Integrated Analysis Report of Water Quality for the Ararat River Watershed

Yadkin-Pee Dee River Basin
Catalog Unit # 03040101

Prepared By
North Carolina Division of Water Quality
Watershed Assessment Team

Version 3.0
July 2009

Suggested Citation

NCDWQ Watershed Assessment Team. 2009. Integrated Analysis Report of Water Quality for the Ararat River Watershed. North Carolina Division of Water Quality (NCDWQ); Version 3, July 2009.

Version History

Version 1.0 – Internal draft; No date
Version 2.0 – Draft submitted to DWQ and EEP staff for review; March 2009
Version 3.0 – Incorporates comments obtained from the review of Version 2.0; July 2009

Table of Contents

Tables and Figures

Executive Summary

The NC Division of Water Quality (NCDWQ) initiated and completed between February 2008 and February 2009 an evaluation of water quality in a 235 mi^2 watershed located around the towns of Mount Airy and Pilot Mountain in Surry County, North Carolina. Specific tasks included: 1) a summary of existing water quality data, 2) a preliminary reconnaissance of water quality conditions at 34 sites, 3) assessments of benthic macroinvertebrate communities and habitat at 14 sites; 4) physical/chemical water quality monitoring at eight sites; and 5) stream corridor assessments in two urban subwatersheds. These tasks were conducted in support of the development of a Local Watershed Plan (LWP) by the NC Ecosystem Enhancement Program (EEP). This report summarizes the results of the first three tasks, and integrates these data with the results associated with tasks 4 and 5 (water quality monitoring and stream corridor assessments) to provide an interpretation of likely stressors contributing to the degradation of water quality, habitat and hydrology functions throughout the planning area.

Existing water quality data collected from 2001 through 2007 (NCDWQ, 2008a) were reviewed and summarized. Data included results from ambient monitoring, biological assessments (fish and benthos), precipitation/stream flow records and discharge monitoring data from regulated facilities. Overall, the review of existing data did not reveal major water quality issues within this watershed. Problems were noted for portions of Lovills Creek and all of Heatherly Creek for biological integrity (based on benthic macroinvertebrates data) and a portion of the Ararat River for violations of the NC water quality standard for turbidity. All three were included on the 2006 North Carolina 303(d) list of impaired streams. Drought conditions were evident in 2002 and 2007 and effects of the drought on water quality were noted. The Town of Mount Airy reported occasional sewerage overflows, one of which in 2007 resulted in a fish kill in a UT to Lovills Creek.

The preliminary water quality reconnaissance by the Watershed Assessment Team (WAT) was conducted in March 2008 at 34 locations in the watershed. During this reconnaissance, field measurements (dissolved oxygen, pH, temperature, specific conductance) and water samples (turbidity, fecal coliform bacteria, nutrients) were collected once from each location. The reconnaissance was performed in order to obtain greater spatial coverage of water quality conditions than was available from existing ambient and biological monitoring sites. The goal was to identify locations for more intensive monitoring based on a comparative analysis of parameter concentrations between locations. Results of the reconnaissance indicated no water quality concerns at 27 sites. A subset of 14 sites was selected for further chemical/physical and biological monitoring as described below.

Benthic macroinvertebrate communities and habitat assessments were conducted at 14 sites in September 2008 by the NCDWQ's Biological Assessment Unit (BAU). Seven of the 14 sites had never been assessed previously. Sites with 2006 data maintained their 2006 bioclassifications except for the most upstream location in the Ararat River at NC 104 which declined from Good to Good-Fair. A bioclassification of Good-Fair was assigned to seven sites. Lovills Creek remained at Fair. The remaining six sites, including Heatherly Creek, did not receive bioclassifications because of small drainage areas, or because of drought effects. BAU reported difficulty regarding interpretation because of the extent and duration of the drought

prior to sampling. There were no taxa-specific indicators of stressors (e.g. nutrients) among any of the taxonomic data. Habitat conditions varied among locations and were not always good predictor of the benthic community, likely due to drought stress. For example Toms Creek had the highest total habitat score but a comparatively less diverse benthic community. Nevertheless, the assessments were beneficial in that they provided evidence of stressors and degraded watershed functions and helped to estimate the potential that exists in terms of supporting a diverse benthic community.

Water chemistry sampling was initiated for a subset of eight of the 14 sites above in October 2008. Sampling was terminated earlier than planned in January 2009 due to changing priorities associated with the development of the local watershed plan. This sampling effort included monthly baseflow sampling for nutrients, metals and fecal coliform bacteria. No major water quality concerns were revealed. Stormflow samples were collected once in January 2009 at two sites. Results indicated water quality concern at one location, Moores Fork, due to high nitrite+nitrate nitrogen concentrations.

NCDWQ staff conducted stream corridor assessments (stream walks) upstream of the sampling stations along approximately five miles of Lovills and Heatherly Creeks in February 2009. The goal was to identify stressors that may be contributing to stream impairment and to identify potential locations for stormwater BMPs. Both streams drain urban catchments and suffer from impacts related to non-point source pollution and increased imperviousness. Much of Lovills Creek flows through an engineered flood control channel devoid of riparian vegetation (is frequently bush-hogged), shade and in-stream woody debris. In Heatherly Creek, the channel was more natural but confined by a rail line in portions and habitats were more favorable. Several potential locations for BMPs were identified along both streams (see Recommendations section).

Overall, water quality across the LWP area reflects relatively good conditions (with noted exceptions). Drought stress affected benthic communities throughout the watershed and likely masked the effects of other stressors. Other likely stressors included increased storm water runoff, scour and sediment from unstable stream banks all of which contributed to habitat degradation. In general, subwatersheds outside of urban influences had more favorable water quality. Sites for which historical data exist have not improved, but also have not declined substantially. These streams need to be reassessed once the drought lessens and flow returns closer to long term averages. Only then will a more accurate assessment of water quality throughout the watershed be obtained. Stormwater and agricultural BMPs and stream restoration projects where recommended would likely improve water quality conditions in those subwatersheds. Subwatersheds where preservation opportunities need to be investigated were noted.

Introduction

This report summarizes the results of several water quality assessments conducted by the NC Division of Water Quality (NCDWQ) in the Ararat River watershed in North Carolina, within the upper Yadkin River Cataloging Unit (# 03040101) between March 2008 and February 2009. These assessments are conducted to support the development of a Local Watershed Plan (LWP) being coordinated by the NC Ecosystem Enhancement Program (EEP). The intent is to identify stressors likely contributing to the degradation of water quality, habitat and hydrology functions throughout the planning area based on the collected data and best professional judgment. These data provide comprehensive watershed information and maps that identify streams and subwatersheds that could benefit from restoration, enhancement and preservation measures or best management practices (BMPs). Recommendations for further data collection and assessment are also provided. Implementing appropriate management strategies help to preserve, protect and improve water quality, and restore other local ecosystem functions.

Several tasks completed during 2008, in addition to stakeholder input, formed the basis for water quality monitoring described and presented in this document. They included the following.

1. A summary of existing water quality data for the Ararat LWP area (NCDWQ, 2008a) reviewed available water quality data collected between 2001 through 2007. This task helped to identify water quality problems and data gaps and where additional monitoring should occur.

2. A water quality reconnaissance (survey) was conducted in March 2008 (NCDWQ, 2008b) and presented in June 2008. This reconnaissance consisted of a one-time collection of field measurements (dissolved oxygen, water temperature, pH and specific conductance) and water samples from 34 sites. Water samples were analyzed for nutrients, turbidity and fecal coliform bacteria. Results identified where water quality concerns existed, and were used to develop a water quality monitoring plan.

3. A GIS based (EcoEngineering, 2008) analysis using existing land use, existing water quality data and GIS data sets matched subwatershed characteristics with plausible conservation and mitigation projects (best, management practices [BMPs], stream restoration or watershed preservation). This served as a basis to develop priorities among subwatersheds

4. A plan to monitor water quality was developed (NCDWQ, 2008c). Goals of the monitoring plan are described in the Overview of Monitoring section below. The types of monitoring conducted included physical and chemical sampling and analyses, benthic macroinvertebrate and habitat surveys and stream corridor assessments. Additional details relative to monitoring type are provided in the Methods section of this report. Due to changes in expected mitigation needs in this area, the monitoring work was concluded earlier than initially planned.

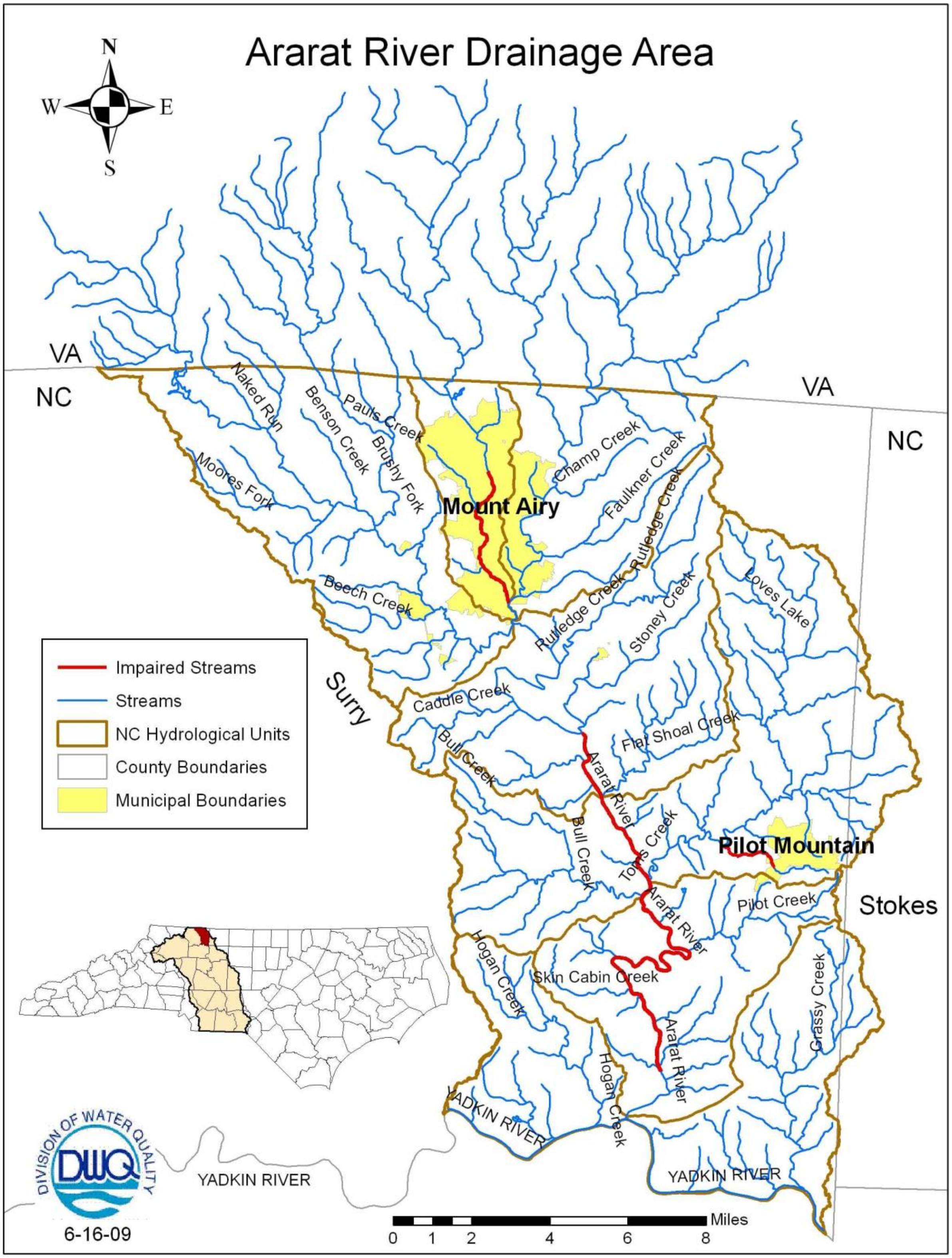


Figure 1. The Ararat River watershed.

Overview of LWP Area

The Ararat River LWP encompasses 235-square miles within the Upper Yadkin Basin Cataloging Unit 03040101, including nine 14-digit Hydrologic Units (HUs). Most of the streams are located in Surry County, NC; however the headwaters of Ararat River, Lovills and Stewarts Creeks are in Virginia and certain headwater portions of Toms Creek are located in Stokes County. The most notable natural feature within the planning area is Pilot Mountain State Park. The most notable unnatural feature is the roughly three miles of engineered flood control channel that carries Lovills Creek through Mount Airy. Mount Airy and Pilot Mountain are the two largest municipalities in the project area and are drained by Lovills and Heatherly Creeks respectively. Land cover is primarily agricultural and forested lands.

Overall, most streams within the LWP area have a classification of either Class C or as a water supply (WS). Toms and Chinquapin Creeks were assigned a High Quality Waters (HQW) supplemental classification. Portions of two streams in close proximity to the border with Virginia carry a Trout Water (Tr) supplemental classification and include Stewarts Creek and the Ararat River. Additional information relative to North Carolina's stream classifications is located in the Appendix.

Summary of Existing Water Quality Data

A brief summary of the existing water quality data report (NCDWQ 2008a) is provided below. Elements of this report will be referenced in the Discussion section of this report.

Within the LWP watershed both the NCDWQ and the Yadkin-Pee Dee River Basin Association (YPDRBA) have programs that collect physical and chemical data. Chemical and physical water quality monitoring data collected from 2001 and 2006 from six sites along the Ararat R. were reviewed and summarized (NCDWQ, 2008a). Few water quality problems were revealed, although turbidity levels exceeded the water quality standard (50 NTU) at each site on occasion. As expected there were localized impacts downstream of Mount Airy's discharge in the Ararat River in terms of elevated specific conductance. Chemical and physical data for other streams in the LWP area were scant other than those that were recorded during biological monitoring throughout this period.

Benthic macroinvertebrate data collected by NCDWQ's Biological Assessment Unit (BAU) from 2001 through 2006 were available for the Ararat River, Faulkner and Flat Shoals Creeks, Lovills and Stewarts Creeks and Rutledge and Heatherly Creeks (see Table 8 in Appendix). Bioclassifications ranged from Fair to Good. Most notable were Lovills and Heatherly Creeks, which received Fair and Not Rated (due to small drainage area) bioclassifications respectively throughout the period. Stewarts Creek received a Fair rating in 2001, but improved to Good-Fair in 2002. No particular stressors other than drought conditions were suggested as stressors to benthic communities.

Fish community data collected by BAU in 2001 and 2006 were available and reviewed for the Ararat River (2006 only), Stewarts, Lovills and Toms Creeks. All were rated Excellent except for Lovills Creek where it was rated Good.

The Ararat River and Lovills and Heatherly Creeks were listed on NCDWQ's 303(d) 2006 Impaired Waters List (NCDWQ, 2006a) for turbidity standard violations (Ararat River only) and biological criteria (benthic macroinvertebrates).

Daily discharge data for the Ararat River at Ararat (from 1990 through 2008) from the United States Geologic Survey (USGS, site number 02113850) real time website interface were reviewed. Drought or low flow conditions were identified during 2000 through 2002 and in 2007. Decreased flow can impact benthic communities by reducing available habitat such as root mats and undercut banks that may not be in contact with water and can also impact instream water chemistry (e.g., lowered dissolved oxygen levels, higher concentrations of contaminants below dischargers).

There are several permitted facilities regulated by the National Pollution Discharge Elimination System (NPDES) program including farm animal operations, major (> 1.0 MGD) and minor (< 1.0 MGD) wastewater treatment facilities, stormwater and groundwater remediation. NCDWQ's regional office staff indicated few known water quality concerns with the facilities other than occasional monitoring parameter violations (see Table 9 in the Appendix). Mount Airy has reported occasional sewerage overflows one of which resulted in a fish kill during 2007 in an un-named tributary (UT) to Lovills Creek. Both Mount Airy and Pilot Mountain wastewater treatment facilities discharge to the Ararat River. Additional details were provided in the summary of existing data report (NCDWQ, 2008a).

Summary of Reconnaissance Sampling

Reconnaissance sampling was conducted in March 2008 to distinguish between areas that may or may not have water quality problems and to obtain greater spatial coverage of water quality conditions than was available from existing monitoring sites. The data were also to be used (along with other data sets) in the GIS-based subwatershed prioritization task to help group subwatersheds by project category type.

There were 34 locations identified for the reconnaissance sampling (Fig 2). Sites were selected based on: 1) availability of existing data for comparison purposes; 2) stream classification and major land use to ensure all types were assessed; 3) stakeholders' knowledge of potential problem areas; 4) windshield surveys conducted by WAT staff that identified potential problem areas; and 5) accessibility.

Field parameters (dissolved oxygen [DO], pH, specific conductance and water temperature), nutrients (nitrite+nitrate nitrogen [NO_2+NO_3], total Kjeldahl nitrogen [TKN], ammonia nitrogen [NH_3] and total phosphorus [TP]), turbidity and fecal coliform bacteria were collected once during baseflow conditions over a five-day period (March 3 – 6 and March 12, 2008) at each location.

Distinguishing patterns among the sites represented some challenges since the range of results observed for all 34 sites for certain parameters was small and the maximum results were not indicative of any water quality problems. Additionally, results did not exceed any NCDWQ standards. All results for turbidity were low and all ammonia results were below laboratory detection limits but one. The highest nitrite+nitrate nitrogen level was 0.90 mg/L and the NCDWQ standard for nitrate nitrogen for bodies of water classified as water supplies is 10 mg/L. Nevertheless, the exercise helped to reduce the potentially large number of monitoring locations to a more manageable set.

Results for fecal coliform bacteria, specific conductance and nitrite+nitrate nitrogen were useful since the ranges of results within each of these three data sets were the largest among all the parameters measured. From this we identified seven sites that had water quality concerns and warranted further investigation. Results from the remaining 27 sites failed to show any water quality problems.

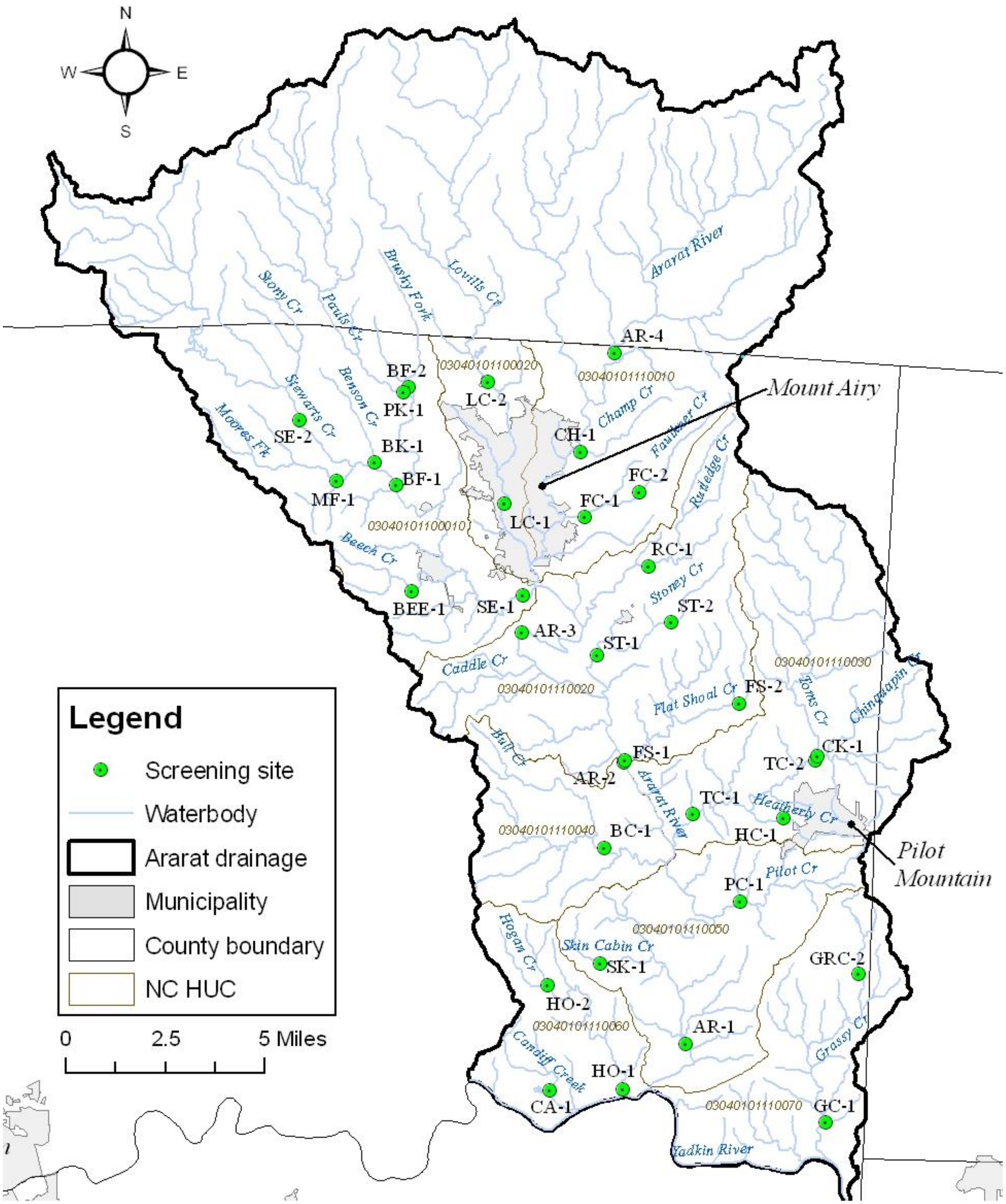


Figure 2. NCDWQ reconnaissance sampling sites.

Summary of GIS-Based Subwatershed Prioritization.

The EEP used the services of EcoEngineering to develop a ranking method for subwatersheds. Details on the approach and methods used are described in a technical memorandum (EcoEngineering, 2008). The LWP area was subdivided into 46 subwatersheds, each of about five square miles in area. Information from a variety of GIS databases was used to develop sub watershed ranks. Databases included information on land use, tax parcel density, water quality data, Natural Heritage Areas and Element Occurrences, etc. From this analysis three project management categories were established to help with indentifying compensatory mitigation projects. These management categories were:

1. Stream Restoration/Agricultural Best Management Practices (BMPs)- will restore stream conditions and stressors found in agricultural buffers with minimal land ownership
2. Stormwater BMPs – will treat runoff from impervious surfaces found in urban areas; and
3. Stream and Wetlands Preservation – will protect water quality and habitat within mostly rural areas containing large tracts of undisturbed native vegetation.

The final prioritization (ranking) had four subwatersheds in the Stormwater BMPs category, six in the Preservation category and 12 in the Stream Restoration/Agricultural BMP category, for a total of 22 (Fig. 3). Two subwatersheds were in both the Preservation and Stream Restoration/Agricultural BMP category so a total of 20 of the 46 delineated sub-watersheds were actually identified as priority areas for additional watershed assessment and project identification work. A sub-set of these priority and non-priority subwatersheds were selected for further water quality monitoring.

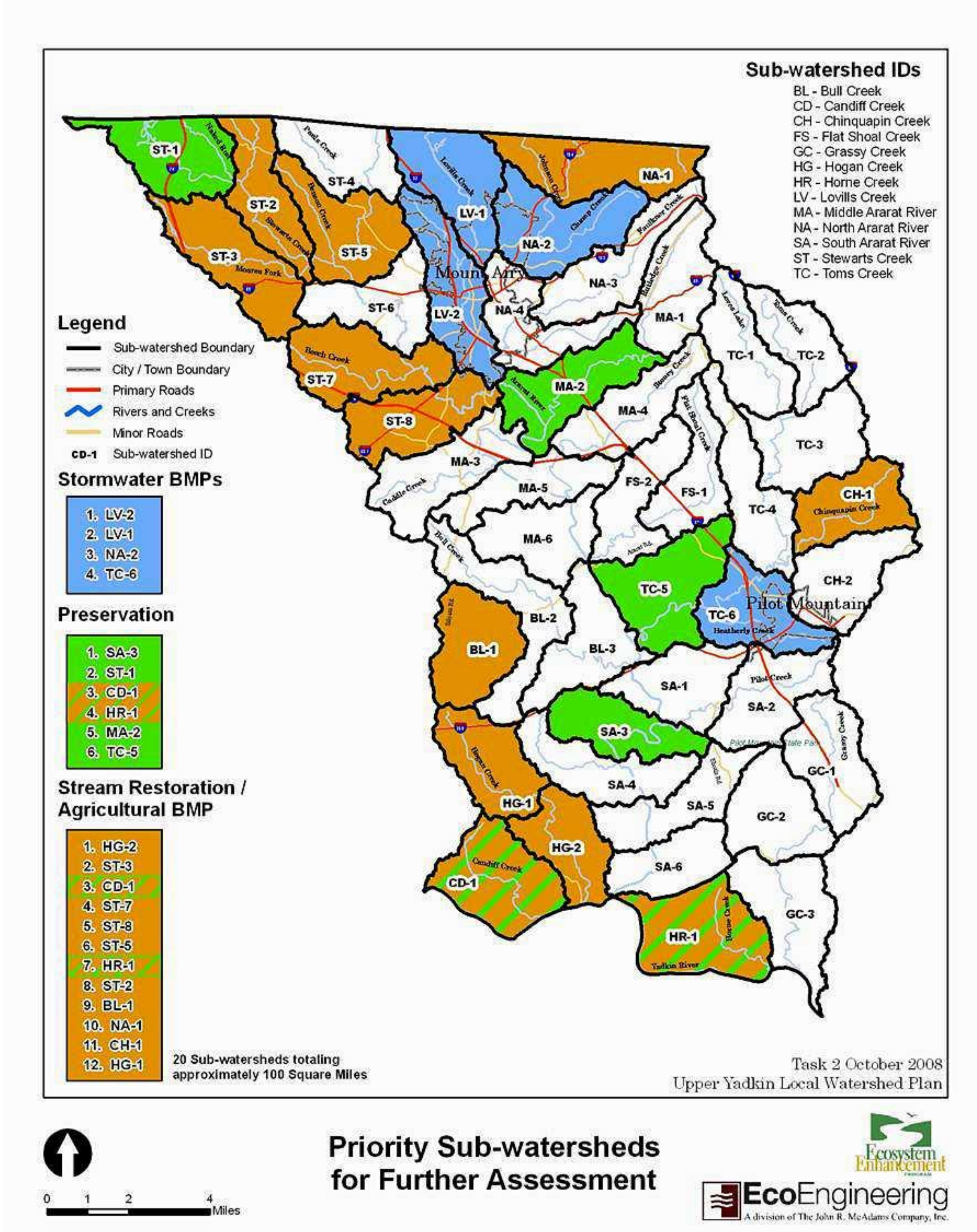


Figure 3. Subwatershed prioritization map.

Overview of Water Quality Monitoring

Approach to Monitoring Site Selection

Monitoring sites summarized in Table 1 and depicted in Figure 4 were chosen to meet the goals listed below as described in the monitoring plan (NCDWQ, 2008c).

Monitoring Goals

1. Characterize and compare water quality, habitat conditions and benthic communities between selected subwatersheds.
2. Assist EEP and local stakeholders in identifying the locations for potential stream restoration, preservation, and BMP projects within selected priority subwatersheds.
3. Conduct stream corridor assessments along Heatherly and Lovills Creeks to identify stressors to the benthic communities.
4. Investigate potential sources of impact to benthic communities along Faulkner Creek indicated by a wide difference in biotic indexes between upstream-downstream monitoring locations in 2006. *Note: Due to a reduction in expected mitigation needs by the Department of Transportation, watershed planning efforts and water quality monitoring efforts were scaled back. This goal and goal 5 below were not addressed.*
5. Investigate sources of elevated fecal coliform bacteria in Champ Creek, Flat Shoal Creek and Moores Fork. *Note: Not conducted- see Goal no. 4.*
6. Characterize the quality of stormwater in Lovills Creek and compare to a reference stream (Toms Creek).

Monitoring locations were chosen, in part, to coincide with subwatershed prioritizations so that monitoring data could be obtained within the management categories of 1) Stream Restoration/Agricultural Best Management Practices, and 2) Stormwater BMPs. This could possible help identify stressors that may be degrading watershed functions. Additionally, this could provide supportive information to help compare water quality, habitat and benthic communities between subwatersheds. However, not all monitoring sites were within subwatersheds identified as a priority.

Six sites selected for monitoring were not in a subwatershed identified as a priority (Table 1). In some cases monitoring was conducted in order to follow-up with water quality concerns that were previously identified. One example is Faulkner Creek, in which benthic sampling in 2006 showed major differences in biological integrity between two sample locations (see monitoring goal number four above.)

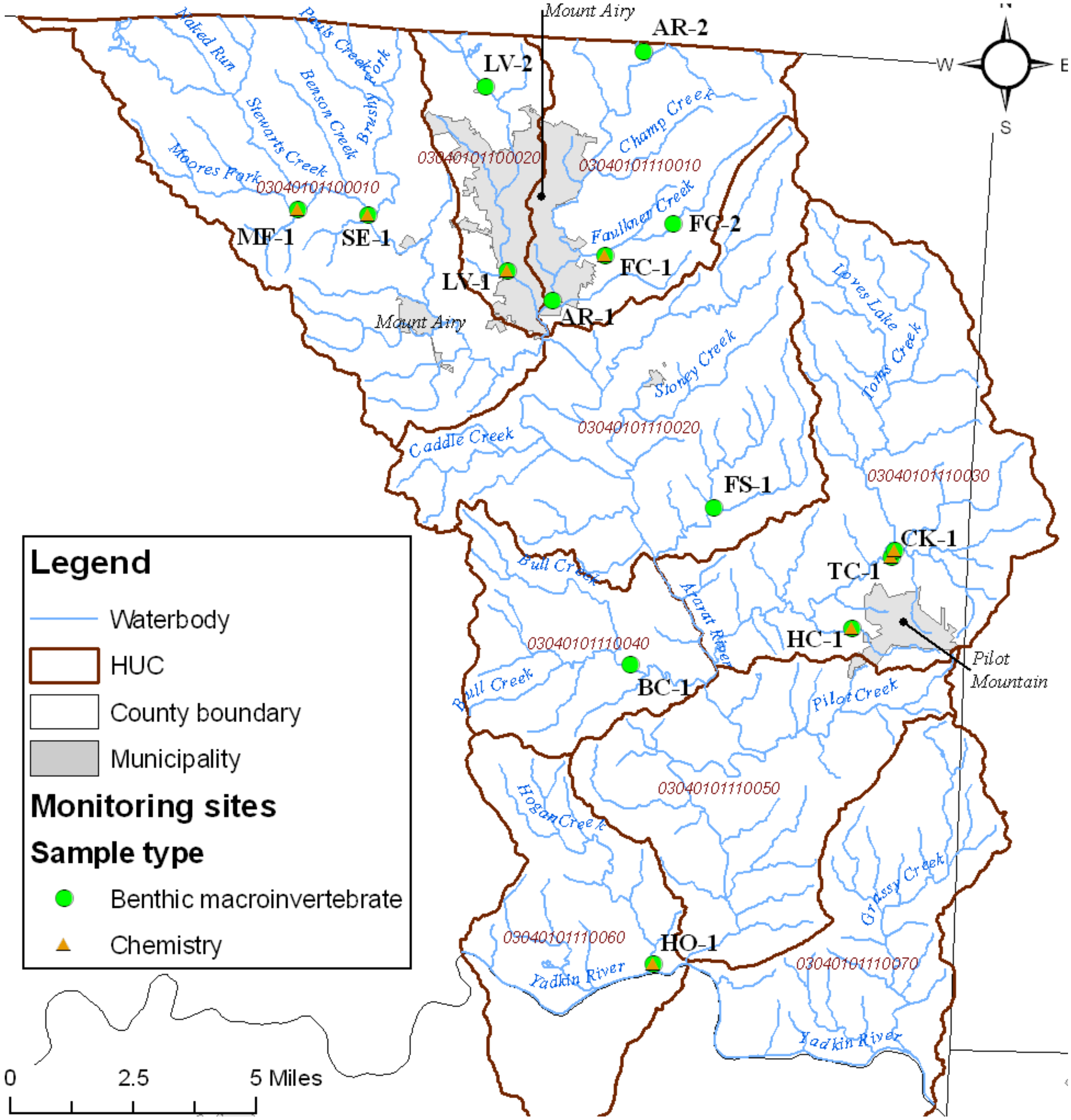


Figure 4. NCDWQ water quality monitoring locations

.

Table 1. NCDWQ WAT and BAU water quality monitoring locations and descriptions.

WAT Code	Monitoring Location[1]	EcoEngineering Subwatershed Category (Code)[2]	Drainage Area (sq. mi.)	Latitude (decimal degrees)	Longitude (decimal degrees)	Chemistry-Baseflow	Chemistry-Stormflow	Benthos and Habitat	Stream Corridor Reconnaissance
SE-1	1. Stewarts Creek at NC 89	Ag BMP and Restoration (ST-2)	63.8	36.5042	-80.6678	●		●	
AR-2	2. Ararat River at NC 104 (US)	Ag BMP and Restoration (NA-1)	35.8	36.5537	-80.5687			●	
CK-1	3. Chinquapin Creek at SR 1830	Ag BMP and Restoration (CH-1)	9.4	36.4080	-80.4742	●		●	
HO-1	4. Hogan Creek at SR 2081	Ag BMP and Restoration (HG-2)	8.6	36.2855	-80.5599	●		●	
MF-1	5. Moores Fork at SR 1620	Ag BMP and Restoration (ST-3)	4.5	36.5055	-80.6934	●		●	
LV-1	6. Lovills Creek at SR 1371 (DS)	Stormwater BMP (LV-2)	35.0	36.4885	-80.6169	●	●	●	●
LV-2	7. Lovills Creek at SR 1700 (US)	Stormwater BMP (LV-1)	26.8	36.5425	-80.6258			●	
HC-1	8. Heatherly Creek at NC 52	Stormwater BMP (TC-1)	1.7	36.3850	-80.4893	●		●	●
AR-1	9. Ararat River at US 52 (DS)	(NA-4)	72.2	36.4799	-80.6003			●	
TC-1	10. Toms Creek at SR 1830	(TC-4)	18.0	36.4062	-80.4753	●	●	●	
BC-1	11. Bull Creek at 2038	(BL-3)	11.0	36.3733	-80.5699			●	
FS-1	12. Flat Shoal Creek at SR 2018 (Longhill Road)	(FS-1)	7.1	36.4198	-80.5404			●	
FC-1	13. Faulkner Creek at SR 1756 (DS)	(NA-3)	5.1	36.4936	-80.5812	●		●	
FC-2	14. Faulkner Creek at SR 1742 (US)	(NA-2)	2.7	36.5032	-80.5567			●	

[1] Numbers refer to the list of sites on pages 18-21. The list provides the reasons why the site was selected for sampling. Notes: Where two monitoring locations were established in one stream the downstream location was coded (DS); upstream location (US). .

[2]Subwatersheds were prioritized by EcoEngineering by the likelihood of need for a specific management category. See text for prioritization methods and Figure 3.

Description of Monitoring Sites

The list below provides a brief description of the monitoring locations and the reasoning behind each selection. This list includes all 14 sites selected for benthic macroinvertebrate sampling and the subset of eight sites selected for chemical monitoring. All locations are classified as class C waters unless otherwise noted. The local watershed codes provided represent the last six digits of the 14 digit Hydrologic Unit (HU). The first eight digits (the USGS Cataloging Unit) for all subwatersheds are the same -- 03040101. Codes within parentheses (such as MF-1) were codes used by WAT as monitoring site location identifiers on Figure 4 and in Table 1.

Five monitoring locations were within subwatersheds prioritized for **stream restoration and agricultural BMPs**. A breakdown of major land uses for each subwatershed along with drainage areas (square miles, in parenthesis) are provided in Figure 5.

Land use categories are from the National Land Cover Database 2001 obtained from the Multi-resolution Land Characteristics Consortium website (MRLC, 2008). An important point to note is that each subwatershed consists of a mixture of land uses. No single land use dominates any of the subwatersheds except for Faulkner Creek at SR 1742, FC-2 which is mostly forested (76 %). Subwatersheds where the evidence suggests that land use is a major factor affecting watershed functions are presented in the Discussion section.

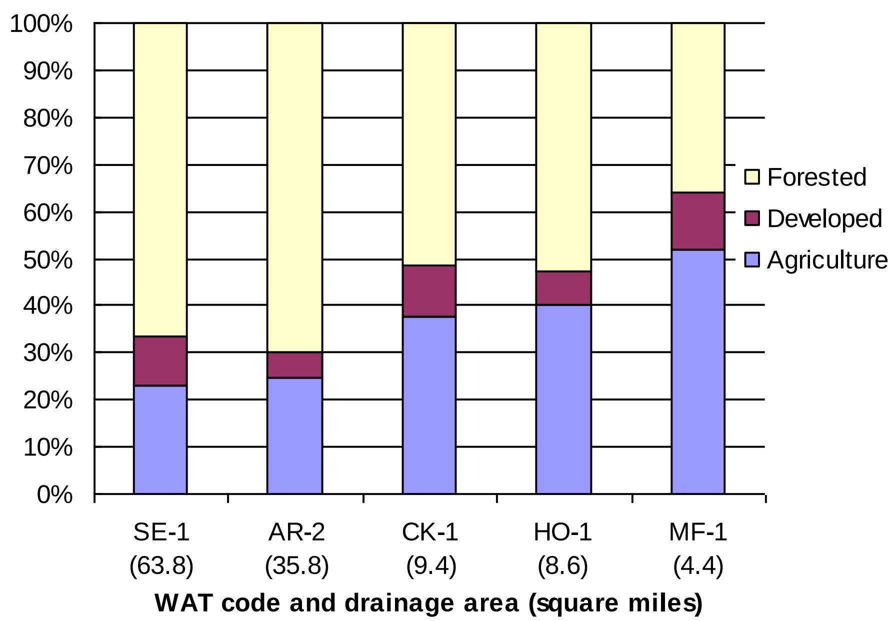


Figure 5. Land uses in subwatershed prioritized for stream restoration and agricultural BMPs.

1. Stewarts Creek at NC 89 (SE-1). Stewarts Creek is a tributary to the Ararat River and was selected for **both chemical and benthic monitoring** because it was one of the largest subwatersheds in the project and there were previous benthic ratings available for comparison purposes. In 2002, the benthic rating was Good-Fair. Upstream portions of this stream have a supplemental classification of Trout waters; downstream portions are assigned WS-IV primary classification i.e., water supply for Mount Airy. It was located in the ST-2 subwatershed delineated by EcoEngineering. Local watershed code – 100010.

2. Ararat River at NC 104 (AR-2). This site is approximately 8 miles upstream of the Ararat River at US 52 (AR-1) monitoring site and roughly 1000 feet from the Virginia border. It was chosen for **benthic monitoring** so that we could compare these data with data from the downstream site which is influenced more by development associated with Mount Airy. Previous benthic and data were also available. In 2006 the benthic rating was Good. The Fish rating in 2006 was Excellent. Primary classification is WS- IV with a secondary classification of Trout waters. The majority of the watershed is located in Virginia. It was in the NA-1 subwatershed delineated by EcoEngineering. Local watershed code – 110010.

3. Chinquapin Creek at SR 1830 (CK-1). This stream is a tributary to Toms Creek. This site was selected for **both chemical and benthic monitoring** to provide additional data from a HQW subwatershed for comparison purposes and because it had one of the lowest nitrite+nitrate nitrogen levels among rapid screening locations (0.18 mg/L). Like Toms Creek it has both WS-II and HQW classifications. It was in the CH-1 subwatershed delineated by EcoEngineering. Local watershed code – 110030.

4. Hogan Creek at SR 2081 (HO-1). This site, a tributary to the Yadkin River near Siloam at the most southern portion of the planning area, was lacking any kind of water quality data. It was selected for both **chemical and benthic monitoring** to represent water quality in this portion of the LWP area for comparison with other subwatersheds. Also, the United States Geologic Survey (USGS) completed a recent water quality study in Hogan Creek upstream of this location (unavailable as of this writing) that could be useful for future comparisons. It was in the HG-2 subwatershed delineated by EcoEngineering. Local watershed code – 110060.

5. Moores Fork at SR 1620 (MF-1). This site is a tributary to Stewarts Creek near NC89. Its primary classification is WS-IV. It was selected for **both chemical and benthic monitoring** because stressors (livestock in the stream and degraded riparian zone) were observed during windshield surveys. No previous benthic data were available. This site also had the highest nitrite+nitrate and total phosphorus levels among rapid screening locations. It was in the ST-3 subwatershed delineated by EcoEngineering. Local subwatershed code – 100010.

Three monitoring locations (numbered 6 through 8 below) were within subwatersheds prioritized for **stormwater BMPs**. A breakdown of major land uses for each subwatershed along with drainage areas (square miles, in parenthesis) are provided in Figure 6.

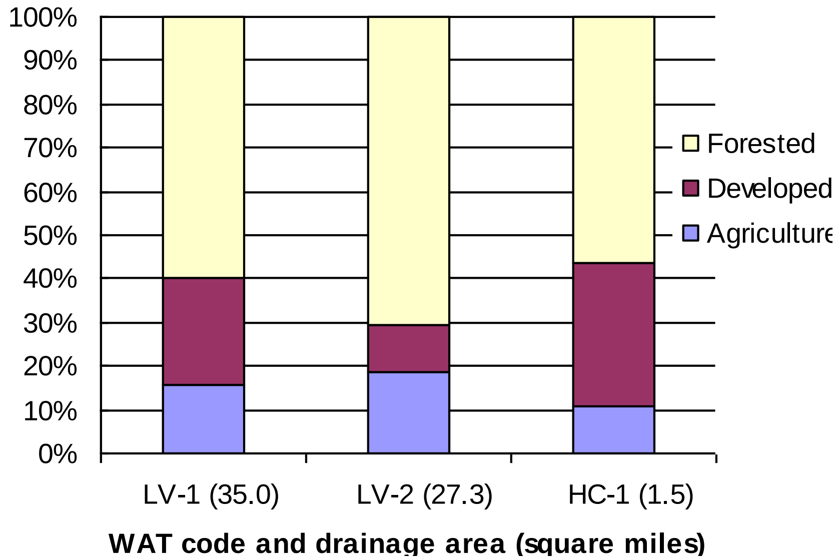


Figure 6. Land uses for subwatersheds prioritized for stormwater BMPs.

6. Lovills Creek at SR 1371 (LV-1). This monitoring site was located in the Town of Mount Airy at the start of a Greenway trail along the stream near US 52. Primary classification is WS-IV water supply for Mount Airy. The stream was selected for **chemical, benthic and stream corridor assessments** to gain a better understanding as to the causes and sources of biological impairment and make recommendations for potential BMPs. This segment was reported as impaired in the 2006 303(d) list. In 2006 the benthic rating was Fair. The fish rating was Good in 2006. It was in the LV-2 subwatershed delineated by EcoEngineering. Local watershed code – 100020.

7. Lovills Creek at SR 1700 (LV-2). This location is roughly 4 miles upstream of Lovills Creek at SR 1371 (LV-1). It was selected for **benthic monitoring** because it is upstream of the urban influences of Mount Airy and previous benthic ratings were available. In 2006 the benthic rating was Good-Fair. Primary classification is WS-IV water supply for Mount Airy. It was in the LV-1 subwatershed delineated by EcoEngineering. Local watershed code – 100020.

8. Heatherly Creek at US 52 (HC-1). This stream drains most of the Town of Pilot Mountain and had the least drainage area of all subwatersheds monitored. This site was selected for **benthic, chemical and stream corridor assessments** to gain a better understanding as to the causes and sources of biological impairment and to make recommendations for potential BMPs. It was reported as impaired on the 2006 303(d) list. The benthic rating in 2006 was Not Rated. It also had the highest specific conductance levels among rapid screening locations (88 µS/cm). It was in the TC-6 subwatershed delineated by EcoEngineering. Local watershed code – 110030.

Six monitoring locations (numbered 9 through 14 below) were within subwatersheds that were not prioritized for reasons explained above. In essence, we were not limited to monitoring only priority subwatersheds because non priority subwatersheds could also contain good candidates for preservation, restoration or BMPs. A breakdown of major land uses for each subwatershed along with drainage areas (square miles, in parenthesis) are provided in Figure 7.

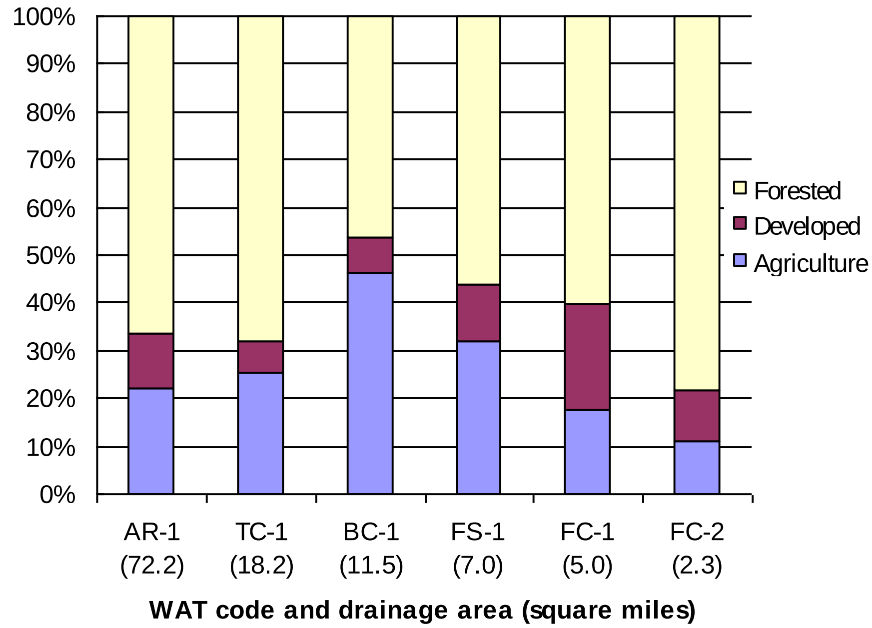


Figure 7. Land uses for other monitored subwatersheds.

9. Ararat River at US 52 (AR-1). This site is located in the most southern portion of Mount Airy's urban drainage area and upstream of the confluence with Lovills Creek. It was selected for **benthic monitoring** in order to assess the affects of urban drainage compared with more rural land use associated with the upstream location and to avoid (monitor upstream of) Mount Airy's wastewater discharge. No previous benthic data were available for this location. Field readings, turbidity and fecal coliform data collected as part of NCDWQ's ambient monitoring program were available. It had the largest drainage area of all the screening sites in the planning area, much of which is in Virginia. Primary classification upstream of this point is WS-IV water supply for Mount Airy. It was in the NA-4 subwatershed delineated by EcoEngineering. Local watershed code – 110010.

10. Toms Creek at SR 1830 (TC-1). This site is located north of Pilot Mountain and drains a mostly forested area. It was chosen for **both chemical and benthic monitoring** to provide reference water quality data. It had one of the lowest nitrite+nitrate nitrogen levels among rapid screening locations (0.16 mg/L). The primary classification is WS-II

with a supplemental classification of high quality waters (HQW). It was in the TC-4 subwatershed delineated by EcoEngineering. Local watershed code – 110030.

11. Bull Creek at SR 2038 (BC-1). This site is a tributary to the Ararat River near NC 268. It was chosen for **benthic monitoring** only. This site was selected to help characterize water quality and habitat conditions in the southwest area of the LWP area where no previously collected data were available. It was in the BL-3 subwatershed delineated by EcoEngineering. Local watershed code – 110040.

12. Flat Shoals Creek at SR 2018 (FS-1). This stream is a tributary to the Ararat River located in the center of the LWP area. This site was chosen for **benthic monitoring** because previous benthic data were available and it would help characterize water quality and habitat conditions in the central portion of the LWP area. In 2006 the benthic rating roughly 2 miles downstream from this location was Good-Fair. It was in the FS-1 subwatershed delineated by EcoEngineering. Local watershed code – 110020.

13. Faulkner Creek at SR 1756 (FC-1). This site is a tributary to the Ararat River in the northeast portion of the planning area and the most downstream location of two in this stream. This site and the upstream location (described below) were chosen for **both chemical and benthic monitoring** in order gain a better understanding of why there was a difference in biological ratings between the two locations, as reported in previous benthic surveys in 2006 (Good-Fair vs. Not Impaired). Benthic reports indicated more pollution tolerant species here than in the upstream location (EPTBI 4.79 vs. 2.89). It was in the NA-3 subwatershed delineated by EcoEngineering. Local watershed code – 110010.

14. Faulkner Creek at SR 1742 (FC-2). This site is located approximately 1.5 miles upstream of Faulkner Creek at SR 1756 (FC-1). It was selected for **benthic monitoring** for the same reasons listed for site FC-1 above. It was in the NA-3 subwatershed delineated by EcoEngineering. Local watershed code – 110010.

Methods

Chemical and Physical Monitoring and Analysis

Field measurements included water temperature (°C), dissolved oxygen (mg/L and % saturation), specific conductance (µS/cm at 25°C), and pH (S.U.). Temperature, oxygen, and specific conductance were measured with a YSI 85 meter, and a Fisher Accumet 61 meter was used for pH. All measurements were made *in situ* in a representative point of the channel that was well-mixed and flowing, generally at or near the thalweg. Meter calibrations and measurements were performed in accordance with the NCDWQ Standard Operating Procedures (SOP) (NCDWQ, 2006b).

Samples for chemical analysis included nutrients (nitrite+nitrate nitrogen, ammonia nitrogen, total Kjeldahl nitrogen and total phosphorus) total suspended residue, turbidity, metals (aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, potassium, sodium and zinc), sulfate and chlorides. Samples were collected for fecal coliform bacteria as well. A detailed parameter list along with respective analytical methods and reporting limits (Practical Quantitation Limit, or PQL) are provided in Table 10 of the Appendix. All samples were collected in accordance with NCDWQ's SOP and were handled, preserved, and analyzed in accordance with NCDWQ Laboratory Section requirements outlined in their sample submission guidance and quality assurance manual (NCDWQ, 2005). All samples were collected as grab samples by direct fill of sample bottles by immersion.

Samples were taken during base flow conditions, defined as >48 hours since the last measurable rain event or during storm events. Base flow chemistry sampling began in October 2008 and continued on a monthly basis through December 2009 in eight locations (Table 1). Heatherly and Lovills Creeks were sampled twice per month. Originally, the plan was to collect samples through March 2009 but due to a reduction in expected mitigation needs by the Department of Transportation and budgetary constraints, watershed planning efforts and water quality monitoring efforts were scaled back; therefore, baseflow sampling concluded in December 2009. Heatherly and Lovills Creeks were sampled four times. The remaining sites were sampled on three occasions. One storm event was monitored on January 6, 2009 in Lovills Creek at SR 1371 (LV-1) and Toms Creek at SR 1830 (TC-1).

Results of all laboratory analyses for each location are provided in the Appendix.

Biological Monitoring

Sampling, identification, and interpretation of results for benthic macroinvertebrate communities were performed by NCDWQ Biological Assessment Unit (BAU) biologists with support from WAT staff members in accordance with BAU Standard Operating Procedures For Benthic Macroinvertebrates (NCDWQ, 2006c). Sites were sampled by either Full Scale, Qual4 or Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) or EPT methods. The methods are based on the number and type of benthic habitats sampled.

For biological communities, NCDWQ has developed systems for rating streams based on the community structure found. The details of these biotic indices are described fully in the BAU SOPs (NCDWQ, 2006c). In summary, water quality ratings or bioclassifications are based on a value that is derived from the pollution tolerances of the number of each taxon found in the sample based on regions of the state and is referred to as the North Carolina Biotic Index (NC BI). Sites for this project which are within the Northern Inner Piedmont ecoregion were assigned bioclassifications using Mountain criteria. The more tolerant to macroinvertebrate community is to pollutants, the **higher** the tolerance score will be. This score is combined with the EPT taxa richness (number of different species) scores to produce a final bioclassification. Final bioclassifications of streams include Poor, Fair, Good-Fair, Good, and Excellent, though small watersheds (<3 sq. mi.) may be rated Not Impaired or Not Rated. The EPT Biotic Index (EPT BI) is calculated from tolerance values use in the NC BI but is only determined for EPT species. It is determined to assist with water quality interpretations and is not used to determine the final bioclassification rating.

Benthic sampling was conducted in 14 locations during a four-day period during the week ending on September 20, 2008. BAU's report was provided to EEP in February 2009 (NCDWQ, 2008d).

Habitat Assessments

Habitat assessments were performed using the standard BAU form (Rev. 6) for the Piedmont/Mountains included in the Benthic Macroinvertebrate SOP (NCDWQ, 2006c). Assessments were made concurrently with benthos sampling by BAU staff.

Stream Corridor Reconnaissance

The methodology use to conduct stream corridor assessments consisted of walking along the stream channel and riparian zone recording observations and measurements of various stream channel and riparian zone attributes and completing BAU's Piedmont/Mountain habitat assessment form. The tasks included those listed below. For this project, WAT staff walked approximately five miles of Heatherly and Lovills Creeks over a 3-day period in February 2009 to identify stressors that may be contributing to stream impairment and to identify locations for stormwater BMPs.

- Observe and rate overall channel structure, noting specific areas of sediment deposition, severe bank erosion, evidence of channelization;
- Measure specific conductance;
- Observe overall riparian area condition and the nature of surrounding land use;
- Identify wastewater discharge pipes, stormwater outfalls, other piped inputs or withdrawals, and tributary inflows;
- Observe water quality conditions (odors, surface films, low flows, etc);
- Note specific areas where pollutants are or may be entering the stream (livestock access areas, dump sites, land clearing adjacent to the stream, etc);
- Identify specific areas that may be candidates for BMPs;
- Provide digital photo documentation of key features; and,
- Complete habitat assessments using BAU's Piedmont/Mountains form (Rev 6). The length of channel evaluated and scored was based on the variability of conditions along each segment evaluated.

Quality Assurance/Quality Control

In addition to field meter calibration procedures and sample collection protocols described above in the chemical and physical monitoring section, field blanks and duplicate samples were collected at one location in base flow and storm conditions and analyzed for the same parameters listed above.

Field blanks test field sampling/handling techniques to check if stream samples have been inadvertently contaminated by the sampling/handling procedure. Duplicate samples test laboratory precision. Field blanks consist of contaminant free distilled water that is transported to the field and used to fill sample containers identical to those used to collect stream samples. From then on field blanks are treated as actual stream samples, shipped to the lab and analyzed for the same parameters as the stream sample. Duplicate samples are those that are collected along with stream samples at a monitoring location so that identical samples are collected at the same time and place. Like field blanks, they are handled and treated as actual stream samples and analyzed for the same parameters as its twin.

Quality control and assurance practices followed by BAU's biologists are described in Standard Operating Procedures for Benthic Macroinvertebrates (NCDWQ, 2006c).

North Carolina Water Quality Standards, Classifications, Project Benchmarks

Water quality classifications are important, since water quality standards, and regulatory requirements relative to development, forestry and agriculture activities, and new or expanding wastewater treatment facilities designed to protect water quality may be different for different stream classes. For example, bodies of water with supplemental water quality classifications for trout (i.e. Tr waters) have more stringent standards for dissolved oxygen, turbidity and temperature. The Appendix has additional information relative to North Carolina's stream classifications and water quality standards.

Data collected for this project will be compared with North Carolina water quality standards and project benchmarks. A project benchmark is the grand mean of various monitored chemical and physical parameters and is portrayed in the figures below and in the Appendix. The grand mean is the mean average of all observations (for a particular parameter) and locations and thusly provides evidence of average water quality conditions across the planning area. For this report, the grand mean will be considered a benchmark for subwatershed comparison purposes. That is, any observation above the grand mean will be interpreted as higher than average for this planning area; alternatively, any observation below the grand mean will be interpreted as lower than average.

Chemical and Physical Water Quality Results

This section discusses notable chemical and physical data collected from each monitoring location. These data will be used to compare water quality conditions between subwatersheds and to identify sources of contaminants. These data are also indicators of potential stressors to water quality and the benthic community (e.g. low dissolved oxygen, etc.) as discussed in the Discussion section that follows.

In the figures below that portray results, the grand mean is the mean average of all observations and locations. For this report, the grand mean will be considered a benchmark for subwatershed comparison purposes. That is, any observation above the grand mean will be interpreted as higher than average; alternatively, any observation below the grand mean will be interpreted as lower than average.

Base Flow

Field Measurements

Field readings of water temperature, pH, dissolved oxygen and specific conductance were within acceptable values (unless otherwise noted) and met North Carolina water quality standards where applicable. These data are provided in the Laboratory Results section in the Appendix.

Specific conductance data presented in Figure 8 below were individual measurements collected from each location. The number of measurements (n) varied by type of monitoring. Reconnaissance sampling was conducted in March, 2008 (n = 1 or 2). Baseflow sampling occurred during October – December, 2008 (n = 3 or 4). Storm event monitoring was in January, 2009 (n = 1).

North Carolina water quality standards do not exist for specific conductance. However, it is useful as a general measure of stream water quality. Each stream tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison purposes. Significant changes in conductivity could then be an indicator of a discharge or other source of pollution or chemical stressors or the result of precipitation.

We did not observe a wide range of specific conductance readings for each individual location during the monitoring period. However, subwatersheds associated with the **highest percentage of developed land** also had elevated specific conductance measurements (Heatherly Creek at 32%; and the downstream locations in Lovills and Faulkner Creeks at 24% and 21% respectively). The Moores Fork subwatershed which is 12% developed also had comparatively elevated measurements (Figure 8). The four remaining locations with favorable specific conductance measurements (Hogan, Chinquapin, Toms and Stewarts Creeks) also had the **lowest percentage of developed land** ranging from 6% to 10%.

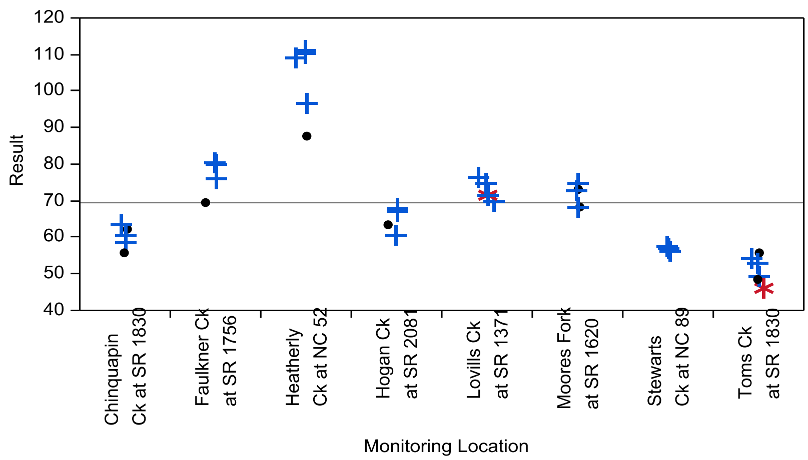


Figure 8. Specific Conductance (µS/cm at 25^o C).

Symbol definitions. Data from reconnaissance are (black dots ●); from base flow monitoring (blue cross +) and from storm conditions (n = 1) (red *). The solid gray line is the grand mean. Reconnaissance monitoring was in March, 2008; baseflow monitoring occurred during October through December, 2008; and, storm event monitoring occurred in January, 2009.

Sodium and Chloride

Sodium and chloride (Figures 9 and 10) are indicators of leaking sewer lines, failing septic systems, fertilizers and road salt stockpiles which can degrade water quality and benthic communities. They enter streams through direct discharge, runoff and groundwater discharge.

Sodium and chloride were elevated in two of the mostly developed subwatersheds (Heatherly and Faulkner Creeks). Elevated concentrations were not observed in Lovills Creek most likely because of the relatively larger drainage area upstream in Virginia (and less developed) that concomitantly results in larger flow and dilution.

Somewhat elevated concentrations of chloride were observed in Moores Fork. Since close to 50% of the land use in the Moores Fork subwatershed is agriculture, the source may be fertilizers.

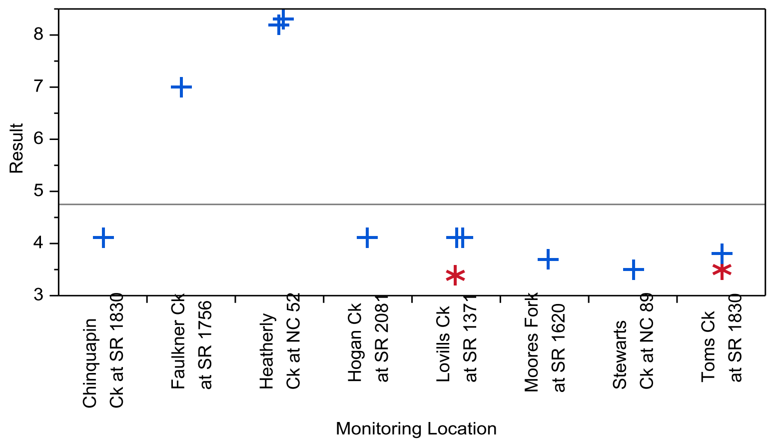


Figure 9. Sodium (mg/L).

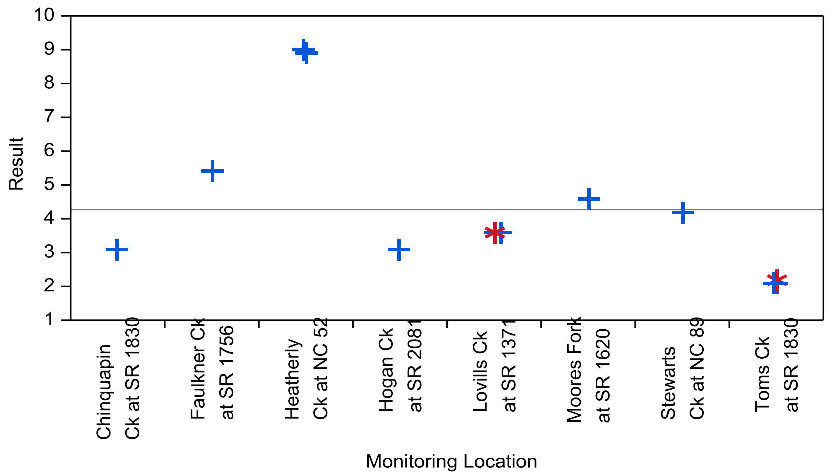


Figure 10. Chloride (mg/L).
Explanations for symbols are provided in Figure 8.

Nutrients

Nutrients (nitrogen in the form of nitrite+nitrate, ammonia and total Kjeldahl nitrogen [which is organic forms of nitrogen plus ammonia nitrogen] and total phosphorus) are indicators of leaking sewer lines, failing septic systems, fertilizers, livestock waste, degraded riparian zones and sediment. Elevated levels alone and in combination with a degraded riparian zone (lack of shading) can contribute to increased algal growth that can in turn decrease dissolved oxygen placing stress on aquatic organisms. The North Carolina water quality standard (for water supplies) for nitrate nitrogen is 10 mg/L which is a public health concern related to methemoglobinemia.

Overall, nutrient levels suggested that an enrichment problem does not exist throughout the watershed planning area. Of the three forms of nitrogen, nitrite+nitrate nitrogen was more frequently observed at elevated levels (Figure 11) but well below the North Carolina water supply standard.

All observations in Moores Fork at SR 1620 for nitrite+nitrate nitrogen were elevated. It is a mostly agricultural subwatershed. Degraded vegetated buffers were observed along upstream segments as well as cattle in the stream. Also, a dairy operation is located in the headwaters.

All observations for nitrite+nitrate nitrogen in Chinquapin, Toms and Heatherly Creeks were favorable or below the grand mean. Toms and Chinquapin Creeks drain mostly forested subwatersheds and Heatherly Creek's subwatershed is mostly developed but has a long segment (about 0.8 miles upstream of the monitoring location) with an intact, mature hardwood forest riparian zone along both sides of the stream. More details related to Heatherly Creek and its subwatershed will be discussed in the Stream Corridor Reconnaissance and Discussion sections that follow.

The Hogan Creek subwatershed, which is mostly forested, also had favorable nitrite+nitrate nitrogen observations.

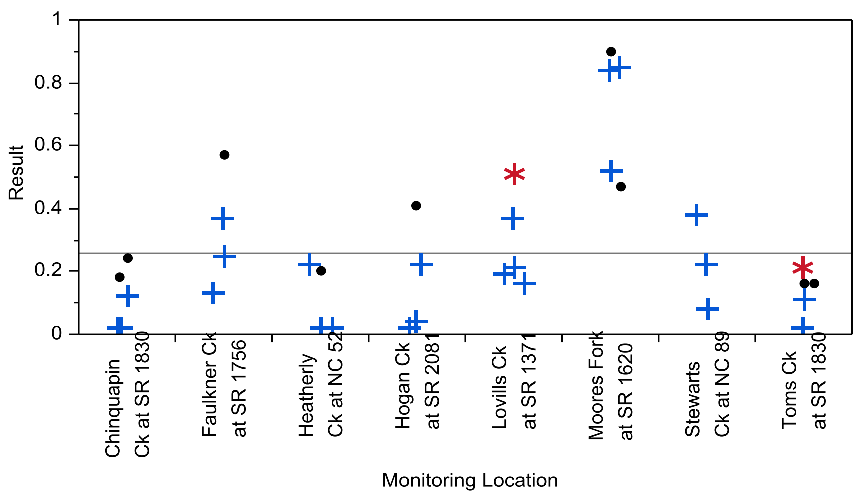


Figure 11. Nitrite+nitrate nitrogen (mg/L).
Explanations for symbols are provided in Figure 7.

Almost all observations for ammonia, total Kjeldahl nitrogen (TKN) and total phosphorus (TP) were observed below the detection limit for all locations. On one occasion, ammonia and TKN concentrations in Stewarts Creek occurred at levels above detection limits (see Appendix). North Surry High School, a minor discharger located about 4000 feet upstream of the monitoring location may be the source.

Total phosphorus (TP) levels were below detection limits for all locations except for one occasion in Moores Fork which can be explained by the extremely turbid conditions during the December base flow monitoring event described in the Additional Observations section below.

Metals

Metals are potentially toxic to aquatic organisms. Toxic effects on organisms are complex and may vary by a number of factors some of which include exposure pathway, chemical form of metal (total vs dissolved), exposure length (acute vs chronic), frequency of exposure and hardness of water. These complex and likely interacting factors create difficulties with data interpretation especially with a limited number of results to evaluate as was the case for this project.

The reason we included metal parameters in the monitoring plan for this project was to help characterized water quality among locations and subwatersheds and to identify sources. If the data indicated elevated concentrations near or above water quality standards, then additional samples were to be collected and also filtered to determine the dissolved fraction to aid with interpretation efforts relative to explaining the condition of aquatic organisms.

For the most part, metals were not detected above laboratory detection limits in any location except where noted below in the Additional Observations and Storm Event Monitoring sections below.

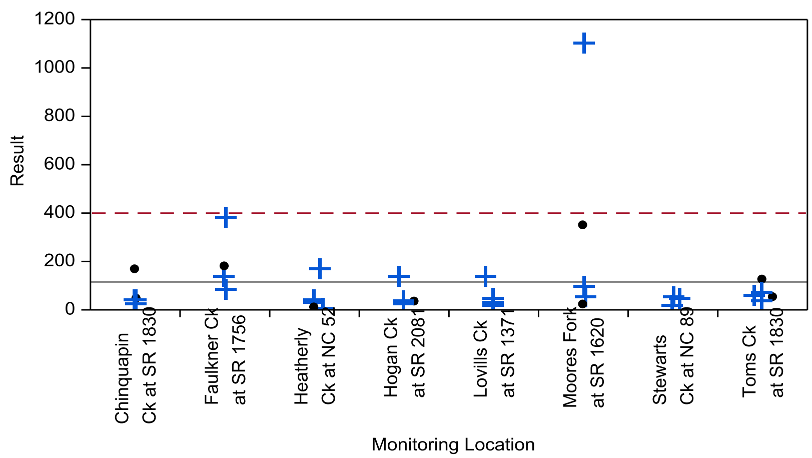


Figure 12. Fecal Coliform (cfu/100 ml)

Explanations for symbols are provided in Figure 8.
The red dashed line at 400 cfu/100ml represents an evaluation threshold.

Fecal Coliform Bacteria

Fecal coliform bacteria are indicators that other pathogenic organisms may be present which could impact human health. They are also indicators of leaking sewer lines, failing septic systems and livestock waste which could also contain human pathogens or other toxicants (if sewage was the source). Other sources of fecal coliform bacteria include wildlife and pets.

Fecal coliform counts were favorable in most subwatershed locations (Figure 12). The highest count (1100 cfu/100 mL) occurred on one occasion in Moores Fork at SR 1620 (MF-1). Data were not collected frequently enough to evaluate whether fecal coliform were exceeding water quality standards, as that determination would require five samples within a 30-day period. A horse pasture upstream of the monitoring location is a possible source.

Additional Observations

During baseflow monitoring in Moores Fork a front-end loader was working in the stream channel removing what was likely a beaver dam upstream of the sampling location (Photo 1). As a result, sediment was resuspended and stream was turbid. In addition to the usual baseflow parameters (nutrients, fecal coliform and residue) samples were also collected for copper, chromium, lead, iron, magnesium, manganese, potassium and zinc.

Photo 1. Turbid conditions in Moores Fork during December monitoring event due to a front end loader upstream working in the stream channel likely to remove a beaver dam.

Fecal coliform, nutrients and residue were elevated. Copper, iron, manganese and zinc were detected above water quality standards or action levels (see Appendix). It was likely that suspended sediment was the source for the metals since the samples were not filtered prior to preservation. Silt and clay sized particles possess cation exchange capacity (Miller and Donahue, 1990) which chemically bind with positively charged ions (cations) such as the metals listed above. Fecal coliform bacteria from a variety of sources can reside in stream sediments (USEPA, 2001).

Storm Event Monitoring

Storm event monitoring was conducted to compare water quality from a mostly developed subwatershed (Lovills Creek) with a mostly forested one (Toms Creek). Storm samples were collected for one event on January 6, 2009 from both locations. According to the USGS gage (site number 02113850) in the Ararat River, about an inch of rain fell prior to the time of sampling. It was not an intense storm but significant enough to affect some parameters described below (and portrayed in the Appendix) but it is difficult to make strong conclusions from one sampling event.

Residue and turbidity increased more in Toms Creek than in Lovills Creek (Figures 13 and 14). Turbidity in Toms Creek exceeded the water quality standard of 50 NTUs.

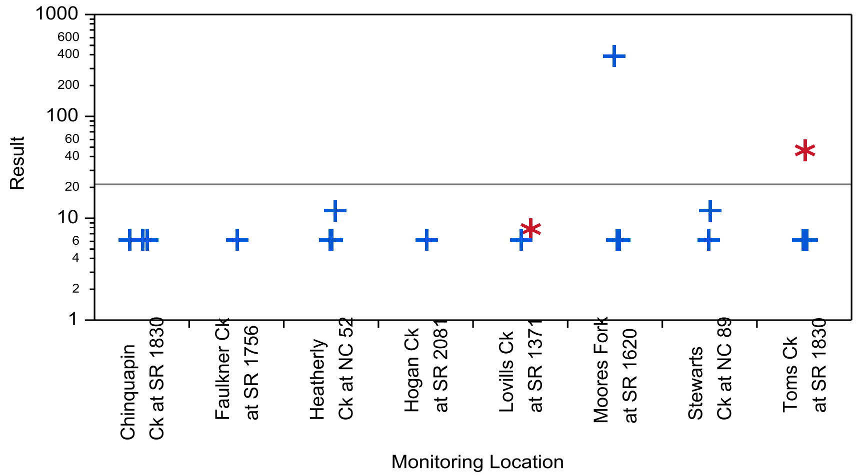


Figure 13. Suspended residue (total) data (mg/L).
Red asterisks (*) are storm event data.

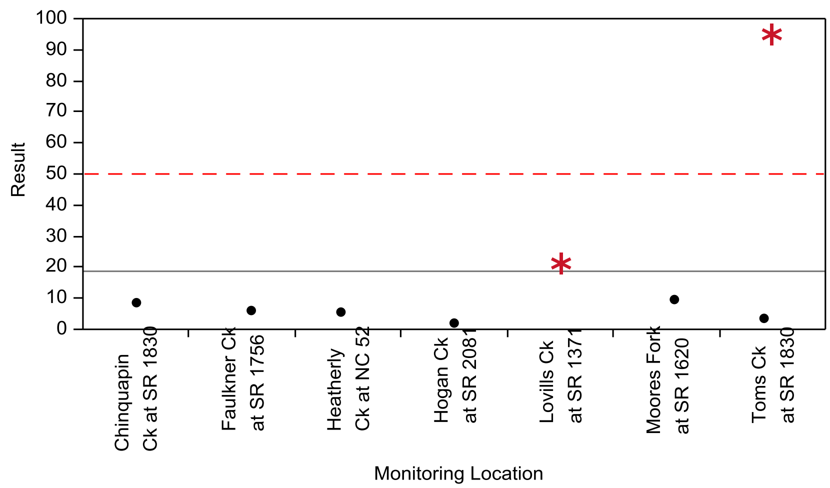


Figure 14. Turbidity (NTU)
Red dashed line (50 NTU) represents the water quality standard.
Red asterisks (*) are storm event data.

Sources for turbidity and residue in the Toms Creek subwatershed may include runoff from recent logging operations (observed in the subwatershed), plowed fields, road cuts, construction sites, stream bank erosion and bedload. It is likely that the storm event was not intense enough throughout the Lovills Creek subwatershed to observe a similar response in residue and turbidity.

Also of note was the slight increase in copper, zinc and sulfate in Lovills Creek but no change of these parameters in Toms Creek (see Appendix). This may be related to the mostly developed land use in the Lovills Creek subwatershed.

Metals are typically detected in more developed subwatersheds because of increased runoff due to more impervious cover that carry pollutants from parking lots and roads that may be accumulating these contaminants. Sources include tires, galvanized pipes, gutters, brake linings and pipes (CWP, 2003). Sources of sulfate include naturally occurring minerals in soil, rock formations and industrial emissions (Richardson and Vepraskas, 2001).

Benthic Macroinvertebrate Surveys

BAU provided a detailed benthic macroinvertebrate sampling report under separate cover (NCDWQ, 2008d). A brief narrative summarizing notable observations from the 2008 assessments is provided below in addition to a comparison with 2006 data making note of differences between years. A more detail interpretation of these data are provided in the Discussion section in terms of stressors that may be impacting benthic communities. In addition, below are tabulated summaries of benthic metric scores, bioclassification ratings and total habitat scores for September 2008 and 2006 (where available) in Tables 2 and 3 below. Table 8 in the Appendix provides additional historical benthic data prior to 2006 that were presented previously in the existing data summary.

Table 2. Selected benthic data and total habitat scores for BAU monitoring locations.

Map Codes		Monitoring Location	Sq. miles	Sample Type		EPT Taxa Richness		EPT BI		NC BI		Bio Class		Total Habitat Score	
WAT (Fig 4.)	**EcoEng. (Fig. 3)**														
		Sites with data from 2006 and 2008		2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008
SE-1	ST-2	Stewarts Creek at NC 89 *	63.8	FS	FS	29	26	4.16	4.61	5.26	5.40	G-F	G-F	--	66
AR-2	NA-1	Ararat River at NC 104	35.8	EPT	FS	29	26	3.88	4.42	--	5.51	G	G-F	79	82
LV-1	LV-2	Lovills Creek at SR 1371 (DS)	35.0	FS	FS	19	13	4.88	4.73	5.60	6.68	F	F	55	50
LV-2	LV-1	Lovills Creek at SR 1700 (US)	26.8	EPT	FS	23	25	4.46	4.29	--	5.42	G-F	G-F	76	53
FC-1	NA-3	Faulkner Creek at SR 1756 (DS)	5.1	EPT	FS	20	14	4.79	4.50	--	6.08	G-F	NR	67	58
FC-2	NA-2	Faulkner Creek at SR 1742 (US)	2.7	Q4	Q4	20	15	2.89	4.05	3.38	4.50	NI	NI	93	86
HC-1	TC-6	Heatherly Creek at NC 52	1.7	Q4	Q4	17	12	4.65	4.57	5.24	5.26	NR	NR	75	77
		Sites with data from 2008 only													
AR-1	NA-4	Ararat River at NC 52	72.2	--	FS	--	22	--	5.00	--	6.05	--	NR	--	82
TC-1	TC-4	Toms Creek at SR 1830	18.0	--	FS	--	18	--	4.57	--	5.26	--	NR	--	89
BC-1	BL-3	Bull Creek at SR 2038	11.0	--	FS	--	15	--	5.27	--	6.03	--	NR	--	71
CK-1	CH-1	Chinquapin Creek at SR 1830	9.4	--	FS	--	21	--	4.94	--	5.30	--	G-F	--	68
HO-1	HG-2	Hogan Creek at SR 2081	8.6	--	FS	--	27	--	4.39	--	5.17	--	G-F	--	84
FS-1	FS-1	Flat Shoals Creek at SR 2018	7.1	--	FS	--	20	--	4.86	--	5.37	--	G-F	--	79
MF-1	ST-3	Moores Fork at SR 1620	4.5	--	EPT	--	20	--	5.54	--	--	--	G-F	--	41
		Mean					20		4.73		5.56				70

Notes: * Data for Stewarts Creek at NC 89 under 2006 were from 2002. Under sample type, FS – Full Scale; EPT – EPT; Q4 – Qual 4 are the methods used to collect aquatic insects. Under Bio Class G – Good; F – Fair; NI – Not Impaired; NR – Not Rated. EPT BI is Biotic Index for Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) only. NC BI is the North Carolina Biotic Index based on tolerance value of each taxon collected including EPTs. See Appendix for details on methods and ratings used by BAU. DS – Downstream and US – Upstream refers to monitoring locations for streams with two location sites.

Benthic data comparisons in 2008 vs 2006

Seven of the fourteen sites had previous benthic data for which to compare. Of those seven, all locations but one (Lovills Creek at SR 1700, LV-2) decreased in EPT taxa richness values over 2006. For other locations, there were generally modest changes in both directions in terms of EPT Biotic Index (EPT BI) between years; some improved and some declined. The most notable changes in EPT BI tolerance values were observed in Faulkner Creek at 1742 (FC-2) which increased (indicating more pollution tolerant taxa) from 2.89 in 2006 to 4.05 in 2008. Other notable changes were for the most upstream location in the Ararat River at NC 104 (AR-2) and in Stewart Creek at NC 89 (SE-1) where both tolerance values increased (indicating more pollutant tolerant taxa) by almost 0.5 points.

North Carolina Biotic Index (NC BI) tolerance values for 2008 increased (indicating more pollution tolerant taxa) over 2006. Heatherly Creek at US 52 (HC-1) was the exception, maintaining almost the same NC BI in both years (5.24 and 5.26). Faulkner Creek at SR 1756 (FC-1) received the second highest NC BI score (6.08) in 2008 (NC BI data for 2006 were not available). Lovills Creek at SR 1371 (LV-1), which was reported as impaired in the 2006 303(d) report, received the worst NC BI score of 6.68 in 2008, a decline from the 2006 score (5.60).

In terms of ratings, none of the locations earned a bioclassification rating better than Good-Fair. Of note was Lovills Creek at SR 1371 (LV-1) which was rated Fair in 2008, in 2006 and for three previous assessments (see Table 8 in the Appendix for a summary of benthic ratings and data prior to 2006). Heatherly Creek at NC 52 (HC-1) was Not Rated in both years due to the small drainage size. The Ararat River at NC 104 (AR-2) was downgraded from Good in 2006 to Good-Fair in 2008. And Faulkner Creek at SR 1756 (FC-1) declined from Good-Fair to Not Rated.

2008 benthic data

The summary that follows is organized by the dominant land use category (developed, agricultural or forested) for a particular subwatershed monitored by BAU. BAU (NCDWQ, 2008d) stated that data interpretations were complicated by the on-going drought the region experienced in September during benthic sampling. Drought stress effects likely included a reduction of available aquatic habitat and a disruption of lifecycles. Low dissolved oxygen is can also be a symptom of drought, but this phenomenon was not observed in the Ararat watershed. Aquatic habitat details will be discussed in the next section. Table 11 in the Appendix provides more detailed benthic data as provided by BAU.

The following subwatersheds had the highest percent forested land use ranging from 63% to 76%.

- It was surprising that the benthic community in Toms Creek at SR 1830 (TC-1) was one of the most degraded. It is designated High Quality Water (HQW) and land use is mostly forested. The NC BI indicated Good-Fair conditions and was above average but EPT taxa richness counts were low (18) which would have resulted in a Fair bioclassification. Because of drought conditions that limited available habitat, it was rated Not Impaired. The total habitat score was the best among locations at 89.

- Of this group, Faulkner Creek at SR 1742 (FC-2) had the best NC BI (4.50) and EPT BI scores (4.05). It was rated Not Impaired. However, BAU noted that in may be under stress because of higher tolerance scores (over 2006 as mentioned above and below) and a decrease in the number of stonefly taxa collected between years. The total habitat score was 86.

- The upstream location in Lovills Creek at SR 1700 (LV-2) is located upstream of the urban influences associated with the Town of Mount Airy with almost all if its drainage in Virginia. Historically, BAU samples this location along with the downstream location (at SR 1371) for comparison purposes. Five monitoring events dating back to 1986 resulted in better ratings than the downstream location. In 2008, EPT richness counts were one of the highest at 25 the only site to increase in EPT taxa. No specific stressors were indicated by the benthic community. The site rated Good-Fair. The total habitat score was 53.

- Stewarts Creek at NC 89 (SE-1) also had one of the highest EPT richness counts at 26. It had similar EPT and NC BI scores as Lovills Creek at SR 1700 (LV-2) which were above average and also received a Good-Fair. The total habitat score was 66. The 2001 assessment resulted in a Fair rating but this was likely due to a coffer dam upstream that reduced habitat availability.

- BAU reported that historical sampling results in the Ararat River at NC 104 (AR-2) indicated a relatively stable community with little change in tolerance scores. EPT richness (26) in 2008 was identical to Stewarts Creek at NC 89 (SE-1) above. BAU also reported that only one stonefly taxa was collected in 2008 and that certain mayfly taxa were collected here but not in the downstream location. These mayfly taxa included *Hexagenia, Heptagenia marginalis, Maccaffertium ithaca, and Stenacron pallidum.* It was rated Good-Fair and the total habitat score was 82.

- The Ararat River at NC 52 (AR-1) is a subwatershed that fell within the mostly forested land use category but is likely influenced by nearby developed land use associated with Mount Airy. Certain mayfly taxa were not collected here but were identified in the upstream location. The NC BI was one of the worst (6.05) and could have been rated Fair, but due to low flows it was Not Rated. The total habitat score was 82.

<u>The following subwatersheds had the highest percent developed land use ranging from 21% to 32%.</u>

- Close to three miles of the Lovills Creek mainstem upstream of the monitoring location at SR 1371 (LV-1) and its tributaries are surrounded by development associated with Mount Airy. The channel along this segment was designed as an engineered flood control channel. A greenway trail parallels most of the three mile segment as well. It was rated Fair in 2008 and on four previous years dating back to 1986. It was listed as impaired on the 2006 303(d) list. It declined by six EPT taxa over 2006 (19 to 13). The NC BI score was the highest (more pollution tolerant taxa) among locations and the total habitat score was one of the lowest at 50. It was thought that an industrial discharge present prior to 2001 was contributing to degraded water quality but conditions have not improved following plant closure and discharge removal in 2001.

- Heatherly Creek at NC 52 (HC-1) has been sampled six times dating back to 1987 with mostly degraded conditions reported. In 1994, no EPT taxa were collected. Pilot Mountain's treated wastewater discharge was relocated to the Ararat River in 1996. Some improvement was observed in subsequent years (see Table 7 in the Appendix). The small drainage area is (1.7 sq. mi.) prevents a formal rating. EPT taxa in 2008 (12) was the lowest among locations and NC BI (5.26) was identical to Toms Creek and slightly better than the average NC BI value of 5.56. The total habitat score was 77.

- Faulkner Creek at SR 1756 (FC-1) was previously sampled in 2002 and 2006 along with the upstream location (presented above for the mostly forested subwatersheds). In 2006, BAU was concerned about the EPT BI disparity between locations in that they suspected the presence of water quality stressors between locations. BAU also reported that the major difference in 2008 (for this downstream location) was that no stoneflies were collected and there was a shift to a more tolerant mayfly community. And, EPT taxa counts were among the lowest (14) and its NC BI value (6.08) was among the highest. This site would have been rated Fair but because of low flows and beaver alterations of habitat it was Not Rated. The total habitat score was 58.

<u>The following subwatersheds had the highest percent agricultural land use ranging from 30% to 50%.</u>

- The most favorable benthic community was observed in Hogan Creek at SR 2081 (HO-1). It received a Good-Fair rating, the second best NC BI score (5.17) and the highest EPT taxa richness (27). Its total habitat score was among the highest at 84. Also noted by BAU was the presence of three taxa (two midges and one mayfly) that were absent from all other locations suggesting that this location supported a more diverse community. It was among the three subwatersheds with the lowest percent developed land use (close to 6%).

- Chinquapin Creek at SR 1830 (CK-1) is designated as HQW and its subwatershed is located adjacent to the Toms Creek subwatershed. It was given a Good-Fair rating. EPT taxa richness was 21 and the NC BI was better than average at 5.30. Three more EPT taxa were collected here than in Toms Creek but EPT and NC BI scores were similar. The total habitat score was 68. No beaver impacts were observed.

- Flat Shoals Creek at SR 2018 (FS-1) had an average EPT taxa richness count of 20, a NC BI of 5.37 (above average) and received a Good-Fair rating. This site was unique in that a taxon of caddisfly (*Rhyacophila torva*) was collected here that was not observed in any other location. The total habitat score was 79.

- Bull Creek at SR 2038 (BC-1) was below average for all metrics and had one of the highest NC BI scores (6.03). It could have been rated Fair but due to low flows the site was Not Rated. The total habitat score was about average at 71. BAU reported that fencing to prevent cattle access was observed.

- The Moores Fork at SR 1620 (MF-1) subwatershed was mostly agricultural but it also contained almost 12% developed land use. EPT richness was average at 20 but the EPT BI of 5.93 was higher than average indicating a more tolerant community. The NC BI was not calculated because only EPTs were collected. It was given a Good-Fair rating. The total habitat was the worst among locations at 41.

Aquatic Habitat Assessments

The purpose of aquatic habitat assessments is to evaluate the quality of stream and riparian habitat that influences structure, function and therefore potential in terms of diversity of the aquatic community (USEPA, 1999). The homogenization of habitat structure by human intervention is considered one of the major stressors of aquatic systems (USEPA, 1999). Natural hydrologic variability, and high flows related to intense precipitation, move and sort sediment through cycles of erosion and deposition creating a variety of habitat conditions (including riffles, pools, bars, woody debris plugs, root mats and leaf packs) that help convey resistance and resilience to biotic communities and maintenance of diversity (Allan, 2004; Sedell et al., 1990).

Aquatic habitat assessments in addition to chemical and physical measurements of water quality can help to gain a clearer picture of reasons for the condition of fish and aquatic insect communities (USEPA, 1999). For example, if habitat potential is favorable and the diversity of aquatic communities is depressed compared with reference conditions then other water quality stressors may be responsible. Habitat conditions also provide evidence of watershed stressors and degraded watershed functions. Diverse communities exist in a range of conditions assuming other stressors do not interfere.

Metrics used by BAU to assess habitat quality for fish and benthic macroinvertebrates are based on key physical characteristics of the stream channel and surrounding riparian area along the stream. The assessment qualitatively evaluates reach scale (100 - 200 meters long) conditions of existing habitat structure (riffles, pools, leaf packs, root mats, sticks and logs, bottom substrate) along with those that have the potential to degrade habitat and water quality such as the condition of riparian vegetation and stream bank stability (i.e. increased sedimentation).

Key habitat attributes are assessed qualitatively and scored for a total habitat score of 100. Habitat ratings (good, fair, poor for example) have not been developed for habitat scores; although in general, higher total habitat scores indicate better habitat quality. Eight different sub-habitat components assessed are included in the list below. The maximum score possible for each sub-metric is shown in parentheses.

I. Channel modification (5) – assesses the evidence of dredging and/or channel alterations;
II. Instream habitat (20) –considers the percentage of a stream reach that is favorable for benthos colonization or fish cover. Type of cover assessed are rocks, macrophytes, sticks and leaf packs, snags and logs, and undercut banks or root mats;
III. Bottom substrate (15) – represents an assessment of the entire reach for the sizes of particles (gravel, cobble, etc.) composing the stream bottom. Embeddedness is only assessed at riffles;
IV. Pool variety (10) – assesses the presence/absence and frequency and sizes of pools;
V. Riffle habitats (16) – assesses length and width of riffles;
VI. Stream bank stability and vegetation (14) – assesses bank stability and types of riparian vegetation (wooded, mixed, grasses, etc.);
VII. Light penetration (10) – assesses whether the riparian vegetation (canopy) can block sunlight on the stream when the sun is directly above the stream; and,
VIII. Riparian vegetation zone width (10) – assesses width of riparian vegetation and whether there are breaks in the vegetation.

BAU (NCDWQ, 2008d) provided a detailed benthic macroinvertebrate sampling report under separate cover. A brief narrative summarizing notable observations is provided below. The Discussion section discusses these data in more detail in terms of causes and sources of habitat functional degradation and how habitat may in turn be affecting the condition of aquatic organisms.

In Table 3 below, habitat metrics are provided for 2008 and for 2006 (where available) for comparison purposes. Mean values are provided for 2008 to help assess conditions across the entire study area. The composition of bottom substrates is provided in Table 4 below for between site comparisons of silt, sand, gravel, etc. Monitoring location codes in the narrative are WAT codes.

Table 3. Selected habitat scores for BAU monitoring locations.

Map Codes WAT (Fig 4)	Map Codes EcoEng (Fig 3)	Location	Channel Modification (5)		Instream Habitat (20)		Bottom Substrate (15)		Pool Variety (10)		Riffle Habitats (16)		Bank Stability (14)		Shading (10)		Riparian Buffer (10)		Total Score (100)	
			2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006
		Sites with data from 2006 and 2008																		
LV-1	LV-2	Lovills Creek at SR 1371 (DS)	4	4	15	13	8	12	6	9	7	9	6	4	0	0	4	4	50	55
LV-2	LV-1	Lovills Creek at SR 1700 (US)	3	4	17	16	3	13	4	8	10	12	8	12	2	4	6	7	53	76
FC-1	NA-3	Faulkner Creek at SR 1756 (DS)	5	5	12	14	3	4	4	10	7	14	12	7	7	9	8	4	58	67
FC-2	NA-2	Faulkner Creek at SR 1742 (US)	5	5	19	19	15	14	4	9	16	15	12	12	10	9	5	10	86	93
HC-1	TC-6	Heatherly Creek at US 52	3	5	15	12	12	8	4	10	14	14	11	10	10	8	8	8	77	75
AR-2	NA-1	Ararat River at NC 104 (US)	5	4	20	16	14	14	4	5	10	13	14	12	9	10	6	5	82	79
		Sites with data from 2008 only																		
SE-1	ST-2	Stewarts Creek at NC 89	3	--	16	--	11	--	4	--	10	--	12	--	4	--	6	--	66	--
HO-1	HG-2	Hogan Creek at SR 2081	5	--	20	--	14	--	6	--	14	--	10	--	7	--	8	--	84	--
CK-1	CH-1	Chinquapin Creek at SR 1830	5	--	16	--	8	--	4	--	10	--	10	--	7	--	8	--	68	--
FS-1	FS-1	Flat Shoal Creek at SR 2018	5	--	17	--	10	--	10	--	14	--	9	--	7	--	7	--	79	--
MF-1	ST-3	Moores Fork at SR 1620	2	--	16	--	8	--	2	--	7	--	4	--	0	--	2	--	41	--
AR-1	NA-4	Ararat River at US 52 (DS)	5	--	18	--	12	--	10	--	10	--	10	--	9	--	8	--	82	--
BC-1	BL-3	Bull Creek at SR 2038	5	--	16	--	6	--	4	--	10	--	10	--	10	--	10	--	71	--
TC-1	TC-4	Toms Creek at SR 1830	5	--	18	--	14	--	8	--	14	--	12	--	10	--	8	--	89	--
		Mean	4	--	17	--	10	--	5	--	11	--	10	--	7	--	7	--	70	--

Notes: Value in parentheses beneath each habitat metric is the maximum possible score for each particular metric. Dashes (--) indicate that no data were available in 2006. BAU data collected in 2006 were for Basinwide Planning and other special studies. DS – Downstream and US – Upstream refers to monitoring locations for streams with two locations.

Total Habitat Data.

Four locations had total habitat scores of less than 60 out of 100 possible points. They are listed below (scores precede the location in the bulleted items below). BAU (NCDWQ, 2006c) considers habitat scores below 65 for the Mountain/Piedmont to be low to poor quality. No land use category dominated the four lowest total habitat scores. However, two of the lowest scores were associated with developed land use.

- 41 - Moores Fork at SR 1620 (MF-1) -- mostly agricultural;
- 50 - Lovills Creek at SR 1371 (LV-1, downstream) -- mostly developed
- 53 - Lovills Creek at SR 1700 (LV-2, upstream) -- mostly forested; and,
- 58 - Faulkner Creek at SR 1756 (FC-1) -- mostly developed.

Stewarts Creek at NC 89 (ST-1) was borderline low to poor quality with a score of 66. It was mostly forested.

Four locations that scored higher than 80, considered to be in the moderate to high quality range (above 65) included the following. The forested land use category was present in three out of the four best total habitat scores.

- 82 - Ararat River at US 52 (AR-1) – mostly forested with nearby developed;
- 84 - Hogan Creek at SR 2081 (HO-1) – mostly agricultural;
- 86 - Faulkner Creek at SR 1742 (FC-2) – mostly forested; and,
- 89 - Toms Creek at SR 1830 (TC-1) – mostly forested.

Summary of Sub-Habitat Metrics

Sub-habitat conditions provide evidence of subwatershed stressors and degraded watershed functions. The most notable conditions (i.e. those judged most extreme – highest or lowest scores) are presented below.

I. Channel modification (5) – assesses the evidence of dredging and/or channel alterations.

   Many streams in Surry County were likely moved, channelized, straightened and dredged in the past to make way for roads, rail lines, development and agriculture. Once streams are impacted, they can restabilize over time (as upstream disturbances diminish) to provide habitat and water quality functions at varying degrees. Where channelization was most apparent was in Lovills Creek at SR 1371 (LV-1) and in Moores Fork at SR 1620.

II. Instream habitat (20) – considers the percentage of a stream reach that is favorable for benthos colonization or fish cover. Type of cover assessed are rocks, macrophytes, sticks and leaf packs, snags and logs, and undercut banks or root mats.

   Instream habitats provide food (energy), refuge, substrates for biomass growth and elemental cycling. It is the most important habitat metric as reflected by its higher weighted score. It addresses both water quality and habitat functions but during a drought these functions are degraded. The lowest scores of were given to Faulkner Creek at SR 1756 (FC-1 -- the most downstream location), Heatherly Creek at NC 52 (HC-1) and Lovills Creek at SR 1371 (LV-1). As you may recall, EPTs and the NC BI scores were below average for these locations. Two locations, Hogan Creek at SR 2081 (HO-1) and the Ararat River at NC 104 (AR-2) received the highest score of 20 for this category. They were among locations with the highest EPTs.

III. Bottom substrate (15) – represents an assessment of the entire reach for the sizes of particles (gravel, cobble, etc.) composing the stream bottom. Embeddedness is only assessed at riffles.

Excessive sedimentation indicates current or historic altered hydrology, channel instability and degraded sediment transport functions. The bottom substrate and riffle embeddedness metric attempts to assess this in terms of aquatic habitat. It is one of the most important habitat metrics because riffles are where a majority of benthic organisms reside and is a zone of reaeration vital for good water quality. The lowest scores for bottom substrates and embeddedness included (repeat offenders) Lovills Creek at SR 1371 (LV-1), Faulkner Creek at SR 1756 (FC-1) and Bull Creek at SR 2038 (BC-1). In Table 4 below, Bull Creek substrates consisted of 55% silt. The Faulkner Creek location had a combined silt and sand substrate of 85%. The Lovills Creek at SR 1371 (LV-1) location had a good mix of substrates but embeddedness was significant.

IV. Pool variety (10) – assesses the presence/absence and frequency and sizes of pools.

Pools are more important as fish habitat. The number, variety and depth indicate habitat complexity and heterogeneity of habitat which is important to benthics. The lowest score (2) was given to Moores Fork at SR 1620 (MF-1).

V. Riffle habitats (16) – assesses length and width of riffles.

The quality, size and number of riffle habitats are important for water quality and habitat functions for the reasons stated above in III. The lowest scores (7) for this metric were again repeat offenders including Lovills Creek at SR 1371 (LV-1), Moores Fork at SR 1620 (MF-1) and Faulkner Creek at SR 1756 (FC-1). One of the highest scores (14) was earned by Hogan Creek at SR 2081 (HO-1).

Table 4. Composition (%) of bottom substrates and particle sizes for BAU benthic sites.

Map Codes WAT (Fig 4)	Map Codes EcoEng (Fig 3)	Location	Sq. miles	Silt (< .08")	Sand (.08")	Gravel (.08" – 2.5")	Rubble (2.5" – 10")	Boulder (> 10")	Bedrock	Embedded
HC-1	TC-6	Heatherly Creek at US 52	1.7	--	20	30	30	**20**	5	20 - 40
FC-2	NA-2	Faulkner Creek at SR 1742 (US)	2.7	20	5	5	**50**	**20**	--	< 20
MF-1	ST-3	Moores Fork at SR 1620	4.5	25	15	**55**	5	--	--	< 50
FC-1	NA-3	Faulkner Creek at SR 1756 (DS)	5.1	**30**	**55**	15	--	--	--	--
FS-1	FS-1	Flat Shoal Creek at SR 2018	7.1	--	15	15	10	15	**45**	--
HO-1	HG-2	Hogan Creek at SR 2081	8.6	**30**	20	30	15	5	--	< 20
CK-1	CH-1	Chinquapin Creek at SR 1830	9.4	10	**45**	30	10	--	5	< 50
BC-1	BL-3	Bull Creek at SR 2038	11.0	**55**	10	30	5	--	--	50
TC-1	TC-4	Toms Creek at SR 1830	18.0	15	25	30	25	5	0	< 20
LV-2	LV-1	Lovills Creek at SR 1700 (US)	26.8	20	5	25	15	10	**25**	--
LV-1	LV-2	Lovills Creek at SR 1371 (DS)	35.1	--	10	30	**40**	10	10	40 - 80
AR-2	NA-1	Ararat River at NC 104 (US)	35.8	15	5	20	**50**	10	--	< 20
SE-1	ST-2	Stewarts Creek at NC 89	63.8	**30**	10	**50**	5	5	--	20 – 40
AR-1	NA-4	Ararat River at US 52 (DS)	72.2	20	15	10	35	**20**	--	20 - 40

Notes: Values in **bold red** represent the two highest percentages for each category

VI. Stream bank stability and vegetation (14) – assesses bank stability and types of riparian vegetation (wooded, mixed, grasses, etc.)

The stability and erosion of stream banks indicates hydrology and water quality functions. Stream banks that are straight or nearly perpendicular to channel bottom may be evidence of incision or downcutting. Excessive streambank erosion is a source of sediment and evidence of degraded hydrology functions. Overall, streambanks were in fair shape (mean score was 10). Locations with straight, deeply incised and steep stream banks included Chinquapin Creek at SR 1830 (CK-1), Toms Creek at SR 1830 (TC-1), Stewarts Creek at NC 89 (SE-1), Bull Creek at SR 2038 (BC-1), Ararat River at US 52 (AR-1) and both Faulkner Creek locations at SR 1756 and SR 1742 (FC-1 and 2)

VII. Light penetration (10) – assesses whether the riparian vegetation (canopy) can block sunlight on the stream when the sun is directly above the stream.

Shading regulates temperature, light and ultraviolet radiation which in turn affects other chemical and biological processes (e.g. primary production, bacterial metabolism and aquatic insect emergence). A lack of shading indicates degraded water quality and habitat functions. The lowest scores (0) were again at Moores Fork at SR 1620 (MF-1) and Lovills Creek at SR 1371 (LV-1).

VIII. Riparian vegetation zone width (10) – assesses width of riparian vegetation and whether there are breaks in the vegetation.

The condition, size and type of riparian vegetation along with the number of breaks within the zone indicate water quality functions. Riparian vegetation provides organic matter and energy to aquatic organisms and microorganisms. Organic debris slows stormwater runoff and along with roots, helps control erosion and intercept pollutants. Breaks allow contaminants from storm water runoff to enter the stream. The lowest riparian buffer scores were observed at Moores Fork at SR 1620 (MF-1), Lovills Creek at SR 1371 (LV-1) and Faulkner Creek at SR 1742 (FC-2) with scores of 2, 4 and 5 (out of a possible 10) respectively (Table 3).

Stream Corridor Reconnaissance

Project staff walked approximately one mile of Heatherly Creek and four miles of Lovills Creek (Figures 15 and 16) over a three day period in February 2009 with the overall objective to identify stressors that may be contributing to biological impairment and degradation of watershed functions and to identify locations for stormwater BMPs. Stressors, degradation of watershed functions and BMP locations will be presented in the Discussion and Recommendation sections. The following tasks were conducted as part of the stream corridor reconnaissance.

- Observe and rate overall channel structure, noting specific areas of sediment deposition, severe bank erosion, evidence of channelization and other BAU habitat metrics;
- Collect specific conductance measurements;
- Observe overall riparian area condition and the nature of surrounding land use;
- Identify wastewater discharge pipes, stormwater outfalls, other piped inputs or withdrawals, and tributary inflows;
- Observe visual water quality conditions (odors, surface films, low flows, etc);
- Note specific areas where pollutants are or may be entering the stream (livestock access areas, dump sites, land clearing adjacent to the stream, etc);
- Identify specific areas that may be candidates for stormwater BMPs; and,
- Provide digital photo documentation of key features.

Figure 15. Stream corridor assessment along Heatherly Creek.

Point A was the starting point and point D was the end point for walking. Point B is the forested areas suggested for preservation. Points C and D are areas potentially suited for structural stormwater BMPs.

Heatherly Creek

Approximately one mile of Heatherly Creek was assessed on February 3, 2009 beginning at the water quality monitoring location (point A in Figure 15 and Photo 1) at NC 52 and ending roughly 0.25 miles upstream of NC 268 (point D in Figure 15).

Photo 1. Starting point of stream corridor assessment and location of chemical and biological monitoring in Heatherly Creek. Point A in Figure 15.

Subwatershed drainage area is 1.7 square miles and is mostly developed. Urban areas include half of downtown Pilot Mountain and other commercial areas.

A rail line parallels the first segment along the left stream bank for 0.7 miles. Stream banks (measured from water's surface) varied from two to six feet. Stream bank erosion varied but overall was insignificant; instream sedimentation was minor. There were many areas of bedrock banks, instream boulders and bedrock outcroppings (Photo 2). Substrate was a good mix of gravel, cobbles and boulders. Riparian zones on both sides were forested. A wide floodplain was accessible along the right side (facing upstream). Overall habitat was good with a total score of 87. No evidence of point discharges was observed along this segment. A pump station for Pilot Mountain's wastewater treatment plant was observed to be in good working order; no overflows were noticed and no leaking sewer pipes were noted.

Photo 2. Bedrock substrate area in Heatherly Creek 0.4 miles upstream from starting point.

The riparian area along the next segment upstream of NC 268 on the left side (facing upstream) was commercial (Photo 3) with a narrow vegetated buffer strip between parking lots and the stream. Parking lot runoff appeared to be filtered to a degree by a grassed buffer strip (Photo 4). Gutter drains from a restaurant were discharging directly to the channel.

The right side consisted of a wide wooded buffer and residential complexes beyond. Stream banks were more eroded but not as high at two to three feet from water's surface. Organic debris dams were observed. Overall habitat and stream banks were similar to the downstream segment. Some stream bank erosion was noted in close proximity to NC 268.

Specific conductance ranged from a high of 180 µS/cm in a small tributary draining a horse pasture south near an area referred to as Hope Valley, to a low of 62 µS/cm in a tributary near a bedrock outcrop area in the mainstem 0.4 miles upstream of the starting point. Mainstem measurements did not vary significantly ranging from 94 in the most downstream location to 78 in the most upstream location at SR1210. The measurements did not indicate water quality problems although comparatively elevated levels of sodium, chloride and sulfate were detected in base flow samples collected in October and November, 2008. A source was not identified.

In summary, Heatherly Creek was observed to be a mostly stable stream with very little current active stream bank erosion. The stream is confined for much of its length by a rail line and bedrock outcroppings; however, this is balanced by access to a wide forested flood plain in the downstream segment. Habitats are only slightly degraded but are likely impacted by scour during significant rain events.

Photo 3. Rock lined stormwater ditch along NC 268 that discharges directly to Heatherly Creek at NC 268.

Photo 4. A grass filter strip (providing some unintentional filtration) that may be suitable for retrofitting to provide improved treatment of runoff from the parking lot.

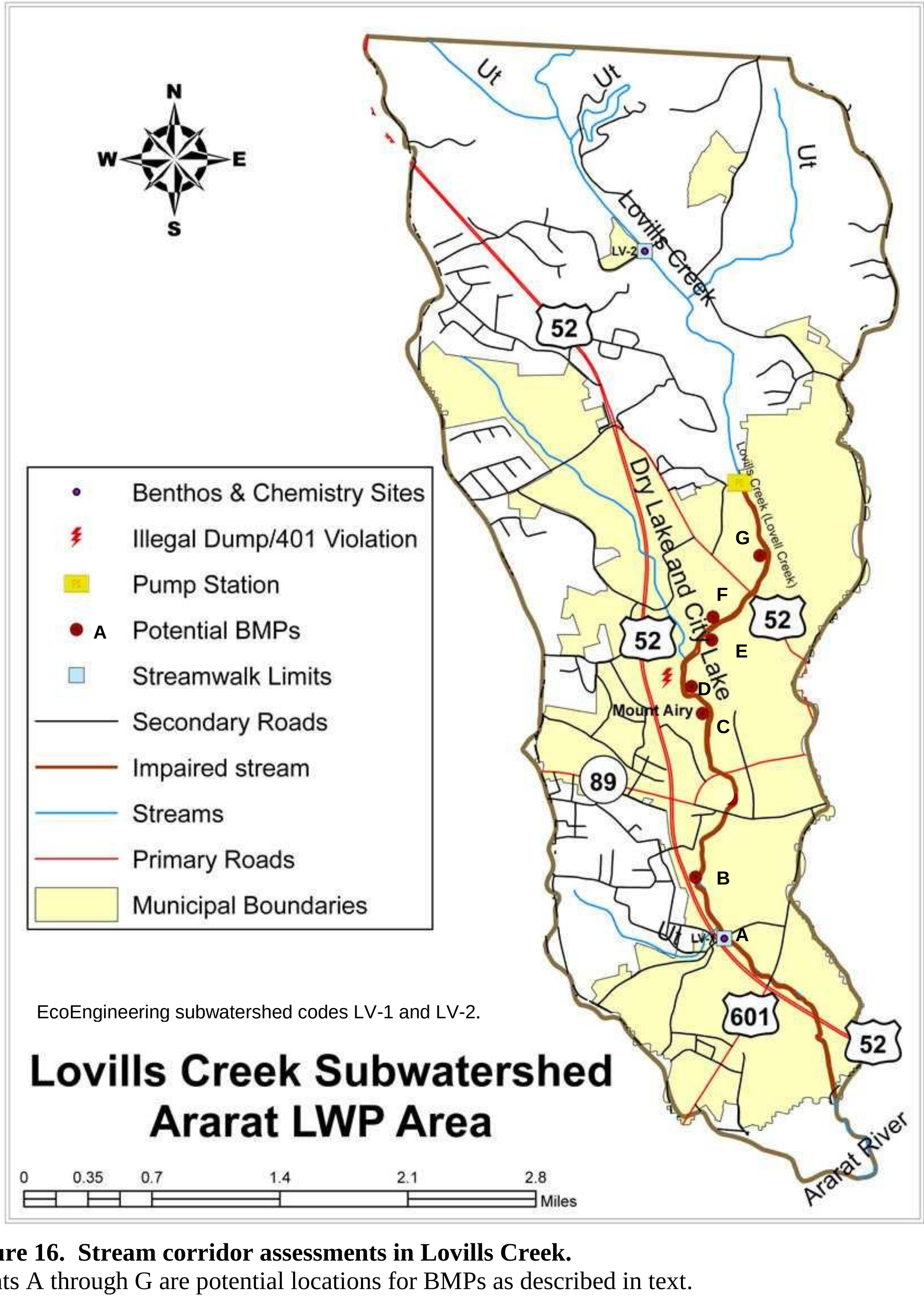


Figure 16. Stream corridor assessments in Lovills Creek.
Points A through G are potential locations for BMPs as described in text.

Lovills Creek

Photo 5. Beginning of greenway trail that paralleled Lovills Creek through Mount Airy.

Lovills Creek was assessed on February 5 and 11, 2009. The first segment walked was associated with the greenway trail (Photo 5) that parallels Lovills Creek for almost 2.5 miles beginning at the most downstream location where water quality monitoring occurred at SR 1371, and continued upstream to West Lebanon Street at Veterans Memorial Park.

The drainage area is 35.0 square miles, much of which is in Virginia. Land use along this segment was mostly developed (urban commercial and industrial). One approximately 50-acre pasture was observed behind a shopping mall adjacent to the stream.

Photo 6. Lovills Creek in an engineered flood control channel.

The most significant characteristic of the channel was that it was a mostly unnatural, engineered, flood control channel approximately three miles in length from SR 1371 upstream to Mount Airy's surface water intake (Photo 6). Stream banks were armored with interlocking concrete pavers (Photo 7) overseeded in grass. Stream bank erosion was absent, as were woody vegetation, root mats and shading. Woody debris within the channel was also absent. Vegetated banks and a bankfull bench were recently mowed. Tractor tire tread marks were observed in one location along the stream bottom substrate.

Frequent breaks (n = 69) were observed along this segment (Photo 8), most of which were paved concrete lined ramps embedded into the stream bank allowing direct storm water discharges. Some breaks were preceded by a vegetated zone providing storm water filtration. Sewer lines and manholes were observed frequently. No sewer line leaks were observed.

Total habitat score was 47 for the entire segment, which was similar to the total score of 50 given by BAU for Lovills Creek at SR 1371.

Specific conductance ranged from 65 µS/cm in the mainstem at SR 1371 to 151 µS/cm in two of six tributaries along this segment. The higher tributary observations may indicate upstream water quality concerns in respective catchments. A recent investigation by NCDENR staff concerning an illegal dump site near an unnamed tributary to Lovills Creek behind the shopping mall revealed an area approximately one acre with a depth of 100 feet filled with various types of trash and debris. Owners also failed to gain certification for piping a nearby tributary to Lovills Creek.

Photo 7. Interlocking concrete pavers lined stream banks to prevent erosion worked very well. None to very little stream bank erosion present along the entire length of channel.

The second segment of Lovills Creek began at West Lebanon Street and continued upstream for 1.7 miles to a golf course on SR 1700. The greenway ended at West Lebanon Street but the engineered channel continued upstream to a low flow dam (Photo 9) at Mount Airy's surface water intake.

As with the previous segment there were several concrete-lined channels and pipes (n = 18) embedded within the streambank allowing stormwater discharge (Photo 8).

Photo 8. Breaks were common and consisted of embedded concrete lined channels. A total of 87 were counted for the entire length of engineered channel.

Land use for this catchment was similar to the previous segment, but became less urban in upstream sections. Land use adjacent to the stream included two golf courses, pasture and cropland, and low density residential and single family homes.

Upstream of the low flow dam the stream channel was natural and included a 2,000-foot segment with a wide riparian zone that was forested on both sides providing organic debris and shade. Bank height varied from two feet to 12 feet from water's surface. Some bank erosion was present (Photos 9 and 10).

A recently cleared utility right-of-way six feet wide and approximately 1,000 feet long along one side of the stream was observed.

In summary, Lovills Creek from SR 1371 upstream to Lebanon Street along the greenway was an aesthetically pleasing engineered riverscape (although without trees and shade) within an otherwise typical urban/commercial landscape. The engineered channel was stable, providing both flood control and recreational opportunities. Numerous stormwater pipes and ditches (n=87) were present and discharged stormwater runoff from surrounding catchments directly to Lovills Creek.

Photo 9. Mount Airy pump station and low flow dam at upstream end of engineered channel in Lovills Creek.

Photo 10. A more natural channel in Lovills Creek upstream of pump station and downstream of golf course.

Discussion

For the purposes of this discussion, **stressors** are forces within the watershed or subwatershed which have the potential to degrade watershed functions. These usually result from past and present human activities although extremes in weather (drought; hurricanes) can also cause stress. For example, urban storm water runoff is a common **stressor** with the potential to adversely impact aquatic habitat and water quality functions with a watershed. Its primary **source** or **origin** or **cause** is hydromodification that increased impervious area associated with development. Some **effects** of urban storm water runoff include streambank instability and erosion, degraded habitat and water quality and reduced benthic diversity.

For Heatherly and Lovills Creeks we attempted to identify **stressors** related to biological impairment in addition to those related to the degradation of watershed functions because they are recognized by the USEPA as impaired. These two streams will be discussed first because more data were available (from stream corridors assessments) than for other locations. They were among the **most degraded**.

The next group discussed will include subwatersheds that we also considered **most degraded** but were not included in the discussion for Heatherly and Lovills Creeks because less data were available (i.e., stream corridor assessments were not conducted) to review. These include the most downstream location in Faulkner Creek at SR 1756 (FC-1), Moores Fork at SR 1620 (MF-1), the Ararat River at NC 52 (AR-1) and Bull Creek at SR 2038 (BC-1).

The next group discussed will include those considered **least degraded** including Hogan Creek at SR 2081 (HC-1), Faulkner Creek at SR 1742 (FC-2), Chinquapin Creek at SR 1830 (CK-1), Lovills Creek at SR 1700 (LV-2), the Ararat River at NC 104 (AR-2), Stewarts Creek at NC 89 (SE-1), Toms Creek at SR 1830 (TC-1) and Flat Shoals at SR 2018 (FS-1).

Table 5 below summarizes the complicated concatenation of circumstances that leads to degraded watershed functions and includes potential stressors, effects and the types of evidence or indicators considered for the Ararat River LWP area.

Table 6 provides a summary of sources and stressors to watershed functions within each subwatershed based on various lines of evidence discussed in the section that follows.

Table 5. Potential stressors, sources and effects in the Ararat River Watershed.

Potential Stressors	Sources	Function Degraded	Effect	Lines of Evidence/Indicators
Sediment	• Eroding stream banks • Cattle trampled banks • Bedload (historic erosion) • Upland soil erosion from construction sites, recently logged parcels	• Habitat • Water Quality • Hydrology	• Increased turbidity and sediment supply • Channel/stream bank instability • Loss of habitat and complexity • Reduction in elemental/nutrient spiraling	• WQ data • Benthic and habitat data • Stream corridors • Land use
Increased storm water runoff and scour	• Hydromodification/channelization; storm drains/pipes • Logging/foresty operations • Increased impervious surfaces • Instream debris dams • Cattle trampled banks • Beaver dams	• Habitat • Water Quality • Hydrology	• Riparian disturbance/degradation • Incision/widening of stream channel • Lowering base flow • Reduced organic debris retention • Reduced surface and subsurface storage • Unstable and steep stream banks	• Benthic and habitat data • Peak flow hydrograph • BPJ and literature • Stream corridors • Land use
Toxicants	• Urban and ag stormwater runoff • Leaking sewer lines • Periodic illicit discharges (outfalls) • Golf courses • Lawns	• Water Quality	• Increased concentration of toxic chemicals • Loss of benthic and fish diversity	• Sewer spill reports • Benthic and fish data • WQ data • Stream corridors • Literature • BPJ
Pathogens	• Wildlife; pets; • Livestock (poultry, cattle, horses) • Leaking sewer and septic systems	• Water Quality	• Increased disease causing organisms • Increased risk to human health	• WQ data
Nutrient enrichment	• Fertilizer; livestock waste • Leaking sewer lines	• Habitat • Water Quality	• Increased algal growth • Low dissolved oxygen • Increased nutrient concentrations	• WQ data • Benthic and habitat data • Stream corridors • Land use
Increased stream temperature and UV radiation	• Parking lot runoff • Lack of riparian shading	• Habitat • Water Quality	• Lowers dissolved oxygen; • Disrupts benthic lifecycles • Loss of benthic and fish diversity	• WQ data • Benthic and fish data • Literature • Stream corridors
Drought	• Natural phenomena	• Habitat • Water Quality • Hydrology	• Lowers baseflow • Loss of habitats • Decreases dissolved oxygen • Disrupts benthic lifecycles	• WQ data • Drought Monitor data • Benthic and habitat data • Stream corridors

Table 6. Summary of sources and stressors to watershed functions in the Ararat River watershed.

Map Codes		Location													
WAT (Fig 4.)	**EcoEng. (Fig. 3)**		**Sediment**	**Unstable stream banks**	**Increased storm runoff**	**Cattle access to stream**	**Hydromodification**	**Beaver**	**Toxicants**	**Pathogens**	**Degraded riparian zone**	**Drought**	**Urban land**	**Ag land use**	**Total**
MF-1	ST-3	Moores Fork at SR 1620	0	1	0	1	1	1	0	1	1	1	0	1	8
LV-1	LV-2	Lovills Creek at SR 1371 (DS)	1	0	1	0	1	0	1	1	1	1	1	0	8
AR-1	NA-1	Ararat River at US 52 (DS)	1	1	1	0	1	0	1	0	1	1	1	0	8
HC-1	TC-6	Heatherly Creek at US 52	0	0	1	0	1	0	1	0	1	1	1	0	6
FC-1	NA-3	Faulkner Creek at SR 1756 (DS)	1	0	1	0	0	1	1	0	0	1	1	0	6
SE-1	ST-2	Stewarts Creek at NC 89	1	1	1	1	0	0	0	0	1	1	0	0	6
CK-1	CH-1	Chinquapin Creek at SR 1830	1	1	0	0	0	0	0	0	1	1	0	1	5
BC-1	BL-3	Bull Creek at SR 2038	1	1	0	0	0	0	0	0	1	1	0	1	5
LV-2	LV-1	Lovills Creek at SR 1700 (US)	1	1	0	0	0	0	0	0	1	1	0	0	4
AR-2	NA-1	Ararat River at NC 104 (US)	1	0	0	0	0	0	0	0	1	1	0	0	3
FS-1	FS-1	Flat Shoal Creek at SR 2018	0	1	0	0	0	0	0	0	0	1	0	1	3
FC-2	NA-2	Faulkner Creek at SR 1742 (US)	0	0	0	0	0	0	0	0	1	1	0	0	2
HO-1	HG-2	Hogan Creek at SR 2081	0	0	0	0	0	0	0	0	0	1	0	1	2
TC-1	TC-4	Toms Creek at SR 1830	0	0	0	0	0	1	0	0	0	1	0	0	2

Notes: 1 = the stressor or source is present; 0 = stressor or source is absent or causing minor stress.

Drought Stress

Drought was a stressor that likely degraded watershed functions and impacted the benthic community in all subwatersheds. It is likely that when flow conditions return to normal, benthic communities will rebound in most locations providing a clearer picture of water quality conditions. To the extent which other stressors impacted watershed functions as reflected or indicated by the condition benthic communities is uncertain and are likely masked by drought effects.

Drought causes stress to aquatic organisms in three ways: 1) limiting habitat access (e.g., reduced base flow resulting in a loss of available habitat like root mats, undercut banks and riffles that would otherwise be submerged and available to benthic organisms; exacerbation of reduced base flow in urban streams due to impervious cover that prevents infiltration to shallow groundwater, further lowering base flow and habitat availability); 2) disrupting lifecycles; and, 3) decreasing dissolved oxygen.

The benthic community was degraded to a degree at all monitoring locations regardless of land use. No location rated better than Good-Fair, five sites were Not Rated and one rated Fair. All locations with previous 2006 samples declined in EPT richness but one (Lovills Creek at SR 1700 (LV-2). NC BI scores declined from 2006 as well.

Evidence of drought was provided by BAU with their review of the National Drought Monitor (2008) that indicated 52 weeks prior to sampling, Surry County experienced a D2 drought 67% of the time. A D2 drought is categorized as a severe drought in which water shortages, crop and pasture losses occur. A previous drought study conducted by BAU was cited which concluded that drought can cause temporary large declines in bioclassification and it may take up to a year for benthics to recover.

BAU also reported that many of the sites sampled for this project were noted as having low flows. One location selected for benthic monitoring in Candiff Creek could not be sampled due to **zero flow**.

Observations by WAT staff during reconnaissance monitoring in March 2009 noted low flows. Low dissolved oxygen was not observed by BAU or WAT (during reconnaissance sampling in March). Therefore it was likely that habitat access and the disruption of benthic lifecycles were the two pathways that drought stress impacted benthic communities.

Drought is likely just one of the potential stressors impacting benthic organisms. The evidence suggests that it is a primary factor contributing to the degradation of water quality and habitat functions.

<u>Lovills and Heatherly Creeks</u>

Stressors degrading watershed functions in Lovills and Heatherly Creeks are likely related to developed land use (for this project, developed land use includes urban areas) that increased stormflow and scour due to increased imperviousness and toxicants. Sediment, increased stream temperature and ultraviolet radiation (UVR) were likely stressors in Lovills Creek only.

Obviously, direct evidence for increased stream temperature is lacking due the season in which monitoring occurred but the lack of shading suggests that stress to aquatic organisms due to increased stream temperature and UVR exposure likely exists during warmer months. Aquatic insects use temperature or temperature change as an environmental cue for emergence (Hauer and Lamberti, 2007), it is plausible that stream segments with higher mean temperatures or temperature extremes may not support more intolerant taxa. Kelly et. al., (2003) found a decrease in total invertebrate biomass, mayflies, stoneflies and community diversity in an unshaded stream reach with higher UVR exposure compared with a segment that was more heavily shaded.

Walsh et al., (2005); Meyer and Paul (2001); and Wheeler et al. (2005) described a "suite of effects" on streams associated with land use termed the "urban stream syndrome". The symptoms include a flashier hydrograph, elevated concentrations of contaminants, altered channel morphology and stability, reduced biotic richness with increase dominance of tolerant species; reduced baseflow, increased suspended solids and temperature and decreased nutrient uptake. In a study of the effects of three land use types (agriculture, forested, urban) on water quality and aquatic biota in the Piedmont region of North Carolina, Lenat and Crawford (1994) found that land use was an important factor controlling the structure of aquatic communities.

In Lovills Creek, the benthic community upstream of the engineered channel and urban environs of Mount Airy were in better condition (Good-Fair rating) than the benthic community sampled downstream (Fair rating) of these factors suggesting stressor impacts (in addition to drought) between the two locations. This pattern was observed for benthic assessments in previous years as well, minus the drought stress. Habitat conditions were similar in both locations although substrates in the upstream location were mostly bedrock and in the downstream location substrates were a good mix of gravel, cobble and boulders and riffles were embedded.

Prior assessments in Heatherly Creek in 2001 and 2004 (see Table 8 in Appendix) involved upstream/downstream locations (to avoid Pilot Mountain's wastewater discharge). Benthic communities in the upstream location (at NC 268) were in better condition both times. Only the downstream location was monitored in 2008.

<u>Habitat degradation.</u> Evidence observed during stream corridor reconnaissance in Lovills Creek suggested that storm flow stressor effects to the benthic community were related to habitat impacts (lack of wooded riparian zones, loss of scant habitat and infrequent riffles) brought about by the engineered stream channel in addition to increased flashiness (caused by increased impervious area and storm drainage systems that increase flood frequency and magnitude)

subsequently removing scant habitats. Dispersal and recolonization by upstream drift organisms was likely limited as well because of catchment development and imperviousness.

The lack of a wooded riparian area along Lovills Creek results in very little input of organic debris, which in turn limits sub-habitats (sticks, logs, root mats and decaying leaf packs) that provide substrates for food, attachment and shelter for aquatic life, and surface area for biofilms to conduct important ecosystem functions such as nutrient cycling and organic matter decomposition (Aldridge et al., 2009). Allan (2004) reported that woody debris was shown to increase local benthic diversity in certain catchments. Scant organic debris from upstream forested segments and surrounding catchments had been transported downstream but does not reside permanently. The channel was engineered to lack complexity and enhance efficient movement of water (including organic debris) downstream. Some organic debris was observed on flood plain benches not in contact with stream water.

Photo 11. Check valve observed along Lovills Creek allows stormwater to discharge and prevents flood water back flow to upstream parking lot.

Habitat and channel conditions in Heatherly Creek were more favorable than those in Lovills Creek but benthos and habitats are likely scoured during storm flow. Currently, the channel is mostly stable. In the past, it is likely that impervious cover and storm drainage associated with the Town of Pilot Mountain and relocation of the stream channel to allow for the rail line, altered hydrologic connections to the stream that concomitantly increased flood frequency and magnitude resulting in channel adjustments (incision and widening) to counter the change in hydrology (Doll et al., 2003). Currently, for the most part, the channel is stable.

<u>Toxicants.</u> Stormwater pipes and ditches (and potentially leaking sewer lines) deliver pollutants from parking lots, roadways, golf courses and yards directly to both Lovills and Heatherly Creek during rain events. Few stormwater management practices were observed (Photo 11). Chemical monitoring did not include organic toxicants and toxic metals data collected were within NCDWQ standards; however, stormwater runoff from urban areas and channel sediments are known to contain multiple pollutants (Walsh et al., 2005) potentially toxic to benthic organisms.

Leaking sewer lines are also potential sources of toxicants although leaks were not observed during stream corridor assessments. However, specific conductance in Heatherly Creek was the highest among sites (as were sodium and chloride) suggesting a potential source of toxicants although no source was identified. Metals were monitored during one storm event in Lovills Creek but concentrations did not exceed water quality standards.

Another likely observed source of toxicants was the illegal landfill adjacent to Lovills Creek discussed above.

Sediment. In addition to potential sediment toxicity, sediment is a potentially a physical stressor in Lovills Creek as well. Riffle habitats were reported 40-80% embeddeded in Lovills Creek. Embeddeddness in Heatherly Creek was less (20 – 40%). Increases in embeddedness levels decrease the space between substrate particles and limit the available area and cover for benthic organisms (Sylte and Fischenich, 2002). Habitat data suggest that, for the most part, riffle embeddedness for better scoring benthic locations (i.e., Hogan Creek, Faulkner Creek at SR 1742 and the Ararat River at NC 104) was less that 20%.

Sources of sediment in Lovills Creek likely include eroding stream banks upstream of engineered channel; exposed soil from turfed areas, lawns, crop fields and construction sites in surrounding upland catchments and from the subwatershed upstream of the engineered channel. Almost no eroding stream banks were observed within the engineered stream channel.

Other Streams and Subwatersheds

The next group discussed will include other subwatersheds we considered **most degraded** based on evidence as described below. See Tables 5 above for a summary of potential stressors, sources, effects and lines of evidence considered. Consider Table 6 for a review and summary of specific stressors and sources applicable to each subwatershed monitored by WAT and BAU discussed below.

Faulkner Creek at SR 1756 (FC-1) may also be experiencing effects related to the "urban steam syndrome". Developed land use (21%) was among the highest next to Heatherly and Lovills Creeks discussed above. Again we have upstream/downstream benthic data to compare. This most downstream location in 2008 and in previous assessments indicated a more tolerant community than upstream suggesting that stressor(s) associated with developed land use between locations (i.e., Mount Airy and Flat Rock) may be responsible. Habitat conditions were also more degraded here than upstream. Substrate was mostly sand and silt, riffle habitats and pools occurred infrequently. Riparian scores were low as well. Stream banks were steep with areas of erosion and channel incision. Specific conductance data from stream reconnaissance in March and collected by BAU were slightly higher than upstream suggesting a source between locations that may be impacting the community as well.

Moores Fork at SR 1620 (MF-1) received the lowest habitat score (41) but managed to receive a Good-Fair rating. One explanation is that the favorable rating was based solely on EPT taxa richness because the EPT sampling methodology was used rather than the Full Scale method. Therefore, other non-EPT taxa were not collected, identified nor included in the rating. So it is difficult to compare this rating with other locations where the Full Scale method was used. However, EPT BI comparisons can be made, but with caution, because less sub-samples were collected than with Full Scale methods.

The EPT BI for this site was the highest among locations suggesting a somewhat more tolerant community than in other locations. Stressors likely include factors related to land use (upstream land use is 50% agricultural and close to 12% is developed), riparian degradation, livestock access and pathogens. Shading is mostly absent in the segment evaluated. Cattle were observed in stream on one occasion and BAU reported manure odors during their sampling. Further upstream in the headwater area a permitted animal operation exists that may be contributing nutrients and bacteria. Fecal coliform indicators were elevated on one occasion and nitrite+nitrate levels were the highest among locations for both the reconnaissance effort and monthly monitoring. Evidence of beaver activity suggests habitat impacts.

Ararat River at NC 52 (AR-1) is another location suffering from symptoms of the "urban stream syndrome" as described above for Lovills Creek. Developed land use is 11% and most of it is urban and nearby the monitoring location. The EPT and NC BI values were among the highest. The benthic community upstream in the Ararat River at NC 104 (AR-2) and upstream of urban influences associated with Mount Airy were in better condition that at this location. Habitat scores were identical for both locations suggesting other stressors related to developed land use may be responsible. Stream banks were straight with areas of erosion and the channel incised. Habitat conditions were more favorable although scour during storm events may be removing insects.

Sediment is likely a stressor in Bull Creek at SR 2038 (BC-1) scouring/removing habitats and benthos. Riffle habitats were also degraded due to embeddedness. There were few pool habitats and mostly silty substrates. The EPT and NC BI scores were among the highest. BAU reported a deeply incised channel, stream banks nearly perpendicular to the channel bottom with some erosion areas. Sources may include current and historic bank erosion due to cattle trampling, degraded riparian zones and past agricultural practices that increased soil erosion from upland areas. Stream corridor assessments were not conducted in this subwatershed so it is difficult to say with certainty that unstable stream banks and degraded riparian zones were prevalent upstream.

The next locations discussed will include those considered **least degraded** based on evidence described below. See Table 5 for a summary of potential stressors and evidence.

Lovills Creek at SR 1700 (LV-2) and the Ararat River at NC 104 (AR-2) were primarily used as reference sites for downstream monitoring locations. That is, they were monitored to provide evidence of benthic community conditions or how the benthic community may respond in the absence of certain stressors that may be present between locations. Most of the watershed upstream of these two locations is within Virginia and is mostly forested thereby providing a fair estimate of somewhat unimpacted watershed functions. Instream habitat in the Ararat River location was ideal scoring a perfect 20. The presence of unique mayflies species in this location vs. downstream suggests stressors between locations, likely associated with the Mount Airy (i.e. urban stream syndrome") as discussed above.

Benthic evidence in Hogan Creek at SR 2081 (HC-1) that includes higher EPT richness, lower NC BI and the presence of a unique mayfly taxon suggests a somewhat more intolerant and diverse community than in other locations. This may be due to favorable instream habitat (perfect score of 20) with a good mix of bottom substrates and low embeddedness. Good instream habitat may be attributed to less scouring of habitat and benthos by storm flows due to less development upstream. Riparian zones and stream banks may be in better shape throughout the subwatershed as well although no evidence was collected to confirm this.

Faulkner Creek at SR 1742 (FC-2) changed for the worst between 2006 and 2008 in terms of the benthic community but was able to maintain a more diverse community compared to the downstream location. Habitat conditions were more favorable as well, although stream banks were describes as steep and straight and the channel incised. This could be attributed to a mostly forested landuse (76%) that lessened the physical impacts associated with storm events. The change in community diversity could be related to drought effects or stress from other nonpoint sources.

Habitat functions in Stewarts Creek at NC 89 (SE-1) are degraded in the subwatershed to a degree but the benthic community was one of the most diverse. Stream banks are nearly perpendicular to the channel bottom with erosion areas present. Also of note was that EcoEngineering identified this subwatershed as one with a concentration of highly erodible soils. Upstream of the sampling location north of NC 89 stream banks appeared to be unstable and lacking riparian vegetation. Water quality monitoring did not reveal concerns relative to pathogens or any other indicators.

Toms Creek at SR 1830 (TC-1) received the highest habitat score (89) but low EPT taxa counts even with the most robust Full Scale sampling methodology employed by BAU. The NC BI was slightly better than average though. BAU concluded that while good habitats were present they were not accessible or only periodically accessible because of less wetted area due to drought compounded by beaver impoundments, both of which most likely contributed to lower diversity.

The one storm event monitored resulted in turbidity levels above the NC water quality standard. This was likely related to stream bank erosion. BAU noted that stream banks were eroding, steep and nearly perpendicular to the channel bottom. Almost all metals were below detection limits except for aluminum, iron and manganese which were detected at somewhat higher concentrations than in base flow monitoring. Reconnaissance sampling in March suggested this location to be among the lowest in terms of nitrite+nitrate nitrogen. Some upstream landuse is developed (6%) and one of the subwatersheds with the highest percentage of forested land and is classified as HQW. Other than drought conditions and beaver activity it is difficult to know with certainty what other factors may be stressing the benthic community.

Habitat functions in Chinquapin Creek at SR 1830 (CK-1) were degraded somewhat due to sediment. Bottom substrates were mostly sand and riffle habitats were less defined. Stream banks were nearly perpendicular to the channel bottom with some erosion and unstable areas noted. The source is likely related to increased peak storm flow due to upstream development. The benthic community was one of the most diverse however. The NC BI value was better than average. Water quality monitoring did not reveal concerns relative to pathogens or other indicators.

Habitat functions in Flat Shoals at SR 2018 (FS-1) were slightly degraded due to riparian impacts. Bottom substrates were mostly bedrock which limits habitat availability. However, the benthic community was one of the most diverse with a better than average NC BI value and a unique caddisfly taxon was present. These conditions may be attributed to land use which is slightly over 50% forested with very little developed land nearby.

Conclusions

Overall, water quality and habitat functions across the LWP area were in relatively good condition (with noted exceptions). Drought (and beaver in a few locations) likely stressed the benthic macroinvertebrates throughout the LWP and may have masked effects of other stressors. Other likely stressors include increased peak storm flow, sediment and degraded habitat and riparian buffers. In general, subwatersheds with the least amount of developed land and urban influences had more favorable water quality and habitat conditions. Toxicants may be a stressor in urban areas.

- Data collected from subwatersheds prioritized for stormwater BMPs (mostly developed subwatersheds) provided evidence of water quality and habitat degradation that was likely due to increased stormwater flow and pollutant runoff. Potential locations for BMPs were identified and are presented in the Recommendation section below.

- Unstable stream banks and incision at several locations suggest that stream restoration is needed in many subwatersheds to prevent further sediment inputs and habitat degradation. Agricultural BMPs would likely help to improve water quality where cattle have access to streams. Locations are recommended below.

- Much of the watershed is forested and remains unprotected and therefore provides many opportunities for preservation throughout the LWP. Preservation would help to maintain current overall good water quality and habitat conditions. Recommended areas are discussed below.

Recommendations

The following recommendations are based on best professional judgment and monitoring data/observations.

Stormwater BMPs

Stormwater best management practices (BMPs) and retrofit opportunities as described in NCDWQ's Stormwater BMP Manual (2007) throughout both catchments need to be identified and implemented to treat or limit pollutants and other damaging effects of stormwater runoff.

Uncovering or "daylighting" buried streams (piped or placed in culverts) may be more effective in some instances (Pinkham, 2000).

There are two major categories of BMPs: nonstructural and structural. Non-structural BMPs are typically passive or programmatic and tend to be source control or pollution prevention BMPs that reduce pollution in runoff by reducing the opportunity for the stormwater runoff to be exposed to the pollutants. A few examples include the following.

- Public education and participation;
- Land use planning and management (preservation, vegetative controls, reduce impervious areas, disconnect impervious areas); and,
- Material use controls (housekeeping practices, pesticide and fertilizer use).

Structural BMPs refer to physical structures designed to remove pollutants from stormwater runoff, reduce downstream erosion, provide flood control, and promote groundwater recharge. Structural BMPs typically require engineering design and engineered construction. A few examples include the following:

- Bioretention;
- Filter Strip;
- Restored Riparian Buffer; and,
- Wet Detention Basin.

Several locations were identified as potential locations for BMPs and are described briefly below.

Heatherly Creek at US 52 (HC-1) - *EcoEngineering Subwatershed Code TC-6* (See Figure 3 for EcoEngineering's map of priority subwatersheds and codes.)

A few areas were identified as potential areas for BMPs. They are described below and are approximated as points in Figure 15.

A large area of idle land behind the commercial area (near point D in Figure 15) could be used for a structural BMP to accept parking lot runoff and gutter drainage from nearby commercial establishments.

Idle land associated with Pilot Mountain's retired wastewater treatment works (point C in Figure 15) could be a location for a wet detention basin.

The forested riparian area along the segment between NC 52 and NC 268 (areas around point B in Figure 15) should remain intact/preserved as it will continue to store flood waters, filter pollutants and protect downstream water quality.

Photo 12. A UT to Lovills Creek where a BMP (restored buffer) may help to improve water quality in Lovills Creek.

Lovills Creek at SR 1371 (LV-1) - *EcoEngineering Subwatershed Code, LV-2.*

Restoration of riparian areas along the engineered channel would help with shade and lack of instream organic debris.

The forested riparian area along the segment upstream of the pump station should remain intact as the favorable habitats here will continue to serve as a source for drift organisms.

Several areas of real estate (some idle) may be potential areas for BMPs. Several of the areas are listed below and are approximated in Figure 16.

- A parking lot at the start of the greenway (point A);
- Idle land along the first UT to Lovills Creek upstream of SR 1371 (point B);
- A pasture field behind the shopping mall (point C);
- An unused parking lot associated with the now closed Proctor Silex Plant (point D);
- An area behind the High School and water filtration plant (point E);
- Areas within Veterans Memorial Park (point F); and,
- Idle land along the west side of Lovills Creek north of Lebanon Street (point G).

Tributary catchments were not assessed but it is likely there are locations where BMPs could be located.

Stream Restoration

Streams and subwatersheds where stream restoration is recommended due to stream bank instability and erosion and riparian zone degradation include the following (see Figure 3).

Stewarts Creek at NC 89 (SE-1) - *EcoEngineering Subwatershed Code ST-2.* Specifically note the segment north of NC 89, upstream of WAT's monitoring location.

Bull Creek at SR 2038 (BC-1) – *EcoEngineering Subwatershed Code BL-3.*

Ararat River at US 52 (AR-1) – *EcoEngineering Subwatershed Code NA-4.* There are likely numerous opportunities for stormwater BMPs within this subwatershed due to the urban nature of the catchment. Potential locations were not investigated however.

Faulkner Creek at SR 1756 (FC-1) – *EcoEngineering Subwatershed Code NA-3.* As stated above, there are likely numerous opportunities for stormwater BMPs here as well but the catchment was not investigated.

Faulkner Creek at SR 1742 (FC-2) – *EcoEngineering Subwatershed Code NA-3*

Toms Creek at SR 1830 (TC-1) – *EcoEngineering Subwatershed Code TC-4*

Chinquapin Creek at SR 1830 (CK-1) – *EcoEngineering Subwatershed Code CH-1*

Lovills Creek at SR 1700 (LV-2) - *EcoEngineering Subwatershed Code LV-1.*

Ararat River at NC 104 (AR-2) – *EcoEngineering Subwatershed Code NA-1.* Portions of this subwatershed downstream of the monitoring location would likely be suitable for agricultural BMPs as well due to the proximity of agricultural land use.

Agricultural BMPs

Fencing to keep livestock from trampling stream banks and degrading riparian zones would be beneficial to water quality and habitat functions at the following location and subwatershed.

Moores Fork at SR 1620 (MF-1) – *EcoEngineering Subwatershed Code ST-3.*

Preservation

Much of the watershed is forested and remains unprotected and therefore provides many opportunities for preservation throughout the LWP to help maintain good water quality where it exists. EcoEngineering's assessment identified several subwatersheds where preservation opportunities are likely to exist (see Figure 3). In addition, based on overall good water quality and habitat data, the following two streams and subwatersheds are recommended for further investigation of preservation opportunities to help maintain current overall good water quality and habitat conditions.

Hogan Creek at SR 2081 (HO-1) – *EcoEngineering Subwatershed Code HG-2.*

Flat Shoals Creek at SR 2018 (FS-1) – *EcoEngineering Subwatershed Code FS-1*

Other Recommendations

- Conduct stream corridor assessments along Faulkner Creek to investigate stressors that may be impacting the benthic community.
- Revisit Champ Creek to determine the source of elevated bacteria observed during the reconnaissance.
- Investigate livestock operations in the headwater areas of the Moores Fork subwatershed.
- Resample benthos once stream flow returns to more normal conditions.

Literature Cited

Aldridge, K. T., J. D. Brookes and G.G. Ganf, 2009. Rehabilitation of Stream Ecosystem Functions through the Reintroduction of Coarse Particulate Organic Matter. Restoration Ecology. 17(1): 97-106.

Allan, J. D., 2004. Landscapes and Riverscapes: The Influence of Land Use on Stream Ecosystems. Annual Review of Ecology, Evolution, & Systematics . 35:257-84.

Center for Watershed Protection (CWP), 2003. Impacts of Impervious Cover on Aquatic Systems. . March.

Doll, B.A., G.L. Grabow, K.R. Hall, J. Halley, W.A. Harman, G.D. Jennings and D.E. Wise, 2003. Stream Restoration: A Natural Channel Design Handbook. NC Stream Restoration Institute, NC State University. 128 pp.

EcoEngineering, 2008. Upper Yadkin Basin Local Watershed Plan, Technical Memorandum, Task 2. EEP-08050, October 2008. (http://www.nceep.net/services/lwps/Ararat_River/Task_2_Final_Report_Upper_Yadkin_LWP.pdf)

Environmental Management Commission (EMC). 2007. Administrative Code 02B .2011: Classifications and Water Quality Standards Applicable to Surface Waters and Wetlands of N.C. http://h2o.enr.state.nc.us/admin/rules/documents/redbook_1may07_full_with_cover.pdf

Hauer, R. H. and G. A. Lamberti, 2007. Methods in Stream Ecology, Second Edition. Academic Press, Elsevier.

Kelly, D. J., M. L. Bothwell and D. W. Schindler, 2003. Effects of Solar Ultraviolet Radiation on Stream Benthic Communities: An Intersite Comparison. Ecology. 84(10) pp. 2724 – 2740.

Lenat, D. R., and J. K. Crawford, 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. Hydrobiologia 294: 185-199.

Meyer J. L. and M. J. Paul, 2001. Streams in the Urban Landscape. Annual Review of Ecology and Systematics 32:333-65.

Miller, W. M., and R. L. Donahue, 1990. Soils - An Introduction to Soils and Plant Growth. Prentice Hall, Inc. Englewood Cliffs, New Jersey.

MRLC, 2008. Mult-resolution Land Characteristics Consortium website at http://www.mrlc.gov/

National Drought Monitor, 2008. National Drought Monitor website http://drought.unl.edu/dm/index.html

NCDWQ, 2005. NCDWQ Laboratory Sample Submission Guidance. NC DWQ Laboratory Section. June. http://h2o.enr.state.nc.us/lab/qa/sampsubguide.htm

NCDWQ, 2006a. North Carolina's 2006 303(d) List. Planning Branch. June.

NCDWQ, 2006b. Standard Operating Procedure Manual for Physical and Chemical Monitoring. Environmental Sciences Section, Intensive Survey Unit. http://h2o.enr.state.nc.us/esb/documents/PHYSICAL-CHEMICAL%20SOP.pdf

NCDWQ, 2006c. Standard Operating Procedures for Benthic Macroinvertebrates. Environmental Sciences Section, Biological Assessment Unit. July. http://h2o.enr.state.nc.us/esb/BAUwww/benthossop.pdf

NCDWQ, 2007. Stormwater Best Management Practices Manual. Provide Section/Unit/etc. July. http://h2o.enr.state.nc.us/su/Manuals_Factsheets.htm

NCDWQ, 2008a. Summary of Existing Water Quality Data for the Ararat River Watershed and Tributaries. Watershed Assessment Team. May.

NCDWQ, 2008b. Water Quality Screening Data Summary. Watershed Assessment Team. June.

NCDWQ, 2008c. Water Quality Monitoring Plan for Prioritized Subwatersheds. Watershed Assessment Team. October.

NCDWQ, 2008d. BAU benthic sampling results for EEP study in Surry County, NC. Environmental Sciences Section, Biological Assessment Unit. September.

Pinkham, R., 2000. Daylighting: New Life for Buried Streams. Rocky Mountain Institute.

Richardson J. L. and M. J. Vepraskas, 2001. Wetland Soils. Genesis, Hydrology, Landscapes and Classification. CRC Press. Boca Raton, FL.

Sedell, J. R., G. H. Reeves, F. R. Hauer, J A. Stanford and C. P. Hawkins, 1990. Role of Refugia in Recovery from Disturbances: Modern Fragmented and Disconnected River Systems. Environmental Management. Vol. 14, No 5, pp. 711-724.

Sylte, T. and C. Fischenich, 2002. Techniques for Measuring Substrate Embeddedness. ERDC TN-EMRRP-SR-36.

USEPA. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers. EPA 841-B-99-002.

USEPA. 2001. Protocol for Developing Pathogen TMDLs. EPA 841-R-00-002.

Walsh, C. J., H. R. Allison, J. W. Feminella, P. D. Cottingham, P. M. Groffman and R. P. Morgan II, 2005. The urban stream syndrome: current knowledge and the search for a cure. Journal of the North American Benthological. Society. 24(3): 706-723.

Wheeler, A. P., P. L. Angermeier and A E. Rosenberger, 2005. Impacts of New Highways and Subsequent Landscape Urbanization on Stream Habitat and Biota. Reviews in Fisheries Science, 13:141-164.

Appendices

North Carolina Stream Classifications, Water Quality Standards and Action Levels

Surface Water Classifications are designations applied to surface water bodies, such as streams, rivers and lakes, which define the best uses to be protected within these waters (for example swimming, fishing, drinking water supply) and carry with them an associated set of water quality standards to protect those uses. Each classification has associated standards that are used to determine if the designated uses are being protected. The NCDWQ Classification and Standards Unit's home page (http://h2o.enr.state.nc.us/csu/) provides details on stream classifications, water quality standards, action levels and hyperlinks to a database that will identify the surface water quality classifications for streams with the LWP area.

Water quality standards (http://www.epa.gov/waterscience/standards/about/) are the foundation of the water quality-based control program mandated by the Clean Water Act. Water quality standards define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. A water quality standard consists of four basic elements:

1. Designated uses of the water body (e.g., recreation, water supply, aquatic life, agriculture);
2. Water quality criteria to protect designated uses (numeric pollutant concentrations and narrative requirements);
3. An antidegradation policy to maintain and protect existing uses and high quality waters; and,
4. General policies addressing implementation issues (e.g., low flows, variances, mixing zones).

An Action Level represents a concentration of a contaminant in water that if reached or exceeded, certain actions may be warranted. Action Levels are applied to substances that generally are not bioaccumulative and have variable toxicity to aquatic life because of chemical form, solubility, stream characteristics (e.g. hardness and/or pH). See Table A1 below and NC DENR Division of Water Quality "Redbook" – Surface Waters and Wetlands Standards (EMC 2007) 15A NCAC 02B .2011 p. 24 (http://h2o.enr.state.nc.us/admin/rules/documents/redbook_1may07_full_with_cover.pdf)

Overall, most streams are either Class C or carry a Water Supply classification. Toms and Chinquapin Creeks were assigned a High Quality Waters (HQW) supplemental classification. Streams with Trout Water supplemental classifications are located at the border with Virginia. The classifications are important, since water quality standards may be different for different stream classes. For example new or expanding wastewater treatment facilities must provide certain levels of treatment prior to discharging to HQWs (in most cases) and development activities that require an Erosion and Sedimentation Control Plan and are within one mile of HQW must follow certain stormwater management rules.

Table 7. NC water quality standards and action levels.

Parameter	Class C
Fecal coliform (cfu/100 ml)	< 200 or if < 20% of samples are >400 [a]
Turbidity (NTUs)	50; 10 [b]
Field Readings	
Water temperature (°C)	29; 20 [b]
Dissolved oxygen (mg/L)	4.0 [c], 5.0 [d], 6.0 [b]
Total dissolved gases (% of saturation)	110%
pH	6.0 - 9.0
Metals	
Arsenic (µg/L)	50
Cadmium (µg/L)	2.0; 0.4 [b]
Chromium (µg/L)	50
Copper (µg/L)	7 [e]
Iron (mg/L)	1 [e]
Lead (µg/L)	25
Manganese (µg/L)	200 [f]
Mercury (µg/L)	0.012
Nickel (µg/L)	88
Zinc (µg/L)	50 [e]
Chlorides (mg/L)	230 [e]
Nitrate (mg/L)	10 [f]

a. Geometric mean is based on five consecutive samples taken during a 30-day period
b. Trout waters.
c. Instantaneous readings.
d. Daily mean.
e. Action level.
f. Water Supply (WS).

Table 8. Summary of benthic macroinvertebrate sampling prior to 2008..

Location *Upstream – US; Downstream – DS; Most Downstream - MDS*	Date	Indices[1] ST	EPT	NCBI	EPTBI	Bioclassification
Ararat R at NC 104 (US)	7/24/2006	.	29	.	3.88	Good
Ararat R at SR 2019 (DS)	7/25/2006	95	41	4.4	4.2	Good
Ararat R at NC 104 (US)	7/23/2001	.	25	.	4.03	Good-Fair
Ararat R at SR 2019 (DS)	7/23/2001	77	28	5.57	4.61	Good-Fair
Ararat R at SR 2080 (MDS)	7/12/2001	82	35	4.94	3.85	Good
Faulkner Cr at SR 1742 (US)	7/24/2006		20		2.89	Not Impaired
Faulkner Cr at SR 1756 (DS)	7/26/2006		20		4.79	Good-Fair
Faulkner Cr at SR 1742 (US)	2/26/2002	65	26	4.2	3.4	Not Impaired
Faulkner Cr at SR 1756 (DS)	2/26/2002	48	11	5.6	4.2	Not Rated
Flat Shoals Cr at SR 2017 (DS)	7/25/2006		25		3.30	Good-Fair
Flat Shoals Cr at SR 1827 (US)	2/26/2002	69	24	4.16	2.81	Not Impaired
Flat Shoals Cr at SR 1827 (US)	7/23/2001	.	20	.	3.46	Good-Fair
Lovills Cr at SR 1700 (US)	7/24/2006	.	23	.	4.46	Good Fair
Lovills Cr at SR 1371 (DS)	7/24/2006	73	19	5.63	4.88	Fair
Lovills Cr at SR 1700 (US)	7/24/2001	.	26	.	4.17	Good-Fair
Lovills Cr at SR 1371 (DS)	7/24/2001	67	14	6.38	4.7	Fair
Stewarts Cr at SR 2258 (DS)	7/25/2006	110	37	5.35	4.56	Good
Stewarts Cr at NC 89 (US)	7/22/2002	78	29	5.2	4.1	Good-Fair

Location *Upstream – US; Downstream – DS; Most Downstream - MDS*	Date	Indices[1] ST	EPT	NCBI	EPTBI	Bioclassification
Stewarts Cr at NC 89 (US)	7/24/2001	.	18	.	4.63	Fair
Stewarts Cr at SR 2258 (DS)	7/24/2001	78	34	5.31	4.47	Good
Rutledge Cr at SR 1774	7/25/2006		28		3.3	Good
Heatherly Cr at US 52 (DS)	7/26/2006	50	17	5.24	4.65	Not Rated
Heatherly Cr at NC 268 (US)	4/19/2004	57	15	5.8	4.7	Not Rated
Heatherly Cr at US 52 (DS)	4/19/2004	44	11	6.5	5.7	Not Rated
Heatherly Cr at NC 268 (US)	8/29/2001	50	17	5.03	4.88	Not Impaired
Heatherly Cr at US 52 (DS)	8/29/2001	44	11	5.80	5.62	Not Rated

[1] ST = **S**pecies **T**otal; EPT = Total number of EPT taxa; NCBI = North Carolina Biotic index; EPT BI = EPT Biotic Index; EPT = **E**phemeroptera + **P**lecoptera + **T**richoptera; BioClass = Biological Classification

Table 9. NPDES facilities with reported violations (January, 2002 - December 2007).

NPDES Permit No.	Facility	Parameter[1]
Minor		
NC0027944	Bassett Furniture Industries	TSS
NC0029190	NCDOT - Surry County Rest Area	BOD, Fecal Coliform, Dissolved Oxygen, Toxicity
NC0031160	NCDENR (Division of Parks & Recreation) - Pilot Mountain State Park WWTF	BOD, Fecal Coliform
NC0038822	Central Care Inc - Central Care WWTP	Total Residual Chlorine, Fecal Coliform, Ammonia-N, pH
NC0039420	Virginia DOT - Virginia DOT/I-77 Rest Area	BOD, Total Residual Chlorine, Fecal Coliform, TSS
NC0041904	Surry County Schools - Flat Rock Elementary School	Fecal Coliform, Toxicity
NC0041939	Surry County Schools - J. Sam Gentry Middle School	Total Residual Chlorine, Fecal Coliform
NC0041947	Surry County Schools - North Surry High School	BOD, Fecal Coliform
NC0041955	Surry County - Beulah Community Center	Total Residual Chlorine
Major		
NC0021121	City Of Mount Airy - Mount Airy WWTP	Mercury, TSS, Lead, Cyanide, Fecal Coliform, Toxicity
NC0026646	Town of Pilot Mountain - Pilot Mountain WWTP	TSS

[1]TSS = Total Suspended Solids, BOD = Biochemical Oxygen Demand

Table 10. Chemical analyses, methods and reporting limits.

Parameter	EPA method	Reporting limit
Fecal coliform	600/8-78-017	1 colony/ 100mL
Turbidity	180.1	1 NTU
Suspended residues	160.2, 160.4	2.5-12 mg/L
Organic carbon	415.1	5 mg/L
Nutrients		
NH_3 as N	350.1, 350.2	0.02 mg/L
NO_2+NO_3 as N	353.2	0.02 mg/L
TKN as N	350.1, 351.2	0.20 mg/L
Total P	365.1	0.02 mg/L
Metals		
Aluminum (Al)	200.7/200.8	50 µg/L
Arsenic (As)	200.8 /200.9	5 µg/L
Cadmium (Cd)	200.8 /200.9	2.0 µg/L
Calcium (Ca)	200.7	0.10 mg/L
Chromium (Cr)	200.8 /200.7	25 µg/L
Copper (Cu)	200.8 /200.9	2.0 µg/L
Iron (Fe)	200.7	50 µg/L
Lead (Pb)	200.8 /200.9	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	10 µg/L
Potassium (K)	200.7	0.10 mg/L
Silver (Ag)	200.8/200.9	5.0 µg/L
Sodium (Na)	200.7	0.10 mg/L
Zinc (Zn)	200.8 /200.7	10 µg/L
Field Measurements		
Dissolved oxygen	--	0.1 mg/L
pH	--	0.1 S.U.
Spec. conductance	--	1 µS/cm at 25°C
Water temperature	--	0.1°C

Table 11. Benthic data 2008.

Stream	HOGAN CR	ARARAT R	ARARAT R	FLAT SHOAL CR	TOMS CR	CHINQUAPIN CR
Site Location	SR 2081	NC 104	US 52	SR 2018	SR 1830	SR 1830
County	Surry	Surry	Surry	Surry	Surry	Surry
Collection date	39706	39709	39709	39707	39707	39707
BAU sample number	10565	10575	10574	10569	10568	10567
Sample method	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale
Criteria	Summer/ Mountain	Summer/ Mountain	Summer/ Mountain	Summer/ Mountain	Summer/ Mountain	Summer/ Mountain
Richness						
Ephemeroptera	17	15	10	11	12	14
Plecoptera	2	1	2	3	3	3
Trichoptera	8	10	10	6	3	4
Total EPT	27	26	22	20	18	21
Odonata	6	7	9	8	8	7
Megaloptera	0	2	2	2	2	2
Coleoptera	10	8	7	7	8	10
Chironomidae	27	30	11	12	13	25
non-Chironomidae Diptera	7	6	3	3	4	5
Oligochaeta	2	3	3	1	1	2
Mollusca	4	5	3	1	2	3
Other taxa	3	2	4	0	3	1
Total taxa richness	86	89	64	54	59	76
Other biological metrics						
EPT abundance	109	93	81	91	79	80
EPT Biotic Index	4.39	4.42	5.00	4.86	4.57	4.94
NCBI	5.17	5.51	6.05	5.37	5.26	5.30
Bioclassification	Good-Fair	Good-Fair	Not Rated	Good-Fair	Not Rated	Good-Fair

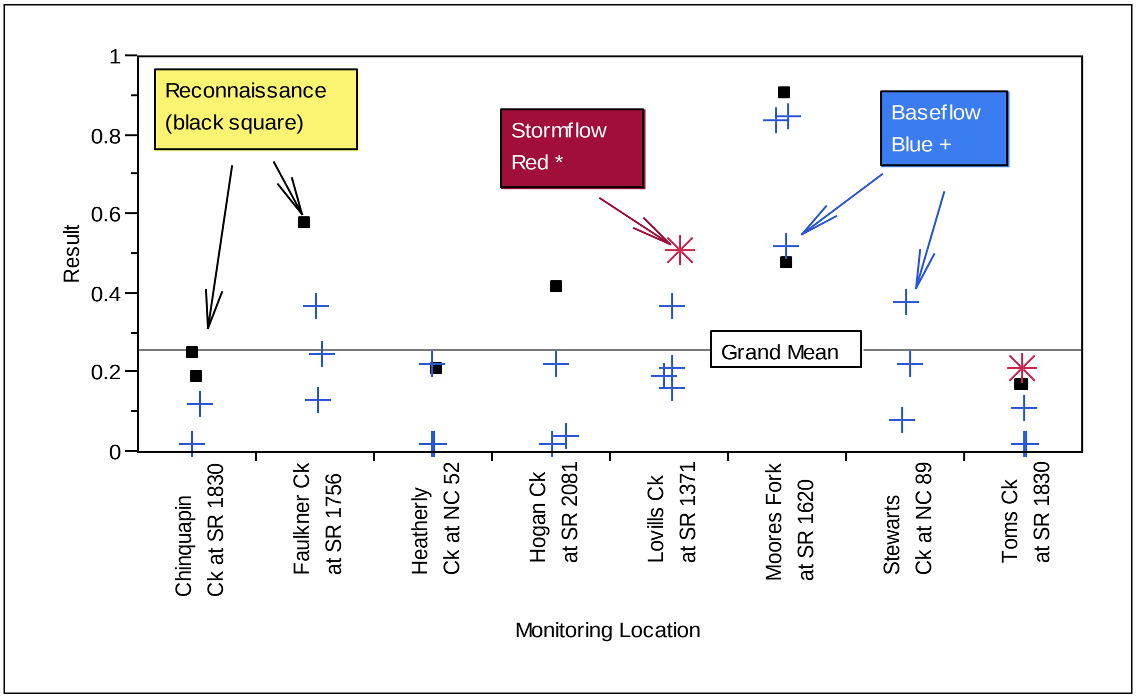
Table 10 Continued.

Stream	HEATHERLY CR	BULL CR	FAULKNER CR	FAULKNER CR	LOVILLS CR	LOVILLS CR
Site Location	US 52	SR 2038	SR 1742	SR 1756	SR 1700	SR 1371
County	Surry	Surry	Surry	Surry	Surry	Surry
Collection date	39707	39706	39709	39709	39708	39708
BAU sample number	10566	10564	10576	10577	10572	10573
Sample method	Qual 4	Full Scale	Qual 4	Full Scale	Full Scale	Full Scale
Criteria	Summer/ Mountain	Summer/ Mountain	Summer/ Mountain	Summer/ Mountain	Summer/ Mountain	Summer/ Mountain
Richness						
Ephemeroptera	7	11	7	9	14	5
Plecoptera	1	0	2	0	1	0
Trichoptera	4	4	6	5	10	8
Total EPT	12	15	15	14	25	13
Odonata	1	7	5	8	10	7
Megaloptera	2	2	1	3	2	0
Coleoptera	4	7	6	8	7	7
Chironomidae	8	22	8	18	21	15
non-Chironomidae Diptera	2	4	2	5	3	2
Oligochaeta	3	2	4	0	2	2
Mollusca	1	2	2	5	4	3
Other taxa	1	3	0	2	3	3
Total taxa richness	34	64	43	63	77	52
Other biological metrics						
EPT abundance	61	68	57	42	95	35
EPT Biotic Index	5.06	5.27	4.05	4.50	4.29	4.73
NCBI	5.24	6.03	4.82	6.08	5.42	6.68
Bioclassification	Not Rated	Not Rated	Not Impaired	Not Rated	Good-Fair	Fair

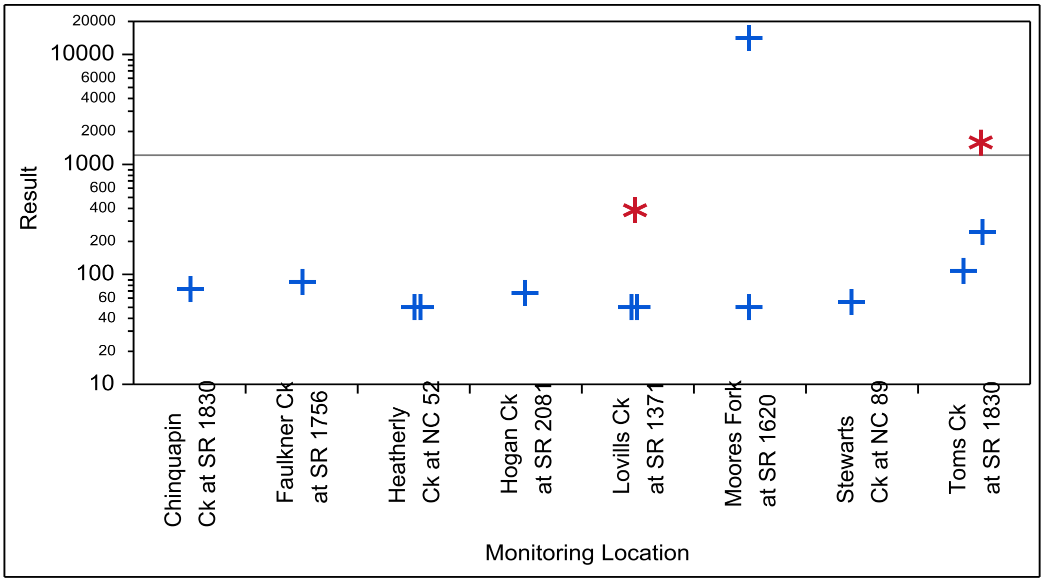
Table 10 Continued

Stream	STEWARTS CR	MOORES FK
Site Location	NC 89	SR 1620
County	Surry	Surry
Collection date	39708	39708
BAU sample number	10571	10570
Sample method	Full Scale	EPT
Criteria	Summer/ Mountain	Summer/ Mountain
Richness		
Ephemeroptera	15	12
Plecoptera	1	1
Trichoptera	10	7
Total EPT	26	20
Odonata	8	0
Megaloptera	2	0
Coleoptera	10	0
Chironomidae	25	0
non-Chironomidae Diptera	5	0
Oligochaeta	3	0
Mollusca	4	0
Other taxa	5	0
Total taxa richness	88	58
Other biological metrics		
EPT abundance	114	86
EPT Biotic Index	4.61	5.54
NCBI	5.40	---
Bioclassification	Good-Fair	Good-Fair

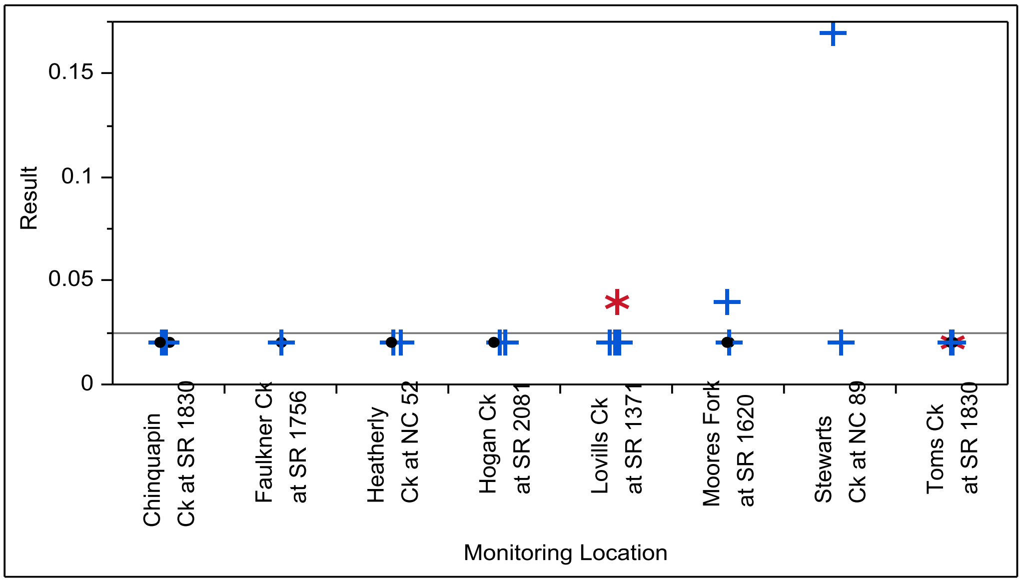
Laboratory Results.



Explanation of the symbols used on the graphs

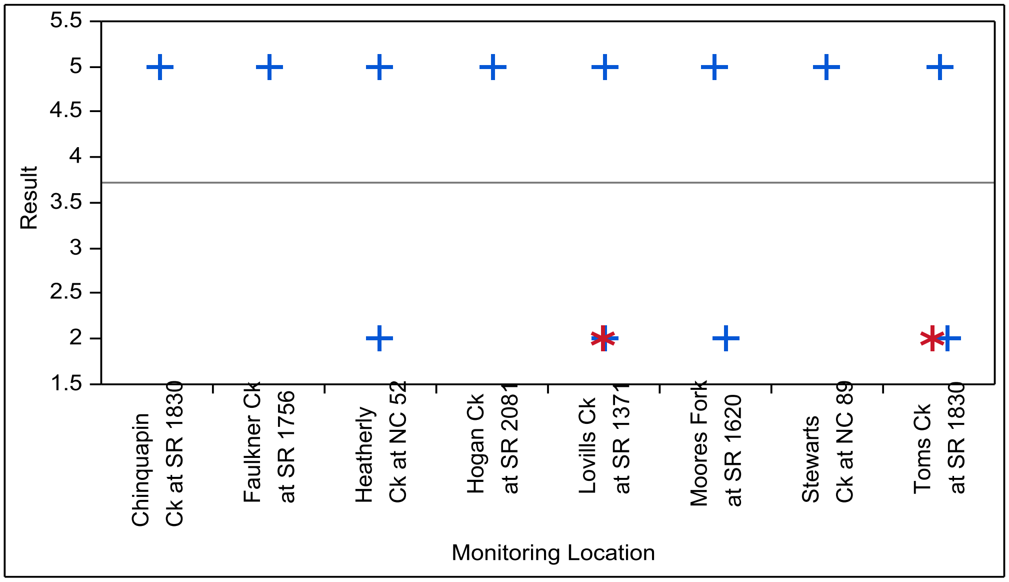


Aluminum (µg/L)



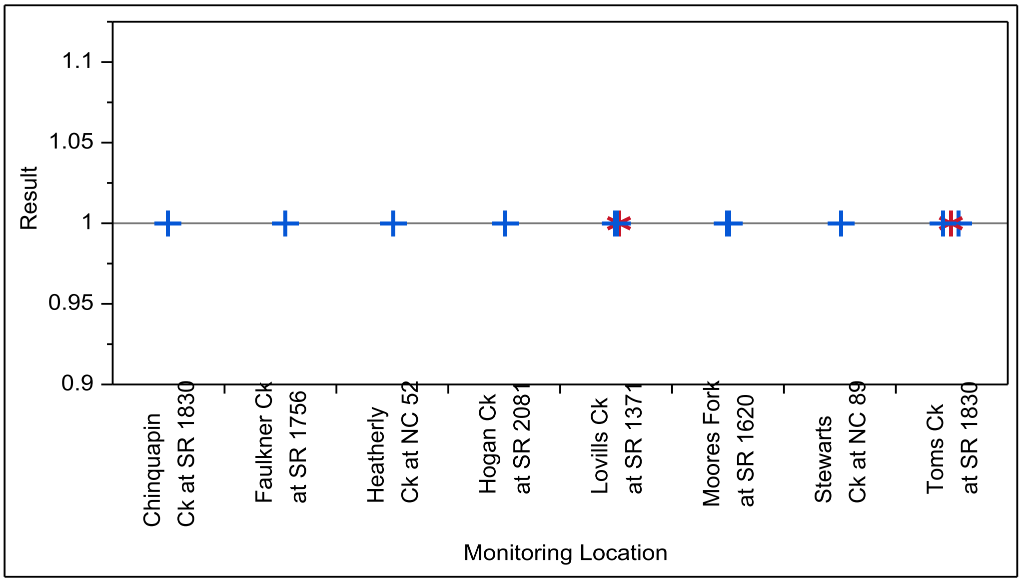
Ammonia Nitrogen as N (mg/L)

Four out of 37 results were greater than the detection level (0.02 mg/L)



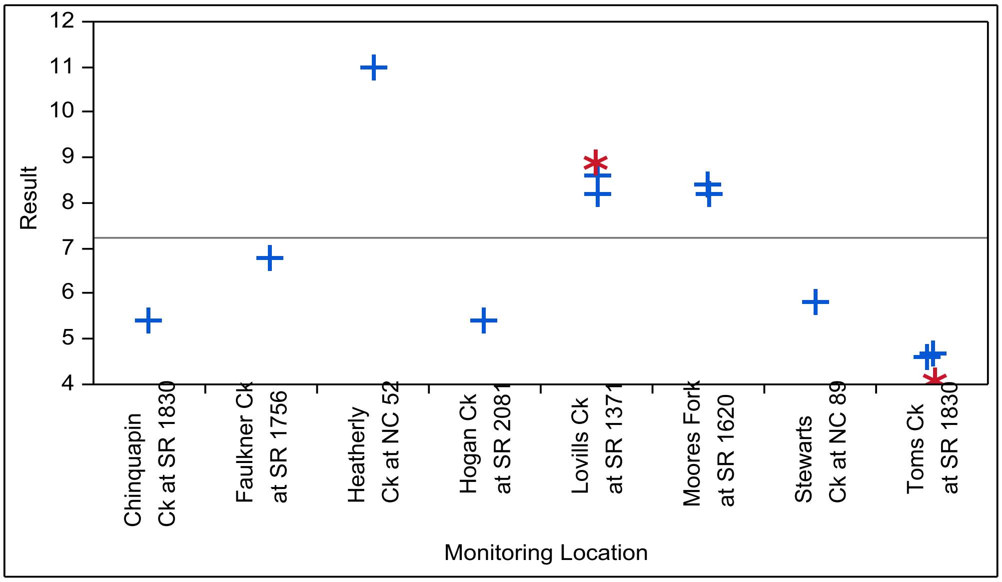
Arsenic (µg/L)

None of the 14 results exceeded the detection levels (5 µg/L or 2 µg/L)

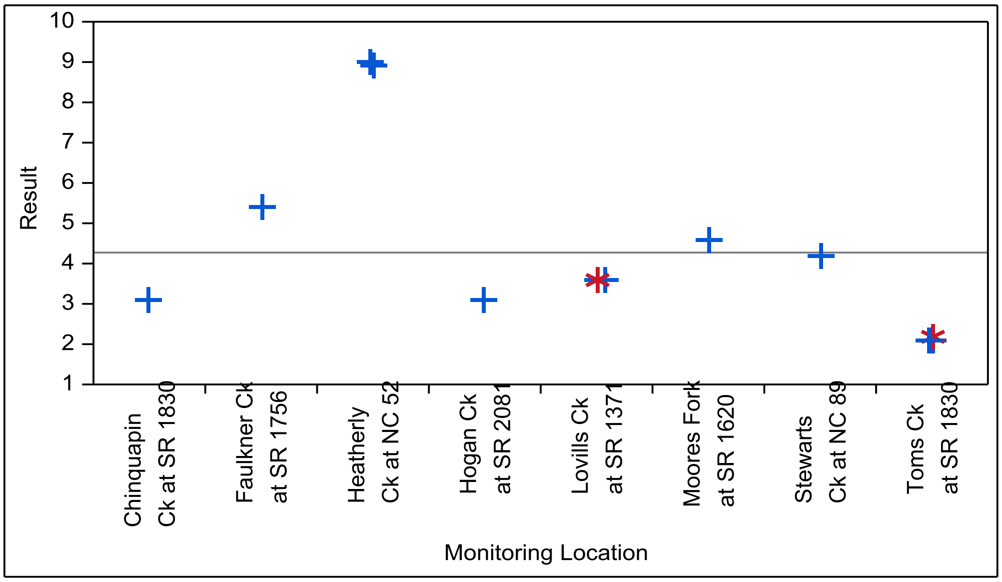


Cadmium (µg/L)

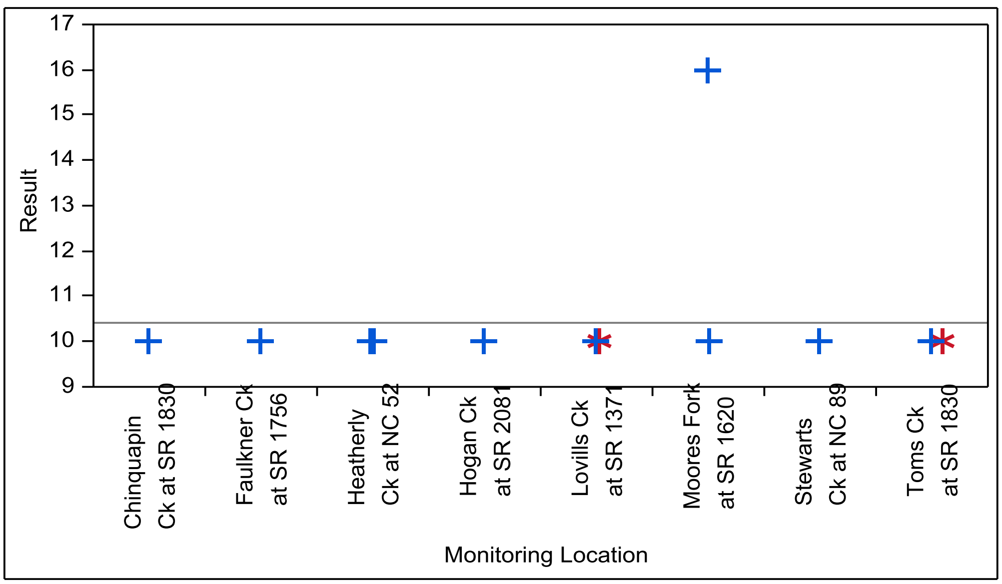
None of the 14 results exceeded the detection level (1 µg/L)



Calcium (mg/L)

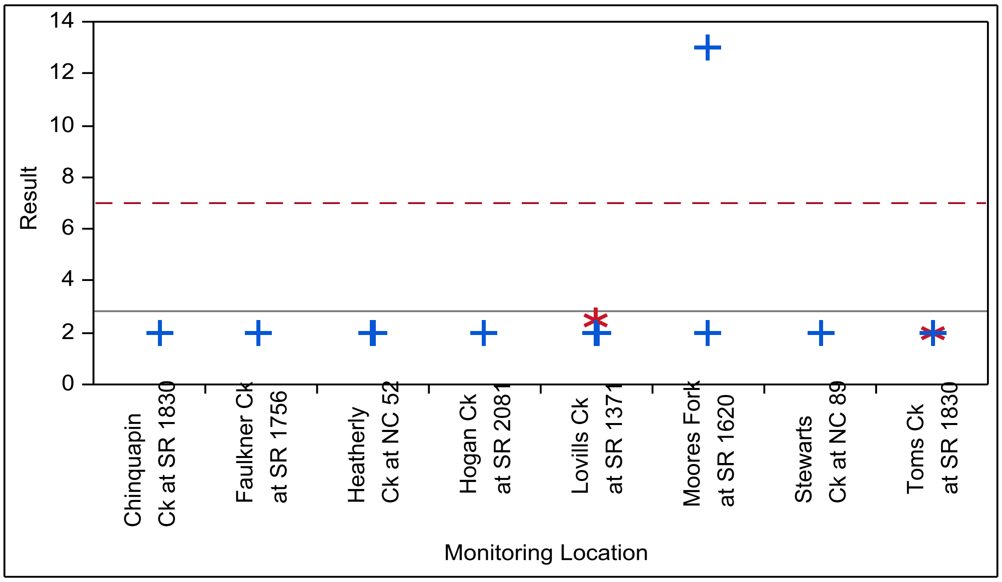


Chloride (mg/L)



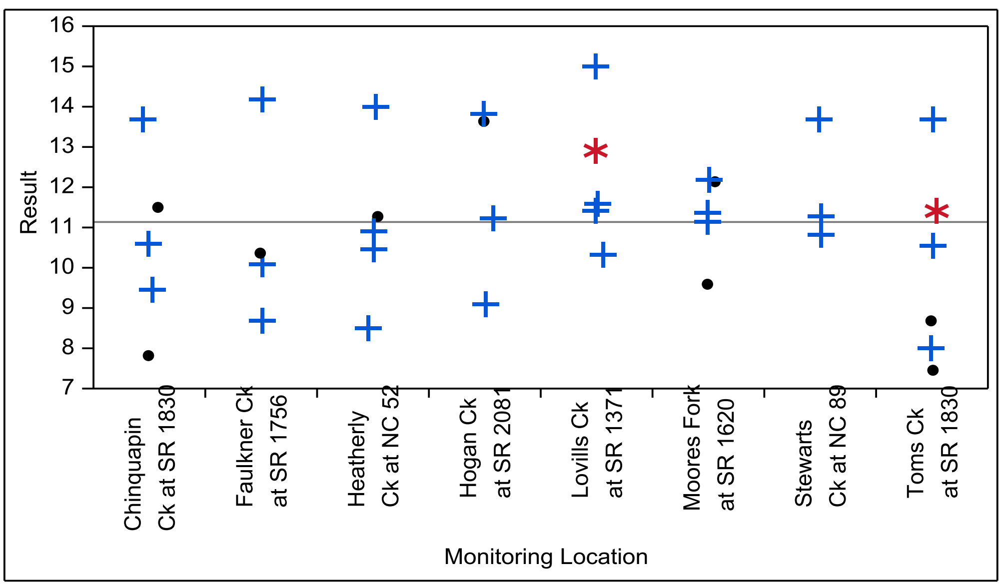
Chromium (µg/L)

One of the 14 results (Moores Fr on 12/3/2008) exceeded the detection level (10 µg/L). The water quality standard for chromium for freshwater is 50 µg/L.

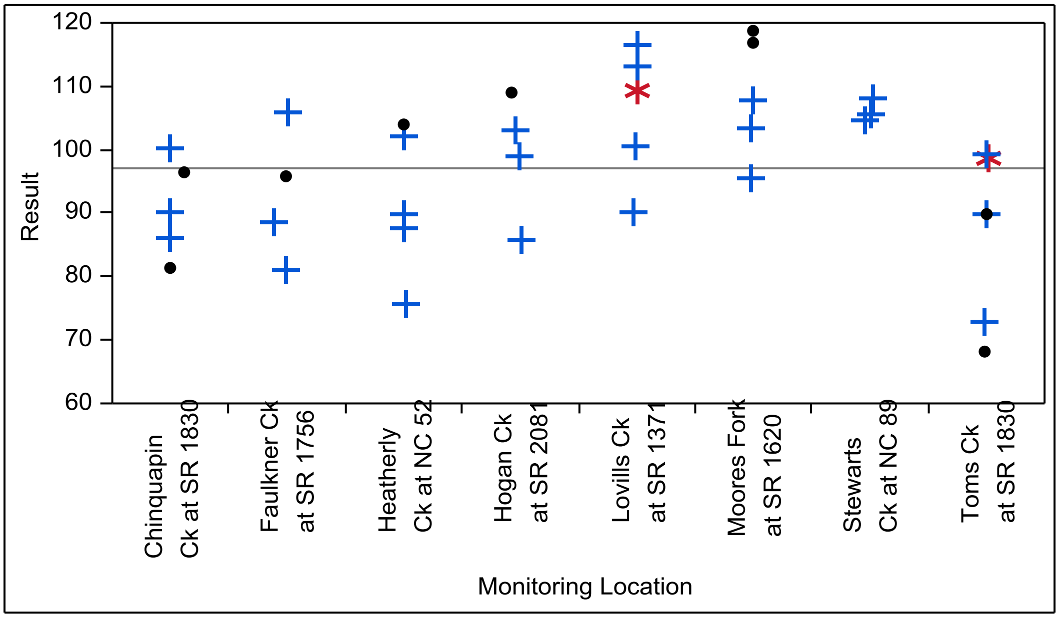


Copper (µg/L)

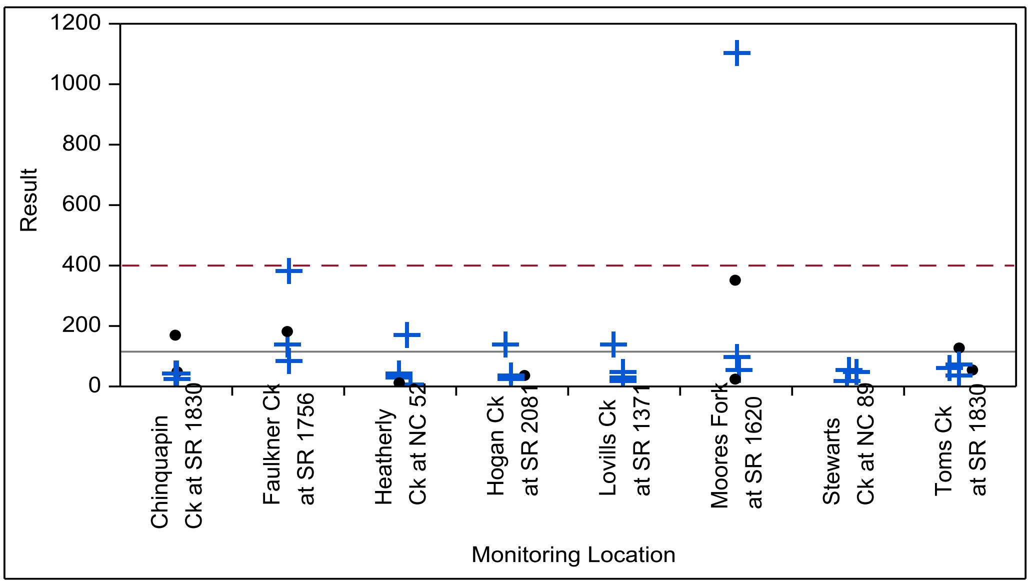
Two of the 14 results exceeded the detection level (2 µg/L). These two results were from: 1) Moores Fr on 12/3/2008; stormflow result (2.5 µg/L) and 2) Lovills Ck at SR 1371 on 1/6/2009; baseflow (13.0 µg/L. The water quality action level for copper is 7.0 µg/L (red dashed line)



Dissolved Oxygen (mg/L)

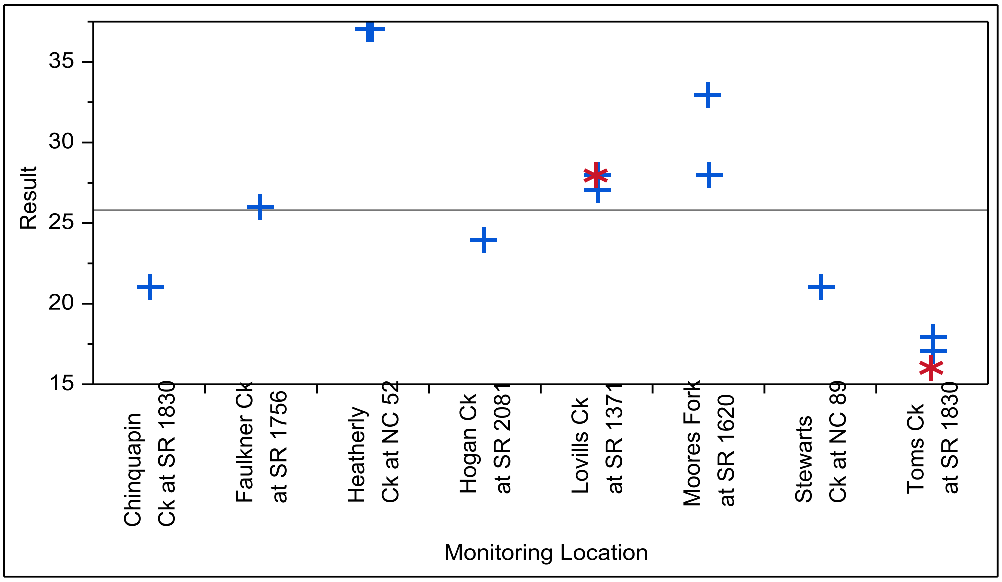


Dissolved Oxygen Saturation (%)

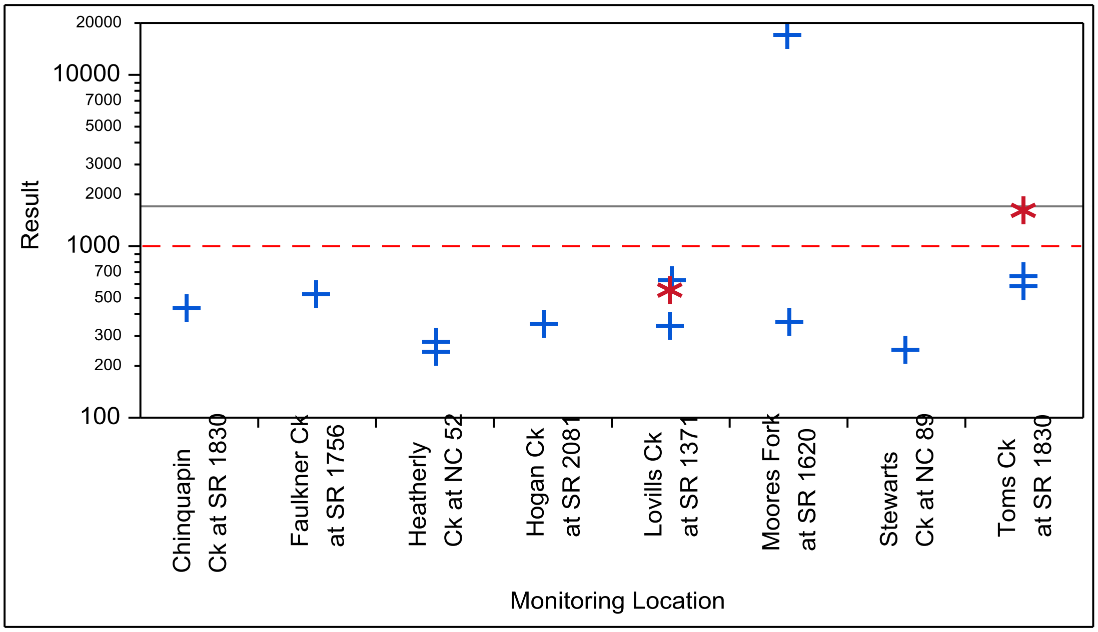


Fecal Coliform (cfu/100 ml)

All 35 results were from samples that exceeded the holding time for analysis.
The dashed line at 400 cfu/100 ml represents an evaluation level for fecal coliform bacteria.

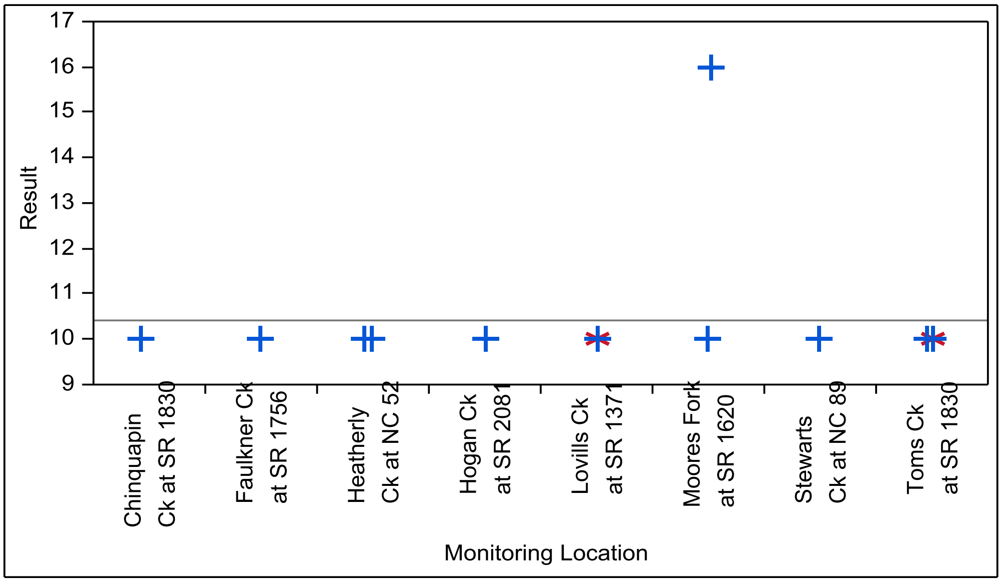


Hardness (mg/L)



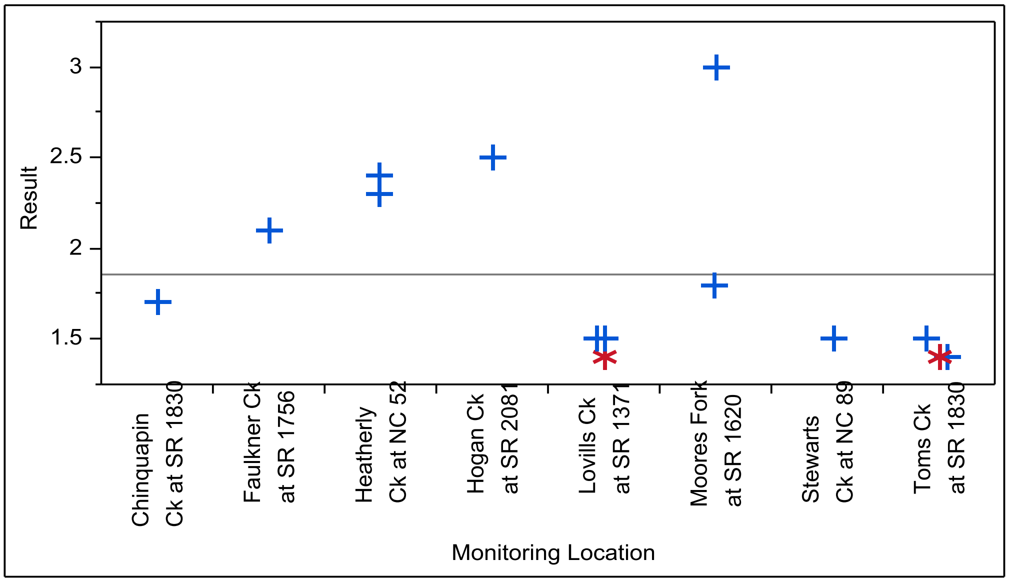
Iron (µg/L)

The dashed red line at 1000 µg/L represents the water quality action level.
Iron is common in piedmont soils.

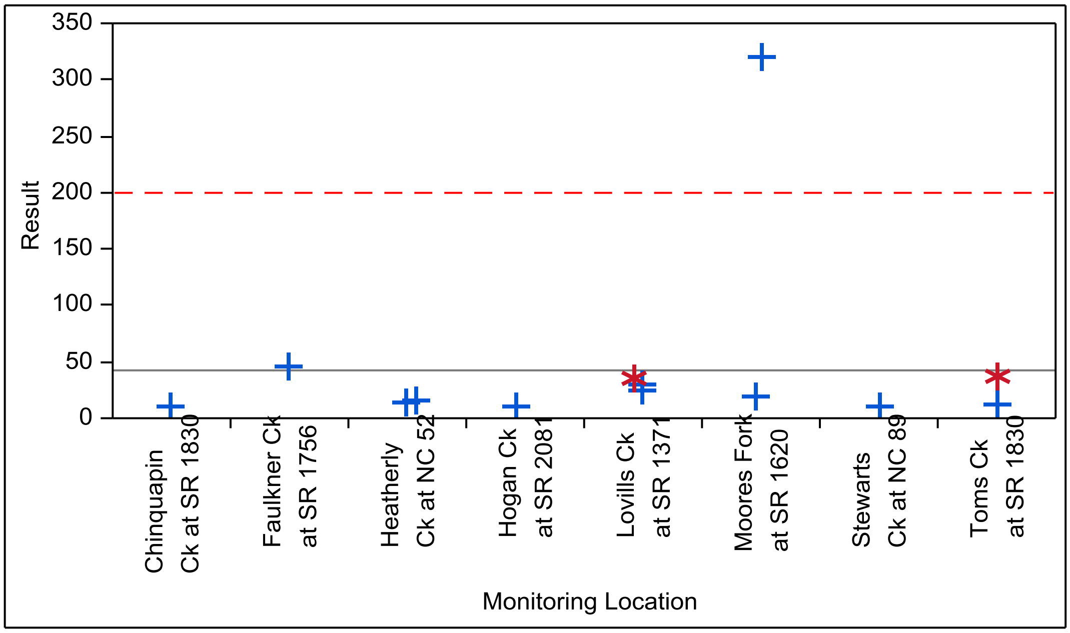


Lead (µg/L)

One of the 14 results exceeded the detection level (10 µg/L).
The one baseflow result that exceeded the detection level occurred at Moores Fork on 12/3/2008.
The water quality standard for lead is 25 µg/L. See 15A NCAC 02B .0211 (3) (l) (viii) for details.

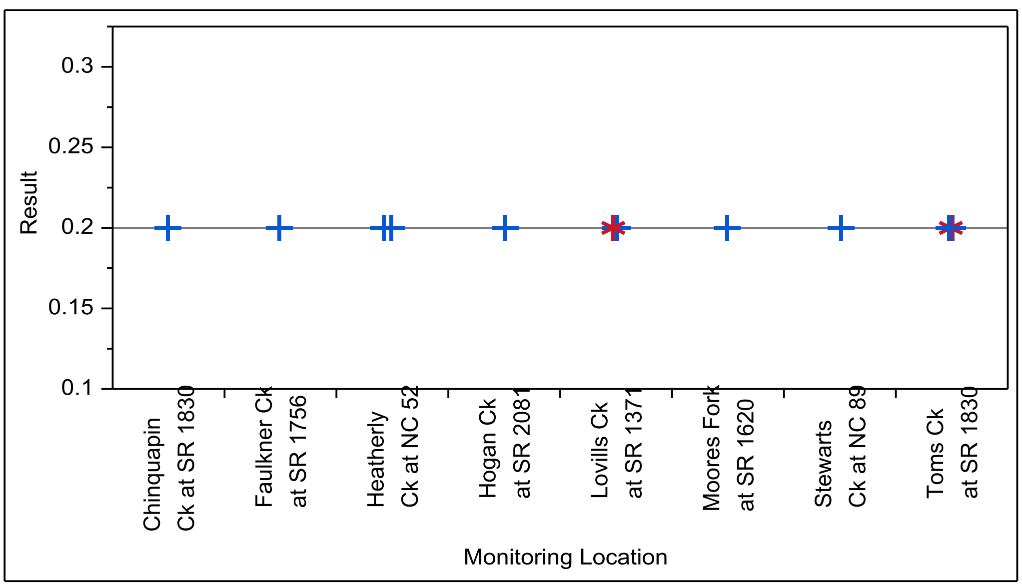


Magnesium (mg/L)



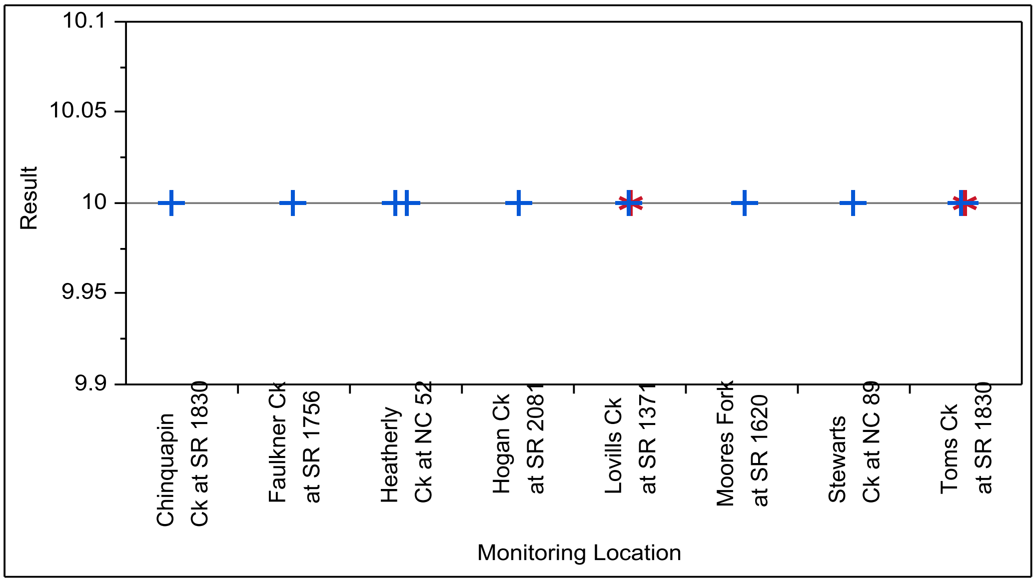
Manganese (µg/L)

Thirteen of the 14 results exceeded the detection level (10 µg/L) One baseflow result (320 µg//L; on 12/3/2009) exceeded the water quality standard of 200 µg/L (red dashed line) for bodies of water classified as a Water Supply. Moores Fork is classified as WS-IV.

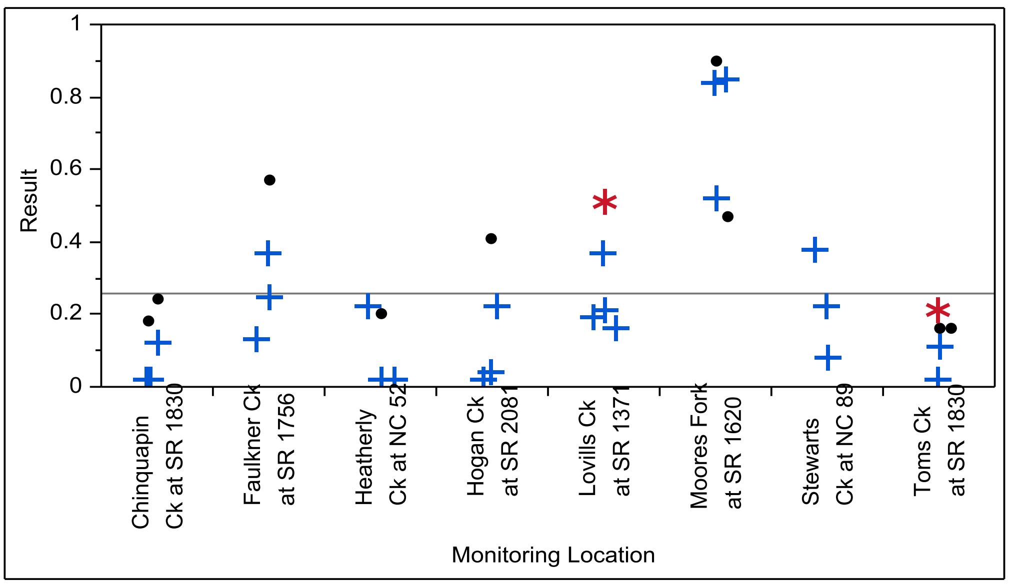


Mercury (µg/L)

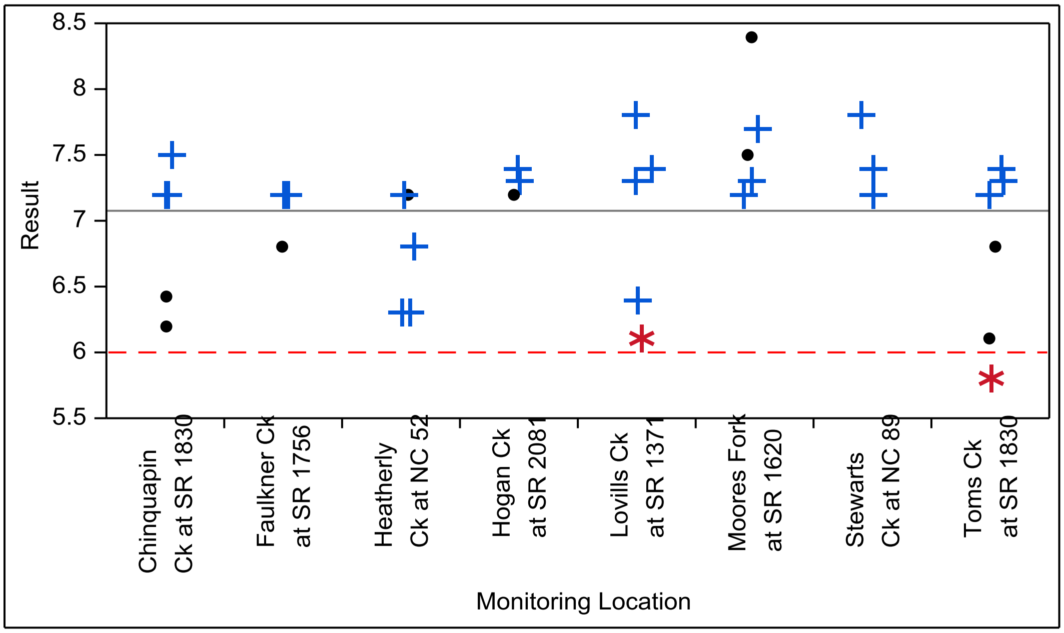
All 14 results were below the laboratory detection level of 0.2 µg/L



Nickel (µg/L)
All 14 results were below the laboratory detection level of 10.0 µg/L

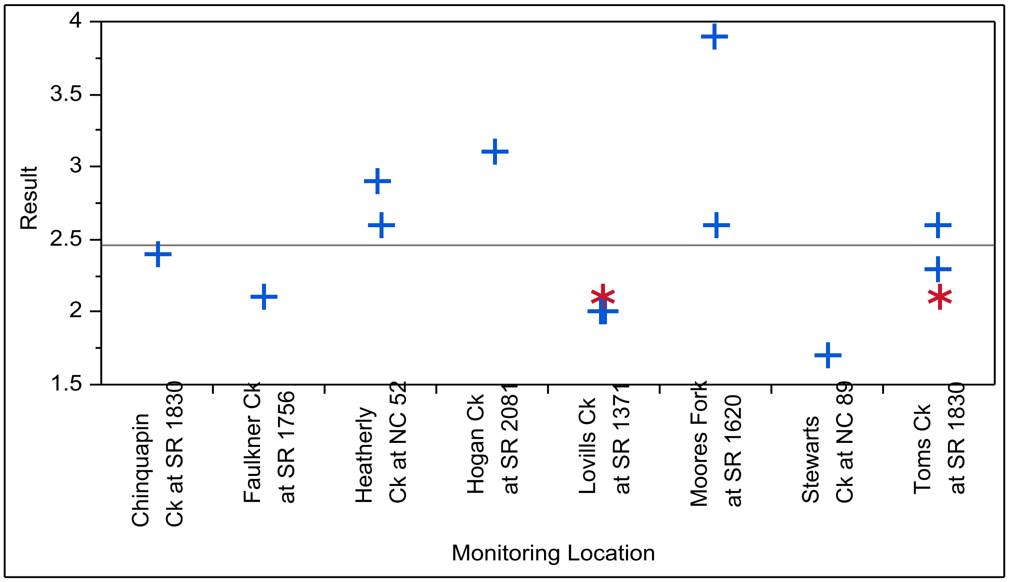


Nitrite/Nitrate Nitrogen as N (mg/L)

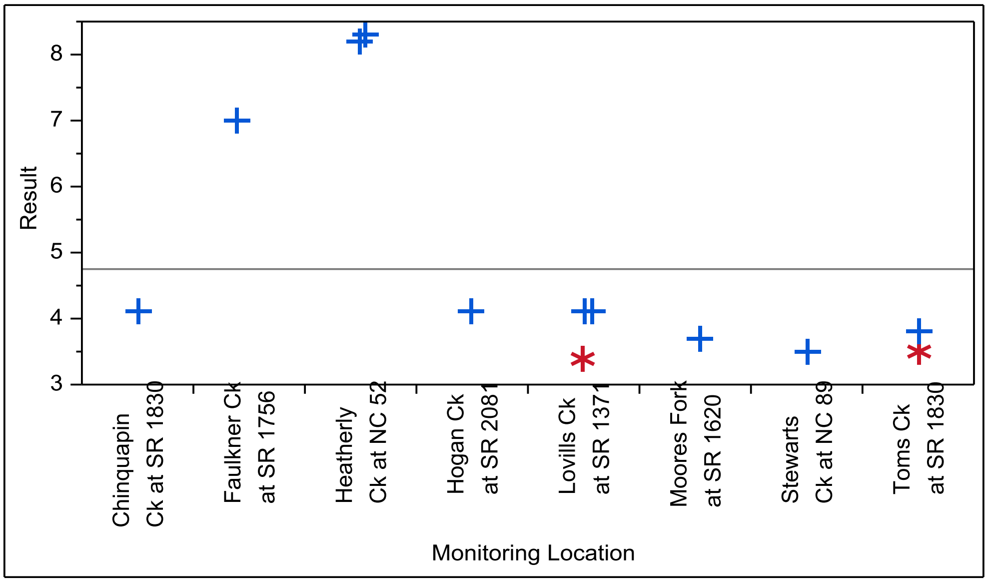


pH (SU)

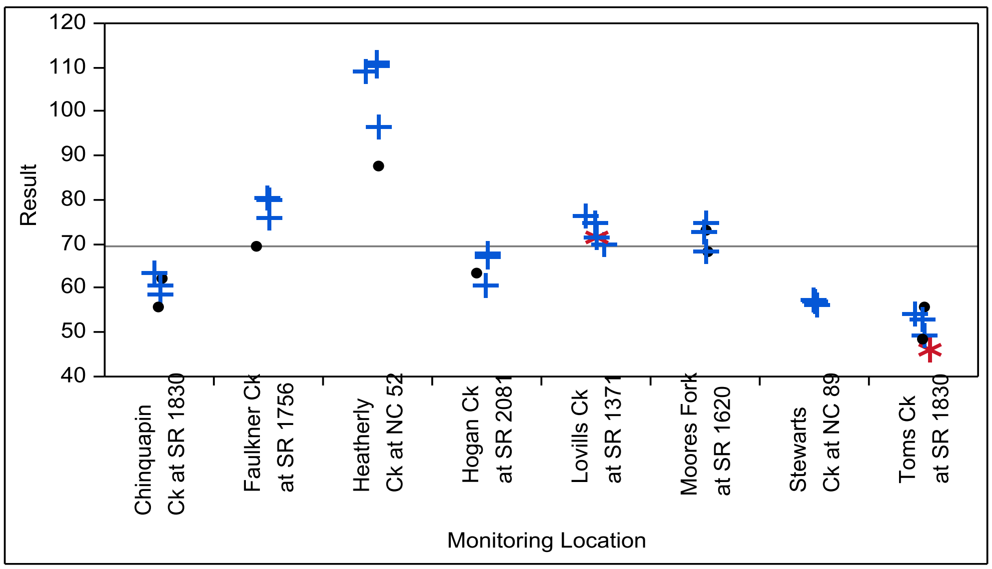
One stormflow result (5.8 su) from Toms Creek (1/6/2009) is below the lower (6.0 su) water quality standard for pH



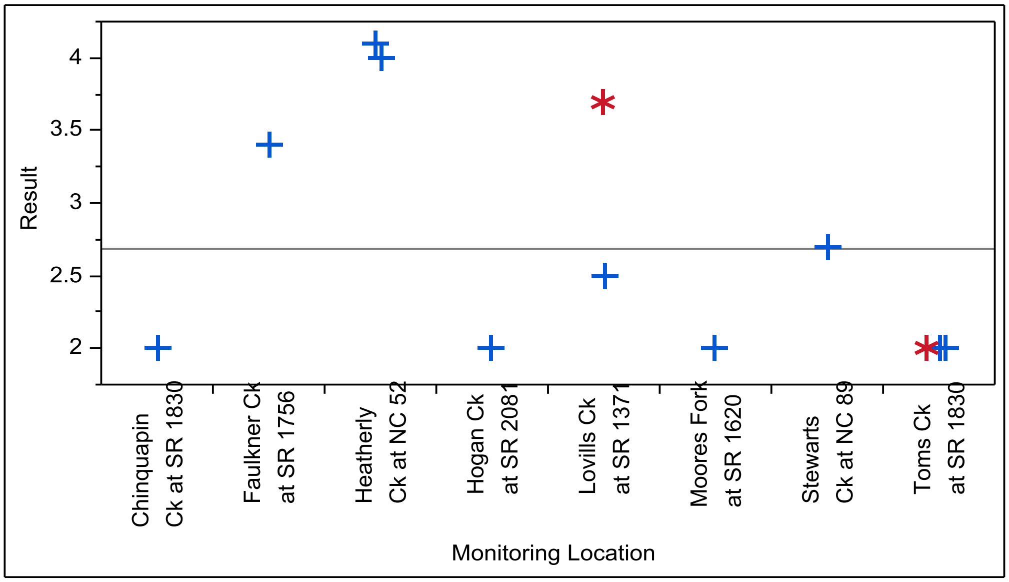
Potassium (mg/L)



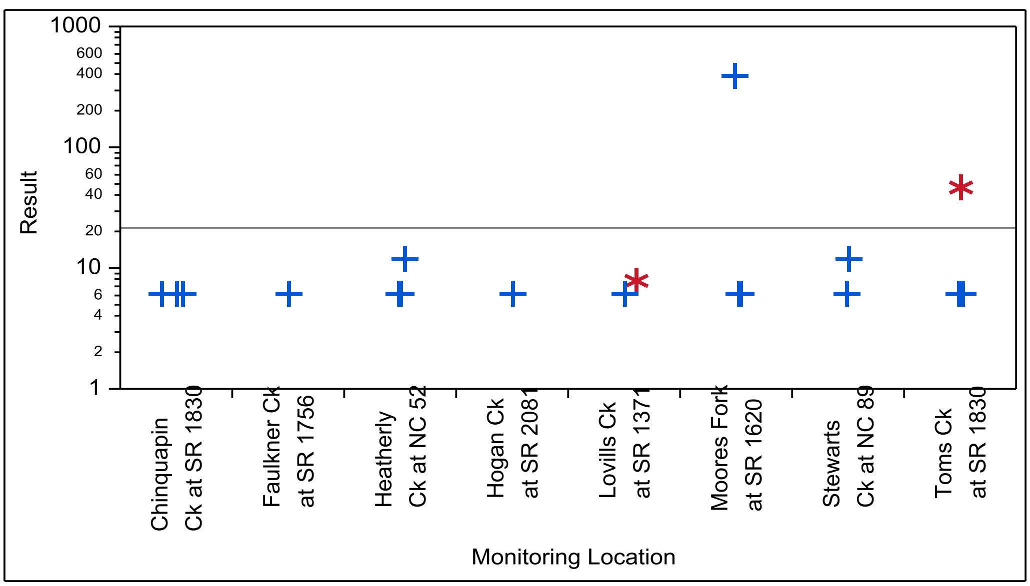
Sodium (mg/L)



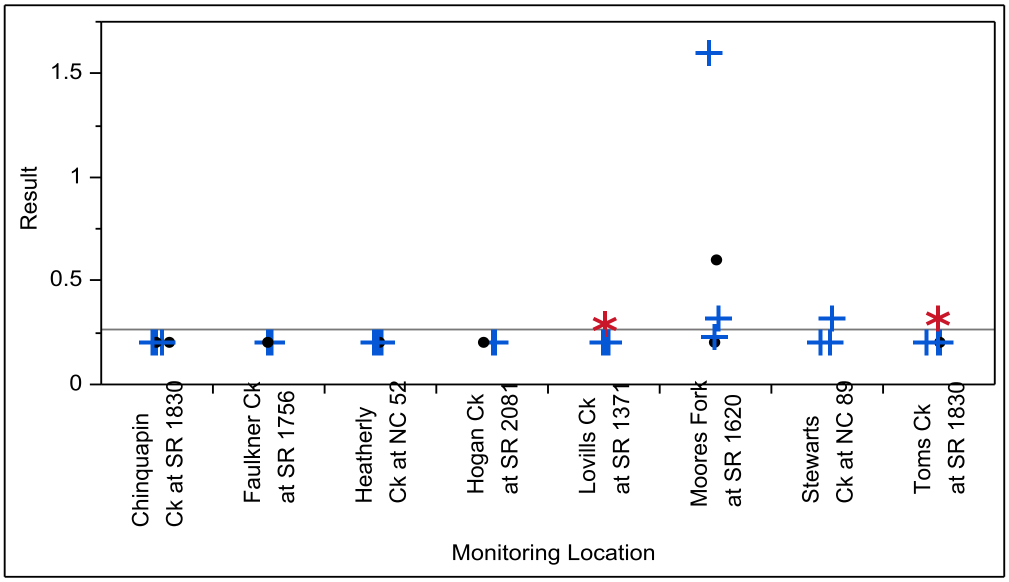
Specific Conductance (µS/cm at 25° C)



Sulfate (mg/L)

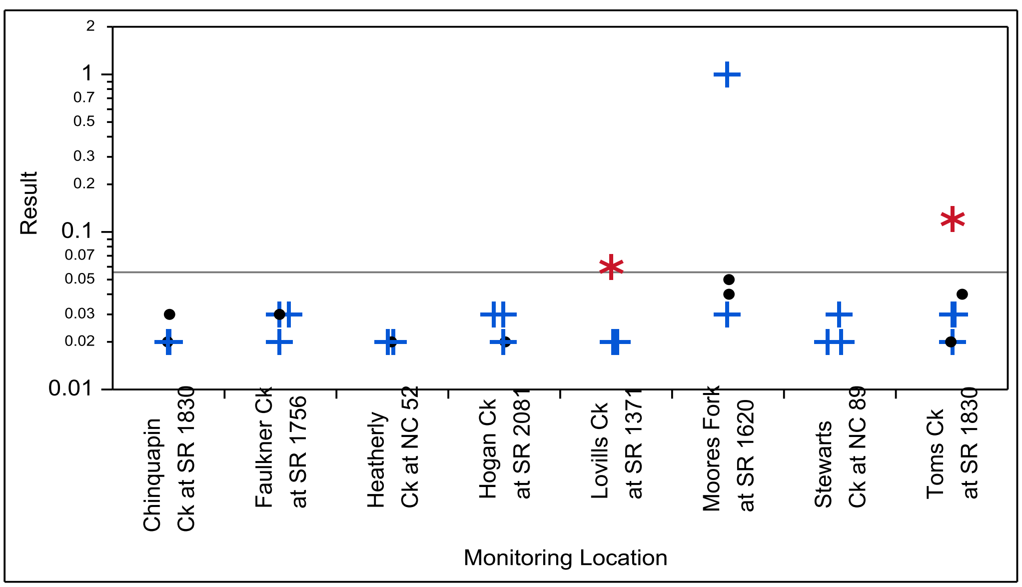


Suspended Residue (mg/L)

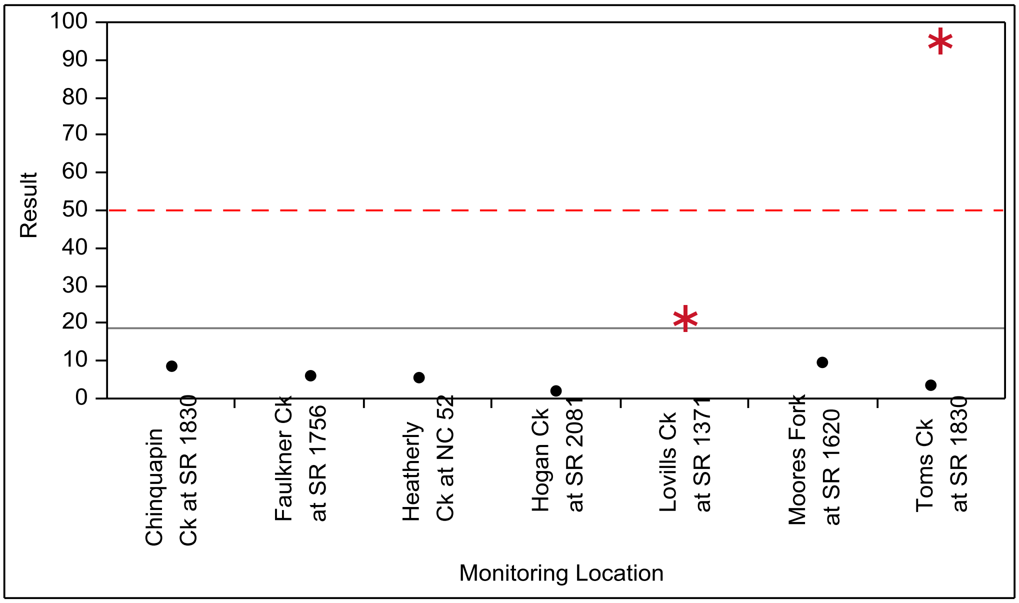


Total Kjeldahl Nitrogen as N (TKN) (mg/L)

Seven of the 35 results exceeded the laboratory detection level for TKN (0.2 mg/L)

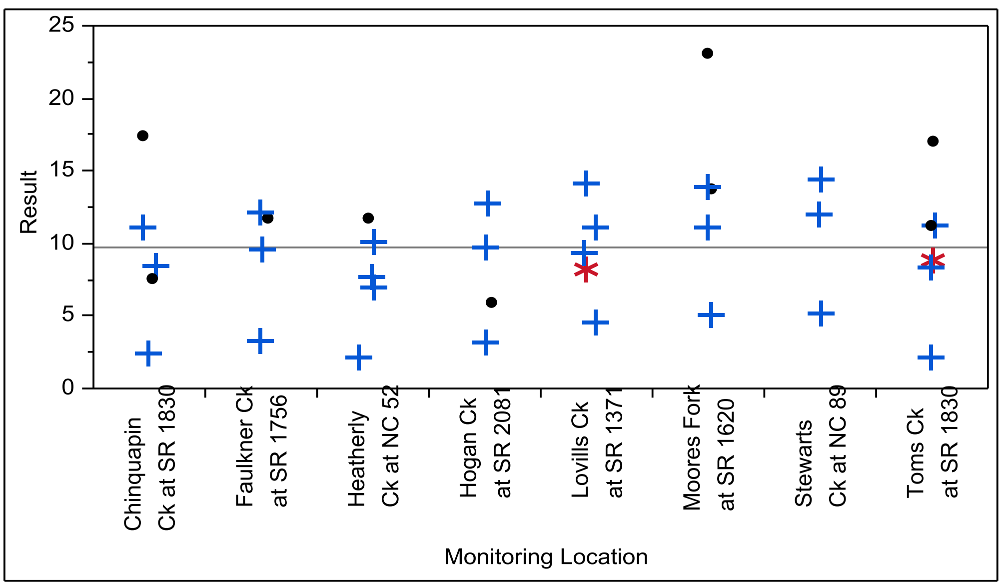


Total Phosphorus (mg/L)

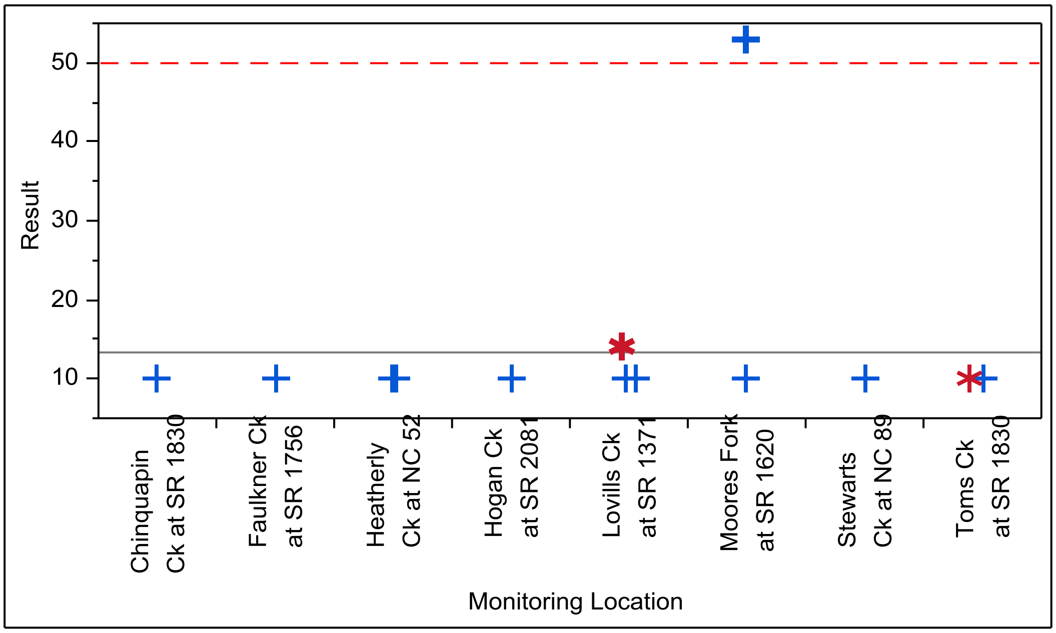


Turbidity (NTU)

Red dashed line (50 NTU) represents the water quality standard



Water Temperature (Celsius)



Zinc (µg/L)

Two of the 14 results for zinc exceeded the laboratory detection level of 10 µg/L. The water quality action level for zinc is 50 µg/L. (red dashed line). 1) Stormflow sample (14 µg/L) at Lovills Cr on 1/6/2009 and 2) Baseflow sample (53 µg/L) at Moores Fork on 12/3/2008.