BIOLOGICAL MONITORING OF CHAPEL HILL STREAMS, NORTH CAROLINA

April – July 2017

Bolin Creek at Village Drive, July 2017

Prepared for the Town of Chapel Hill by:

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ATTENTION: PLEASE READ THIS SECTION FIRST

This report provides information on the present status of water quality in Chapel Hill's streams and evaluates any temporal changes in water quality.

This is the second annual report by Eaton Scientific (2016-2017), following five annual reports by Lenat Consulting (2011-2015), on water quality and habitat quality of streams in Chapel Hill, North Carolina. This report includes biological monitoring data on Bolin Creek, Booker Creek, Morgan Creek, and their tributaries. This report, as well as reports from previous years, can be obtained from the Town of Chapel Hill's Biological Monitoring webpage. A companion report also has been prepared for the Town of Carrboro with information on Bolin Creek and Morgan Creek; see the Town of Carrboro's Benthic Monitoring webpage for more information.

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 see with the naked eye. They constitute a large proportion of the aquatic life in streams and serve as indicators 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.

The information provided in the Introduction, Methods and review of Prior Biological Data sections is largely repeated from earlier reports. Additional biological data from sites collected in previous years, but not in 2017, are found in earlier reports, but are also summarized in this report. Flow Data has been updated to include data into 2017.

Sites are described (with photos) in Appendices 4-5. An evaluation of each site is provided in the Results and Discussion section, and a summary of site ratings is provided in the Summary and Conclusions section.

Tables 27-29 (pages 35-38) provide the quickest summary of this study. To understand the summary tables, the reader must understand the terms "Taxa Richness" (especially "EPT Taxa Richness"), "NC Biotic Index" and "Bioclassifications" (see Introduction and Methods). Streams are rated as Excellent, Good, Good-Fair, Fair, or Poor using information on the macroinvertebrate community.

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. The reader will often find some species names used in the discussion, especially concerning *tolerant* or *intolerant* species.

Individuals who have read prior reports may wish to skip to the Results and Discussion and Summary and Conclusions sections.

NOTE: In 2017, NCDWR clarified that the incorrect Biotic Index criteria had been used in previous Town monitoring reports for the Fair/Good-Fair cut off for Qual 4 samples; as a result, some previous ratings have been updated in this report, and the ratings reported here are considered the most current for all past years. Previous reports also included ratings for some sites that were not strictly based on NCDWR 2016, and past ratings for those sites have been corrected as well. Sites affected by these changes are Old Field Creek, Battle Branch, Wilson 1, Wilson 2, and Pritchard Branch.

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INTRODUCTION

Water quality in Chapel Hill was evaluated in April and July of 2017 by sampling benthic macroinvertebrates at 23 sites, including the three long-term sites on Bolin and Morgan Creeks in July. An additional 20 tributary sites were sampled in April, most of which had been sampled previously.

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 for many months, 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 the North Carolina Department of Environment and Natural Resources (2003): Assessment Report - Biological Impairment in the Little Creek Watershed Cape Fear River Basin.

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. Based on 2011 land cover data, approximately 52 percent of the Little Creek catchment is developed (urban), and this percentage has likely increased since that time. The upper three quarters of this area lies in the Carolina Slate Belt, and streams here exhibit the narrow valleys and rocky substrates associated with this geologic zone. Little Creek and the downstream reaches of Booker and Bolin Creek are located in a Triassic basin and exhibit its characteristic broad

floodplains and sandy substrates. Visual assessment suggests that most streams downstream of East Franklin Street were channelized (straightened and dredged) in the past. An OWASA (Orange Water and Sewer Authority) sewer easement follows Booker, Bolin and Little Creeks for much of their length.

Bolin Creek

The headwaters of Bolin Creek are located northwest of the intersection of Homestead Road (SR1777) and Old NC 86 (SR1109), 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. Previous reports include information from some of the smaller tributaries not sampled in 2017, including an unnamed Tributary of Tanyard Branch at Baldwin Park, 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 relatively undeveloped area and drains progressively more urban and developed areas in Carrboro and Chapel Hill as it flows toward 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 Place (formerly University Mall).

In 2017, eight samples were collected in the Bolin Creek watershed. These sites include two sites on the mainstem: above Village Drive and above Franklin Street, plus six more sites on tributaries: Jolly Branch, an unnamed tributary (UT) at Severin Drive, Tanyard Branch (near Carver Street), Mill Race Branch, Cole Springs Branch, and Battle Branch.

Booker Creek

The headwaters of Booker Creek rise southwest of the intersection of Airport Road (NC 86) and Weaver Dairy Road in Chapel Hill. Booker Creek is joined by two named tributaries: Cedar Fork and Crow Branch. The mainstem of Booker Creek has been dammed to create Lake Ellen (surface area of seven acres, built in 1961) and, further downstream, Eastwood Lake (surface area of 47 acres, built in 1937). Unlike Bolin Creek, which drains progressively more developed areas as it flows downstream, most of the Booker Creek watershed is heavily developed.

In 2017, Booker Creek and its tributaries were sampled at seven locations. The mainstem of Booker Creek was sampled in four locations: above MLK Jr. Boulevard (below Aquatics Center Drive), above Piney Mountain Road, above Tadley Greenway, and below Willow Drive. Cedar Fork, a major tributary of Booker Creek, was sampled at Brookview Drive, below Kenmore Road, and a UT to Cedar Fork was sampled south of Brookview Drive. Crow Branch could not be sampled in 2017 due to low flow conditions.

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, a drinking water supply owned by OWASA, with a surface area of about 200 acres. 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, have streambeds largely comprised of sand and gravel. These streams are similar to headwater tributaries of Pokeberry Creek in Chatham County (Lenat, unpublished data). Wilson Creek originates in Chatham County and flows north to Morgan Creek.

In 2017, seven sites were sampled in the Morgan Creek catchment. The largest tributary to Morgan Creek, Wilson Creek, was sampled in four locations: above Wave Road, behind Solar Strata (within the approved Obey Creek Development), above Arlen Park Drive in Southern Village, and a UT with

a mostly undeveloped watershed (within the Obey Creek Development). Pritchard Branch was sampled at Chase Park Apartments, Fan Branch was sampled below Parkview Crescent Drive in Southern Village, and the mainstem of Morgan Creek was sampled at Ashe Place. Additionally, a sample was collected from Morgan Creek much further upstream, at NC 54 in Carrboro, in April 2017.

Upper New Hope Creek Catchment

Many small streams on the eastern side of Chapel Hill flow to New Hope Creek, which flows into the Upper New Hope Arm of Jordan Lake. Those include Old Field Creek in the Eubanks Road vicinity, Dry Creek, partially located behind East Chapel Hill High School, and the stream leading from Clark Lake off Pope Road on the Durham border. A portion of New Hope Creek's watershed is in Durham.

Old Field Creek, a tributary to New Hope Creek, was sampled near its headwaters, accessed via the Chapel Hill Transit property, in 2017, and has been sampled annually since 2011 (except for in 2016).

METHODS

All collection methods are derived from techniques used by the NC Division of Water Resources (Lenat 1988; NCDWR 2016). 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 on the NCDWR Biological Assessment Branch website at: https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/biological-assessment-branch.

Three of NCDWR's collection methods have been used for monitoring water quality in the Chapel Hill/Carrboro watersheds. These methods are intensive "Standard Qualitative" collections, and more rapid "EPT" and "Qual-4" collections. These three methods are briefly described below.

Overview of Sample Methods

Standard Qualitative Method

(Bolin Creek sites 4-5 and Morgan Creek site 2)

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

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

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

EPT Method

Morgan Creek sites

The EPT method is a more rapid collection technique, limited to four samples: one kick, one bank sweep, one 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

Smaller tributary sites

The Qual-4 method uses the same four samples as the EPT method, but all benthic macroinvertebrates are collected. NCDWR 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

The ultimate result of a benthos sample is a bioclassification. Bioclassifications used by NCDWR 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), as species richness is the most direct measure of biological diversity. The term EPTS means the number of EPT taxa collected at a site. 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.

Biotic Index Criteria

To supplement EPT taxa richness criteria, the North Carolina Biotic Index (NCBI, or BI) 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 BI values 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 Table 1 below).

Table 1. Thresholds for determining NC Biotic Index (BI) and EPT Taxa Richness scores using Full Scale (Standard) Method Criteria for Piedmont Streams (NC Division of Water Resources 2016).

Score	NC Biotic Index (BI) Values	EPT Taxa Richness Values
5	<5.14	>33
4.6	5.14-5.18	32-33

Score	NC Biotic Index (BI) Values	EPT Taxa Richness Values
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 (BI) value and EPT taxa richness value in assigning bioclassifications, so the bioclassification score is calculated by adding the BI value and the EPT value and dividing by two. 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, and a drainage area less than or equal to 3.0 square miles) are expected to have lower EPT taxa richness relative to larger streams. NCDWR (formerly NCDWQ) has developed criteria for small piedmont stream based solely on biotic index values:

Table 2. NC Biotic Index (BI) thresholds for determining bioclassifications using Small Stream Criteria (NCDWR 2016).

Bioclass Rating	BI Values
Excellent	<4.31
Good	4.31-5.18
Good-Fair	5.19-5.85
Fair	5.86-6.91
Poor	>6.91

Small Stream Criteria were developed only for perennial streams – streams with water all year. Many of the small streams in Chapel Hill are intermittent and thus they cannot be rated.

NOTE: In 2017, NCDWR clarified that the incorrect Biotic Index criteria had been used in previous Town monitoring reports for the Fair/Good-Fair cut off for Qual 4 samples; as a result, some previous ratings have been updated in this report, and the ratings reported here are considered the most current for all past years. Previous reports also included ratings for some sites that were not strictly based on NCDWR 2016, and past ratings for those sites have been corrected as well. Sites

affected by these changes are Old Field Creek, Battle Branch, Wilson 1, Wilson 2, and Pritchard Branch.

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 has been documented 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

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 for the gage Morgan Creek at NC54 near White Cross using daily flow data from 1999 to 2017.

Table 3 shows mean monthly flow data. 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. Low flows have not been an issue in 2016 and 2017. Monthly mean data is not available past June 2017, but the following graph shows daily flows for January through July 2017 (Figure 1). This combined data suggests adequate winter and spring flows in 2017 in the Carrboro/Chapel Hill area.

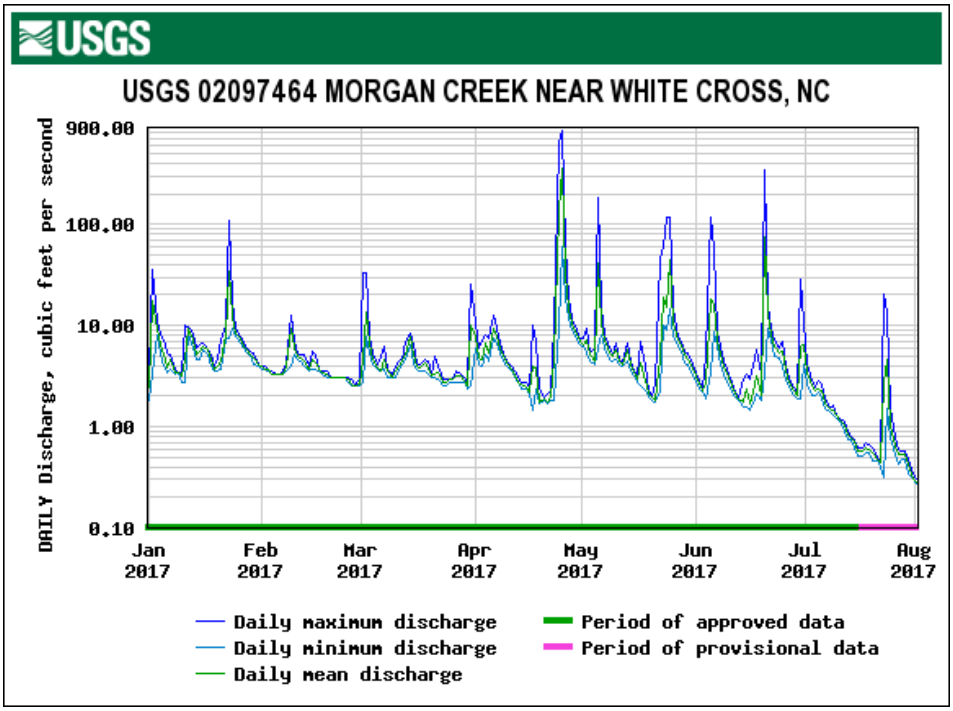
Table 3. Mean Monthly Flow (cfs) in Upper Morgan Creek (similar to Bolin Creek), 1999-2017. Yellow highlighting indicates low flows (<0.5cfs), and red highlighting indicates severely low flows (<0.1cfs).

USGS Streamgage at Morgan Creek near White Cross (drainage area 8.3 square miles)												
	MONTH											
YEAR	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	0.0002	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*

USGS Streamgage at Morgan Creek near White Cross (drainage area 8.3 square miles)												
	MONTH											
YEAR	1	2	3	4	5	6	7	8	9	10	11	12
2014	15	13	21	15	12	0.8	0.3	1.1	0.3	0.6	1.6	4.8
2015	6.7	7.1	14.5	13.5	2.7	1.2	1	0.09	1.2	10	12	44
2016	10	18	14	6.9	6.9	6.3	9	17	2.8	16	1.8	1.5
2017	6.9	3.8	4.4	22	8.3	7.1	**	**	**	**	**	**

**Data may not be complete for these months so the average is not as comparable to other months*
***Data not yet available for July-Dec 2017*

Figure 1. Daily discharge (cfs) at USGS streamgage on Morgan Creek near White Cross, January 2017 to August 2017.



SAMPLING SITES

Evaluations of each sampling site are summarized below (see Site Evaluations), and more detailed site descriptions (with photos) are presented in Appendix 4 and Appendix 5. See Appendix 3 for a map that shows the locations of the sites sampled in 2017.

Table 4 (below) provides data on habitat ratings and substrate composition at all sites sampled in 2017. The habitat rating is based on standard NC Division of Water Resources 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.

Table 4. Site characteristics of Chapel Hill, North Carolina streams, April and July 2017.

STREAM/SITE	HABITAT COMPONENT SCORING (Total 0-100)*									Width (m)	SUBSTRATE (%)					COMMENTS
	CM	IH	BS	PV	RH	BSV	LP	RVZW	Total		B	R	Gr	Sa	Si	
Small Streams																
Booker Creek Sites																
Booker Cr 1, abv MLK Jr. Blvd	4	11	12	6	7	5/5	10	4/4	**69**	2	25	35	25	15	0	Downstream from Homestead Park and suburban residential. Good habitat.
Booker Cr abv Piney Mtn Rd	5	11	12	10	14	6/7	10	5/4	**84**	3	30	35	5	20	10	Good habitat. Below Lake Ellen.
Booker Cr abv Tadley Grnwy	3	7	8	8	3	2/1	10	5/5	**52**	5	0	0	10	70	20	Triassic Basin. Sand/gravel. Below Eastwood Lake.
Booker Cr 2, below Willow Dr	3	7	8	8	3	2/7	10	5/5	**58**	4	0	0	10	80	10	Triassic Basin. Sand/gravel, entrenched and widened. Overbank sand deposition starting to restore a more natural channel. Dense commercial development just upstream.
Cedar Fk 1, below Brookview	5	12	12	10	10	6/5	10	4/4	**78**	5	50	30	10	10	0	Houses close to stream in older neighborhood. Lots of bedrock.
UT Cedar Fk 1, S of Brookview Dr	4	10	12	6	10	6/5	7	5/2	**67**	1	25	40	25	10	0	Small stream, but good fauna – five stonefly taxa and crayfish and salamanders abundant in 2017.
Cedar Fk 2, below Kenmore Rd	4	11	12	8	10	6/7	10	4/5	**77**	2	30	40	10	10	10	Good habitat, but poor fauna.
Bolin Creek Sites																
Jolly Branch	5	7	11	8	10	5/5	10	5/5	**71**	1	10	30	30	30	0	Some bank erosion, but largely forested. Good habitat but low flow.
UT Bolin at Severin Dr	3	10	8	10	10	7/2	7	5/0	**62**	2	45	20	10	20	5	Small stream. Boulder/rubble.
Tanyard Branch, near Carver St	4	12	12	6	7	5/7	10	3/4	**70**	5	60	20	10	10	0	Urban. Receiving stream of much of W. Franklin St. stormwater. Heavy filamentous algae in 2017.
Mill Race Branch, Bolinwood Dr	4	11	11	8	10	3/7	10	5/3	**71**	3	10	20	35	35	0	Urban. Sandy, embedded substrate. Fauna sparse. Receiving stream for downtown Chapel Hill stormwater.
Cole Springs Br, near Cedar St	5	10	11	10	16	7/5	10	4/4	**82**	2	30	20	10	40	0	Old residential area, forested riparian zone, good habitat.
Battle Br, near Weaver Rd Grnwy	4	7	3	8	7	5/5	7	5/2	**53**	3	0	0	10	90	0	Sandy transition stream, with severe bank erosion. Receiving stream for UNC campus stormwater.
New Hope Creek Site																
Old Field Creek	4	8	11	8	7	6/7	10	5/2	**68**	3	15	55	20	10	0	Lots of bedrock but with layer of silt. Low flow. Chicken feathers in stream during 2017 site visit.

STREAM/SITE	HABITAT COMPONENT SCORING (Total 0-100)*									Width (m)	SUBSTRATE (%)					COMMENTS
	CM	IH	BS	PV	RH	BSV	LP	RVZW	Total		B	R	Gr	Sa	Si	
Morgan Creek Sites																
Morgan Creek 1, NC 54	4	16	3	4	16	6/7	7	5/5	**73**	8	60	20	5	10	5	Within Carrboro's jurisdiction. Largely rural.
Wilson Cr 1, abv Wave Rd	5	14	8	4	16	6/5	10	5/5	**78**	1	0	0	20	80	0	Sandy transition stream, with less developed catchment.
UT Wilson, Obey Creek Dev	5	16	11	6	16	6/7	10	5/5	**87**	0.8	0	10	30	60	0	Small, relatively undeveloped watershed.
Wilson Cr 1A, Obey Creek Dev	5	12	11	8	7	3/5	10	5/5	**71**	2	0	10	30	55	5	Behind Strata Solar and below potential Obey Creek Development outfalls.
Wilson Cr 2, abv Arlen Park Dr	5	12	8	10	7	3/7	10	3/2	**67**	3	0	0	30	50	20	Big oxbow, lots of sand. High-density development at site, but older development upstream with large lots, mostly forested.
Fan Branch, below Parkview Dr	5	7	3	0	3	3/7	10	5/5	**48**	2	0	0	5	90	5	Urban/suburban (Southern Village), but good buffer zone.
Pritchard Branch, at Chase Apts	5	15	12	6	16	6/7	10	5/0	**82**	1	20	60	10	10	0	Urban. Receiving stream for downtown Chapel Hill stormwater. Rocky substrate, embedded with incised channel.
Large Streams																
Bolin Cr 4, abv Village Dr	4	15	15	6	16	3/7	9	5/2	**82**	8	30	20	20	20	10	Rocky. Downstream from Carrboro.
Bolin Cr 5, abv Franklin St	3	11	11	10	3	6/5	10	1/4	**65**	10	20	10	10	60	Tr	Rocky near Franklin St, but sandy upstream. Heavily developed catchment.
Morgan Cr 2, at Ashe Pl	5	15	12	10	16	7/7	10	5/4	**91**	7	30	40	20	10	Tr	Older residential neighborhood with good buffer zone. Rocky substrate in riffles, with sand deposition in pools. Flow only in riffles in 2017.

**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 5. Water chemistry data for monitoring sites sampled in April & July 2017.

SITE	Dissolved Oxygen (mg/L)	Conductivity* (µS/cm)	pH	Temperature (degrees C)
SMALL STREAMS (April 2017)				
Booker Creek Sites				
Booker Cr 1, abv MLK Jr. Blvd	7.8	197	7.2	19.2
Booker Cr abv Piney Mtn Rd	8.3	220	7.3	18.4
Booker Cr abv Tadley Grnwy	7.2	160	6.9	19.2
Booker Cr 2, below Willow Dr	4.3	191	6.9	17.5
Cedar Fk 1, below Brookview	7.7	182	6.9	18.3
UT Cedar Fk 1, S of Brookview Dr	6.6	167	7.1	20.2
Cedar Fk 2, below Kenmore Rd	6.9	205	6.3	18.4
Bolin Creek Sites				
Jolly Branch	8.6	248	7.1	20.7
UT Bolin at Severin Dr	8.8	180	6.5	16.5
Tanyard Branch, near Carver St	9.8	364	7	16.2
Mill Race Branch, Bolinwood Dr	8.4	173	7.3	21
Cole Springs Branch, near Cedar St	9.3	271	7.3	18.4
Battle Branch, near Weaver Rd Grnwy	10.1	248	7.2	20.5
New Hope Creek Site				
Old Field Creek	7.6	271	7	18.7
Morgan Creek Sites				
Wilson Cr 1, abv Wave Rd	9.2	126	6.9	14.2
UT Wilson, Obey Creek Dev	9.7	112	6.5	14.3
Wilson Cr 1A, Obey Creek Dev	10.6	123	6.7	15.1
Wilson Cr 2, abv Arlen Park Dr	11.4	124	6.9	17.6
Fan Branch, below Parkview Dr	8.7	134	6.5	20
Pritchard Branch, at Chase Apts	9.7	262	7,0	20.1
LARGE STREAMS (July 2017)				
Bolin Cr 4, abv Village Dr	7.2	128	7.2	24.3
Bolin Cr 5, abv Franklin St	6.5	204	6.9	24.7
Morgan Cr 2, at Ashe Pl	7.7	132	6.9	27.4

**High conductivity values were often associated with urban runoff and impervious surfaces.*

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 Resources (formerly 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 (Table 6) are taken from the Cape Fear River basin report (NCDENR 2003), with more recent NCDWR data from Morgan Creek at NC 54 included as well.

Table 6. NC Division of Water Resources data for Chapel Hill benthic monitoring sites, 1985-2013, including both Standard Qualitative and EPT samples.

SITE NAME	DATE (Month/Year)	TOTAL SPECIES	EPT SPECIES	BI VALUE	BIOCLASS*
Bolin Creek at SR 1777	7/2001	87	24	6.0	Good-Fair
	2/2001	82	17	6.4	Not Rated
	4/2000	-	26	-	Good
	3/1998	-	23	-	Good
	4/1993	-	24	-	Good
Bolin Creek at Village Rd	3/2002	40	7	7.0	Fair (follows Drought)
	7/2001	52	9	6.6	Fair
	2/2001	54	6	7.0	Poor
	2/1998	59	26	5.1	Good
	4/1993	-	24	-	Good-Fair
Bolin Creek, E Franklin St	7/2001	41	4	6.9	Poor
	3/2001	53	4	7.1	Poor
	3/1998	37	13	6.3	Fair
	2/1998	-	4	-	Poor
	2/1993	32	8	6.5	Fair
	4/1986	89	28	6.1	Good-Fair
Booker Creek, Piney Mtn Rd	7/2001	35	4	6.1	Not Rated
	2/2001	39	8	6.3	Not Rated
	3/1998	-	10	-	Fair
Booker Creek, Barbara Ct	7/2001	45	3	6.6	Not Rated
	2/2001	31	4	7.3	Not Rated
Booker Creek, Walnut St	7/2001	31	4	7.3	Not Rated
	2/2001	51	7	6.9	Not Rated
Morgan Creek, NC 54	6/2013	-	19	-	Good-Fair
	3/2009	-	26	-	Good
	3/2008	-	12	-	Not Rated (Drought)
	6/2004	-	18	-	Good-Fair
	10/2003	-	22	-	Good
	7/2003	-	20	-	Good-Fair
	5/2003	-	16	-	Good-Fair

SITE NAME	DATE (Month/Year)	TOTAL SPECIES	EPT SPECIES	BI VALUE	BIOCLASS*
	3/2003	-	12	-	Not Rated (Drought)
	1/2003	-	8	-	Not Rated (Drought)
	9/2002	-	2	-	Not Rated (Drought)
	4/2000	-	36	-	Excellent
	2/1998	80	33	4.4	Excellent
	10/1996	64	22	5.0	Good
	7/1993	61	22	4.9	Good
	2/1993	90	36	4.5	Excellent
	4/1985	109	32	5.7	Good
Morgan Creek near Botanical Garden	3/1998	46	20	6.1	Good-Fair
	4/1993	-	16	-	Fair
	2/1993	26	26	6.0	Good-Fair
Little Creek at Pinehurst Dr	7/2001	27	5	6.8	Not Rated
	3/2001	45	3	7.3	Poor
	2/1993	37	7	7.1	Fair

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

The 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."

NCDWR collections from Morgan Creek at NC54 in 2002 and 2003 were intended to show recovery from the 4-month drought. These data indicate 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

(See Tables 27-29, Appendices 1 and 2A-2C)

Long-term Trends in 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) in Carrboro, and at Estes Drive (#4) in Chapel Hill. 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 water quality 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:

MONTH			
FROM	**TO**	**YEAR**	**NOTES**
September	December	2001	4 months, with lowest flow in Oct-Nov
June	September	2002	4 months, with streams drying up much of this time
June	-	2004	2003-2004 would be expected to be a period of recovery
July	October	2005	4 months, with streams going dry in September
August	-	2006	
July	December	2007	7 months, with streams going dry for 4-6 months
June	September	2008	No streams went completely dry; another period of recovery
July	October	2009	4 months, with severe drought for 2-3 months
June	August	2010	Severe drought in August
August	November	2011	
August	-	2015	

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 ratings 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 2017.

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. Beginning in 2012, tributaries (small streams) are sampled in Spring (April) and the larger streams are sampled in Summer (June/July). Note that Summer 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.

Tables 27, 28 and 29 present a summary of the biological monitoring for Chapel Hill streams for 2017. A list of selected intolerant species is presented in Tables 30 and 31, producing a score (the "Sum" line) that is useful in comparing sites. Species are only included in Tables 30 and 31 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 #16".

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 conditions have improved in the last 4 years (2013-2017). The NCDWR 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 and Morgan Creek site 1 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. In 2016, the results showed a return to 2014 borderline conditions – if one more EPT had been collected, the site would have rated Good-Fair. In 2017, EPT taxa richness and abundance declined to levels not seen since 2013 and was rated Fair. The biotic index stayed stable so this may not be a new trend of declining water quality.

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 2013-2017.

An additional, more subtle, metric is EPTN – the number of individual EPT (intolerant taxa) collected at a site. This metric can give more information than just the EPTS – the number of EPT taxa. For example, if one site had 5 EPT taxa that were all Rare, the EPTN would be 5. If another site had an EPTS of 5, but they were all Abundant, that would give an EPTN of 50. This could be interpreted that the site with EPTN=50 had slightly better water quality than the site with EPTN=5 since more intolerant animals are able to live there.

Table 7. Bolin Creek at Village Drive ("Bolin 4") data from Town of Carrboro, Town of Chapel Hill, and NCDWR, 1993-2017.

DATE	TOTAL SPECIES	EPTS (# OF EPT SPECIES)	BI	EPTN (# OF EPT INDIVIDUALS)	BIOCLASS
7/2017	59	8	6.1	46	Fair
7/2016	63	11	6.1	71	Fair
6/2015	53	12	5.8	69	Good-Fair
6/2014	57	10	6.3	64	Fair
6/2013	33	6	5.9	53	Fair

DATE	TOTAL SPECIES	EPTS (# OF EPT SPECIES)	BI	EPTN (# OF EPT INDIVIDUALS)	BIOCLASS
6/2012	52	8	6.8	48	Fair
3/2011	58	8	6.7	21	Fair
3/2010	42	9	5.8	35	Fair
7/2009	58	10	6.2	73	Good-Fair
12/2008	44	12	5.9	63	Fair
8/2006**	21	6	-	19	Poor?
9/2004**	25	8	-	46	Fair
9/2003**	25	8	-	48	Fair
3/2002*	40	7	7	-	Fair (follows Drought)
7/2001*	52	9	6.6	-	Fair
2/2001*	54	6	7	-	Poor?
9/2000**	45	4	-	26	Poor
2/1998*	59	26	5.1	-	Good
4/1993*	-	24	-	-	Good-Fair

**NCDWR 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 NCDWR collections in 1998 and 2008. In 2012-2017, 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 2012-2016, supported the higher rating. This site is quite sandy upstream of the bridge area, but NCDWR 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. Total Taxa Richness peaked in 2016, possibly due to higher flows providing additional habitat, then fell back to levels that are more normal in 2017. EPT taxa richness in 2014-2015 was the highest since 1998. In 2016, EPTS declined slightly, however, in 2017 most metrics returned to near 2015 levels. Lower water levels in 2017 compared to 2016 likely led to a reduction in microhabitats and a reduction in Total Species (Taxa) in 2017.

Table 8. Bolin Creek above Franklin Street ("Bolin 5") data from NCDWR and Town of Chapel Hill, 1986 to 2017.

DATE	TOTAL SPECIES	EPTS	BI	BIOCLASS
7/2017	37	8	6	Fair
7/2016	62	7	6.4	Fair
6/2015	46	9	5.9	Fair
6/2014	48	8	6.8	Fair
6/2013	34	4	6.2	Fair
6/2012	30	5	6.5	Fair
3/2011	50	4	7.2	Poor
7/2001*	41	4	6.9	Poor
3/2001*	53	4	7.1	Poor
3/1998*	37	13	6.3	Fair
2/1998*	-	4	-	Poor
2/1993*	32	8	6.5	Fair

DATE	TOTAL SPECIES	EPTS	BI	BIOCLASS
4/1986*	89	28	6.1	Good-Fair

**NCDWR data*

Morgan Creek Site 2 at Ashe Place (near the NC Botanical Garden). Prior NCDWR 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 2012-2013 collections also resulted in a Fair bioclassification, but the only abundant intolerant species was *Chimarra*. This site improved to Good-Fair in 2014 – 2017. Although some intolerant taxa have not returned, in 2017 the mayfly *Isonychia* was Abundant here for the first time since 2011.

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

Table 9. Morgan Creek at Ashe Place ("Morgan Creek 2") data from NCDWR and Town of Chapel Hill, 1993 to 2017.

DATE	TOTAL SPECIES	EPTS	BI	BIOCLASS*
7/2017	66	16	5.9	Good-Fair
7/2016	75	17	6.3	Good-Fair
6/2015	-	15 (17*)	-	Good-Fair
6/2014	58	17	6.1	Good-Fair
6/2013	50	9	6.6	Fair
6/2012	39	9	6.3	Fair
3/2011	63	12	6.7	Fair
3/1998**	46	20	6.1	Good-Fair
4/1993**	-	16 (18*)	-	Good-Fair
2/1993**	71	26	6	Good-Fair

**Converted to equivalent full-scale sample*
***NCDWR data*

Small Streams

Many small stream sites have been regularly sampled from 2011 – 2015. Limited sampling in 2016 preceded a busy 2017 (20 small stream sites).

Many sites now have 5-6 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 Streams (Rocky)

Pritchard Branch. Pritchard Branch is a rocky tributary to Morgan Creek in southwestern Chapel Hill. There is residential development in this catchment (especially 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 Branch 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 periphyton community was observed in 2014-17.

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 (2012-2015) clearly indicates improving water quality, although the amount of improvement will be limited by the amount of urban area in the headwaters of this catchment. The community in 2017 declined slightly from 2015, but not enough to drop a bioclassification.

NOTE: In 2017, NCDWR clarified that the incorrect Biotic Index criteria had been used in previous Town monitoring reports for the Fair/Good-Fair cut off for Qual 4 samples; as a result, the bioclass rating of Fair for this site reported in 2015 should have been Good-Fair (G-F) instead. See page 12 above for the correct Small Stream BI criteria thresholds.

Table 10. Pritchard Branch data, 2012-2015 & 2017.

	2012	2013	2014	2015	2017
Total Taxa Richness	19	28	26	22	18
EPT Taxa Richness	3	3	5	5	4
EPT Abundance	3	27	32	26	24
NC Biotic Index	6	6	6.6	5.3	5.85
Overall Rating*	Fair	Fair	Fair	G-F	G-F

**Orange highlighting indicates a change in overall rating from previous reports due to an error in the criteria used to determine the overall rating. Previous reports showed a Fair-Poor rating in 2012-2014 and Fair in 2015, when the rating should have been Fair in 2012-2014 and Good-Fair (G-F) in 2015.*

Fan Branch. In 2017, Fan Branch was sampled for the first time since 2013. Despite having a decidedly suburban watershed, the stream supported many intolerant taxa (*Telaganopsis deficiens, Plauditus dubiatus, Diplectrona modesta, Lepidostoma* and *Elimia*), though *Haploperla brevis* was the only Abundant taxon. The presence of several very tolerant taxa here that were Common or Abundant (*Chironomus, Cricotopus bicintus* and*, Limnodrilus hoffmeisteri*) suggest this watershed may be prone to degradation from its consistently Good-Fair rating with additional development in the watershed. The 2015 Good rating is probably related to favorable flow conditions that year, since an improvement in water quality was noted in several sites that year including Fan Branch and Old Field Creek.

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Table 11. Fan Branch data, 2011-2013, 2015 & 2017.

	2011	2012	2013	2015	2017
Total Taxa Richness	35	37	41	43	47
EPT Taxa Richness	14	11	14	14	13
EPT Abundance	65	46	65	76	37
NC Biotic Index	5.4	5.7	5.2	4.6	5.6
Overall Rating	G-F	G-F	G-F	Good	G-F

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% Cobble. 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 2013-2017. The fauna was very depauperate in 2014, due to scour after heavy rainfall and was further complicated by stream restoration work prior to the 2014 collection,

which caused a short-term increase in sedimentation and turbidity. Since that time, the EPT taxa richness has increased, and in 2017, the biotic index improved to give the site a Fair rating.

Table 12. Mill Race Branch data, 2011-2015 & 2017.

	2011	2012	2013	2014	2015	2017
Total Taxa Richness	18	20	18	11	19	25
EPT Taxa Richness	3	3	2	1	3	5
NC Biotic Index	7.7	7.9	7.5	6.8	6.9	6.6
Overall Rating	Poor	Poor	Poor	Poor	Poor	Fair

UT Bolin Creek at Severin Street. In the early part of this decade, this small headwater stream received Good and Excellent ratings. In 2017, the rating dropped to Fair. This is likely due to sampling at the end of Severin Street, which is several dozen meters below the usual sampling reach that had better flow. It is expected that moving the site back to the original reach in future years will return the bioclassification to Good/Excellent.

Table 13. UT of Bolin Creek at Severin Street data, 2011-2013 & 2017.

	2011	2012	2013	2017*
Total Taxa Richness	21	21	24	35
EPT Taxa Richness	9	8	9	9
EPT Abundance	33	41	49	19
NC Biotic Index	5.1	4.2	4.1	6.6
Overall Rating	Good	Excellent	Excellent	Fair

**Sample in 2017 was not collected at the same location as previous samples.*

Tanyard Branch. Tanyard Branch receives stormwater from downtown Chapel Hill through two 48" pipes upstream from this site. This site has consistently been rated Poor from 2011-2017. Heavy filamentous algae growth suggests nutrients are causing low DO problems here.

Table 14. Tanyard Branch data, 2011-2014 & 2017.

	2011	2012	2013	2014	2017
Total Taxa Richness	7	11	13	13	17
EPT Taxa Richness	2	3	2	1	3
EPT Abundance	11	23	13	1	14
NC Biotic index	7.2	7.7	7.4	7.4	7.5
Overall Rating	Poor	Poor	Poor	Poor	Poor

Old Field Creek. Old Field Creek runs north into New Hope Creek. A landfill is located within the Old Field catchment, but there is no current evidence that it is causing problems. The problems in Old Field Creek seem to be more associated with low flow. The macroinvertebrate fauna has produced successively higher ratings over the years: Poor in 2011, Fair in 2012-2014 and Good-Fair in 2015 as several years of normal flows were experienced. The trend ended in 2017 following an extremely low flow August 2016, when the rating returned to Fair.

NOTE: In 2017, NCDWR clarified that the incorrect Biotic Index criteria had been used in previous Town monitoring reports for the Fair/Good-Fair cut off for Qual 4 samples; as a result, the bioclass rating of Good-Fair for this site reported in 2014 should have been Fair instead. See page 12 above for the correct Small Stream BI criteria thresholds.

More constant flow (and better water quality) was indicated by the abundance of *Maccaffertium modestum, Cheumatopsyche, Amphinemura*, and *Perlesta* in 2014-2015, and suggested that this stream supports its designated uses when flowing. In 2017, most of these same taxa were found, but they were rare, suggesting a lack of flow, rather than a decline in water quality is affecting the stream.

Table 15. Old Field Creek data, 2011-2015 & 2017.

	2011	2012	2013	2014	2015	2017
Total Taxa Richness	22	27	33	37	40	46
EPT Taxa Richness	1	4	5	12	11	7
EPT Abundance	1	10	23	54	60	10
NC Biotic Index	7.6	6.5	6.3	6.2	5.7	6.4
Overall Rating*	Poor	Fair	Fair	Fair	G-F	Fair

**Orange highlighting indicates a change in overall rating from previous reports due to an error in the BI criteria threshold that was used to determine the overall rating. Previous reports showed a Good-Fair rating in 2014, when the rating should have been Fair.*

Cedar Fork. Cedar Fork is located in an older residential area with large lots, but the houses are often placed very close to the stream. Cedar Fork (Site 1) was first sampled in 2011 and had abundant growth of filamentous algae in most years, although the abundance of attached algae was reduced by scour in 2014. The macroinvertebrate fauna (*Physa* common-abundant) indicated problems associated with low dissolved oxygen. In 2014, a special study was conducted of Cedar Fork that sampled four (4) sites on mainstem Cedar Fork (Sites 1-4), as well as three (3) unnamed tributaries (UT Sites 1-2/2A). In 2015, an additional mainstem site (Site 3A near Steeplechase Road) was sampled, but that site as well as the most upstream Cedar Fork site (Site 3 near Silo Road) were ultimately determined to be too small to receive a bioclassification, and were dropped from further sampling. Site 4 (Cedar Fork near Scott Lane) was determined to be too small in 2014. The southern (unnamed) tributaries (UT Sites 1-2/2A) support many intolerant species and have had good water quality, and do not contribute to the problems previously observed at the most downstream site (Cedar Fork Site 1). The northern section of Cedar Fork, however, shows problems along the entire length of the stream; a lack of buffer area around most of the stream may contribute to these problems. UT Site 2A (UT Cedar Fork, N of Brookview Drive) could not be sampled in 2017 due to low flow.

In 2017, three Cedar Fork sites were sampled, and are listed below in upstream-downstream order.

UT Cedar Fork, S of Brookview Drive (Site UT 1). This tiny site was previously sampled in 2014. Though there was very little flow, there were five stonefly taxa, the intolerant mayfly *Paraleptophlebia* and the rare caddisfly *Neophylax atlanta*. While the site was given a Good-Fair rating in 2017, the biotic index was only 0.04 - too high to assign a Good rating.

Cedar Fork at Brookview Dr (Site 1). This portion of Cedar Fork, near the lake, had rocky riffles and good riparian zone, with the only break being a sewer easement. The site was given a Good-Fair rating in 2017, up from the Fair rating in 2014.

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 first 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 a Fair rating in 2015, but there were minimal between-year changes in the invertebrate community. In 2017, this site again received a Poor rating.

Table 16. Cedar Fork data for three sites sampled in 2014, 2015, and 2017.

	UT Cedar Fork Site 2 (S of Brookview Dr)		Cedar Fork Site 1 (Brookview Dr)		Cedar Fork Site 2 (Kenmore Rd)		
	2014	2017	2014	2017	2014	2015	2017
Total Taxa Richness	37	33	32	32	19	28	31
EPT Taxa Richness	12	11	8	7	4	4	4
EPT Abundance	62	45	32	45	19	31	15
NC Biotic Index	5.5	5.2	6.5	5.7	7.2	6.9	7.1
Overall Rating*	G-F	G-F	Fair	G-F	Poor	Fair	Poor

**G-F = Good-Fair*

Upper Booker Creek. Two 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 under Lower Booker Creek.

Booker Creek 1 (above MLK Jr. 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 NCDWR 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.

In 2017, the site was moved several hundred yards upstream to an area of easier access and improved habitat. Though it appears that low flow could be a problem in drought years, the intolerant caddisfly, *Chimarra*, was common, and the intolerant snail, *Elimia,* was abundant. The biotic index was over a point lower than has been recorded here previously and the site was rated Good-Fair.

Table 17. Booker Creek above MLK Jr. Boulevard data, 2011-2015 & 2017.

	2011	2012	2013	2014	2015	2017
Total Taxa Richness	20	25	27	28	32	40
EPT Taxa Richness	2	3	3	3	6	4
NC Biotic Index	7.5	6.4	6.3	6.2	6.7	5.6
Overall Rating*	Poor	Fair	Fair	Fair	G-F	G-F

**G-F = Good-Fair*

Booker Creek, above Piney Mountain Road. The NC Division of Water Resources sampled this site in 1998 and 2001. The spring samples (February 2001, March 1998) had produced EPT taxa richness of 8-10. Samples from April 2015 and 2017 produced an EPT taxa richness of 8 and 6, respectively. This was the only Booker Creek site with intolerant stoneflies (*Perlesta*), but several of the EPT found at the upstream MLK site were reduced or absent (*Maccafertium modestum,* and *Chimarra*). The bioclassification dropped from Good-Fair at the MLK site to Fair at the Piney Mountain site in both years, indicating a decline in water quality. In December 2016, an abandoned outlet pipe from Lake Ellen collapsed, releasing large amounts of sediment and dead fish downstream into this reach. The presence of the

freshwater sponge here in 2017 suggests that some of the problems here are related to low dissolved oxygen.

Table 18. Booker Creek above Piney Mountain Road data, 1998, 2001, 2015, & 2017.

	1998*	2001*	2015	2017
Total Taxa Richness	-	39	38	49
EPT Taxa Richness	10	8	8	6
NC Biotic Index	-	6.3	6.7	6.4
Overall Rating	Fair	Not rated	Fair	Fair

**Data reported by NCDWR for Spring 1998 and 2001.*

Cole Springs Branch. Cole Springs Branch is 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 has 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 ornatus/atlanta* 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, Psephenus 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. The bioclassification returned to a Good rating in 2017 largely because the majority of Abundant taxa were intolerant (tolerance value <4), thus bringing down the biotic index below 5 for the first time since 2013.

Table 19. Cole Springs Branch data, 2011-2015 & 2017.

	2011	2012	2013	2014	2015	2017
Total Taxa Richness	29	38	35	35	26	35
EPT Taxa Richness	8	11	10	7	10	9
EPT Abundance	40	43	47	26	25	35
NC Biotic Index	4.6	4.7	4.9	5.8	5.6	4.8
Overall Rating*	Good	Good	Good	G-F	G-F	Good

**G-F = Good-Fair*

*Table 20. Cole Springs Branch selected intolerant taxa data, 2011-2015 & 2017.**

Selected Intolerant taxa	2011	2012	2013	2014	2015	2017
Haploperla brevis	A	A	A	C	C	A
Neophylax oligius	A	A	A	-	R	C
Psephenus herricki	C	A	A	R	C	A

**R=Rare, C=Common, A=Abundant*

Jolly Branch. This site has been consistently rated as Good-Fair, however the stream fauna includes many intolerant species. With EPT taxa richness increasing and the biotic index decreasing, water quality may be improving.

Table 21. Jolly Branch data, 2011-2014 & 2017.

	2011	2012	2013	2014	2017
Total Taxa Richness	33	24	39	37	48
EPT Taxa Richness	8	6	11	10	13
EPT Abundance	46	35	49	39	36
Biotic index	6.2	6.1	5.5	5.4	5.4
Overall Rating*	G-F	G-F	G-F	G-F	G-F

**G-F = Good-Fair*

Transitional Area Streams (Sandy)

Wilson Creek. Over the past five years (with the exception of 2016), Wilson Creek has been monitored every year at two locations: above Wave Road (Site 1), near the Chatham County line, and above Arlen Park Drive (Site 2) in Southern Village. In 2016, two sites within the proposed Obey Creek Development were established and sampled in July: Wilson 1A and UT Wilson. In 2017, these sites were sampled in April.

Wilson 1A (withing the Obey Creek development) is located almost midway between sites Wilson 1 and 2, and near the downstream end of the proposed development. The catchment here is approximately 1.7 mi^2 with a watershed that was 74% forested and 10% developed, based on 2011 land use data. UT Wilson Creek (also within the Obey Creek development) was a sample on the largest tributary in this segment of stream and has a watershed of 0.2 mi^2 (130 acres). UT Wilson Creek is perennial, which is uncommon for streams this small in either the Slate Belt or the Triassic Basin. Since the stream temperature was nearly 3^oC cooler than nearby Wilson Creek, it is possible that the stream is spring fed. The current plan for the Obey Creek development is to preserve this tributary stream and its watershed; land use data from 2011 showed the watershed was 95% forested and <3% developed.

Wilson Creek appears 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). As indicated above, 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.

The upstream site (Wilson 1) has shown a steady decline in taxa richness. The greatest decline was in 2015 (see Table 22), when EPT abundance dropped by over one third (1/3). Despite a mistaken rating of Good in 2015, when it should have been Excellent and is now reported as such, only this year (2017) has the biotic index risen to where it is now 0.03 too high to rate Excellent.

Lower Wilson Creek (Wilson 2) also showed a decline in taxa richness from its peak in 2015 (see Table 22) to levels closer to 2012. While Total and EPT Taxa Richness varied only slightly from 2015 to 2017, the EPT Abundance dropped by nearly 50%, leading to a more tolerant community and increase in the Biotic Index. Use of incorrect biocriteria prior to 2015 led to consistently incorrect bioclassifications, which have been corrected in Table 22 below. Sampling of Wilson Creek 1A and UT Wilson Creek in summer 2016 and spring 2017 confirmed that water quality was high (Good and Excellent, respectively) in this section of the creek.

NOTE: In 2017, NCDWR clarified that incorrect Biotic Index criteria had been used in previous Town monitoring reports for the Fair/ Good-Fair cut off for Qual 4 samples. As a result, the bioclass rating of Wilson 1 in 2015 and has been corrected in Table 22 below. See page 12 above for the correct Small Stream Criteria for BI thresholds. Ratings for Wilson 2 have also been corrected to reflect criteria in NCDWR 2016.

Table 22. Wilson Creek ("Wilson 1" and "Wilson 2") data, 2011, 2012, 2013, 2014, 2015 & 2017.

	Wilson 1				Wilson 2					
	2012	2013	2015*	2017	2011	2012	2013	2014	2015*	2017
Total Taxa Richness	45	50	43	35	45	47	38	41	47	49
EPT Taxa Richness	23	20	17	16	17	19	11	16	22	20
EPT Abundance	103	104	68	63	54	54	17	54	122	63
NC Biotic Index	4.0	4.1	3.8	4.33	6.0	5.3	6.0	5.0	4.3	5.6
Overall Rating**	Excellent	Excellent	Excellent	Good	Fair	G-F	Fair	G-F	Excellent	G-F

**Yellow highlighting indicates a notable decline in EPT Taxa Richness and Abundance in Wilson 1 (upstream) in 2015, and blue highlighting indicates a notable increase in EPT Taxa Richness and Abundance and in Wilson 2 in 2015 (downstream).*

***Orange highlighting indicates a change in overall rating from previous reports due to an error in applying criteria that were used to determine the overall rating. Previous reports showed a Good rating for Wilson 1 in 2015, when the rating should have been Excellent. In previous reports, Wilson 2 rated as G-F in 2011, Good in 2012, G-F in 2013, and Good in 2014; the ratings above reflect corrections to those ratings based on NCDWR 2016. G-F = Good-Fair.*

Table 23. Wilson Creek at Obey Creek Development ("Wilson 1A") and UT to Wilson Creek at Obey Creek Development ("UT Wilson") data, 2016-2017.

	Wilson 1A		UT to Wilson	
	Summer 2016*	Spring 2017	Summer 2016*	Spring 2017
Total Taxa Richness	38	50	35	35
EPT Taxa Richness	12	23	10	18
EPT Abundance	47	109	79	72
NC Biotic Index	5.5	4.5	4.2	3.6
Overall Rating	Good-Fair	Good	Excellent	Excellent

**Small Stream ratings are for collections made in the spring. These samples were collected in the summer, under more stressful conditions. Spring sampling in 2017 yielded increased EPT taxa richness and decreased biotic indices reflecting these less stressful conditions.*

Battle Branch. Battle Branch has instream habitat similar to Wilson Creek, but the fauna indicates much worse water quality. In 2014, conductivity was higher at this site (212-244 µS/cm) than at the Fan Branch and Wilson Creek sites (<140 µS/cm). Salamanders have been abundant in past collections. Battle Branch showed improvement from 2011 to 2012-2013, suggesting higher flows may be the cause of this change.

NOTE: In 2017, NCDWR clarified that incorrect Biotic Index criteria had been used in previous Town monitoring reports for the Fair/ Good-Fair cut off for Qual 4 samples. As a result, the bioclass rating of Good-Fair for this site reported from 2011 to 2014 should have been Fair instead and has been corrected in Table 23 below. See page 12 above for the correct Small Stream Criteria for BI thresholds.

Using the correct NCDWR (2016) BI criteria, this stream has consistently earned a Fair rating. Other instances where this error led to an incorrect bioclassification are Old Field Creek, Wilson Creek 1 and 2, and Pritchard Branch.

Table 24. Battle Branch data, 2011-2014 & 2017.

	2011	2012	2013	2014	2017
Total Taxa Richness	17	33	34	20	39
EPT Taxa Richness	4	6	4	4	5
EPT Abundance	12	17	19	10	9
NC Biotic index	6.7	6.0	6.1	6.4	6.4
Overall Rating*	Fair	Fair	Fair	Fair	Fair

**Orange highlighting indicates a change in overall rating from previous reports due to an error in the BI criteria threshold that was used to determine the overall rating. Previous reports consistently showed a Good-Fair rating in 2011-2014, when the rating should have been Fair. This change does not indicate any change in actual water quality from 2011 to 2017.*

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 in lower Booker Creek.

Lower Booker Creek

These sites are quite different from the rocky sites seen further upstream in Booker Creek. They have clay banks, with a sand and gravel substrate. Both sites had abundant *Chironomus* larvae (a midge), permitting an evaluation of instream toxicity in 2015 (see Toxicity Assessment above).

Booker Creek at Tadley Greenway. This site was sampled for the first time in April 2015. Highly tolerant snails, midges and worms, mostly those genera that indicate low dissolved oxygen and organic loading, dominated: *Physa, Conchapelopia group, Chironomus, Dicrotendipes* and *Limnodrilus.* In 2017, the dominant taxa were similar, except the tolerant midge *Dicrotendipes* was replaced by the tolerant midge *Cricotopus bicinctus*. Town staff identified an unpermitted outdoor swimming pool discharge in 2016 upstream from this site and has since eliminated it. It is hoped that the removal of periodic inputs of toxic chlorine will reduce the dominance of very tolerant taxa at this site. The dominance of such tolerant species produced a very high biotic index value (7.9 in 2015 and 7.7 in 2017) and a Poor rating both years. About 30% of the *Chionomus* larvae in 2015 had deformities, producing a "Toxic Score" (Lenat 1993) of 65 (see Toxicity Assessment above). This clearly indicates some in-stream toxicity, in addition to low dissolved oxygen concentrations. While *Chironomus* were abundant in 2017, there were not enough collected (20-30) to do a deformity assessment.

Table 25. Booker Creek at Tadley Greenway data, 2015 & 2017.

	2015	2017
Total Taxa Richness	35	36
EPT Taxa Richness	4	3
NC Biotic Index	7.9	7.7
Overall Rating	Poor	Poor

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 at this site. This algal growth was much less abundant after 2013. In 2017, a petroleum sheen was observed at this site.

NCDWR made collections twice at a site near Willow Drive in 2001 (Walnut Street) 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 (see Toxicity Assessment above). Other low-dissolved oxygen indicators (*Physa, Limnodrilus),* however, were rare or absent, suggesting that low dissolved oxygen is less of a problem here than at the Tadley Greenway site. While there were not enough *Chironomus* collected in 2017 to perform a deformity analysis, it does not appear that water quality has improved at this site.

Table 26. Booker Creek at Willow Drive data, 2011-2015 & 2017.

	2011	2012	2013	2014	2015	2017
Total Taxa Richness	31	28	32	30	27	35
EPT Taxa Richness	1	2	2	3	1	3
NC Biotic Index	8.2	8.1	7.6	7.6	7.3	7.7
Overall Rating	Poor	Poor	Poor	Poor	Poor	Poor

SUMMARY AND CONCLUSIONS

Large Streams

Current Status and Short-term Changes. Bolin Creek has always shown 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 usually a decline of one bioclassification between the upstream and downstream sites on Bolin Creek. In 2017, the sample was collected from below a sewer pipe section in an OWASA easement, and in previous years, the sample was from above the pipe. In 2017, however, both sites were solidly rated Fair. Morgan Creek was rated Good upstream (at NC54 in Carrboro) and Good-Fair downstream (in Chapel Hill at Ashe Place), a decline of one bioclassification.

Long-term 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 Resources (formerly the Division of Water Quality), 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. Morgan Creek also shows a slight, consistent decline in water quality from above the Chapel Hill/Carrboro area (Good to Good-Fair) to the site in southern Chapel Hill (Good-Fair to Fair).

Small 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 streams in the Slate Belt ecoregion usually having the most diverse aquatic communities. Many of these streams go dry during summer droughts, but spring sampling (April) has allowed an evaluation of water quality in these small

streams.

Below are brief summaries of small streams grouped by their bioclassification ratings for 2017.

Poor

- *Tanyard Branch.* This stream drains a highly developed urban area, and receives stormwater from much of W. Franklin Street (downtown Chapel Hill). The consistently high conductivity here, even during low flows, suggests an undetected discharge or groundwater contamination in addition to the effects of the stormwater runoff.

- *Booker Creek, Tadley Greenway.* Slow flows and reduced habitat, plus its location below a small lake, combine to create water quality problems at this site. This site is also downstream from dense residential development with little to no stream buffers.

- *Booker Creek, Willow Drive.* This stream drains a highly developed catchment. The fauna suggests organic loading and low dissolved oxygen are problems.

- *Cedar Fork 2, Kenmore Road.* This site, the most upstream site sampled in Cedar Fork, has very sparse fauna, possibly due to low flows.

Fair

- *Pritchard Branch.* Pritchard Branch drains parts of downtown Chapel Hill. Water quality appears to have improved since 2012, and now rates in the Fair/Good-Fair range. In 2017, taxa richness was low and intolerant aquatic insect species were usually rare or absent.

- *Booker Creek, above Piney Mountain Road.* Increased urbanization between this site and MLK Jr. Boulevard upstream is likely the cause of the decline in water quality. This site also experienced increased sediment loading in December 2016 due to the failure of an abandoned outlet pipe in the Lake Ellen dam, causing the lake level to partially drop and drain into this reach of Booker Creek.

- *Mill Race Branch.* This site is within an urban area with poor buffer zones, and this stream receives stormwater from downtown Chapel Hill. Previous years have rated this stream Poor.

- *Old Field Creek.* It is unknown what problems there may be at this site. The Orange County landfill is upstream. This stream may also go dry frequently. The bioclassification for this site was upgraded from Poor in 2011 to Fair in 2012, where it has remained since. (See above for more information on changes in this site's rating from previous reports.)

- *Battle Branch.* This stream drains a residential area, but has a good buffer zone. This site has rated consistently Fair. (See above for more information on changes in this site's rating from previous reports.)

- *UT Bolin Creek, Severin Street.* This small stream, with minimal development in the watershed, was rated Good or Excellent until this year when the sampling location was accidentally moved downstream to an area with less flow.

Good-Fair

- *Wilson Creek 2, Arlen Park Drive.* This site, one of the few perennial tributaries of Morgan Creek, is within a heavily developed area, but with good buffer zones and good upstream water quality. This stream alternated between a Fair and a Good-Fair rating from 2011 to 2014, and in 2017. It was rated Excellent in 2015, though it appears to be sampling error that led to the 40% increase in EPT Taxa Richness and over 100%

increase in EPT Abundance in that year. (See above for more information on changes in this site's rating from previous reports.)

- *Fan Branch.* This stream is in a highly developed area, but with a good buffer zone and many intolerant taxa. This site has consistently rated Good-Fair since it was first sampled in 2011.

- *Jolly Branch.* This stream may be intermittent, but with some highly intolerant species and a good buffer zone. This site has been consistently rated as Good-Fair since 2011.

- *Cedar Fork 1, Brookview Drive.* This site is within a residential area. This stream improved from Fair in 2014 to Good-Fair in 2017.

- *Booker Creek 1, above MLK Jr. Blvd*. This stream drains a developed residential area. The bioclassification for this site was upgraded from Poor in 2011 to Fair in 2012 and 2013, then to Good-Fair in 2015 and continued that rating in 2017. The fauna indicates there may be intermittent flow for this portion of Booker Creek.

Good and Excellent

- *Wilson Creek 1, above Wave Road.* Upper Wilson Creek has been rated as either Excellent (2012-2015) or Good (2017). It has a heavy sediment load, although the source of nonpoint runoff in this catchment is not clear. (See above for more information on changes in this site's rating from previous reports.)

- *UT Wilson Creek, Obey Creek Development.* This appears to be another small stream with good habitat and a good buffer zone; this seems to be where to find high quality streams in this part of the State. It was rated Excellent in both July 2016 and April 2017.

- *Wilson Creek 1A, Obey Creek Development.* This site is located between Wilson 1 and 2, within the currently undeveloped but approved Obey Creek mixed-use development. While sandy, this site still rated Good-Fair when sampled in July 2016, and Good in April 2017.

- *Cole Springs Branch*. This stream drains a residential area with large lots and a good buffer zone. Some upstream activity added sand to the streambed in recent years, but this did not initially affect the aquatic fauna. Two intolerant species virtually disappeared from this stream segment in 2014 and 2015 (*Neophylax ornatus/atlanta* and *Psephenus herricki*), but were Common and Abundant, respectively, in 2017 and the site returned to a rating of Good.

- *UT Cedar Fork 1, South of Brookview Drive.* This is a very small stream, probably with flow problems in dry years, but supported many different stoneflies despite size. Larval salamanders and crayfish were also abundant in 2017. While the site was rated Good-Fair, its BI was only 0.04 short of a Good rating, and the overall community was more like a Good stream than a Good-Fair stream.

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 Town limits. Only two small streams were sampled in 2016 (Wilson Creek 1A and UT Wilson), but in previous years, 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 27. Taxa richness and summary parameters for larger stream sites in Bolin Creek (sites B4 and B5) and Morgan Creek (site M2), Chapel Hill, North Carolina, 2011-2017.

	March 2011			June 2012			June 2013			June 2014			June 2015			July 2016			July 2017		
TAXA SITE:	**B4**	**B5**	**M2**	**B4**	**B5**	**M2**	**B4**	**B5**	**M2**	**B4**	**B5**	**M2**	**B4**	**B5**	**M2**	**B4**	**B5**	**M2**	**B4**	**B5**	**M2**
Ephemeroptera	4	1	7	3	3	6	3	1	3	4	4	9	4	5	8	5	4	8	3	5	7
Plecoptera	1	-	-	1	-	-	-	-	-	1	-	-	1	-	1	1	-	-	1	-	1
Trichoptera	3	3	5	4	2	3	3	3	6	5	4	8	7	4	6	5	3	9	4	3	8
Coleoptera	2	-	6	5	3	3	6	3	4	6	2	4	2	3	-	5	7	7	4	6	6
Odonata	2	6	3	3	5	2	1	4	2	6	5	4	5	6	-	4	5	9	5	5	7
Megaloptera	-	-	1	1	-	-	-	-	1	-	-	-	2	1	-	1	-	-	-	1	-
Diptera; Misc.	8	6	5	2	2	4	4	2	3	4	3	3	4	4	-	3	4	-	3	3	3
Diptera: Chironomidae	22	20	23	19	12	13	9	12	21	19	20	16	15	19	-	25	28	21	10	29	22
Oligochaeta	8	6	3	2	2	1	1	4	2	4	6	3	3	2	-	4	3	4	2	1	2
Crustacea	4	2	3	3	1	3	2	1	3	3	1	3	2	1	-	3	1	1	1	1	1
Mollusca	4	4	5	5	-	3	3	2	4	3	1	3	6	2	-	5	4	6	2	1	4
Other	1	2	2	3	-	1	1	2	1	2	2	3	3	1	-	2	3	3	2	4	4
Total Taxa Richness	59	50	63	51	30	39	33	34	50	57	48	58	53	46	-	63	62	75	37	59	66
EPT Taxa Richness	8	4	12	8	5	9	6	4	9	10	8	17	12	9	17*	11	7	17	8	8	16
EPT Abundance	21	26	74	48	34	67	53	40	42	64	48	97	69	47	75	71	54	80	57	46	85
EPT Score	1.6	1	2	1.6	1	1.6	1.4	1	1.6	2	1.6	2.6	2	1.6	2.6	2	1.4	2.6	1.6	1.6	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	-	6.1	6.4	6.3	6	6.1	5.9
BI Score	2	2	2	2	2.4	3	3	3	2	3	2	3	3.4	3	-	3	3	3	3	3	3
Site Score	1.8	1.5	2	1.8	1.7	2.3	2.2	2	1.8	2.5	1.8	2.8	2.7	2.3	-	2.5	2.2	2.8	2.3	2.3	2.8
Overall Rating**	Fair	Poor	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair/ G-F	Fair	G-F	G-F	Fair	G-F	Fair/ G-F	Fair	G-F	Fair	Fair	G-F

**4-sample EPT collection; EPT taxa richness count has been corrected to the predicted 10-sample value for easy comparison with the other sites.*

***G-F=Good-Fair*

*Table 28. Taxa richness and summary parameters for small Slate Belt streams, Chapel Hill, NC.**

SITE:	Pritchard Br	Mill Race Br	Tanyard Br	Old Field Cr	Cedar Fk 1, Brookview	UT Cedar Fk 1, S of Brookview	Cedar Fk 2, Kenmore	Booker Cr 1, MLK Blvd	Booker Cr, Piney Mtn	Cole Sprgs Br	Jolly Br	UT Bolin Cr, Severin St
TAXA Width (m):	1	3	5	3	5	1	2	2	3	2	1	2
Ephemeroptera	1	1	1	3	2	3	1	1	3	2	6	5
Plecoptera	-	1	-	1	2	5	-	2	-	2	5	1
Trichoptera	3	3	2	3	3	3	3	3	2	5	5	3
Coleoptera	1	-	-	2	2	1	2	5	2	2	4	1
Odonata	1	2	1	4	1	-	3	4	3	2	1	-
Diptera; Misc.	1	3	2	4	3	6	4	3	2	3	6	3
Diptera: Chironomidae	7	11	8	20	17	11	13	17	20	15	18	18
Oligochaeta	1	2	2	3	2	-	-	2	4	1	1	1
Crustacea	1	-	-	2	1	3	1	1	3	1	3	2
Mollusca	2	2	1	3	2	-	4	2	5	1	2	-
Other	-	-	-	1	2	1	-	2	3	1	-	1
2017 Data												
Total Taxa Richness	18	25	17	46	32	33	31	40	49	35	48	35
EPT Taxa Richness	4	5	3	7	7	11	4	4	6	9	13	9
EPT Abundance	24	16	14	10	45	45	15	26	22	35	36	19
NC Biotic Index	5.85	6.6	7.5	6.4	5.7	5.2	7.1	5.6	6.4	4.8	5.4	6.6
Overall Rating	**G-F**	**Fair**	**Poor**	**Fair**	**G-F**	**G-F**	**Poor**	**G-F**	**Fair**	**Good**	**G-F**	**Fair**
2015 Data												
Total Taxa Richness	22	19	NS	40	NS	NS	28	32	38	26	NS	NS
EPT Taxa Richness	5	3	NS	11	NS	NS	4	6	8	10	NS	NS
EPT Abundance	26	17	NS	60	NS	NS	31	46	32	25	NS	NS
NC Biotic Index	5.3	6.9	NS	5.7	NS	NS	6.9	6.7	6.7	5.6	NS	NS
Overall Rating	**G-F**	**Poor**	**NS**	**G-F**	**NS**	**NS**	**Fair**	**G-F**	**Fair**	**G-F**	**NS**	**NS**

SITE:	Pritchard Br	Mill Race Br	Tanyard Br	Old Field Cr	Cedar Fk 1, Brookview	UT Cedar Fk 1, S of Brookview	Cedar Fk 2, Kenmore	Booker Cr 1, MLK Blvd	Booker Cr, Piney Mtn	Cole Sprgs Br	Jolly Br	UT Bolin Cr, Severin St
2014 Data												
Total Taxa Richness	26	11	13	37	32	37	19	28	NS	35	37	NS
EPT Taxa Richness	5	1	1	12	8	12	4	3	NS	7	10	NS
EPT Abundance	27	1	1	54	32	62	19	16	NS	26	39	NS
NC Biotic Index	6.6	6.8	7.4	6.2	6.5	5.5	7.2	6.2	NS	5.8	5.4	NS
Overall Rating	**Fair**	**Poor**	**Poor**	**Fair**	**Fair**	**G-F**	**Poor**	**Fair**	**NS**	**G-F**	**G-F**	**NS**
2013 Data												
Total Taxa Richness	28	18	13	33	29	NS	NS	27	NS	35	39	24
EPT Taxa Richness	3	2	2	5	5	NS	NS	3	NS	10	11	9
EPT Abundance	3	4	13	23	27	NS	NS	21	NS	47	49	49
NC Biotic Index	6	7.5	7.4	6.3	6.9	NS	NS	6.3	NS	4.9	5.5	4.1
Overall Rating	**Fair**	**Poor**	**Poor**	**Fair**	**Fair**	**NS**	**NS**	**Fair**	**NS**	**Good**	**G-F**	**Excellent**
2012 Data												
Total Taxa Richness	19	20	11	27	27	NS	NS	25	NS	38	24	21
EPT Taxa Richness	3	3	3	4	7	NS	NS	3	NS	11	6	8
EPT Abundance	3	6	23	10	29	NS	NS	14	NS	43	35	41
NC Biotic Index	6	7.9	7.7	6.5	6.5	NS	NS	6.4	NS	4.7	6.1	4.2
Overall Rating	**Fair**	**Poor**	**Poor**	**Fair**	**Fair**	**NS**	**NS**	**Fair**	**NS**	**Good**	**G-F**	**Excellent**
2011 Data												
Total Taxa Richness	NS	18	7	22	20	NS	NS	20	NS	29	33	21
EPT Taxa Richness	NS	3	2	1	2	NS	NS	2	NS	8	8	9
EPT Abundance	NS	14	11	1	13	NS	NS	4	NS	40	46	33
NC Biotic Index	NS	7.7	7.2	7.6	7.3	NS	NS	7.5	NS	4.6	6.2	5.1
Overall Rating	**NS**	**Poor**	**Poor**	**Poor**	**F-P**	**NS**	**NS**	**Poor**	**NS**	**Good**	**G-F**	**Good**

**Orange highlighting indicates a change in rating from previous reports. See Results and Discussion section above for each individual site. NS = Not Sampled, G-F = Good-Fair, F-P = Fair-Poor*

*Table 29. Taxa richness and summary parameters for small Triassic and "Transition" streams, Chapel Hill, NC.**

SITE:	Battle Br	Fan Br	Wilson Cr 1, Wave Rd	UT Wilson, Obey Cr Dev	Wilson Cr 1A, Obey Cr Dev	Wilson Cr 2, Arlen Pk Dr	Booker Cr, Tadley Grnwy	Booker Cr 2, Willow Dr
TAXA Width (m):	**3**	**2**	**1**	**0.8**	**2**	**3**	**5**	**4**
Ephemeroptera	1	4	6	3	9	7	1	1
Plecoptera	-	2	5	4	7	5	-	-
Trichoptera	4	7	5	11	7	2	2	2
Coleoptera	2	2	1	5	1	2	1	1
Odonata	2	5	1	2	2	4	2	4
Diptera; Misc.	1	2	3	4	3	5	3	2
Diptera: Chironomidae	24	19	11	3	16	15	17	16
Oligochaeta	4	3	-	1	1	1	4	2
Crustacea	-	2	2	1	1	1	1	2
Mollusca	1	1	1	1	2	1	4	5
Other	-	-	-	-	1	-	1	2
2017 Data								
Total Taxa Richness	39	47	35	35	50	49	36	35
EPT Taxa Richness	5	13	16	18	23	20	3	3
EPT Abundance	9	37	63	72	109	63	3	5
NC Biotic Index	6.4	5.6	4.33	3.6	4.5	5.6	7.9	7.7
Overall Rating	**Fair**	**G-F**	**Good**	**Excellent**	**Good**	**G-F**	**Poor**	**Poor**
2015 Data								
Total Taxa Richness	NS	43	43	NS	NS	47	35	27
EPT Taxa Richness	NS	14	17	NS	NS	22	4	1
EPT Abundance	NS	76	68	NS	NS	122	6	3
NC Biotic Index	NS	4.6	3.8	NS	NS	4.3	7.9	7.3
Overall Rating	**NS**	**Good**	**Excellent**	**NS**	**NS**	**Excellent**	**Poor**	**Poor**

SITE:	Battle Br	Fan Br	Wilson Cr 1, Wave Rd	UT Wilson, Obey Cr Dev	Wilson Cr 1A, Obey Cr Dev	Wilson Cr 2, Arlen Pk Dr	Booker Cr, Tadley Grnwy	Booker Cr 2, Willow Dr
2014 Data								
Total Taxa Richness	20	NS	NS	NS	NS	41	NS	30
EPT Taxa Richness	4	NS	NS	NS	NS	16	NS	3
EPT Abundance	10	NS	NS	NS	NS	54	NS	5
NC Biotic Index	6.4	NS	NS	NS	NS	5.0	NS	7.6
Overall Rating	**Fair**	**NS**	**NS**	**NS**	**NS**	**G-F**	**NS**	**Poor**
2013 Data								
Total Taxa Richness	34	41	50	NS	NS	38	NS	32
EPT Taxa Richness	4	14	20	NS	NS	11	NS	2
EPT Abundance	19	65	104	NS	NS	17	NS	11
NC Biotic Index	6.1	5.2	4.1	NS	NS	6.0	NS	7.6
Overall Rating	**Fair**	**Good**	**Excellent**	**NS**	**NS**	**Fair**	**NS**	**Poor**
2012 Data								
Total Taxa Richness	33	37	45	NS	NS	47	NS	28
EPT Taxa Richness	6	11	23	NS	NS	19	NS	2
EPT Abundance	17	46	103	NS	NS	54	NS	4
NC Biotic Index	6.0	5.7	4.0	NS	NS	5.3	NS	8.1
Overall Rating	**Fair**	**Good**	**Excellent**	**NS**	**NS**	**G-F**	**NS**	**Poor**
2011 Data								
Total Taxa Richness	17	35	NS	NS	NS	45	NS	31
EPT Taxa Richness	4	14	NS	NS	NS	17	NS	1
EPT Abundance	12	65	NS	NS	NS	54	NS	1
NC Biotic Index	6.7	5.4	NS	NS	NS	6.0	NS	8.2
Overall Rating	**Fair**	**Good**	**NS**	**NS**	**NS**	**Fair**	**NS**	**Poor**

**Orange highlighting indicates a change in rating from previous reports. See Results and Discussion section above for each individual site. NS = Not Sampled, G-F = Good-Fair.*

Table 30. Selected intolerant species at larger Chapel Hill streams: Bolin Creek (B4, B5) and Morgan Creek (M1, M2), June 2012-July 2017.

	June 2012				June 2013				June 2014				June 2015				July 2016			July 2017			
Taxon	**B4**	**B5**	**MI**	**M2**	**B4**	**B5**	**MI**	**M2**	**B4**	**B5**	**MI**	**M2**	**B4**	**B5**	**MI**	**M2**	**B4**	**B5**	**M2**	**B4**	**B5**	**M1**	**M2**
Leucrocuta aphrodite	-	-	A	-	-	-	A	-	-	-	A	-	-	-	A	-	-	-	-	-	-	A	-
Isonychia spp	-	-	R	C	-	-	-	-	-	-	A	-	-	-	A	-	-	-	C	-	-	C	A
Aconeuria abnormis	R	-	C	-	-	-	-	-	R	-	C	-	C	-	A	-	C	-	-	R	-	A	R
Perlesta sp	-	-	C	-	-	-	A	-	-	-	C	-	-	-	A	R	-	-	-	-	-	A	-
Chimarra sp	C	A	-	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Neophylax oligius	-	-	-	-	-	-	-	-	-	-	A	R	-	-	A	-	-	-	-	-	-	R	-
Paraleptophlebia sp	-	-	R	-	-	-	C	-	-	-	-	-	-	-	R	-	-	-	-	-	-	R	-
Habrophlebia vibrans	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psephenus herricki	C	-	C	C	A	-	A	R	A	R	A	-	A	R	A	R	A	R	-	A	R	A	-
Elimia sp	-	-	-	-	R	R	-	-	R	-	-	-	A	-	C	-	C	R	-	C	-	C	-
Sum*	7	10	21	9	22	11	46	11	22	11	56	11	33	11	74	12	26	12	13	24	11	58	21

**Rare = 1, Common = 3, and Abundant = 10. Taxa must be Common or Abundant at one or more sites.*

Table 31. Selected intolerant species (Tolerance Value < 3.4) at smaller Chapel Hill streams, July 2017.

Taxon	Booker Cr abv MLK	Booker Cr Piney Mtn	Booker Cr Tadley	Booker Cr Willow Dr	Cedar Fk 2 Kenmore Dr	UT Cedar S Brookview	Cedar Fk 1 Brookview	Jolly Br	UT Bolin at Severin St	Tanyard Br	Mill Race Br	Cole Spgs Br Cedar St	Battle Br	Old Field Cr	Morgan Cr NC 54	Pritchard Br	Fan Br	Wilson Cr 1 Wave Rd	UT Wilson	Wilson Cr 1A at Obey Cr	Wilson Cr 2 Arlen Pk Dr
Acroneuria abnormis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	R	-
Chimarra spp	C	-	-	-	R	-	A	C	-	-	R	C	R	-	A	C	-	-	R	R	R
Diplectrona modesta	-	-	-	-	-	-	-	R	R	-	-	-	R	-	R	R	R	-	C	-	-
Lepidostoma	-	-	-	-	-	-	-	-	-	-	-	R	-	-	C	-	C	R	A	C	R
Neophylax oligius	-	-	-	-	-	-	-	-	-	-	-	C	-	-	R	-	-	-	C	C	-
Dixa sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anchytarsus bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-
Helichus lithophagus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Optioservus ovalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psephenus herricki	-	-	-	-	C	-	A	-	-	-	-	A	R	-	A	-	-	-	R	C	-
Elimia sp	A	-	-	-	-	-	-	-	-	-	-	A	-	-	C	A	R	C	A	C	-
Sum*	**13**	**0**	**0**	**0**	**4**	**0**	**20**	**4**	**1**	**0**	**1**	**27**	**3**	**0**	**38**	**14**	**5**	**6**	**31**	**14**	**2**

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

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Appendix 1. Benthic macroinvertebrates collected from Bolin Creek (B4, B5) and Morgan Creek (M1, M2), Chapel Hill, June 2012-July 2017.*

	June 2012					June 2013					June 2014					June 2015					July 2016				July 2017		
Taxa **Site:**	**B4**	**B5**	**M1**	**M2**		**B4**	**B5**	**M1**	**M2**		**B4**	**B5**	**M1**	**M2**		**B4**	**B5**	**M1**	**M2**		**B4**	**B5**	**M2**		**B4**	**B5**	**M2**
EPHEMEROPTERA																											
Baetis flavistriga (summer)	A	A	-	A		A	A	C	C		A	A	R	A		A	A	C	A		A	A	C		A	A	C
Baetis intercalaris (summer)	-	R	R	A		-	-	-	-		-	R	-	A		-	-	-	C		R	-	A		-	R	A
Baetis pluto	-	-	-	-		-	-	-	-		R	-	A	A		-	-	A	A		R	R	A		-	-	C
Acentrella nadineae	-	-	-	R		-	-	-	-		-	-	-	C		-	-	-	R		-	-	R		-	-	-
Acerpenna pygmea	-	-	-	-		-	-	-	-		-	-	-	-		-	R	-	-		-	-	-		-	-	-
Centroptilum triangulifer	-	-	R	-		-	-	-	-		-	-	R	-		R	-	-	-		-	-	R		-	-	-
Procloeon sp	-	-	-	-		-	-	-	-		-	-	R	R		-	-	-	-		-	-	-		-	-	-
Labiobaetis propinquus	-	-	-	-		-	-	-	-		-	-	C	C		-	R	-	-		-	-	-		-	R	R
Maccaffertium modestum	A	C	A	A		C	-	A	A		A	A	A	A		A	C	A	A		A	A	A		A	A	A
Stenonema femoratum	-	-	C	-		-	-	A	-		-	-	R	-		-	-	R	-		-	-	-		-	-	-
Stenacron interpunctatum	C	-	-	A		A	-	A	C		A	C	A	C		A	R	A	C		A	C	-		C	R	R
Stenacron pallidum	-	-	-	-		-	-	R	-		-	-	-	-		-	-	-	-		-	-	-		-	-	-
Leucrocuta aphrodite	-	-	A	-		-	-	A	-		-	-	A	-		-	-	A	-		-	-	-		-	-	-
Caenis spp	-	-	-	-		-	-	C	-		-	-	-	A		-	-	-	R		-	-	R		-	-	-
Tricorythodes sp	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	R		-	-	-		-	-	-
Isonychia spp	-	-	R	C		-	-	-	-		-	-	A	-		-	-	A	-		-	-	C		-	-	A
Paraleptophlebia sp	-	-	R	-		-	-	C	-		-	-	-	-		-	-	R	-		-	-	-		-	-	-
Habrophlebia vibrans	-	-	-	-		-	-	C	-		-	-	-	-		-	-	-	-		-	-	-		-	-	-
Hexagenia sp	-	-	-	-		-	-	R	-		-	-	-	-		-	-	-	-		-	-	-		-	-	-
PLECOPTERA																											
Acroneuria abnormis	R	-	C	-		-	-	-	-		R	-	C	-		C	-	A	-		C	-	-		R	-	R
Perlesta sp	-	-	C	-		-	-	A	-		-	-	C	-		-	-	A	R		-	-	-		-	-	-
Neoperla sp	-	-	-	-		-	-	-	-		-	-	-	-		-	-	R	-		-	-	-		-	-	-

	June 2012					June 2013					June 2014					June 2015					July 2016				July 2017		
Taxa Site:	**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 2**		**B 4**	**B 5**	**M 2**
Leuctra sp	-	-	-	-		-	-	-	-		-	-	-	-		-	-	R	-		-	-	-		-	-	-
TRICHOPTERA																											
Cheumatopsyche spp	A	A	A	A		A	A	A	A		A	C	A	A		A	A	A	A		A	A	A		A	C	A
Hydropsyche betteni	A	-	-	A		A	A	R	A		A	A	A	A		A	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		A	A	A		A	A	A
Polycentropus sp	-	-	R	-		-	-	-	R		-	-	C	R		-	-	C	R		-	-	C		-	-	C
Phylocentropus sp	-	-	-	-		-	-	-	-		-	-	-	-		R	-	-	R		C	-	-		-	-	-
Hydroptila sp	-	-	-	-		-	-	-	-		R	R	-	R		R	-	R	-		-	-	R		-	-	R
Neophylax oligius	-	-	-	-		-	-	-	-		-	-	A	R		-	-	A	-		-	-	-		-	-	-
Pycnopsyche sp	-	-	-	-		-	-	-	-		-	-	-	-		-	-	R	-		-	-	-		-	-	-
Ceraclea spongillovorax	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-		-	-	-		-	-	R
Ceraclea transversa	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-		-	-	R		-	-	-
Oecetis sp A	R	-	-	-		-	-	-	-		-	-	-	-		-		-	-		-	-	C		-	-	-
Oecetis persimilis	-	-	-	-		-	-	-	-		-	-	-	R		-	-	-	-		-	-	-		-	-	R
Triaenodes ignitus	-	-	-	-		-	-	-	R		R	-	-	C		R	R	-	A		C	-	C		C	-	A
Nectopsyche exquisita	-	-	-	-		-	-	-	-		-	-	-	-		R	-	-	-		-	-	R		-	-	-
COLEOPTERA																											
Anyronyx variegatus	-	-		-		-	-		-		-	-		-		-	-				-	R	R		-	R	-
Microcyllopus pusillis	-	-		-		-	-		-		-	-		-		-	-				-	R	-		-	-	R
Macronychus glabratus	-	R		-		-	-		-		-	-		-		-	R				C	R	C		-	C	C
Dubiraphia sp	R	-		-		R	R		-		R	-		-		-	-				C	R	C		R	R	R
Stenelmis spp	A	C		C		C	A		A		A	A		C		C	C				C	A	A		C	C	C
Ectopria nervosa	-	-		-		-	-		-		-	-		-		-	-				-	-	-		-	R	-
Psephenus herricki	C	-		C		A	-		R		A	R		-		A	R				A	R	-		A	R	-
Helichus spp	R	R		-		R	R		-		R	-		R		-	-				R	-	R		-	-	R
Coptotomus sp	-	-		-		-	-		-		R	-		-		-	-				-	-	-		-	-	-
Neoporus sp	-	-		-		R	-		R		A	-		R		-	-				-	R	R		R	-	R

	June 2012					June 2013					June 2014					June 2015					July 2016				July 2017		
Taxa Site:	**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 2**		**B 4**	**B 5**	**M 2**
Neoporus mellitus gr	-	-		R		R	-		R		-	-		R		-	-				-	-	C		-	-	-
Peltodytes sp	R	-		-		-	-		-		-	-		-		-	-				-	-	-		-	-	-
ODONATA																												
Argia spp	-	C		A		-	A		A		C	A		A		C	A				R	R	A		C	R	C
Calopteryx sp	-	-		-		-	-		-		-	-		-		-	R				R	R	C		C	C	C
Enallagma spp	-	R		-		R	R		-		C	R		-		-	C				-	-	R		-	R	C
Gomphus sp	-	-		-		-	-		-		R	-		-		-	-				-	-	A		-	-	R
Hagenius brevistylus	-	-		-		-	-		-		R	-		-		R	-				-	-	-		R	R	C
Progomphus obscurus	-	R		R		-	-		-		-	-		-		-	-				-	-	R		-	-	-
Stylogomphus albistylus	-	R		-		-	R		-		R	R		-		R	R				R	C	-		-	R	R
Macromia sp	-	-		-		-	-		-		-	-		R		-	-				-	-	-		-	-	-
Libellula sp	R	-		-		-	-		-		-	-		-		-	-				-	-	-		-	-	-
Pachydiplax longipennis	R	-		-		-	-		R		-	-		-		-	-				-	-	-		-	-	-
Perithemis	-	-		-		-	-		-		-	-		-		-	-				-	-	C		-	-	-
Somatochlora sp	R	R		-		-	-		-		C	A		-		R	R				R	C	R		R	-	-
Boyeria vinosa	-	-		-		-	R		-		-	-		C		C	C				-	-	C		C	-	C
Basiaeshna janata	-	-		-		-	-		-		-	C		R		-	-				-	-	R		-	-	-
MEGALOPTERA																												
Sialis sp	R	-		-		-	-		-		-	-		C		R	-				R	-	A		-	-	-
Corydalus cornutus	-	-		-		-	-		C		-	-		C		-	-				-	-	A		-	R	A
DIPTERA: MISC.																												
Antocha spp	-	-		R		R	-		C		-	-		C		-	R				C	R	C		R	C	C
Tipula spp	C	C		C		C	C		A		C	C		-		C	R				A	C	C		C	R	-
Palpomyia complex	-	-		-		-	-		-		-	-		R		-	-				-	R	R		-	-	-
Simulium spp	A	A		A		A	A		A		A	A		A		A	A				A	A	-		C	C	C
Forcipiomyia	-	-		-		-	-		-		-	-		-		-	-				-	-	-		-	-	R
Odontomyia	-	-		-		-	-		-		-	-		-		-	-				-	-	R		-	-	-

	June 2012				June 2013				June 2014				June 2015				July 2016			July 2017		
Taxa Site:	B4	B5	M1	M2	B4	B5	M1	M2	B4	B5	M1	M2	B4	B5	M1	M2	B4	B5	M2	B4	B5	M2
DIPTERA: CHIRONOMIDAE																						
Ablabesmyia janta/parajanta	R	-		-	-	-		R	-	-		-	C	R			-	-	R	-	-	-
Ablabesmyia mallochi	C	R		R	-	-		R	R	C		C	C	A			-	-	C	-	C	C
Conchapelopia group	R	R		C	C	C		A	R	R		C	C	A			-	R	A	C	C	A
Labrundinia pilosella	-	-		-	-	-		R	-	-		-	-	R			-	-	-	-	R	-
Natarsia spp	R	C		-	-	-		R	-	-		R	-	R			-	A	R	-	-	-
Nilotanypus sp	-	R		-	-	R		-	R	-		R	-	-			-	R	R	-	R	R
Procladius sp	C	-		-	-	-		-	-	-		-	-	R			-	-	R	-	-	C
Cardiocladius sp	-	-		-	-	-		R	-	R		C	-	-			-	-	-	-	R	-
Corynoneura spp	-	-		-	-	R		-	R	R		-	-	-			-	A	-	-	-	R
Thienemaniella spp	R	-		R	-	-		R	-	-		R	-	-			-	A	-	-	-	-
Zavrelimyia spp	-	-		-	-	-		-	-	-		-	-	-			-	-	-	-	R	-
Potthastia longimana	-	-		-	-	-		-	-	-		-	-	-			-	-	-	-	-	R
Brillia sp	-	-		-	R	-		R	-	-		-	-	R			-	-	-	-	-	-
Cricotopus annulator	-	-		-	R	-		-	-	-		-	-	-			-	C	-	-	-	-
Cricotopus bicinctus	C	-		R	-	-		-	C	-		-	R	-			-	C	-	R	R	-
Cricotopus cylindraceus	-	-		-	-	-		-	-	-		-	-	-			-	-	-	-	-	-
Cricotopus fugax	-	-		-	-	-		-	-	-		-	-	-			-	R	-	-	-	-
Cricotopus infuscatus	-	-		-	-	-		-	-	-		-	-	-			-	R	-	R	R	-
Cricotopus patens	-	-		-	-	-		-	-	-		-	-	-			-	-	-	-	R	C
Cricotopus triannulatus gr	R	-		-	-	R		-	R	-		R	-	-			-	-	-	-	C	-
Cricotopus vieriens gp	-	-		-	-	-		-	-	-		-	-	-			-	-	-	-	-	-
Eukiefferiella claripennis gr	R	-		-	-	C		-	-	R		-	-	-			-	-	-	-	-	-
Nanocladius spp	-	-		-	-	-		C	-	R		R	-	-			-	-	R	-	-	R
Orthocladiius carlatus	-	-		-	-	-		-	-	-		-	-	-			-	-	-	R	R	R
Orthocladius dorenus	-	-		-	-	-		-	-	-		-	-	-			-	R	-	-	-	-
O. (Eud.) dubitatus	-	R		-	-	-		-	R	-		-	-	-			-	-	-	-	R	R

	June 2012					June 2013					June 2014					June 2015					July 2016				July 2017		
Taxa Site:	**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 2**		**B 4**	**B 5**	**M 2**
Orthocladius robacki	-	-		-		-	-		-		-	-		-		-	-				-	-	-		-	R	-
Pagastiella sp	-	-		-		-	-		-		-	-		-		-	-				-	-	R		-	-	-
Parametriocnemus lundbecki	-	R		-		A	A		C		-	C		-		R	R				-	-	-		-	-	-
Rheocricotopus robacki	-	-		-		-	-		R		-	-		-		-	-				-	-	-		-	R	-
Synorthocladius sp	R	-		-		-	-		-		R	R		R		-	-				-	R	-		-	-	R
Tvetenia bavarica gr	-	-		-		-	C		-		-	-		-		-	-				-	-	-		-	-	-
Xylotopus par	-	-		-		-	-		-		-	-		-		-	-				-	-	-		-	-	-
Chironomus sp	-	-		-		-	-		-		-			R		R	C				-	R	-		-	R	-
Cryptochironomus fulvus	-	R		R		-	-		R		-	C		R		-	R				R	-	C		-	-	C
Cryptotendipes sp	-	-		R		-	-		-		-	R		-		-	-				-	-	-		-	-	-
Dicrotendipes neomodestus	R	-		C		-	-		R		R	C		-		R	-				C	C	C		-	C	C
Endochironomus nigricans	-	-		-		-	-		-		-	-		-		-	-				-	R	-		-	-	-
Microtendipes pedellus	-	-		-		C	C		R		C	C		R		C	C				A	C	A		-	R	R
Paratendipes sp	-	R		-		-	R		R		A	C		-		R	C				R	A	-		-	-	-
Phaenopsectra spp	R	C		-		-	-		R		R	A		-		R	C				C	-	-		-	R	R
Phaenopsectra flavipes gr	R	-		-		-	R		-		R	-		-		-	-				-	-	-		-	-	-
Polypedilum flavum	A	A		A		A	C		A		C	-		A		R	-				C	C	A		C	A	A
Polypedilum illinoense gr	-	-		R		-	C		A		-	A		R		-	R				R	R	-		C	-	R
Polypedilum fallax	-	-		-		-	R		-		-	-		-		-	R				-	-	-		-	-	-
Polypedilum halterale gr	-	C		-		-	-		-		-	-		-		-	-				-	-	-		R	R	R
Polypedilum scalaenum gr	C	-		R		R	-		-		C	A		-		C	C				R	R	R		-	-	-
Polypedilum ontario	-	-		-	-	-	-		-	-	-	-		-	-	-	-				-	-	-		-	-	R
Pseudochironomus sp	-	-		-		-	-		-		-	-		-		R	-				-	-	-		-	-	-
Stenochironomus sp	R	-		-		-	-		R		-	-		-		-	-				-	C	-		-	R	-
Stictochironomus devinctus	-	-		-		-	-		-		-	-		-		-	-				C	-	-		-	-	-
Tribelos sp	C	-		R		R	R		-		C	-		-		A	C				A	A	-		R	C	R
Xenochironomus xenolabis	-	-		-		-	R		-		-	-		R		-	R				-	R	A		-	-	-

	June 2012					June 2013					June 2014					June 2015					July 2016				July 2017		
Taxa Site:	**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 2**		**B 4**	**B 5**	**M 2**
Cladotanytarsus sp	-	-		-		-	-		-		-	R		-		-	-				-	-	C		-	-	-
Rheotanytarsus spp	-	-		R		R	-		C		C	C		C		-	-				R	R	C		C	R	C
Paratanytarsus sp	R	-		-		R	-		-		-	C		-		-	-				R	-	-		-	R	-
Tanytarsus spp	C	R		C		-	C		C		-	A		-		R	C				-	C	A		R	C	R
OLIGOCHAETA																											
Limnodrilus spp	C	A		-		-	-		R		-	R		-		R	R				C	-	R		-	-	-
Ilyodrilus templetoni	-	-		-		-	-		-		-	R		-		-	-				-	-	-		-	-	-
Allonais	-	-		-		-	-		-		-	-		-		-	-				-	R	-		-	-	-
Nais spp	-	-		-		-	R		-		R	C		R		-	-				-	-	R		-	-	-
Stylaria lacustris	-	-		-		-	R		-		-	-		R		R	-				-	-	-		-	-	-
Slavinia appendiculata	-	-		-		-	-		-		R	R		-		-	-				-	-	-		R	-	R
Ecclipidrilus spp	-	-		-		-	-		-		-	-		R		-	C				-	-	-		-	-	-
Lumbriculus variegatus	-	-		-		C	R		-		R	C		-		C	-				A	A	C		A	C	C
Cambarinicolidae	-	-		-		-	-		-		R	R		-		-	-				-	-	-		-	-	-
CRUSTACEA																											
Crangonyx spp	R	-		R		-	-		-		-	-		-		-	-				-	-	-		-	-	-
Hyallela azteca	A	-		R		R	-		A		C	-		C		R	-				R	-	-		-	-	-
Caecidotea sp	C	-		R		R	-		R		R	-		-		-	-				R	C	-		-	-	-
Cambarus spp	-	A		-		-	C		C		C	C		C		C	C				C	-	A		C	R	R
Procambarus acutus	-	-		-		-	-		-		-	-		R		-	-				-	-	-		-	-	-
MOLLUSCA																											
Elimia sp	-	-		-		R	R		-		R	-		-		A	-				C	R	-		C	-	-
Campeloma decisum	R	-		-		-	-		-		-	-		-		-	-				C	-	-		-	-	-
Physa sp	A	-		C		C	-		R		R	C		R		R	R				R	-	R		-	R	-
Stagnicola sp?	R	-		-		-	-		-		-	-		-		-	-				-	-	-		-	-	-
Helisoma anceps	C	-		C		-	-		R		R	-		-		C	-				-	-	R		-	-	-
Menetus dilatus	-	-		-		-	-		-		-	-		-		-	-				C	-	R		-	-	R

	June 2012					June 2013					June 2014					June 2015					July 2016				July 2017		
Taxa **Site:**	**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 1**	**M 2**		**B 4**	**B 5**	**M 2**		**B 4**	**B 5**	**M 2**
Ferrissia sp	-	-		-		R	C		-		-	-		-		R	-				-	R	R		C	-	C
Laevapex fuscus	-	-		-		-	-		R		-	-		C		-	-				-	-	-		-	-	-
Pisidium spp	R	-		-		-	-		-		-	-		-		-	-				-	R	-		-	-	-
Sphaerium	-	-		-		-	-		-		-	-		-		-	-				-	-	A		-	-	C
Corbicula fluminea	A	-		A		-	-		A		-	-		R		-	-				R	R	A		-	-	A
OTHER - TURBELLARIA																											
Dugesia tigrina	R	-		R		-	-		-		-	R		C		-	-				C	R	R		C	R	R
Cura foremanii	-	-		-		A	R		-		C	R		-		A	-				-	-	-		-	-	-
Hydrolimax grisea	-	-		-		-	-		-		-	-		R		-	-				-	-	-		-	-	-
OTHER - HEMIPTERA																											
Aquarius sp	-	-		-		-	-		-		-	-		-		-	-				-	-	-		-	-	R
Corixidae	R	-		-		-	-		-		-	-		-		R	-				-	-	-		-	-	-
Rhagovelia sp	-	-		-		-	-		-		-	-		-		-	-				-	-	-		-	-	R
Ranatra sp	-	-		-		-	-		-		-	-		-		R	-				-	-	-		-	-	-
OTHER - HIRUDINEA																											
Helobdella triserialis	R	-		-		-	-		-		-	-		-		-	-				-	-	-		-	-	-
Placobdella papillfera	-	-		-		-	R		-		-	-		-		-	-				-	R	-		-	-	-
Placobdella parasitica	-	-		-		-	-		-		R	-		-		-	-				-	-	-		-	-	-
OTHER																											
Neuroptera: Climacia	-	-		-		-	-		-		-	-		C		-	-				-	-	-		-	-	-
Prostoma graecens	-	-		-		-	-		-		-	-		-		-	R				-	-	-		-	-	R
Hydracarina	-	-		-		-	-		-		-	-		-		-	-				R	R	-		R	A	C
Porifera	-	-		-		-	-		-		-	-		-		-	-				-	-	-		-	-	C

**R=Rare, C=Common, A=Abundant.*

NOTE: Many Morgan Creek collections are limited to the most intolerant (EPT) groups.

Appendix 2A. Benthic macroinvertebrates collected at small streams in Chapel Hill, April 2017: Booker Creek and Cedar Fork sites.*

Site: / Taxa / Biotic Index Value	Booker Cr abv MLK	Booker Cr Piney Mtn	Booker Cr Tadley Grnwy	Booker Cr Willow	Cedar Fk Kenmore	UT Cedar S Brookview	Cedar Fk Brookview
EPHEMEROPTERA							
Family Baetidae							
Baetis flavistriga (6.8)	-	A	-	-	A	C	A
Family Caenidae							
Caenis spp (6.8)	-	-	-	R	-	-	-
Family Heptageniidae							
Maccaffertium modestum (5.7)	A	R	R	-	-	C	R
Stenacron interpunctatum (6.4)	-	R	-	-	-	-	-
Family Leptophlebiidae							
Paraleptophlebia spp (1.2)	-	-	-	-	-	C	-
PLECOPTERA							
Family Capniidae							
Allocapnia sp (3.3)	-	R	-	-	-	A	-
Family Chloroperlidae							
Haploperla brevis	-	-	-	-	-	A	R
Family Leuctridae							
Leuctra spp	-	-	-	-	-	R	-
Family Nemouridae							
Amphinemoura (3.8)	-	-	-	-	-	C	-
Family Perlidae							
Perlesta spp (2.9)	-	C	-	-	-	A	C
TRICHOPTERA							
Family Hydropsychidae							
Cheumatopsyche spp (6.6)	A	C	R	C	C	R	A
Diplectrona modesta (2.3)	-	-	-	-	-	-	
Hydropsyche betteni (7.9)	-	C	-	-	R	-	A
Family Leptoceridae							
Oecetis persimilis (4.6)	-	-	R	-	-	-	-
Triaenodes ignitus (4.6)	-	-	-	R	-	-	-
Family Limnephilidae							
Ironoquia punctatissima (6.7)	C	-	-	-	-	-	-
Family Philopotamidae							
Chimarra spp (3.3)	C	-	-	-	R	-	A
Family Rhyacophilidae							

Site: / Taxa / Biotic Index Value	Booker Cr abv MLK	Booker Cr Piney Mtn	Booker Cr Tadley Grnwy	Booker Cr Willow	Cedar Fk Kenmore	UT Cedar S Brookview	Cedar Fk Brookview
Rhyacophila glaberrima	-	-	-	-	-	R	-
Family Ueonidae							
Neophylax atlanta	-	-	-	-	-	R	-
MISC DIPTERA							
Family Ceratopogonidae							
Palpomyia complex (5.7)	R	-	-	R	-	R	-
Family Culicidae							
Aedes spp	-	-	R	-	-	-	-
Anopheles spp	-	-	R	-	-	R	-
Culex spp	-	-	-	-	-	A	-
Family Dixidae							
Dixella indiana (4.9)	-	-	-	-	-	R	-
Family Ephydridae							
Ephydra spp	-	-	-	-	R	-	-
Family Simuliidae							
Simulium spp (4.9)	A	A	R		R	R	A
Family Tipulidae							
Limnophila spp	-	-	-	-	-	-	R
Limona spp (9.3)	-	-	-	-	R	-	R
Tipula spp (7.5)	C	C		R	R	R	R
DIPTERA; CHIRONOMIDAE							
Ablabesmyia janta/parahanta (7.4)	-	-	R	-	-	-	-
Ablabesmyia mallochi (7.4)	-	R	-	R	-	-	-
Ablabesmyia peeliensis	-	-	-	R	-	-	-
Chironomus spp (9.3)	-	C	A	C	C	-	-
Corynoneura spp (5.7)	R	R	-	-	-	-	R
Cladotanytarsus viridiventris (4.0)	-	-	-	-	-	-	-
Cricotopus annulator (8.4)	-	R	R	C	-	-	-
Cricotopus bicintus (C/O sp 1) (8.7)	-	C	A	C	R	C	C
Cricotopus cylindracaeus	-	-	-	-	-	R	-
Cryptochironomus fulvus (6.7)	-	-	-	R	-	-	-
Eukiefferiella claripenis (6.2)	-	-	-	-	-	R	-
Microtendipes pedellus (4.6)	-	R	R	-	R	-	-
Nanocladius crassicornis (7.4)	-	-	-	-	-	-	R
Nilotanypus fimbratus (4.9)	R	-	-	-	-	-	-
Orthocladius omumbratus (8.1)	R	-	-	-	-	-	-
Orthocladius robacki (6.4)	R	-	C	R	-	-	-
Orthocladius rubicundus	-	-	-	R	-	-	-
Parametriocnemus spp (3.7)	A	A	-	-	C	C	A
Paratanytarsus spp (8.0)	R	C	C	-	R	-	-

Site: / Taxa / Biotic Index Value	Booker Cr abv MLK	Booker Cr Piney Mtn	Booker Cr Tadley Grnwy	Booker Cr Willow	Cedar Fk Kenmore	UT Cedar S Brookview	Cedar Fk Brookview
Paratendipes albimanus (5.6)	-	R	-	-	-	R	-
Phaenopsectra punctipes gr (7.1)	-	R	C	C	-	-	R
Polypedilum aviceps (3.6)	A	A	-	-	R	A	A
Polypedilum flavum (5.7)	A	-	C	C	-	-	C
Polypedilum halterale (7.4)	-	-	R	R	-	-	-
Polypedilum illinoense (8.7)	C	-	R	A	-	R	R
Potthastia longimana (8.4)	C	R	-	R	-	-	-
Procladius spp (8.8)	-	C	-	-	-	-	-
Psectrotanypus dyari	-	-	C	-	-	-	-
Rheocricotpus robacki (4.7)	C	C	-	-	-	-	C
Rheotanytarsus spp (6.5)	C	A	C	-	R	-	-
Tanytarsus acifer	R	C	-	-	R	-	-
Tanytarsus buckleyi	-	C	-	-	R	-	R
Tanytarsus hastatus (6.6)	-	-	R	-	-	-	-
Tanytarsus sp U (6.6)	R	R	C	R	-	-	-
Thienemaniella spp (6.4)	R	-	-	-	-	R	R
Thienemannimyia group (8.4)	C	A	A	A	A	A	A
Tribelos jacundum (5.7)	-	-	-	R	-	-	-
Tvetenia bavarica (3.6)	C	A	-	-	R	R	C
Zavrelimyia spp (6.1)	-	-	-	-	C	R	-
COLEOPTERA							
Family Dryopidae							
Helichus fastigiatus (4.1)	C	-	-	-	-	-	-
Family Dytiscidae							
Neoporus spp (7.0)	-	R	-	-	-	R	-
Family Elmidae							
Ancyronyx variegatus (6.8)	R	-	-	-	-	-	-
Dubiraphia spp (5.5)	C	-	-	-	-	-	-
Stenelmis spp (5.6)	C	C	C	R	C	-	C
Family Psephenidae							
Ectopria nervosa (4.3)	R	-	-	-	-	-	-
Psephenus herricki (2.3)	-	-	-	-	C	-	A
ODONATA							
Family Aeshnidae							
Boyeria vinosa (5.6)	-	-	-	R	-	-	-
Family Calopterygidae							
Calopteryx spp (7.5)	R	-	-	-	R	-	R
Family Coenagrionidae							
Argia spp (8.3)	C	C	A	A	C	-	-
Enallagma sp (8.5)	-	C	R	R	-	-	-

Site: / Taxa / Biotic Index Value	Booker Cr abv MLK	Booker Cr Piney Mtn	Booker Cr Tadley Grnwy	Booker Cr Willow	Cedar Fk Kenmore	UT Cedar S Brookview	Cedar Fk Brookview
Family Gomphidae							
Gomphus spp (5.9)	C	-	-	-	-	-	-
Progomphus obscurus (8.2)	-	-	-	R	-	-	-
Family Libelluliidae							
Perithemis spp (9.4)	R	R	-	-	C	-	-
OLIGOCHAETA							
Megadrile	-	R	-	-	-	-	-
Family Lumbriculidae (7.0)	R		A	R			
Family Tubificidae							
Branchyura sowerbbyi (8.6)	-	R	-	-	-	-	-
Ilyodrilus templetoni (9.3)	-	R	C	-	-	-	-
Limnodrilus hoffmeisteris (9.4)	-	-	C	-	-	-	-
Nais sp (8.7)	R	-	-	-	-	-	-
Slavina appendiculata (8.4)	-	R	-	-	R	-	-
Specaria josinae	-	-	C		-	-	-
Stylaria lacustris (8.4)	-	-	-	R	-	-	-
CRUSTACEA							
Family Asellidae							
Caecidotea spp (8.4)	-	R	-	-	R	R	-
Family Cambaridae							
immature crayfish (7.5)	C	C	R	R	R	A	C
Family Crangonicidae							
Crangonyx (7.2)	-	R	-	-	-	A	-
Family Hyalidae							
Hyallela azteca (7.2)	-	-	-	R	-	-	-
MOLLUSCA							
Family Ancylidae							
Ferrissia spp	-	-	R	-	-	-	R
Family Lymnaeidae							
Pseudosuccinea columella (7.7)	-	-	-	R	R	-	R
Family Pleuroceridae							
Elimia spp (2.7)	A	-	-	-	-	-	-
Family Physidae							
Physa sp (8.7)	R	A	C	C	R	-	C
Family Planorbidae							
Mentus dilatus (7.6)	-	R	R	A	-	-	R
Family Corbiculidae							
Corbicula fluminea (6.6)	-	R	R	C	-	-	-
Family Sphaeriidae							
Musculium spp	-	R	-	-	-	-	-

Site: / Taxa / Biotic Index Value	Booker Cr abv MLK	Booker Cr Piney Mtn	Booker Cr Tadley Grnwy	Booker Cr Willow	Cedar Fk Kenmore	UT Cedar S Brookview	Cedar Fk Brookview
Sphaerium spp (7.2)	-	C	-	R	-	-	-
OTHER TAXA							
Order Hemiptera							
Ranatra spp	-	R	-	-	-	-	-
Subclass Hirudinea							
Erbopdella/Mooreobdella spp (8.6)	-	-	R	-	-	-	-
Family Hydrachnidae							
Hydracarina spp (5.5)	-	R	-	C	-	-	-
Nematoda	R	-	-	-	-	-	-
Nemertea	R	-	-	-	-	-	-
Phylum Platyhelminthes							
Cura foremani (5.5)	-	-	-	-	-	R	-
Dugesia tigrina (7.1)	-	-	-	R	-	-	-
Phylum Porifera							
Spongilla spp	-	R	-	-	-	-	-

**R = Rare, C = Common, A = Abundant*

Appendix 2B. Benthic macroinvertebrates collected at small streams in Chapel Hill, April 2017: Jolly Branch, UT Bolin near Severin, Tanyard Branch, Mill Race Branch, Cole Springs Branch, Battle Branch, and Old Field Creek sites.*

Site: / Taxa / Biotic Index Value	Jolly Br	UT Bolin near Severin	Tanyard Br	Mill Race Br	Cole Spgs Br	Battle Br	Old Field Cr
EPHEMEROPTERA							
Family Baetidae							
Baetis flavistriga (6.8)	C	C	A	A	A	C	-
Baetis pluto (3.4)	R	R	-	-	-	-	-
Plauditus dubiatus (2.2)	C	-	-	-	-	-	-
Family Caenidae							
Caenis spp (6.8)	-	-	-	-	-	-	R
Family Heptageniidae							
Maccaffertium modestum (5.7)	C	C	-	-	C	-	R
Stenacron interpunctatum (6.4)	-	R	-	-	-	-	R
Stenacron pallidum (2.8)	R	-	-	-	-	-	-
Family Leptophlebiidae							
Paraleptophlebia spp (1.2)	C	R	-	-	-	-	-
PLECOPTERA							
Family Chloroperlidae							
Haploperla brevis	-	-	-	-	A	-	-
Family Nemouridae							
Amphinemoura (3.8)	R	C	-	-	-	-	-
Family Perlidae							
Perlesta spp (2.9)	A	-	-	R	R	-	C
TRICHOPTERA							
Family Hydropsychidae							
Cheumatopsyche spp (6.6)	C	-	C	C	-	C	R
Diplectrona modesta (2.3)	R	R	-	-	R	R	-
Hydropsyche betteni (7.9)	-	C	R	R	-	R	-
Family Lepidostomatidae							
Lepidostoma sp (1.0)	-	-	-	-	R	-	-
Family Leptoceridae							
Triaenodes marginatus	-	-	-	-	-	-	R
Family Philopotamidae							
Chimarra spp (3.3)	C	-	-	R	C	R	-
Family Rhyacophilidae							
Rhyacophila fenestra/ledra (4.6)	R	-	-	-	-	-	R
Rhyacophila glaberrima	-	-	-	-	-	-	-

Site: / Taxa / Biotic Index Value	Jolly Br	UT Bolin near Severin	Tanyard Br	Mill Race Br	Cole Spgs Br	Battle Br	Old Field Cr
Family Ueonidae							
Neophylax atlanta	R	C	-	-	C	-	-
Neophylax oligius (2.4)	-	-	-	-	C	-	-
MISC DIPTERA							
Family Ceratopogonidae							
Palpomyia complex (5.7)	-	R	-	-	-	-	R
Family Culicidae							
Anopheles spp	R	-	-	R	-	-	R
Family Dixidae							
Dixella indiana (4.9)	R	-	-	-	-	-	-
Family Ephydridae							
Ephydra spp	C	-	-	-	-	-	-
Family Empididae	-	-	-	-	-	-	-
Family Simuliidae							
Simulium spp (4.9)	C	R	-	A	A	A	R
Family Psychodidae							
Psychoda spp	-	-	R	R	-	-	-
Family Tipulidae							
Antocha spp (4.4)	R	-	-	-	R	-	-
Tipula spp (7.5)	C	C	R	-	R	-	R
DIPTERA; CHIRONOMIDAE							
Ablabesmyia mallochi (7.4)	C	-	-	-	-	-	C
Ablabesmyia peeliensis	-	-	-	-	-	R	-
Brillia flavifrons (5.7)	-	-	-	R	R	-	-
Chironomus spp (9.3)	-	-	-	-	R	C	-
Corynoneura spp (5.7)	-	C	-	-	R	R	-
Cricotopus annulator (C/O sp 6) (8.4)	-	R	-	R	-	-	-
Cricotopus bicintus (C/O sp 1) (8.7)	C	R	A	R	C	C	C
Cricotopus cylindracaeus	R	-	-	-	-	-	R
Cricotopus infuscatus gr (9.0)	-	-	C	-	-	-	-
Cryptochironomus fulvus (6.7)	-	R	-	-	-	-	-
Dicrotendipes neomodestus (7.9)	-	R	R	-	-	R	R
Eukiefferiella claripenis (6.2)	-	-	A	A	R	-	-
Microtendipes pedellus (4.6)	A	C	-	-	-	R	A
Orthocladius omumbratus (8.1)	-	R	-	-	-	-	-
Orthocladius robacki (6.4)	-	-	C	-	-	C	-
Orthocladius rubicundus	-	-	-	R	-	-	-
Paracladopelma undine	R	-	-	-	R	-	R
Parametriocnemus spp (3.7)	A	C	C	R	A	A	C
Paratanytarsus spp (8.0)	R	A	-	-	-	R	C
Paratendipes albimanus (5.6)	R	-	-	-	C	C	R

Site: / Taxa / Biotic Index Value	Jolly Br	UT Bolin near Severin	Tanyard Br	Mill Race Br	Cole Spgs Br	Battle Br	Old Field Cr
Phaenopsectra punctipes gr (7.1)	-	-	-	R	-	R	-
Phaenopsectra obediens gr (6.5)	-	-	-	-	-	R	-
Polypedilum aviceps (3.6)	C	-	-	-	A	R	-
Polypedilum flavum (5.7)	C	R	-	R	C	C	C
Polypedilum halterale (7.4)	-	-	-	-	-	-	R
Polypedilum illinoense (8.7)	R	R	-	-	-	R	R
Polypedilum tritum	-	-	-	-	-	R	-
Potthastia longimana (8.4)	-	R	R	R	R	C	-
Procladius spp (8.8)	-	-	-	-	-	-	R
Rheocricotpus robacki (4.7)	-	-	-	-	R	-	-
Rheotanytarsus spp (6.5)	-	-	-	-	-	R	-
Stictochironomus devinctus	R	-	-	-	-	-	-
Synorthocladius (4.2)	-	-	-	-	-	-	-
Tanytarsus acifer	R	C	-	-	-	R	C
Tanytarsus buckleyi	R	-	-	-	-	-	R
Tanytarsus sp N	-	R	-	-	-	-	-
Tanytarsus sp U (6.6)	-	-	-	-	-	R	-
Thienemaniella spp (6.4)	-	-	-	R	-	C	R
Thienemannimyia group (8.4)	A	C	R	A	A	C	A
Tribelos jacundum (5.7)	R	R	-	-	-	-	R
Tvetenia bavarica (3.6)	C	C	-	-	C	C	C
Zavrelimyia spp (6.1)	C	R	-	-	-	R	C
COLEOPTERA							
Family Dryopidae							
Helichus fastigiatus (4.1)	R	-	-	-	-	-	C
Family Dytiscidae							
Neoporus spp (7.0)	A	R	-	-	-	-	R
Family Elmidae							
Dubiraphia spp (5.5)	R	-	-	-	-	-	-
Stenelmis spp (5.6)	C	-	-	-	R	C	-
Family Psephenidae							
Psephenus herricki (2.3)	-	-	-	-	A	R	-
ODONATA							
Family Aeshnidae							
Boyeria vinosa (5.6)	-	-	-	-	-	-	R
Family Calopterygidae							
Calopteryx spp (7.5)	R	-	R	R	R	C	C
Family Coenagrionidae							
Argia spp (8.3)	-	-	-	C	-	R	-
Family Cordullidae							
Somatochlora spp (8.9)	-	-	-	-	-	-	R

Site: / Taxa / Biotic Index Value	Jolly Br	UT Bolin near Severin	Tanyard Br	Mill Race Br	Cole Spgs Br	Battle Br	Old Field Cr
Family Gomphidae							
Gomphus spp (5.9)	-	-	-	-	-	-	R
Stylogomphus albistylus (5.0)	-	-	-	-	R	-	-
OLIGOCHAETA							
Family Lumbriculidae (7.0)	R	R		R	C	R	R
Family Tubificidae							
Ilyodrilus templetoni (9.3)	-	-	-	-	-	R	-
Limnodrilus hoffmeisteris (9.4)	-	-	R	-	-	R	-
Nais sp (8.7)	-	-	-	-	-	-	R
Pristinella (7.7)	-	-	-	R	-	R	-
Slavina appendiculata (8.4)	-	-	R	-	-	-	R
CRUSTACEA							
Family Asellidae							
Caecidotea spp (8.4)	C	A	-	-	-	-	C
Family Cambaridae							
Immature crayfish (7.5)	C	-	-	-	R	-	R
Family Crangonicidae							
Crangonyx (7.2)	R	C	-	-	-	-	-
MOLLUSCA							
Family Ancylidae							
Ferrissia spp	C	-	-	-	-	-	-
Family Lymnaeidae							
Pseudosuccinea columella (7.7)	-	-	-	R	-	-	R
Family Pleuroceridae							
Elimia spp (2.7)	-	-	-	-	A	-	-
Family Physidae							
Physa sp (8.7)	R	-	A	A		A	R
Family Planorbidae							
Mentus dilatus (7.6)	-	-	-	-	-	-	R
OTHER TAXA							
Family Hydrachnidae							
Hydracarina spp (5.5)	-	R	-	-	R	-	R

**R = Rare, C = Common, A = Abundant*

Appendix 2C. Benthic macroinvertebrates collected at small streams in Chapel Hill, April 2017: Morgan Creek at NC54, Pritchard Branch, Fan Branch, and Wilson Creek sites.*

Site: / Taxa / Biotic Index Value	Morgan at NC54	Pritchard Br	Fan Br at Parkview Dr	Wilson Cr at Wave Rd	UT Wilson Cr	Wilson Cr at Obey Cr Dev	Wilson Cr abv Arlen Pk Dr
EPHEMEROPTERA							
Family Baetidae							
Acentrella alachua (3.0)	-	-	-	-	-	R	-
Baetis flavistriga (6.8)	A	A	-	-	-	R	R
Baetis pluto (3.4)	A	-	-	A	-	A	R
Heterocloeon amplum (3.6)	R	-	-	-	-	-	-
Plauditus dubiatus (2.2)	-	-	R	A	-	A	C
Family Caenidae							
Caenis spp (6.8)	A	-	-	-	-	-	-
Family Ephemerellidae							
Danella simplex (3.4)	C	-	-	-	-	C	C
Ephemerella dorothea (3.3)	R	-	R	C	C	A	R
Eurylophella verisimilis (3.9)	A	-	-	R	-	C	C
Telagonopsis deficiens (2.6)	-	-	R	R	-	R	-
Family Heptageniidae							
Leucrocuta spp (2.0)	A	-	-	-	-	-	-
Maccaffertium modestum (5.7)	A	-	C	C	R	C	C
Stenacron interpunctatum (6.4)	C	-	-	-	-	-	-
Stenacron pallidum (2.8)	R	-	-	-	-	-	-
Family Isonychiidae							
Isonychia spp (3.6)	C	-	-	-	-	-	-
Family Leptophlebiidae							
Paraleptophlebia spp (1.2)	R	-	-	-	C	-	-
PLECOPTERA							
Family Capniidae							
Allocapnia sp (3.3)	-	-	-	R	A	C	R
Family Chloroperlidae							
Haploperla brevis	-	-	A	A	A	A	A
Family Nemouridae							
Amphinemoura (3.8)	A	-	-	C	A	A	C
Family Perlidae							
Acroneuria abnormis (2.1)	A	-	-	-	-	R	-
Eccoptura xanthines (4.7)	C	-	A	C	-	A	C
Perlesta spp (2.9)	A	-	-	A	C	A	A
Family Perlodidae							

Site: / Taxa / Biotic Index Value	Morgan at NC54	Pritchard Br	Fan Br at Parkview Dr	Wilson Cr at Wave Rd	UT Wilson Cr	Wilson Cr at Obey Cr Dev	Wilson Cr abv Arlen Pk Dr
Isoperla kerchneri (3.2)	C	-	-	-	-	R	-
TRICHOPTERA							
Family Hydropsychidae							
Cheumatopsyche spp (6.6)	R	-	R	C	C	A	A
Diplectrona modesta (2.3)	R	R	R	-	C	-	-
Hydropsyche betteni (7.9)	A	A	R	-	-	C	C
Hydropsyche venularis (5.1)	-	-	-	-	-	-	R
Family Lepidostomatidae							
Lepidostoma sp (1.0)	C	-	C	R	A	C	R
Family Leptoceridae							
Ceraclea ancylus	R	-	-	-	-	-	-
Triaenodes ignitus (4.6)	R	-	R	-	C	-	C
Family Limnephilidae							
Ironoquia punctatissima (6.7)	-	-	C	R	C	-	R
Pycnopsyche gentilis (1.8)	-	-	-	R	R	-	-
Pycnopsyche spp (2.5)	-	-	R	-	R	-	-
Family Philopotamidae							
Chimarra spp (3.3)	A	C	-	-	R	R	R
Dolophilodes spp (1.0)	-	-	-	-	-	R	-
Family Polycentropidae							
Polycentropus spp (3.1)	R	-	-	-	-	-	-
Family Rhyacophilidae							
Rhyacophila carolina (0.4)	-	-	-	-	R	-	-
Rhyacophila fenestra/ledra (4.6)	R	-	-	-	-	-	-
Rhyacophila glaberrima	R	-	-	R	-	-	R
Family Ueonidae							
Neophylax atlanta	-	-	-	-	A	R	-
Neophylax oligius (2.4)	R	-	-	-	C	C	-
MISC DIPTERA							
Family Ceratopogonidae							
Palpomyia complex (5.7)	R	-	-	-	-	C	C
Family Culicidae							
Aedes spp	-	-	-	-	-	-	R
Family Simuliidae							
Simulium spp (4.9)	A	A	R	A	C	A	A
Family Ptychopteridae							
Bitticomorpha sp	-	-	-	R	-	-	-
Family Tipulidae							
Antocha spp (4.4)	-	-	-	-	R	-	-
Hexatoma spp (3.5)	-	-	-	-	-	-	R

Site: / Taxa / Biotic Index Value	Morgan at NC54	Pritchard Br	Fan Br at Parkview Dr	Wilson Cr at Wave Rd	UT Wilson Cr	Wilson Cr at Obey Cr Dev	Wilson Cr abv Arlen Pk Dr
Limnephila spp	-	-	-	-	R	-	-
Polymeda/Ormosa (5.7)	R	-	-	-	-	-	-
Tipula spp (7.5)	-	-	C	C	R	R	R
DIPTERA; CHIRONOMIDAE							
Ablabesmyia peeliensis	R	-	-	-	-	-	-
Brillia flavifrons (5.7)	R	-	C	-	-	C	A
Chironomus spp (9.3)	-	-	C	-	-	-	A
Cladopelma spp	-	-	C	-	-	-	-
Cricotopus annulator (C/O sp 6) (8.4)	R	-	R	-	-	-	-
Cricotopus bicintus (C/O sp 1) (8.7)	R	C	A	R		C	C
Cryptochironomus fulvus (6.7)	R	-	-	-	-	-	-
Lopescladius (1.2)	R	-	-	-	-	-	-
Microtendipes pedellus (4.6)	-	-	R	-	-	-	-
Nilotanypus fimbratus (4.9)	-	-	-	-	-	R	-
Orthocladius carlatus	-	-	-	-	-	R	-
Orthocladius dentifer	-	R	-	-	-	-	-
Orthocladius robacki (6.4)	-	-	C	-	-	-	-
Orthocladius rubicundus	-	-	-	-	-	R	-
Paramerina sp (4.1)	R	-	-	-	-	-	-
Parametriocnemus spp (3.7)	C	C	A	A	R	A	A
Paratanytarsus spp (8.0)	A	-	C	R	-	A	A
Paratendipes albimanus (5.6)	C	-	A	R	-	R	A
Phaenopsectra punctipes gr (7.1)	R	-	R	-	-	-	-
Phaenopsectra obediens gr (6.5)	R	-	C	-	-	-	C
Polypedilum aviceps (3.6)	C	R	A	C	R	A	C
Polypedilum flavum (5.7)	A	-	C	C	-	A	A
Polypedilum illinoense (8.7)	C	-	-	C	-	R	R
Potthastia longimana (8.4)	-	-	R	-	-	-	-
Psectrocladius spp (3.6)	-	-	R	-	-	-	-
Rheocricotpus robacki (4.7)	-	-	-	R	-	C	R
Rheotanytarsus spp (6.5)	-	R	C	-	-	R	-
Tanytarsus acifer	-	-	-	-	-	-	C
Tanytarsus sepp (6.9)	-	-	-	-	-	-	R
Tanytarsus sp U (6.6)	-	R	-	-	-	-	C
Thienemaniella spp (6.4)	-	-	-	R	-	R	-
Thienemannimyia group (8.4)	A	C	A	C	R	R	A
Tribelos jacundum (5.7)	R	-	-	-	-	-	-
Tvetenia bavarica (3.6)	-	-	R	R	-	R	-
COLEOPTERA							
Family Dryopidae							

Site: / Taxa / Biotic Index Value	Morgan at NC54	Pritchard Br	Fan Br at Parkview Dr	Wilson Cr at Wave Rd	UT Wilson Cr	Wilson Cr at Obey Cr Dev	Wilson Cr abv Arlen Pk Dr
Helichus fastigiatus (4.1)	C	-	A	R	A	-	R
Family Dytiscidae							
Neoporus mellitus (3.9)	-	-	-	-	-	-	R
Neoporus spp (7.0)	C	-	-	-	-	-	-
Family Elmidae							
Ancyronyx variegatus (6.8)	-	-	-	-	C	-	-
Dubiraphia spp (5.5)	-	-	-	-	R	-	-
Oulimnius sp (1.2)	R	-	-	-	-	-	-
Stenelmis spp (5.6)	C	-	C	-	R	-	-
Family Psephenidae							
Psephenus herricki (2.3)	A	-	-	-	R	C	-
ODONATA							
Family Aeshnidae							
Boyeria vinosa (5.6)	-	-	R	R	-	R	C
Family Calopterygidae							
Calopteryx spp (7.5)	C	C	C	-	-	R	-
Family Coenagrionidae							
Argia spp (8.3)		-	-	-	-	-	R
Enallagma sp (8.5)	R	-	-	-	-	-	-
Family Corduligastridae							
Cordulegaster spp (5.7)	-	-	C	-	C	-	-
Family Cordullidae							
Somatochlora spp (8.9)	R	-	-	-	-	-	-
Family Gomphidae							
Gomphus spp (5.9)	C	-	R	-	-	-	C
Stylogomphus albistylus (5.0)	-	-	R	-	R	-	R
OLIGOCHAETA							
Megadrile	C	-	-	-	-	-	-
Family Lumbriculidae (7.0)		R	C		R	R	
Family Tubificidae							
Isochaetides curvisetosus (6.8)	-	-	R	-	-	-	-
Limnodrilus hoffmeisteris (9.4)	-	-	C	-	-	-	R
Nais sp (8.7)	R	-	-	-	-	-	-
MEGALOPTERA							
Family Corydalidae							
Nigronia serricornis (4.6)	R	-	-	-	-	-	-
CRUSTACEA							
Family Asellidae							
Caecidotea spp (8.4)	R	-	-	-	-	-	-
Family Cambaridae							

Site: / Taxa / Biotic Index Value	Morgan at NC54	Pritchard Br	Fan Br at Parkview Dr	Wilson Cr at Wave Rd	UT Wilson Cr	Wilson Cr at Obey Cr Dev	Wilson Cr abv Arlen Pk Dr
Immature crayfish (7.5)	-	C	R	C	C	R	R
Family Crangonicidae							
Crangonyx (7.2)	C	-	C	R	-	-	-
MOLLUSCA							
Family Viviparidae							
Campeloma decisum (5.8)	R	-	-	-	-	-	-
Family Pleuroceridae							
Elimia spp (2.7)	C	A	R	C	A	C	-
Family Physidae							
Physa sp (8.7)	R	R	-	-	-	R	R
Family Planorbidae							
Mentus dilatus (7.6)	R	-	-	-	-	-	-
OTHER TAXA							
Family Hydrachnidae							
Hydracarina spp (5.5)	R	-	-	-	-	R	-

**R = Rare, C = Common, A = Abundant*

Appendix 3. Map of benthic macroinvertebrate monitoring sites in Chapel Hill, April and July 2017.

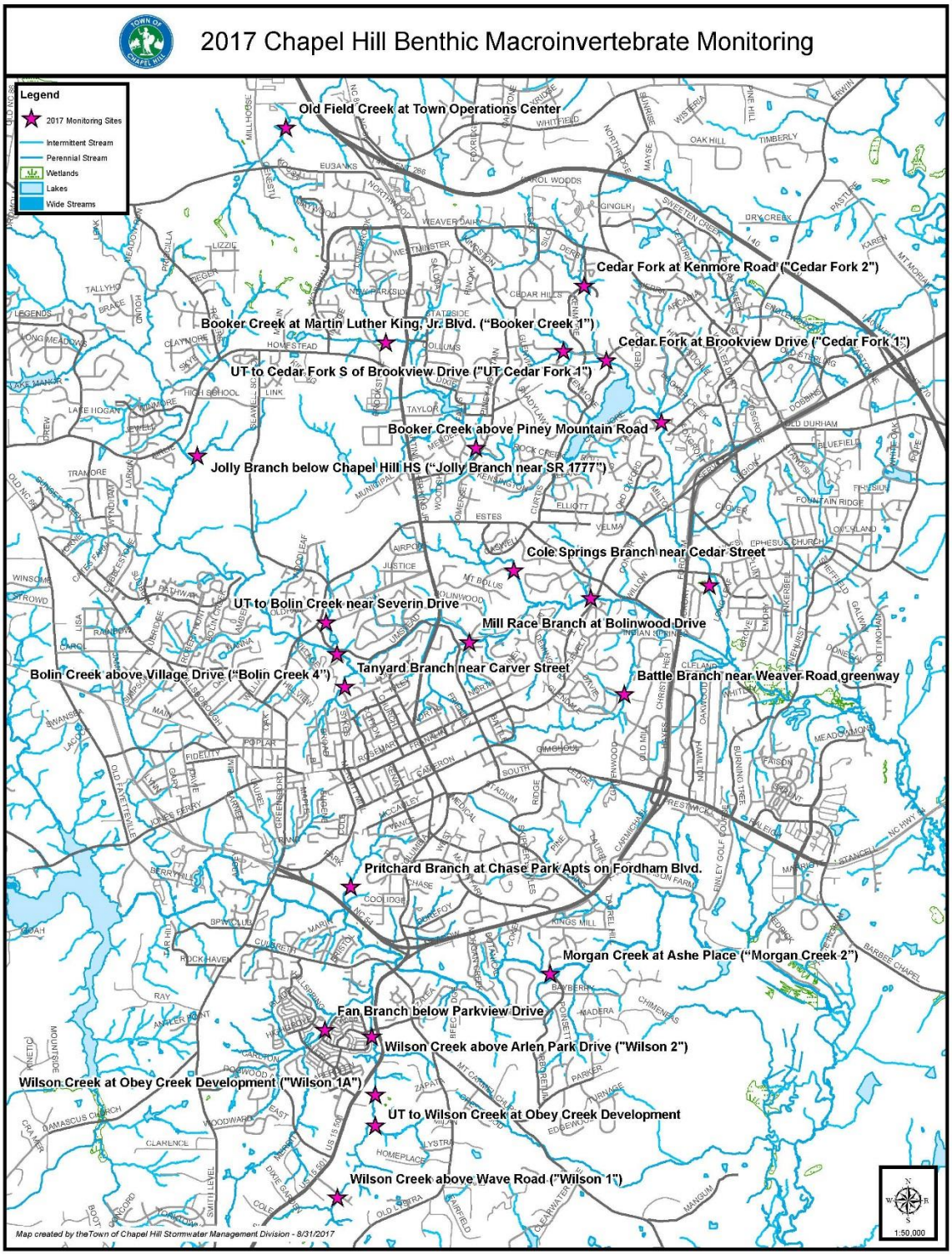

Figure 2. Map of benthic monitoring sites, 2017.

Appendix 4. Chapel Hill Large Stream Sites, July 2017.

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 with Carrboro) 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 sites may have characteristics of both Slate Belt and Triassic Basin ecoregions.

Bolin Creek 4 (Village Drive). This site was moved slightly downstream into Chapel Hill (Village Drive) in 2011 so data from this site could be used by both Towns of Carrboro and Chapel Hill.

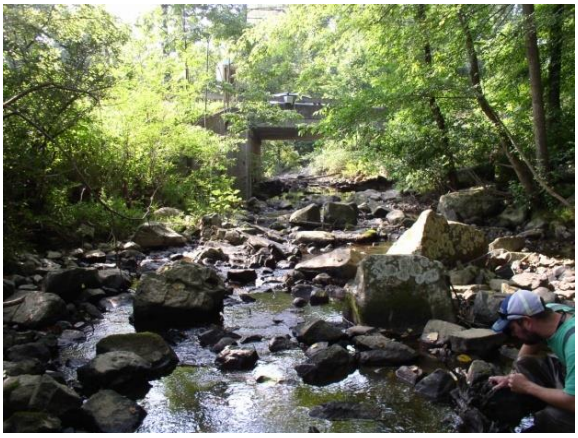

Figure 3. Bolin Creek Site 4, July 2017.

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 2012-2017. Specific conductance for this site in July 2017 (128 µS/cm) was similar to 2016 (139 µS/cm).

Bolin Creek 5 (Franklin St). Bolin Creek has good rocky substrate near the Franklin Street bridge, but the stream bottom is mostly sand further upstream.

Figure 4. Bolin Creek Site 5, July 2017.

A greenway path parallels Bolin Creek in this area. This site drains a heavily developed catchment, including the downtown areas of both Carrboro and Chapel Hill. Specific conductance was much higher at Site 5 than at Site 4 (Village Drive) in July 2017: 128 vs. 204 µS/cm, possibly due to the entry of Tanyard Branch between the two sites. Lower water levels in 2017 compared to 2016 likely led to a reduction in microhabitats and a reduction in Total Taxa in 2017.

Morgan Creek 2 (Ashe Place). This site is located near the NC Botanical Garden and 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. Flows were very low in 2016, only being visible in the riffles, but were better in 2017.

Figure 5. Morgan Creek Site 2 (Ashe Place), July 2017.

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

Figure 6. Morgan Creek Site 1 (NC 54), April 2017.

With an 8 square mile watershed, this site is technically not a small stream in the sense of small stream criteria. It is, however relatively small compared to the Bolin Creek and lower Morgan Creek (large stream) sites. In past years, this site has been sampled using the EPT method, which would be proper for large streams. In 2017, the site was sampled using the Quall 4 method; however the EPT count would be the same, so the samples are comparable.

Prior surveys by the NCDWR generally produced a Good or Excellent bioclassification for this site. Recent collections have produced only Good-Fair ratings.

Appendix 5. Chapel Hill Small Stream Sites, April 2017.

Small streams are grouped into three 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" streams share characters of both geologic zones, 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 streams usually have a boulder-rubble substrate, although the more developed areas have sandy pools and/or embedded riffles. Triassic sites are largely sand and clay, with a very swampy floodplain. The Transition 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.

Figure 7. Pritchard Branch, April 2017.

The stream appears both entrenched and widened by erosion. The invertebrate fauna was sparse in 2017. Conductivity values were moderately elevated in 2017 (262 µS/cm) at the time of the invertebrate collections.

Mill Race Branch. Mill Race Branch is located in a largely residential area, and receives stormwater from downtown Chapel Hill. A portion of this stream is also piped through a parking lot upstream. Mill Race Branch was sampled off Bolinwood Drive, just above its confluence with Bolin Creek. The substrate is largely gravel and sand, but with small rocky riffles areas.

Figure 8. Mill Race Branch, April 2017.

In 2017, there was little periphyton growth on rocks, and the fauna was very sparse. Conductivity values were moderately elevated (274 µS/cm) in 2017.

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

Figure 9. Tanyard Branch, April 2017.

There is a forested riparian zone, but the stream runs through a heavily developed residential area and receives substantial stormwater from W. Franklin Street (downtown Chapel Hill). The stream substrate was rocky, but 40-80% was embedded with sand and was covered by a thick mat of filamentous algae. Conductivity values were highly elevated (364 µS/cm) at the time of the invertebrate collections.

Old Field Creek. Old Field Creek was sampled north of town, near the Chapel Hill Town Operations and Transit Center. The surrounding area is largely forested, but there is some development (including a landfill) further upstream.

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Figure 10. Old Field Creek, April 2017.

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 there was still a small amount of flow when it was sampled in 2017. It was unclear why there were chicken feathers in the stream during the 2017 site visit. Conductivity was moderately elevated (271 µS/cm) at the time of the invertebrate collections in 2017.

Cedar Fork 1, Brookview Drive. Cedar Fork is located in the northern section of Chapel Hill; it is one of the largest tributaries of Booker Creek (4 meters wide). The stream was sampled off Brookview Drive, just above a small lake (Eastwood Lake).

Figure 11. Cedar Fork at Brookview Drive, April 2017.

The surrounding land is an older residential area with large lots. Many of the houses, however, are placed very close to the stream. The substrate was rocky and there was severe bank erosion at bends. Conductivity was measured at 182 µS/cm in 2017.

Unnamed Tributary (UT) 1 to Cedar Fork, South of Brookview Drive. This small (1 meter wide), shallow stream parallels Brookview Drive and is one of two tributaries that enter Cedar Fork between sites 1 and 2. The other tributary was not sampled because it was smaller and had even less flow.

Figure 12. UT Cedar Fork, South of Brookview Drive, April 2017.

The substrate was rocky and supported a large number of crayfish and larval salamanders. The conductivity (167 µS/cm) was less than the mainstem of Cedar Fork.

Cedar Fork 2, below Kenmore Drive. This segment of Cedar Fork had good habitat, with 65% boulder rubble substrate. There was a good buffer zone downstream of Kenmore Drive, but there was more development in the upstream area. The conductivity (205 µS/cm) and the fauna did not indicate good water quality.

Figure 13. Cedar Fork 2, below Kenmore Drive, April 2017.

Booker Creek 1, above MLK Jr. Blvd. This site is located above MLK Jr. Boulevard, downstream from Homestead Park, and is accessed via Northern Park Drive (Aquatics Drive). Booker Creek has a forested buffer next to the stream, but it drains a largely residential area. The substrate is rocky, but flows are low enough that this stream may have intermittent flow in some years.

Figure 14. Booker Creek Site 1 (above MLK), April 2017.

Booker Creek, above Piney Mountain Rd. This site is located above Piney Mountain Road. This is a rocky site with good habitat, very similar to Bolin Creek upstream in Carrboro. Historic data from NCDWR collections have been evaluated as either Fair or Not Rated, with EPT taxa richness of 8-10 in spring collections. Conductivity here was moderate (220 µS/cm).

Figure 15. Booker Creek, above Piney Mountain Road, April 2017.

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 forested. This rocky stream had excellent habitat for aquatic fauna. The stream was mostly boulder and rubble with sand and gravel embedding some riffles. Given the relatively undisturbed watershed, conductivity was high (271 µS/cm) in 2017.

Figure 16. Cole Springs Branch, April 2017.

Jolly Branch near Homestead Road (SR 1777). This site was accessed by walking about 100 meters downstream of SR 1777 (Homestead Road), crossing Bolin Creek, and going about 30 meters upstream on Jolly Branch. This small stream (1 meter wide) had

good rocky habitat, but showed severe bank erosion in many places.

The surrounding area was largely forested, although there are residential areas further upstream, as well as Chapel Hill High School and Smith Middle School. The aquatic life at Jolly Branch indicates that it may stop flowing (or go dry) during drought periods.

Figure 17. Jolly Branch, April 2017.

UT Bolin Creek near Severin Street. This very small stream (1-2 meters wide) was sampled at the end of Severin St, which was downstream of the usual sampling location. It is located in an older residential area with a forested buffer zone adjacent to the stream. The substrate was primarily boulder/rubble, with barely perceptible flow that may be largely subsurface. The fauna was limited, but contained several intolerant species.

Figure 18. UT Bolin Creek near Severin Street, April 2017.

TRANSITION STREAMS

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

Figure 19. Battle Branch, April 2017.

Fan Branch below Parkview Drive. This site is located downstream from Parkview Crescent Drive. The stream channel for Fan Branch was entrenched and substrate composition was 95% sand and gravel. However, there was good bank and leaf pack habitat. The sampling site is within the Southern Village development, but there is a good buffer zone adjacent to the stream.

Figure 20. Fan Branch, April 2017.

Wilson Creek 1, above Wave Road. This site is located upstream from Wave Road. Although it is intended as a control site, upper Wilson Creek is still a very sandy stream with gravel riffles. At the sampling site, there are many open areas adjacent to the stream. Despite the sand, the conductivity was low (126 µS/cm) and the invertebrate community was intolerant.

Figure 21. Wilson Creek 1 (above Wave Road), April 2017.

UT Wilson Creek (Obey Creek Development). UT Wilson Creek was sampled for the first time in July 2016. The sample was collected at the mount of a small (130 acres), undeveloped, catchment upstream from Wilson Creek 1A, which will be preserved as part of the Obey Creek development.

Figure 22. UT Wilson Creek within the Obey Creek development, April 2017.

Although this stream was very small and very sandy (90% gravel, sand and silt), it supported a surprisingly diverse invertebrate community in 2017 and had the lowest conductivity of all sites sampled (111 µS/cm).

Wilson Creek 1A (Obey Creek Development). This site is located behind Strata Solar, within the Obey Creek Development site. This stream was sampled for the first time in 2016. It is a sandy stream with bank erosion, but prior samples upstream and downstream have indicated good water quality. This section of stream appears to carry a heavy sediment load, as evidenced by the half-buried tire.

Figure 23. Wilson Creek within the Obey Creek Development, April 2017.

Wilson Creek 2, above Arlen Park Drive. Wilson Creek was sampled above Arlen Park Drive, in a residential area of the Southern Village development. The upstream area is an older residential area (mostly forest) with large lot sizes. The stream continues its sandy character; however, there is also adequate habitat for invertebrates. This part of Wilson Creek probably has more permanent flow than Wilson Creek 1.

Figure 24. Wilson Creek 2 above Arlen Park Drive, April 2017.

TRIASSIC STREAMS

Booker Creek, above Tadley Greenway.

This site is located just below the confluence of Booker Creek and Cedar Fork and Eastwood Lake. The substrate was primarily sand, silt and clay. While there was very little flow when the stream was sampled, the banks were severely eroded.

Figure 25. Booker Creek above Tadley Greenway, April 2017.

Booker Creek 2, below Willow Drive.

This segment of Booker Creek 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. In 2017, there was a heavy growth of filamentous algae and small patches of a petroleum sheen on the water.

Figure 26. Booker Creek below Willow Drive, April 2017.