BIOLOGICAL MONITORING OF CHAPEL HILL STREAMS, NORTH CAROLINA April-June 2014

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ATTENTION: PLEASE READ THIS SECTION FIRST

This lengthy report might at first seem incomprehensible to the average citizen, but it is fairly easy to understand with minimal effort. The long lists of scientific names (in the appendices) are intended for specialists; they provide support for the scientific validity of conclusions about water quality.

This study uses information about freshwater macroinvertebrates – "bugs" to the non-biologist. Invertebrates are animals without a backbone; "macro" means they are large enough to be seen with the naked eye. They constitute a large proportion of the aquatic life in streams and can be used as an indicator of the health of the entire stream community. Furthermore, they are indicators of the ability of the stream to support fishing, swimming and other uses by Chapel Hill's citizens. The use of the macroinvertebrate community to assess stream water quality is supported by decades of scientific research. With increasing levels of pollution, we expect to see both fewer species and a shift in community structure to more tolerant groups.

To understand the summary tables, the reader must understand the terms "Taxa Richness" (especially "EPT Taxa Richness"), "NC Biotic Index" (See page 2, page 5) and "Bioclassications". Streams are rated as Excellent, Good, Good-Fair or Fair, using information on the macroinvertebrate community. This report provides information on the present status of water quality in Chapel Hill's streams and looks for any temporal changes in water quality. Sites are described (with photos) in Appendices 4-5. A summary is given on pages 19-20; summary tables are on pages 21-24.

HOW TO READ THIS REPORT
This is the 4th report by Lenat Consulting on water quality and habitat quality of streams in Chapel Hill, North Carolina. It includes data on Bolin Creek, Booker Creek, Morgan Creek, Little Creek and their tributaries. A companion report also has been prepared for the Town of Carrboro, with information on Bolin Creek and selected tributaries. Reports by LCS to the town of Carrboro can be obtained at http://www.townofcarrboro.org/pzi/Env/Water/bcmonitor.htm.

Data from four sites have been included in both reports: Morgan Creek at NC 54, Bolin Creek at Village Drive, and Jolly Branch. There is some duplication between these reports, especially in the introduction, summary of flow data, methods, and summary of prior biological monitoring.

Long lists of species are primarily confined to the appendices, but the reader will often find some species names used in the discussion, especially in regard to *tolerant* or *intolerant* species. Tables 2 and 3 provide the quickest summary this study. The Introduction, Methods and Review of Other Biological Data are largely repeated from earlier reports; flow information has been updated to include data through 2014. **Individuals who have read prior reports may wish to skip to the Results and Discussion sections**.

INTRODUCTION (Most of this section is taken from prior reports)
Water quality in Chapel Hill was evaluated in April and June of 2014 by sampling benthic macroinvertebrates at 23 sites: 2 Bolin Creek sites, 2 Morgan Creek sites, and 19 smaller tributaries. The tributaries were sampled in April, while the larger streams were sampled in June. The 2014 collections included a special study on Cedar Fork, with 5 additional sites in this catchment.

There are several reasons for using biological surveys in monitoring water quality. Conventional water quality surveys do not integrate fluctuations in water quality between sampling periods. Therefore, short-term critical events may often be missed. The biota, especially benthic macroinvertebrates, reflect both long and short-term conditions. Since many species in a macroinvertebrate community have life cycles of a year or more, the effects of a short-term pollutant will generally not be overcome until the following generation appears.

Macroinvertebrates are useful biological monitors because they are found in all aquatic environments, they are less mobile than many other groups of organisms, and they are small enough to be easily collectable. Moreover, chemical and physical analysis for a complex mixture of pollutants is generally not feasible. The aquatic biota, however, show responses to a wide array of potential pollutants, including those with synergistic or antagonistic effects. Additionally, the use of benthic macroinvertebrates has been shown to be a cost-effective monitoring tool (Lenat 1988). The sedentary nature of the benthos ensures that exposure to a pollutant or stress reliably denotes local conditions, and allows for comparison of sites that are in close proximity (Engel and Voshell 2002).

Analysis of stream life is one way to detect water quality problems (Rosenberg et al 1986). Different kinds of stress will often produce different benthic macroinvertebrate communities. For example, the species associated with organic loading (and low dissolved oxygen) are well known. More recent studies have begun to identify the biological impacts of sedimentation and toxic stress. Identification at, or near, the species level is desirable for many groups of organisms (Resh and Unzicker 1975), and recent work by Lenat and Resh (2001) has shown the benefits of precise taxonomy for both pollution monitoring and conservation biology.

Organisms cannot always be identified at the species level, thus counts of the number of kinds of stream organisms often include identifications at higher levels (genus, family, etc.). Each different type of organism in these situations is called a "taxon" and the plural form of this word is "taxa". Thus "taxa richness" is a count of the number of different types of organisms. **"EPT Taxa Richness" is a count taxa in the most intolerant groups.**

LITTLE CREEK CATCHMENT

The following overview of this catchment is modified from a report by North Carolina Department of Environment and Natural Resources (2003): Assessment Report - Biological Impairment in the Little Creek Watershed Cape Fear River Basin. Little Creek was not sampled in 2014.

Located in Orange and Durham Counties, Little Creek flows into the New Hope arm of B. Everett Jordan Lake, draining a 24.6-square mile area in subbasin 03-06-06 of the Cape Fear River basin. Two major tributaries, Booker Creek and Bolin Creek, drain the majority of the Little Creek catchment. The watershed includes extensive areas of residential and commercial development, as well as a portion of the campus of the University of North Carolina at Chapel Hill (UNC). As of 1999, impervious areas (such as roads and buildings) covered approximately 15 percent of the study area. This percentage has probably increased since that time. The upper three quarters of this area lies in the Carolina Slate Belt, and streams here exhibit the narrow valleys and rocky substrates associated with this geologic zone. Little Creek and the downstream reaches of Booker and Bolin Creek are located in a Triassic basin and exhibit its characteristic broad floodplains and sandy substrates. Visual assessment suggests that most streams downstream of East Franklin Street were channelized (straightened and dredged) in the past. An OWASA (Orange Water and Sewer Authority) sewer easement follows Booker, Bolin and Little Creeks for much of their length.

Bolin Creek

The headwaters of Bolin Creek are located northwest of the intersection of Homestead Road (SR 1777) and Old NC 86 (SR 1109), north of Carrboro. Bolin Creek is joined by the following named tributaries, in order from upstream to downstream: Jones Creek, Jolly Branch, Tanyard Branch, and Battle Branch. This report also includes information from some of the smaller tributaries, including an unnamed tributary at Severin Street, an unnamed Tributary of Tanyard Branch at Baldwin Park, Mill Race Branch, Cole Springs Branch, and Library Branch. Bolin Creek is dammed several times in its headwaters, most notably to form Lake Hogan, a 12-acre impoundment located just downstream of Old NC 86. Bolin Creek begins in a fairly undeveloped area and drains progressively more urban and developed areas in Carrboro and Chapel Hill as it flows towards its confluence with Booker Creek. Bolin Creek is approximately eleven miles long, mostly located within the planning jurisdiction of Carrboro. The 12-square mile watershed includes about half of Carrboro's downtown commercial district, the majority of Chapel Hill's central business district and approximately 146 acres of the University of North Carolina at Chapel Hill (UNC) campus (primarily draining to Battle Branch). The stream also drains a variety of residential areas in Chapel Hill and Carrboro, and the dense commercial district along Estes Drive near University Mall.

Booker Creek

The headwaters of Booker Creek rise southwest of the intersection of Airport Road (NC 86) and Weaver Dairy Road in Chapel Hill. Booker Creek is joined by two named tributaries: Cedar Fork and Crow Branch. The mainstem of Booker Creek has been dammed to create Lake Ellen (surface area of seven acres, built in 1961) and, further downstream, Eastwood Lake. Unlike Bolin Creek, which drains progressively more developed areas as it flows downstream, most of the Booker Creek watershed is heavily developed.

MORGAN CREEK CATCHMENT

Morgan Creek originates in a rural and residential area west of Chapel Hill, although much of this area is undergoing further residential development. It is the major tributary of University Lake. Downstream of University Lake, the stream flows through residential areas in the southern part of Chapel Hill. Major tributaries downstream of University Lake include Fan Branch and Wilson Creek. Most of the Morgan Creek catchment is located in the Slate Belt ecoregion, producing rocky streams. The Southern tributaries, however, had stream beds largely comprised of sand and gravel. These streams are similar to headwater tributaries of Pokeberry Creek in Chatham County (Lenat, unpublished data).

OTHER STREAMS
This report also includes data from Old Field Creek, which flows north into New Hope Creek.

METHODS [Note: this section largely repeated from prior report.]
All collection methods are derived from techniques used by the NC Division of Water Quality (Lenat 1988). These methods have been in use by North Carolina since 1982, and have been thoroughly tested for accuracy and repeatability. More details can be found at their web site: http://portal.ncdenr.org/web/wq/ess/bau. Three of DWQ's collection methods have been used for the Bolin Creek study: intensive "Standard Qualitative" collections and more rapid" EPT" and "Qual-4" collections. These three methods are briefly described below.

Standard Qualitative Method – Overview [Bolin Creeks sites 4-5 and Morgan Creek site 2]
The standard qualitative technique includes 10 separate samples and is designed to sample all habitats and all sizes of invertebrates. This collection technique consists of two kicknet samples (kicks), three sweep-net samples (sweeps), one leaf-pack sample, two fine-mesh rock and/or log wash samples, one sand sample, and visual collections. Invertebrates are separated from the rest of the sample in the field ("picked") using forceps and white plastic trays, and preserved in glass vials containing 70-95% ethanol.

Organisms are picked roughly in proportion to their abundance, but no attempt is made to remove all organisms. If an organism can be reliably identified as a single taxon in the field, then no more than 10 individuals need to be collected. Some organisms are not picked, even if found in the samples, because abundance is difficult to quantify or because they are most often found on the water surface or on the banks and are not truly benthic.

Organisms are classified as Abundant if 10 or more specimens are collected, Common if 3-9 specimens are collected, and Rare if 1-2 specimens are collected.

EPT Method – Overview [Morgan Creek at NC 54]
The EPT method is a more rapid collection technique, limited to 4 samples: 1 kick, 1 bank sweep, 1 leaf pack and visuals. Furthermore, collections are limited to the most intolerant "EPT" groups: Ephemeroptera, Plecoptera and Trichoptera. Note that the EPT method is a subset of the standard qualitative method described above.

Qual-4 Method – Overview [Smaller tributary sites and Little Creek]
The Qual-4 method uses the same 4 samples as the EPT method, but all benthic macroinvertebrates are collected. DWQ uses this method to evaluate small streams (drainage area < 3 square miles) and assigns ratings based solely on the biotic index values. This method is intended for use, however, only in perennial streams. For this reason, the majority of bioclassifications assigned to the Chapel Hill tributaries are tentative ratings supplemented by best professional judgment.

Assigning Bioclassifications - Overview
The ultimate result of a benthos sample is a bioclassification. Bioclassifications used by NC DWQ are Excellent, Good, Good/Fair, Fair or Poor for standard qualitative samples; they are based on both EPT taxa richness and the biotic index values. A score (1-5) is assigned for both EPT taxa richness and the NC biotic index. The final site classification is based on the average of these two scores. In some situations, adjustments must be made for stream size or the season, but such adjustments were not required for this study.

EPT Criteria
The simplest method of data analysis is the tabulation of species richness (number of species), and species richness is the most direct measure of biological diversity. The association of good

water quality with high species (or taxa) richness has been thoroughly documented. Increasing levels of pollution gradually eliminate the more sensitive species, leading to fewer EPT taxa. A score from 1 to 5 is assigned to each site, with 1 for Poor EPT taxa richness and a 5 for Excellent EPT taxa richness (see below).

The relationship of total taxa richness to water quality is nonlinear, as this metric may increase with mild enrichment of nitrogen and/or phosphorus. Taxa richness for the most intolerant groups (Ephemeroptera + Plecoptera + Trichoptera) is more reliable, but must be adjusted for ecoregion. Piedmont criteria were used for the Bolin Creek study.

Biotic Index Criteria

To supplement EPT taxa richness criteria, the North Carolina Biotic Index (NCBI) was derived as another (independent) method of bioclassification to support water quality assessments (Lenat 1993). This index is similar to the Hilsenhoff Biotic Index (Hilsenhoff, 1987) with tolerance values derived from the NC database. Biotic indices are based on a 0-10 scale, where 0 represents the best water quality and 10 represents the worst. Abundance values used in the biotic index calculation are 10 for Abundant taxa, 3 for Common taxa, and 1 for Rare taxa. The highest values (>5.1) indicate the worst water quality and receive a score of 5; the lowest values indicate Excellent water quality and receive a score of 1 (see below)

NC Division of Water Quality: Scoring for Biotic Index and EPT taxa richness values for Piedmont streams

Score	BI Values	EPT Values
5	<5.14	>33
4.6	5.14-5.18	32-33
4.4	5.19-5.23	30-31
4	5.24-5.73	26-29
3.6	5.74-5.78	24-25
3.4	5.79-5.83	22-23
3	5.84-6.43	18-21
2.6	6.44-6.48	16-17
2.4	6.49-6.53	14-15
2	6.54-7.43	10-13
1.6	7.44-7.48	8-9
1.4	7.49-7.53	6-7
1	>7.53	0-5

Derivation of Final Bioclassification for Standard Qualitative Samples

For most mountain, piedmont and coastal plain (Coastal A) streams, equal weight should be given to both the NC Biotic Index value and EPT taxa richness value in assigning bioclassifications. For these metrics, bioclassifications are assigned from the following site scores:

Excellent: 5 Good: 4 Good-Fair: 3 Fair: 2 Poor: 1

"Borderline" values are assigned near half-step values (1.4. 2.6, etc.) and are defined as boundary EPT values $\pm$1 (except coastal plain), and boundary biotic index values $\pm$0.05. The two ratings are then averaged together, and rounded up or down to produce the final classification. When the EPT and BI score differ by exactly one unit, the EPT abundance value is used to decide on rounding up or rounding down.

Small Stream Criteria

Small streams (<4 meters wide) are expected to have lower EPT taxa richness relative to larger streams. NC DWQ has developed criteria for small piedmont stream based solely on biotic index values:

Excellent	<4.4
Good	4.4-5.4
Good-Fair	5.5-6.0
Fair	6.1-7.0
Poor	>7.0

These criteria were developed only for permanent criteria; *most of the Chapel Hill small streams are intermittent.*

SAMPLING SITES (Figure 1)

More detailed site descriptions (with photos) are presented in Appendices 4-5.

Table 1 gives data on habitat ratings and substrate composition at all sites sampled in 2014. The habitat rating is based on standard Division of Water Quality procedures, and produces a value between 0 and 100. A higher value indicates better habitat quality. Abundant growths of filamentous algae were observed at many sites in March 2011, but such growths were not seen in later collections. With the exception of the Triassic sites, most Chapel Hill streams had adequate habitat to support a diverse benthic macroinvertebrate community.

FLOW DATA

The fauna of Chapel Hill streams have been frequently affected by droughts, with some streams becoming entirely dry during severe droughts. Changes due to water quality problems cannot be discerned without taking into consideration this natural stress. The data below is taken from the USGS web site, using data from 1999 to 2013. The USGS measures daily flow at Morgan Creek at NC 54 and Cane Creek; both streams are in Orange County and both are similar in geology to the Bolin Creek catchment. The Cane Creek site, however, may be affected by the upstream Cane Creek Reservoir, so this year's report only shows the Morgan Creek flow information.

Mean Monthly flow (cfs) in Upper Morgan Cr (similar to Bolin Creek), 1999-2014.
Morgan Creek nr White Cross (Drainage area 8.3 square miles)

Year	Month: 1	2	3	4	5	6	7	8	9	10	11	12
1999	13	4	5	10	0.9	0.5	0.4	0.09	40	8	7	4
2002	7	4	4	2	0.7	0.03	0.04	0.01	0.04	6	4	15
2003	6	20	32	39	11	7	6	3	2	2	2	5
2004	2	8	5	4	3	0.4	0.7	5	7	2	4	3
2005	7	7	15	6	2	0.7	0.3	0.2	0.01	0.2	0.6	7
2006	3	2	2	2	0.7	1.7	5	0.08	0.5	1.9	16	6
2007	13	7	9	12	1.8	0.6	0.2	0.002	0.000	0.008	0.003	0.2
2008	0.4	1.3	9	6	2	0.4	1.6	4	15	0.3	1.4	9
2009	5	3	19	6	3	4	0.4	0.2	0.05	0.05	7.7	18.7
2010	13	21	7	3	4	0.6	0.1	0.02	0.6	0.3	0.6	0.8
2011	0.7	1.4	3	4	1.1	0.1	0.6	0.004	0.01	0.03	1.5	3
2012	2	3	7	3	2	0.5	0.2	0.3	8	0.8	0.5	0.8
2013	7	9	4	6	9	8	13	4	0.7	2*	1*	8*
2014	11*	10*	11*	11	15*							

*Estimated from graph of daily flows

Flow data from further downstream on Morgan Creek at Chapel Hill (41 square miles) did not indicate any months with average flows less than 7 cfs (1999-2012).

Low flows (less than 0.5 cfs) are highlighted in yellow; severe low flows (less than 0.1 cfs) are highlighted in red. Values past September 2012 are median monthly values (not means).

Summer flows for 2013 were much higher than for 2004-2012; 2013-2014 fall/winter/spring flows were relatively high.

Table 1. Site characteristics, Chapel Hill Streams, 2014, Orange County.

	Habitat Scoring (0-100)										Substrate (%)					
Stream	CM	IH	BS	PV	RH	BSV	LP	RVZW	Total	Width	B	R	Gr	Sa	Si	Comments
Slate Belt (Rocky)																
Bolin Cr #4	4	16	12	6	14	6/6	10	4/3	82	6	30	35	20	15	Tr	Rocky.
Bolin Cr #5	4	20	12	6	14	5/7	10	1/3	82	8	10	20	15	55	Tr	Rocky near Franklin St, but sandy upstream. Recent habitat scoring focuses on near-bridge riffles.
Morgan Cr	4	20	12	6	14	6/6	7	4/3	85	11	5	25	25	45	Tr	Sand deposited in pools.
Pritchard Br	5	11	8	6	14	6/0	7	3/1	61	2	15	25	20	40	Tr	Urban. Embedded, with Incised channel. Rip-rap added in 2012/2013, but with severe bank erosion.
Mill Race Br	4	11	6	4	16	5/5	7	4/1	63	2	5	20	25	50	Tr	Urban. Sandy, embedded substrate. Fauna sparse. Amount of sand increased in 2014, little Aufwuchs. Stream restoration in progress; machinery in stream.
Tanyard Br*	4	16	12	10	10	6/3	2	4/3	70	3	10	25	35	30	Tr	Good habitat, but fauna very sparse. Heavily developed catchment.
UT Tanyard Br	No sample in 2014															
Old Field Cr	4	20	12	6	7	6/6	10	2/3	76	4	30	20	30	25	10	Lots of bedrock, much better flow in 2014. Lots of filamentous algae.
Cedar Fk 1	5	16	12	6	14	7/2	2	2/4	70	3	40	35	15	10	Tr	Houses close to stream, older neighborhood. Lots of bedrock.
Cedar Fk 2	4	20	15	10	16	5/5	7	2/4	88	3	35	30	25	10	-	Good habitat, but poor fauna. Midges dominant.
Cedar Fk 3	2	16	11	0	14	6/2	10	4/2	69	3	10	15	10	60	5	Lots of fine sand. Scoured and widened? Poor habitat and no buffer.
Cedar Fk 4	5	20	8	10	12	5/5	7	5/1	76	1	30	40	20	10	Tr	Ditch adjacent to apartment complex.
UT Cedar Fk 2 A	4	15	12	10	16	7/7	7	5/3	86	1	25	40	20	15	Tr	Too small, no flow for months?
UT Cedar Fk 2 B	5	15	12	10	14	7/7	10	5/4	89	1	30	40	20	10	Tr	N of Brookview. High gradient, bedrock area upstream
UT Cedar Fk 1	4	19	12	6	16	6/5	7	4/2	81	1	15	45	25	15	-	S of Brookview. Small, but good fauna.
Booker Cr 1	5	20	3	6	3	6/7	10	4/5	69	3	5	10	10	65	10	Sandy, few riffles.
Library Br	No sample in 2014															
Cole Springs Br	4	12	12	8	16	7/7	7	4/5	84	3	30	30	20	20	-	Old residential area, forested riparian, good habitat. Declining? Evidence of recent sediment input.
Jolly Br	5	16	14	6	14	6/6	7	4/4	82	2	30	30	25	15	-	Some bank erosion, but largely forested. Good habitat.
UT at Severin	No sample in 2014															
UT at Bayberry	5	16	12	6	16	6/6	7	4/4	82	1	15	60	20	5	-	Small and rocky. Good buffer zone.
Sandy Transition Streams																
Battle Br	5	11	11	4	7	2/2	2	3/3	50	2	10	15	35	50	Tr	Sandy with severe bank erosion. Scoured? Midges dominant. Salamanders abundant.
Fan Br	No sample in 2014															
Wilson Cr 1	No sample in 2014															
Wilson Cr 2	5	20	4	10	3	6/6	10	4/4	71	3	-	5	15	70	10	High density development at site, but older development upstream with large lots, mostly forested, sandy.
Triassic (Clay/Sand)																
Little Cr	No sample in 2014															
Dry Cr	5	18	1	0	3	6/6	7	4/4	54	<1	-	-	-	5	95	Poor habitat (mostly clay), but good riparian buffer. Many seeps in this area, swamp habitat upstream
Booker Cr 2	4	15	3	0	3	7/6	7	544	53	5.5	-	5	25	65	5	Poor habitat (sand/clay), entrenched and widened.

Habitat Components: CM = Channel Modification (0-5), IH = Instream Habitat (0-20), BS = Bottom Substrate (1-15), PV = Pool Variety (0-10), RH = Riffle Habitats (0-16), BSV = Bank Stability and Vegetation (0-7 for both left and right banks), LP = Light Penetration (0-10), RVZM = Riparian Vegetative Zone Width (0-5 for both left and right banks).
Substrate: Boulder (B), Rubble (R), Gravel (Gr), Sand (Sa), Silt (Si), Tr = Trace (<10%). Stream width is in meters.

PRIOR BIOLOGICAL DATA

Benthic macroinvertebrates have been collected in Orange County for over 30 years. One of the first publications was a list of species found in Cane Creek, prior to the existence of the Cane Creek Reservoir (Lenat 1983). The NC Division of Water Quality has multiple collections from Morgan Creek and Bolin Creek, including both standard qualitative and EPT samples. EPT samples use a shorter 4-sample method (vs. 10 samples for the standard qualitative), and are limited to the Ephemeroptera, Plecoptera, and Trichoptera (see Methods).

The following data are taken from the Cape Fear River basin report (NC DWQ 2003):

NC DWQ data, 1985-2003. Standard Qualitative and EPT samples.

	Date	Total S	EPT S	BI	Bioclass*
Bolin Cr at SR 1777	7/01	87	24	5.96	Good-Fair
	2/01	82	17	6.40	Not Rated
	4/00	-	26	-	Good
	3/98	-	23	-	Good
	4/93	-	24	-	Good
Bolin Cr at Village Rd	3/02	40	7	7.00	Fair (follows Drought)
	7/01	52	9	6.6	Fair
	2/01	54	6	7.00	Poor
	2/98	59	26	5.1	Good
	4/93	-	24	-	Good-Fair
Bolin Cr, E Franklin St	7/01	41	4	6.9	Poor
	3/01	53	4	7.1	Poor
	3/98	37	13	6.3	Fair
	2/98	-	4	-	Poor
	2/93	32	8	6.5	Fair
	4/86	89	28	6.1	Good-Fair
Booker Cr, Piney Mtn Rd	7/01	35	4	6.1	Not Rated
	2/01	39	8	6.3	Not Rated
	3/98	-	10	-	Fair
Booker Cr, Barbara Ct	7/01	45	3	6.6	Not Rated
	2/01	31	4	7.3	Not Rated
Booker Ct, Walnut St	7/01	31	4	7.3	Not Rated
	2/01	51	7	6.9	Not Rated
Morgan Cr, NC 54	06/13	-	19	-	Good-Fair
	03/09	-	26	-	Good
	03/08	-	12	-	Not Rated (Drought)
	06/04	-	18	-	Good-Fair
	10/03	-	22	-	Good
	7/03	-	20	-	Good-Fair
	5/03	-	16	-	Good-Fair
	3/03	-	12	-	Not Rated (Drought)
	1/03	-	8	-	Not Rated (Drought)
	9/02	-	2	-	Not Rated (Drought)
	4/00	-	36	-	Excellent
	2/98	80	33	4.4	Excellent
	10/96	64	22	5.0	Good
	7/93	61	22	4.9	Good
	2/93	90	36	4.5	Excellent
	4/85	109	32	5.7	Good

Morgan Creek near the Botanical gardens	3/98	46	20	6.1	Good-Fair
	4/93	-	16	-	Fair
	2/93	71	26	6.0	Good-Fair
Little Cr at Pinehurst Dr	7/01	27	5	6.8	Not Rated
	3/01	45	3	7.3	Poor
	2/93	37	7	7.1	Fair

*DWQ did not assign ratings to streams in the Triassic basin, pending development of criteria for this ecoregion.

NC Department of Environment and Natural Resources (2003) provided the following summary of the Bolin Creek data:

> "When Bolin Creek was first sampled at East Franklin Street in 1986, the benthic community was reasonably diverse, and the stream, though showing indications of impact, was not considered impaired. Impairment was evident when the stream was next sampled in 1993 and has persisted at this downstream site. Upstream sites supported a reasonably intact benthic fauna until 2000, when impairment became evident as far upstream as Waterside Drive in Carrboro, located between Homestead Road and Estes Drive Extension. It is probably too soon to evaluate whether this decline in the benthic community is persistent, or was due to a specific perturbation from which this portion of the stream will yet recover. Currently, only the upper portion of Bolin Creek (Homestead Road) appears to support an adequate benthic fauna.
>
> The causes of impairment in the portion of Bolin Creek between Airport Road and Waterside Drive are less clear than in the downstream section of Bolin Creek. In-stream habitat is adequate. Some effects of toxicity and scour are likely, although these impacts appear less pronounced than in lower Bolin Creek, and likely decline significantly at the upstream end of this section."

DWQ collections from Morgan Creek in 2002 and 2003 were intended to show recovery from the 4- month drought. These data indicated that the stream took about one year to recover from extreme low flow. It had shown a decline over time, never attaining the very high EPT taxa richness values seen in 1985, 1993, 1998, and 2000.

RESULTS AND DISCUSSION (Tables 2-4, Appendices 1-2)

Early samples from Bolin Creek (prior to 2000) indicated Good water quality in the upper section, declining slightly to Good-Fair further downstream. Surveys in 2000, however, produced a Fair rating for sites at Waterside Drive (#3) and Estes Drive (#4). It appears that nonpoint source runoff had a significant negative effect on water quality in Bolin Creek between 1998 and 2000. Note that changes in habitat were not responsible for any these changes.

After August 2001, Bolin Creek was potentially affected by a series of severe droughts, with very low flows (see USGS flow data for Morgan Creek) in:

-Sept-Dec 2001 (4 months, with lowest flow in Oct-Nov)
-June-Sept 2002 (4 months with streams drying up much of this time)
-June 2004
Note that 2003-2004 would be expected to be a period of recovery.
-July-Oct 2005 (4 months with streams going dry in September)
-Aug 2006
-July-Dec 2007 (6 months, with streams going dry for 4-6 months)
-June and September 2008 – no streams went completely dry. Another period of possible recovery.
-July-Oct 2009 (4 months with severe drought for 2-3 months)
-June-August 2010 (severe drought in August)
-August-November 2011

These repeated shocks to the stream biota would be expected to severely affect the diversity of the stream fauna, and bioclassifications based on taxa richness counts might underestimate water quality conditions. The repeated Fair and Poor rating assigned to much of Bolin Creek in Carrboro and Chapel Hill during this period have been used to show that Bolin Creek does not support designated uses, but note that some intolerant species were still abundant at most Bolin sites through 2014. The exception to this pattern was Bolin Creek at Village Drive in 2012. Morgan Creek at NC 54 (intended as a control site) had lost some components of a normal stream fauna (*Elimia*, most Baetidae, *Chimarra*), but still supported a community that included some highly intolerant aquatic species through 2014. Some recovery is evident in the 2013 and 2014 samples.

Routine sampling in Carrboro and Chapel Hill had been switched from summer months to winter/spring months to avoid these periods of extreme low flow. In 2012-2014, tributaries were sampled in April and the larger streams were sampled in June. Note that June collections may miss some of the spring species, which may have emerged in April and May. "Emergence" is the natural process of going from the aquatic nymph to the aerial adult. In comparing data from March 2011 with June samples, some species may disappear due to emergence, rather than being lost due to a change in water quality. Many of the data tables and appendices (especially Appendices 1-2 and Table 4A) identify such spring species.

The 2014 spring samples followed a period of unusually cold weather, and the some species may have delayed the started their life cycles (hatching of eggs, growth of larvae). This appears to be the case for some stoneflies (*Perlesta, Haploperla*), and some baetids (esp. *Plauditus dubius).* Metrics at community level, however, still show the expected patterns.

Tables 2 and 3 present a summary of the biological monitoring for Chapel Hill streams for 2011-2014. A list of selected intolerant species is presented in Tables 4A and 4B, producing a score (the "Sum" line) that is useful in comparing sites. Species are only included in Tables 4A and 4B that were Common or Abundant at one or more sites. Although scientific names are used in the latter tables, you can simply consider these as "intolerant species #1" through "intolerant species #22".

None of the Chapel Hill sites had a community that would indicate organic loading. Some sites, however, have had a stream fauna (especially the snail *Physa*) that suggested low dissolved oxygen concentrations. Listed below, by year, are all sites where *Physa* was abundant (A) in at least one year; C = Common.

	Year			
Site	2011	2012	2013	2014
Tanyard Br	A	A	A	A
UT Tanyard Br	-	A	C	-
Dry Cr	A	A	A	A
Cedar Fork	A	A	C	C
Bolin Cr 4	A	A	C	
Old Field Cr	C	A		
Booker Cr 2		A	C	
UT Morgan/Bayberry			A	
Pritchard Br				A

It is likely that higher flows in 2013 ands 2014 produced higher dissolved oxygen concentrations. Sites that consistently have abundant *Physa* (and therefore low dissolved oxygen concentrations) are Tanyard Branch and Dry Creek.

Site Evaluations

It is important to realize that stream-flow conditions over the last few years make it difficult to accurately rate water quality in Chapel Hill streams. *Repeated drought conditions have resulted in very low flow rates, with some streams going completely dry. This would be expected to reduce the diversity of the fauna, but would have less effect on the tolerance of the aquatic fauna. For this reason, more emphasis is placed on biotic index ratings than taxa richness ratings.*
The DWQ system for rating small piedmont and mountain streams relies entirely on biotic index values, but note that it is not intended to apply to intermittent streams.

Large Streams

Note: Bolin Creek sites 1-3 are in Carrboro; they are discussed in a separate report.

Bolin Creek Site 4 (Village Drive). This site is intended to be equivalent to the Estes Drive site that has been monitored by the Town of Carrboro since 2000 and was also sampled by the NC Division of Water Quality from 1993-2002. When all sources of data are combined, the pattern clearly shows a large decline in water quality between 1998 and 2001.

The Estes Drive/Village Drive site had usually received a Fair rating during drought years, but recovered to Good-Fair in December of 2008 during a period of higher summer flows. The return of severe summer-drought conditions in 2010 and 2011, however, brought the bioclassification for this segment of Bolin Creek back down to Fair for all collections through 2013. The biotic index for this segment of Bolin Creek was significantly higher (6.7-6.8) in 2011 and 2012 relative to prior collections (5.8-6.4), but the 2013-2014 collections again produced a lower biotic index (5.9-6.3). This suggests some recovery, largely due to the appearance of the intolerant caddisfly, *Chimarra*. The 2014 collection produced a rating right on the borderline between a Fair and a Good-Fair rating. The abundance of the snail *Physa* in both 2011 and 2012 indicated that this segment of Bolin Creek had experienced low dissolved oxygen concentrations, but this problem was not evident in 2013-2014.

Date	Total S	EPT S	BI	Bioclass*
6/14	57	10	6.3	Fair/Good-Fair
6/13	33	6	5.9	Fair
6/12	51	8	6.8	Fair
3/11	59	8	6.7	Fair
3/10**	42	9	6.2	Fair
12/08**	44	12	6.0	Good-Fair
3/02*	40	7	7.0	Fair (follows Drought)
7/01*	52	9	6.6	Fair
2/01*	54	6	7.0	Poor
2/98*	59	26	5.1	Good
4/93*	-	24	-	Good-Fair

*DWQ data
**Carrboro data, seasonal correction for winter and spring data

Bolin Creek Site 5 (Franklin Street). This site received a Poor bioclassification in 2011, similar to DWQ collections in 1998 and 2008. In 2012-2014, however, the Franklin Street site was assigned a Fair bioclassification, indicating a modest improvement in water quality. The abundance of one intolerant caddisfly (*Chimarra*), from 2012-2014, supported the higher rating. This site is quite sandy upstream of the bridge area, but DWQ collections in 1986 demonstrated that habitat for this site is capable of supporting a Good or Good-Fair aquatic fauna. Urban runoff (toxics) is the most likely cause of problems in lower Bolin Creek. This is a common pattern for streams draining major cities throughout North Carolina. EPT taxa richness in 2014 was the highest since 1998.

Date	Total S	EPT S	BI	Bioclass*
6/14	48	8	6.8	Fair
6/13	34	4	6.2	Fair
6/12	30	5	6.5	Fair
3/11	50	4	7.2	Poor
7/01*	41	4	6.9	Poor
3/01*	53	4	7.1	Poor
3/98*	37	13	6.3	Fair
2/98*	-	4	-	Poor
2/93*	32	8	6.5	Fair
4/86*	89	28	6.1	Good-Fair

*DWQ data

Morgan Creek Site 1, NC 54. This site has been used as a reference site for studies in Carrboro, and there also have been many collections by the Division of Water Quality. Sampling at Morgan Creek Site 1 was limited to the intolerant "EPT" taxa, so it was not possible to calculate a biotic index value. EPT taxa richness was much lower in 2012 (11) than in 2011 (18), but some of this decline was due to the change in sampling period from April to June. Some recovery was seen in 2013-2014, with EPT taxa richness of 17-19.

The upper part of Morgan Creek has been drastically affected by extreme low flows in summer months. One highly intolerant mayfly (*Leucrocuta*) was very abundant at this site in all years, and other intolerant species were also collected (Table 3). Looking back to DWQ data from 1985-2000, this segment of Morgan Creek shows a long-term decline in water quality.

Date	Total S	EPT S	BI	Bioclass*
6/14	-	17	-	Good-Fair
6/13	-	17	-	Good-Fair
6/13*	-	19	-	Good-Fair
6/12	-	11	-	Good-Fair
3/11	-	18	-	Good-Fair
3/09*	-	26	-	Good
3/08*	-	12	-	Not Rated (Drought)
6/04*	-	18	-	Good-Fair
10/03*	-	22	-	Good
7/03*	-	20	-	Good-Fair
5/03*	-	16	-	Good-Fair
3/03*	-	12	-	Not Rated (Drought)
1/03*	-	8	-	Not Rated (Drought)
9/02*	-	2	-	Not Rated (Drought)
4/00*	-	36	-	Excellent
2/98 *	80	33	4.4	Excellent
10/96*	64	22	5.0	Good
7/93*	61	22	4.9	Good
2/93*	90	36	4.5	Excellent
4/85*	109	32	5.7	Good

*DWQ data

Morgan Creek at Ashe Place (near the Botanical Garden). Prior DWQ sampling (1993, 1998) produced a Good-Fair rating for this site. Collections from March 2011 produced only a Fair bioclass, but the fauna had some common or abundant intolerant species, including *Isonychia*, *Chimarra*, and *Psephenus herricki*. The June 2012 and 2013 collections also resulted in a Fair bioclassification, but the only abundant intolerant species was *Chimarra* in 2013. This site improved to Good-Fair in 2014, although some taxa (esp. *Isonychia*) have not returned. Much of the increased EPT taxa richness was due to the appearance of a more diverse array of baetid mayfly species (6), including *Baetis pluto* and *Acentralla nadineae.*

Morgan Creek had a bloom of bright green filamentous algae during the March 2011 collections, but this problem was not observed in later collections.

Date	Total S	EPT S	BI	Bioclass*
6/14	58	17	6.1	Good-Fair
6/13	50	9	6.6	Fair
6/12	39	9	6.3	Fair
3/11	63	12	6.7	Fair
3/98*	46	20	6.1	Good-Fair
4/93*	-	16	-	Fair
2/93*	71	26	6.0	Good-Fair

*DWQ data

Small Streams

Many sites now have four years of data, allowing a better long-term assessment of water quality. Some differences between years, however, can result from small changes in stream temperature, causing a change in either the time of emergence or the hatching of eggs. For example, *Baetis flavistriga*, *Baetis pluto*, and *Isonychia* were much less abundant in 2013 than in 2012 or 2014, likely due to a delay in the hatching of these taxa in 2013.

Slate Belt (Rocky Streams)

-Pritchard Branch. Pritchard Branch is a rocky tributary to Bolin Creek in southwestern Chapel Hill. There is residential development in this catchment (esp. in the headwaters), but a good buffer zone was seen around the stream. This stream also drains the southern portion of downtown Chapel Hill. Pritchard Creek showed signs of recent sediment inputs in 2012-2013, with deposition of new sand, scoured substrate and bank erosion. The substrate was heavily scoured in 2012-2013, having a very “clean” appearance. A more normal Aufwuchs community was observed in 2014.

The only common or abundant intolerant species in this stream in 2012 and 2013 was the snail *Elimia*, but in 2014 the caddisfly *Diplectrona modesta* was Abundant and the caddisfly *Chimarra* was Common. This clearly indicates improving water quality, although the amount of improvement will be limited by the amount of urban area in the headwaters of this catchment.

	2012	2013	2014
Total Taxa Richness	19	28	26
EPT Taxa Richness	3	3	5
EPT Abundance	3	27	32
NC Biotic Index	6.0	6.0	6.6
Rating	F-P	F-P	F-P

-Mill Race Branch. All metrics indicated Poor water Quality in Mill Race Branch from 2011 through 2014, likely due to urban runoff. This catchment has poor riparian buffer zones with severe bank erosion. The stream substrate is largely sand and gravel (75%), with only 20% rubble. The abundance of hydropsychid caddisflies in 2011 suggested the Mill Race Branch can be a perennial stream, but it may sometimes experience periods of low flow. Common

and abundant macroinvertebrate species sometimes indicated problems associated with both low dissolved oxygen (*Physa*) and toxics (*Cricotopus annulator group*, *Conchapelopia group*), although these taxa were not abundant in 2013 and 2014. The fauna was very depauperate in 2014, due to scour after heavy rainfall. Taxa richness metrics indicated a slight decline in water quality, but without the development of a tolerant benthic community.

	2011	2012	2013	2014
Total Taxa Richness	18	20	18	11
EPT Taxa Richness	3	3	2	1
NC Biotic Index	7.7	7.9	7.5	6.8
Rating	Poor	Poor	Poor	Poor

-Tanyard Branch. Like Mill Race Branch, Tanyard Branch had a very sparse fauna and appeared to have perennial flow. The majority of downtown Chapel Hill drains to this stream. The fauna at Tanyard Branch in (2012-2014) suggested problems with both low dissolved oxygen concentrations (*Physa*) and toxics (2 species of *Cricotopus* in prior collections). Total taxa richness was unusually low (7-13), in spite of suitable habitat. This site had a Poor rating in all years.

	2011	2012	2013	2014
Total Taxa Richness	7	11	13	13
EPT Taxa Richness	2	3	2	1
NC Biotic Index	7.2	7.7	7.4	7.4
Rating	Poor	Poor	Poor	Poor

-Old Field Creek. Old Field Creek runs north into New Hope Creek. A landfill is located within the Old Field catchment, but there is no current evidence that it is causing problems. The macroinverterbrate fauna has produced successively higher ratings over the years: Poor in 2011, Fair in 2012-2013 and Good-Fair in 2014. More constant flow in the later years may account for part of this improvement, or better management of the catchment. The abundance of the caddisfly *Ironoquia punctatissima* in 2014 still suggested a temporary stream, but more constant flow (and better water quality) was indicated by the abundance of *Maccaffertium modestum*, *Cheumatopsyche*, and *Amphinemura*. The Good-Fair rating indicates that this stream should supports designated uses.

	2011	2012	2013	2014
Total Taxa Richness	22	27	33	37
EPT Taxa Richness	1	4	5	12
EPT Abundance	1	10	23	54
NC Biotic Index	7.6	6.5	6.3	6.2
Rating	Poor	Fair	Fair	G-F

-Cedar Fork. Cedar Fork is located in an older residential area with large lots, but the houses are often placed very close to the stream. Cedar Fork had abundant growth of filamentous algae in most years, although the abundance of attached algae was reduced by scour in 2014. The macroinvertebrate fauna (*Physa* common-abundant) indicated problems associated with low dissolved oxygen. This site received a Fair-Poor rating in 2011, based on the high biotic index (7.3) and very low EPT taxa richness (2). A higher rating (Fair) was assigned in 2012-2014 due to higher EPT taxa richness (5-8) and a lower biotic index (6.5-6.9). Although flow-dependent species were found here in all years, the abundance of the caddisfly *Ironoquia* in some years indicated that this stream may be intermittent. There has been no recent changes in water quality for this segment of Cedar Fork. See also the following special study on the Cedar Fork catchment.

	2011	2012	2013	2014
Total Taxa Richness	20	27	29	31
EPT Taxa Richness	2	7	5	8
NC Biotic Index	7.3	6.5	6.9	6.5
Rating	F-P	Fair	Fair	Fair

-Cedar Fork and tributaries (2014 Special study). Listed in upstream-downstream order.

Cedar Fork 4. Cedar Fork Site 4 is a very small stream that looks much like a drainage ditch. The presence of rip-rap has produced a rocky streambed. This steam is too small for a bioclassification, but the tolerant fauna does suggest water quality problems.

Cedar Fork 3. An undersized culvert causes water to back up in this area during high flow, adding to the sediment problems. This site received a Fair rating.

Cedar Fork 2. This portion of Cedar Fork has good habitat, with a good buffer zone around the site. However, it received a poor rating with a very limited fauna.

Cedar Fork 1. This downstream site has been sampled four times and always received a Fair rating (See above).

UT Cedar Fork 2/2A. Two sites were sampled on this small tributary. The most upstream site was too small to be rated, but the next site (north of Brookview Drive) received an Excellent rating, with many highly intolerant species.

UT Cedar Fork 1. This small tributary (south of Brookview) road had the highest EPT taxa richness in this special study, including several very intolerant species. It received a Good rating.

The southern tributaries on Cedar Creek (the unnamed tributaries) have good water quality and do not contribute to the problems that have been previously observed at the most downstream site on Cedar Fork (Site 1). The northern section of the creek, however, shows problems along the entire length of the stream. A lack of buffer area around most of the stream may contribute to these problems.

-Booker Creek 1 (MLK). Booker Creek had a very sparse fauna with intolerant mayflies and stoneflies absent in all years. The headwaters of Booker Creek improved from Poor in 2011 to Fair in 2012-2014, but there were no large changes in the stream fauna. The Fair rating is similar to that produced by DWQ sampling in 2001. Booker Creek had some flow-dependent species in 2012, but these were already in the pupal stage, indicating this stream may become intermittent during summer months. The only encouraging signs in 2014 were that one fairly intolerant caddisfly (*Chimarra*) was Common, and the mussel *Elliptio complanata* was found to present in this segment of Booker Creek.

	2011	2012	2013	2014
Total Taxa Richness	20	25	27	28
EPT Taxa Richness	2	3	3	3
NC Biotic Index	7.5	6.4	6.3	6.2
Rating	Poor	Fair	Fair	Fair

-Cole Springs Branch. Cole Springs Branch was located in a largely forested area; this older residential area had large lot sizes and a wide forested buffer zone adjacent to the stream. Some upstream activity had added sand to the streambed in in recent years, but this did not initially affect the aquatic fauna. Total taxa richness has remained stable, but EPT taxa richness declined slightly in 2014. More distinct changes, however, were seen in 2014 for EPT abundance and the biotic index. Two intolerant species virtually disappeared from this segment of Cole Springs Branch in 2014: *Neophylax atlanta* and *Psephenus herricki*. These changes were sufficient to drop the rating from Good in 2011-2013 to Good-Fair in 2014.

	2011	2012	2013	2014
Total Taxa Richness	29	38	35	35
EPT Taxa Richness	8	11	10	7
EPT Abundance	40	43	47	26
NC Biotic Index	4.6	4.7	4.9	5.8
Rating	Good	Good	Good	G-F

-Jolly Branch. Jolly Branch is located near the Carrboro/Chapel Hill boundary; it has been included in the reports to both towns. The lack of some expected species in most years (for example heptagenid mayflies and hydropsychid caddisflies) clearly indicated stream flow has often been intermittent. The abundance of *Ironoquia* in 2011, 2013 and 2014 also suggested intermittent flow. Abundant EPT species in most years included two stoneflies *(Perlesta, Amphinemura*) and one caddisfly (*Rhyacophila fenestra*), indicating no significant water quality problems. The stoneflies were less abundant in 2014, but this may be due to colder water temperatures and delayed development of these species. This site was tentatively given a Good-Fair rating in all years, but appeared to have the best water quality in 2013-2014. Higher stream flows in the last two years may have contributed to the modest improvement.

	2011	2012	2013	2014
Total Taxa Richness	33	24	39	37
EPT Taxa Richness	8	6	11	10
NC Biotic Index	6.2	6.1	5.5	5.4
Rating	G-F	G-F	G-F	G-F

-Unnamed Tributary to Morgan Creek at Bayberry Drive. This is another very small rocky stream, only one meter wide. This site had a high diversity of intolerant stoneflies and caddisflies. This stream was assigned an Excellent rating in all years, although total taxa richness and EPT taxa richness was greatest in 2013. Of particular interest was the presence of 3 species within the intolerant caddisfly genus *Rhyacophila* in 2013. Abundant intolerant taxa included *Haploperla brevis, Diplectrona modesta, Chimarra, Lepidostoma,* and *Psephenus herricki*.

	2012	2013	2014
Total Taxa Richness	29	48	28
EPT Taxa Richness	14	18	16
NC Biotic Index	4.6	4.2	4.3
Rating	Ex	Ex	Ex

Transitional Area Streams (Sandy)

-Wilson Creek. Wilson Creek appeared to be affected by sedimentation, but the sand/gravel substrate may actually reflect local geology. Similar streams have been observed a little further south in the headwaters of Pokeberry Creek in Chatham County (Lenat, unpublished). The lower end of Wilson Creek is located in a high-density residential area, but most of the catchment is comprised of heavily-forested older residential areas with large lot sizes. In 2014, samples were only collected at the downstream site on Wilson Creek (Wilson #2).

The abundance of filamentous algae at this site is of concern, suggesting some nutrient enrichment. It would be helpful to walk further upstream, looking for the source of these nutrients. It is likely that cattle (or other animals) need to be fenced out of the stream.

	2011	2012	2013	2014
Total Taxa Richness	45	47	38	41
EPT Taxa Richness	17	19	11	16
EPT Abundance	54	54	17	54
NC Biotic Index	6.0	5.3	6.0	5.0
Rating	G-F	Good	G-F	Good

This site alternates between a Good-Fair and a Good rating. The greatest impact was observed in 2013.

-Battle Branch. Battle Branch had instream habitat similar to Wilson Creek, but the fauna indicated much worse water quality. In 2013, Conductivity was higher at this site (212-244 umhos/cm) than at the Fan Branch and Wilson Creek sites (<140 umhos/cm).

Salamanders were vey abundant in recent collections. Battle Branch showed a significant improvement from 2011 (Fair) to 2012-2014 (Good-Fair). Higher flow rates are likely the cause of this change. The presence of some intolerant taxa (*Chimarra, Psephenus herricki*) supports a Good-Fair classification.

	2011	2012	2013	2014
Total Taxa Richness	17	33	34	20
EPT Taxa Richness	4	6	4	4
NC Biotic Index	6.7	6.0	6.1	6.4
Rating	Fair	G-F	G-F	G-F

Triassic Basin Streams

Triassic basin geology (clays) tends to produce very flashy streams that go dry during summer droughts. This undoubtedly contributes to low diversity at these two sites.

-Booker Creek 2 (Willow Road). Booker Creek is a channelized stream in a heavily developed catchment. Abundant filamentous algae and silt covered most of the stream bottom during years with low flow. This algae was much less abundant in 2014. DWQ collected twice at a site near Willow Drive in 2001 (Walnut St) and obtained total taxa richness of 31-51, EPT taxa richness of 4-7, and a biotic index of 6.9-7.3. The 2011-2014 collections indicate a substantial long-term decline in water quality, with only 1-3 EPT species and an extremely high biotic index (7.6-8.2). A Poor rating is assigned to this portion of Booker Creek. The abundance of the midge *Chironomus* indicated some organic loading to lower Booker Creek during low-flow years, although this taxon was not found in 2013 or 2014. The composition of the macroinvertebrate community suggested slightly higher dissolved oxygen conditions in the lower part of Booker Creek in 2013 and 2014 relative to prior collections. This may reflect a reduction in sewer leaks in Booker Creek upstream of Willow Road.

	2011	2012	2013	2014
Total Taxa Richness	31	28	32	30
EPT Taxa Richness	1	2	2	3
NC Biotic Index	8.2	8.1	7.6	7.6
Rating	Poor	Poor	Poor	Poor

-Dry Creek. Upper Dry Creek is too small to receive a rating, and likely goes dry during drought periods. The stream bottom is clay with roots and leafpacks. Dry Creek was usually dominated by tolerant species and had a fauna typical of swamp streams. The abundance of the caddisfly *Ironquia punctatissima* suggested that this stream is frequently dry; the abundance of the snail *Physa* suggested that this stream has low dissolved oxygen concentrations.

	2011	2012	2013	2014
Total Taxa Richness	18	18	20	27
EPT Taxa Richness	2	3	3	3
NC Biotic Index	7.9	6.5	7.3	7.3
Rating	Not Rated			

Summary and Conclusions

Larger Streams

Current Status and Short-term changes. Bolin Creek always shows a decline in water quality between Village Drive and Franklin Street, going from Good-Fair to Fair or from Fair to Poor. In other words, there is a decline of one bioclassification between the upstream and downstream sites on Bolin Creek. In 2014, the upper site was rated as Fair/Good-Fair, while the lower site was rated as Fair.

All of the larger sites have shown short-term improvements in water quality. The Village Drive site has gone from Fair in 2010-2013 to Fair/Good-Fair in 2014; The Franklin Street site improved from Poor in 2011 to Fair in 2012-2014. The taxa richness of the most intolerant species (EPT Taxa Richness) went from 4-5 in 2001-2013 to 8 in 2014. The downstream site on Morgan Creek showed a substantial improvement from Fair in 2012-2013 (EPT taxa richness = 9) to Good-Fair in 2014 ((EPT taxa richness = 17). Some of this improvement may be due to higher flows in 2014; some may be due to better management of the watershed. The composition of the fauna suggests some problems with low dissolved oxygen in upper Bolin Creek in 2011-2012.

Long-tern changes. Some of the larger sites (Bolin Creek and Morgan Creek) have information on the benthic macroinvertebrate fauna going back to the mid 1980s, allowing an examination of long-term changes in water quality. This analysis combines data from the NC Division of Water Quality (now the Division of Water Resources), the Town of Carrboro and the Town of Chapel Hill. Both sites on Bolin Creek showed a severe long-term decline in water quality; the upper site (Village Drive) went from Good in 1998 to Fair or Poor from 2001 to 2002. The lower site (Frankin Street) underwent a similar decline, but at a much earlier date. This site went from Good-Fair in 1986 to Fair or Poor from 1993-2014. It would be of great interest to track land use changes over this period of time.

The upper site on Morgan (NC 54) had several had three Excellent rating from 1985 to 2000, but has usually rated as Good-Fair since that time. This segment of Morgan Creek went dry during the droughts of 2002 and 2003, causing a crash in the invertebrate fauna. While there has been some recovery since that time, continuing development in this watershed may limit the amount of improvement.

Smaller Streams

Current Status. Much better water quality can be found in many of the small streams in Chapel Hill, usually those in older neighborhoods with adequate buffer zones around the stream. Local geology also affects stream classification, with the best stream in the slate belt ecoregion.

Not Rated

-*Dry Creek*. This small stream is frequently dry. The composition of the fauna suggests that it may experience low dissolved oxygen concentrations.

-*Little Creek.* This site is within the "Triassic" ecoregion, and DWQ has not yet derived criteria for stream in this area. The benthic macroinvertebrate community, however, suggests Fair-Poor water quality. It showed some modest improvement in 2013, but was not sampled in 2014

Poor and Fair-Poor

-*Pritchard Branch*. This small stream had showed evidence of a pollution event in 2012 and 2013, including sand deposition. Some intolerant species were found in 2014, suggesting improving water quality.

-*Mill Race Branch.* This is an urban area with poor buffer zones.

-*Tanyard Branch.* This stream drains a highly developed urban area. The composition of the fauna suggests that it may experience low dissolved oxygen concentrations.

-*Booker Creek 2* (downstream). This stream drains a highly developed catchment. The fauna had suggested some organic loading and low dissolved oxygen in 2011 and 2012, but this problem was not observed in 2013 and 2014.

Fair

-*Cedar Fork*. This is a residential area with poor buffer zones. A special 2014 study of this catchment showed Good-Excellent water quality in the southern tributaries, but Poor-Fair conditions in the northern part of the catchment.

-*Booker Creek 1* (upstream). Residential area. The bioclassification for this site was upgraded from Poor in 2011 to Fair in 2012-2014. The fauna indicated intermittent flow in some years for this portion of Booker Creek.

Note: The NC Division of Water Resources considers a Poor rating to indicate a stream that does not support designated uses; A Fair rating indicates a stream that partially supports designated uses. Good-Fair, Good and Excellent ratings (below) indicate stream that fully support designated uses.

Good-Fair

-*Jolly Branch*. This stream is intermittent, but supports some highly intolerant species. It has a good buffer zone.

-*Battle Branch*. This stream drains a residential area, but with good buffer zone.

-*Old Field Creek.* Old Field Creek probably had reduced flow or went dry in 2011 and 2012, producing a Poor rating in 2011 and a Fair rating in 2012-2013. This stream showed a large improvement to Good-Fair in 2014, perhaps due to higher flows in this year.

-*Cole Springs Branch*. This stream drains a residential area with large lots and good buffer zone. It had been rated as Good in the 1st three years of this study, but declined to Good-Fair in 2014. This warrants further investigation of activities in this catchment.

Good

-*Fan Branch*. In highly developed area, but with good buffer zone and good upstream water quality. No Sample on 2014

-*Wilson Creek 2* (downstream). Also in heavily developed area, but with good buffer zone and good upstream water quality. This is one of the few permanent tributaries. This stream alternates between a Good-Fair and a Good rating; it was rated as Good in 2014.

-*Unnamed tributary 1 to Cedar Creek* (south of Brookview Drive). This stream was sampled for the first time in 2014, revealing a previously unknown area of high water quality.

Excellent

-*UT Bolin Creek* at Severin Dr (No sample in 2014) and *UT Morgan Creek* at Bayberry Dr. These are minute streams, but with good habitat and a good buffer zone. They are similar to UT Bolin Creek at Seawell Rd in Carrboro.

-*Wilson Creek 1* (upstream; not sampled in 2014). The least developed stream. This stream should be investigated to determine the source of nutrient enrichment. Both Wilson Creek sites have very abundant growths of filamentous algae.

-*Unnamed tributary 2 to Cedar Creek* (north of Brookview Drive). This stream was sampled for the first time in 2014, revealing a previously unknown area of high water quality.

Short-term changes. Cole Springs Branch was the only site that showed a significant decline in water quality in 2014. Improvements were seen at Jolly Branch (2011-12 vs. 2013-14), Pritchard Branch, and Old Field Creek.

Streams with Good-Fair, Good or Excellent ratings often were associated with older developments and forested buffer zones. It is encouraging to see that such areas of higher water quality can still be maintained within the city limits. Some of the smaller streams showed signs of intermittent flow, i.e. going dry in the summer months. Even in areas where the larger streams have poor water quality, it is useful to look for these pockets of higher ecological value. Urban planners must “think small” and conduct surveys in winter or spring months.

Table 2. Taxa richness and summary parameters, Bolin Creek, Morgan Creek and Little Creek, Chapel Hill, North Carolina, 2011-2014. No Little Creek collection in 2014.

	March 2011					June 2012					June 2013					June 2014			
Site:	B4	B5	M1*	M2	Little	B4	B5	M1*	M2	Little	B4	B5	M1*	M2	Little	B4	B5	M1*	M2
Ephemeroptera	4	1	9	7	-	3	3	7	6	2	3	1	11	3	2	4	4	10	9
Plecoptera	1	-	6	-	-	1	-	2	-	-	-	-	1	-	-	1	-	2	-
Trichoptera	3	3	3	5	3	4	2	2	3	2	3	3	5	6	3	5	4	5	8
Coleoptera	2	-		6	1	5	3		3	1	6	3		4	1	6	2		4
Odonata	2	6		3	1	3	5		2	-	1	4		2	4	6	5		4
Megaloptera	-	-		1	-	1	-		-	-	-	-		1	-	-	-		2
Diptera; Misc.	8	6		5	3	2	2		4	3	4	2		3	2	4	3		3
Diptera: Chironomidae	22	20		23	14	19	12		13	11	9	12		21	14	19	20		16
Oligochaeta	8	6		3	2	2	2		1	1	1	4		2	1	4	6		3
Crustacea	4	2		3	3	3	1		3	1	2	1		3	-	3	1		3
Mollusca	4	4		5	4	5	-		3	1	3	2		4	2	3	1		3
Other	1	2		2	-	3	-		1	2	1	2		1	3	2	2		3
Total Taxa Richness	59	50		63	31	51	30		39	24	33	34		50	32	57	48		58
EPT Taxa Richness	8	4	21*	12	3	8	5	13*	9	4	6	4	19	9	5	10	8	20*	17
EPT Abundance	21	26	67	74	5	48	34	44	67	24	53	40	87	42	25	64	48	106	97
EPT Score	1.6	1	3	2	1	1.6	1	2	1.6	1	1.4	1	3	1.6	1	2	1.6	3	2.6
NC Biotic Index	6.7	7.0	-	6.7	7.3	6.8	6.5		6.3	6.7	5.9	6.2		6.6	6.2	6.3	6.8		6.1
BI Score	2	2	-	2	2	2	2.4		3	2	3	3		2	3	3	2		3
Site Score	1.8	1.5	3-4?	2	1.5	1.8	1.7		2.3	1.5	2.2	2		1.8	2	2.5	1.8		2.8
Rating	Fair	Poor	Good?	Fair	NR	Fair	Fair	G-F?	Fair	NR	Fair	Fair	G-F	Fair	NR	F/G-F	Fair	G-F	G-F

*M1 is a 4-sample EPT collection, EPT taxa richness count has been corrected to predicted the 10-sample value for easy comparison with the other sites.
NR = Little Creek Not Rated (Fair or Poor?)

Table 3A. Taxa richness and summary parameters, Slate Belt streams, Chapel Hill, North Carolina, April 2014. Jolly and UT Bolin (at Seawell School Road). Summaries are also included from prior years. are shared sites with Carrboro.

Site:	PF	MR	Tan	UTTan	OF	Cedar	Bk1	Libr	Cole	Jolly	UTSev	UTBay	UT Bolin
Width (m):	1.5	2	2	1	2.5	3	2	1	2	1	<1	1	<1
Ephemeroptera	-	-	-	*	6	2	-	*	1	1	*	4	6
Plecoptera	-	-	-		2	2	-		1	2		4	3
Trichoptera	5	1	1		4	4	3		5	7		8	10
Coleoptera	2	1	-		1	-	2		1	2		2	4
Odonata	1	-	-		6	3	4		2	2		1	1
Diptera; Misc.	1	1	-		3	2	1		3	3		2	3
Diptera: Chironomidae	11	4	5		10	15	12		11	14		5	11
Oligochaeta	3	3	3		-	2	1		5	1		2	2
Crustacea	1	1	1		4	1	3		2	3		1	3
Mollusca	2	-	1		1	1	2		1	1		1	2
Other	-	-	1		-	-	-		-	1		-	2
Abundance of indicators													
Low DO (Physa)			+										
Toxics (Certain midges)													
Total Taxa Richness	26	11	13		37	31	28		35	37		28	47
EPT Taxa Richness	5	1	1		12	8	3		7	10		16	19
EPT Abundance	27	1	1		54	31	16		26	39		72	99
EPT Score	1	1	1		2	2	1		2	2		3	3
NC Biotic index	6.6	6.8	7.4		6.2	6.5	6.2		5.8	5.4		4.3	4.9
BI Score (Normal Streams)	2	2	2		3	2.4	3		3.4	4		5	5
Bi Rating (Small Streams)	Fair	Fair	Poor		Fair	Fair	Fair		Good	G-F		Ex	Good
Flow													
(Perennial or Intermittent)	?	Per	Per		Int	Int	Int		Per	Int		P/I	P
Combined Site Score	1.5	1.5	1.5		2.5	2.2	2		2.7	3		4	4
Overall Rating	**F-P**	**Poor**	**Poor**		**G-F**	**Fair**	**Fair**		**G-F**	**G-F**		**Ex**	**Ex**
Change vs. 2013	+	0	0		+	0	0		-	0		0	0
*No sample in 2014													
2013 Data													
Total Taxa Richness	28	18	13	16	33	29	27	26	35	39	24	48	
EPT Taxa Richness	3	2	2	3	5	5	3	4	10	11	9	18	
EPT Abundance	3	4	13	14	23	27	21	6	47	49	49	76	
NC Biotic index	6.0	7.5	7.4	7.4	6.3	6.9	6.3	5.2	4.9	5.5	4.1	4.2	
Overall Rating	**F-P**	**Poor**	**Poor**	**Poor**	**Fair**	**Fair**	**Fair**	**G-F**	**Good**	**G-F**	**Ex**	**Ex**	
2012 Data													
Total Taxa Richness	19	20	11	21	27	27	25	28	38	24	21	29	32
EPT Taxa Richness	3	3	3	4	4	7	3	7	11	6	8	14	14
EPT Abundance	3	6	23	22	10	29	14	9	43	35	41	38	
NC Biotic index	6.0	7.9	7.7	7.8	6.5	6.5	6.4	4.7	4.7	6.1	4.2	4.6	4.0
Overall Rating	**F-P**	**Poor**	**Poor**	**Poor**	**Fair**	**Fair**	**Fair**	**G-F**	**Good**	**G-F**	**Ex**	**Ex**	**Ex**
2011 Data													
Total Taxa Richness	-	18	7	12	22	20	20	24	29	33	21	-	38
EPT Taxa Richness	-	3	2	2	1	2	2	6	8	8	9	-	15
EPT Abundance	-	14	11	11	1	13	4	6	40	46	33		
Biotic index	-	7.7	7.2	7.5	7.6	7.3	7.5	5.6	4.6	6.2	5.1	-	4.2
Overall Rating	**-**	**Poor**	**Poor**	**Poor**	**Poor**	**F-P**	**Poor**	**G-F**	**Good**	**G-F**	**Good**	**-**	**Ex**

*Flow: Per = Perennial, Int = intermittent (Based on faunal composition)
**Rating: Ex = Excellent, G-F = Good-Fair, F = Fair, P = Poor. Small stream criteria may not work for Intermittent streams. Fair and Poor ratings are used to designate streams that do not support designated uses.
Site abbreviations: PF = Prichard Branch, Cedar = Cedar Fork, OF = Old Field Creek, Bk1 = Booker Cr #1, MR = Mill Race Branch, Tan = Tanyard Branch, UTTan = UT Tanyard Branch, Cole = Cole's Spring Branch, Jolly = Jolly Branch, Libr = Library Branch, UTBay = UT Morgan Cr at Baybery Dr.

Table 3B. Taxa richness and summary parameters, Triassic and "Transition" streams, Chapel Hill, North Carolina, April 2014. (No collections at Fan Branch and Upper Wilson Creek in 2014).

Site:	Batt	Fan	Wil1	Wil2	Dry	Bk2
Width (m):	2	3	2	3	1	4.5
Ephemeroptera	-			4	1	1
Plecoptera	-			5	-	-
Trichoptera	4			7	2	2
Coleoptera	1			4	-	-
Odonata	1			3	2	3
Diptera; Misc.	1			2	1	2
Diptera: Chironomidae	9			12	13	16
Oligochaeta	2			2	5	3
Crustacea	1			1	1	1
Mollusca	1			1	2	2
Abundance of indicators						
Low DO (Physa)					+	
Toxics (Certain midges)						
Total Taxa Richness	20			41	27	30
EPT Taxa Richness	4			16	3	3
EPT Abundance	10			54	12	5
EPT Score	1			3.0	1	1
NC Biotic index	6.4			5.0	7.3	7.6
BI Score (Normal Streams)	3			5	2	1
Bi Rating (Small Streams)	G-F			Good	Poor	Poor
Flow						
(Perennial or Intermittent)	P/I			Per	I	I
Combined Site Score	2			4	1	1
Overall Rating	**G-F**			**Good**	**NR**	**Poor**
Change vs. 2013	**0**			**-**	**0**	**0**
2013 Data						
Total Taxa Richness	34	41	50	38	20	32
EPT Taxa Richness	4	14	20	11	3	2
EPT Abundance	19	65	104	17	7	11
NC Biotic index	6.1	5.2	4.1	6.0	7.3	7.6
BI Score (Normal Streams)	3	4.4	5	3	2	1
Overall Rating	**G-F**	**Good**	**Ex**	**G-F**	**NR**	**Poor**
2012 Data						
Total Taxa Richness	33	37	45	47	18	28
EPT Taxa Richness	6	11	23	19	3	2
EPT Abundance	17	46	103	54	12	4
Biotic index	6.0	5.7	4.0	5.3	6.5	8.1
Overall Rating	**G-F**	**Good**	**Ex**	**Good**	**NR**	**Poor**
2011 Data						
Total Taxa Richness	17	35	-	45	18	31
EPT Taxa Richness	4	14	-	17	2	1
EPT Abundance	12	65		54	11	1
Biotic index	6.7	5.4	-	6.0	7.9	8.2
Overall Rating	**Fair**	**Good**	**-**	**G-F**	**NR**	**Poor**

*Flow: Per = Perennial, Int = intermittent (Based on faunal composition)
**Rating: Ex = Excellent, G-F = Good-Fair, Small stream criteria may not work for Intermittent streams. Fair and Poor ratings are used to designate streams that do not support designated uses.

Site abbreviations: Batt = Battle Branch, Wil = Wilson Creek (#1 and #2), Fan = Fan Branch, Bk2 = Booker Creek #2, Dry = Dry Creek

Table 3C. Taxa richness and summary parameters, Cedar Fork catchment, Chapel Hill, North Carolina, April 2014. Cedar Fork sites with most upstream sites listed first.

	Unnamed Tribs			Cedar Fork			
Site:	UT2	UT2A	UT1	4	3	2	1
Width (m):	1	1	1	1	3	3	3
Ephemeroptera	-	1	2	-	-	-	2
Plecoptera	1	2	4	-	-	-	2
Trichoptera	5	7	6	3	2	4	4
Coleoptera	-	2	1	2	4	1	-
Odonata	-	-	1	-	-	-	3
Diptera; Misc.	1	1	4	1	1	1	2
Diptera: Chironomidae	5	5	14	4	14	8	15
Oligochaeta	3	1	2	2	6	3	2
Crustacea	3	2	3	2	4	1	1
Mollusca	-	-	-	1	2	1	1
Other	-	-	-	2	-	-	-
Abundance of indicators							
Low DO (Physa)	-	-	-	+	-	-	-
Toxics (Certain midges)	-	-	-	-	-	-	-
Total Taxa Richness	18	21	37	17	33	19	32
EPT Taxa Richness	6	10	12	3	2	4	8
EPT Abundance	26	42	62	14	13	19	32
EPT Score	1	2	2	1	1	1	2
NC Biotic index	6.0	3.9	5.5	7.5	6.8	7.2	6.5
BI Score (Normal Streams)	3.0	5.0	4.0	1.4	2.0	2.0	2.4
Bi Rating (Small Streams)	Fair	Ex	G-F	Poor	Fair	Poor	Fair
Flow							
(Perennial or Intermittent)	I	I	I	I	I/P	P	P
Combined Site Score	2.0	3.5	3.0	1.2	1.5	1.5	2.2
Suggested Overall Rating	**NR**	**Ex**	**Good**	**NR**	**Fair**	**Poor**	**Fair**

NR = Not Rated
*Flow: Per = Perennial, Int = intermittent (Based on faunal composition)
**Rating: Ex = Excellent, G-F = Good-Fair, Small stream criteria may not work for Intermittent streams. Fair and Poor ratings are used to designate streams that do not support designated uses.

Table 4A. Selected intolerant species at larger Chapel Hill streams: Bolin Creek (B4, B5), Morgan Mill Creek (MM1, MM2) and Little Creek, March 2011 and June 2012-2014. Taxa must be Common or Abundant at one or more sites. Note that "Spring" species (see below) have emerged prior to June collections. No collection from Little Creek in 2014.

	March 2011					June 2012					June 2013								
Site:	B4	B5	MI	M2	Little	B4	B5	MI	M2	Little	B4	B5	MI	M2	Little	B4	B5	MI	M2
Leucrocuta aphrodite	-	-	C	-	-	-	-	A	-	-	-	-	A	-	-	-	-	A	-
Isonychia spp	-	-	-	A	-	-	-	R	C	-	-	-	-	-	-	-	-	A	-
Aconeuria abnormis	-	-	-	-	-	R	-	C	-	-	-	-	-	-	-	R	-	C	-
Perlesta sp	-	-	-	-	-	-	-	C	-	-	-	-	A	-	-	-	-	C	-
Chimarra sp	R	A	-	A	-	C	A	-	C	-	A	A	A	A	A	A	A	A	A
Neophylax oligius	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	R
Paraleptophlebia sp	-	-	C	-	-	-	-	R	-	-	-	-	C	-	-	-	-	-	-
Habrophlebia vibrans	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-
Psephenus herricki	A	-		C	-	C	-	C	C	-	A	-	A	R	-	A	R	A	-
Elimia sp	C	-		-	-	-	-	-	-	-	R	R	-	-	-	R	-	-	-
Spring (March) only																			
Ameletus lineatus	-	-	C	-	-														
Isoperla namata gr	-	-	A	-	-														
Clioperla clio	-	-	A	-	-														
Rhyacophila fenestra	-	-	C	-	-														
Sum*	14	10	30	23	0	7	10	21	9	0	21	11	46	11	10	22	11	56	11

*Using Rare = 1, Common = 3, and Abundant = 10.

Table 4B. Selected intolerant species at smaller Chapel Hill streams, March 2011 and April 2012-2014. Taxa must be Common or Abundant at one or more sites. Site abbreviations: PF = Prichard Branch, Cedar = Cedar Fork, OF = Old Field Creek, Bk1 = Booker Cr #1, MR = Mill Race Branch, Tan = Tanyard Branch, UTTan = UT Tanyard Branch, Cole = Cole's Spring Branch, Jolly = Jolly Branch, Libr = Library Branch, UTSev = UT Bolin Creek at Severin St, UTBay = UT Morgan Cr at Bayberry Dr.

March 2011

Site:	Prit	MR	Tan	UTTan	OF	CFk	Bk1	Libr	CSpr	Jolly	UTSev	UTBa	Batt	Fan	Wils1	Wils2	Dry	Bk2
Ameletus lineatus		-	-		-	-	-	R	-	C	C		-	-		C	-	-
Paraleptophlebia sp		-	-		-	-	-	C	-	-	-		R	-		-	-	-
Haploperla brevis		-	-		-	-	-	R	A	-	-		-	C		R	-	-
Isoperla namata		-	-		-	-	-	-	-	-	-		-	C		C	-	-
Amphinemura sp		-	-		-	-	-	R	-	A	A		-	A		A	-	R
Chimarra sp		-	-		-	-	C	-	-	-	-		C	R		R	-	-
Diplectrona modesta		R	-		-	-	-	R	R	-	R		-	R		C	-	-
Rhyacophila fenestra		-	-		-	-	-	-	-	A	R		-	A		-	-	-
Neophylax oligius		-	-		-	-	-	-	A	-	-		-	-		-	-	-
Neophylax ornatus		-	-		-	-	-	-	-	R	A		-	-		-	-	-
Psephenus herricki		-	R		-	-	-	-	C	-	R		R	-		C	-	-
Elimia sp		-	-		-	-	-	A	A	-	-		-	A		-	-	-
		1	1		0	0	3	17	34	24	26		5	38		24	0	1

April 2012

Site:	Prit	MR	Tan	UTTan	OF	CFk	Bk1	Libr	CSpr	Jolly	UTSev	UTBa	Batt	Fan	Wils1	Wils2	Dry	Bk2
Ameletus lineatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Baetis pluto	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	A	-	-
Paraleptophlebia sp	-	-	-	-	-	-	-	-	-	-	A	A	-	-	R	R	-	-
Ephemerella dorothea	-	-	-	-	-	-	-	-	-	-	-	-	-	C	A	R	-	-
Isonychia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	C	-	-
Haploperla brevis	-	-	-	-	-	-	-	-	A	-	-	C	R	C	A	C	-	-
Eccoptura xanthenes	-	-	-	-	-	-	-	-	-	-	-	R	-	-	C	-	-	-
Perlesta sp	-	-	-	-	-	-	-	-	-	A	C	A	-	A	A	A	-	-
Amphinemura sp	-	-	-	R	R	-	-	R	R	A	A	C	-	A	C	R	R	-
Chimarra sp	-	-	-	R		-	R	R	A	-	-	R	C	-	-	-	-	-
Rhyacophila fenestra	-	-	-	-	-	-	-	-	-	A	R	C	-	-	-	R	-	-
Rhyacophila glaberrima	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	-
Neophylax oligius	-	-	-	-	-	-	-	-	A	-	-	-	-	-	A	A	-	-
Neophylax ornatus	R	-	-	-	-	-	-	C	C	R	A	R	-	-	R	-	-	-
Pycnopsyche sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-
Lepidostoma sp	-	-	-	-	-	-	-	-	-	-	-	R	-	C	R	-	-	-
Psephenus herricki	-	-	-	-	-	-	-	-	A	-	-	R	A	-	C	R	-	-
Elimia sp	A	-	-	-	-	-	-	A	A	-	-	-	-	C	-	-	-	-
Sum	**11**	**0**	**0**	**2**	**1**	**0**	**1**	**15**	**54**	**31**	**37**	**34**	**14**	**32**	**83**	**41**	**1**	**0**

April 2013

Site:	Prit	MR	Tan	UTTan	OF	CFk	Bk1	Libr	CSpr	Jolly	UTSev	UTBa	Batt	Fan	Wils1	Wils2	Dry	Bk2
Ameletus lineatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	C	-	-
Paraleptophlebia sp	-	-	-	-	-	-	-	-	-	R	A	A	-	-	-	-	-	-
Ephemerella dorothea	-	-	-	-	-	-	-	-	-	-	-	-	-	A	A	R	-	-
Haploperla brevis	-	-	-	-	-	-	-	-	A	-	-	A	-	A	A	R	-	-
Eccoptura xanthenes	-	-	-	-	-	-	-	-	-	-	-	R	-	A	R	-	-	-
Perlesta sp	-	-	-	-	-	-	-	-	-	A	C	A	-	A	A	C	-	-
Amphinemura sp	-	-	-	-	R	-	-	R	R	A	A	A	-	A	A	R	-	-
Chimarra sp	R	-	-	R	-	R	R	-	C	-	R	R	A	R	-	-	-	-
Rhyacophila fenestra	-	-	-	-	-	-	-	-	-	A	-	R	-	-	C	-	-	-
Rhyacophila glaberrima	-	-	-	-	-	-	-	-	-	R	C	R	-	-	-	-	-	-
Neophylax oligius	-	-	-	-	-	-	-	-	A	-	-	-	-	R	C	-	-	-
Neophylax ornatus		-	-	-	-	-	-	-	-	C	C	A	A	-	-	-	-	-
Pycnopsyche sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Lepidostoma sp	-	-	-	-	-	-	-	R	R	-	-	A	-	C	A	-	-	-
Psephenus herricki	R	-	-	-	-	R	-	R	A	-	-	C	C	-	C	R	-	-
Elimia sp	C	-	-	-	-	-	-	A	A	-	-	-	-	C	A	-	-	-
Sum*	**5**	**0**	**0**	**1**	**1**	**2**	**1**	**13**	**45**	**35**	**30**	**67**	**23**	**58**	**74**	**10**	**0**	**0**

Table 4B. Continued

April 2014

Site:	Prit	MR	Tan	OF	CFk	Bk1	CSpr	Jolly	UTBa	Batt	Wils2	Dry	Bk2
Stenacron carolina	-	-	-	-	-	-	-	-	R	-	-	-	-
Ameletus lineatus	-	-	-	-	-	-	-	-	-	-	-	-	-
Paraleptophlebia sp	-	-	-	-	-	-	-	-	R	-	-	-	-
Ephemerella dorothea	-	-	-	-	-	-	-	-	-	-	C	-	-
Haploperla brevis	-	-	-	-	-	-	C	-	-	-	-	-	-
Eccoptura xanthenes	-	-	-	-	-	-	-	-	C	-	C	-	-
Perlesta sp	-	-	-	R	-	-	-	R	R	-	C	-	-
Amphinemura sp	-	-	-	A	R	-	-	R	A	-	A	-	-
Isoperla namata gr	-	-	-	-	-	-	-	-	-	-	R	-	-
Chimarra sp	C	-	-	R	C	C	C	C	A	C	-	-	-
Diplectrona modesta	A	-	-	-	-	-	R	-	A	-	R	-	-
Rhyacophila fenestra	-	-	-	C	-	-	-	A	R	-	R	-	-
Neophylax oligius	-	-	-	-	-	-	-	-	-	-	C	-	-
Neophylax ornatus		-	-	-	-	-	-	A	R	-	-	-	-
Pycnopsyche sp	-	-	-	-	-	-	-	-	-	-	R	-	-
Lepidostoma sp	-	-	-	-	-	-	R	-	A	-	R	-	-
Psephenus herricki	-	-	-	-		-	R	-	A	-	R	-	-
Elimia sp	C	-	-	-	-	-	A	-	-	-	R	-	-
Sum*	**16**	**0**	**0**	**15**	**3**	**3**	**19**	**25**	**58**	**3**	**29**	**0**	**0**
Change vs. 2013	**+**	**0**	**0**	**+**	**0**	**0**	**-**	**0**	**0**	**-**	**+?**	**0**	**0**

*Using Rare = 1, Common = 3, and Abundant = 10.

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Appendix 1. Benthic macroinvertebrates collected from Bolin Creek (B4, B5), Morgan Creek (MM1, MM2) and Little Creek, Chapel Hill, March 2011 and June 2012-2014. R=Rare, C=Common, A=Abundant. Upstream Morgan Creek collections (M1: NC 54) limited to most intolerant (EPT) groups. Blue highlights indicate most intolerant species; red highlights indicate most tolerant species. Yellow highlights show selected between-year changes. Species found only in the spring (and therefore missing from the later June samples) are grouped together at the end of each section.

	March 2011				June 2012				June 2013				June 2014			
	B4	B5	M1	M2	B4	B5	M1	M2	B4	B5	M1	M2	B4	B5	M1	M2
Baetis flavistriga (summer)	-	-	-	-	A	A	-	A	A	A	C	C	A	A	R	A
Baetis intercalaris (summer)	-	-	-	-	-	R	R	A	-	-	-	-	-	R	-	A
Baetis pluto	-	-	-	-	-	-	-	-	-	-	-	-	R	-	A	A
Acentrella nadineae	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	C
Centroptilum triangulifer	A	-	-	R	-	-	R	-	-	-	-	-	-	-	R	-
Procloeon sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R
Labiobaetis propinquus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	C
Maccaffertium modestum	-	C	R	A	A	C	A	A	C	-	A	A	A	A	A	A
Stenonema femoratum	-	-	C	-	-	-	C	-	-	-	A	-	-	-	R	-
Stenacron interpunctatum	C	-	-	A	C	-	-	A	A	-	A	C	A	C	A	C
Stenacron pallidum	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Leucrocuta aphrodite	-	-	C	-	-	-	A	-	-	-	A	-	-	-	A	-
Caenis spp	-	-	C	A	-	-	-	-	-	-	C	-	-	-	-	A
Isonychia spp	-	-	-	A	-	-	R	C	-	-	-	-	-	-	A	-
Paraleptophlebia sp	-	-	C	-	-	-	R	-	-	-	C	-	-	-	-	-
Habrophlebia vibrans	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-
Hexagenia sp	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Plauditus dubius gr*	-	-	A	R	-	-	-	-	-	-	R	-	-	-	-	-
Acentrella ampla*	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-
Siphlonurus sp*	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Eurylophella spp*	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Ameletus lineatus*	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-
PLECOPTERA																
Acroneuria abnormis	-	-	-	-	R	-	C	-	-	-	-	-	R	-	C	-
Perlesta sp	-	-	-	-	-	-	C	-	-	-	A	-	-	-	C	-
Isoperla namata gr*	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-
I. burkesi*	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Clioperla clio*	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphinemura sp*	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leuctra sp*	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-
TRICHOPTERA																
Cheumatopsyche spp	C	A	-	A	A	A	A	A	A	A	A	A	A	C	A	A
Hydropsyche betteni	R	C	-	A	A	-	-	A	A	A	R	A	A	A	A	A
Chimarra sp	R	A	-	A	C	A	-	C	A	A	A	C	A	A	A	A
Polycentropus sp	-	-	-	R	-	-	R	-	-	-	-	R	-	-	C	R
Hydroptila sp	-	-	-	-	-	-	-	-	-	-	-	-	R	R	-	R
Neophylax oligius	-	-	R	-	-	-	-	-	-	-	-	-	-	-	A	R
Oecetis sp A	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Oecetis persimilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
Triaenodes ignitus	-	-	-	R	-	-	-	-	-	-	-	R	R	-	-	C
Ironoquia punctatissima*	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhyacophila fenestra*	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-

	March 2011			June 2012			June 2013			June 2014		
	B4	B5	M2	B4	B5	M2	B4	B5	M2	B4	B5	M2
COLEOPTERA												
Ancyronyx variegata	-	-	R	-	-	-	-	-	-	-	-	-
Macronychus glabratus	-	-	-	-	R	-	-	-	-	-	-	-
Dubiraphia sp	-	-	R	R	-	-	R	R	-	R	-	-
Stenelmis crenata	R	-	C	A	C	C	C	A	A	A	A	C
Psephenus herricki	A	-	C	C	-	C	A	-	R	A	R	-
Helichus spp	-	-	R	R	R	-	R	R	-	R	-	R
Coptotomus sp	-	-	-	-	-	-	-	-	-	R	-	-
Neoporus SP	-	-	-	-	-	-	R	-	R	A	-	R
Neoporus mellitus gr	-	-	R	-	-	R	R	-	R	-	-	R
Peltodytes sp	-	-	-	R	-	-	-	-	-	-	-	-
ODONATA												
Argia spp	-	R	-	-	C	A	-	A	A	C	A	A
Calopteryx sp	-	C	R	-	-	-	-	-	-	-	-	-
Enallagma spp	R	C	A	-	R	-	R	R	-	C	R	-
Gomphus sp	-	R	R	-	-	-	-	-	-	R	-	-
Hagenius brevistylus	-	-	-	-	-	-	-	-	-	R	-	-
Progomphus obscurus	-	A	-	-	R	R	-	-	-	-	-	-
Stylogomphus albistylus	-	-	-	-	R	-	-	R	-	R	R	-
Macromia sp	-	-	-	-	-	-	-	-	-	-	-	R
Libellula sp	-	-	-	R	-	-	-	-	-	-	-	-
Pachydiplax longipennis	R	-	-	R	-	-	-	-	R	-	-	-
Somatochlora sp	-	R	-	R	R	-	-	-	-	C	A	-
Boyeria vinosa	-	-	-	-	-	-	-	R	-	-	-	C
Basiaeshna janata	-	-	-	-	-	-	-	-	-	-	C	R
MEGALOPTERA												
Sialis sp	-	-	R	R	-	-	-	-	-	-	-	C
Corydalus cornutus	-	-	-	-	-	-	-	-	C	-	-	C
DIPTERA: MISC.												
Antocha spp	R	-	R	-	-	R	R	-	C	-	-	C
Tipula spp	R	C	C	C	C	C	C	C	A	C	C	-
Palpomyia complex	R	-	R	-	-	-	-	-	-	-	-	R
Anopheles sp	-	-	-	-	-	R	-	-	-	-	-	-
Empididae	-	-	-	-	-	-	-	-	-	R	R	-
Dolichopodidae	-	-	-	-	-	-	R	-	-	-	-	-
Dixella indiana	-	-	-	-	-	-	-	-	-	R	-	-
Simulium spp	A	C	A	A	A	A	A	A	A	A	A	A
Cnephia mutate*	C	-	-	-	-	-	-	-	-	-	-	-
Prosimulium spp*	C	-	A	-	-	-	-	-	-	-	-	-
DIPTERA: CHIRONOMIDAE												
Ablabesmyia janta/parajanta	-	-	C	R	-	-	-	-	R	-	-	-
Ablabesmyia mallochi	A	A	A	C	R	R	-	-	R	R	C	C
Clinotanypus pinguis	-	-	R	-	-	-	-	-	-	-	-	-
Conchapelopia group	C	R	R	R	R	C	C	C	A	R	R	C
Labrundinia pilosella	-	-	-	-	-	-	-	-	R	-	-	-
Natarsia spp	-	-	-	R	C	-	-	-	R	-	-	R
Nilotanypus sp	-	-	-	-	R	-	-	R	-	R	-	R
Procladius sp	R	-	C	C	-	-	-	-	-	-	-	-

	March 2011			June 2012			June 2013			June 2014		
	B4	B5	M2	B4	B5	M2	B4	B5	M2	B4	B5	M2
Cardiocladius sp	-	C	-	-	-	-	-	-	R	-	R	C
Corynoneura spp	R	R	R	-	-	-	-	R	-	R	R	-
Thienemaniella spp	-	-	C	R	-	R	-	-	R	-	-	R
Brillia sp	-	-	-	-	-	-	R	-	R	-	-	-
Cricotopus bicinctus	A	-	A	C	-	R	-	-	-	C	-	-
Cricotopus triannulatus gr	-	-	-	R	-	-	-	R	-	R	-	R
Diplocladius cultriger*	R	R	R	-	-	-	-	-	-	-	-	-
Eukiefferiella claripennis gr	R	R	R	R	-	-	-	C	-	-	R	-
Hydrobaenus sp*	-	C	C	-	-	-	-	-	-	-	-	-
Nanocladius spp	C	R	-	-	-	-	-	-	C	-	R	R
Orthocladius spp												
O. obumbratus	A	A	A	-	-	-	-	-	-	-	-	-
O. dorenus	A	A	A	-	-	-	-	-	-	-	-	-
O. oliveri*	-	-	A	-	-	-	-	-	-	-	-	-
O. (Eud.) dubitatus	-	R	R	-	R	-	-	-	-	R	-	-
Parametriocnemus lundbecki	R	-	-	-	R	-	A	A	C	-	C	-
Paraphaenocladius sp	-	R	-	-	-	-	-	-	-	-	-	-
Rheocricotopus robacki	-	-	R	-	-	-	-	-	R	-	-	-
Synorthocladius sp	-	-	-	R	-	-	-	-	-	R	R	R
Tvetenia bavarica gr	C	-	-	-	-	-	-	C	-	-	-	-
Diamesa sp*	C	-	-	-	-	-	-	-	-	-	-	-
Potthastia longimanus	R	R	C	-	-	-	-	-	-	-	-	-
Chironomus sp	C	-	-	-	-	-	-	-	-	-	-	R
Cryptochironomus spp	-	C	C	-	R	R	-	-	R	-	C	R
Cryptotendipes sp	-	-	-	-	-	R	-	-	-	-	R	-
Dicrotendipes spp	R	-	-	R	-	C	-	-	R	R	C	-
Microtendipes spp	C	R	-	-	-	-	C	C	R	C	C	R
Paratendipes sp	R	-	R	-	R	-	-	R	R	R	A	C
Phaenopsectra spp	-	R	R	R	C	-	-	-	R	R	A	-
Phaenopsectra flavipes gr	C	-	-	R	-	-	-	R	-	R	-	-
Polypedilum flavum	C	R	A	A	A	A	A	C	A	C	-	A
Polypedilum illinoense gr	-	A	A	-	-	R	-	C	A	-	A	R
Polypedilum fallax	-	-	-	-	-	-	-	R	-	-	-	-
Polypedilum scalaenum gr	-	-	-	C	-	R	R	-	-	C	A	-
Polypedilum halterale gr	-	-	-	-	C	-	-	-	-	-	-	-
Stenochironomus sp	-	-	-	R	-	-	-	-	R	-	-	-
Tribelos sp	-	R	-	C	-	R	R	R	-	C	-	-
Xenochironomus xenolabis	-	-	-	-	-	-	-	R	-	-	-	R
Cladotanytarsus sp	-	-	-	-	-	-	-	-	-	-	R	-
Rheotanytarsus spp	-	-	R	-	-	R	R	-	C	C	C	C
Paratanytarsus sp	-	-	-	R	-	-	R	-	-	-	C	-
Tanytarsus spp	A	R	-	C	R	C	-	C	C	-	A	-
OLIGOCHAETA												
Limnodrilus spp	C	C	-	C	A	-	-	-	R	-	R	-
Ilyodrilus templetoni	R	-	-	-	-	-	-	-	-	-	R	-
Spirosperma nikolsyii	R	-	-	-	-	-	-	-	-	-	-	-
Nais spp	-	R	R	-	-	-	-	R	-	R	C	R
Dero sp	C	-	-	-	-	-	-	-	-	-	-	-
Stylaria lacustris	R	R	C	-	-	-	-	R	-	-	-	R
Slavinia appendiculata	-	R	-	-	-	-	-	-	-	R	R	-
Ecclipidrilus spp	R	-	-	-	-	-	-	-	-	-	-	R
Lumbriculus variegatus	C	R	-	-	-	-	C	R	-	R	C	-
Cambarinicolidae	-	-	-	-	-	-	-	-	-	R	R	-

	March 2011			June 2012			June 2013			June 2014		
	B4	B5	M2	B4	B5	M2	B4	B5	M2	B4	B5	M2
CRUSTACEA												
Crangonyx spp	C	-	C	R	-	R	-	-	-	-	-	-
Hyallela azteca	A	-	-	A	-	R	R	-	A	C	-	C
Caecidotea sp	R	R	C	C	-	R	R	-	R	R	-	-
Cambarus spp	C	C	A	-	A	-	-	C	C	C	C	C
Procambarus acutus	-	-	-	-	-	-	-	-	-	-	-	R
MOLLUSCA												
Elimia sp	C	-	-	-	-	-	R	R	-	R	-	-
Campeloma decisum	R	-	-	R	-	-	-	-	-	-	-	-
Physella sp	A	C	C	A	-	C	C	-	R	R	C	R
Stagnicola sp?	-	-	-	R	-	-	-	-	-	-	-	-
Helisoma anceps	C	R	R	C	-	C	-	-	R	R	-	-
Menetus dilatatus	-	-	C	-	-	-	-	-	-	-	-	-
Ferrissia sp	-	-	-	-	-	-	R	C	-	-	-	-
Laevapex fuscus	-	-	R	-	-	-	-	-	R	-	-	C
Pisidium spp	-	R	R	R	-	-	-	-	-	-	-	-
Corbicula fluminea	-	R	-	A	-	A	-	-	A	-	-	R
OTHER												
Turbellaria												
Dugesia tigrina	R	-	C	R	-	R	-	-	-	-	R	C
Cura foremanii	-	-	-	-	-	-	A	R	-	C	R	-
Hyhdrolimax grisea	-	-	-	-	-	-	-	-	-	-	-	R
Hemiptera: Corixidae	-	-	-	R	-	-	-	-	-	-	-	-
Hirudinea												
Helobdella triserialis	-	-	-	R	-	-	-	-	-	-	-	
Placobdella papillefera	-	-	-	-	-	-	-	R	-	-	-	-
Placobdella parasitica	-	-	-	-	-	-	-	-	-	R	-	-
Neuroptera: Climacia	-	-	-	-	-	-	-	-	-	-	-	C

Appendix 2. Benthic macroinvertebrates collected at small streams in Chapel Hill, April 2014.
R = Rare, C = Commonn, A = Abundant. Site abbreviations: Prit = Prichard Branch, Cedar = Cedar Fork, OF = Old Field Creek, Bk1 = Booker Cr #1, MR = Mill Race Branch, Tan = Tanyard Branch, CSpr = Cole's Spring Branch.

Site[1]:	Prit	MR	Tan	OF	Cedar	Bk1	CSpr
Width (m):	1.5	2	2	4.5	3.5	2	2
EPHEMEROPTERA							
Plauditus dubius gr	-	-	-	-	-	-	-
Baetis flavistriga	-	-	-	R	C	-	-
Centroptilum triangulifer	-	-	-	R	-	-	-
Eurylophella verisimilis	-	-	-	R	-	-	-
Maccaffertium modestum	-	-	-	A	R	-	C
Stenonema femoratum	-	-	-	C	-	-	-
Stenacron interpunctatum	-	-	-	C	-	-	-
PLECOPTERA							
Perlesta sp	-	-	-	R	C	-	-
Haploperla brevis	-	-	-	-	-	-	C
Leuctra sp	-	-	-	-	-	-	-
Amphinemura sp	-	-	-	A	R	-	-
TRICHOPTERA							
Cheumatopsyche spp	C	-	R	A	A	A	A
Hydropsyche betteni	R	R	-	-	A	-	C
Diplectrona modesta	A	-	-	-		-	R
Chimarra sp	C	-	-	R	C	C	C
Polycentropus sp	-	-	-	-	-	-	C
Rhyacophila fenestra	-	-	-	C	-	-	-
Neophylax oligius	-	-	-	-	-	-	-
Neophylax ornatus	C	-	-	-	-	-	-
Ironoquia punctatissima	-	-	-	A	R	C	-
COLEOPTERA							
Stenelmis crenata	C	-	-	-	-	-	-
Dubiraphia sp	-	-	-	-	-	R	-
Psephenus herricki	-	-	-	-	-	-	R
Helichus spp	R	-	-	R	-	R	-
Enochrus sp	-	R	-	-	-	-	-
ODONATA							
Argia spp	R	-	-	-	R	R	-
Calopteryx sp	-	-	-	A	R	C	R
Enallagma sp	-	-	-	R	R	R	-
Stylogomphus albistylus	-	-	-	R	-	-	R
Somatochlora sp	-	-	-	C	-	R	-
Helocordulia uhleri	-	-	-	R	-	-	-
DIPTERA: MISC.							
Tipula sp	C	R	-	A	C	A	A
Simulium spp	-	-	-	A	R	C	A
Dixella indiana	-	-	-	R	-	-	-

Site[1]:	Prit	MR	Tan	OF	Cedar	Bk1	CSpr
Physella sp	A	-	A	R	C	-	-
DIPTERA: CHIRONOMIDAE							
Ablabesmyia mallochi	-	-	-	-	C	-	-
Conchapelopia group	C	-	-	R	R	C	R
Zavrelimyia sp	-	-	-	-	-	-	C
Clinotanypus pinguis	-	-	-	-	-	R	-
Corynoneura spp	-	-	-	R	-	-	-
Thienemaniella sp	-	-	-	-	-	-	R
Cricotopus bicinctus	-	-	-	-	R	-	-
Cricotopus annulator gr	-	C	-	-	-	-	-
Eukiefferiella claripennis gr	R	C	R	R	R	-	R
Orthocladius spp							
O. obumbratus	C	-	-	C	C	A	R
O. dorenus	A	A	A	-	A	-	A
O. robacki	-	-	-	C	-	-	-
Parametriocnemus lundbecki	C	-	-	C	R	A	A
Paraphaenocladius sp	R	-	-	-	-	-	-
Rheocricotopus tuberculatus	-	-	-	R	-	-	-
Diamesa sp	A	-	-	-	A	-	R
Potthastia longimana	-	-	-	-	R	-	-
Dicrotendipes spp	R	C	C	-	R	-	-
Microtendipes spp	-	-	-	R	R	A	-
Paratendipes sp	-	-	-	-	-	R	-
Phaenopsectra spp	-	-	-	C	R	-	-
Polypedilum flavum	-	-	-	-	A	-	-
Polypedilum aviceps	R	-	-	A	-	A	C
Polypedilum halterale	-	R	-	-	-	R	-
Polypedilum illinoense	-	-	-	-	-	-	-
Polypedilum scalaenum	-	-	-	R	R	R	R
Polypedilum tritum	-	-	-	-	-	-	R
Tribelos sp	-	-	-	-	-	A	-
Paratanytarsus spp	-	C	-	-	-	C	-
Rheotanytarsus sp	R	-	-	-	R	-	R
Tanytarsus spp	-	-	-	-	-	C	-
OLIGOCHAETA							
Limnodrilus spp	-	R	R	-	-	-	R
Ilyodrilus templetoni	-	-	-	-	-	-	R
Spirosperma nikolskyi	-	-	-	-	-	-	R
Nais spp	A	-	-	-	A	-	C
Dero sp	R	-	-	-	-	-	-
Slavina appendiculata							
Ecclipidrilus spp	-	R	-	-	-	-	R
Lumbriculus variegata	R	-	-	-	R	A	C
CRUSTACEA							
Crangonyx spp	-	-	-	A	R	C	R
Caecidotea forbesi	-	-	-	A	-	R	-
Cambarus spp	R	R	R	A	-	A	C
Procambarus sp	-	-	-	R	-	R	-
MOLLUSCA							
Elimia sp	C	-	-	-	-	A	A
Physella sp	A	-	A	R	C	-	-
Pisidium spp	-	-	-	-	-	-	R
Elliptio complanata	-	-	-	-	-	R	-
OTHER							
Erpobdella/Mooreobdella	-	-	C	-	-	-	-

Appendix 2B. Benthic macroinvertebrates collected at small stream in Chapel Hill, April 2014. Streams are grouped by geologic region, then by size within each region. R = Rare, C = Commonn, A = Abundant. Site abbreviations: Jolly = Jolly Branch, UTSev = UT Bolin Creek at Severin St, UTBa = UT Morgan Cr at Baybery Dr, Batt = Battle Branch, Wil = Wilson Creek (#1 and #2), Fan = Fan Branch, Bk2 = Booker Creek #2, Dry = Dry Creek

Site:	Jolly	UTBa	Batt	Wils2	Dry	Bk2
Width (m):	1	1	2	3	1	4.5
EPHEMEROPTERA						
Plauditus dubius gr	-	-	-	A	R	-
Baetis flavistriga	-	-	-	R	-	-
Ephemerella dorothea	-	-	-	C	-	-
Eurylophella verisimilis	-	-	-	-	-	-
Paraleptophlebia sp	-	R	-	-	-	-
Maccaffertium modestum	-	A	-	A	-	R
Stenacron interpunctatum	R	R	-	-	-	-
Stenacron carolina	-	R	-	-	-	-
PLECOPTERA						
Perlesta sp	R	R	-	R	-	-
Haploperla brevis	-	A	-	-	-	-
Eccoptura xanthenes	-	R	-	C	-	-
Isoperla namata gr	-	-	-	R	-	-
Amphinemura sp	R	A	-	A	-	-
Leuctra sp	-	-	-	R	-	-
TRICHOPTERA						
Cheumatopsyche spp	R	R	C	C	R	C
Hydropsyche betteni	R	-	C	-	-	-
Diplectrona modesta	-	A	-	R	-	-
Chimarra sp	C	A	C	-	-	-
Rhyacophila fenestra	A	R	-	R	-	-
Polycentropus sp	-	R				
Neophylax oligius	R	-	-	C	-	-
Neophylax ornatus	A	R	-	-	-	-
Ironoquia punctatissima	A	C	R	R	A	R
Lepidostoma sp	-	A	-	R	-	-
Triaenodes ignitus	-	-	-	C	-	-
COLEOPTERA						
Stenelmis crenata	C	-	-	R	-	-
Macronychus glabratus	-	-	-	R	-	-
Psephenus herricki	-	A	-	R	-	-
Ectopria nervosa	R	-	R	-	-	-
Helichus spp	-	R	-	R	-	-
ODONATA						
Calopteryx sp	C	C	C	C	-	-
Ischnura sp	-	-	-	-	-	C
Enallagma sp	-	-	-	R	-	-
Argia sp	-	-	-	-	-	R
Cordulegaster sp	-	-	-	-	-	-
Progomphus obscurus	-	-	-	-	-	C
Stylogomphus albistylus	-	-	-	-	-	-
Helocordulia uhleri	R	-	-	-	R	-
Somatochlora sp	-	-	-	-	R	-
Boyeria vinosa	-	-	-	R	-	-

Site[1]:	Jolly	UTBa	Batt	Wils2	Dry	Bk2
DIPTERA: MISC.						
Antocha spp	R	-				
Tipula sp	A	A	A	C	A	R
Pseudolimnophila sp	-	-	-	-	-	R
Palpomyia complex	R	-				
Simulium spp	-	R	-	A	-	-
DIPTERA: CHIRONOMIDAE						
Ablabesmyia mallochi	-	-	-	R	R	R
Conchapelopia group	R	-	-	-	C	C
Natarsia sp	R	-	-	-	-	-
Zavrelimyia sp	R	-	-	-	-	-
Cricotopus bicinctus	-	-	-	-	-	C
Cricotopus annulator gr	R	-				
Diplocladius cultriger	-	-	-	-	R	-
Eukiefferiella claripennis gr	-	R	-	-	-	R
Tvetenia bavarica gr	R	-	-	R	-	-
Orthocladius spp						
O. dorenus	C	R	A	C	-	R
O. obumbratus	-	-	A	C	A	A
O. robacki	-	-	-	A	A	-
Parametriocnemus lundbecki	C	-	-	-	R	-
Rheocricotopus unidentatus	R	-	-	-	-	-
Diamesa sp	C	C	R	R	-	-
Potthastia longimana	-	R	-	-	-	C
Cryptochironomus spp	-	-	R	R	-	C
Dicrotendipes spp	R	-	C	-	R	C
Microtendipes spp	C	-	-	-	-	-
Paratendipes sp	-	-	-	-	R	-
Phaenopsectra spp	-	-	R	-	-	R
Phaenopsectra flavipes gr	-	-	-	-	R	R
Polypedilum aviceps	A	C	A	C	-	-
Polypedilum flavum	-	-	-	R	-	A
Polypedilum illinoense	R	-				
Polypedilum scalaenum	-	-	R	R	R	C
Polypedilum fallax	-	-	-	R	R	-
Tribelos jucundum	-	-	-	-	R	C
Rheotanytarsus spp	-	-	-	-	-	R
Tanytarsus spp	-	-	-	R	R	C
OLIGOCHAETA						
Limnodrilus spp	-	-	-	R	-	R
Spirosperma nikolsyii	-	-	-	-	C	-
Nais spp	-	C	R	-	R	C
Slavina appendiculata	-	-	-	-	R	-
Stylaria lacustris						
Ecclipidrilus spp	-	R	-	-	-	-
Lumbriculus variegata	-	-	R	C	A	C

Site[1]:	Jolly	UTBa	Batt	Wils2	Dry	Bk2
CRUSTACEA						
Crangonyx spp	A	C	R	-	C	-
Caecidotea forbesi	R	-	-	-	-	-
Cambarus sp	C	-	R	C	-	C
Procambarus acutus	-	-	-	-	R	-
MOLLUSCA						
Elimia sp	-	-	-	R	-	-
Physella sp	-	C	R	-	A	R
Stagnicola sp	-	-	-	-	R	-
Ferrissia sp	C	-	-	-	-	-
Corbicula fluminea	-	-	-	-	-	C
OTHER						
Protoma graecens	R	-	-	-	-	-

Appendix 3. Benthic macroinvertebrates collected in the Cedar Fork catchment, Chapel Hill, April 2014. A=Abundant, C=Common, R=Rare. See text and appendices for site descriptions.

	Unnamed Tributaries			Cedar Fork			
Site[1]:	UT2	UT2A	UT1	4	3	2	1
Width (m):							
EPHEMEROPTERA							
Baetis flavistriga	-	-	-	-	-	-	R
Procloeon sp	-	-	R	-	-	-	-
Paraleptophlebia sp	-	A	C	-	-	-	-
Maccaffertium modestum	-	-	-	-	-	-	R
PLECOPTERA							
Perlesta sp	-	-	A	-	-	-	-
Haploperla brevis	-	-	A	-	-	-	-
Amphinemura sp	-	A	R	-	-	-	R
Leuctra sp	C	A	C	-	-	-	-
TRICHOPTERA							
Cheumatopsyche spp	-	-	C	A	C	A	A
Hydropsyche betteni	-	R	-	-	-	C	A
Diplectrona modesta	R	C	-	-	-	-	-
Chimarra sp	R	C	A	R	-	C	C
Rhyacophila fenestra	A	C	R	-	-	-	-
Rhyacophila glaberrima	-	R	R	-	-	-	-
Neophylax ornatus	R	C	A	-	-	-	-
Ironoquia punctatissima	A	R	A	C	A	C	R
COLEOPTERA							
Stenelmis crenata	-	-	-	-	A	R	-
Helichus spp	-	-	-	R	C	-	
Copelatus sp	-	-	-	R	C	-	-
Neoporus spp	-	R	R	-	R	-	-
ODONATA							
Argia sp	-	-	-	-	-	-	R
Enallagma sp	-	-	-	-	-	-	R
Calopteryx sp	-	-	-	-	-	-	R
Helocordulia uhleri	-	-	R	-	-	-	-
DIPTERA: MISC.							
Tipula sp	C	R	A	R	C	A	C
Pseudolimnophila sp	-	-	R	-	-	-	-
Palpomyia complex	-	-	R	-	-	-	-
Simulium spp	-	-	-	-	-	-	R
Dixella indiana	-	-	C	-	-	-	-

Site[1]:	UT2	UT2A	UT1	4	3	2	1
DIPTERA: CHIRONOMIDAE							
Ablabesmyia mallochi	-	-	R	-	R	-	C
Clinotanypus pinguis	-	-	C	-	-	-	-
Conchapelopia group	-	-	C	-	R	-	R
Natarsia sp	-	-	C	-	-	-	-
Zavrelimyia sp	R	-	C	-	-	-	-
Corynoneura spp	-	-	-	-	-	-	R
Cricotopus bicinctus	-	-	-	-	-	-	R
Diplocladius cultriger	-	C	-	R	C	R	-
Eukiefferiella claripennis gr	-	-	R	-	R	R	R
Eukiefferiella brevicalcar gr	-	R	-	-	-	-	-
Orthocladius spp							
O. obumbratus	C	-	A	A	A	A	C
O. robacki	-	-	-	-	A	R	-
O. dorenus	-	-	R	-	-	A	A
Parametriocnemus lundbecki	R	R	R	-	-	-	R
Diamesa sp	C	C	C	-	-	-	A
Potthastia longimana	-	-	-	-	R	R	R
Chironomus spp	-	-	-	-	R	-	-
Dicrotendipes sp	-	-	-	-	-	-	R
Dicrotendipes simpsoni	-	-	-	-	R	-	-
Microtendipes spp	-	-	R	-	R	-	R
Paratendipes sp	R	-	C	-	C	-	-
Phaenopsectra spp	-	-	-	-	-	-	
Polypedilum aviceps	-	-	A	-	A	-	A
Polypedilum flavum	-	-	-	-	-	C	-
Polypedilum illinoense	-	-	C	R	R	R	-
Polypedilum scalaenum	-	-	-	-	-	-	R
Tanytarsus spp	-	-	C	-	C	-	-
OLIGOCHAETA							
Limnodrilus spp	-	-	-	-	-	R	-
Ilyodrilus templetoni	R	-	-	-	R	-	-
Spirosperma nikolsyii	-	-	-	-	C	-	-
Nais spp	-	-	A	C	C	A	A
Slavina appendiculata	-	-	-	-	R	C	-
Ecclipidrilus spp	C	R	-	-	-	-	-
Lumbriculus variegata	C	-	A	A	C	-	R
Haplotaxis gordiodes	-	-	-	-	R	-	-
CRUSTACEA							
Crangonyx spp	A	A	A	C	C	-	R
Caecidotea forbesi	A	-	C	-	R	R	-
Cambarus sp	C	C	A	R	A	-	-
Procambarus acutus	-	-	-	-	R	-	-
MOLLUSCA							
Physa sp	-	-	-	A	R	C	C
Pisidium sp	-	-	-	-	R	-	-
OTHER							
Cura foremanii	-	-	-	R	-	-	-
Prostoma graecens	-	-	-	R	-	-	-

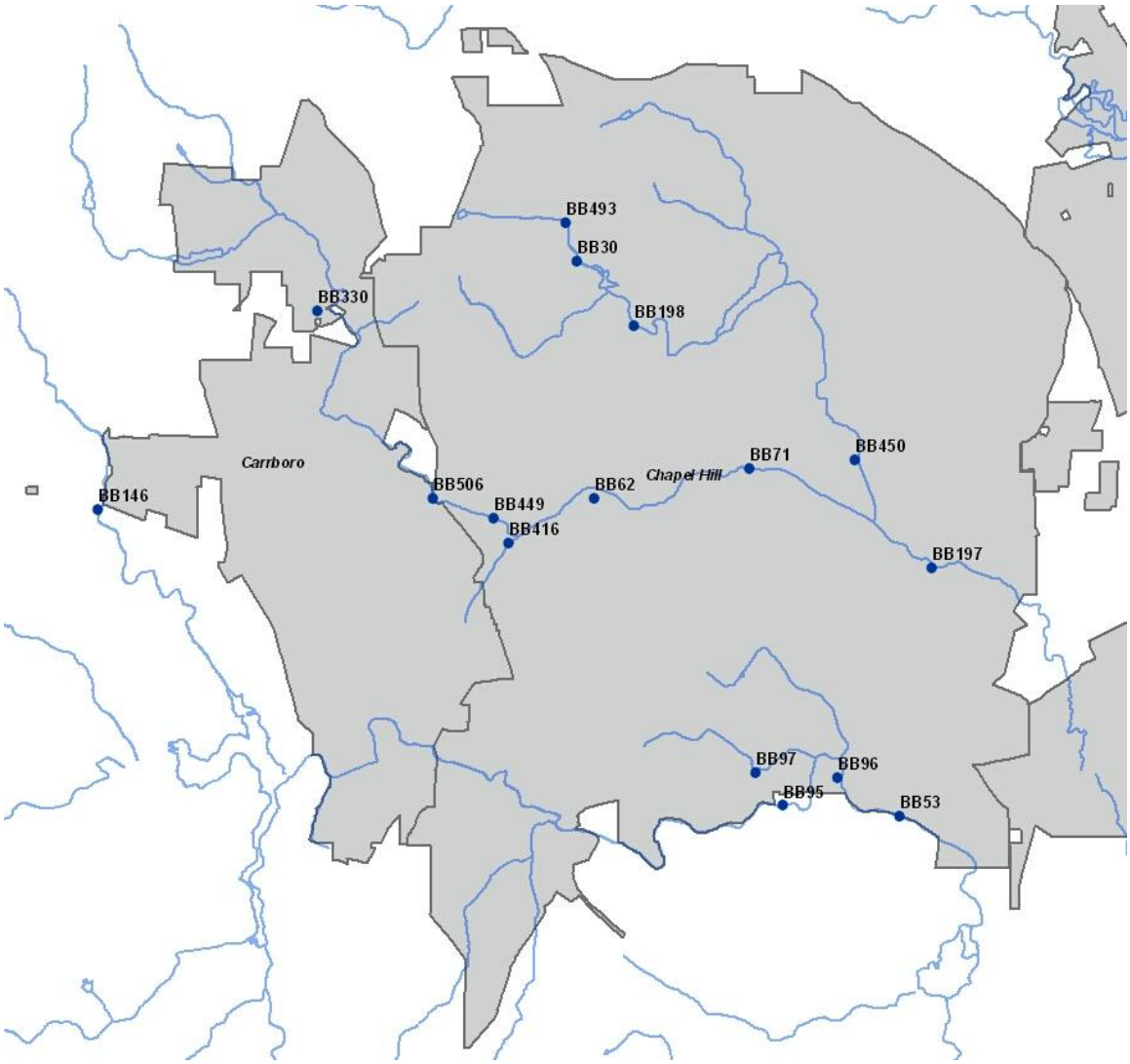


Figure 1. Monitoring sites, Chapel Hill, April-June 2014 (To be replaced?)

Appendix 5. Chapel Hill Large Stream Sites, June 2014

Bolin Creek sites are numbered from most upstream (Site 1) to most downstream (Site 5). Sites 1-3 are in Carrboro and are not included in this report. Site 4 was moved from Estes Drive (at the town boundary) to Village Drive in Chapel Hill. Bolin Creek sites are largely in the Slate Belt geologic region and are expected to have a very rocky stream bottom. The lower Bolin Creek site may have characteristics of both ecoregions.

Bolin Creek 4. Site 4 was moved slightly downstream into Chapel Hill (Village Drive) in 2011, so that data from this site could be used by both towns.

Bolin Creek Site 4, June 2014.

This portion of Bolin Creek is similar to the site on Estes Drive, having good rocky substrate. Attached filamentous algae was very abundant at the Village Drive site in March 2011, but was not a problem in 2012-2014.

Bolin Creek 5 (Franklin St). Bolin Creek has good rocky substrate near the bridge, but the stream bottom is mostly sand further upstream. A greenway path parallels Bolin Creek in this area.


Bolin Creek Site 5 (Franklin), June 2012.

This site drains a heavily developed catchment, including the downtown areas of both Carrboro and Chapel Hill.

Morgan Creek 1 (NC 54). Morgan Creek has been used as a reference site for Carrboro surveys, although this stream is frequently affected by droughts. Prior surveys by the NC Division of Water Quality generally produced a Good or Excellent bioclassification for this site. Recent collections have produced only a Good-Fair ratings.


Morgan Cr Site 1 (NC 54), June 2012.

This catchment has a largely rural character. Habitat quality, stream width and substrate composition are similar to Bolin Creek.

Morgan Creek 2 (Ashe St). This site is located near the UNC Botanical Garden and it is downstream of University Lake. Although this part of Morgan Creek is located in a residential area, there is a forested buffer zone along most of the stream.

There was good rocky substrate in the riffles, but pools areas were being filled-in by sand deposition.

Morgan Creek Site 2 (Ashe), June 2012

Appendix 4A. Carrboro Small Stream Sites, April 2014

These streams are grouped into 3 categories, according to local geology. Slate Belt streams are expected to have a very rocky substrate and are located in the western part of Chapel Hill. Triassic streams naturally have a stream bottom of sand and clay and are located in the eastern part of Chapel Hill. Some "Transition" stream share characters of both geologic zone, although the substrate is largely sand and gravel. Within each of these three groups, streams have been sorted by size (as measured by stream width). Slate Belt stream usually have a boulder-rubble substrate, although the more developed area have sandy pools and/or embedded riffles. Triassic site are largely sand and clay, with a very swampy floodplain. The Transitional sites are very sandy, with gravel/rubble riffles. Site photos come from both the 2012-2014 collections, with an emphasis of the 2014 project.

SLATE BELT STREAMS

Pritchard Branch. Pritchard Branch is a tributary of Morgan Creek in the southwest portion of Chapel Hill. Although this is a naturally rocky stream, there have been large inputs of sand. Filamentous algae was abundant on the streambed. Pritchard Branch drains the southern part of downtown Chapel Hill.

Pritchard Branch, April 2014

The stream appears both entrenched and widened by erosion. The invertebrate fauna was extremely sparse in 2013, but was more abundant in 2014. Conductivity values were moderately elevated in both 2012 and 2013 (232-259 umhos/cm) at the time of the invertebrate collections. The 2013 collection also has low dissolved oxygen (4.8 mg/l). Water chemistry data is not available from 2014.

Mill Race Branch. Mill Race Branch is located in a largely residential area; it was sampled off Bolinwood Drive just above its confluence with Bolin Creek. The substrate was largely gravel and sand, but with small rocky riffles areas. At the time of the 2014 collection, restoration work caused considerable disturbance to the stream, both at and above our sampling area.

Mill Race Branch, April 2014

There was little periphyton growth on rocks, and the fauna was very sparse. Conductivity values were moderately elevated (240 umhos/cm) in both 2012 and 2013, Conductivity was not measured in 2014.

Tanyard Branch. Tanyard Branch is a small stream (2 meters wide) that was sampled near the end of Carver Street.

Tanyard Branch, April 2014

There is a forested riparian zone, but the stream runs through a heavily developed residential area. The stream substrate was rocky, but 40-80% embedded with sand. Conductivity values were highly elevated (252-352 umhos/cm) at the time of the invertebrate collections.

UT Tanyard Branch below Baldwin Park.
No 2014 collections.

Old Field Creek. Old Field Creek was sampled north of town, near the Chapel Hill Operations Center. The surrounding area is largely forested, but there is some development (including a landfill) further upstream. Conductivity values were moderately elevated (269-289 umhos/cm) at the time of the invertebrate collections in 2012-2013. Such data are not available for 2014.

The stream is very rocky (often having extensive areas of bedrock), with good root and leafpack habitat. The composition of the fauna suggested that this stream is sometimes intermittent, although flows were higher than normal in 2014.


Old Field Creek, April 2013.

Cedar Fork. Cedar Fork is located in the northern section of Chapel Hill; it is one of the largest tributaries of Booker Creek (3 meters wide). The stream was sampled off Brookview Street, just above a small lake.

Cedar Fork, April 2014.

The surrounding land is an older residential area with large lots. Many of the houses, however, are placed very close to the stream. The substrate was rocky and there was severe bank erosion at bends.

Booker Creek 1 (Above MLK Blvd). Booker Creek had higher flows in 2014 relative to prior years. The surrounding area provided a forested buffer next to the stream, but it drains a largely residential area.

The overall community composition suggested that this stream has intermittent flow in some years, but good flow was observed in 2014.

Booker Creek Site 1 (MLK) April 2014.

Library Branch.
No 2014 Collections.

Cole Springs Branch. Cole Springs Branch was sampled near the end of Cedar Drive. This stream drains an older residential area with large lots and a good buffer zone; the area sampled was largely forest. This rocky stream had excellent habitat for aquatic fauna. In 2011, the stream was mostly boulder and rubble with little sand and gravel. In 2012 and 2013, however, there had been inputs of sand with sand deposition in areas of lower gradient.

Cole Springs Branch, April 2014

Jolly Branch near SR 1777 (just downstream of Bolin Creek 3). This site was accessed by walking about 100 meters downstream of SR 1777 (Homestead), crossing Bolin Creek, and going about 30 meters upstream on Jolly Branch. This small stream (1 meter wide) had good rocky habitat, but showed severe bank erosion in many places.

The surrounding area was largely forested, although there are residential areas further upstream. The aquatic life at Jolly Branch indicates that it may stop flowing (or go dry) during drought periods.


Jolly Branch, April 2013.

UT Bolin Creek at Severin St.
No 2014 Collection.

.

UT Morgan Creek at Bayberry Drive. This very small stream was similar in size and habitat to the Severin UT, but in a less developed catchment.

UT Morgan Creek at Bayberry, April 2014

TRANSITION STREAMS

Battle Branch. Battle Branch was sampled near Glendale Road. This stream is located in an older residential area, with forest and hiking paths next to the stream. The substrate is largely sand and gravel, with occasional rubble riffles. Battle Branch was entrenched with severely eroding banks.

Battle Branch, April 2014

Fan Branch.
No 2014 Collections

Wilson Creek 1 (Upstream at Wave Rd)).
No 2014 Collections

.Wilson Creek 2 (Downstream). Wilson Creek was sampled at Arlen Park Drive, in a new residential area. The upstream area, however, is an older residential area (mostly forest) with large lot sizes.

Wilson Creek 2 (downstream), April 2013.

Although this small stream was very sandy (95 % gravel, sand and silt), it supported a surprisingly diverse invertebrate community. This part of Wilson Creek may have more permanent flow than Wilson Creek 1.

TRIASSIC STREAMS

Dry Creek. This very small stream (1 meter wide) was sampled upstream of Erwin Road. The substrate was mostly clay/silt, likely due to the Triassic Basin geology. Roots and logs were the most important habitat for the aquatic fauna.

Dry Creek, April 2012.

The stream was entrenched near the road, but was more swamp-like further upstream. This stream probably goes dry during summer months. Debris piles along the banks suggested that this stream goes over its banks after heavy rain events.

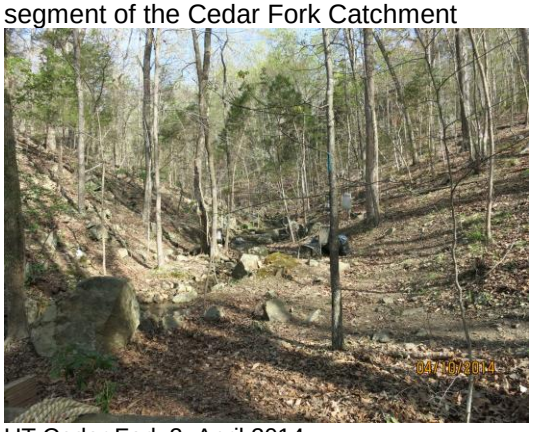
Booker Creek 2 (Willow Drive). This segment of Booker Cr drains a largely residential catchment. The stream appears to have been channelized at some time, with a very entrenched channel. The substrate is entirely sand and clay.

This site had the lowest dissolved oxygen of the 2012 samples: 4.7 mg/l; dissolved oxygen increased in 2014 to 6.9 mg/l.

Booker Creek 2, April 2014

Appendix 4B. Cedar Fork Sites, April 2014, Chapel Hill, Orange County.

Prior Chapel Hill surveys (2011-2013) had demonstrated water quality problems in the Cedar Fork catchment. A special study was Unnamed Tributary 2 to Cedar Fork near Emily Road. This small stream may have insufficient flow to support a normal benthic fauna. The site at UT 2A (below) was added to give a better idea of water quality in this segment of the Cedar Fork Catchment



UT Cedar Fork 2, April 2014.

Unnamed Tributary 2A to Cedar Fork North of Brookview Drive. This site was added to replace the upstream site (UT2); it is located on the same stream, but further down in the catchment.

UT Cedar Fork 2A, April 2014.

This is a very small (1 meter wide) high gradient stream. The substrate is mostly bedrock and boulder (85%). Although this stream may go dry in the summer, it supported a fairly diverse invertebrate community.

Unnamed Tributary 1 to Cedar Fork South of Brookview Drive. This small (1 meter wide) stream had good habitat and supported a diverse invertebrate community. It is intended to evaluate water quality in a southwest portion of the Cedar Fork catchment.

UT Cedar Fork 1, April 2014.

Cedar Fork was sampled at four locations: Cedar Fork 4 near Scott Lane. This stream was too small to be rated. The primary substrate was rip-rap that had fallen into the stream. This segment of Cedar Fork may lack flow for extended time periods.

Cedar Forkk 4, April 2014.

Cedar Fork Tributaries

Cedar Fork 3 near Silo Drive. This portion of Cedar Fork is very sandy. There is often little buffer between the stream and residential areas.

Cedar Fork 3, April 2014.

Cedar Fork 2, Kenmore Drive. This segment of Cedar Fork had good habitat, with 65% boulder rubble substrate. There was a good buffer zone downstream of Kenmore Drive, but there was more development in the upstream area. The fauna did not indicate good water quality.

Cedar Fork 2, April 2014.

Cedar Fork 1, Brookview Drive. This is the site usually sampled during Chapel Hill surveys, with yearly data from 2011-2013. Recent storms had caused severe bank erosion and scour.

Cedar Fork 1, April 2014.

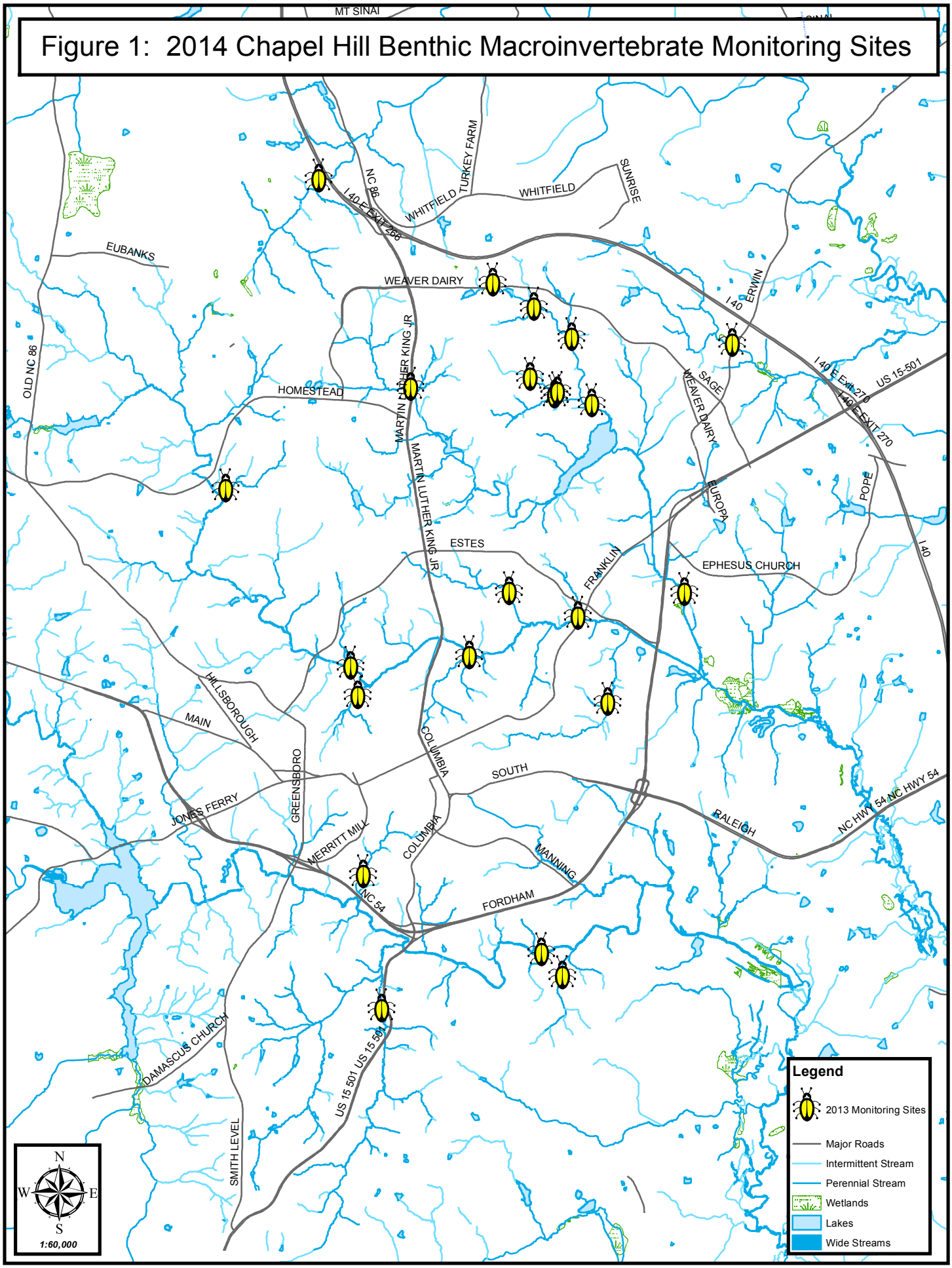


Figure 1: 2014 Chapel Hill Benthic Macroinvertebrate Monitoring Sites
MT SINAI
NC 86
I40 E EXIT 266
WHITFIELD
TURKEY FARM
WHITFIELD
SUNRISE
EUBANKS
WEAVER DAIRY
I 40
ERWIN
OLD NC 86
HOMESTEAD
MARTIN LUTHER KING JR
SAGE
WEAVER DAIRY
I40 E Exit 270
US 15-501
I40 E EXIT 270
EUROPA
POPE
ESTES
MARTIN LUTHER KING JR
FRANKLIN
EPHESUS CHURCH
I40
HILLSBOROUGH
MAIN
COLUMBIA
SOUTH
GREENSBORO
JONES FERRY
MERRITT MILL
COLUMBIA
RALEIGH
NC HWY 54
NC HWY 54
MANNING
NC 54
FORDHAM
DAMASCUS CHURCH
US 15 501 US 15 501
SMITH LEVEL
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Legend
2013 Monitoring Sites
Major Roads
Intermittent Stream
Perennial Stream
Wetlands
Lakes
Wide Streams