and the other major tributary to Spainhour Creek, the UT to Spainhour Creek, have been included in this study.

Toxicity

Benthic community analysis and toxicity test results suggest that toxicity is a major cause of degradation in the Blair Fork watershed. The benthic community at Blair Fork demonstrated a typical characteristic of toxic stress: only very tolerant taxa were found at Blair Fork, while intolerant taxa, such as stoneflies, were absent. Intolerant taxa were found in the UT to Spainhour Creek, demonstrating that these taxa are present in less-impacted streams in the Spainhour Creek watershed.

The results of the toxicity tests conducted in April 2005 indicate toxic inputs to Blair Fork. The landfill UT to Blair Fork at NC 90 had positive results to three of the five toxicity tests conducted, the highest number of results of all sites sampled in the Lower Creek watershed. The landfill UT to Blair Fork at NC 90 had an IC 50 value of 19.5% and an IC 20 value of 3.54% in the Checklight Test, an IC20 value of 90.6% in the Crustacean toxicity test, and an IC20 value of 91.4% in the Cladoceran toxicity test (Table 3.1). Biostimulation above 20% in the algal toxicity test was also observed at this site and at two other sites in the Blair Fork watershed.

Multiple detections of toxicity at the landfill UT to Blair Fork at NC 90 may indicate the potential for toxic impacts to various trophic levels, and test results showed that levels of toxicity found at the landfill UT to Blair Fork at NC 90 would likely be significant in the ecosystem and could result in substantial long-term negative impacts. Toxicity was observed in specialized subtests that assess toxicity due to organic compounds. Positive results to the Checklight toxicity tests were also observed at Blair Fork downstream of the landfill at NC 90 (IC20 value of 65.6%) and Blair Fork at 1944 Valway (IC20 value of 29.3%).

The primary source of toxicity appears to be the closed landfill, which is located west of the landfill UT to Blair Fork at NC 90 near the landfill pond above NC 90. Multiple positive results of the toxicity tests were detected in the landfill UT to Blair Fork at NC 90, which runs from the landfill to Blair Fork. The number of positive results to toxicity tests declines with downstream distance from the site at the landfill UT to Blair Fork at NC 90. Toxicity was detected in two tests at Blair Fork downstream of the landfill at NC 90 and in one test at Blair Fork at 1944 Valway. No positive results to toxicity tests were found at Blair Fork upstream of the landfill at NC 90, which may indicate the closed landfill as a source of toxicity. High specific conductance levels at the landfill UT to Blair Fork at NC 90 and the landfill pond above NC 90 also indicate potential contamination from the landfill. High specific conductance can be a sign of chemical substances, including metals and sodium, which may have leaked from the landfill.

Habitat degradation

Habitat assessment data point to excess sediment deposition as one type of habitat degradation in the Blair Fork watershed. The percentage of silt and sand that comprise the stream's substrate (90%) was twice as high at Blair Fork than at Smoky Creek, the comparison site for Blair Fork. Instream habitat diversity and lack of embeddedness were also lower at Blair Fork than at the comparison site. Stormwater scour, which causes streambank erosion by scouring away the soil at the edges of the banks and depositing it into the water in the stream, is a main cause of sedimentation. Unstable, sloughing banks and extreme bank failure were noted in Blair Fork, and BEHI scores ranged from high to very high, indicating that streambank erosion may be a source of sand and silt. Impervious surfaces in the watershed contribute to stormwater scour and runoff by increasing water velocity and the transport of sediment to the stream during stormflow, while channelization also adds to stormwater scour by increasing water velocity in the channel. Frequent breaks in the buffers also contribute to sediment inputs by allowing sediments to enter the channel with stormwater runoff.

Another type of habitat degradation found in Blair Fork was uniform instream velocity and diversity. Very few pools or riffles were observed in the creek, and signs of channelization were present in the creek. Channelization reduces riffles and velocity diversity by minimizing stream meanders.

Few types of instream habitat were observed in Blair Fork, which received an instream structure score of 8, compared to a score of 12 at the reference site on Smoky Creek (Table 5.4). The lack of instream habitat diversity can be attributed to channelization, which increases water velocity that washes organic material downstream, and stormwater scour, which sweeps away small organic and inorganic materials that can add to habitat diversity. Structural hardening and riprap, which were observed in both reaches analyzed in this study, further limit organic habitat inputs by reducing vegetation along the banks and in the buffer zone. Additionally, excess sediment covers the streambed with sand in many areas and smothers both organic and inorganic habitat.

Other stressors

A variety of other factors contribute to the degradation observed in the Blair Fork watershed. Nutrient levels were high in Blair Fork, particularly at the Landfill UT to Blair Fork at NC 90, which recorded, at baseflow, the highest ammonia, nitrite-nitrate, and TKN concentrations recorded during baseflow or stormflow conditions in the entire Lower Creek watershed. Similarly, the highest phosphorus concentrations in the Lower Creek watershed were found at the UT to Blair Fork at US 321 at baseflow. The high concentrations of nutrients in the Blair Fork watershed may be attributed to the closed landfill, urban sources, and straight pipes. Straight pipes were observed in Reach 2 of Blair Fork, which is located upstream of the Blair Fork at 1944 Valway water quality monitoring site. This site had high levels of ammonia nitrogen and TKN at baseflow, which may be attributed to the straight pipes.

Manganese concentrations at baseflow were above acute benchmarks at the Landfill UT to Blair Fork and the Landfill pond above NC 90, and they were above chronic benchmarks at sites downstream of the landfill, including Blair Fork downstream of landfill at NC 90 and Blair Fork at 1944 Valway. At baseflow, 100% of samples at Blair Fork at SR 1525 and 50% of samples at Blair Fork at 1944 Valway had fecal coliform bacteria concentrations over 400 col/100 ml (Table 2.2).

5.2 Spainhour Creek

The impaired biological integrity of this stream was listed as a reason for including it on the 2004 North Carolina Water Quality Assessment and Impaired Waters List (NCDWQ Draft, 2004a). The high tolerance of the benthic community in Spainhour Creek may be attributed to habitat and water quality degradation.

Habitat degradation

Several types of habitat degradation that could reduce the stream's ability to provide sufficient habitat for benthos and other aquatic life were observed.

Excess sediment deposits were observed during habitat assessments throughout the Spainhour Creek watershed. In addition, Spainhour Creek had high levels of suspended residue and turbidity during stormflow conditions, while during baseflow conditions, turbidity did not exceed the state standard of 50 NTU. The habitat assessments combined with the water quality monitoring data point to stormflow scour as a main cause of sedimentation. High water velocity and volume cause streambank erosion by scouring away the soil at the edges of the banks and depositing it into the water in the stream. Stormwater scour was particularly noted as a source of streambank erosion and sedimentation in Reach 1. Stormwater scour and channelization, which increase water velocity, may also provide adequate force to flush benthic macroinvertebrates downstream. The high to very high BEHI classification also indicates that streambank erosion may be a source of sand and silt. In addition, urban runoff is listed as one of the sources of impairment in the North Carolina Water Quality Assessment and Impaired Waters List (NCDWQ Draft, 2004a). Impervious surfaces in the watershed contribute to stormwater runoff by increasing water velocity and the transport of sediment to the stream during stormflow. Frequent breaks in the buffers also contribute to sediment inputs by allowing sediments to enter the channel with stormwater runoff.

Uniform instream velocity and depth were observed during stream walks in Spainhour Creek. Channelization, which reduces riffles and velocity diversity by minimizing stream meanders, appears to be the main cause for the lack of diversity of stream velocity and depth. In Reach 1 in particular, the channel was channelized in many areas, and it was noted as not having a thalweg (Appendix).

Few types of organic habitat were observed in Spainhour Creek, which received an instream structure score of 8, compared to a score of 12 at the reference site on Smoky Creek (Table 5.4). The lack of instream habitat diversity can be attributed to channelization, which increases water velocity that washes organic material downstream, and stormwater scour, which sweeps away small organic material that can add to habitat diversity. A lack of vegetated buffers, which were observed throughout Spainhour Creek, also reduces habitat by limiting sources of the organic materials, such as leaves and sticks. In reaches four and five in particular, lawns were the prevalent land cover type. Additionally, excess sediment covers the streambed with sand in many areas and smothers other types of habitat.

<u>Toxicity</u>

Positive results to the Cladoceran toxicity test (IC20 value of 49.7%) were observed at Spainhour Creek below NC 18 (Table 3.1). Sources of toxicity may include the closed landfill on Blair Fork, a tributary to Spainhour Creek, as well as fertilizers and pesticides that may be used at the plant nursery. Since Spainhour Creek is in a commercial/industrial watershed, toxicants may also come from urban land uses.

<u>Other stressors</u>

A variety of other factors contribute to the degradation observed in the Spainhour Creek watershed. High concentrations of nitrite-nitrate and TKN at baseflow in the Plant nursery UT to Spainhour suggest that the plant nursery is a major contributor of nutrients to the stream. High levels of these nutrients and total phosphorus, which was also found in Spainhour Creek, may also be attributable to overflowing sewer manholes or failing collection system pipes, both of which were observed by DWQ staff. Storm sewers are a known source of impairment in Spainhour Creek, as they were listed as a source of impairment in the North Carolina Water Quality Assessment and Impaired Waters List (NCDWQ Draft, 2004a). Problems with the Lenoir central sewer collection may also be responsible for the high fecal coliform bacteria concentrations that were recorded at baseflow. Poor riparian buffers also contribute to increased inputs, allowing nutrients, metals, and other pollutants to enter the channel with stormwater runoff.

Copper, zinc, and lead exceeded benchmark concentrations at stormflow in Spainhour Creek (Tables 2.1 – 2.3). Five of six stormflow zinc samples and one of six lead samples were above their hardness-adjusted benchmarks. While copper was observed in rural as well as urban watersheds in the Lower Creek watershed, zinc and lead were only found in urban streams. Urban sources, including runoff from roads and commercial/industrial development, as well as potential sewage leaks or overflows are likely responsible for Spainhour's high zinc and lead concentrations.

5.3 UT to Spainhour Creek

The UT to Spainhour Creek is a tributary to Spainhour Creek, a 303(d) listed stream. The benthic community at the UT to Spainhour Creek was much less impacted than the communities at either Blair Fork or Spainhour Creek.

Habitat degradation

The UT to Spainhour Creek showed signs of degradation due to habitat degradation, though habitat degradation was not as severe on the UT to Spainhour Creek as it was in the other two subwatersheds.

Sedimentation was one type of habitat degradation found in the UT to Spainhour Creek. Almost half of the substrate was comprised of sand and silt, and the lack of embeddedness score was low (5), though it was the same as that at the comparison site at Smoky Creek. Bank erosion may be a main source of excess sediment. BEHI scores ranged from moderate to very high, and the BEHI for the most typical reach in the UT to Spainhour Creek was rated as very high. Breaks in the riparian buffer also allow sediment to enter the stream during stormflow events.

Inadequate instream habitat was also noted as a type of habitat degradation in the stream. While higher than either Blair Fork or Spainhour Creek (8 at both), the instream structure score at the UT to Spainhour Creek (10) was lower than that at the comparison site (12). Signs of channelization, which increases water velocity and sweeps away small pieces of habitat, were present. Limited vegetation in the riparian zone also reduces the organic inputs that create instream habitat, such as leaves, sticks, and snags.

5.5 Greasy Creek

Two sites on Greasy Creek were sampled, an upstream site (Greasy Creek at SR 1305) and a downstream site (Greasy Creek at SR 1425). Greasy Creek above the upper site does not appear to be impaired, based on benthic community monitoring data, although the site is only one EPT taxon away from a Fair (impaired) rating. Habitat at this site is the best in the Lower Creek watershed. In the lower site (Greasy Creek at SR 1425), however, habitat and water quality degradation contribute to the high tolerance of the benthic community.

Habitat degradation

Sediment deposition is one of the types of habitat degradation found at Greasy Creek at SR 1425. The percentage of substrate composed of silt and sand increased from 55% at the upper Greasy Creek site to 80% at the lower Greasy Creek site. The two reaches of Greasy Creek analyzed during stream walks showed similar results. The substrate at Reach 2 was comprised of a mix of gravel, cobble, and boulders. The substrate at Reach 1 consisted of sand and gravel above areas with cattle access to the stream and shifted to predominately sand below the most upstream cattle crossing in the reach.

Excess sediment deposition comes from many instream and upland sources. Poor soil binding and bank instability, caused by cattle trampling of banks and poorly vegetated banks, have caused bank erosion, which appears to be a major source of sediment to Greasy Creek. Sediment may also be entering the stream in runoff from pastures, roads, and the ornamental plant nursery, as well as residential areas. Frequent breaks in the riparian zone, which were observed in Reach 1, facilitate the entry of stormwater runoff into the creek.

Lack of edge habitat is another type of habitat degradation at the lower Greasy Creek site. Cattle trampling of banks eliminated all vegetative growth on the banks and the riparian zone along many sections of Reach 1.

Toxicity

Positive results to the Cladoceran toxicity test (IC 20 value of 43.6%) were observed at Greasy Creek at SR 1425 (Table 3.1). Further investigation is needed to determine the source of the toxicants.

Other stressors

Nutrient data show that Greasy Creek at SR 1525 had the second and third highest TKN concentrations (1.2 and 1.8 mg/L) and the highest phosphorus concentration at stormflow (0.83 mg/L) in the Lower Creek watershed. Since nutrient concentrations in Greasy Creek were high primarily during stormflow conditions, runoff from upland pastures, roads, and the ornamental plant nursery are likely sources of TKN and phosphorus. Sources of TKN, or ammonia plus organic nitrogen, include the decay of organic material such as plant material and animal wastes and fertilizers. In Greasy Creek, cattle waste and fertilizers applied at the ornamental plant nursery may be sources of TKN. The nursery and cattle waste may also be sources of the high phosphorus concentrations recorded at this site.

Turbidity and residue were very high in Greasy Creek. The lower Greasy Creek site had the highest fixed residue concentration (626 mg/L) and the two highest turbidity levels (390 and 450 NTU) at stormflow in the Lower Creek watershed. High turbidity and fixed residue may be attributed to sand and silt in the stream. High fixed residue concentrations were only observed during stormflow, therefore, inorganic residue may be entering the stream with runoff. Greasy Creek also had the highest concentration of volatile residue (144 mg/l) at stormflow in the Lower Creek watershed (Figure 2.3). High levels of volatile residue can be attributed to animal waste, pesticides, fertilizers, and other types of organic residue.

Fecal coliform bacteria samples taken from Greasy Creek exceeded 400 col/100 ml in 40% of baseflow samples. Cattle waste and problems with the Lenoir central sewer collection may be responsible for the high fecal coliform bacteria concentrations that were recorded at baseflow.

Greasy Creek exceeded acute copper benchmarks in four of five stormflow samples, and was one of three sites in the Lower Creek watershed to exceed acute lead benchmarks at stormflow (Tables 2.2 and 2.3).

5.6 UT to Lower Creek

UT to Lower Creek is an urbanized tributary to Lower Creek located in the City of Lenoir. Much of the information used to determine impairment or degradation in other streams in the Lower Creek watershed were not available for the UT to Lower Creek watershed. No benthic or habitat assessment data were collected, and stream walks were not conducted. However, physical/chemical water quality monitoring data and toxicity tests demonstrate that the UT to Lower Creek is very impacted.

Toxicity

Toxicity appears to be a cause of degradation in the UT to Lower Creek watershed. The UT to Lower Creek at NC 18 had positive results to the CheckLight toxicity tests that were conducted. It was one of only two sites that had toxicity at a 50% effect level in the CheckLight bacterial assay (IC50 value of 75.7%), which indicates a high level of inhibitory effects to aquatic biota. This test result suggests levels of toxicity to aquatic biota that would likely be significant in the ecosystem and could result in substantial long-term negative impacts. The positive results to the CheckLight assay were observed in a specialized subtest that assesses toxicity due to organic compounds.

<u>Other stressors</u>

Pollution from commercial, industrial, and residential development may be a source of degradation in the UT to Lower Creek watershed. Semivolatile organic compounds detected here included methoxy propyl acetate, which is used in paints and lacquers, heptanone C7.H14.O, a solvent and ingredient in lacquers, chloroform and three unidentified organic compounds (Table 2.5)

Industry is the most probable source of the semivolatile organic pollutants. As discussed in Section 2.7, these compounds may have entered the creek through a possible direct discharge or through release into the air, attachment to raindrops, and precipitation back into the creek. In addition, runoff from roads, railroads, and commercial development, as well as potential direct inputs from industries, may be the source of toxicants in the stream.

The UT to Lower Creek at NC 18 was found to have a high concentration of TKN and nitrate+nitrite during both base and stormflow conditions, and the UT to LC at Underdown had high nitrate nitrite during baseflow (Figure 2.1 and 2.2). Nitrate is highly mobile and can infiltrate ground water when derived from agricultural fertilizer, animal waste, or decaying plant material (USGS 2005). Sources of TKN may include the decay of organic material, such as plant material and animal wastes, and urban and industrial disposal of sewage and organic waste (USGS 2005). These baseflow data may indicate a potential direct discharge into the creek or ground water contamination in the area.

Metals were very high at the UT to Lower Creek at NC 18. It had higher levels of zinc, manganese, copper, and lead at baseflow than any of the other sites in the Lower Creek watershed.

UT to Lower Creek exceeded the 400 colonies per 100 ml criteria in 40 percent of the fecal coliform bacteria baseflow samples. It may be worth investigating potential sources of the bacteria, such as the sewer collection system.

5.7 Lower Creek

Turbidity, caused by urban runoff, storm sewers, municipal point sources, and non-urban development, was listed as a reason for including Lower Creek on the 2004 North Carolina Water Quality Assessment and Impaired Waters List (NCDWQ Draft, 2004a).

<u>Habitat degradation</u>

Sediment deposition appears to be the primary type of habitat degradation in Lower Creek. The percentage of sand and silt comprising the stream's substrate ranged from 50% - 98%, and embeddedness was high across all sites. Riffles were absent at all sites, indicating potential smothering by sediment. Excess sediment deposits were observed in the habitat assessments conducted at the four monitoring sites and along the studied reach. Other signs of sediment inputs in the stream included mid-channel bar development and pools filling in with sand. Lower Creek had high levels of suspended residue and turbidity during stormflow conditions, while during baseflow conditions, turbidity did not exceed the state standard of 50 NTU.

Both instream sources, such as bank erosion, and upland sources, including runoff from urban areas, contribute sediment to streams. Since both turbidity and fixed residue were high during storm events, stormflow scour, which strips soils from banks and into the stream, and stormflow runoff, which carries sediment inputs from upland roads, developments, pastures, and croplands, are major sources of sediment. High water velocity and volume cause streambank erosion by scouring away the soil at the edges of the banks and depositing it into the water in the stream. Especially as Lower Creek runs through the City of Lenoir, impervious surfaces are high, which increases stormwater runoff and scour. Stormwater scour and channelization, which was also noted in the stream and increases water velocity, may also provide adequate force to flush benthic macroinvertebrates downstream.

Steep, eroding banks, which were observed throughout Lower Creek, are also a likely source of sediment, especially during storms when increased water velocity and energy speed erosive processes. Riparian buffer areas along Lower Creek were generally thin and sparsely vegetated. As a result, poorly binded soils in the buffer areas and upland inputs can easily wash into the stream during storm events.

Uniform instream velocity and depth were observed during stream walks in Lower Creek. At all four sites included in this study, no riffles were observed and pools were infrequent. Channelization, which reduces riffles and velocity diversity by minimizing stream meanders, appears to be the main cause for the lack of diversity of stream velocity and depth.

Inadequate instream habitat was also noted as a type of habitat degradation in Lower Creek. Sticks and snags were the only common instream habitat type observed in the reach analyzed during stream walks. The lack of instream habitat diversity can be attributed to channelization, which increases water velocity that washes organic material downstream, and stormwater scour, which sweeps away small organic material that can add to habitat diversity. A lack of vegetated buffers, particularly along the left bank of Lower Creek, also reduces habitat by limiting sources of the organic materials. While inadequate instream habitat was observed along the reach included in this study, instream structure scores at the four monitoring sites were equal to or only slightly lower than the instream structure score calculated at the comparison site at Gunpowder Creek (Table 5.7), indicating that the lack of instream habitat may be a localized problem in Lower Creek.

Other stressors

Among the nutrients analyzed in this study, only phosphorus exceeded benchmark values in Lower Creek. High phosphorus concentrations may be attributed manure or fertilizers.

Copper exceeded benchmark concentrations at stormflow in three of six samples in Lower Creek (Figure 2.7A). However, copper was observed in rural as well as urban watersheds in the Lower Creek watershed, indicating that urban pollution may not be responsible for copper levels in the watershed.

Lower Creek exceeded the 400 colonies per 100 ml criteria in 38 percent of the fecal coliform bacteria baseflow samples. It may be worth investigating potential sources of the bacteria, such as the sewer collection system.

References

Briel, LI. 1997. Water quality in the Appalachian Valley and Ridge, the Blue Ridge and Piedmont physiographic provinces, eastern US. USGS professional paper 1422-D.

Checklight Water Quality Monitoring Kits. 2004. Frequently Asked Questions. http://www.checklight.co.il/faq.html

Kelling, Ray. 2005. Organic chemistry branch manager, DWQ Laboratory, Raleigh, NC. Personal communication.

Merschat, Carl. 2005. NC Geological Survey, DENR, Asheville Regional Office. Personal communication.

NCDENR-DWQ. 2004. Surface Waters and Wetlands Standards. 15A NCAC 2B Section .0211 Fresh surface water quality standards for Class C waters. Raleigh, NC. August 1.

NCDWQ. 2001. Standard Operating Procedures for Benthic Macroinvertebrates, Environmental Sciences Branch. Biological Assessment Unit

NCDWQ. 2002a. Guidance for Sample Submission. NCDWQ Laboratory Section. April. Available on-line at http://h2o.enr.state.nc.us/lab/qa/sampsubguide.htm
Current sample preservation requirements are available on-line at http://h2o.enr.state.nc.us/lab/qa/preservguid.htm

NCDWQ. 2002b. TMDL study of Lower Creek/Spainhour Creek, Catawba River Basin, Subbasin 31, Caldwell County. March 2003.

NCDWQ. 2003a. Intensive Survey Unit Standard Operating Procedures. Environmental Sciences Branch. August. Available on-line at http://www.esb.enr.state.nc.us/isu.html

NCDWQ. 2003b. Standard Operating Procedure for Benthic Macroinvertebrates, Biological Assessment Unit, July 2003 http://www.esb.enr.state.nc.us/BAUwww/benthossop.pdf

NCDWQ Draft. 2004a. North Carolina Water Quality Assessment and Impaired Waters List (2004 Integrated 305(b) and 303(d) Report). Public Review Draft. Available on-line at http://h2o.enr.state.nc.us/tmdl/documents/2004IRC ategories4-7_000.PDF

NCDWQ. 2004b. Technical Brief: Supplemental Monitoring of Benthic Macroinvertebrate Communities in Greasy and Lower Creeks, 2004. Lower Creek Local Watershed Plan. NC Divison of Water Quality – Watershed Assessment Team. December 21, 2004.

NCDWQ. 2005a. Total Maximum Daily Load (TMDL) for Turbidity: Lower Creek (Subbasin 03-08-31) Catawba River Basin North Carolina. November 2004.

NCDWQ. 2005b. Draft Report – Toxicity Assessment of Catawba Basin Surface Waters Collected In Caldwell County, April 2005. NC Division of Water Quality - Aquatic Toxicology Unit.

Oak Ridge National Laboratory. 2004. Risk Assessment Information System.http://risk.lsd.ornl.gov/homepage/eco_tool.shtml)

Reid, Jeffrey C. 1993. A geochemical atlas of North Carolina, U.S.A., *in* F.W. Dickson and L.C. Hsu (*Editors*), Geochemical Exploration 1991, J. Geochemical Exploration, v. 47, p. 11-27. On-line at http:// http://www.geology.enr.state.nc.us/NUREgeochem/custm.htm (copper), and http://www.geology.enr.state.nc.us/NUREgeochem/alstm.htm (aluminum).

Rosgen, D.L. 1996. Applied River Morphology. Pagosa Springs, Colo. Wildland Hydrology Books.

Suter G.W. and C.L. Tsao. 1996. Toxicological benchmarks for screening of potential contaminants of concern for effects on aquatic biota. Revision. Report ES/ER/TM-96/R2. US Dept of Energy. Oak Ridge National Laboratory, Oak Ridge, TN.

US Department of Health and Human Services. 2004. Public Health Statement for Chloroform. Agency for Toxic Substances and Disease Registry. http://www.atsdr.cdc.gov/toxprofiles/phs6.html

USEPA. 1995. Final Water Quality Guidance for the Great Lakes System. 40 CFR Parts 9, 122, 123, 131, 132. Federal Register. 60:56:15365-15425. March 23.

USEPA. 2002. National Recommended Water Quality Criteria: 2002. (NAWQC). EPA-822-R-02-047. November.

USEPA. 2004. Water Quality Standards Database (WQSDB). http://www.epa.gov/wqsdatabase/

USEPA. 2005. An Industry Overview of Furniture/Wood Manufacturing and Refinishing *in* EnviroSense: Common Sense Solutions to Environmental Problems. http://es.epa.gov/techinfo/facts/refinish.html

USGS. 2005. Chesapeake Bay River Input Monitoring Program: Water Chemistry at the RIM Stations, Sources and Chemical Behavior of Water-Quality Constituents. (http://va.water.usgs.gov/chesbay/RIMP/waterchem.html)

Appendix. Narrative summary of conditions in impaired streams and their tributaries in the Lower Creek watershed.

A narrative summary of conditions at each reach is provided in this appendix. Locations of each reach are provided in Figures 1.1 and 5.1.

B.1. Zacks Fork

Zacks Fork Creek was walked from its confluence with Lower Creek to an upstream site located near a walking bridge in the town's soccer field.

Reach 1

The most downstream reach, from Zacks Fork Creek at its confluence with Lower Creek to a forested area in the Lenoir Golf Club course at NC Route 18, is flanked on both sides by the golf course, which extends to the edge of the creek in most areas. The monitoring site at US 321A (Z1) is located within this reach. The water was slightly turbid and roots mats comprise the only common type of instream habitat favorable for benthos colonization or fish cover. The substrate in this reach is nearly all sand, and no pools or riffles were observed. As the bank and riparian vegetation on both sides of the creek is golf course turf, the stream receives no shade. The bank erosion hazard index (BEHI) for this reach ranged from 36.5 (high) to 43.5 (very high). A 100 foot long, two meter wide woody buffer offers the only riparian buffer vegetation in the reach, however, more bank erosion was observed in this woody section than in the parts of the reach where golf course turf extends to the edge of the stream. Three of the four box culverts under US 321A were filled with sediment. The stream is not confined, but signs of recent channelization are present. *The habitat score for this reach was 16.*

Reach 2

Tall, eroding banks and a very sandy streambed characterize the second reach of Zacks Fork Creek, which runs from the forested area in the golf course to US 321. Throughout the entire reach, an enormous amount of sand was observed; some sand ripples were over three inches in height. Breaks in the riparian buffer, which was dominated by young forest on the left bank and commercial development on the right, were common on both sides of the stream. The bank erosion hazard index (BEHI) for all sections of this reach received a score of High. The stream is partially confined by a powerline right-of-way, parking lots, and roads.

An earthen channel large enough to accommodate high stormflow was observed along the left bank. Garbage and drums were common in the side channel, at which a specific conductance concentration of 158 μS/cm was recorded. Eleven pipes, the majority of which carry stormwater, were noted along this reach. Outfall effects include erosion and scouring; one pipe has scoured out a channel 6 feet deep.

The more downstream section of this reach, which runs through a forested area in the golf course, has higher sinuosity, coarser sediment, and more riffles than the more upstream sections of the reach. The riparian buffer on the left bank, which is about 6 meters wide, is dominated by trees and shrubs, while there is no woody vegetation on the right bank. The golf course, a powerline right-of-way, and a road are located within the right bank's riparian area. The powerline right-of-way in particular limits vegetation in the buffer area.

Commercial development is the primary land use type on both sides of the creek in the upstream section of the reach. Impervious cover is high, and woody vegetation extends only to the tops of the banks. A small area on the left bank, however, does seem to offer restoration possibilities, particularly in the back of the bank across from US 321. *The habitat score for this reach was 45.*

Reach 3

A wide and shallow channel, thin buffer, and sandy substrate typify the third reach along Zacks Fork Creek, located between US 321 and a major unnamed tributary to Zacks Fork Creek. Instream habitat is moderately favorable for colonization by benthic macroinvertebrates. Pools are small and infrequent, and the only riffles are those caused by debris jams. Breaks in the right bank's riparian zone, which was 6-12 meters wide, are rare, whereas breaks are common in the very thin (<6 meters) riparian zone on the left bank. A common problem in this reach is overflowing manholes. Residents in the area have stated that manholes on the creek bank overflowed 3-4 times in the past year (summer 2003-summer 2004), and that other manholes in the area have also overflowed.

For the first (most downstream) 60 meters of the reach, rip rap has been applied to stabilize the stream. Kudzu dominates both banks, and parking lots, for a motel and a restaurant, are located on both sides of the creek. In the next section of the reach, commercial development, rip rap, and especially high banks (12-20 feet) continue along the left bank, while a thin but forested buffer and residential development are adjacent to the right bank. While there is little potential for channel restoration on the left bank, buffer restoration along its high banks seems possible. An old road along part of the right bank, while not currently in use, limits restoration potential on the right side of the stream.

Residential development dominates the riparian area on both sides of the creek in the most upstream section of the reach. However, while impervious surface and lawns dominate the left bank, shrubs and trees, including extensive bamboo, and a greenway 10 meters from the creek are the primary land cover types along the right bank. If the bamboo is removed and the creek side of the greenway is left to reforest, the right bank in this section of the reach is likely to become stable without further intervention. Restoration is possible along the left bank only if residents are willing to restore sections of the creek in their backyards. *The habitat score for this reach was 36.*

Reach 4

The reach between the major unnamed tributary to Zacks Fork Creek and an athletic field has more excessive erosion than was observed in the more downstream reaches (Reaches 1-3) of the creek. As in Reach 3, instream habitat is moderately favorable for colonization by benthic macroinvertebrates, most likely due to the health state of the riparian vegetation along this reach. Sand is excessive throughout the entire reach, and both pools and riffles are infrequent. Land use on the right bank is predominately residential, and some riprap and concrete have been used for stabilization. A large church lawn is the main land use on the left bank. The vegetation on both banks, which is dominated by young forest and turf/crop, appears relatively healthy. However, both banks are actively sloughing, and stormwater pipes increase scouring and erosion in the channel. Workers have cleared many of the trees along the left bank's sewer right-of-way, which is located less than 10 meters from the creek. Buffer restoration along the left bank in particular could help to reduce bank failure and erosion. *The habitat score for this reach was 41.*

Reach 5

The fifth most downstream reach of Zacks Fork Creek, located between the athletic field and an old dam, is very different than the rest of the creek. Banks are very unstable, and the channel is actively widening and knocking out its banks. The channel appears natural, however, as it is very sinuous and exhibits no signs of channelization. As in several of the more downstream reaches, deep sand is common throughout the entire streambed. Residential development is the main land use on the right bank while the athletic fields are the primary land use on the left bank.

Frequent breaks were observed in the riparian buffer, which fluctuates from over 18 meters to less than 6 meters wide on both banks. Diverse trees, shrubs, and grasses comprise the majority of the bank vegetation on both sides of the creek. The existing forest appears to be healthy and native on the left bank, and exotic species were only observed in the upper section of the reach. While houses were set back from the right bank, many yards extend to the edge of the riparian area, and some sheds are located next to the creek. Stormwater from residential areas appears to cause severe erosion in some areas of the reach. Homeowners seem to enjoy the creek, as lights and benches were observed along the reach, so they may be interested in and receptive to restoration. *The habitat score for this reach was 57.*

The monitoring site at SR 1531 is located at the upstream end of this reach.

Reach 6

The most upstream reach of Zacks Fork Creek extends from the old dam to the pedestrian bridge in the soccer fields. The channel is sinuous and has large pools, though sand was prevalent on the bottoms of the pools. Banks are very high near the dam at the downstream end of the reach and gradually decrease in height towards the upstream end of the reach. The channel is actively aggrading and widening, and the banks appear to be providing most of the sediment inputs.

The upstream and downstream sections of the reach differ widely. The more downstream section of the reach is heavily forested, and the riparian buffer is over 18 meters wide and intact (i.e., no breaks were observed). Nevertheless, severe erosion was present in this section of the reach. In the upstream section of the reach, buffer vegetation extended less than 6 meters from the stream and breaks in the riparian zone are common. Along the soccer fields, which are located on the right bank of the stream, grass was the only type of vegetation in the buffer zone. Though erosion is present throughout the reach, bank sloughing was more severe in the upstream section. A sewer right-of-way along the left bank is located very close to the creek in this reach. Currently, a restoration project is being built in this reach. *The habitat score for this reach was 48.*

B.2. Spainhour Creek

Reach 1

Spainhour Creek has been channelized in many areas, and the creek is generally wide and shallow. The most downstream reach, which is located from the confluence with Lower Creek to Creekway Road, is the most degraded reach of Spainhour Creek. It is constrained by Broyhill industrial complex and a powerline right-of-way on the left bank and by commercial and residential development on the right bank. The channel is straight, with few bends, and has no thalweg. There is little roughness in the stream except along the banks, where root mats and undercuts are common. The substrate is nearly all sand. The riparian zone on the right bank is characterized by extensive bamboo and severe erosion. On both banks, breaks in the riparian zone are common, and the riparian buffer is less than 6 meters wide. Sparse mixed vegetation, including shrubs, grasses, and exotics, dominate both the banks and the riparian zone. The four BEHIs ranged from 27.2 – 40.3 (moderate-very high), and the typical bank received a score of 27.2. The overall habitat score for this reach was 30.

Stormwater scour is a major cause of erosion in this reach. On the right bank, a stormwater outfall pipe from Winn Dixie located eight meters from the stream has eroded the land to the level of the stream bottom, creating a huge hole. A second pipe has fallen from its original site, creating a large scour area around the pipe that extends to the level of the stream bottom. A third pipe located near a shopping center dumpster also caused stormwater scour. On the left bank, a stormwater outfall pipe from the Broyhill factory emitted potential sewage into the creek. In total, six stormwater outfall pipes were causing scour in the stream.

Reach 2

For most of its length, Spainhour Creek is actively widening in the reach located between Creekway Road and the hayfield. The creek is sinuous within its former banks, and it is forming a new floodplain within the incised channel. The left bank of the most downstream section of this reach has the most stable banks of the reach, due to the presence of a wooded riparian area, but in general banks are high and unstable, and the riparian buffer is narrow and contains frequent breaks. Sand is the predominate substrate, and the channel is wide and shallow where it is not sinuous. Pools are infrequent but diverse in size. The BEHI for the worst section within the reach, where the pasture is adjacent to the stream, was 45.8 (very high), while the BEHI typical of the reach was 36 (high). The overall habitat score for this reach was 38.

Reach 3

Hayfields line the next reach of Spainhour Creek, which is located from the hayfield to Broadway Street. Pieces of glass, metal, and tires were frequently found in the channel, and a sewer overflow was found. The riparian buffer is characterized by a poor understory, exotics, and mixed hardwoods, and the average width of the buffer is 12-18 meters. As in the previous reach, the channel appears to be widening and aggrading, as extensive point bar development was observed, and pools are filling in with sediment. The overall habitat score for this reach was 42.

Reach 4

The fourth reach of Spainhour Creek, from Broadway Street to Meadow Lane, is confined by a sewer line on the right bank. In the upstream section of this reach, residential development on the left bank also limits restoration potential, since there is little space to restore buffer vegetation. Sand was again the dominant substrate in this reach. On the left bank, lawns are the most prevalent land cover in the upstream section of the reach, and exotic vegetation, especially bamboo, multiflora rose, and privet, dominate the downstream section. The right banks are more stable and forested. The channel appears to be widening and aggrading, as bank erosion and mid-channel sand bars were observed. The overall habitat score for this reach was 46.

Reach 5

Severe bank erosion, potentially leading to the loss of buildings, was noted in the reach from Meadow Lane to the confluence with Blair Fork. Signs of recent bank fortification (using tires) were noted. Banks are very unstable and actively eroding, and the channel is heavily incised. The bottom substrate is composed of heavily embedded gravel, and many pools have filled in with sand. Sparse mixed vegetation line both the right and left banks, and the riparian buffer is not intact, has common breaks, and is 6-12 meters wide. The land uses in the riparian zone on both sides of the creek are residential and commercial, and roads line both sides of the creek. Scour was also noted in this reach, though it was less of a problem than in Reach 1. The overall habitat score for this reach was 38.

B.3. Blair Fork

Reach 1

The first reach along Blair Fork, from the UT to Spainhour Creek to the first railroad bridge at Greer Janitorial Supplies, is characterized by a wide, shallow, and incised channel and limited riparian buffer vegetation. Excessive periphyton growth, a sign of nutrient enrichment, was noted on the substrate, which is mostly embedded gravel. Only one pool was observed in this reach. The left banks are moderately stable, with a generally healthy mix of shrubs and trees, while the right banks have poorer soil binding and more sparse vegetation. Unstable and sloughing banks were particularly evident along the lumberyard located on the right side of the creek. Riprap and other stabilizing materials have been used around the commercial section of the reach, and structural hardening is present along the lumberyard. Bank erosion caused by stormwater scour was observed at several locations along the right bank.

Land use on the left bank on the downstream section of the reach is primarily residential, while a hillock area with a mature forest system dominates the left bank in the upstream section of the reach. The riparian zone on the entire right bank and on the left bank along the residential area is roughly 2 meters wide, while the riparian vegetation on the left bank along the hillock area exceeds 50 meters in width. The adjusted bank erosion hazard indices for this reach ranged in value from 34 (high) to

42.5 (very high). The three BEHIs conducted for this reached ranged from 34 – 42.5 (high – very high). The overall habitat score for this reach was 38**.**

Reach 2

Three distinct sections of the reach between the first railroad bridge at Greer Janitorial Supplies and the upstream confluence with NC 90 were observed. The first section of the stream reach, from the railroad bridge to the lumber supply yard, is straight, incised, rip-rapped, and tightly confined between railroad tracks and a road. The janitorial company and a log processing plant are also adjacent to the stream. A very thin zone of shrubby vegetation is present in the riparian area. The BEHI for this section was 41.6 (very high).

Along the second section of the reach, located behind the furniture market, the right bank adjoins a forested hill, and riffles and cobble are present in some areas of the section. The left bank, which is bermed, is up against the furniture market. Wood scraps and other debris have been dumped along the left bank, possibly as an attempt at stabilization. A straight pipe into the stream, which emitted a low flow and a sewage odor, was observed along the left bank. The BEHI for this section was 32.5 (high).

The third section of the reach, like the first, is straight, incised, and heavily confined. The railroad, a road, a powerline right-of-way, and a sewer right-of-way line the creek, and very little riparian vegetation is present. The BEHI for this section was 35.3 (high).

In all three sections of the reach, the substrate is nearly all sand, and pools and riffles are infrequent. Both banks have poor soil binding and sparse, mixed vegetation, including many exotic species. The majority of the riparian buffers are less than 3 meters wide, though the section of the right bank along the forested hill is over 30 meters wide. In general, the stream is slowly widening. Undercutting caused by stormwater scour was noted where a side stream and several stormwater outfall pipes entered Blair Fork. The overall habitat score for this reach was 42.

B.4. UT to Spainhour Creek

This reach exhibits some good habitat, including lots of cobble, well-defined riffles, and some undercut banks. Where it is given space, the stream becomes sinuous. However, it is somewhat incised and partially confined by structural hardening. The creek is straightened and runs between a road and powerline right-of-way, which parallel the right bank, and pasture, residential development, and forested areas on the left bank. Residential development and lawns on the right bank extend to the creek.

Pools are very infrequent, and the stream receives full sun in all but a few areas. The riparian buffer is not intact, and breaks are frequent. Buffer width ranges from over 30 meters along forested areas to less than 2 meters. Exotic species, including honeysuckle, multiflora rose, and kudzu, dominate the right bank's buffer zone. Erosion caused by a channelized side stream that was directed around a garden was observed on the right bank, and several metal pipes and culverts were also noted on the right bank. Three BEHIs were calculated in this reach and range from 26.2 to

45.6. The BEHI for the most typical section of the reach was 44.4 (very high). The overall habitat score for this reach was 58.

B.5. Greasy Creek

Streams walks and habitat assessments were also conducted along two reaches of Greasy Creek on May 10, 2005. A narrative summary of conditions at each reach follows.

Reach 1

This reach, located downstream of SR 1310, was characterized by extensive impacts caused by cattle, which are degrading the stream by trampling and collapsing the banks and increasing sediment inputs. The substrate consisted of sand and gravel, though sand was especially prevalent below the most upstream cattle crossing in the reach. Throughout the reach, the riparian zone was less than 6 meters wide, and trees and exotic species, including multiflora rose, were the primary vegetation in the riparian zone. An ornamental plant nursery, roughly 100 meters wide and 600 meters long, was the dominant land use on the left bank of the downstream section of the reach. A dirt road, which runs between the nursery and the creek, limits buffer vegetation on the left bank, and fertilizers and runoff from the nursery may be entering the creek. Breaks in the riparian zone caused by cattle access to the creek were common on both sides of the creek in the upstream section of the reach. The total habitat score for this reach is 36.

Reach 2

This reach, located upstream of SR 1310, was in much better condition. The channel was moderately sinuous and it appeared to be natural, i.e., channelization was either old or never occurred. The instream habitat was favorable for colonization by benthic macroinvertebrates. The substrate was comprised of a good mix of gravel, cobble, and boulders, which were somewhat (20-40%) embedded by sand. Sand decreased in the more upstream sections of the reach. Pools were common and a variety of pool sizes were observed. Vegetation on the right bank consisted of native trees, and the banks appeared to be stable. The riparian buffer was over 18 meters wide and breaks in the buffer were rare. Breaks in the riparian buffer were also rare on the left bank; however, buffers were narrower, ranging from less than 6 meters to 12 meters wide. The left bank's vegetation was also less healthy, as it was dominated by sparse mixed vegetation, and collapsing banks were noted near the hayfield. An earthen channel with high (over 7 feet tall) banks on the left bank of Greasy Creek was observed emitting iron bacteria into the stream. The total habitat score for this reach is 77.

B.6. Lower Creek

A stream walk and habitat assessment was also conducted along one reach of Lower Creek on May 9, 2005. A narrative summary of conditions at the reach follows.

Reach 1

Lower Creek was walked at an upstream reach beginning at the intersection of NC 90 and NC 18. The channel in this reach was incised and aggrading, as pools are filling in with sand and mid-channel bars are developing. The water in this reach was turbid and milky, despite the fact that no rain had occurred since the previous week. Sticks and snags were the only common instream habitat types observed in this reach. Periphyton growth was seen on bed sediment, which was dominated by sand with occasional areas of gravel. Banks were high and actively eroding. Vegetation on the left bank consisted primarily of trees and shrubs, and the riparian area along the left bank was less than 6 meters wide and had frequent breaks. Vegetation on the right bank was sparser and soil binding was poor. The riparian buffer on the right bank was less than 6 meters wide and was characterized by frequent breaks, which allow sediment and pollutants to directly enter the stream. The overall habitat score for this reach was 47.