BIOLOGICAL MONITORING OF CHAPEL HILL STREAMS, NORTH CAROLINA April-June 2015

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Bolin Creek at Piney Mountain Road, April 2015

ATTENTION: PLEASE READ THIS SECTION FIRST
This is the 5th 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, 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 the town's website.

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 how well the stream supports 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 5-6) 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 page 23; summary tables are on pages 25-32.

Although 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 2015. **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 2015 by sampling benthic macroinvertebrates at 22 sites: 2 Bolin Creek sites and 20 smaller tributaries. The tributaries were mostly sampled in April, while the larger streams were sampled in June.

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 of the taxa in the most intolerant groups. Higher EPT taxa richness is associated with good water quality; low EPT taxa richness is associated with poor water quality.

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 2015.

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.

<u>Bolin Creek</u>
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.

<u>Booker Creek</u>
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]
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 sites]
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]
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 ±1 (except coastal plain), and boundary biotic index values ±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	<4.3
Good	4.3-5.2
Good-Fair	5.2-5.9
Fair	6.0-6.9
Poor	>6.9

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

Toxicity Assessment Using Chironomidae Deformities
When there are large numbers of the chironomid, *Chironomus*, the degree of in-stream toxicity can be evaluated by tabulating deformities of its mouthparts. This situation occurred only in lower Booker Creek. The technique was developed (Lenat 1993) to help separate out the effects of low dissolved oxygen from any toxic effects when both types of stress might be occurring at the same site. *Chironomus* is associated with organic loading and low dissolved oxygen, but high numbers of mentum deformities are observed only when there is also some degree of toxicity. A "toxic score" is calculated using both the percentage and severity of the deformities. The following Toxic Score criteria are derived from Lenat (1993):

Non-Toxic: <20
Toxic fair: 20-70
Toxic Poor: >70

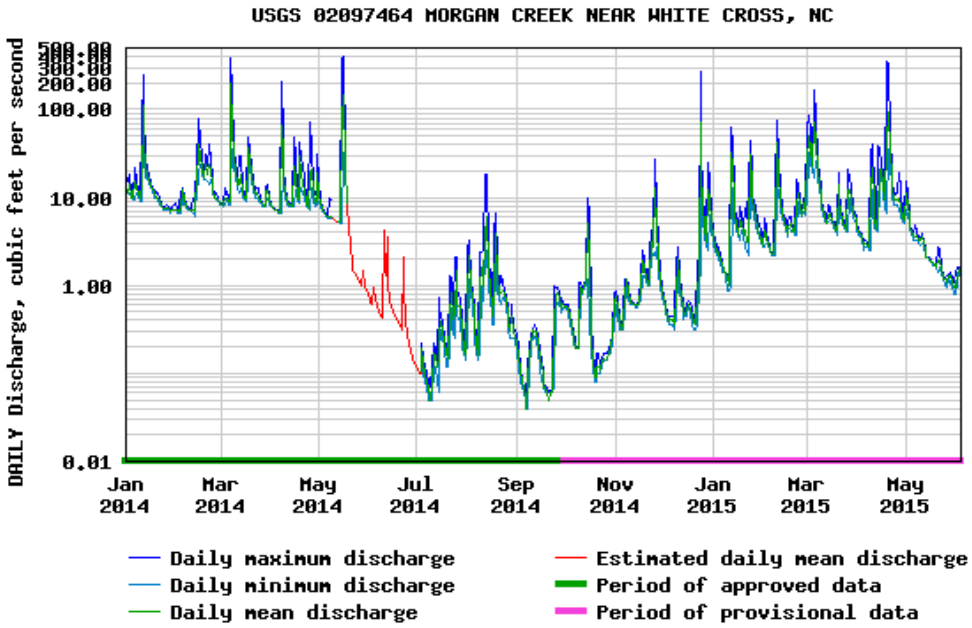
SAMPLING SITES (Figure 1)
More detailed site descriptions (with photos) are presented in Appendices 4-5.
Table 1 gives data on habitat ratings and substrate composition at all sites sampled in 2015. The habitat rating is based on standard Division of Water Quality procedures, and produces a value between 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 2015 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.

Low flows (less than 0.5 cfs) are highlighted in yellow; severe low flows (less than 0.1 cfs) are highlighted in red. Summer flows for 2014 were much higher than for 2004-2013; 2013-2015 fall/winter/spring flows were relatively high. Monthly mean data is not available past September 2014, but the following graph shows daily flows for 2014-2015. This combined data suggests adequate winter and spring flows in 2015 in the Carrboro/Chapel Hill area.

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	15	13	21	15	12	0.8	0.3	1.1	0.3			



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 (1999-2015).

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	7/7	7	4/1	78	6.5	30	35	20	15	Tr	Rocky. Downstream of Carrboro.
Bolin Cr #5	4	20	8	6	14	3/5	7	0/3	70	8	10	20	15	55	Tr	Rocky near Franklin St, but sandy upstream. Recent habitat scoring focuses on near-bridge riffles.
Morgan Cr	No data									11	5	25	25	45	Tr	Sand deposited in pools.
Pritchard Br	3	15	6	6	16	5/3	7	5/0	66	2	20	30	25	25	Tr	Urban. Embedded, with Incised channel. Rip-rap added in 2012/2013, but with severe bank erosion.
Mill Race Br	3	15	11	4	16	5/5	7	1/3	69	2	10	20	35	35	-	Urban. Sandy, embedded substrate. Fauna sparse. Some habitat "restoration" work in 2014. Scoured?
Old Field Cr	4	15	3	8	7	5/5	8	4/4	63	4	35	20	30	15	Tr	Lots of bedrock, much better flow in 2014-2015. Moss.
Cedar Fk, Silo	3	15	6	4	14	2/2	7	3/3	59	1.5	20	25	5	50	Tr	Likely too small for normal stream fauna.
Cedar Fk, Steeplechase	5	16	12	6	14	6/5	10	4/1	79	3	35	30	25	10	-	Good habitat, but poor fauna. Midges dominant.
Cedar Fk, #2	4	19	15	6	16	6/6	10	4/4	90	3	30	40	20	10	-	Good habitat, but poor fauna
Booker Cr Parkside	5	15	4	4	7	6/6	8	2/3	61		1	Tr	10	20	50	20 Too small for normal stream fauna
Booker Cr MLK	5	15	6	8	7	6/6	10	3/3	69	2.5	35	25	15	15	-	Good habitat.
Booker Cr Pine Mtn	5	16	11	10	12	5/5	8	4/4	80	3	15	25	30	25	-	Good habitat.
Crow Br	5	11	3	4	12	5/5	10	3/4	62	2	40	35	15	10		Intermittent. Lots of bedrock.
Cole Springs Br	4	16	12	10	16	6/6	10	4/4	88	3	35	30	20	15	-	Old residential area, forested riparian, good habitat. Evidence of recent sediment input.
Stillhouse Br	5	20	14	6	16	7/7	10	4/4	93	1.5	20	30	40	10	-	Small and rocky. Good buffer zone. Similar to Bayberry UT "Clean" rocks, some scour?
Sandy Transition Streams																
Fan Br	5	15	3	8	3	6/6	10	4/3	63	2.5	-	-	Tr	100	-	Turbid, scoured?
Wilson Cr 1	5	16	4	8	3	6/6	10	3/4	65	3.5	-	-	10	90	Tr	Former rubble riffle at road buried by sand inputs. Scoured?
Wilson Cr 2	5	16	4	4	7	6/6	10	4/4	65	3.5	-	-	25	75	Tr	High density development at site, but older development upstream with large lots, mostly forested, sandy.
Triassic Basin																
Booker Cr, Tadley	4	11	3	8	3	5/5	10	4/4	57	7	-	-	20	70	10	Sand/gravel. Lots of dead *Corbicula*.
Booker Cr, Willow	2	15	3	6	3	5/6	10	3/3	56	5	-	-	20	70	10	Sand/gravel, entrenched and widened. Overbank sand deposition Starting to restore a more natural channel.

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.

Table 1, Continued. Water chemistry data, June 2015. Dissolved Oxygen (DO, mg/l), Conductivity (uhmos/cm), and Temperature (°C)

Note: Water chemistry data was collected much later in the year than the benthic macroinvertebrtae data, at a time of higher temperatures and lower flow rates.

Site	DO	Conductivity	pH	Temperature
Old Field Cr (Town Ctr)	5.1	207	6.5	22
Cedar Fork				
Steeplechase Rd	1.8	201	6.3	24
Kenmore Rd	2.8	191	6.7	23
Brookview Dr	2.5	191	6.8	24
Pritchard Br	5.4	264	6.7	21
Mill Race Br, Bolinwood Dr	7.4	265	7.1	23
Booker Cr				
New Parkside Dr	3.3	218	6.6	24
MLK Blvd	5.1	161	6.7	23
Piney Mtn Rd	5.9	128	6.4	24
Tadley Greenway	4.8	151	6.7	27
Willow Dr	4.2	193	6.7	26
Crow Br, MLK	4.0	248	6.6	21
Stillhouse Br*	2.3	231	6.3	23
Cole Springs Br, Cedar St	6.6	261	6.9	23
Bolin Cr				
Site 4, Village	7.6	131	6.8	24
Site 5, Franklin St	5.9	214	6.8	24
Wilson Cr				
Wave Rd	6.4	141	6.7	22
Arlen Park Dr	6.3	89	6.6	22
Fan Br, Parkview Cr	7.3	142	6.7	21

*Unusual values may reflect the effects of summer drought and low flow.

Low dissolved oxygen values were observed in Cedar Fork (3 sites), Booker Creek (3 sites + Crow Branch), and Stillhouse Branch. The low values at the latter site were unexpected, and may reflect unusual conditions as the stream is going dry during summer low flows. High conductivity values were often associated with urban runoff and impervious surfaces: Pritchard V}Branch, Mill Race Branch, Crow Branch, Cole Springs Branch and lower Bolin Creek.

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

	Date	Total S	EPT S	BI	Bioclass*
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)

Long-term trends, Bolin Creek. 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 2015.

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 2012-2015, 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.

Tables 2 and 3 present a summary of the biological monitoring for Chapel Hill streams for 2011-2015. 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	2015
Cedar Fork	A	A	C	C	A*
Bolin Cr 4	A	A	C		
Old Field Cr	C	A			C
Booker Cr, Willow		A	C		
Pritchard Br				A	

*3 sites

It is likely that higher flows in 2013-2015 produced higher dissolved oxygen concentrations. Note, however, the prevalence of *Physa* at multiple sites on Cedar Fork in 2015. Sites that also consistently had abundant *Physa* (and therefore low dissolved oxygen concentrations) are Tanyard Branch and Dry Creek, although these sites were not sampled in 2015.

Samples from 2015 that also had abundant *Physa* included both Booker Creek (Piney Mountain and Tadley), and Crow Branch.

Site Evaluations

It is important to realize that drought conditions during some 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. Flow condition have improved in the last 3 years (2013-2015).*
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 for the period 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 July of 2009. 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 2014. 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 2013-2015 collections again produced a lower biotic index (5.8-6.3). This suggests some recovery, largely due to the appearance of the intolerant caddisfly, *Chimarra*. Recovery was also evident by the increased abundance of the intolerant snail, *Elimia*, in 2015. The 2014 collection produced a rating right on the borderline between a Fair and a Good-Fair rating, but the Good-Fair rating was not achieved until 2015.

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 2013-2015.

Date	Total S	EPT S	BI	EPT N	Bioclass
6/15	53	12	5.8	69	Good-Fair
6/14	57	10	6.3	64	Fair
6/13	33	6	5.9	53	Fair
6/12	52	8	6.8	48	Fair
3/11	58	8	6.7	21	Fair
3/10	42	9	5.8	35	Fair
7/09	58	10	6.2	73	Good-Fair
12/08	44	12	5.9	63	Fair
8/06**	21	6	-	19	Poor?
9/04**	25	8	-	46	Fair
9/03**	25	8	-	48	Fair
3/02*	40	7	7.0	-	Fair (follows Drought)
7/01*	52	9	6.6	-	Fair
2/01*	54	6	7.0	-	Poor?
9/00**	45	4	-	26	Poor
2/98*	59	26	5.1	-	Good
4/93*	-	24	-	-	Good-Fair

*DWQ data, 1993 collections were limited to EPT taxa
**Early Carrboro data, Ecological Consultants/Pennington.
Bioclass based only on EPT Taxa richness

Bolin Creek Site 5 (Franklin Street). This site received a Poor bioclassification in 2011, similar to DWQ collections in 1998 and 2008. In 2012-2015, 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 2012-2015, 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 2014-2015 was the highest since 1998.

Date	Total S	EPT S	BI	Bioclass*
6/15	46	9	5.9	Fair
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 2013-2015, 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, but water quality has actually improved since 2012. Of particular significance was the abundance of an intolerant caddisfly (*Neophylax oligius*) in 2014 and 2015. The overall abundance of intolerant species has shown a steady increase from 2012-2015.

Morgan Creek, NC 54

Date	Total S	EPT S	BI	Bioclass*
6/15	-	19		Good-Fair
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 2012-2015 collections also resulted in a Fair bioclassification, but the only abundant intolerant species was *Chimarra*. This site improved to Good-Fair in 2014 and 2015, 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*
6/15	-	15 (17*)	-	Good-Fair
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 (18*)	-	Good-Fair
2/93**	71	26	6.0	Good-Fair

*Converted to equivalent full-scale sample

**DWQ data

Small Streams

Many sites now have 4-5 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.

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 and 2015

The only common or abundant intolerant species in this stream in 2012 and 2013 was the snail *Elimia*, but in 2014-2015 the caddisfly *Diplectrona modesta* was Abundant and the caddisfly *Chimarra* was present. Some further improvement was seen in 2015, mainly through the loss of some highly tolerant species. The pattern over 4 years clearly indicated 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	2015
Total Taxa Richness	19	28	26	22
EPT Taxa Richness	3	3	5	5
EPT Abundance	3	27	32	26
NC Biotic Index	6.0	6.0	6.6	5.3
Rating	F-P	F-P	F-P	Fair

-Mill Race Branch. All metrics indicated Poor water Quality in Mill Race Branch from 2011 through 2015, 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 2013-2015. The fauna was very depauperate in 2014, due to scour after heavy rainfall. This was further complicated by stream restoration work prior to the 2014 collection, which caused a short-term increase in sedimentation and turbidity. The resulting decline in the benthic community was seen only in 2014, with some "recovery" in 2015.

	2011	2012	2013	2014	2015
Total Taxa Richness	18	20	18	11	19
EPT Taxa Richness	3	3	2	1	3
NC Biotic Index	7.7	7.9	7.5	6.8	6.9
Rating	Poor	Poor	Poor	Poor	Poor

-Tanyard Branch. No Sample in 2015. This site has consistently been rated Poor from 2011-2015.

-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 2014-2015. 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 2014-2015 still suggested a temporary stream, but more constant flow (and better water quality) was indicated by the abundance of *Maccaffertium modestum*, *Cheumatopsyche*, *Amphinemura,* and *Perlesta*. The Good-Fair rating in 2014-2015 indicated that this stream supports designated uses.

	2011	2012	2013	2014	2015
Total Taxa Richness	22	27	33	37	40
EPT Taxa Richness	1	4	5	12	11
EPT Abundance	1	10	23	54	60
NC Biotic Index	7.6	6.5	6.3	6.2	5.7
Rating	Poor	Fair	Fair	G-F	G-F

Cedar Fork

The most downstream site on Cedar Fork was not sampled in 2015, although 3 upstream sites were evaluated. Sites are listed in upstream/downstream order. Two unnamed western tributaries also were sampled in 2014, and found to have good-excellent water quality. These two small tributaries supported many intolerant species.

Abundant species at all three sites included the caddisfly *Ironoquia punctatissima* and the snail *Physa*. The former species suggests that this portion of Cedar Fork is intermittent, while the latter species suggests low dissolved oxygen. The low dissolved oxygen was confirms by water chemistry data collected by the town in June 2015. Sites 3 and 3A may be too small to support a normal stream community.

Cedar Fork at Silo Road (Site 3). . An undersized culvert causes water to back up in this area during high flow, adding to the sediment problems. This site was rated as Fair in 2014, based on EPT taxa richness of 2 and a Biotic Index of 6.8. The 2015 samples produced only 1 EPT taxon and a biotic index of 7.4, suggesting a between-year decline in water quality. This site, however, is too small to receive a bioclassification.

Cedar Fork at Steeplechase Road (Site 3A). This site was sampled for the 1st time in 2015 and appeared very similar to the upstream site at Silo.

Cedar Fork at Kenmore Road (Site 2). This portion of Cedar Fork has good habitat, with a good buffer zone around the site. This site was 1st sampled in 2014, and was assigned a Poor rating based on EPT taxa richness of 4 and a biotic index of 7.2. It also received Fair rating in 2015, but there were minimal between-year changes in the invertebrate community.

	Cedar Fk		
Site:	3	3A	2
Abundance of indicators			
Low DO (Physa,)	+	+	+
Total Taxa Richness	28	19	28
EPT Taxa Richness	1	2	4
EPT Abundance	10	11	31
NC Biotic index	7.4	7.3	6.9
Suggested Overall Rating	**NR**	**NR**	**Fair**
(NR = Not Rated)			

Upper Booker Creek
Three headwater sites on Booker Creek are in the Slate Belt ecoregion, producing rocky streams. The two downstream sites are discussed in the section on Triassic streams.

-Booker Creek at New Parkside Drive. This site was too small to support a normal stream community. Water chemistry data collected by the town in June 2015 indicated low dissolved oxygen (3.3 mg/l) and high specific conductance. There were only 3 EPT species collected (none abundant), but the relatively low biotic index (6.5) did not indicate dominance by highly tolerant species.

-Booker Creek (MLK Blvd). This Booker Creek site had a very sparse fauna through 2014, with intolerant mayflies and stoneflies absent. This headwater site on Booker Creek improved from Poor in 2011 to Fair in 2012-2014. However, there were no large changes in the stream fauna over this time period. The Fair rating from this period was similar to that produced by DWQ sampling in 2001.

In 2015, the number of EPT taxa doubled, largely due to the appearance of 3 mayfly species. One of these, *Maccaffertium modestum*, was abundant. The intolerant caddisfly, *Chimarra*, increased from common in 2014 to abundant in 2015. The bioclassification increased from Fair in 2012-2014 to Good-Fair in 2015. Part of this increase may reflect more sustained flow due to higher rainfall in recent years.

	2011	2012	2013	2014	2015
Total Taxa Richness	20	25	27	28	32
EPT Taxa Richness	2	3	3	3	6
NC Biotic Index	7.5	6.4	6.3	6.2	6.7
Rating	Poor	Fair	Fair	Fair	G-F

-Booker Creek, Piney Mountain Road. This site was sampled for the 1st time by Lenat Consulting, but the NC Division of Water Resources collected sampled here in 1998 and 2001. The spring samples (2/01, 3/98) had produced EPT taxa richness of 8-10. Samples from April 2015 produced an EPT taxa richness of 8, very similar to the 1998-2001 results. This was the only Booker creek site with intolerant stoneflies (*Perlesta*), but many of the EPT found at the upstream MLK site were reduced or absent (*Maccafertium modestum, Chimarra*, and *Cheumatopsyche*). The bioclassification dropped from Good-Fair at the MLK site to Fair at the Piney Mountain site, indicating a decline in water quality.

-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 fairly 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 oligius/ornatus* and *Psephenus herricki*. These changes were sufficient to drop the rating from Good in 2011-2013 to Good-Fair in 2014.

EPT taxa richness showed some recovery in 2015, but the abundance of key species (*Haploperla brevis, Neophylax oligius, Psephensu herricki*) remained low (see below). In fact, there were no abundant EPT species in either 2014 or 2015 and the bioclassification remained at Good-Fair in 2015.

	2011	2012	2013	2014	2015
Total Taxa Richness	29	38	35	35	26
EPT Taxa Richness	8	11	10	7	10
EPT Abundance	40	43	47	26	25
NC Biotic Index	4.6	4.7	4.9	5.8	5.6
Intolerant species Score	34	54	45	19	23
Rating	Good	Good	Good	G-F	G-F

Selected Intolerant taxa					
Haploperla brevis	A	A	A	C	C
Neophylax oligius	A	A	A	-	R
Psephenus herrricki	C	A	A	R	C

(R=Rare, C=Common, A=Abundant)

-Jolly Branch.
No sample in 2015. This site has been consistently rated as Good-Fair, and the stream fauna included many intolerant species.

-Unnamed Tributary to Morgan Creek at Bayberry Drive, Stillhouse Branch.
No sample in 2015 for the Bayberry UT, but a neighboring stream (Stillhouse Branch) was sampled. Data from the Bayberry UT is shown for 2012-2014, and the 2015 data is for Stillhouse Branch. Highly intolerant species were dominant at Stillhouse Branch, producing an unusually low Biotic Index (3.5). Unusual species at this site included *Ameletus lineatus, Stenacron carolina, Paraleptophlebia,* and *Neophylax ornatus.*

	Bayberry UT			
	2012	2013	2014	2015
Total Taxa Richness	29	48	28	29
EPT Taxa Richness	14	18	16	18
NC Biotic Index	4.6	4.2	4.3	3.5
Rating	Ex	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.

	Wilson 1			Wilson 2				
	2012	2013	2015	2011	2012	2013	2014	2015
Total Taxa Richness	45	50	43	45	47	38	41	47
EPT Taxa Richness	23	20	17	17	19	11	16	22
EPT Abundance	103	104	68	54	54	17	54	122
NC Biotic Index	4.0	4.1	3.8	6.0	5.3	6.0	5.0	4.3
Rating	Ex	Ex	Good	G-F	Good	G-F	Good	Ex

-Battle Branch.
No sample in 2015. This stream had been consistently rated as Good-Fair.

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.

Lower Booker Creek
These sites are quite different from the rocky sites seen further upstream. They have clay banks, with a sand and gravel substrate. Both sites had abundant *Chironomus* larvae (a midge), permitting an evaluation of instream toxicity.

-Booker Creek at Tadley Greenway. This site was sampled for the first time in April 2015. It was dominated by highly tolerant snails, midges and worms, mostly those genera that indicate low dissolved oxygen and organic loading: *Physa, Conchapelopia group, Chironomus, Dicrotendipes* and *Limnodrilus.* It is possible that there is some sewer leakage or sewer overflow into this section of Booker Creek. The dominance of such tolerant species produced a very high biotic index value (7.9) and a Poor rating. About 30% of the *Chionomus* larvae had deformities, producing a "Toxic Score" (Lenat 1993) of 65. This clearly indicates some in-stream toxicity, in addition to low dissolved oxygen concentrations.

-Booker Creek at 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 algal growth was much less abundant after 2013. DWQ made collections 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 2011-2015 collections indicate a substantial long-term decline in water quality, with only 1-3 EPT species and an extremely high biotic index (7.3-8.2). A Poor rating is consistently assigned to this portion of Booker Creek, although the biotic index values suggest some moderate improvement from 2011-2015.

The abundance of the midge *Chironomus* had indicated some organic loading to lower Booker Creek during low-flow years, although this taxon was not found in 2013 or 2014. It became abundant again, however, in 2015, and about 30% of the larvae had deformed mouthparts. A "Toxic Score" of 70 (Lenat 1993) indicated substantial in-stream toxicity. Other low-dissolved oxygen indicators (*Physa, Limnodrilus),* however, were rare or absent, suggesting that low-dissolved oxygen is less of a problem here that at the Tadley Greenway site.

	2011	2012	2013	2014	2015
Total Taxa Richness	31	28	32	30	27
EPT Taxa Richness	1	2	2	3	1
NC Biotic Index	8.2	8.1	7.6	7.6	7.3
Rating	Poor	Poor	Poor	Poor	Poor

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 udsually a decline of one bioclassification between the upstream and downstream sites on Bolin Creek. In 2015, the upper site was rated as Good-Fair, while the lower site was rated as Fair. The Village Drive site improved from Fair in 2014 to Good-Fair in 2015 (equivalent to the 2008 rating).

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 long-term decline in water quality, likely reflecting greater urban land use in Carrboro and Chapel Hill.

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 streams in the slate belt ecoregion. Many of these streams go dry during summer droughts, but spring sampling (April) has allowed a evaluation of water quality in these small streams.

Not Rated

-*Dry Creek*. This small stream is frequently dry. The composition of the fauna suggests that it may experience low dissolved oxygen concentrations. This site was not sampled in 2015.

-*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, suggested Fair-Poor water quality. It showed some modest improvement in 2013, but was not sampled in 2014 or 2015.

-Upper Cedar Fork. Two sites on Cedar Fork (Silo Drive and above) were considered too intermittent to support a normal stream fauna. The abundance of the snail Physa are these sites, however, does indicate low dissolved oxygen concentrations in 2015.

Poor and Fair-Poor

-*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 sites (Tadley Greenway and Willow Drive). This stream drains a highly developed catchment. The fauna had suggested some organic loading and low dissolved oxygen in 2011, 2012 and 2015. Analysis of deformities for one resident species indicated that toxicity is also a problem in lower Booker Creek.

Fair

-*Pritchard Branch*. Pritchard Branch drains parts of downtown Chapel Hill. This small stream had showed evidence of a pollution event in 2012 and 2013, including sand deposition. More intolerant species were found in 2014 and 2015, suggesting improving water quality.

-*Cedar Fork*. This is a residential area with poor buffer zones. Special studies in 2014 and 2015 of this catchment showed Good-Excellent water quality in the southern tributaries, but Fair conditions in the middle and lower segments

-*Booker Creek at Piney Mountain Rd* (middle section). Residential area. This site showed a significant decline from the Good-Fair rating at MLK Boulevard.

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 streams 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. Not sampled in 2015

-*Battle Branch*. This stream drains a residential area, but with good buffer zone. Not sampled in 2015.

-*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 and 2015, 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 and 2015. This warrants further investigation of activities in this catchment.

-*Booker Creek at MLK*. Although draining a developed catchment, this site improved to a Good-Fair rating in 2015.

Good or Excellent

-*Fan Branch*. Located in highly developed area, but with good buffer zone and good upstream water quality.

-*Wilson Creek 1* (upstream; not sampled in 2014). Upper Wilson Creek has been rated as either Excellent (2012-2013) or Good (2015). It had an increased sediment load in 2015, although the source of nonpoint runoff in this catchment is not clear. This stream also should be investigated to determine the source of nutrient enrichment, as both Wilson Creek sites have very abundant growths of filamentous algae.

-*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 has alternated between a Good-Fair and a Good rating; but it was rated as Excellent in 2015.

-*Unnamed tributary 1 to Cedar Creek* (south of Brookview Drive) and *Unnamed tributary 2 to Cedar Creek* (north of Brookview Drive). This streams were sampled once in 2014, revealing a previously unknown area of high water quality.

-*UT Bolin Creek* at Severin Dr (No sample in 2014-2015) and *UT Morgan Creek* at Bayberry Dr (No sample in 2015). 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.

-*Stillhouse Branch*. This small stream was first sampled in 2015; it is very near UT Bolin at Bayberry. Stillhouse Branch contained many highly intolerant species.

Short-term changes. Between 2014 and 2015, improvements in water quality were seen at Upper Bolin Creek (Fair→ Good-Fair), Pritchard Branch (Fair/Poor→ Fair), and lower Wilson Creek (Good→ Excelllent). Smaller improvements were also seen at Mill Race Branch. A decline was observed only at upper Wilson Creek, were increased sedimentation appears to have impacted the stream. Many of these changes may be related to higher flows in 2015.

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 and Morgan Creek, Chapel Hill, North Carolina, 2011-2015.

	March 2011				June 2012				June 2013				June 2014				June 2015			
Site:	B4	B5	M1*	M2	B4	B5	M1*	M2	B4	B5	M1*	M2	B4	B5	M1*	M2	B4	B5	M1	M2
Ephemeroptera	4	1	9	7	3	3	7	6	3	1	11	3	4	4	10	9	4	5	8	8
Plecoptera	1	-	6	-	1	-	2	-	-	-	1	-	1	-	2	-	1	-	4	1
Trichoptera	3	3	3	5	4	2	2	3	3	3	5	6	5	4	5	8	7	4	7	6
Coleoptera	2	-		6	5	3		3	6	3		4	6	2		4	2	3		
Odonata	2	6		3	3	5		2	1	4		2	6	5		4	5	6		
Megaloptera	-	-		1	1	-		-	-	-		1	-	-		2	1	-		
Diptera; Misc.	8	6		5	2	2		4	4	2		3	4	3		3	4	4		
Diptera: Chironomidae	22	20		23	19	12		13	9	12		21	19	20		16	15	19		
Oligochaeta	8	6		3	2	2		1	1	4		2	4	6		3	3	2		
Crustacea	4	2		3	3	1		3	2	1		3	3	1		3	2	1		
Mollusca	4	4		5	5	-		3	3	2		4	3	1		3	6	2		
Other	1	2		2	3	-		1	1	2		1	2	2		3	3	1		
Total Taxa Richness	59	50		63	51	30		39	33	34		50	57	48		58	53	46		
EPT Taxa Richness	8	4	21*	12	8	5	13*	9	6	4	19	9	10	8	20*	17	12	9	22*	17*
EPT Abundance	21	26	67	74	48	34	44	67	53	40	87	42	64	48	106	97	69	47	112	75
EPT Score	1.6	1	3	2	1.6	1	2	1.6	1.4	1	3	1.6	2	1.6	3	2.6	2	1.6	3.4	2.6
NC Biotic Index	6.7	7.0	-	6.7	6.8	6.5		6.3	5.9	6.2		6.6	6.3	6.8		6.1	5.8	5.9	-	-
BI Score	2	2	-	2	2	2.4		3	3	3		2	3	2		3	3.4	3		
Site Score	1.8	1.5	3-4?	2	1.8	1.7		2.3	2.2	2		1.8	2.5	1.8		2.8	2.7	2.3	-	-
Rating	Fair	Poor	Good?	Fair	Fair	Fair	G-F?	Fair	Fair	Fair	G-F	Fair	F/G-F	Fair	G-F	G-F	G-F	Fair	G-F	G-F

*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 2015. Summaries are also included from prior years.

Site:	PF	MR	Tan	UTTan	OF	Cedar	Bk1	Libr	Cole	Jolly	UTSev	UTBay	SH
Width (m):	1.5	2	2	1	2.5	3	2	1	2	1	<1	1	<1
Ephemeroptera	1	1	*	*	5	*	-	*	3	*	*	*	3
Plecoptera	-	-			3		-		1				5
Trichoptera	4	3			3		3		6				10
Coleoptera	2	-			3		2		2				1
Odonata	2	1			4		4		2				-
Diptera; Misc.	2	2			4		1		2				2
Diptera: Chironomidae	5	5			10		12		4				2
Oligochaeta	4	6			4		1		3				2
Crustacea	1	1			3		3		1				2
Mollusca	1	-			1		2		2				1
Other	-	-			-		-		-				1
Abundance of indicators													
Low DO (Physa)													
Toxics (Certain midges)													
Total Taxa Richness	22	19			40		28		26				29
EPT Taxa Richness	5	3			11		3		10				18
EPT Abundance	26	17			60		16		25				122
EPT Score	1	1			2		1		2				3
NC Biotic index	5.3	6.9			5.7		6.2		5.6				3.5
BI Score (Normal Streams)	4	2			4		3		4				5
Bi Rating (Small Streams)	G-F	Fair			G-F		Fair		Good				Excellent
Flow													
(Perennial or Intermittent)	?	Per			Int		Int		Per				Int?
Combined Site Score	2.5	1.5			3.0		2		3.0				4
Overall Rating	**Fair**	**Poor**			**G-F**		**Fair**		**G-F**				**Ex**
Change vs. 2014	+	0?			0		0		0				

*No sample in 2015; Cedar Fork was sampled further upstream in 2015 and Booker Creek sampled at 5 sites (The MLK site is shown here). See tables below for other Cedar Fork and Booker sites. Stillhouse is a new site, but is equivalent in size and quality to the UT Bolin Creek presented in Table 3B.

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
2014 Data													
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
NC Biotic index	6.6	6.8	7.4		6.2	6.5	6.2		5.8	5.4		4.3	4.9
Overall Rating	**F-P**	**Poor**	**Poor**		**G-F**	**Fair**	**Fair**		**G-F**	**G-F**		**Ex**	**Ex**
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 2015. (No collections at Battery and Dry Creeks in 2015).

Site:	Batt	Fan	Wil1	Wil2	Dry	Bk2
Width (m):	2	3	2	3	1	4.5
Ephemeroptera	*	5	6	8	*	-
Plecoptera		4	4	5		-
Trichoptera		5	7	9		1
Coleoptera		3	3	3		2
Odonata		1	3	3		2
Diptera; Misc.		5	2	3		2
Diptera: Chironomidae		8	9	9		11
Oligochaeta		6	5	3		3
Crustacea		4	3	3		1
Mollusca		2	1	1		4
Other		-	-	-		1
Abundance of indicators						
Low DO (Physa, Chironomus)						+
Total Taxa Richness		43	43	47		27
EPT Taxa Richness		14	17	22		1
EPT Abundance		76	68	122		3
EPT Score		2.4	2.6	3.4		1.0
NC Biotic index		4.6	3.8	4.3		7.3
BI Score (Normal Streams)		5	5	5		2
Bi Rating (Small Streams)		Good	Ex	Ex		Poor
Flow (Perennial or Intermittent)		Per?	Per	Per		Per?
Combined Site Score		3.7	3.8	4.2		1.5
Overall Rating		**Good**	**Good**	**Ex**		**Poor**
Change vs. 2013		**0**	**-?**	**+**		**0**
2014 Data						
Total Taxa Richness	20			41	27	30
EPT Taxa Richness	4			16	3	3
EPT Abundance	10			54	12	5
NC Biotic index	6.4			5.0	7.3	7.6
Overall Rating	**G-F**			**Good**	**NR**	**Poor**
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
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 and Booker Creek catchments, Chapel Hill, North Carolina, April 2015. Most upstream sites are listed first.

	Cedar Fk			Booker Cr					
Site:	3	3A	2	Park	MLK	PM	Tadley	Willow	Crow Br
Width (m):	1.5	2	3	1	2.5	3	7	5	2
Ephemeroptera	-	1	1	-	3	3	2	-	-
Plecoptera	-	-	-	-	-	1	1	-	1
Trichoptera	1	1	3	3	3	4	1	1	2
Coleoptera	4	2	2	4	3	2	-	2	1
Odonata	-	-	1	2	2	3	1	2	1
Diptera; Misc.	1	1	2	1	1	3	1	2	2
Diptera: Chironomidae	12	6	10	11	11	11	18	11	6
Oligochaeta	5	3	3	4	2	6	5	3	5
Crustacea	3	3	3	3	3	3	4	1	3
Mollusca	2	2	3	3	4	2	1	4	1
Other	-	-	-	-	-	-	1	1	-
Abundance of indicators									
Low DO (Physa, Chironomus)	+	+	+	+		+	++	+	+
Total Taxa Richness	28	19	28	31	32	38	35	27	22
EPT Taxa Richness	1	2	4	4	6	8	4	1	3
EPT Abundance	10	11	31	7	46	32	6	3	21
EPT Score	1	1	1	1	1.4	1.6	1	1	1
NC Biotic index	7.4	7.3	6.9	6.5	5.8	6.7	7.9	7.3	6.5
BI Score (Normal Streams)	2	2	2	2.4	3.4	2	1	2	2.2
Bi Rating (Small Streams)	Poor	Poor	Fair	Fair	G-F	Fair	Poor	Poor	Fair
Flow (Perennial or Intermittent)	Int	Int	Int	Int	Int	Int	Per?	Per?	Int
Combined Site Score	1.5	1.5	1.5	1.7	2.4	1.8	1	1.5	1.6
Suggested Overall Rating	**NR**	**NR**	**Fair**	**NR**	**G-F**	**Fair**	**Poor**	**Poor**	**NR**

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) and Morgan Creek (M1, M2), June 2012-2015. Taxa must be Common or Abundant at one or more sites.

	June 2012				June 2013				June 2014				June 2015			
Site:	B4	B5	MI	M2	B4	B5	MI	M2	B4	B5	MI	M2	B4	B5	MI	M2
Leucrocuta aphrodite	-	-	A	-	-	-	A	-	-	-	A	-	-	-	A	-
Isonychia spp	-	-	R	C	-	-	-	-	-	-	A	-	-	-	A	-
Aconeuria abnormis	R	-	C	-	-	-	-	-	R	-	C	-	C	-	A	-
Perlesta sp	-	-	C	-	-	-	A	-	-	-	C	-	-	-	A	R
Chimarra sp	C	A	-	C	A	A	A	A	A	A	A	A	A	A	A	A
Neophylax oligius	-	-	-	-	-	-	-	-	-	-	A	R	-	-	A	-
Paraleptophlebia sp	-	-	R	-	-	-	C	-	-	-	-	-	-	-	R	-
Habrophlebia vibrans	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-
Psephenus herricki	C	-	C	C	A	-	A	R	A	R	A	-	A	R	A	R
Elimia sp	-	-	-	-	R	R	-	-	R	-	-	-	A	-	C	-
Sum*	7	10	21	9	21	11	46	11	22	11	56	11	33	11	74	12

*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	A	-	-	-	R	-	-
Sum*	**16**	**0**	**0**	**15**	**3**	**13**	**19**	**25**	**58**	**3**	**29**	**0**	**0**

April 2015

Site:	Prit	MR	OF	Bk1	CSpr	SH	Fan	Wils1	Wils2	Bk2
Stenacron carolina	-	-	-	-	-	C	-	-	-	-
Ameletus lineatus	-	-	-	-	-	A	-	-	-	-
Paraleptophlebia sp	-	-	-	-	-	A	-	R	R	-
Ephemerella dorothea	-	-	-	-	-	-	A	C	A	-
Haploperla brevis	-	-	-	-	C	R	A	C	A	-
Eccoptura xanthenes	-	-	-	-	-	R	A	-	R	-
Perlesta sp	-	-	A	-	-	R			R	-
Amphinemura sp	-	-	A	-	-	A	C	C	C	-
Chimarra sp	R	R	-	A	C	R	-	R	-	-
Wormaldia sp	-	-	-	-	-	A	-	-	-	-
Diplectrona modesta	A	C	-	-	C	R	-	R	-	-
Neophylax oligius	-	-	-	-	R	-	-	A	A	-
Neophylax ornatus		-	C	-	-	A	-	R	C	-
Pycnopsyche sp	-	-	-	-	-	C	-	C	C	-
Lepidostoma sp	-	-	-	-	-	C	A	A	A	-
Psephenus herricki	-	-	-	R	C	-	-	C	C	-
Elimia sp	A	-	-	A	A	A	C	A	A	-
Sum*	**26**	**4**	**23**	**21**	**23**	**74**	**46**	**49**	**65**	**0**
Change vs. 2014	**+**	**+?**	**+**	**+**	**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) and Morgan Creek (MM1, MM2), Chapel Hill, June 2012-2015. R=Rare, C=Common, A=Abundant. Many Morgan Creek collections limited to most intolerant (EPT) groups. Yellow highlights show selected between-year changes.

	June 2012				June 2013				June 2014				June 2015			
	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	A	A	C	A
Baetis intercalaris (summer)	-	R	R	A	-	-	-	-	-	R	-	A	-	-	-	C
Baetis pluto	-	-	-	-	-	-	-	-	R	-	A	A	-	-	A	A
Acentrella nadineae	-	-	-	R	-	-	-	-	-	-	-	C	-	-	-	R
Acerpenna pygmea	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-
Centroptilum triangulifer	-	-	R	-	-	-	-	-	-	-	R	-	R	-	-	-
Procloeon sp	-	-	-	-	-	-	-	-	-	-	R	R	-	-	-	-
Labiobaetis propinquus	-	-	-	-	-	-	-	-	-	-	C	C	-	R	-	-
Maccaffertium modestum	A	C	A	A	C	-	A	A	A	A	A	A	A	C	A	A
Stenonema femoratum	-	-	C	-	-	-	A	-	-	-	R	-	-	-	R	-
Stenacron interpunctatum	C	-	-	A	A	-	A	C	A	C	A	C	A	R	A	C
Stenacron pallidum	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Leucrocuta aphrodite	-	-	A	-	-	-	A	-	-	-	A	-	-	-	A	-
Caenis spp	-	-	-	-	-	-	C	-	-	-	-	A	-	-	-	R
Tricorythodes sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
Isonychia spp	-	-	R	C	-	-	-	-	-	-	A	-	-	-	A	-
Paraleptophlebia sp	-	-	R	-	-	-	C	-	-	-	-	-	-	-	R	-
Habrophlebia vibrans	-	-	-	-	-	-	C	-	-	-	-	-				
Hexagenia sp	-	-	-	-	-	-	R	-	-	-	-	-				
PLECOPTERA																
Acroneuria abnormis	R	-	C	-	-	-	-	-	R	-	C	-	C	-	A	-
Perlesta sp	-	-	C	-	-	-	A	-	-	-	C	-	-	-	A	R
Neoperla sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Leuctra sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-
TRICHOPTERA																
Cheumatopsyche spp	A	A	A	A	A	A	A	A	A	C	A	A	A	A	A	A
Hydropsyche betteni	A	-	-	A	A	A	R	A	A	A	A	A	A	A	A	A
Chimarra sp	C	A	-	C	A	A	A	C	A	A	A	A	A	A	A	A
Polycentropus sp	-	-	R	-	-	-	-	R	-	-	C	R	-	-	C	R
Phylocentropus sp	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R
Hydroptila sp	-	-	-	-	-	-	-	-	R	R	-	R	R	-	R	-
Neophylax oligius	-	-	-	-	-	-	-	-	-	-	A	R	-	-	A	-
Pycnopsyche sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Oecetis sp A	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oecetis persimilis	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Triaenodes ignitus	-	-	-	-	-	-	-	R	R	-	-	C	R	R	-	A
Nectopsyche exquisita	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-

	June 2012			June 2013			June 2014			June 2015	
	B4	B5	M2	B4	B5	M2	B4	B5	M2	B4	B5
COLEOPTERA											
Macronychus glabratus	-	R	-	-	-	-	-	-	-	-	R
Dubiraphia sp	R	-	-	R	R	-	R	-	-	-	-
Stenelmis crenata	A	C	C	C	A	A	A	A	C	C	C
Psephenus herricki	C	-	C	A	-	R	A	R	-	A	R
Helichus spp	R	R	-	R	R	-	R	-	R	-	-
Coptotomus sp	-	-	-	-	-	-	R	-	-	-	-
Neoporus sp	-	-	-	R	-	R	A	-	R	-	-
Neoporus mellitus gr	-	-	R	R	-	R	-	-	R	-	-
Peltodytes sp	R	-	-	-	-	-	-	-	-	-	-
ODONATA											
Argia spp	-	C	A	-	A	A	C	A	A	C	A
Calopteryx sp	-	-	-	-	-	-	-	-	-	-	R
Enallagma spp	-	R	-	R	R	-	C	R	-	-	C
Gomphus sp	-	-	-	-	-	-	R	-	-	-	-
Hagenius brevistylus	-	-	-	-	-	-	R	-	-	R	-
Progomphus obscurus	-	R	R	-	-	-	-	-	-	-	-
Stylogomphus albistylus	-	R	-	-	R	-	R	R	-	R	R
Macromia sp	-	-	-	-	-	-	-	-	R	-	-
Libellula sp	R	-	-	-	-	-	-	-	-	-	-
Pachydiplax longipennis	R	-	-	-	-	R	-	-	-	-	-
Somatochlora sp	R	R	-	-	-	-	C	A	-	R	R
Boyeria vinosa	-	-	-	-	R	-	-	-	C	C	C
Basiaeshna janata	-	-	-	-	-	-	-	C	R	-	-
MEGALOPTERA											
Sialis sp	R	-	-	-	-	-	-	-	C	R	-
Corydalus cornutus	-	-	-	-	-	C	-	-	C	-	-
DIPTERA: MISC.											
Antocha spp	-	-	R	R	-	C	-	-	C	-	R
Tipula spp	C	C	C	C	C	A	C	C	-	C	R
Palpomyia complex	-	-	-	-	-	-	-	-	R	-	-
Anopheles sp	-	-	R	-	-	-	-	-	-	C	C
Empididae	-	-	-	-	-	-	R	R	-	-	-
Dolichopodidae	-	-	-	R	-	-	-	-	-	-	-
Dixella indiana	-	-	-	-	-	-	R	-	-	R	-
Simulium spp	A	A	A	A	A	A	A	A	A	A	A
DIPTERA: CHIRONOMIDAE											
Ablabesmyia janta/parajanta	R	-	-	-	-	R	-	-	-	C	R
Ablabesmyia mallochi	C	R	R	-	-	R	R	C	C	C	A
Conchapelopia group	R	R	C	C	C	A	R	R	C	C	A
Labrundinia pilosella	-	-	-	-	-	R	-	-	-	-	R
Natarsia spp	R	C	-	-	-	R	-	-	R	-	R
Nilotanypus sp	-	R	-	-	R	-	R	-	R	-	-
Procladius sp	C	-	-	-	-	-	-	-	-	-	R
Cardiocladius sp	-	-	-	-	-	R	-	R	C	-	-
Corynoneura spp	-	-	-	-	R	-	R	R	-	-	-
Thienemaniella spp	R	-	R	-	-	R	-	-	R	-	-
Brillia sp	-	-	-	R	-	R	-	-	-	-	R
Cricotopus bicinctus	C	-	R	-	-	-	C	-	-	R	-
Cricotopus triannulatus gr	R	-	-	-	R	-	R	-	R	-	-
Eukiefferiella claripennis gr	R	-	-	-	C	-	-	R	-	-	-
Nanocladius spp	-	-	-	-	-	C	-	R	R	-	-
O. (Eud.) dubitatus	-	R	-	-	-	-	R	-	-		

	June 2012			June 2013			June 2014			June 2015	
	B4	B5	M2	B4	B5	M2	B4	B5	M2	B4	B5
Parametriocnemus lundbecki	-	R	-	A	A	C	-	C	-	R	R
Rheocricotopus robacki	-	-	-	-	-	R	-	-	-	-	-
Synorthocladius sp	R	-	-	-	-	-	R	R	R	-	-
Tvetenia bavarica gr	-	-	-	-	C	-	-	-	-	-	-
Chironomus sp	-	-	-	-	-	-	-	-	R	R	C
Cryptochironomus spp	-	R	R	-	-	R	-	C	R	-	R
Cryptotendipes sp	-	-	R	-	-	-	-	R	-	-	-
Dicrotendipes spp	R	-	C	-	-	R	R	C	-	R	-
Microtendipes spp	-	-	-	C	C	R	C	C	R	C	C
Paratendipes sp	-	R	-	-	R	RR	A	C	-	R	C
Phaenopsectra spp	R	C	-	-	-	R	R	A	-	R	C
Phaenopsectra flavipes gr	R	-	-	-	R	-	R	-	-	-	-
Polypedilum flavum	A	A	A	A	C	A	C	-	A	R	-
Polypedilum illinoense gr	-	-	R	-	C	A	-	A	R	-	R
Polypedilum fallax	-	-	-	-	R	-	-	-	-	-	R
Polypedilum scalaenum gr	C	-	R	R	-	-	C	A	-	C	C
Polypedilum halterale gr	-	C	-	-	-	-	-	-	-	-	-
Pseudochironomus sp	-	-	-	-	-	-	-	-	-	R	-
Stenochironomus sp	R	-	-	-	-	R	-	-	-	-	-
Tribelos sp	C	-	R	R	R	-	C	-	-	A	C
Xenochironomus xenolabis	-	-	-	-	R	-	-	-	R	-	R
Cladotanytarsus sp	-	-	-	-	-	-	-	R	-	-	-
Rheotanytarsus spp	-	-	R	R	-	C	C	C	C	-	-
Paratanytarsus sp	R	-	-	R	-	-	-	C	-	-	-
Tanytarsus spp	C	R	C	-	C	C	-	A	-	R	C
OLIGOCHAETA											
Limnodrilus spp	C	A	-	-	-	R	-	R	-	R	R
Ilyodrilus templetoni	-	-	-	-	-	-	-	R	-	-	-
Nais spp	-	-	-	-	R	-	R	C	R	-	-
Stylaria lacustris	-	-	-	-	R	-	-	-	R	R	-
Slavinia appendiculata	-	-	-	-	-	-	R	R	-	-	-
Ecclipidrilus spp	-	-	-	-	-	-	-	-	R	-	C
Lumbriculus variegatus	-	-	-	C	R	-	R	C	-	C	-
Cambarinicolidae	-	-	-	-	-	-	R	R	-	-	-
CRUSTACEA											
Crangonyx spp	R	-	R	-	-	-	-	-	-	-	-
Hyallela azteca	A	-	R	R	-	A	C	-	C	R	-
Caecidotea sp	C	-	R	R	-	R	R	-	-	-	-
Cambarus spp	-	A	-	-	C	C	C	C	C	C	C
Procambarus acutus	-	-	-	-	-	-	-	-	R	-	-
MOLLUSCA											
Elimia sp	-	-	-	R	R	-	R	-	-	A	-
Campeloma decisum	R	-	-	-	-	-	-	-	-	-	-
Physa sp	A	-	C	C	-	R	R	C	R	R	R
Stagnicola sp?	R	-	-	-	-	-	-	-	-	-	-
Helisoma anceps	C	-	C	-	-	R	R	-	-	C	-
Ferrissia sp	-	-	-	R	C	-	-	-	-	R	-
Laevapex fuscus	-	-	-	-	-	R	-	-	C	-	-
Pisidium spp	R	-	-	-	-	-	-	-	-		
Corbicula fluminea	A	-	A	-	-	A	-	-	R		

	June 2012			June 2013			June 2014			June 2015	
	B4	B5	M2	B4	B5	M2	B4	B5	M2	B4	B5
OTHER											
Turbellaria											
Dugesia tigrina	R	-	R	-	-	-	-	R	C	-	-
Cura foremanii	-	-	-	A	R	-	C	R	-	A	-
Hydrolimax grisea	-	-	-	-	-	-	-	-	R	-	-
Hemiptera											
Corixidae	R	-	-	-	-	-	-	-	-	R	-
Ranatra sp	-	-	-	-	-	-	-	-	-	R	-
Hirudinea											
Helobdella triserialis	R	-	-	-	-	-	-	-	-	-	-
Placobdella papillfera	-	-	-	-	R	-	-	-	-	-	-
Placobdella parasitica	-	-	-	-	-	-	R	-	-	-	-
Neuroptera: Climacia	-	-	-	-	-	-	-	-	C	-	-
Prostoma graecens	-	-	-	-	-	-	-	-	-	-	R

Appendix 2. Benthic macroinvertebrates collected at small streams in Chapel Hill, April 2015.
R = Rare, C = Commonn, A = Abundant. Site abbreviations:

	Cedar Fork			Booker Cr					
Site[1]:	3	3A	2	Up	MLK	PM	Tadley	Willow	Crow
Width (m):	1.5	2	3	1	2.5	3	7	5	2
EPHEMEROPTERA									
Plauditus dubius gr	-	R	-	-	-	-	-	-	-
Baetis flavistriga	-	-	A	-	C	A	-	-	-
Maccaffertium modestum	-	-	-	-	A	-	R	-	-
Stenacron interpunctatum	-	-	-	-	C	R	-	-	-
Caenis sp	-		-	-	-	C	C	-	-
PLECOPTERA									
Perlesta sp	-	-	-	-	-	C	R	-	A
TRICHOPTERA									
Cheumatopsyche spp	-	-	R	C	A	R	R	C	-
Hydropsyche betteni	-	-	-	-	-	C	-	-	-
Chimarra sp	-	-	A	C	A	R	-	-	-
Rhyacophila glaberrima	-	-	-	-	-	-	-	-	R
Ironoquia punctatissima	A	A	A	R	A	A	-	-	A
COLEOPTERA									
Stenelmis crenata	A	A	A	C	R	R	-	C	-
Dubiraphia sp	-	-	-	R	-	-	-	-	-
Psephenus herricki	-	-	-	-	R	-	-	-	-
Ectopria nervosa	-	R	-	-	R	-	-	-	-
Helichus spp	R	-	-	C	C		-	-	R
Neoporus sp	C	-	R	-	-	-	-	C	-
Copelatus sp	R	-	-	-	-	-	-	-	-
Dineutus sp	-	-	-	-	-	R	-	-	-
ODONATA									
Argia spp	-	-	-	R	-	R	R	R	-
Calopteryx sp	-	-	-	-	C	C	-	-	-
Enallagma sp	-	-	-	C	-	-	-	-	-
Stylogomphus albistylus	-	-	-	-	-	R	-	-	-
Somatochlora sp	-	-	R	-	-	-	-	-	R
Pachydiplax longipennis	-	-	-	-	-	-	-	R	-
Cordulegaster sp	-	-	-	-	R	-	-	-	-
DIPTERA: MISC.									
Tipula sp	A	C	A	R	-	C	-	C	A
Simulium spp	-	-	C	-	C	A	R	A	C
Palpomyia complex	-	-	-	-	-	R	-	-	-

	Cedar Fork			Booker Cr					
Site[1]:	3	3A	2	Up	MLK	PM	Tadley	Willow	Crow
Width (m):	1.5	2	3	1	2.5	3	7	5	2
DIPTERA: CHIRONOMIDAE									
Ablabesmyia mallochi	-	-	-	-	-	R	R	R	-
Conchapelopia group	C	A	A	C	R	A	A	A	C
Zavrelimyia sp	R	-	-	-	-	-	-	-	-
Procladius sp	R	-	-	-	-	-	C	-	-
Psectrotanypus dyari	-	-	-	-	-	-	R	-	-
Cricotopus bicinctus	-	-	-	-	-	-	C	C	-
Cricotopus annulator gr	-	-	-	-	-	-	-	R	-
Eukiefferiella claripennis gr	A	C	A	C	-	R	-	-	C
Tvetenia bavarica gr	-	-	-	-	-	R	-	-	-
Orthocladius obumbratus	-	-	-	C	C	-	-	-	-
Paratrichocladius sp	C	R	R	-	-	-	R	-	-
Parametriocnemus lundbecki	R	C	C	A	C	R	-	R	C
Paraphaenocladius sp	-	-	-	-	-	-	R	-	-
Rheocricotopus robacki	R	-	-	-	-	-	-	-	-
Psectrocladius sordidellus gr	C	-	-	-	-	-	-	-	-
Potthastia longimana	-	R	C	-	C	-	R	R	R
Cladopelma sp	-	-	R	-	-	-	-	-	-
Cryptochironomus sp	-	-	-	-	-	-	R	-	-
Chironomus sp	C	-	C	A	C	R	A	A	R
Dicrotendipes spp	-	-	-	-	-	-	A	-	-
Dicrotendipes simpsoni	-	-	-	-	-	-	R	-	-
Lipiniella sp	-	-	-	-	-	-	-	R	-
Microtendipes spp	-	-	-	C	C	C	-	-	-
Nilothauma sp	-	-	-	-	-	-	R	-	-
Paratendipes sp	-	-	-	R	-	-	-	-	-
Phaenopsectra flavipes gr	-	-	-	-	-	-	C	A	-
Polypedilum flavum	R	R	C	-	A	A	C	-	-
Polypedilum aviceps	-	-	-	A	-	-	-	-	R
Polypedilum fallax	-	-	-	R	-	-	-	-	-
Polypedilum illinoense	-	-	-	-	R	-	C	-	-
Tribelos jucundus	-	-	-	-	R	-	-	-	-
Cladotanytarsus sp	-	-	-	-	-	-	R	-	-
Paratanytarsus spp	R	-	R	C	-	R	-	-	-
Rheotanytarsus sp	-	-	C	R	R	C	-	A	-
Tanytarsus spp	R	-	-	-	R	C	C	R	-
OLIGOCHAETA									
Limnodrilus spp	-	-	-	C	-	R	A	C	-
Ilyodrilus templetoni	C	-	-	C	-	-	R	-	-
Spirosperma nikolskyi	C	R	R	-	-	-	-	-	-
Nais spp	C	R	R	R	R	-	-	-	R
Chaetogaster sp	-	-	-	-	-	-	-	-	R
Slavina appendiculata	-	-	-	-	-	-	R	-	-
Stylaria lacustris	-	-	-	-	-	R	-	C	-
Ecclipidrilus spp	-	-	-	-	-	R	-	-	-
Lumbriculus variegata	C	C	A	-	C	C	C	C	A
Rhynchelmis bolinensis	-	-	-	-	-	-	-	-	A
Enchytraeidae	-	-	-	R	-	R	-	-	-
Megadriles	-	-	-	-	-	C	C	-	C
Haplotaxis sp	R	-	-	-	-	-	-	-	-

	Cedar Fork			Booker Cr					
Site[1]:	3	3A	2	Up	MLK	PM	Tadley	Willow	Crow
Width (m):	1.5	2	3	1	2.5	3	7	5	2
CRUSTACEA									
Crangonyx spp	C	A	A	R	R	C	R	-	A
Hyalella azteca	-	-	-	-	-	-	R	-	-
Caecidotea forbesi	C	C	C	R	R	A	-	-	A
Cambarus spp	A	A	C	C	C	R	C	C	R
Procambarus sp	-	-	-	-	-	-	R	-	-
MOLLUSCA									
Elimia sp	-	-	-	-	A	-	-	-	-
Physa sp	A	A	A	-	R	A	A	R	A
Ferrissia sp	-	-	-	C	-	-	-	R	-
Micromenetus dilatatus	-	-	R	C	R	-	-	-	-
Pisidium spp	C	-	R	C	C	-	-	-	-
Sphaerium sp	-	R	-	-	-	-	-	C	-
Corbicula sp	-	-	-	-	-	R	Dead	R	-
OTHER									
Dugesia tigrina	-	-	-	-	-	-	R	R	-

Appendix 2B. Benthic macroinvertebrates collected at small stream in Chapel Hill, April 2014. R = Rare, C = Commonn, A = Abundant. Site abbreviations: Wil = Wilson Creek (#1 and #2), Fan = Fan Branch.

Site:	Prit	Mill R	OF	Cole	StillH	Fan	Wil1	Wil2
Width (m):	2	2	4	3	1.5	2.5	3.5	3.5
EPHEMEROPTERA								
Plauditus dubius gr	-	-	A	R	-	R	C	A
Plauditus cestus	-	-	-	-	-	-	-	R
Baetis flavistriga	C	A	R	C	-	R	-	A
Baetis pluto	-	-	-	-	-	-	A	A
Ephemerella dorothea	-	-	-	-	-	A	C	A
Eurylophella verisimilis	-	-	-	-	-	-	C	-
Serratella deficiens	-	-	-	-	-	R	-	-
Dannella simplex	-	-	-	-	-	-	-	R
Paraleptophlebia sp	-	-	-	-	A	-	R	R
Maccaffertium modestum	-	-	C	C	-	C	A	A
Stenonema femoratum	-	-	A	-	-	-	-	-
Stenacron carolina	-	-	-	-	C	-	-	-
Stenacron interpunctatum	-	-	R	-	-	-	-	-
Ameletus lineatus	-	-	-	-	A	-	-	-
PLECOPTERA								
Perlesta sp	-	-	A	-	R	R	R	A
Haploperla brevis	-	-	-	C	R	A	C	A
Eccoptura xanthenes	-	-	-	-	R	A	-	R
Isoperla n. sp.	-	-	R	-	-	-	-	-
Amphinemura sp	-	-	A	-	A	C	C	C
Leuctra sp	-	-	-	-	R	-	R	R
TRICHOPTERA								
Cheumatopsyche spp	R	-	R	R	-	C	C	C
Hydropsyche betteni	A	C	-	C	-	C	-	A
Diplectrona modesta	A	C	-	C	C	A	R	R
Chimarra sp	R	R	-	C	R	-	R	-
Wormaldia sp	-	-	-	-	A	-	-	-
Polycentropus sp	R	-	-	R	C	-	-	R
Rhyacophila carolina	-	-	-	-	R	-	-	-
Neophylax oligius	-	-	-	R	-	-	A	A
Neophylax ornatus	-	-	C	-	A	-	R	C
Psilotreta sp	-	-	-	-	R	-	-	-
Ironoquia punctatissima	-	-	A	C	C	A	R	C
Pycnopsyche sp	-	-	-	-	C	-	C	C
Lepidostoma sp	-	-	-	-	C	A	A	A
Triaenodes ignitus	-	-	-	-	-	-	C	-
COLEOPTERA								
Stenelmis crenata	R	-	C	-	-	C	-	-
Macronychus glabratus	-	-	-	-	-	-	-	R
Psephenus herricki	-	-	-	C	-	-	C	C
Helichus spp	-	-	R	-	R	R	R	R
Anchytarsus bicolor	-	-	-	-	-	R	R	-
Neoporus spp	R	-	R	R	-	-	-	-

Site:	Prit	Mill R	OF	Cole	StillH	Fan	Wil1	Wil2
Width (m):	2	2	4	3	1.5	2.5	3.5	3.5
ODONATA								
Calopteryx sp	C	R	C	C	-	-	R	R
Argia sp	R	-	R	-	-	-	-	-
Cordulegaster sp	-	-	-	-	-	-	R	-
Progomphus obscurus	-	-	-	-	-	-	R	-
Stylogomphus albistylus	-	-	C	-	-	-	-	R
Somatochlora sp	-	-	R	R	-	-	-	-
Boyeria vinosa	-	-	-	-	-	R	-	R
MEGALOPTERA								
Corydalus cornutus	-	-	-	-	-	-	-	R
DIPTERA: MISC.								
Antocha spp	-	-	C	-	-	R	-	-
Tipula sp	A	C	A	A	A	R	C	R
Pseudolimnophila sp	-	-	R	-	-	-	-	-
Hexatoma sp	-	-	R	-	-	-	-	-
Palpomyia complex	-	-	-	-	-	R	-	-
Simulium spp	C	R	-	R	-	R	-	-
Dixa sp	-	-	-	-	R	R	R	R
Empididae	-	-	-	-	-	-	-	R
DIPTERA: CHIRONOMIDAE								
Conchapelopia group	C	A	C	-	-	-	-	C
Tanypus sp	-	-	-	-	-	-	R	-
Zavrelimyia sp		-	R	-	-	-	-	-
Brillia sp	-	-	-	-	-	C	R	-
Cricotopus bicinctus	-	-	-	-	-	-	-	R
Eukiefferiella claripennis gr	C	A	R	R	-	-	-	-
Tvetenia bavarica gr	A	-	R	-	-	-	-	-
Orthocladius obumbratus	-	-	-	-	-	-	-	C
Parametriocnemus lundbecki	C	R	R	R	R	C	C	R
Paratrichocladius sp	R	-	-	-	-	-	-	-
Psetrocladius sordidellus gr	-	-	-	-	R	-	-	-
Theinemanniella sp	-	R	-	-	-	-	-	-
Potthastia longimana	-	-	R	-	-	R	-	-
Odontomesa fulva	-	-	-	-	-	R	-	-
Cryptochironomus spp	-	-	-	-	-	-	R	-
Chironomus sp	-	R	-	-	-	C	-	-
Dicrotendipes spp	-	-	-	-	-	-	-	R
Microtendipes spp	-	-	R	-	-	-	-	R
Polypedilum aviceps	-	-	-	R	-	A	C	C
Polypedilum flavum	-	-	R	-	-	-	-	-
Polypedilum halterale gr	-	-	-	-	-	R	R	-
Polypedilum scalaenum gr	-	-	R	-	-	-	-	-
Polypedilum fallax	-	-	-	-	-	-	R	R
Stenochironomus sp	-	-	-	-	-	-	R	-
Stictochironomus sp	-	-	-	-	-	-	R	-
Tribelos jucundum	-	-	R	-	-	-	-	R
Paratanytarsus sp	-	-	-	-	-	R	-	-
Tanytarsus spp	-	-	-	R	-	-	-	-

Site:	Prit	Mill R	OF	Cole	StillH	Fan	Wil1	Wil2
Width (m):	2	2	4	3	1.5	2.5	3.5	3.5
OLIGOCHAETA								
Limnodrilus spp	-	R	R	-	-	-	R	C
Ilyodrilus templetoni	-	-	-	R	-	C	-	-
Spirosperma nikolsyii	-	-	-	-	-	R	-	-
Nais spp	R	C	-	C	-	-	R	-
Pristinella sp	-	R	-	-	-	-	-	-
Slavina appendiculata	-	-	R	-	-	-	-	-
Ecclipidrilus spp	R	-	-	C	R	R	R	-
Lumbriculus variegata	-	C	R	-	-	R	C	R
Enchytraeidae	C	C	-	-	R	R	-	-
Megadriles	C	A	C	-	-	C	R	A
CRUSTACEA								
Crangonyx spp	-	R	R	-	A	C	R	C
Caecidotea forbesi	-	-	C	-	-	R	R	-
Cambarus sp	R	-	A	A	C	A	C	A
Procambarus acutus	-	-	-	-	-	-	-	R
Palaemonetes paludosus	-	-	-	-	-	R	-	-
MOLLUSCA								
Elimia sp	A	-	-	A	A	C	A	A
Physa sp	-	-	C	R	-	-	-	-
Ferrissia sp	-	-	-	-	-	R	-	-
OTHER								
Cura foremanii	-	-	-	-	R	-	-	-

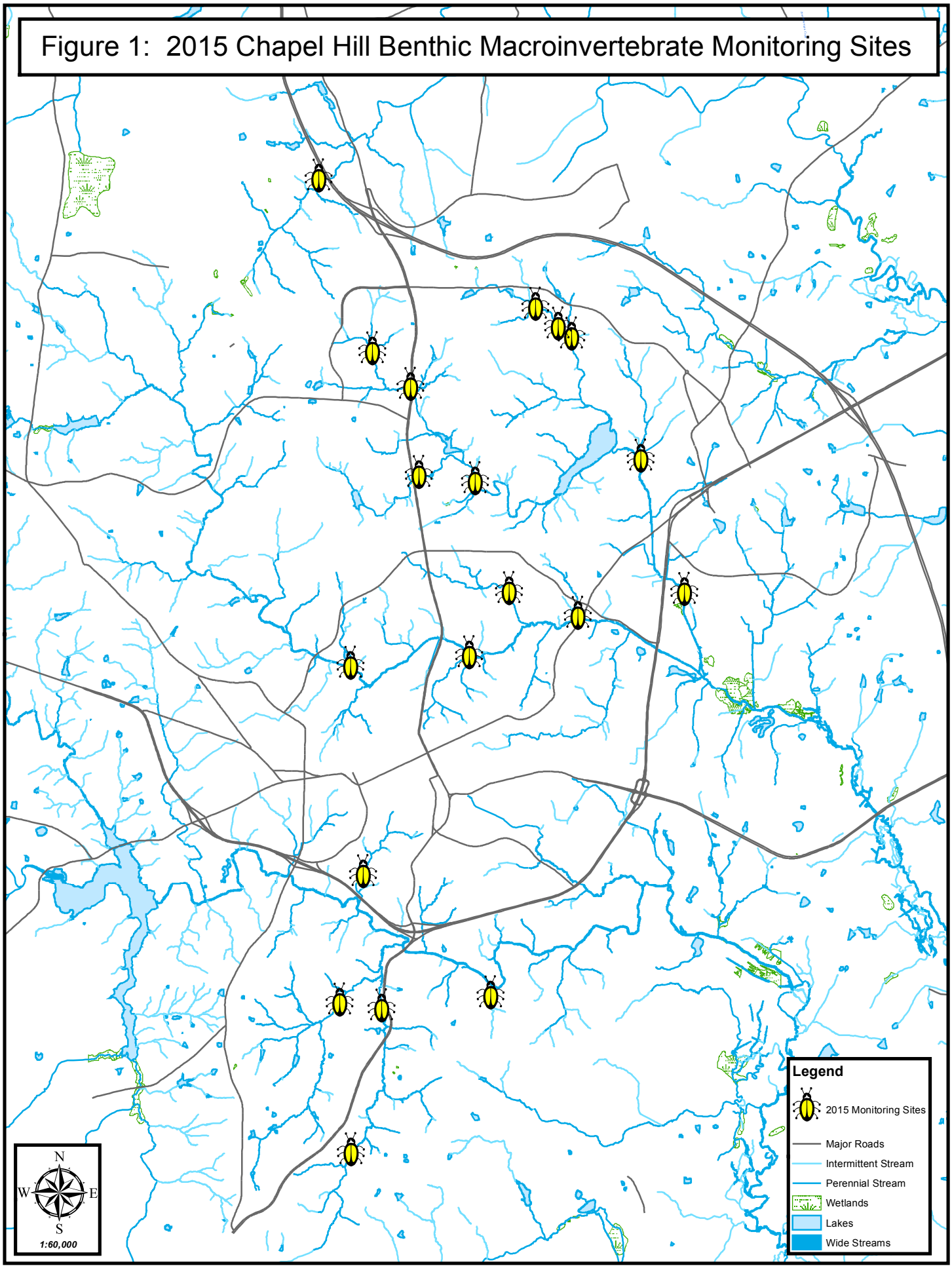
Figure 1: 2015 Chapel Hill Benthic Macroinvertebrate Monitoring Sites
Legend
2015 Monitoring Sites
Major Roads
Intermittent Stream
Perennial Stream
Wetlands
Lakes
Wide Streams
N
W
E
S
1:60,000

Appendix 4. Chapel Hill Large Stream Sites, June 2015.

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 2015.

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 2012-2015. Specific conductance was lower than expected for this site in June 2015: 131 uhmos/cm.

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 2015.

This site drains a heavily developed catchment, including the downtown areas of both Carrboro and Chapel Hill. Compared to Site 4, specific conductance was much higher at Site 4 in June 2015: 131 vs. 214 uhmos/cm.

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 for this site.

Morgan Cr Site 1 (NC 54), June 2015.

The Morgan Creek 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 2015

Appendix 5A. Carrboro Small Stream Sites, April 2015

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.

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. Pritchard Branch drains the southern part of downtown Chapel Hill.

Pritchard Branch, April 2015

The stream appears both entrenched and widened by erosion. The invertebrate fauna was extremely sparse in 2013, but was more abundant in 2014-2015. Conductivity values were moderately elevated in 2012, 2013 and 2015 (232-264 umhos/cm) at the time of the invertebrate collections. The 2013 collection also has low dissolved oxygen (4.8 mg/l).

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, but the area was stabilized by the time of our 2015 collections.

Mill Race Branch, April 2015

There was little periphyton growth on rocks, and the fauna was very sparse. Conductivity values were moderately elevated (240-265 umhos/cm) in 2012, 2013, and 2015.

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. A slightly lower value was recorded in June 2015 (207 umhos /cm, but this is likely within the range of expected variability.

Old Field Creek, April 2015.

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 and 2015.

Booker Creek (3 sites in the Slate Belt; 2 other Booker Creek sites are listed under the Triassic Section)

Booker Creek, New Parkside Drive (most upstream site). This very small site had a mostly sand substrate, although rubble was present in areas of old construction. The stream appeared to be too small to support a normal stream community. Water chemistry from June 2015 indicated high specific conductance (218 umhos/cm) and low dissolved oxygen (3.3 mg/l)

Booker Creek at New Parkside Drive, April 2015

Booker Creek 1 (Above MLK Blvd). Booker Creek had higher flows in 2014 and 2015 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 and 2015.

Booker Creek Site 1 (MLK), April 2015.

Booker Creek, Piney Mountain Road. This is a new site, although there is historic data from DWR collections. It had been give evaluated as either Fair or Not Rated, with EPT taxa richness of 8-10 in spring collections. This is a rocky site with good habitat, very similar to Bolin Creek upstream in Carrboro.

Booker Creek, Piney Mountain Rd, April 2015.

Crow Branch, MLK Blvd. Crow Branch is a small tributary of Booker Creek. In June 2015, this site had low dissolved oxygen (4.0 mg/l) and high specific conductance (248 umhos/cm). Baased on the fauna, this site is not big enough to support a normal stream fauna.

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.

Cole Springs Branch, April 2015

In 2011, the stream was mostly boulder and rubble with little sand and gravel. In later collections, however, there had been inputs of sand, with sand deposition in areas of lower gradient.

Specific conductance (umhos/cm) increased at this site from 193 in 2013 to 261 in 2015 coincident with a negative change in the aquatic fauna.

Stillhouse Branch. This stream drains part of the Botanical Garden property and is expected to have a largely undisturbed catchment. Because of its small size, it may not flow during summer months.

Stillhouse Branch, April 2015

This small stream is in the same area as UT Bolin Creek at Bayberry' another small high-quality stream.

TRANSITION STREAMS

Fan Branch. The stream substrate was mostly sand, although roots, leaves and snags serve as habitat for the macroinvertebrates. Fan Branch is located in a residential area, but has a good buffer zone. The stream was very turbid during the 2015 collection.

Fan Branch, April 2015

Wilson Creek 1 (Upstream at Wave Rd). This is a sandy stream with bank erosion, but prior samples have indicated good water quality. It became more turbid during the 2015 high-flow conditions, and sediment inputs had buried the rubble areas near the road crossing.

Wilson Creek above Wave Rd, April 2013

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. This site had the lowest conductivity (89 umhos/cm) of all sited monitored by the town in June 2015.

Wilson Creek 2 (downstream), April 2015.

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

Booker Creek – 2 sites (3 sites are also listed in the Slate Belt Section). Both of these sites had low dissolved oxygen concentrations (4.2-4.8 mg/l) in June 2015. Both sites have little rocky substrate, although there are gravel riffles.

Booker Creek at Tadley Greenway. This portion of Booker Creek appears to have been channelized in the past. Habitat is limited for macroinvertebrates.

Booker Creek at Tadley Greenway, April 2015

Booker Creek at 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, but returned to a low level in June 2015: 4.2 mg/l.

Booker Creek at Willow, April 2015

Although this portion of Booker Creek has been channelized in the past, the stream is slowly restoring a pool-riffle sequence.

Cedar Fork Sites

Cedar Fork was sampled at four locations, all in the Slate Belt ecoregion. Water chemistry samples in June 2015 indicated very low dissolved oxygen at 4 Cedar Fork sites: 1-8-2.5 mg/l.

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. The stream may be too small at this site to support a normal stream community. This site was previously sampled in 2014.

Cedar Fork at Silo, April 2015.

Cedar Fork at Steeplechase. This is a new site, designed help isolate problems in the Cedar Fork catchment. Although the habitat is good, the stream may still be too small for a normal stream community.

Cedar Fork at Steeplechase, April 2015

Cedar Fork (Old Cedar Fork Site 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. This site was previously sampled in 2014.

Cedar Fork at Kenmore, April 2015.