Division of Water Quality
Biological Assessment Unit, November 16, 2009

MEMORANDUM

To: Anjie Ackerman (Environmental Planner, Ecosystem Enhancement Program)

Through: Eric Fleek (Acting Biological Assessment Unit Supervisor) EF
and Jay Sauber (Acting Environmental Sciences Section Chief)

From: Victor Holland (Environmental Specialist) VH

Subject: Ecosystem Enhancement Program (EEP) Baseline Macroinvertebrate Monitoring in the Goose and Crooked Creek Drainages (Yadkin Subbasin 12), Union County, July 2009.

EXECUTIVE SUMMARY

In July of 2009, Anjie Ackerman (EEP) requested that the BAU conduct benthic macroinvertebrate sampling at 10 sites within the Goose Creek and Crooked Creek catchments to support the development of a Local Watershed Plan (LWP) and for potential uses in both wetland and stream restoration projects (NCDWQ 2009). Barnes Creek, a tributary to the Uwharrie River in the Yadkin Basin was the Slate Belt Level IV Ecoregion reference stream selected for this study. Four of the 10 selected sampling locations in the Goose and Crooked Creek catchments were not sampled due to lack of sufficient stream flows. As requested, benthic macroinvertebrate sampling was conducted at seven locations during the summer of 2009.

All Crooked and Goose Creek macroinvertebrate monitoring stations within this study received Poor or Fair bioclassifications indicating continued impaired water quality in the catchment.
Many factors are potentially contributing to its degraded water quality including point and nonpoint sources. Increases in urban activities near headwater reaches may be leading to increased erosion, scour, sediment load, and periodic toxicity. Additionally, several permitted Wastewater Treatment Plants (WWTPs) are located upstream from benthic sampling locations likely contributing to more tolerant macroinvertebrate assemblages.

Studies suggest drought conditions in the Slate Belt Level IV Ecoregion continue to affect benthic communities up to one year following recovery (NCDWQ 2004). Severe drought conditions observed in 2007 and 2008 without persistent flows subsequent to the drought may contribute to lack of macroinvertebrate colonization. Fluctuating drought conditions could lead to escalated point and nonpoint source pollution via pollutants remaining in stagnant streams for longer periods and/or accumulated pollutant runoff during storm events. Either of these factors could contribute to inputs of higher pollutant concentrations and the streams ultimate degraded state, especially at headwater sampling locations in the Slate Belt Ecoregion. The attached report details the data collection, analysis, and conclusions.

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Macroinvertebrate Monitoring in Goose and Crooked Creek (Yadkin HUC 03040105), July 2009

INTRODUCTION

Goose Creek and Crooked Creek flow northeasterly into Rocky River. North and South Fork Crooked Creek are tributaries to Crooked Creek and Duck Creek is a tributary to Goose Creek (Figure 1). The Goose Creek catchment has been more comprehensively studied than the Crooked Creek drainage in the last decade due to the presence of the Federally Endangered Carolina heelsplitter (*Lasmigona decorata*). Increased urbanization in the headwaters of Goose and Crooked Creeks is a continuing concern regarding this endangered mussel species and water quality in general. The goal of this study is to determine current water quality status of both the headwaters and downstream segments of Goose and Crooked Creeks. Water chemistry and fecal coliform counts will occur in conjunction with benthic samples (NCDWQ 2009). An additional goal is to identify segments of the streams with potential for further stormwater Best Management Practices (BMPs) and/or stream/wetland restoration efforts.

WATERSHED DESCRIPTION

The Goose and Crooked Creek drainages are located in rapidly developing areas within Mecklenburg and Union counties, NC in the Yadkin River Basin (HUC 03040105). Barnes Creek (HUC 03040103), a tributary to the Uwharrie River, is the reference site sampled in the Yadkin-Pee Dee River Basin. This reference site is located approximately 80 miles southeast of the Goose and Crooked Creek catchments. All macroinvertebrate monitoring stations (Table 3 and Figure 1) are located in the Carolina Slate Belt Level IV Ecoregion (Griffith et al. 2002). This ecoregion extends from southern Virginia to eastern Georgia. It is known to exhibit poorly sustained base flows due to thin soils with low water storage capacities during base-flow periods (Weaver et al. 1998).

Upstream reaches are experiencing rapid urbanization while downstream locations are dominated by rural areas with the presence of some active agriculture. Potential point source stressors include current active NPDES dischargers within these catchments. All active permitted NPDES dischargers upstream from proposed benthic sampling locations (Figure 1) are listed in Table 2. There is only one active major NPDES permitted discharger (discharge > 1 MGD) located within the sampling area. Two active Ambient Monitoring System (AMS) stations are located within the Goose Creek catchment (Table 1 and Figure 1). There are no AMS stations within the Crooked Creek drainage.

Duck Creek, North and South Fork Crooked Creek, Crooked Creek and Goose Creek are all Class C waters from their source to eventual confluence with Rocky River. Duck Creek, North and South Fork Crooked Creek, and Goose Creek are currently listed as impaired on the 303d list for fecal coliform bacteria and biological integrity (benthos). Main-stem Crooked Creek downstream from North and South Fork Crooked Creek is not currently listed as impaired. Causes of impairment are likely due to both nonpoint and point source stressors, including increased urban runoff leading to flow flashiness and scour impacts.

PREVIOUS MONITORING WITHIN THE STUDY AREA

Table 4 shows results of all historic macroinvertebrate sampling locations within the study area. North Fork Crooked Creek has rated Good-Fair or Fair since 1995. South Fork Crooked Creek was only sampled in 1995 when it rated Fair. In 2009 this location was not sampled due to low flow and water levels. Crooked Creek at SR 1547 increased from a Fair to Good-Fair rating between 1996 and 2001. Duck Creek rated Fair in 1998 and could not be sampled in 2009 due

to low flow conditions. Goose Creek at SR 1524 and SR 1525 received Good-Fair and Poor ratings respectively in 1998. From 1996 to 2001 Goose Creek at U.S. 601 was rated Poor based on benthic samples but in 2006 was rated Fair suggesting slightly better water quality. Goose Creek at SR 1547 was rated Fair in 1998 and was not sampled again until 2009. Barnes Creek at SR 1303 is the Slate Belt Ecoregion reference stream selected for this study and has rated either Good or Excellent since 1985.

In 2009, four out of the 10 macroinvertebrate monitoring locations in the Goose and Crooked Creek catchments were not sampled due to lack of sufficient flows including: Duck Creek at U.S. 601, South Fork Crooked Creek at SR 1515 and SR 1367, and North Fork Crooked Creek at SR 1520.

METHODS

Habitat Evaluation

Qualitative habitat and land use data collections were conducted at all sampling locations to assess the presence/absence of in-stream habitat and potential sources of stressors within the catchment. Habitat parameters assessed included: channel modification; relative abundance of in-stream structure; substrate type; presence of riffles/pools; riparian zone width and function, and stability as it relates to erosion and surrounding land use. This evaluation results in a score from 1 to 100. Higher numbers typically reflect increased habitat quality with reduced anthropogenic influence.

Physical-Chemical

Several physicochemical properties are collected at each sampling site. Field measurements include specific conductance, water temperature, pH, and dissolved oxygen using both YSI 85 and Accumet AP 61 meter. Pre and post-meter calibrations were completed daily.

Benthos

In July, 2009 macroinvertebrates were collected from Goose, Crooked, and Barnes Creek (reference) sampling locations (Table 3). The Division of Water Quality's Standard Qualitative (Full Scale) sampling methods were used. Full scale samples are conducted in wadeable streams with drainage areas > 3 mi^2 (NCDWQ 2005). This sampling method consists of 10 separate samples including three sweep-net samples; two kick net samples, one leaf pack, two fine-mesh log and/or rock wash, one sand sample, and visuals of substrates not otherwise easily sampled by previous techniques. Habitats such as riffles, macrophytes, root mats/undercut banks, and detritus deposits are sampled using these techniques. Samples are picked at the site and preserved in ethanol for laboratory analysis. Benthic sampling is performed to obtain an inventory of aquatic fauna at the specific sampling location. Each taxon is classified as Rare (1-2 specimens, denoted by "R" on taxa tables), Common (3-9 specimens, "C"), Abundant (≥ 10 specimens, "A"). Data from each site is entered into a database.

Data Analyses

Several data-analysis summaries (metrics) are used to detect water quality issues. These metrics are based on long-term intensive studies showing that unstressed stream/river systems generally exhibit higher macroinvertebrate diversity and higher proportions of pollution intolerant taxa. On the contrary, relatively higher proportions of pollution tolerant taxa are found in polluted streams and rivers. Diversity of benthic fauna is evaluated using taxa richness defined as the total number of different taxa present (S). Stream communities are evaluated using a biotic index that is generated from the reaction of various taxa to different stressors. This is known as the North Carolina Biotic Index (NCBI or BI) (NCDWQ 2005). These values allow comparisons among sample sites and reference sites. Individual species and associated community biotic index values are rated on a 0-10 scale. Higher values represent more tolerant taxa and potential stream pollution. Indicator taxa, EPT abundance (EPT N), EPTBI, and S are used to further

elucidate between-site differences. All stream stations received bioclassifications based on biocriteria for wadeable streams with drainage areas > 3 mi^2 (Full Scale). There are five possible classifications including: Excellent, Good, Good-Fair, Fair, and Poor. Bioclassifications were generated based on the NCBI, EPTBI, and EPTS thresholds for the Piedmont Ecoregion and Full-Scale macroinvertebrate collection method.

Land Use Analysis

A land use analysis was conducted using Geographic Information Systems (GIS) for the Goose Creek and Crooked Creek catchments. Percentages were calculated from both 2001 and 2007 GIS rasters for Union County, NC to observe spatial and temporal trends among sample sites. The proportions represent land use parameters upstream from each sample site. Land use parameters include: agricultural, barren land, developed (urban), forest, grass, and water bodies. Data from 2007 was obtained from Tetra Tech, Inc.

MONITORING SITES

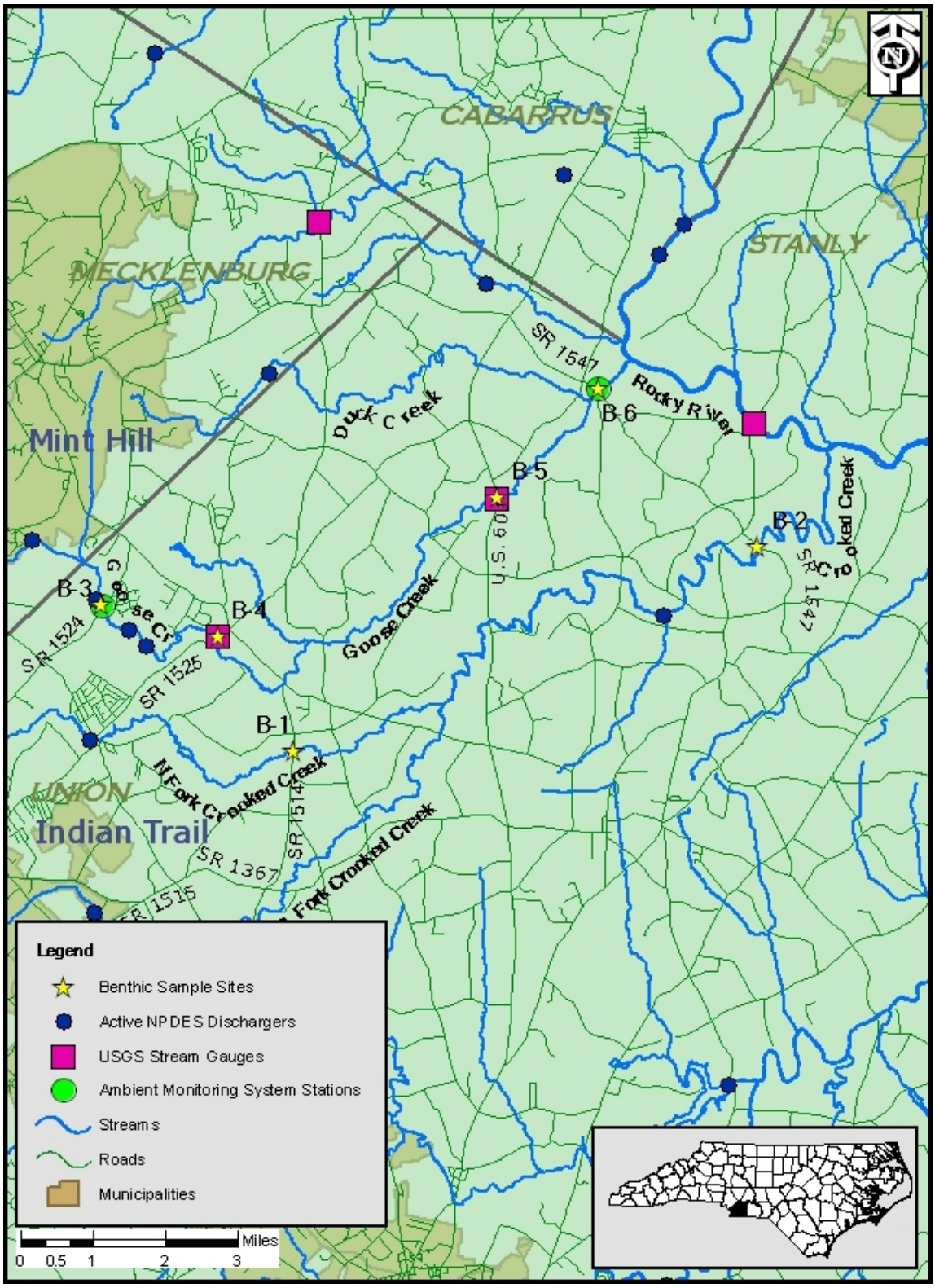


Figure 1. Location of macroinvertebrate monitoring stations (yellow stars) sampled in July, 2009.

Table 1. Active Ambient Monitoring System Stations within the Goose Creek catchment.

Station	Location	Class
Q8360000	Goose Creek at SR 1524	C
Q8374000	Goose Creek at SR 1547	C

Table 2. Permitted active NPDES dischargers located upstream from proposed sampling locations.

Permit	Facility	County	Receiving Water Body	Permitted Flow (MGD)
NC0069841	Crooked Creek WWTP #2	Union	S. Fork Crooked Creek	1.9
NC0035041	Hemby Acres WWTP	Union	N. Fork Crooked Creek	0.3
NC0063584	Oxford Glen WWTP	Mecklenburg	Stevens Creek	0.075
NC0072508	Hunly Creek WWTP	Union	Goose Creek	0.02
NC0034762	Fairfield Plantation WWTP	Union	Goose Creek	0.07
NC0065684	Country Wood WWTP	Union	Goose Creek	0.67
NC0065749	Ashe Plantation WWTP	Mecklenburg	Duck Creek	0.1
NC00685812	Grassy Branch WWTP	Union	Grassy Branch	0.05

Table 3. Macroinvertebrate monitoring stations in the Goose Creek, Crooked Creek, and Barnes Creek catchments, July, 2009.

Stream	N FK CROOKED CR	CROOKED CR	GOOSE CR	GOOSE CR	GOOSE CR	GOOSE CR	BARNES CR
Site Location	SR 1514	SR 1547	SR 1524	SR 1525	US 601	SR 1547	SR 1303
County	Union	Union	Union	Union	Union	Union	Montgomery
Site ID	QB358	QB344	QB351	QB352	QB355	QB354	QB276
Basin	Yadkin	Yadkin	Yadkin	Yadkin	Yadkin	Yadkin	Yadkin
Subbasin	12	12	12	12	12	12	9
Latitude (º)	35.1024	35.1450	35.1301	35.1250	35.1539	35.1759	35.4396
Longitude (º)	-80.5854	-80.4717	-80.6310	-80.6028	-80.5350	-80.5116	-79.9979
Drainage area (mi²)	15.1	47.3	8.4	11.0	24.1	44.0	23.1
Stream Segment AU	13-17-20-1	13-17-20	13-17-18b	13-17-18b	13-17-18b	13-17-18b	13-2-18-(2.5)
Stream Classification	C	C	C	C	C	C	C
Level 4 Ecoregion	45c	45c	45c	45c	45c	45c	45c
Type of Sample	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale
Map #	B-1	B-2	B-3	B-4	B-5	B-6	B-7

Table 4. Sites previously sampled in the Goose Creek, Crooked Creek, and Barnes Creek catchments.

Waterbody	Location	County	Date	Sample Type	Total EPT Taxa	EPT BI	Total Taxa	BI	Bioclass
N FK CROOKED CR	SR 1514	UNION	9/12/1995	Full Scale	12	5.79	59	6.46	Good-Fair
	SR 1514	UNION	6/27/2000	Full Scale	7	6.79	53	6.98	Fair
N FK CROOKED CR	SR 1520	UNION	6/27/2000	Full Scale	6	6.50	57	7.23	Fair
S FK CROOKED CR	SR 1367	UNION	9/12/1995	Full Scale	8	6.22	42	6.71	Fair
S FK CROOKED CR	SR 1515	UNION	9/13/1995	Full Scale	5	6.83	54	6.89	Fair
CROOKED CR	SR 1547	UNION	8/20/1996	EPT	12	4.93			Fair
	SR 1547	UNION	8/22/2001	Full Scale	18	5.16	68	5.93	Good-Fair
	SR 1547	UNION	8/23/2006	Full Scale	11	5.79	63	6.27	Good-Fair
DUCK CR	US 601	UNION	4/21/1998	Full Scale	14	5.52	64	6.42	Fair
GOOSE CR	SR 1524	UNION	4/22/1998	EPT	16	4.66			Good-Fair
GOOSE CR	SR 1525	UNION	4/21/1998	Full Scale	4	6.95	35	6.95	Poor
GOOSE CR	US 601	UNION	8/20/1996	EPT	2	6.07			Poor
	US 601	UNION	4/21/1998	Full Scale	10	5.88	47	7.37	Poor
	US 601	UNION	8/22/2001	Full Scale	5	5.98	48	7.16	Poor
	US 601	UNION	8/22/2006	Full Scale	11	6.65	67	6.87	Fair
GOOSE CR	SR 1547	UNION	5/1/1998	EPT	11	6.00			Fair
BARNES CR	SR 1303	MONTGOMERY	5/20/1985	Full Scale	36	3.88	100	4.83	Excellent
	SR 1303	MONTGOMERY	8/1/1985	Full Scale	29	3.89	87	4.81	Excellent
	SR 1303	MONTGOMERY	7/8/1987	Full Scale	27	3.79	90	4.93	Good
	SR 1303	MONTGOMERY	7/20/1987	EPT	28	4.05			Excellent
	SR 1303	MONTGOMERY	7/11/1989	Full Scale	24	3.80	83	4.89	Good
	SR 1303	MONTGOMERY	8/7/1996	Full Scale	36	3.41	99	4.46	Excellent
	SR 1303	MONTGOMERY	8/9/2001	Full Scale	40	3.55	108	4.22	Excellent
	SR 1303	MONTGOMERY	9/28/2001	Full Scale	38	3.03	79	4.16	Excellent

RESULTS AND DISCUSSION

North Fork Crooked Creek, SR 1514, Union County

Figure 2. Upstream view of North Fork Crooked Creek at SR 1514, Union County, NC, sampled on July 14, 2009.

Date: July 14, 2009
Drainage area: 15.1 square miles
Qualitative Visible land use (%): 30 forest, 30 residential, 40 fallow fields
Width (m): 5
Depth (m): Avg: 0.2 Max: 0.5
Canopy (% cover): 90, mixed hardwood
Substrate (%): boulder (0), cobble (0), gravel (50), sand (25), silt/fine particulate (25)
Riparian quality: riparian zone intact (>18m)
Instream habitat: Rocks and macrophytes absent. Sticks/leafpacks and snags/logs are common. Undercut banks abundant.
Dissolved Oxygen (mg/L): 5.2
Specific conductance (µmhos/cm): 425
Temperature (°C): 22.5
pH: 7
Habitat Score: 61

North Fork Crooked Creek at SR 1514 had the lowest EPT taxa richness (4) and abundance (EPTN = 31) and highest NCBI (7.09) (Table 5, Appendix 1) compared to all other sampling locations. Tolerant taxa were dominant at this site including: *Hydropsyche betteni* (abundant) and *Cheumatopsyche spp.* (abundant). *Maccaffertium modestum* was absent from this site and abundant at all other sampling sites within this study suggesting a lack of riffle habitat. Low flows were noted at the site in addition to lack of habitat favorable for macroinvertebrate colonization including the absence of cobble riffle substrates and submerged root mats. Additionally, this stream segment is suffering from severe bank erosion leading to increased scouring and sediment input. The severe erosion and scouring suggest this site receives periodic drastic increases in flow followed by quick lower water levels which can lead to rapid inputs of accumulated nonpoint pollutants from upstream. A sewage smell was noted and conductivity was high at 425 µmhos/cm (Table 6). High amounts of upstream urban land use activities in addition to point source dischargers are likely contributing to the degraded macroinvertebrate community here. This site could be good candidate for implementation of future upstream stormwater BMPs and/or stream restoration activities. However, any issues with upstream dischargers such as Hemby Acres WWTP would need to be resolved.

Crooked Creek at SR 1547, Union County

Figure 3. Downstream view of Crooked Creek at SR 1547, Union County, NC, sampled on July 14, 2009.

Date: July 14, 2009
Drainage area: 47.3 square miles
Qualitative Visible land use (%): 80 forest, 10 residential, 10 fallow fields
Width (m): 10
Depth (m): Avg: 0.1 Max: 0.25
Canopy (% cover): 60, hardwood
Substrate (%): boulder (10), cobble (40), gravel (30), sand (10), silt/fine particulate (10)
Riparian quality: Intact wide riparian zone (>18m). Erosion moderate.
Instream habitat: Rocks abundant. Macrophytes common, sticks/leafpacks common, snags/logs rare, and undercut banks and root mats rare.
Dissolved Oxygen (mg/L): 6.5
Specific conductance (µmhos/cm): 471,**Temperature (°C):** 26.1, **pH:** 7.8, **Habitat Score:** 88

Ten EPT taxa were present at the downstream Crooked Creek site. This site received a Fair (NCBI = 6.65, EPTBI = 5.67) rating suggesting slight decline in water quality compared to the 2006 sample. EPT taxa richness and EPTBI remained similar from 2006 to 2009 (Table 5) however the NCBI value was elevated from 6.27 to 6.65. This is potentially due to the higher abundance of tolerant taxa in 2009 such as the chironomids *Cricotopus bicinctus* and *Dicrotendipes neomodestus* (Appendix 1). Both taxa are tolerant of high nutrients/organic wastes. The presence of so many low dissolved oxygen tolerant taxa such as the midges *Polypedilum illinoense*, *Phaenopsectra obediens*, and *Dicrotendipes neomodestus*; the odonates *Argia spp.* and *Ischnura spp*.; the flatworm *Dugesia tigrina*; and the slow water limpet *Laevapex fuscus* suggests the site suffers from periodic low oxygen levels compounded by the low flows common in slate belt streams. Observations at the site imply that macroinvertebrates are not limited by habitat but more likely general water quality. Conductivity was high at 471 µmhos/cm (Table 6). There are two minor dischargers and one major discharger (>1 MGD) located upstream from this sample site (Table 2) likely contributing to degraded water quality. Any upstream WWTP discharge issues would need to be resolved before additions of stormwater BMPs in order to detect positive effects on stream water quality.

Goose Creek at SR 1524, Union County

Figure 4. Upstream view of Goose Creek at SR 1524, Union County, NC, sampled on July 13, 2009.

Date: July 13, 2009
Drainage area: 8.4 square miles
Qualitative Visible land use (%): 50 forest, 30 residential, 20 golf course
Width (m): 8
Depth (m): Avg: 0.2 Max: 0.5
Canopy (% cover): 85, mixed hardwood
Substrate (%): boulder (20), cobble (20), gravel (20), sand (20), silt/fine particulate (20)
Riparian quality: Intact riparian zone. Narrow on the right bank (< 6m). Erosion severe.
Instream habitat: Rocks common. Macrophytes rare, sticks/leafpacks common, snags/logs and undercut banks/root mats common.
Dissolved Oxygen (mg/L): 6.7
Specific conductance (µmhos/cm): 121
Temperature (°C): 23.7
pH: 7.0
Habitat Score: 77

Goose Creek at SR 1524 also received a Fair bioclassification in 2009 compared to Good-Fair in 1998. Despite this rating, water quality in this reach seems the best compared to all other sample sites within the Goose Creek catchment (EPTBI = 6.11, NCBI = 6.40) (Table 5). Thirteen EPT taxa were collected at the site. Most are fairly tolerant taxa with the exception of *Chimarra spp.* and *Mystacides sepulchralus* (both rare at the site). Intolerant taxa abundant in 1998, such as *Serratella deficiens*, were absent in 2009. The intolerant beetle *Psephenus herricki* was common at the site (Appendix 1). This site is located ~100 meters downstream from the Hunley Creek WWTP (Table 2), which is a minor discharger that has had occasional violations of ammonia and chlorine. The absence of long-lived stoneflies and other common intolerant taxa could be due to multiple variables. These could include drought, periodic toxicity, lack of upstream riparian buffers, and/or runoff from the upstream golf course and residential areas leading to the increased erosion and sediment accumulation observed. This site may be a good candidate for future stormwater BMP implementation, stream bank stability, riparian buffer enhancements, and/or other restoration activities.

Goose Creek at SR 1525, Union County

Figure 5. Downstream view of Goose Creek at SR 1525, Union County, NC, sampled on July 14, 2009.

Date: July 14, 2009
Drainage area: 11.0 square miles
Qualitative Visible land use (%): 50 forest, 20 residential, 20 goat pasture, 10 fallow fields
Width (m): 10
Depth (m): Avg: 0.1 Max: 0.5
Canopy (% cover): 80, mixed hardwood
Substrate (%): bedrock (10), boulder (30), cobble (20), gravel (20), sand (10), silt/fine particulate (10)
Riparian quality: Intact riparian zone. Width 12-18m on left bank. Moderate Erosion.
Instream habitat: Rocks abundant. Macrophytes absent, sticks/leafpacks common, snags/logs and undercut banks/root mats common.
Dissolved Oxygen (mg/L): 7.1
Specific conductance (µmhos/cm): 193
Temperature (°C): 23.1
pH: 7.2
Habitat Score: 90

This Goose Creek site has improved slightly from Poor in 1998 to Fair in 2009. EPT taxa richness increased from 4 in 1998 to 6 in 2009. However, this is a 2-fold decrease in EPT taxa richness when compared to the SR 1524 site just upstream (Table 5, Figure 1). The SR 1525 site has the lowest EPTN (35) and highest NCBI (7.01) suggesting the worst water quality among all Goose Creek sites in 2009. Chironomid taxa richness doubled from 13 just upstream at the SR 1524 site to 25 at this site potentially signifying some nutrient enrichment from upstream sources. The Country Woods WWTP is the nearest of three WWTPs located within 1 mile upstream of the site (Figure 1, Table 2). A sewage smell was observed. Macroinvertebrate assemblages suggest impaired water quality despite high quality habitat suggesting either point source or nonpoint source pollution inputs at this site.

Goose Creek at U.S. 601, Union County

Figure 6. Upstream view of Goose Creek at U.S. 601, Union County, NC, sampled on July 14, 2009.

Date: July 14, 2009
Drainage area: 24.1 square miles
Qualitative Visible land use (%): 40 forest, 35 active crops, 25 fallow fields
Width (m): 10
Depth (m): Avg: 0.1 Max: 0.5
Canopy (% cover): 90, mixed hardwood
Substrate (%): boulder (25), cobble (25), gravel (10), sand (20), silt/fine particulate (20)
Riparian quality: Intact riparian zone. Width 6-12m on right bank. Moderate Erosion.
Instream habitat: Rocks abundant. Macrophytes common, sticks/leafpacks common, snags/logs and undercut banks/root mats common.
Dissolved Oxygen (mg/L): 5.8
Specific conductance (µmhos/cm): 232
Temperature (°C): 24.2
pH: 7.1
Habitat Score: 88

Goose Creek at U.S. 601 rated Fair based on benthic macroinvertebrates in 2009 for the second consecutive time since 2006 (Table 5). This site had a Poor bioclassification from 1996-2001. The Fair rating suggests a water quality improvement following the removal of discharge from the Fairview Elementary WWTP just upstream in 2005. Despite observations of high quality habitat, a pollution tolerant benthic community assemblage continues to reside here suggesting point source dischargers and/or nonpoint source runoff limiting water quality. Four total point source dischargers are located upstream from this site (Figure 1). Conductivity was elevated (232 µmhos/cm), however, water quality improved slightly from the SR 1525 site when comparing benthic metrics (Table 5).

Goose Creek at SR 1547, Union County

Figure 7. Upstream view of Goose Creek at SR 1547, Union County, NC, sampled on July 15, 2009.

Date: July 15, 2009
Drainage area: 77.0 square miles
Qualitative Visible land use (%): 100 forests
Width (m): 11
Depth (m): Avg: 0.1 Max: 0.25
Canopy (% cover): 90, mixed hardwood
Substrate (%): boulder (20), cobble (20), gravel (20), sand (20), silt/fine particulate (20), trace of bedrock
Riparian quality: Intact wide (>18m) riparian zone. Moderate to severe erosion.
Instream habitat: Rocks abundant. Macrophytes absent, sticks/leafpacks common, snags/logs common and undercut banks/root mats rare.
Dissolved Oxygen (mg/L): 6.8
Specific conductance (µmhos/cm): 229
Temperature (°C): 21.2
pH: 7.3
Habitat Score: 86

This Goose Creek site is just upstream from its confluence with Rocky River. The benthic community assemblage at this site remained similar to that found during sampling in 1998 (Table 5). EPT abundance (69) in 2009 was much higher than in 1998 (35), however, slightly more pollution tolerant EPT taxa were present in 2009 (EPTBI = 6.47) compared to 1998 (EPTBI = 6.0). Conductivity was elevated (229 µmhos/cm). This site is downstream from Ashe Plantation WWTP, a minor permitted discharger to Duck Creek, a tributary of Goose Creek (Figure 1). Five total permitted dischargers are located upstream from this sampling station. Most of these downstream Goose Creek sites have exceptional habitat available for macroinvertrate colonization suggesting impaired water quality from upstream point source or nonpoint source pollution inputs.

Barnes Creek at SR 1303, Montgomery County

Date: July 15, 2009
Drainage area: 23.1 square miles
Qualitative Visible land use (%): 100 forest
Width (m): 11
Depth (m): Avg: 0.2 Max: 1.0
Canopy (% cover): 75, hardwood
Substrate (%): bedrock (10), boulder (30), cobble (30), gravel (15), sand (10), silt/fine particulate (5)
Riparian quality: Breaks rare. Wide (>18m) riparian zone. Minimal erosion.
Instream habitat: Rocks abundant. Macrophytes absent, sticks/leafpacks common, snags/logs rare and undercut banks/root mats common.
Dissolved Oxygen (mg/L): 7.7, **Specific conductance (µmhos/cm):** 51, **Temperature (°C):** 23.8, **pH:** 7.1, **Habitat Score:** 92

Figure 8. Downstream view of Barnes Creek at SR 1303, Union County, NC, sampled on July 15, 2009.

Barnes Creek at SR 1303 was selected for benthic sampling as a Slate Belt reference site for comparison to that of the Goose and Crooked Creek catchments. This stream is a tributary to the Uwharrie River in rural Montgomery County. The reach of stream sampled is almost completely surrounded by forest with little to no anthropogenic activity upstream. The site obtained a benthic bioclassification of either Good or Excellent every time it has been sampled since 1985. It has been rated Good on three occasions out of nine including this year. Intolerant taxa were common at this site including several fairly rare taxa for the Piedmont such as *Maccaffertium vicarium* (abundant), *Epeorus vitreus* (common), *Acroneuria abnormis* (abundant) and *Neoperla spp.* (common). Stoneflies such as *Acroneuria abnormis* are commonly found in fairly clean North Carolina Piedmont streams. No stoneflies were collected in Goose or Crooked Creeks further suggesting impaired water quality at those sites. Based on DWQ habitat forms Barnes Creek received a high habitat score (92), somewhat comparable to that of downstream reaches of Goose and Crooked Creeks (Table 6). Total EPT taxa (27) and EPT abundance (125) was at least double that of all Goose and Crooked Creek samples (Table 5). The EPTBI (4.17) and NCBI (4.97) are low suggesting good water quality within the reach. Specific conductance (51 µmhos/cm) was less than half that of any sites sampled in Goose or Crooked Creeks. Chironomid richness was moderate (18) but biomass was low (Appendix 1). Only one chironomid taxa *Cladotanytarsus sp. E* was abundant at the site and the majority of other chironomid taxa were rare. The intolerant beetles *Psephenus herricki* and *Optioservus ovalis* were also abundant in Barnes Creek.

SUMMARY

Of the six Goose and Crooked Creek samples collected in July, 2009, none of them obtained a bioclassification above Fair based on macroinvertebrate assemblages. Trends suggest further impaired water quality in Goose and Crooked Creek headwaters. This is likely due to a combination of point and/or nonpoint sources in addition to low base flows notorious in the Slate Belt Ecoregion. Potentially the most important factor continuing to affect these streams is rapid expansive urbanization of the Goose and Crooked Creek headwaters. Goose Creek at SR 1524 went from a bioclassification of Good-Fair in 1998 to Fair in 2009. The mid-stream site Goose Creek at SR 1524 and U.S. 601 showed slight improvements in water quality since 1998 and 2001. The downstream Goose Creek site at SR 1547 remained at Fair consistent with historic samples. North Fork Crooked Creek at SR 1514 was rated Good-Fair in 1995. Since 1995, water quality in this reach has been on the decline to Fair in 2000 and Poor in 2009 based on benthic macroinvertebrates (Tables 4 and 5). Water quality in downstream Crooked Creek declined to Fair since 2001 when it was rated Good-Fair. A high abundance of chironomid taxa such as *Cricotopus bicinctus* and *Dicrotendipes neomodestus* also suggest some nutrient/organic wastes enrichment at the SR 1547 site. Elevated conductivity, especially in the Crooked Creek

catchment suggests point source discharge problems. Implementation of stormwater BMPs and stream restoration activities could benefit the Goose and Crooked Creek catchment. However, any point source discharge issues would need to be resolved before stream restoration activities are implemented.

Land Use

Agricultural and urban land use activities and associated increased impervious surface in smaller headwater streams is known to negatively affect water quality downstream (Alexander et al. 2007, Meyer et al. 2007). Commercial/Industrial and residential land use has significantly increased in the Goose and Crooked Creek watersheds since 1992 (Tetra Tech 2008). Both catchments have similar percentages of developed land. The Crooked Creek catchment has a slightly higher percentage of high density impervious surfaces; particularly commercial land use (7.4%) compared to that of the Goose Creek drainage at 4.1%.

Rapid continued urbanization in the headwaters of Goose and Crooked Creek could lead to the impaired water quality found in both upstream and downstream sample locations. Urban land use percentages are highest in the headwaters of both the Crooked and Goose Creek catchments (Figure 9). Percentage of forests continues to decrease from 2001 to 2007 throughout both catchments. Trends suggest urban areas decrease spatially as you move downstream in both drainages. These observations imply stream and/or wetland restoration efforts focused in the headwaters may benefit downstream water quality. Commercial/Industrial and residential land use in headwaters leads to more impervious surface and ultimately, to a modified hydrologic regime. Stormwater runoff over impervious surfaces with reduced riparian buffers may lead to the rapid movement of water downstream increasing scour, erosion, and sediment input. North Fork Crooked Creek at SR 1514 may be an example of this altered hydrologic flow. Virtually no course substrate was observed at this site potentially due to high flows through the channel during stormwater events. Altered hydrology in addition to fluctuated drought conditions known to occur in the Slate Belt can escalate the effects of nonpoint sources via buildup of pollutants and quick runoff of these sources into the catchment.

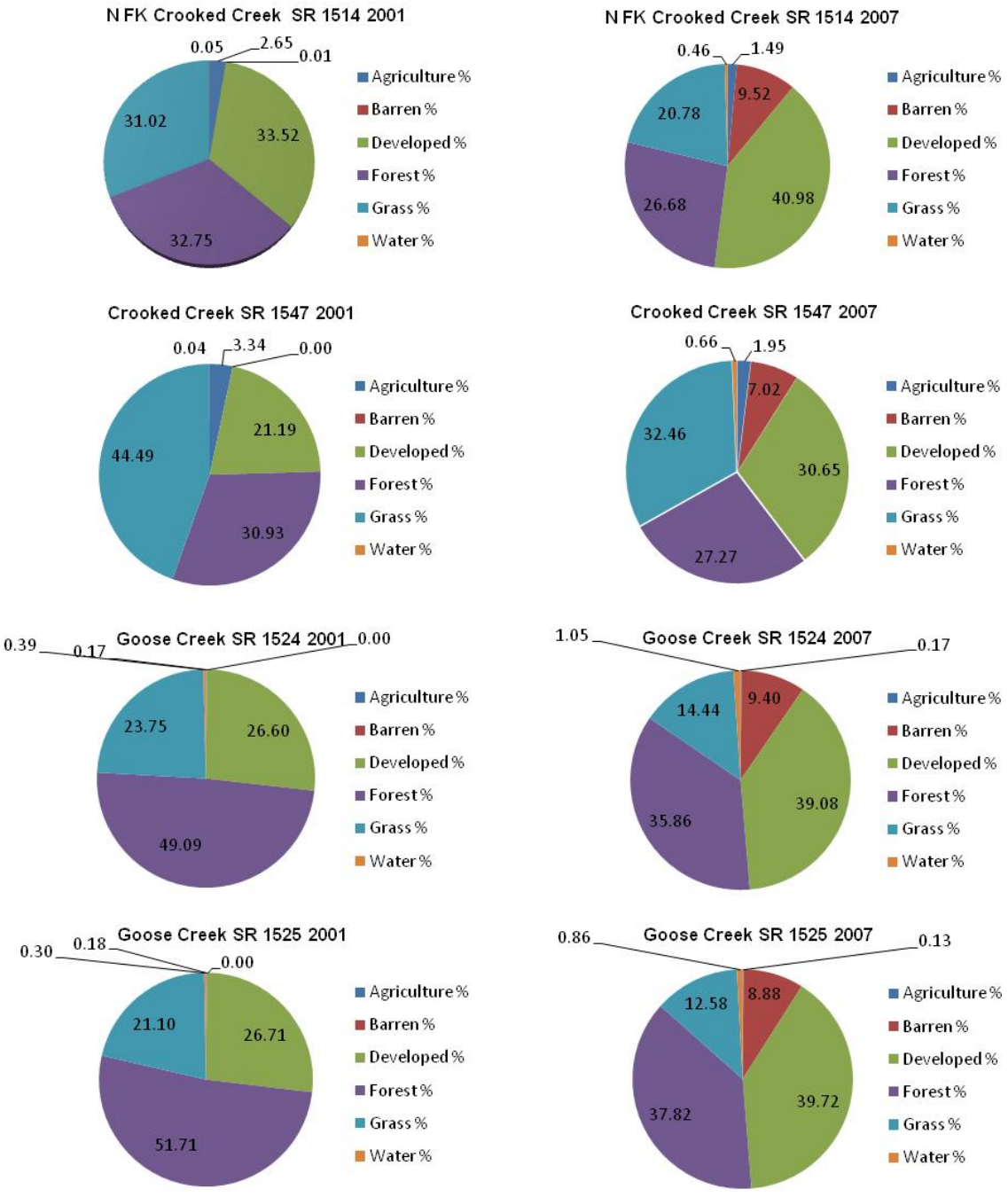
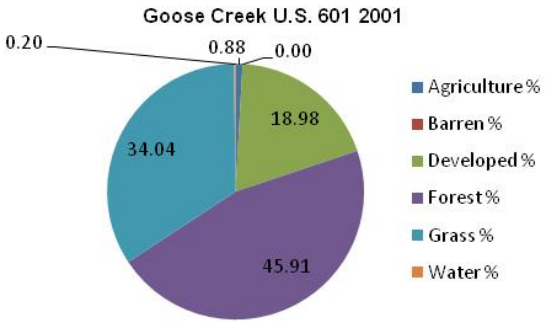
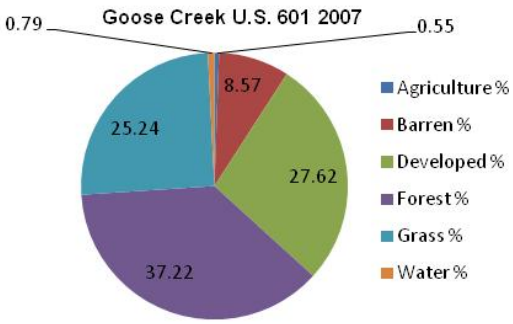
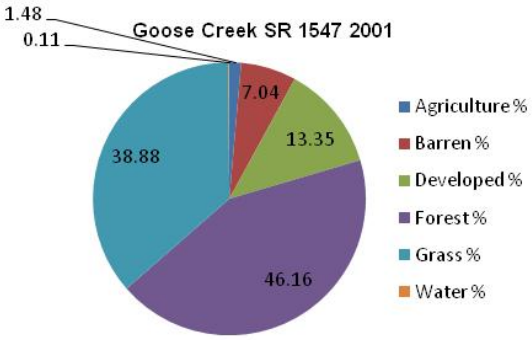


Figure 9. Land use comparisons among Goose Creek and Crooked Creek benthic sites in 2001 and 2007.







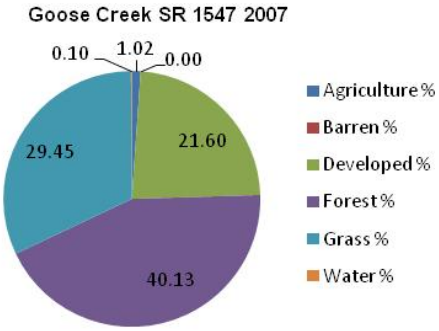


Figure 9 cont.

CONCLUSIONS

- Benthic macroinvertebrate data suggests water quality degradation in the North Fork Crooked Creek at SR 1514 and Goose Creek at SR 1524. This impaired water quality in the headwaters may be due to increased stormwater runoff from rapidly expanding commercial/industrial and residential land use and/or point source dischargers located upstream from the sites.
- Benthic samples suggest impaired waters in Crooked Creek at SR 1547 for the first time since 1996. The exact source of this impairment is not known. Possibilities include the presence of upstream dischargers in combination with increased impervious surface in the headwaters leading to stormwater runoff events. Pollutants entering Crooked Creek could be escalated during fluctuating drought conditions common in the Slate Belt.
- North Fork Crooked Creek at SR 1514 is a recommended candidate for future stormwater BMP implementation and/or stream restoration activities. This stream reach suffers from severe erosion, lack of course substrate, and narrow/patchy riparian zones. restoration activities such as riparian buffer enhancement, stream bank stabilization, and additions of course substrate for water velocity control during storm events may benefit downstream water quality. Additions of course substrate and riparian buffer enhancements may also provide enhanced habitat favorable for macroinvertebrate colonization. Any upstream noncompliance issues with point source dischargers would need to be resolved prior to these enhancement activities.
- Goose Creek at SR 1524 may also be a good candidate for future stormwater BMP implementation and/or riparian buffer widening/stream bank stabilization. Despite the Fair bioclassification, benthic metrics suggests this site has the best water quality compared to all sites in the catchment. This may be due a combination of better habitat and only one nearby upstream discharger.
- Multiple sources could be contributing to degraded water quality in Goose and Crooked Creek. Habitat quality increases and impervious surfaces decrease as you move downstream. Enhancing buffers/stormwater BMPs in the headwaters may help to filter excess stormwater pollutants before entering Goose and Crooked Creek. Multiple point source dischargers are located upstream from Goose Creek sample sites (Figure 1, Table 2). Limiting concentrations of point source discharge downstream may also benefit aquatic life and water quality.

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References

Alexander, R.B., Boyer, E.W., Smith, R.A., Schwartz, G.E., and Moore, R.B. 2007. The role of headwater streams in downstream water quality. Journal of the North American Water Resources Association Vol. 43. No. 1: 41-59.

Griffith, G.E., Omernik, J.M., Comstock, J.A. Schafale, M.P., McNab, W.H., Lenat, D.R., MacPherson, T.F., Glover, J.B. and V.B. Shelburne. 2002. Ecoregions of North Carolina and South Carolina. (color poster with map, descriptive text, summary tables and photographs): Reston, VA, U.S. Geological Survey (map scale 1:1,500,000).

Meyer, J. L., Strayer, D.L., Wallace, J. B., Eggert, S.L., Helfman, G.S., Leonard, N.E. 2007. The contribution of headwater streams to biodiversity in river networks. Journal of The American Water Resources Association Vol. 43, No. 1.: 86-103.

NCDWQ.2004. Effects of Long Term Drought on Benthic Macroinvertebrate Communities in NC Streams and Tracking Their Recovery, 2002-2004. NC Dept. of Environment and Natural Resources, Division of Water Quality. Biological Assessment Unit. August, 2004.

NCDWQ.2006. Standard Operation Procedures for Benthic Macroinvertebrates. Biological Assessment Unit. NC Dept. of Environment and Natural Resources, Division of Water Quality. July, 2006.

NCDWQ.2009. Water Quality Monitoring Plan for Goose and Crooked Creeks (DRAFT). NC Dept. of Environment and Natural Resources, Division of Water Quality. Surface Water Protection Section. March, 2009.

TETRA TECH.2008. Goose Creek and Crooked Creek LWP Phase I Preliminary Findings in: Goose and Crooked Creeks Local Watershed Plan. Centralina Council of Governments. December, 2008.

Weaver, Curtis J., and Pope, Benjamin F. 2001. Low-Flow characteristics and discharge profiles for selected streams in the Cape Fear River Basin, North Carolina, through 1998. U.S. Geological Survey. Water Resources Investigational Report 01-4094

Table 5. Summary benthic data for Goose Creek, Crooked Creek, and Barnes Creek study sites sampled from 1998 to 2009, Yadkin River Basin, Union and Montgomery Counties.

Stream	N FK CROOKED CR	N FK CROOKED CR	CROOKED CR	CROOKED CR	GOOSE CR	GOOSE CR	GOOSE CR	GOOSE CR	GOOSE CR	GOOSE CR	GOOSE CR	GOOSE CR	BARNES CR	BARNES CR
Site Location	SR 1514	SR 1514	SR 1547	SR 1547	SR 1524	SR 1524	SR 1525	SR 1525	US 601	US 601	SR 1547	SR 1547	SR 1303	SR 1303
County	Union	Union	Union	Union	Union	Union	Union	Union	Union	Union	Union	Union	Montgomery	Montgomery
Collection date	27-Jun-00	14-Jul-09	23-Aug-06	14-Jul-09	22-Apr-98	13-Jul-09	21-Apr-98	14-Jul-09	22-Aug-06	14-Jul-09	1-May-98	15-Jul-09	15-May-06	15-Jul-09
BAU sample number	8133	10670	10061	10743	7554	10669	7553	10671	10060	10672	7558	10744	9908	10745
Sample method	Full Scale	Full Scale	Full Scale	Full Scale	EPT	Full Scale	Full Scale	Full Scale	Full Scale	Full Scale	EPT	Full Scale	Full Scale	Full Scale
Criteria	Summer/ Piedmont	Summer/ Piedmont	Summer/ Piedmont	Summer/ Piedmont	Spring/ Piedmont	Summer/ Piedmont	Spring/ Piedmont	Summer/ Piedmont	Summer/ Piedmont	Summer/ Piedmont	Spring/ Piedmont	Summer/ Piedmont	Spring/ Piedmont	Summer/ Piedmont
Richness														
Ephemeroptera	5	2	6	5	9	6	2	3	6	5	7	7	21	19
Plecoptera	0	0	0	0	1	0	0	0	0	0	2	0	6	2
Trichoptera	2	2	5	5	6	7	2	3	5	7	2	6	10	6
Total EPT	7	4	11	10	16	13	4	6	11	12	11	13	37	27
Odonata	9	2	5	7		7	3	4	9	6		6	5	9
Megaloptera	0	0	0	0		0	0	0	0	0		0	2	3
Coleoptera	6	4	9	5		7	2	6	7	6		9	7	11
Chironomidae	16	12	24	18		13	16	25	24	24		24	31	18
non-Chironomidae Diptera	3	2	1	5		4	3	5	3	4		4	4	2
Oligochaeta	2	2	3	2		2	4	5	3	1		2	2	3
Mollusca	4	3	6	7		5	2	6	4	6		7	4	6
Other taxa	6	4	4	4		2	1	2	6	2		6	2	4
Total taxa richness	53	33	63	58		53	35	59	67	61		71	94	83
Other biological metrics														
EPT abundance	54	31	85	77	51	55	8	35	58	54	35	69	149	125
EPT Biotic Index	6.79	7.00	5.79	5.67	4.66	6.11	6.95	6.58	6.65	6.38	6.00	6.47	4.24	4.17
NCBI	6.98	7.09	6.27	6.65		6.40	6.95	7.01	6.87	6.80		6.82	5.01	4.97
Seasonal Correction							*0.20*						*0.20*	
Corrected NCBI							*7.15*						*5.21*	
Bioclassification	Fair	Poor	Good-Fair	Fair	Good-Fair	Fair	Poor	Fair	Fair	Fair	Fair	Fair	Excellent	Good

Table 6. Summary of habitat and physicochemical data for benthic sample sites within the Goose Creek, Crooked Creek, and Barnes Creek catchments, Union and Montgomery Counties, July 2009

Stream	N FK CROOKED CR	CROOKED CR	GOOSE CR	GOOSE CR	GOOSE CR	GOOSE CR	BARNES CR
Site Location	SR 1514	SR 1547	SR 1524	SR 1525	US 601	SR 1547	SR 1303
County	UNION	Union	Union	UNION	Union	UNION	UNION
Collection date	14-Jul-09	14-Jul-09	13-Jul-09	14-Jul-09	14-Jul-09	15-Jul-09	15-Jul-09
BAU sample number	10670	10743	10669	10671	10672	10744	10745
Habitat Scores							
Channel modification (5)	5	5	5	5	5	5	5
In-stream habitat (20)	11	18	18	19	19	16	20
Bottom substrate (15)	6	11	12	12	13	12	15
Pool variety (10)	8	10	8	10	8	10	10
Riffle habitats (16)	5	15	12	15	15	14	15
Bank stability/vegetation (14)	6	12	5	10	10	9	12
Light penetration (10)	10	7	10	10	10	10	7
Riparian zone width (10)	10	10	7	9	8	10	8
Total Habitat (100)	61	88	77	90	88	86	92
Other Habitat							
Average stream width (m)	5	10	8	10	10	11	11
Average stream depth (m)	0.25	0.1	0.2	0.1	0.1	0.1	0.2
Canopy (%)	90	60	85	80	90	90	75
Substrate (%)							
Bedrock	0	0	0	10	0	0	10
Boulder	0	10	20	30	25	20	30
Cobble	0	40	20	20	25	20	30
Gravel	50	30	20	20	10	20	15
Sand	25	10	20	10	20	20	10
Silt	25	10	20	10	20	20	5
Physicochemical							
Temperature (ºC)	22.5	26.1	23.7	23.1	24.2	21.0	23.8
Dissolved oxygen (mg/L)	5.2	6.5	6.7	7.1	5.8	6.8	7.7
Specific conductance (µmhos/cm)	425	471	121	193	232	229	51
pH	7.0	7.8	7.0	7.2	7.1	7.3	7.1

Appendix 1.

			CROOKED CR SR 1514 Union County	CROOKED CR SR 1547 Union County 14 Jul 2009	GOOSE CR SR 1524 Union County 13 Jul 2009	GOOSE CR SR 1525 Union County 14 Jul 2009	GOOSE CR US 601 Union County 14 Jul 2009	GOOSE CR SR 1547 Union County 15 Jul 2009	BARNES CR SR 1303 Montgomery County 15 Jul 2009
Ephemeroptera	Baetidae	ACENTRELLA FEMORELLA (WALTZ)							C
		ACENTRELLA TURBIDA							C
		BAETIS FLAVISTRIGA	R	C	A		C	A	C
		BAETIS INTERCALARIS	A	A	C	R		A	C
		BAETIS PLUTO			R				C
		CENTROPTILUM SPP							R
		HETEROCLOEON CURIOSUM							R
		PROCLOEON SPP					R	R	R
		PSEUDOCLOEON PROPINQUUM						R	
	Caenidae	CAENIS SPP		A	R	C	A	A	A
	Ephemeridae	EPHEMERA SPP							R
	Heptageniidae	EPEORUS VITREUS							C
		HEPTAGENIA MARGINALIS							C
		LEUCROCUTA SPP							A
		MACCAFFERTIUM MODESTUM		A	A	A	A	A	A
		MACCAFFERTIUM VICARIUM							A
		STENACRON INTERPUNCTATUM							C
		STENACRON PALLIDUM							C
		STENONEMA FEMORATUM							C
	Isonychiidae	ISONYCHIA SPP		C	C		C	R	A
Plecoptera	Perlidae	ACRONEURIA ABNORMIS							A
		NEOPERLA SPP							C
Trichoptera	Dipseudopsidae	PHYLOCENTROPUS SPP					R		
	Helicopsychidae	HELICOPSYCHE BOREALIS		A				R	
	Hydropsychidae	CERATOPSYCHE SPARNA							R
		CHEUMATOPSYCHE SPP	A	A	A	A	A	A	A
		HYDROPSYCHE BETTENI	A	A	A	A	A	A	C
		HYDROPSYCHE ROSSI					R		
		HYDROPSYCHE VENULARIS							R
	Hydroptilidae	HYDROPTILA SPP		A		R	C	R	
	Leptoceridae	MYSTACIDES SEPULCHRALIS			R				
		NECTOPSYCHE EXQUISITA		R	R				
		OECETIS PERSIMILIS			R		R	C	
		TRIAENODES IGNITUS			C		R		
		TRIAENODES PERNA/HELO							C
	Philopotamidae	CHIMARRA SPP			R			R	A
Odonata	Aeshnidae	BASIAESCHNA JANATA		C			C	C	C
		BOYERIA VINOSA		R	R			R	A
	Calopterygidae	CALOPTERYX SPP	C		C	A	C	R	
	Coenagrionidae	ARGIA SPP		R	C	C			R
		ENALLAGMA SPP	R		R				
		ISCHNURA SPP		R					
		NEHALENNIA SPP			R				
	Corduliidae	CORDULIIDAE						R	
		EPITHECA CYNOSURA							R
		HELOCORDULIA SPP							C
		NEUROCORDULIA SPP		R					
		SOMATOCHLORA SPP		A		R	C	R	R
	Gomphidae	GOMPHUS SPP					R		R
		HAGENIUS BREVISTYLUS				R			
		OPHIOGOMPHUS SPP					R		
		PROGOMPHUS OBSCURUS			R		R		
		STYLOGOMPHUS ALBISTYLUS			R				R
	Macromiidae	MACROMIA SPP		R				R	C
Hemiptera	Gerridae	GERRIDAE						R	
	Nepidae	RANATRA SPP							R

Appendix 1 cont.

			N FK CROOKED CR SR 1514 Union County 14 Jul 2009	CROOKED CR SR 1547 Union County 14 Jul 2009	GOOSE CR SR 1524 Union County 13 Jul 2009	GOOSE CR SR 1525 Union County 14 Jul 2009	GOOSE CR US 601 Union County 14 Jul 2009	GOOSE CR SR 1547 Union County 15 Jul 2009	BARNES CR SR 1303 Montgomery County 15 Jul 2009
Megaloptera	Corydalidae	CORYDALUS CORNUTUS							A
		NIGRONIA SERRICORNIS							A
	Sialidae	SIALIS SPP							C
Coleoptera	Dryopidae	HELICHUS SPP			R	R		R	C
	Dytiscidae	COPELATUS SPP		R					
		NEOPORUS SPP				R			C
	Elmidae	ANCYRONYX VARIEGATUS	A	A	C	C	C	C	R
		DUBIRAPHIA SPP		C	C	C		C	A
		MACRONYCHUS GLABRATUS	R	C	C	C	A	C	
		MICROCYLLOEPUS PUSILLUS			R		R	R	R
		OPTIOSERVUS OVALIS							A
		STENELMIS SPP	R	A	A	C	A	A	A
	Haliplidae	HALIPLUS SPP	R						
		PELTODYTES SPP						R	
	Hydrophilidae	BEROSUS SPP					C	C	R
		CYMBIODYTA SPP							R
		DERALLUS ALTUS							R
		ENOCHRUS SPP					R		
	Psephenidae	PSEPHENUS HERRICKI			C			R	A
Chironomidae	Chironomidae	ABLABESMYIA MALLOCHI	R	C		C	C	C	C
		ABLABESMYIA RHAMPHE GR			R	R	R		R
		CHIRONOMUS SPP			R			C	
		CLADOTANYTARSUS SP B				R	R		
		CLADOTANYTARSUS SP E				R			A
		CLADOTANYTARSUS SP F					C	R	
		CORYNONEURA SPP	R			R			
		CRICOTOPUS BICINCTUS	R	A		R		C	
		CRICOTOPUS INFUSCATUS GR						R	
		CRYPTOCHIRONOMUS SPP		A	R	R		C	
		CRYPTOTENDIPES SPP					R		
		DICROTENDIPES NEOMODESTUS		A		R		C	
		DICROTENDIPES SIMPSONI					R		
		LABRUNDINIA PILOSELLA				R			
		MICROTENDIPES PEDELLUS GR			C	A	C	R	R
		NANOCLADIUS ALTERNANTHERAE					R		
		NANOCLADIUS BRANCHICOLUS							R
		NANOCLADIUS DOWNESI							R
		NATARSIA SP A			R	R	R	C	
		ORTHOCLADIINAE		R					
		ORTHOCLADIUS CARLATUS							R
		ORTHOCLADIUS RUBICUNDUS				R			
		PARATANYTARSUS DISSIMILIS				C			
		PARATANYTARSUS QUADRATUS GR			R			R	
		PARATENDIPES SPP		R				C	R
		PHAENOPSECTRA OBEDIENS GR		C			C		
		PHAENOPSECTRA PUNCTIPES GR						R	R
		POLYPEDILUM AVICEPS							R
		POLYPEDILUM FLAVUM	C	A	R	R	R	C	R
		POLYPEDILUM ILLINOENSE GR	C	C	C	A	A	R	
		POLYPEDILUM SCALAENUM GR	R	A		R	A	C	
		PROCLADIUS SPP		C		R	R	A	
		PSEUDOCHIRONOMUS SPP					R		R
		RHEOTANYTARSUS SPP	C	C		R	R	R	R
		STENOCHIRONOMUS SPP	C		R	R	C	R	R
		STICTOCHIRONOMUS SPP					R		

Appendix 1 cont.

			N FK CROOKED CR SR 1514 Union County 14 Jul 2009	CROOKED CR SR 1547 Union County 14 Jul 2009	GOOSE CR SR 1524 Union County 13 Jul 2009	GOOSE CR SR 1525 Union County 14 Jul 2009	GOOSE CR US 601 Union County 14 Jul 2009	GOOSE CR SR 1547 Union County 15 Jul 2009	BARNES CR SR 1303 Montgomery County 15 Jul 2009
		TANYTARSUS SP A	C	A	R	R	C	C	
		TANYTARSUS SP C						C	
		TANYTARSUS SP G		A					
		TANYTARSUS SP L				C	R	R	
		TANYTARSUS SP P		C					
		TANYTARSUS SP S				R			
		TANYTARSUS SP U			R				
		TANYTARSUS SPP		R				R	
		THIENEMANIELLA SPP	A	C	C	C	R		R
		THIENEMANNIMYIA GR	A			C	C	A	R
		TRIBELOS FUSCICORNE					R		
		TRIBELOS JUCUNDUM	C	R	C	C		A	C
		XYLOTOPUS PAR					R		R
non-Chironomidae Diptera	Ceratopogonidae	CULICOIDES SPP					R		
		PALPOMYIA COMPLEX			R	R			
	Culicidae	ANOPHELES SPP		R		R		R	
	Empididae	EMPIDIDAE		C		R			
	Rhagionidae	ATHERIX SPP							R
	Simuliidae	SIMULIUM SPP	C	A	A	C	C	R	A
	Tipulidae	ANTOCHA SPP						C	
		MOLOPHILUS SPP			R				
		TIPULA SPP	R	A	C	C	A	C	
		TIPULIDAE		C			R		
Oligochaeta	Lumbriculidae	LUMBRICULIDAE	R	C	A	C		C	R
	Megadrile	MEGADRILE OLIGOCHAETE	C		R			R	C
	Tubificidae	AULODRILUS PLURISETA				R			
		BRANCHIURA SOWERBYI		R					
		LIMNODRILUS HOFFMEISTERI				R			
		SPIROSPERMA NIKOLSKYI				R			
		TUBIFICIDAE				R	R		R
Crustacea	Cambaridae	CAMBARIDAE		R	C	R	R	R	R
	Palaemonidae	PALAEMONETES SPP	R						
	Talitridae	HYALELLA SPP	C						A
Gastropoda	Ancylidae	LAEVAPEX FUSCUS		C	R		R		R
	Hydrobiidae	HYDROBIIDAE							R
	Lymnaeidae	PSEUDOSUCCINEA COLUMELLA			R	C	R		
	Physidae	PHYSA SPP	A	A	A	A	A	A	R
	Planorbidae	HELISOMA ANCEPS			R	C	C	C	
		HELISOMA TRIVOLVIS		A					
		MICROMENETUS DILATATUS		C		R		R	
	Pleuroceridae	ELIMIA SPP							C
	Viviparidae	CAMPELOMA DECISUM		A					
Bivalvia	Corbiculidae	CORBICULA FLUMINEA	A	C		R	R	R	R
	Sphaeriidae	MUSCULIUM SPP						R	
		PISIDIUM SPP			C	R		A	C
		SPHAERIUM SPP	C	A			R	R	
Other	Erpobdellidae	ERPOBDELLA/MOOREOBDELLA	R						
	Hydracarina	HYDRACARINA	R	C	R		R	R	C
	Planariidae	CURA FOREMANII		R				C	
		DUGESIA TIGRINA		C		R		C	
	Sisyridae	SISYRA SPP						R	