Dallas/Fort Worth International Airport Bioassessment Report

(With Changes Accepted)

October 2017

Report Prepared by

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Executive Summary

During July and August 2014, a habitat evaluation and benthic macroinvertebrate bioassessment study designed to assess the potential influence of the Dallas/Fort Worth International (DFW) Airport on receiving waters in its watershed was initiated by the University of North Texas (UNT) Benthic Ecology Laboratory. The study was performed following methods prescribed in the Texas Commission of Environmental Quality (TCEQ) guidelines published in their Surface Water Quality Monitoring Procedures Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue (RG-415) and Volume 2: Methods for Collecting and Analyzing Biological Community and Habitat Data (RG-416). Similar surveys have been performed at DFW in 2004, 2005, and 2008. The purpose of these multi-year monitoring studies is to collect data that can be used to characterize water quality and biological conditions, identify significant long-term trends, and evaluate the effectiveness of DFW programs designed to protect water resources within its watershed. This report summarizes, analyzes, and provides a synthesis of the habitat, land use and benthic macroinvertebrate community results.

The watershed in the vicinity of the DFW Airport is heavily urbanized and industrialized. The airport is only one entity that influences water quality of streams in the area. In order to evaluate the impact of airport activities on the quality of the receiving water, sampling sites outside and within the potential influence of the airport were selected. A total of 13 sampling sites were established (Table 3). Sampling sites (Figure 1) within the airport's watershed but outside the influence of the airport included Little Bear Creek. Other sampling sites within the watershed that are potentially impacted by the airport include Big Bear Creek at Grapevine-Euless Rd bridge, Bear Creek Tributary 14, Bear Creek Tributary 19, Bear Creek downstream of the golf course, Trigg Lake and Trigg Lake Tributary, Bear Creek at County Line Road, Grapeview Creek, and Hackberry Creek. In addition, reference sites outside the DFW airport watershed included, the Elm Fork of the Trinity River, South Bear Creek at Hwy 377 in southeast Parker County, and a pond located at the UNT Water Research Field Station.

Physicochemical parameters were within expected ranges for urban streams in this region (Table 7). All dissolved oxygen (DO) measurements were within the TCEQ's *Texas Surface Water Quality Standards* for a "high" aquatic life use classification ((TCEQ), 2012). Habitat quality index (HQI) classifications calculated from the habitat assessments ranged from "limited," Grapevine Creek, to "high" at Little Bear Creek (urbanized reference site), the Elm Fork of the Trinity River (reference site 1), and South Bear Creek at Hwy 377 (reference site 2) (Table 8). All other streams received a classification of intermediate. Only minor changes were observed in HQI classifications between monitoring years for those sampling sites included in previous surveys. Evaluation of the individual HQI score components indicates any reductions in HQI scores relative to previous years are likely the result of recent drought conditions that have reduced stream flow and in-channel water levels relative to previous years. No evidence from this analysis suggests the minor changes in HQI scores documented in this report are the result of land use practices on DFW property. In general, the habitat quality index classifications calculated in this analysis are comparable to what should be expected for urban prairie streams in this region.

Benthic macroinvertebrate communities at all sites exhibited taxa richness and evenness scores that met or exceeded expectations for this urbanized watershed. Benthic-Index of Biotic Integrity (B-IBI) classifications calculated from the benthic macroinvertebrate samples ranged from "intermediate", at Little Bear Creek (LBA) outside the influence of DFW Airport, to "exceptional" at Bear Creek at County Line Road (BCC), downstream of the Airport and one reference site (Elm Fork of the Trinity River). All other stream sites received a classification of "high" aquatic life use. In comparison to surveys preformed in previous years, most benthic community metrics improved or remained similar. Overall, benthic macroinvertebrate communities present in DFW Airport receiving waters revealed a high aquatic life use, especially considering the urban setting in which these streams reside.

Results from the bioassessments at Trigg Lake and the UNT Water Research Field Station revealed that Trigg Lake is in good ecological health. High dissolved oxygen levels throughout the benthic zone, well established and diverse riparian vegetation, and a comparatively diverse benthic macroinvertebrate community sets this lake apart from the reference site at the Water Research Field Station.

Land use analysis was performed using eCognition Essentials 1.3 software (Trimble 2016) to analyze 5-meter resolution color-infrared RapidEye Satellite digital imagery of the study area. Ancillary information provided by DFW Airport and the North Central Texas Council of Governments (NCTCOG) aided in improving the results. Land use analysis revealed little changes in land use between 2008 and 2014 on DFW Airport Property. Percent impervious surface (a combination of percent transportation land use and buildings land use) increased slightly from 27.2% in 2008 to 29.1% in 2014. The most abundant land use classification within the DFW Airport Property was the Mowed/Grazed/Herbaceous class at 46.1%. Overall, land use results in the study area were as expected in this rapidly growing urban region.

Acknowledgements

Thanks is given to Jeff A. Mabe, Heather A. Perry, Amy E. Scott, Lauren K. Pulliam, Bethany L. Hambrick and Heather Krell who were involved with the initial collection and processing of benthic samples. A special thanks needs to be given to Dr. Bruce Hunter who was the Co-Principal investigator on the first phase of this contract. Bruce retired before the final phase of the project was funded but graciously shared his expertise on processing the satellite imagery. Although too many to acknowledge individually, the assistance provided by undergraduate Bugsters in the Benthic Ecology Lab is greatly appreciated.

Introduction

This report summarizes the results of aquatic habitat surveys and benthic community sampling events that took place on 14 July 2014 and from 4 – 14 August 2014. Sampling was conducted in the watershed upstream, adjacent to and downstream of the Dallas/Fort Worth International (DFW) Airport and at reference sites located outside of the airport watershed. Results included in this report reflect the findings of the first phase of the DFW Airport receiving water bioassessment project, the Habitat Quality Index scores, as well as results from the benthic macroinvertebrate sampling and land use analysis with the goal of developing a full understanding of the condition of DFW Airport's receiving waters.

Bioassessments

Cairns and Pratt (1993) define a bioassessment, or biological assessment, as surveillance of the environment using responses of living organisms to determine whether the environment is able to sustain life. This idea was developed in North America in the early twentieth century (Rosenberg & Resh, 1993). However, the modern practices of bioassessments can be traced to the pioneering work of Ruth Patrick. Together with her team of scientists from the Philadelphia Academy of Natural Sciences, Ruth Patrick conducted a watershed survey with the goal of evaluating if monitoring biological communities within a stream could serve as indicators of stream health. The results of this study was that the integration of diversity of organisms present along with consideration of ecological conditions within a watershed provides long-term information about stresses those communities have experienced (Patrick, 1949, 1950). Whereas water quality measures only collect data from one point in time, biomonitoring provides a picture of the interactions taking place over longer periods. Patrick's research has led to the development of the contemporary Federal and State protocols for assessing ecological health of surface waters.

Many different aquatic plants and animals can be used when monitoring the health of an ecosystem. In stream environments, benthic macroinvertebrates are commonly used for this purpose because of their ubiquitous occurrence, sedentary and long-lived life cycles. Benthic macroinvertebrates are animals without backbones (invertebrates) that inhabit the substrate in aquatic ecosystems. They vary in size, but are generally visible without a microscope at least when they are mature. A more quantitative definition defines macroinvertebrate as those retained by mesh sizes of at least 0.5 mm (Merritt, Cummins, & Berg, 2008). The group is comprised of a diverse array of organisms that include snails, freshwater clams, and aquatic insects. A list of common benthic macroinvertebrates orders can be found in Table 1. The order names found there will be used throughout this report. Benthic macroinvertebrates are relatively easy to collect and identify compared to other taxonomic groups. In addition, a wealth of knowledge pertaining to their responses to anthropogenic perturbations is available (Cairns Jr. & Pratt, 1993; Rosenberg & Resh, 1993; Walsh et al., 2005). The above characteristics contribute to the success of benthic invertebrates as biological sentinels.

Table 1. Common benthic macroinvertebrate orders and associated common names.

Order	Common Name
Ephemeroptera	Mayfly
Odonata	Dragonfly and Damselfly
Plecoptera	Stonefly
Hemiptera	True Bugs (i.e. Water striders, water boatmen, etc.)
Trichoptera	Caddisfly
Coleoptera	Beetle
Diptera	True Fly (Crane fly, Mosquito, etc.)
Diptera: Chironomidae	Non-biting Midge
Amphipoda	Scuds
Bivalvia	Mussels
Gastropoda	Snails
Annelida/Oligochaeta	Aquatic worms

Interpretation of Benthic Macroinvertebrate Populations

A variety of data measures exist to evaluate the ecological condition of an aquatic ecosystem. Common metrics include metrics associated with the taxonomic richness of the populations, their tolerance to stressors, and community ecological characteristics. Taxonomic richness of the population is the number of different organisms, or taxa, present. Diversity considers both the number of individuals (taxa richness) and their relative contribution to the number of individuals among those taxa (evenness). Tolerance values (TV) have been assigned to commonly collected benthic macroinvertebrates. The scores, ranging from 1 to 10, are most often based on an organism's tolerance to low dissolved oxygen and high organic content. A tolerant organism (TV ≥ 8.5) is one that can withstand these conditions with minimal stress. Under these conditions, tolerant organisms will out-compete intolerant organisms (TV ≤ 4) and will be found in disproportionate numbers in benthic populations. A major shortcoming of these classification is they do not normally evaluate an organism tolerance to any other type of pollutant. Therefore, it is important to use caution when considering these values.

Community composition considers the taxa and populations of macroinvertebrates present. Benthic macroinvertebrate communities present in a stream should be similar to those found in streams of similar size and flow in a given geographical region. Communities will become more dissimilar as stressor impacts increase.

The Benthic Index of Biological Integrity (B-IBI) evaluates stream integrity by combining a series of metrics to generate an overall biological integrity score. The resulting score considers community structure, tolerance values, and functional feeding groups (FFG) (Table 2). The results of these evaluations are integrated into a metric that is used to describe a stream's ecological integrity. It is recognized that biological communities reflect conditions such as geology, soil, and meteorological conditions naturally present in their physio geographic region. Metrics used in B-IBI's are often calibrated to different eco-regions by studying the variation of the response in "least impacted streams" available in the area. This study uses the metric criteria for the Central Bioregion published in the TCEQ manual ((TCEQ), 2014).

Table 2. Functional feeding groups (FFG) classification and descriptions.

Classification	Description
Grazers/Scrapers (SCR)	Grazers of attached periphyton; piercers of plant tissues
Filterers (FC)	Collectors of suspended fine particulate organic matter (FPOM)
Gatherers (CG)	Collectors of deposited fine particulate organic matter (FPOM)
Shredders (SHR)	Consume living plant tissues or decomposing coarse particulate organic matter (CPOM)
Predators (P)	Piercers, engulfers, and parasites of living animal tissues

Urban Land Use

It has long been noted that urbanization causes changes to hydrologic regimes within the watershed (Leopold, 1968). More recently, the term "urban stream syndrome" has been coined to describe the symptoms that accompany changes in land use within a stream's watershed typical of urban environments. Consistent symptoms have been shown to include altered hydrographs, altered channel morphology and stability, elevated levels of nutrients and contaminants, as well as reduced biotic richness with an increased dominance of pollution tolerant species (Crawford & Lenat, 1989; Leopold, 1968; Meyer, Paul, & Taulbee, 2005; Paul & Meyer, 2001; Walsh et al., 2005).

Impervious surface cover (ISC), such as roads, parking lots, rooftops, etc., has long been recognized as a key predictor of the ill effects of urbanization on water quality and nearby ecosystems (Espy, Morgan, & Masch, 1966; Klein, 1979). In relation to aquatic ecosystems, ISC can increase the amount of water, sediment, and pollutant loading that a stream receives during a storm event (Hatt, Fletcher, Walsh, & Taylor, 2004). These factors contribute to degradation of water quality (Conway, 2007) and negatively influence stream life (Arnold & Gibbons, 1996; Brabec, Schulte, & Richards, 2002; Tippler, Wright, & Hanlon, 2012; Walsh, Sharpe, Breen, & Sonneman, 2001). Many researchers have attempted to determine the percent ISC "threshold" within a watershed in which negative impacts are observed. The values generated in these studies varies widely but most often range from 10-20% (Conway, 2007; Kim, Jeong, Jeon, & Bae, 2016; Klein, 1979; Liu, Wang, Li, & Peng, 2013; Morse, Huryn, & Cronan, 2003). One study specifically looked at ISC impact on stream macroinvertebrate communities and found that a decline in taxonomic richness occurred in watersheds that had over 6% of its land covered in impervious surfaces (Morse et al., 2003). The actual percentage may depend on a combination of factors, such as the presence of riparian buffers and other specific land uses in the area.

Like impervious surfaces, the practice of channelizing streams, has negative impacts on the biota. These manmade changes to the channel and substrate removes and reduces the diversity of available habitat for aquatic organisms to live. Violin et al. (2011) found that channel habitat complexity (ranging from a straight/channelized stream to a complex channel) and impervious surface cover (ranging from low imperviousness to high imperviousness) were the best predictors of changes from sensitive to more tolerant taxa.

Organic enrichment is another water quality stressor associated with urbanization, particularly, dense residential land use (Kaye, Groffman, Grimm, Baker, & Pouyat, 2006; Milesi et al., 2005). Heavy irrigation and nitrogen based fertilizer use in the urban setting are often associated with intensely managed lawns and golf courses (Filipovic, Toor, Ondrasek, & Kodesová, 2015; Law, Band, & Grove, 2004; Raciti et al., 2011; Robbins & Birkenholtz, 2003). These anthropogenic sources of nitrogen contribute to pollution of ground and surface water by increasing primary production and algal growth (Manuel, 2014).

Sampling Sites

Habitat and benthic macroinvertebrate monitoring was performed at ten locations within the Dallas Fort Worth Airport watershed (Figure 1) and three reference sites (Figure 1: inset) located outside of the airport's watershed (Table 3). Bear Creek was sampled at three locations, upstream (BBC), downstream of the golf course (BCB), and downstream of the airport (BCC). Three Bear Creek tributaries that reside on airport property were sampled as well: Bear Creek Tributary 14 (BCT14), Bear Creek Tributary 19 (BCT19), and Trigg Lake Tributary (TLT). Trigg Lake was surveyed as well. Just outside airport property, a sampling site was established on Little Bear Creek (LBA). This site lies outside of the influence of DFW Airport, and serves as an urbanized reference site within the watershed. Additionally, two separate watersheds on the northeast side of airport property, Grapevine Creek (GVC) and Hackberry Creek (HBC) were surveyed, with one survey site established on each stream. Three study sites outside of the DFW Airport watershed were established to represent reference conditions under low levels of urbanization. These reference sites include the Elm Fork of the Trinity River (EFT), South Bear Creek (SBC) at Hwy 377 in southeast Parker County, and the University of North Texas Water Research Field Station pond (WRFS). These reference sites differ from reference sites used in previous studies due to a lack of flow in those streams. All sampling was conducted within TCEQ's critical assessment period to facilitate evaluation of aquatic life conditions during critical flow and temperature conditions and to minimize temporal variation within benthic macroinvertebrate communities, as well as physical and chemical parameters ((TCEQ), 2014).

Table 3. 2014 Sampling Site Information for DFW Sites and Reference Sites

Site ID	Stream & Location	Latitude	Longitude	Sampling Date
BBC	Big Bear Creek at Grapevine-Euless Rd	32.89499	-97.08208	8/4/14
BCT14	Bear Creek Tributary 14	32.89258	-97.07427	8/14/14
BCT19	Bear Creek Tributary 19 @ Airfield Rd	32.87209	-97.05695	8/7/14
LBA	Little Bear Creek - above the golf course	32.86065	-97.06379	8/7/14
BCB	Bear Creek - below the golf course	32.85067	-97.05293	8/8/14
TLT	Trigg Lake Tributary	32.84365	-97.04201	8/13/14
BCC	Bear Creek at County Line Rd	32.83264	-97.03021	8/4/14
GVC	Grapevine Creek	32.93799	-97.02183	8/11/14
HBC	Hackberry Creek	32.90813	-97.01000	8/11/14
EFT^	Elm Fork of the Trinity River	33.33704	-97.03105	7/14/14
SBC^	South Bear Creek @ Hwy 377	32.89499	-97.08208	8/5/14
TL	Trigg Lake	32.85352	-97.04438	8/13/14
WRFS^	Water Research Field Station	33.20027	-97.21513	8/12/14

^ denotes Reference Site.

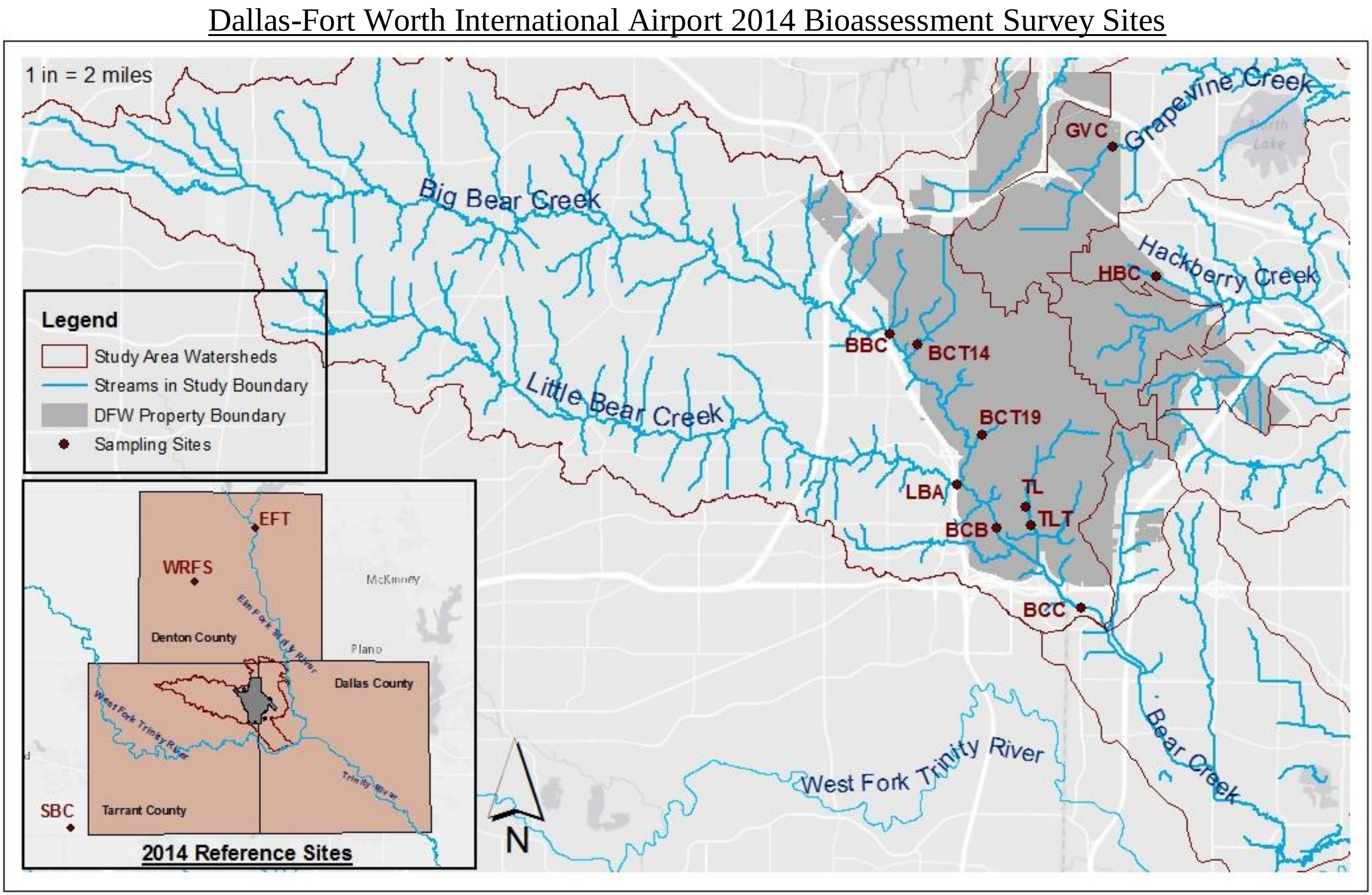

Figure 1. 2014 DFW Airport Bioassessment Sampling Sites (Reference sites - inset)

Methods

Physicochemical Measurements

The physicochemical measurements were performed following methods prescribed in the Texas Commission of Environmental Quality guidelines in the Surface Water Quality Monitoring Procedures Volume 1: Physical and Chemical Monitoring Methods ((TCEQ), 2012).

Instantaneous flow measurements were made using a Marsh-McBirney flowmeter and a top-setting wading rod. Dissolved oxygen (DO) and temperature were determined using a YSI model 85 dissolved oxygen probe. Conductivity was measured using a YSI model 33 conductivity meter. While pH was determined using a YSI Ecosense pH10 pen meter. Dissolved oxygen, conductivity, and pH meters were calibrated each morning prior to field sampling with quality control standards.

A temperature and DO depth profile was completed at Trigg Lake and the pond at UNT's Water Research Field Station using the YSI model 85 instrument. Temperature and DO were taken at the surface and at 1 meter intervals until the bottom was reached. Due to the rapid changes in temperature and DO at the UNT Water Research Field Station pond these parameters were measured at 0.3 meter intervals until the bottom was reached.

Habitat Quality Assessment

Physical habitat conditions were evaluated at each study location following the Texas Commission on Environmental Quality's (TCEQ) Physical Habitat of Aquatic Systems (Chapter 9) in Surface Water Quality Monitoring Procedures Volume 2 ((TCEQ), 2014). Prescribed habitat parameters were measured along parallel transects (5 or 6 depending on reach length) running perpendicular to the channel. Measured habitat parameters were used to evaluate and rate nine habitat characteristics and derive an overall station habitat quality index (HQI) score (Table 4). Table 4 also provides a brief description of each habitat parameter assessed (See also, Part III of Table 2A in Appendix 2 for more information). A descriptive habitat quality classification (limited, intermediate, high, or excellent) was assigned to each study site based on its HQI score (Table 5). The worksheets published by the TCEQ and used for this assessment can be found in Table 2A in Appendix 2.

Table 4. Habitat Parameters Evaluated at Each Study Site for the Habitat Quality Index

Habitat Parameters	Brief Description
Available Instream Cover	Amount of suitable habitat for aquatic organisms
Bottom Substrate Stability	Proportion of substrate of a stable size
Number of Riffles	Number of fast moving shallow water areas
Dimensions of Largest Pool	Size of slow moving deep water areas
Channel Flow Status	Water level relative to normal conditions
Bank Stability	Potential for bank erosion
Channel Sinuosity	Number of natural bends or meanders
Riparian Buffer Vegetation	Width of vegetated buffer on river banks
Aesthetics of Reach	Overall visual quality of the river study area

Table 5. Habitat Quality Index Classification Based on the Habitat Quality scores.

Habitat Quality Index	Habitat Quality Index Classification
26 – 31	Exceptional
20 – 25	High
14 – 19	Intermediate
$\leq$ 13	Limited

The TCEQ does not publish guidelines for evaluating pond and lake habitats. Therefore, a modified version of the Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) approach was used to document presence/absence of certain habitat characteristics ((EPA), 1997). This habitat data does not result in a TCEQ HQI score but does provide information that can be used in a long-term evaluation of Trigg Lake.

Benthic Macroinvertebrate Sampling and Analysis

Benthic Macroinvertebrate Sampling

Lotic Samples. Benthic macroinvertebrate samples were collected in riffles and/or runs within each reach. Five one-minute D-frame kick net samples were taken in a "zig-zag" pattern from the downstream end of the riffle to the upstream end. Each single kick sample was accomplished by positioning the bottom of the net frame on the substrate with the opening of the net facing upstream. By disturbing the benthic substrate upstream of the net the flow is utilized to trap any organisms in the 0.5 mm mesh net. If no flow was detected, then a jab sample was collected. Jab samples are defined as timed thrusts of a D-Frame kick net through areas of suitable habitat. Large substrate and debris were picked out, inspected, and any attached organisms were removed in the net. The debris was then discarded.

After every kick, the collected material was washed by running clean filtered stream water through it two or three times. The sample was then transferred to a clean enamel pan. Any invertebrates clinging to the sample net were removed and placed in the enamel pan. Small debris was not inspected in the field. The samples were then placed in the sample containers. Care was taken to never fill the containers more than half full of collected material, to ensure that there was adequate space left for preservation fluid. The samples were then preserved with 95% Ethanol.

This procedure was repeated four times for a total of five replicates from each sampling location. Each sample was labelled with site location, sample type, date, time, and replicate information.

Lentic Samples. A Ponar grab sampler was used to sample lentic habitats at Trigg Lake and UNT's Water Research Field Station. Five randomly spaced samples were collected at Trigg Lake and three randomly spaced samples were collected from UNT's Water Research Field Station. The differences in the number of samples is due to the differences in the size of the water bodies. Each sample was washed through a 0.5 mm mesh bucket and transferred to a clearly labeled sample container. Preservation and labeling methods were analogous to other samples types.

Benthic Macroinvertebrate Processing

Once the samples were returned to the laboratory for processing and identification of macroinvertebrates, the samples were poured into a sieve with 0.5 mm mesh and thoroughly rinsed and cleaned with a gentle water spray. The sample was then carefully transferred to a labelled bottle and stored for further processing and identification.

A dissecting microscope was used to sort and identify macroinvertebrates to the lowest practical level. For most groups, this was genus. In some instances, due to damaged specimens or those in early developmental stages were left at family. The number of individuals within each taxonomic group was counted and recorded. Each taxonomic group was placed in a separate vial preserved with 70% ethanol and archived.

Archive vials were labeled with the following information: project ID, collection date, type of sample collection, sample station number, and a brief description of the sampling locality. A second label was included in each vial that had the identification, the name of the determiner, and the year the determination was made. Two reference collections were made that contains representatives of all taxa. One set was provided to the study sponsor and the second set was retained in the University of North Texas Natural Heritage Museum.

Benthic Macroinvertebrate Community Structure Analysis

Community structure and function were analyzed by utilizing the multi-metric B-IBI ((TCEQ), 2014). Table 6 contains each metric used in the index, a brief definition, and the expected response of those metrics to disturbances. The B-IBI generates a score that is used to assign an Aquatic Life Use (ALU) classification to the benthic community. The scoring criteria and associated ALU classifications can be found in Appendix 2B. Additional metrics were chosen to provide a well-rounded summary of the benthic community.

Table 6. B-IBI metrics used to analyze benthic macroinvertebrate community structure.

TCEQ B-IBI Metrics	**Brief Definition**	**Expected Response to Disturbance**
Total Taxa	Number of different taxa (richness)	Decrease
Diptera Taxa	Number of different Dipteran taxa	Decrease
Ephemeroptera Taxa	Number of different Ephemeroptera taxa	Decrease
Intolerant Taxa	Number of different intolerant (TV$\leq$ 4) taxa	Decrease
% EPT Taxa	Percentage of common (generally) intolerant groups	Decrease
% Chironomidae	Percentage of a (generally) tolerant group	Increase
% Tolerant Taxa	Percentage of tolerant (TV $\geq$ 8.5) individuals	Increase
% Grazers/Scrapers	Percentage of grazer/scraper taxa	Decrease
% Gatherers	Percentage of gatherer taxa	Decrease
% Filterer	Percentage of filterer taxa	Decrease
% Dominance (3 taxa)	Combined percentage of 3 most common taxa	Increase
Additional Metrics	**Brief Definition**	**Expected Response to Disturbance**
Evenness	Distribution of abundance between taxa	Decrease
Shannon Diversity Index	Accounts for taxa richness and relative abundance	Decrease
% Dominant FFG	Percentage of the most abundant FFG	Increase
% Oligochaetes (Lentic Metric)	Percentage of aquatic worms present	Increase

Evenness is a measure of how dominant taxa groups are within the sampled population. It is calculated as follows:

$$Evenness = \frac{H'}{log_2 R}$$

where R is the number of different taxa present, or richness, and H' is as follows:

$$Shannon\ Diveristy\ Index, H' = -\sum (p_i \times log_2(p_i))$$

where p_i is the proportion of individuals belonging to taxa *i*.

The number generated for evenness is between 0 and 1. If one taxa, or group of taxa, is in higher proportion than other groups then the score for evenness will closer to 0. If the population is more evenly distributed between taxa then the score will be closer to 1.

Benthic Macroinvertebrate Community Similarity Analysis

Modified Morisita's similarity was used to measure similarity of benthic community structure between sites (Brower & Zar, 1984; Horn, 1966; Morisita, 1959). This community similarity index refers to the probability that individuals randomly drawn from each of two communities will belong to the same species, relative to the probability of randomly selecting a pair of individuals of the same species from one of the communities (Brower & Zar, 1984). The modified Morisita's index of community similarity is:

$$C_H = \frac{2\sum_{i=1}^{S} x_i y_i}{\left(\frac{\sum_{i=1}^{S} x_i^2}{X^2} + \frac{\sum_{i=1}^{S} y_i^2}{Y^2}\right) XY}.$$

where x_i is the number of individuals in species i in community 1 and X is the total number of individuals in community 1; likewise y_i is the number of individuals in species i in community 2 and Y is the total number of individuals in community 2.

The modified Morisita's similarity values may range from 0 (no similarity) to approximately 1.0 (identical). This index has the desirable characteristic of having little influence by the size of samples. Dendograms of the modified Morisita's coefficient matrices were produced using the unweighted pair group method of cluster analysis.

Land Use Analysis

Land use classification was completed using 5-meter resolution color-infrared RapidEye Satellite digital imagery of the study area, as well as ancillary information provided by DFW Airport and the North Central Texas Council of Governments (NCTCOG). The imagery was acquired on April and August of 2014.

Using eCognition Essentials 1.3 software (Trimble 2016), land use classifications were generated for the following land uses: Bare Ground, Buildings, Manicured, Mowed/Grazed/Herbaceous, Transportation, Water, and Wooded. These classes are based on the work done by Anderson, Hardy, Roach, and Witmer (1976). ArcGIS 10.3 (ESRI) was used to analyze and generate the land use maps provided.

The study area was divided into 10 sub-watersheds: Upper Bear Creek, Lower Bear Creek, Grapevine Creek, Hackberry Creek, South Fork Hackberry Creek, Cottonwood Branch North & South, Denton Creek, Estelle Creek, and Mud Springs Creek. Only those in association to our sampling sites are discussed here. Land use results are summarized in Appendix 1D as well as in printed maps and data files included with this report.

Results and Discussion

This section is organized by first summarizing each category of measurements. Maximums and minimums of each measurement will be acknowledged and discussed. The following sections will comprise of an in-depth examination of the results of the habitat quality assessment, the benthic macroinvertebrate assessment, and the land use analysis at each stream study site. Study sites are organized by watershed starting with the most upstream site to furthest downstream site, followed by remaining sites and finally, reference streams. Lastly, lake sites are summarized and discussed separately.

Physicochemical Measurements

Physicochemical parameters measured during this study are presented in Table 7. It should be noted that all physicochemical measurements reported here are based on single measurements made at the time of sampling and do not permit the critical evaluation of changes in these parameters among sampling years. However, all values measured in this sampling event are within expected ranges urban streams in this eco-region.

Table 7. Water quality parameters measured at the time of benthic macroinvertebrate sampling.

Site ID*	Time	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Flow (CFS)
BBC	2:00 PM	30.4	8.12	500	7.92	0.16
BCT14	10:00 AM	22.7	5.64	1750	7.85	No flow
BCT19	12:00 PM	27.5	5.34	850	7.83	0.06
LBA	1:00 PM	29.9	7.50	600	8.21	0.79
BCB	9:00 AM	27.1	7.21	600	7.71	0.93
TLT	2:00 PM	32.2	17.70	610	9.02	No flow
BCC	9:00 AM	27.4	8.44	990	8.22	0.80
GVC	1:30 PM	29.2	4.20	800	7.48	No flow
HBC	9:00 AM	26.4	5.25	700	7.74	0.01
EFT^	10:00 AM	26.4	6.80	330	7.95	44.27
SBC^	11:00 AM	24.3	5.26	520	7.44	0.08

* Refer to Table 2 for Site ID descriptions.
^ denotes Reference Site.

All dissolved oxygen (DO) measurements were within the TCEQ's *Texas Surface Water Quality Standards* for a "high" aquatic life use classification ((TCEQ), 2012). The lowest DO value (4.2 mg/l) was recorded at Grapevine Creek and the highest (17.7 mg/l) occurred at Trigg Lake Tributary. These sites representing the extremes of the DO measurements had little to no water flow. The Trigg Lake Tributary DO measurement likely represents a supersaturated condition that is a result of high photosynthetic activity by the abundant filamentous algae occurring at this station. The low DO measurement at Grapevine Creek likely reflects the observed high turbidity of this site, which may reduce photosynthetic activity, and/or the timing of the DO measurement which was taken in the early morning before photosynthetic activity could increase local DO concentrations.

Generally, pH values were similar between stream sites. One outlier, Trigg Lake Tributary, had a pH of 9.02. This alkaline condition is likely due to the abundant photosynthetic activity mentioned previously. Carbon dioxide dissolved in water disassociates to form carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions which buffer the pH of natural waters. Photosynthesis removes CO^2 from the water and can increase the pH. This is especially true in non-flowing water bodies. A slightly alkaline condition in heavily vegetated waters is expected during the growing season and is not surprising considering the high algal population observed in this pooled stream.

Conductivity was lowest at the Elm Fork of the Trinity River reference site (330 μS/cm) and highest at Bear Creek Tributary 14 (1750 μS/cm). More information is needed to determine the cause of the elevated conductivity at Bear Creek Tributary 14.

Flow conditions of the surveyed streams were generally low and reflected the drought conditions prevalent just prior to and during the sampling period. Three sites (Bear Creek Tributary 14, Grapevine Creek, and Trigg Lake Tributary) had no flow and no discharge measurements were made. Water flow is one of the most important factors influencing macroinvertebrate populations. Some benthic macroinvertebrates utilize flowing water to acquire food and oxygen while others have adaptions better suited for still water habitats (Minshall, 1984). Therefore, if flow differs greatly between sites, so will the community of organisms that live there.

Habitat Quality Assessment

Habitat assessments quantify, in part, a stream's potential to support a diverse and ecologically healthy aquatic community. See Table 4 (and Part III of Table 2A in Appendix 2) for a brief description of habitat parameters assessed. Habitat quality classifications for the study streams ranged from limited at Grapevine Creek and high at Little Bear Creek upstream of the golf course, the Elm Fork of the Trinity River, and South Bear Creek at Hwy 377 (Table 8). All other streams received a classification of intermediate. A site-by-site description of habitat quality is provided in later sections along with comparisons between previous studies, if available.

Table 8. Habitat Quality Index (HQI) metrics, scores & ALU Classification for 2014 study.

	Site ID*										
TCEQ HQI Metrics	**BBC**	**BCT14**	**BCT19**	**LBA**	**BCB**	**TLT**	**BCC**	**GVC**	**HBC**	**EFT^**	**SBC^**
Available Instream Cover	2	2	2.5	3	2	2	4	1	2	3	3
Bottom Substrate Stability	2	1.5	2	2.5	2	1	3	1	1	3	3
Number of Riffles	3	1	3	4	2	1	3	1	3	4	3
Dimensions of Largest Pool	4	2	4	4	4	3	1	3	2	1	4
Channel Flow Status	1	0	2	3	2	2	2	1.5	2	3	1
Bank Stability	1	1	1	1	1	1.5	2	1	2	1	2
Channel Sinuosity	1	3	1	1	1	1	1	2	1	1	2
Riparian Buffer Vegetation	3	3	2.5	1	3	2	2	1.5	2	3	3
Aesthetics of Reach	1	1	1	1	1	1	1	1	1	2	2
Total	**18**	**14.5**	**19**	**20.5**	**18**	**14.5**	**19**	**13**	**16**	**21**	**23**
Aquatic Life Use Designation+	**I**	**I**	**I**	**H**	**I**	**I**	**I**	**L**	**I**	**H**	**H**

+ H = High; I = Intermediate; L = Limited. * Refer to Table 3 for Site ID descriptions.
^ Denotes Reference Sites.

Land Use Classification and Analysis

Land use analysis for land area within DFW Airport property results were as expected (Figure 2). Manicured classes were only found in the Bear Creek watershed due to the presence of a golf course. Impervious surface area, which is a combination of transportation land area and buildings, was determined to be 29.1% (Figure 2). The impacts on water quality of impervious surfaces and manicured lawns are discussed in detail in the introductory “Urban Land Use” section of this report. The amount of imperviousness within DFW Airport Property is less than the amount determined for the entire study watershed (34.2%) (Tables 9 & 10). The “Unclassified” land use class, seen in Figure 2, is a portion of DFW Airport property that lies outside the bounds of the study watersheds.

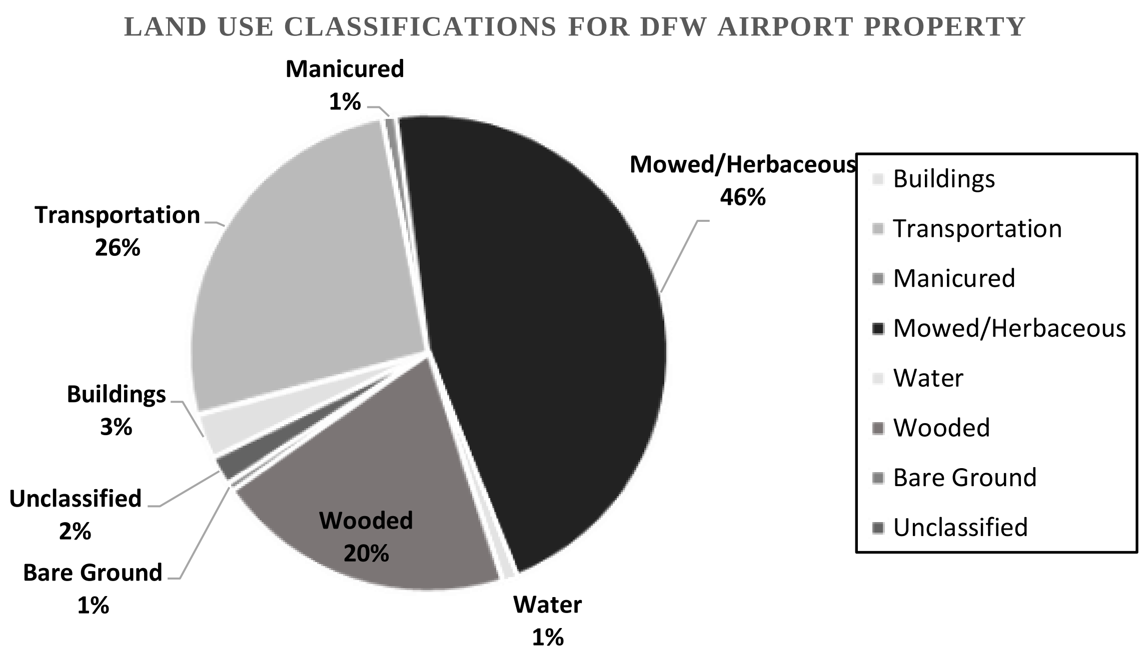

Figure 2. Land Use Classification for DFW Airport Property

Table 9. Land Use Classifications for select watersheds within DFW Airport Property.

	Watershed within DFW Airport Property			
Classification	**Upper Bear Creek**	**Grapevine Creek**	**Hackberry Creek**	**Total Classes DFW**
Bare Ground	0.4%	0.2%	0.3%	0.6%
Buildings	3.0%	8.6%	1.0%	3.1%
Manicured	2.0%	0.0%	0.0%	0.9%
Mowed/Grazed/Herbaceous	37.4%	47.4%	49.6%	46.1%
Transportation	26.9%	38.3%	33.3%	26.1%
Water	1.3%	0.4%	0.6%	1.0%
Wooded	28.8%	4.0%	15.2%	20.3%
Total (Acres)	**8,246.7**	**2,698.1**	**797.1**	**17,188.2**
% Impervious	30.0%	47.5%	34.3%	29.1%

Table 10. Land Use Classifications for select watersheds within entire study area.

	Watershed within Entire Study Area			
Classification	**Upper Bear Creek**	**Grapevine Creek**	**Hackberry Creek**	**Entire Study Area**
Bare Ground	1.4%	2.2%	3.9%	1.7%
Buildings	11.8%	12.0%	10.7%	11.6%
Manicured	1.0%	0.1%	1.9%	1.2%
Mowed/Grazed/Herbaceous	44.1%	41.9%	41.2%	43.3%
Transportation	20.4%	27.5%	31.1%	22.7%
Water	1.2%	5.9%	1.9%	2.0%
Wooded	20.2%	10.2%	9.4%	17.6%
Total (Acres)	**49,965.58**	**8,570.11**	**6,216.88**	**98,228.7**
% Impervious	32.2%	39.5%	34.3%	34.2%

Appendix 1D contains all land use data generated during this study (2014) as well as the 2008 study. Due to the size of the data set, only watersheds containing sampling sites are reported here. Overall, between the 2008 and 2014 study, many land use class proportions remained similar. The only classes to change noticeably, were the Transportation and Wooded land uses. Transportation land use increased from 18.6% (2008) to 22.7% (2014) while the Wooded classification decreased from 21.4% in 2008 to 17.6% in 2014. This change is expected in this rapidly growing urban region.

Benthic Macroinvertebrate Communities

Overview

Results of the descriptive metrics used in this study are summarized and discussed in this section and in Table 11. Caution needs to be exercised when considering any single metric to describe the entire benthic macroinvertebrate community. Later in this section a detailed summary of each site synthesizes all the data collected during this study.

Approximately, 90,000 individuals representing four Phyla (Platyhelminthes, Annelida, Mollusca, Arthropoda) and 86 taxa (Appendix 1C) were collected from the study area. Three groups of aquatic insects Diptera: Chironomidae (26%), Ephemeroptera (17%), and Trichoptera (11%) accounted for 54% of the total number of benthic macroinvertebrates collected. The abundance, or total number of organisms collected at each site, ranged from 3129 at Hackberry Creek (HBC) to 13867 at Grapevine Creek (GVC).

The highest number of taxa (richness) was measured at Grapevine creek (47), a site that lacked flow during the time of sampling. The community composition at Grapevine Creek was, as expected, dominated by the aquatic insects associated with slow/still water (i.e. true bugs (Hemiptera) and aquatic beetles (Coleoptera)). At sites with flowing water, the highest taxa richness was observed at Little Bear Creek (44 taxa) and Bear Creek Tributary 19 (43 taxa). Little Bear Creek had a high diversity of dragonflies and damselflies (Odonata). This site had abundant aquatic macrophytes and emergent vegetation, providing ideal habitat for Odonata taxa. Bear Creek Tributary 19 had a higher number of Coleoptera and Ephemeroptera taxa. Although still considered a high number of different taxa, in comparison to other study sites, Big Bear Creek at Euless-Grapevine Road (BBC), had the lowest taxa richness of 29 taxa. Overall, taxa richness was excellent at all sites.

In ecosystems impacted by changes in environmental conditions, aquatic invertebrates tolerant of those changes will dominate the community composition. Evenness is a measure of the distribution of the number of individuals among the taxa in a sample, or dominance. Values for evenness can range from 0 to 1. Low evenness scores, those closer to 0, indicate the dominance of one or a few taxa. A score of 1 indicates the same number of individuals are present for every taxa group. Healthy aquatic ecosystems have high numbers of taxa with no taxa represented by a great number of individuals. In practice, a comparison of evenness scores across the study sites provides another method of evaluating the health of a stream. In this study, evenness scores ranged from 0.55, at Little Bear Creek, to 0.76 at Bear Creek at County Line Road (BCC). The macroinvertebrate sample collected at Little Bear Creek contained 46% of the sub-family Chironominae (Diptera: Chironomidae). The next most abundant group was the amphipods (*Hylella azteca)* (18%). The sample collected at BCC only contained 12% Chironominae, with *Stenelmis sp*. (Coleoptera: Elmidae) being the most numerous group (14%).

The number of intolerant taxa present at each site ranged from 4 at Hackberry Creek to 10 at the Elm Fork Trinity River. Most sites had 5 to 6 representative taxa from intolerant, or sensitive, groups. That is, taxa with tolerant values of less than or equal to 4. This metric is used as an indicator of the ecological health of a site. The presence of sensitive taxa suggests an ecosystem healthy enough to support them. At the other end of the tolerance spectrum, a high proportion of tolerant taxa is not necessarily indicative of poor water quality conditions. Some tolerant taxa are always present in populations. The absence of intolerant organisms is the most telling. Another instance of why reliance on a single metric is poor practice.

Based on Texas State Standards community structure and relative abundance of each functional feeding group were within expected values for urban streams in this eco-region. However, the proportion of predators were slightly elevated for all sites. Expected proportions of predators typically range from 5-20% in a well-balanced ecosystem ((TCEQ), 2014; Cummins, 1979). Sites averaged 27% predators and many sites exceeded that average. High proportions of predators can be attributed to an overall higher production and turnover of prey items whose elevated levels may be credited to high nutrient inputs, especially in an urban setting. However, the increased predator population observed in this study is likely to be associated with normal dynamics of benthic populations. Numerous early developmental stages of Odonata, which are predators, were the taxa responsible for the high predator proportions. Adult dragonflies were numerous throughout the study area and were observed mating and laying eggs. Many of these organisms will not survive to later instars and those proportions will likely balance out with time.

Table 11. Select metrics used to summarize benthic macroinvertebrate communities.

Site ID*	Abundance	Richness	Evenness	Intol. Taxa (TV≤ 4)	Percent Chironomidae	Dominant Taxon	Dominant 3 Taxa	Dominant FFG**
BBC	7837	29	0.668	6	20%	24%	58%	FC 49%
BCT14 ~	5688	36	0.730	5	18%	14%	39%	P 42%
BCT19	6293	43	0.567	7	51%	39%	59%	P 34%
LBA	10032	44	0.547	5	51%	46%	69%	CG 34%
BCB	3244	35	0.672	5	33%	26%	53%	FC 38%
TLT ~	12272	42	0.667	8	26%	20%	49%	CG 31%
BCC	13866	34	0.764	5	22%	14%	38%	CG 37%
GVC ~	13867	47	0.606	7	12%	35%	62%	CG 38%
HBC	3129	30	0.702	4	25%	29%	51%	CG 39%
EFT^	6018	38	0.711	10	9%	22%	49%	FC 40%
SBC^	4258	34	0.579	7	25%	40%	70%	CG 33%

* Refer to Table 3 for Site ID descriptions. ** Refer to Table 2 for FFG descriptions.
~ Denotes sites that lacked flow. ^ Denotes Reference Sites.

Benthic Index of Biological Integrity

Twelve metrics are used by the TCEQ to generate an Index of Biotic Integrity (IBI) score. (See Table 6 for metric descriptions and expected responses to disturbances.) As seen in Table 12, each site within the study was designated "Intermediate", "High", or "Exceptional" Aquatic Life Use (ALU). The TCEQ B-IBI criteria that generates these scores can be found in Appendix 2B. Only one site had an "Intermediate" score of 29, at Little Bear Creek (LBA). Two sites, one reference site (EFT) and one study site (BCC), had "Exceptional" scores of 47 and 41, respectively. All other sites were scored as "High".

Table 12. TCEQ B-IBI Integrity scores and associated aquatic life use designation for all stream sites.

	Site ID*										
TCEQ B-IBI Metrics	**BBC**	**BCT 14**	**BCT 19**	**LBA**	**BCB**	**TLT**	**BCC**	**GVC**	**HBC**	**EFT^**	**SBC^**
Total Taxa	3	5	5	5	5	5	5	5	3	5	5
Diptera Taxa	3	5	5	3	3	5	3	5	3	3	3
Ephemeroptera Taxa	5	3	5	3	5	3	3	3	3	5	3
Intolerant Taxa	3	3	3	3	3	5	3	3	3	5	3
% EPT Taxa	5	1	3	1	3	1	3	3	3	5	5
% Chironomidae	3	3	1	1	1	1	3	3	1	3	1
% Tolerant Taxa	3	3	3	3	3	3	3	3	3	3	3
% Grazers/Scrapers	3	1	3	1	1	5	5	3	5	5	5
% Gatherers	5	5	5	5	5	5	5	5	5	5	5
% Filterer	3	3	3	3	3	1	3	1	1	3	3
% Dominance (3 taxa)	3	5	3	1	5	5	5	3	5	5	1
Total	39	37	39	29	37	39	41	37	35	47	37
Aquatic Life Use Designation+	**H**	**H**	**H**	**I**	**H**	**H**	**E**	**H**	**H**	**E**	**H**

\+ E = Exceptional; H = High; I = Intermediate * Refer to Table 3 for Site ID descriptions.
^ denotes Reference Site.

Community Similarity Analysis

A cluster analysis dendrogram based on modified Moriseta's similarity is displayed in Figure 3. A similarity value greater than 50% is used to define a cluster of sites with similar community composition. The most similar stations (87%), based on this analysis, were sites at Bear Creek Tributary 19 (BCT19) and Little Bear Creek (LBA). These sites had the lowest level of evenness and were both dominated by the family Chironomidae (~50% at both stations).

The next most similar cluster (75%) included Big Bear Creek at Grapevine-Euless Road (BBC), the furthest upstream site, and Bear Creek below the golf course (BCB). These sites had similar evenness and high proportions of filter feeding caddisflies, *Cheumatopsyche sp.* (Hydropsychidae) and *Chimarra sp.* (Philopotamidae) caddisflies. These two sites were also clustered, although less so, with the two references sites, the Elm Fork of the Trinity River (EFT) and South Bear Creek (SBC). All four sites had a notable presence of the filter-feeding caddisflies mentioned above, as well as, *Fallceon sp.* (Baetidae) and Chironominae (Chironomidae: Diptera).

Two, of the three sites that lacked flow, Bear Creek Tributary 14 (BCT14) and Grapevine Creek (GVC) had Morisita's Similarity values of 68% which reflects the similarity of the taxa composition. Taxa at these sites was dominated by Amphipoda. In comparison, the third site that lacked flow, Trigg Lake Tributary (TLT), had a higher abundance of hemipterans and a distinct assemblage of micro caddisflies (Hydroptilidae) taxa (See individual site discussion for further explanation). The proximity to, and occasional water supply from, Trigg Lake likely influenced the taxa found here. All other stations remained at around 55% similar and distinct taxa compositions were more difficult to distinguish.

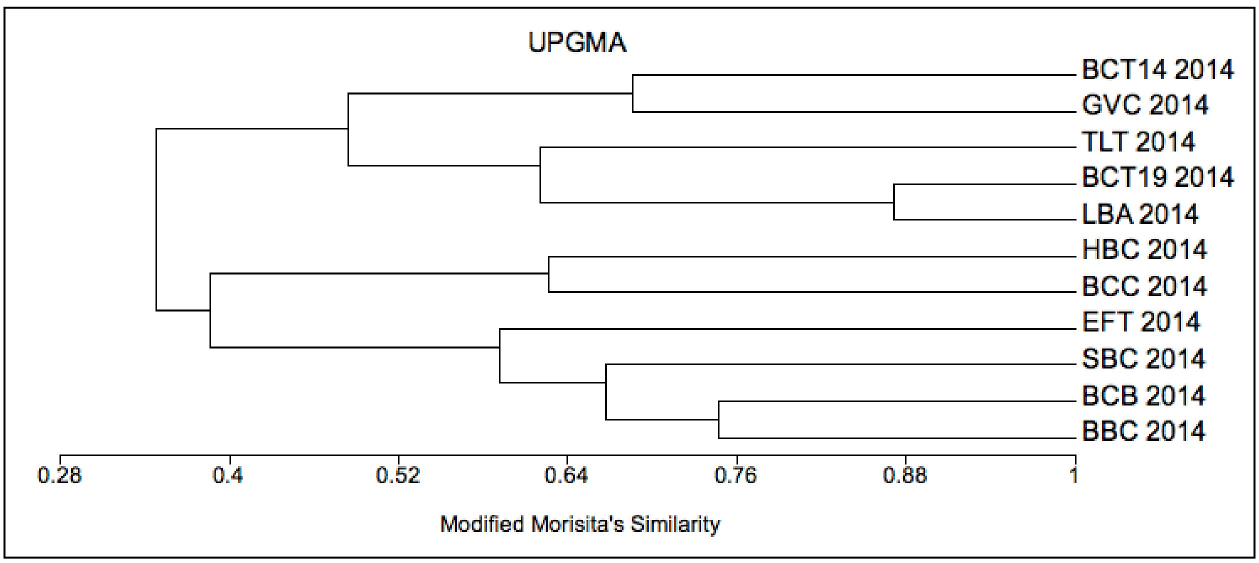

Figure 3. Community Similarity as measured by Modified Moriseta's Similarity. Clusters produced by Unpaired Group Mean Average.

Site by Site Results and Discussion

To better analyze and describe conditions at each site, this section will combine results from the habitat quality assessment, the benthic macroinvertebrate assessment, and the land use analysis. If available, a discussion of data obtained during previous studies will be included. Study sites are organized by watershed starting with most upstream site to furthest downstream site, followed by remaining sites and finally reference streams. Lastly, lake sites are summarized and discussed.

Big Bear Creek

BBC*: At Grapevine-Euless Rd bridge, upstream of golf course (32.89499, -97.08208)*

Big Bear Creek at Grapevine Euless Road is the furthest upstream site within the Bear Creek watershed. While it is located on DFW airport property, much of the watershed upstream of this site drains densely residential land uses.

Habitat Quality. The Big Bear Creek site received a total habitat quality index score of 18 and an intermediate habitat quality index classification. This score is based on several habitat parameters that were observed within the 220 m surveyed reach. The available instream cover consisted mainly of woody debris, small amounts of cobble and gravel, and large pieces of cement and boulders at the upstream portion of the reach. These large boulders were placed under the bridge to reduce erosion and are not naturally occurring. However, they can still serve as suitable habitat (cover) for aquatic organisms. The available instream cover within the entire reach was considered rare, a score of 2, due to the unstable nature of woody debris and homogeneity of cover types. The bottom substrate was dominated by sand, with approximately 33% consisting of gravel or larger for the entire reach. For this reason, bottom substrate stability was given a score of 2, or moderately unstable. Only transect one had the large proportion of the more stable, boulder sized substrate placed there in order to reduce erosion around the base of the bridge. Three riffles were observed within the surveyed reach, producing an index score of 3. Two pools were observed, with at least one of them qualifying for an index score of 4, meaning that it covered more than 50% of the channel width and was greater than one meter in depth. Channel flow status was considered to be low, resulting in an index score of 1, at the time of the survey. Bank stability was determined to be moderately unstable, an index score of 1, due to abundant evidence of erosion and the presence of bare banks observed during the assessment. Bank angles averaged 16.9 degrees, which would usually result in a higher bank stability score. Since flow conditions were low at the time of the survey, these angles reflect slopes at the low water interface, not the bank slope at normal flow conditions where more erosion was evident. Channel sinuosity received an index score of 1 due to the presence of only one poorly defined bend within the surveyed reach. The extent of the riparian buffer vegetation was greater than 20 m (riparian buffer vegetation index score of 3) at all transects except for the right bank of transect one. Transect one was located at a heavily trafficked bridge reducing the vegetated buffer to less than 5 m. Finally, the aesthetics of the reach were considered common and received an index score of 1. This score was based on the proximity to roads and the bridge at the upstream transect as well as the amount of urban debris found within the reach. The habitat quality index score of 18 assigns an “intermediate” HQI classification to this reach. This reduces the HQI classification of “high” from the 2008 survey (Table 13). This decline is likely due to the lower flow conditions observed during this most current survey. Low flow conditions can reduce the amount of instream cover available to aquatic organisms. It also appears that riparian buffer vegetation improved since the 2008 survey.

Table 13. BBC HQI score, ALU classification, and flow conditions over sampling years.

Survey Year	HQI Score	ALU Classification	Flow (cfs)
2004	16.0	Intermediate	10.90
2005	17.0	Intermediate	3.42
2008	21.0	High	21.42
2014	18.0	Intermediate	0.16

Benthic Macroinvertebrates. A total of 7,837 benthic macroinvertebrate individuals were collected at this site. Big Bear Creek had a “high” IBI score of 39. However, taxa richness, while still high, was the lowest (29) among sites. The substrate where samples were collected consisted of medium to large boulders and sand, offering potential for high macroinvertebrate diversity. Three taxa *Cheumatopsyche sp.* (Trichoptera: Hydropsychidae), *Fallceon sp*. (Ephemeroptera: Baetidae), and *Chimarra sp.* (Trichoptera: Philopotamidae) made up 58% of the total individuals collected at this site (24%, 19%, and 15% respectively.)

The filter-collector (FC) functional feeding group (FFG) was represented by 49% of the individuals found here (Table 14). Trichoptera groups, *Cheumatopsyche sp*. (Hydropsychidae) and *Chimarra sp.* (Philopotamidae) made up over 80% of that FFG and a combined 38% of the entire sample. Filter feeding collectors feed on suspended fine particulate organic matter. The presence and dominance of these organisms can indicate increased organic nutrient loading (Cummins, 1979). Organic enrichment, a common occurrence in urban watersheds where high fertilizer use occurs, increases primary productivity in stream ecosystems, resulting in abundant food resources for filter feeding organisms. *Cheumatopsyche sp.*, a relatively tolerant taxon, is a ubiquitous filter feeding Caddisfly found in stream ecosystems. The high abundance of *Chimarra sp*., an intolerant taxon (TV = 2), provides evidence that suggests suitable conditions for a wider range of organisms than a typical urban stream.

Table 14. Big Bear Creek at Euless-Grapevine Road (BBC) Benthic Macroinvertebrate Metrics

Study Year	Abundance	Richness	Evenness	Intol. Taxa (TV≤ 4)	Percent Chironomidae	Dominant 1 Taxa / 3 Taxa	Dominant FFG	B-IBI Score & ALU
2004	1224	17	0.589	3	51%	38% / 75%	CG 43%	32 H
2005	3303	22	0.533	3	30%	55% / 77%	FC 59%	29 I
2008								
2014	7837	29	0.668	6	20%	24% / 58%	FC 49%	39 H

Evenness (0.668) saw an improvement from previous studies (Table 14). As did richness and the number of intolerant taxa. Suggesting overall increase in habitat quality of this site over the years of the survey despite upstream urban inputs and severe drought conditions during the 2014 survey.

One noticeable change between study years was the composition shift of three abundant taxa groups *Cheumatopsyche sp.* (Trichoptera: Hydropsychidae), *Fallceon sp.* (Ephemeroptera: Baetidae) and the family Chironomidae (Diptera). In the 2004 study, Chironomidae made up 51% of the total population, while *Fallceon sp.* and *Cheumatopsyche sp.* only make up 28% and

10%, respectively. During the study the following year (2005), *Cheumatopsyche sp*. was collected as the dominant taxa at 55% and Chironomidae 30%. The 2014 study saw the Chironomidae family reduced to 20% and a more even distribution of other taxa populations. The reduction in the chironomids (Diptera) populations and increases in the mayfly (Ephemeroptera) and caddisfly (Trichoptera) populations improves the evenness within the community structure. It should also be noted that, in general, caddisflies and mayflies are regarded as more sensitive to pollutants. Collectively increased evenness values and an increase in the population of organisms with a greater sensitivity to pollutants recorded in the current study indicates improved habitat conditions (Figure 4).

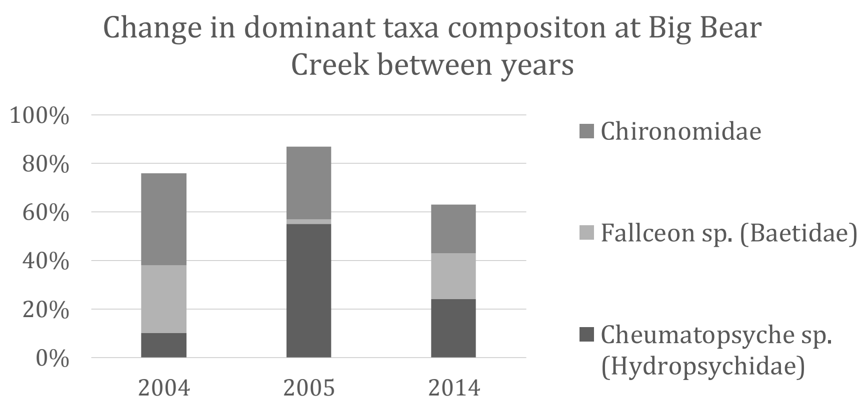

Figure 4. Composition shift of three abundant taxa at BBC.

Bear Creek Tributary 14

BCT14: Downstream of Outfall 14 (32.89258, -97.07427)

Approximately 800 m downstream of the Big Bear Creek site is the confluence of the tributary Bear Creek 19. The study reach is located 500 m upstream of where the two streams meet. At the time of sampling there was no flow, only standing pools of water, providing a fundamentally different habitat when compared to flowing water habitats.

Habitat Quality. This 150 m reach received a total habitat quality index score of 14.5, which classifies this site as having an intermediate HQI classification. The score and classification are based on several habitat parameters that were scored as follows. Available instream cover received an index score of 2, or rare. This was based upon a 54% average instream cover and the following unstable instream cover types: algae, gravel, root masses and woody debris, overhanging vegetation, and undercut banks. Bottom substrate stability was characterized by a limited abundance of gravel sized or larger substrate (average 31%), with bedrock, sand, and silt as the dominant substrate type at different transects. This reach, therefore, received a bottom substrate stability index score of 1.5. There were no riffles observed in this reach (number of riffles index score of 1) and numerous small standing pool habitats (dimensions of largest pool index score of 2). During the survey period, there was no flow within the channel, resulting in a channel flow status index score of 0. Bank stability was determined to be moderately unstable (bank stability index score of 1) based upon high average bank erosion potential (70.5%) and high average bank slopes (58.6 degrees). Channel sinuosity was considered high (channel sinuosity index score of 3) based upon the presence of at least 3 well-defined bends. The extent of the riparian vegetation buffer was greater than 20 m and scored as extensive, an index score of 3. Overall, the aesthetics of the stream were determined to be common, with an index score of 1, based upon the observed stream uses (airport, municipal, and urban runoff), and the channel modifications (gas pipeline installation). A habitat quality index score of 14.5 assigns an "intermediate" HQI classification to this stream.

Table 15. BCT14 HQI score, ALU classification, and flow conditions over sampling years.

Survey Year	HQI Score	ALU Classification	Flow (cfs)
2004	--	--	--
2005	18.0	Intermediate	0.08
2008	21.0	High	0.28
2014	14.5	Intermediate	No Flow

-- Site not sampled.

This stream was surveyed in 2005, 2008, as well as 2014. There was an increase in the HQI classification from the 2005 survey (intermediate) to the 2008 survey (high). This is likely due to the alteration of flow and creation of riffle habitats resulting from large debris dams that were a result of fallen trees. This was observed in the 2008 survey. Also noted in previous reports, the reach surveyed during 2008 was further upstream from the 2005 surveyed reach due to sedimentation caused by the removal of trees and the installation of the natural gas pipeline. This could result in differing scores and classifications. The 2014 bioassessment determined the HQI classification to be intermediate once again. The major difference between the 2014 and the 2008 survey is the lack of flow and numerous extended dry reaches in this stream. This impacts the number of riffles and pool habitats present. The change in flow conditions experienced at this site is a common occurrence during this study period. Supra-seasonal drought was a prevailing stressor, influencing water flow statuses at all sites.

Benthic Macroinvertebrates. Cobble and gravel sized substrate was present in small quantities here but were densely covered with algae that dominated the small pools. Macroinvertebrates were collected from undercut banks as they were the most suitable habitat present due to the lack of flow. Bear Creek Tributary 14 contained 36 different taxa groups and were rather evenly distributed among those taxa, more so than most other sites (Evenness metric of 0.730). Non-insects like the amphipod, *Hylella azteca*, 14%, and Bivalves, 14%, were the most abundant groups. Combined proportions of the Chironomidae (Diptera) family we comparatively low (18%). Macroinvertebrate predators make up the dominant FFG (42%). Many dragonflies (Anisoptera), damselflies (Zygoptera), and hemipterans were collected. While a majority of these individuals were mid to early instar nymphs, it is feasible that these populations were sustained on the large amounts of amphipods present and prey capture made easier by the pooled-up nature of the stream. Overall, the B-IBI score for this site was high (37).

Even though flow conditions were different between years (Table 15), the site on Bear Creek Tributary 14 improved in evenness and reduced dominance of few taxa (Table 16).

Table 16. Bear Creek Tributary 14 (BCT14) Benthic Macroinvertebrate Metrics

Study Year	Abundance	Richness	Evenness	Intol. Taxa (TV≤ 4)	Percent Chironomidae	Dominant 1 Taxa / 3 Taxa	Dominant FFG**	B-IBI Score & ALU
2004	--	--	--	--	--	--	--	--
2005	6539	30	0.566	6	34%	37% / 67%	CG 62%	33 H
2014	5688	36	0.730	5	18%	14% / 39%	P 42%	37 H

-- Site not sampled.

Bear Creek Tributary 19

BCT19: Downstream of Outfall 19 at Airfield Drive (32.87209, -97.05695)

Further downstream, another tributary joins Big Bear Creek. The surveyed reach lies roughly 600 m upstream from its confluence with Big Bear Creek.

Habitat Quality. The 150 m surveyed reach on Bear Creek Tributary 19 received a total habitat quality index score of 19, classifying this site as having an intermediate HQI classification. This reach was characterized by an abundant amount of unstable algal cover resulting in a cover index score of 2.5. The average instream cover was 68% with the majority consisting of algae, followed by cobble, overhanging vegetation, undercut banks, few macrophytes, and large concrete debris. Bottom substrate stability was determined to be moderately unstable, receiving an index score of 2, and was characterized by scarce amounts of gravel or larger sized substrate (28%) and bedrock and sand/silt as the dominant substrate type. Riffle habitats were common (number of riffles index score of 3). Three large pool habitats were observed (dimensions of largest pool index score of 4). Moderate flow conditions, resulting in an index score of 2, were observed as well. Bank stability received an index score of 1. This was based upon a bank slope of 37.1 degrees and an average bank erosion potential of 45%. Two moderately defined bends characterized the channel sinuosity of the surveyed reach, resulting in an index score of 1. The extent of the riparian vegetation buffer was determined to be between extensive and wide (riparian buffer vegetation index score of 2.5). The overall aesthetics of the surveyed reach was determined to be common, receiving an “aesthetics of reach” index score of 1. This score is based upon the observed stream uses including airport runoff and the presence of large urban debris (fallen bridge debris upstream and heavy channel stabilization with large rocks underneath the downstream bridge). A total habitat quality index score of 19 assigns an “intermediate” HQI classification to this stream.

Table 17. BCT19 HQI score, ALU classification, and flow conditions over sampling years.

Survey Year	HQI Score	ALU Classification	Flow (cfs)
2004	--	--	--
2005	24.0	High	0.99
2008	17.5	Intermediate	0.14
2014	19.0	Intermediate	0.06

-- Site not sampled.

This site was surveyed in 2005 and 2008 as well as during this current study. From 2005 to 2008 the habitat quality index classification went from high to intermediate (Table 17). This decrease may have been due to the destruction of the siltation fencing along the downstream transect, modifications to the instream substrate composition (large rock placement under bridge), and manipulation of upstream and downstream riparian areas (tree removal). From the 2008 survey to the present, the habitat quality index classification remained at intermediate. However, riparian areas had recovered by the 2014 survey.

Benthic Macroinvertebrates. Canopy cover was dense within the study reach, averaging 98% cover. Much of the reach contained bedrock with gravel sized substrate settled on top. This type of macroinvertebrate habitat would be subject to scour during large rain events and is not considered stable. However, this station did contain a diverse array of substrate types (boulders, macrophytes, undercut banks, etc.) providing habitat for a diverse array of macroinvertebrates. Taxa richness (43 taxa) at this site was among the highest of all sampling sites. Abundance was 6,293 individuals with 39% of those within the sub-family Chironominae (Diptera: Chironomidae) (All Chironomidae, 51%). The next most abundant taxa, *Caenis sp.* (Ephemeroptera: Caenidae) and *Fallceon sp.* (Ephemeroptera: Baetidae), only made up 11% and 9%, respectively, of the total sampled population. These proportions resulted in a lower than average evenness at this site (0.567). However, the calculated IBI remained high with a score of 39. This score is a slight increase from the 2005 survey (Table 18), metrics pertaining to taxa richness aided in improving that score.

Table 18. Bear Creek Tributary 19 (BCT19) Benthic Macroinvertebrate Metrics

Study Year	Abundance	Richness	Evenness	Intol. Taxa (TV≤ 4)	Percent Chironomidae	Dominant 1 taxa / 3 taxa	Dominant FFG	B-IBI Score & ALU
2004	--	--	--	--	--	--	--	--
2005	9225	28	0.545	6	70%	38% / 72%	CG 38%	35 H
2014	6293	43	0.567	7	51%	39% / 59%	P 34%	39 H

-- Site not sampled.

Little Bear Creek

LBA: Upstream of the golf course (32.86065, - 97.06379)

Little Bear Creek, is the next largest sub watershed in the study area. The study site is directly upstream of its confluence with the Big Bear Creek. This site also serves as an urbanized reference site for the study because it lies outside of DFW property but remains influenced by densely residential urban land use within its watershed.

Habitat Quality. Little Bear Creek upstream of the golf course received a habitat quality index score of 20.5, resulting in a HQI classification of high. This score is based on several habitat parameters observed in the 250 m reach that was assessed. Available instream cover consisted of macrophytes, algae, cobble and gravel, some woody debris, a few undercut banks, and some man-made/placed structures. An index score of 3, or common, was assigned to this reach due to the diversity of cover types and an average instream cover of 65%. Much of that percentage consists of the manmade structures placed there to stabilize the substrate. This gabion mesh was present in the first three transects and is being used to stabilize the bottom of the stream channel. Therefore, bottom substrate stability received an index score of 2.5. Also contributing to this score was the percentage of substrate consisting of gravel sized or larger was 52% and a dominant substrate type of cobble and sand. There were 5 riffles within the reach, resulting in an index score of 4, or abundant. The last two transects were large pools that covered the majority of the channel and had depths over 1 m. This qualified the site for dimensions of largest pool index score of 4. Channel flow status was considered high, resulting in an index score of 3.

Bank stability was determined to be moderately unstable (bank stability index score 1) based upon an average erosion potential of 48% and an average bank slope of 31 degrees. Channel sinuosity received an index score of 1 due to the presences of only 1 moderately defined bend in the upstream portion of the surveyed reach. The three downstream transects were channelized with rock gabion mesh under the Hwy 360 bridges before entering the golf course area. This region of the reach also had a narrow (<5 m) riparian buffer region compared to the upstream sites (10-20 m). For this reason, the reach received a riparian buffer vegetation index score of 1. The aesthetics of the reach was considered common (aesthetics of reach index score of 1) due to stream channelization, proximity to Highway 360, and the amount of urban debris found within the surveyed reach. A habitat index score of 20.5 assigns a "high" HQI classification to this stream. This is an increase from the "intermediate" determined in the 2008 survey (Table 19). This improvement in score is an example of how reduced flows can improve HQI scores by exposing more riffle areas and instream cover types.

Table 19. LBA HQI score, ALU classification, and flow conditions over sampling years.

Survey Year	HQI Score	ALU Classification	Flow (cfs)
2004	--	--	--
2005	--	--	--
2008	16.0	Intermediate	5.60
2014	20.5	High	0.79

-- Site not sampled.

Benthic macroinvertebrates. Little Bear Creek contained many riffles. These riffle substrates consisted of cobble and sand along with long stretches of manmade riprap. This riprap was primarily associated with sections of the stream directly under overhead bridges, while not natural, the riprap provided a stable substrate for macroinvertebrate habitat as well as establishment of macrophytes. Macrophytes were abundant in areas not shaded by the highway bridges. Collectively, these factors provided a heterogeneous mix of suitable substrate/habitat for macroinvertebrates. The taxa richness was 44 at this site, the second highest in the entire study. The high diversity of macroinvertebrates measured at this site is attributed to the high diversity of habitats found in this reach of Little Bear Creek. In contrast the evenness value of 0.547 was the lowest recorded during this study. The low evenness value is caused by populations of two taxa, Chironominae (Chironomidae: Diptera) and the amphipod, *Hylella azteca*, that account for 64% of 10,032 organisms, 46% and 18% respectively (Table 20). The high taxa richness observed at this site included all taxa expected, many that are classified as pollutant intolerant. This is evidence that even though the watershed upstream of the Little Bear Creek station is dominated by dense urban land uses, the water quality at this station is sufficient to maintain a high diversity of macroinvertebrates. The high dominance of two taxa and the resulting low evenness was the main factor in generating the low IBI score at Little Bear Creek of 29, or intermediate. The contrast in the high HQI score and taxa richness value but a low IBI score, is attributed to the unique habitat available at this site and the biological characteristics of the two dominant organisms.

Table 20. Little Bear Creek (LBA) Benthic Macroinvertebrate Metrics

Study Year	Abundance	Richness	Evenness	Intol. Taxa (TV≤ 4)	Percent Chironomidae	Dominant 1 Taxa / 3 Taxa	Dominant FFG	B-IBI Score & ALU
2004	--	--	--	--	--	--	--	--
2005	--	--	--	--	--	--	--	--
2014	10032	44	0.547	5	51%	46% / 69%	CG 34%	29 I

I = Intermediate, -- Site not sampled.

Many Chironominae taxa are epiphytic (live on or in plants), and amphipods are detritivores, feeding on decaying plant material. Both taxa often have high populations and dominate the community composition in beds of aquatic plants. The rock rubble riffles present at this site provide habitat for additional taxa. Collectively, these habitats contribute to a high diversity of macroinvertebrates. The expected high populations of Chironominae and amphipods associated with the plant community control the community composition and decrease the evenness values measured at this site. While indexes provide useful summaries for comparison and interpretation of community responses to the environment it is always important to understand the ecology of the system.

Bear Creek

BCB: Downstream of the golf course (32.85067, -97.05293)

A second site on Bear Creek was sampled downstream of the afore mentioned tributaries and roughly 300 m below the golf course that is located on DFW Airport property.

Habitat Quality. The middle reach site of Bear Creek received a total habitat quality index score of 18, classifying this site as having an intermediate HQI classification. This score and classification are based on several habitat parameters that were observed within the 500 m surveyed reach. The average available instream cover was 26.3% and was therefore rated as rare, receiving an index score of 2. Cover types consisted of algae, overhanging vegetation, some boulders and cobble, few macrophytes, and undercut banks. Most these cover types are not considered stable and further supports an index score of 2. Dominant substrate in the upper reaches consists of cobble and bedrock while the lower transects are silted pools. Bottom substrate stability was given an index score of 2 with an average of 23.3% gravel or larger sized substrate. Only one riffle was observed within the surveyed reach, which consisted of bedrock instead of cobble or gravel. This produces an index score of 2 for the number of riffles present. The pools were considered large with depths surpassing 1 m and therefore received an index score of 4. Moderate flow was observed at this site and was given an index score of 2 for channel flow status. Bank stability was determined to be moderately unstable based on the average erosion potential of 41.3% and an average bank angle of 50.4 degrees. This resulted in a bank stability index score of 1. Channel sinuosity received an index score of 1 and is reported at low with only 2 poorly defined bends. The riparian buffer vegetation was considered extensive, greater than 20 m, at all transects. This produced an index score of 3. Lastly, the aesthetics of the reach were considered common, an index score of 1, due to the golf course just upstream and the turbid nature of the water. The resulting habitat quality index score for this site is 18, or classified as intermediate. This is a slight improvement from previous surveys while maintaining the same HQI classification of intermediate (Table 21). In 2008, this site received a score of 15.5, the key difference being an increase of the extent of the riparian buffer vegetation.

Table 21. BCB HQI score, ALU classification, and flow conditions over sampling years.

Survey Year	HQI Score	ALU Classification	Flow (cfs)
2004	19.0	Intermediate	42.68
2005	16.0	Intermediate	6.80
2008	15.5	Intermediate	12.17
2014	18.0	Intermediate	0.93

Benthic Macroinvertebrates. Bedrock and silt dominated the substrate of this reach and riffles were rare. Macroinvertebrate samples were taken at the only riffle present within the reach. This Bear Creek site had one of the lowest abundances (3,244 total organisms) but an average taxa richness (35). Evenness here was 0.672, contributing to a IBI classification of high and a score of 37. Chironominae (Diptera: Chironomidae) and *Cheumatopsyche sp.* (Trichoptera: Hydropsychidae) were the dominate taxa at 26% and 14% respectively. Like the most upstream site on Big Bear Creek (BBC), filtering collectors were the dominant FFG at 38%. The filtering collectors group contained representatives from two genera of Trichoptera (*Cheumatopsyche sp.* and *Chimarra sp*.), the sub-family Chironominae, and the class Bivalvia. As discussed previously, an abundance of filter feeding collectors can indicate increased primary production caused by organic enrichment (Cummins, 1979) that often occurs downstream of a golf course with high fertilizer use.

Over the 10 year span of the study, many of the metrics seen in Table 22 have improved. Most notably, taxa richness and a reduction in the three taxa dominance.

Table 22. Bear Creek below Golf Course (BCB) Benthic Macroinvertebrate Metrics

Study Year	Abundance	Richness	Evenness	Intol. Taxa (TV≤ 4)	Percent Chironomidae	Dominant 1 Taxa / 3 Taxa	Dominant FFG	B-IBI Score & ALU
2004	1015	13	0.623	2	78%	38% / 81%	P 55%	21 I
2005	9046	24	0.646	5	35%	33% / 62%	FC 42%	33 H
2014	3244	35	0.672	5	33%	26% / 53%	FC 38%	37 H

Trigg Lake Tributary

TLT: Downstream of Trigg Lake dam (32.850952, -97.043780)

Trigg Lake Tributary flows from Trigg Lake to Bear Creek after travelling approximately 1300 m. The habitat and benthic bioassessment took place near the 300 m marker downstream from Trigg Lake dam. The lake was constructed as a stormwater retention pond for the airport and will be discussed separately in a later section.

Habitat Quality. The 150 m surveyed reach at Trigg Lake Tributary received a habitat index score of 14.5, classifying this site as having an intermediate habitat quality. Instream cover was generally abundant, an average of 52% for the transect measurements, but the majority was composed of loose algae that could be characterized as unstable (easily removed under increased flow conditions). Although the percentage of instream cover was comparatively high, the unstable and homogeneous nature of the cover resulted in a reduced cover index score of 2. Bottom substrate stability was determined to be unstable, with an index score of 1, based upon 16% average gravel sized or larger substrate composition and a dominant substrate type of bedrock/mudstone. There were no riffle areas observed within the surveyed reach, receiving an index score of 1. The entire reach was one large pool habitat with a maximum depth between 0.5-1 m (dimensions of largest pool index score of 3). Due to the unique nature of this type of outfall system, where Trigg Lake dam restricts flow for most of the year, the TCEQ habitat scoring criteria for stream flow is for channel flow status. A lack of flow characterizes this reach at the time of the survey, but since it is a dam, we would consider no flow to be "normal flow conditions." For this reason, a score of moderate, channel flow status index score of 2, was given to this site. The water fills greater than 75% of the channel. Bank stability was given an index score of 1.5, placing it between moderately stable and moderately unstable. This was based upon 36.5% average bank erosion potential and an average bank slope of 32.3 degrees. There were two poorly defined bends observed in the stream channel resulting in a channel sinuosity index score of 1. The extent of the riparian buffer was determined to be wide (riparian buffer vegetation index score of 2) due to both banks having a buffer width of greater than 20 m in the upstream portions and a buffer width of 10 m in the two downstream transects. The overall aesthetics of the surveyed reach was determined to be common, resulting in an index score of 1. This was due to the streams source water, when flowing, coming from Trigg Lake, a major catchment of airport runoff, and its developed urban surroundings. A habitat quality index score of 14.5 assigns a HQI classification of "intermediate" to this stream. Which is no change in classification from the previous 2008 study (Table 23).

Table 23. TLT HQI score, ALU classification, and flow conditions over sampling years.

Survey Year	HQI Score	ALU Classification	Flow (cfs)
2004	--	--	--
2005	--	--	--
2008	14.5	Intermediate	0.15
2014	14.5	Intermediate	No Flow

-- Site not sampled.

Benthic macroinvertebrates. The substrate at this site was dominated by sand and bedrock. The main source of instream habitat was provided by macrophytes, which were prolific. During the time of sampling this site lacked flow. The study reach consisted of one long continuous pool habitat. Taxa richness and evenness were both higher than average at 42 and 0.667, respectively. The most common taxa collected at Trigg Lake Tributary were from the sub-family Chironominae (Diptera: Chironomidae). This group made up 20% of the population. The next most abundant organism were gastropods, many of whom belong to the family Lymnaidae. This Gastropoda group made up 17% of the 12,272 organisms collected at this site. One change in taxa composition that took place across all sites that lacked flow, although occurred most prominently here, was the shift from the Elmid beetle genus *Stenelmis sp*. in flowing water habitats to *Dubiraphia sp*. in sites that lacked flow. *Dubiraphia sp*. is one of the only Elmid beetles found in lentic habitats and it has a slightly lower tolerance value (5) than the *Stenelmis sp*. (7). Another group that had a high occurrence here, and little at other sites, were two Hydroptilidae Caddisflies, *Ochotrichia sp*. (299 total abundance) and *Oxyethira sp*. (51 total abundance) (Trichoptera). These taxa are considered intolerant of low oxygen conditions with tolerance values of 4 and 2, respectively. The presence of these organisms elevated the count of intolerant taxa, contributing to the "High" ALU classification and the IBI score of 39.

Table 24. Trigg Lake Tributary (TLT) Benthic Macroinvertebrate Metrics

Study Year	Abundance	Richness	Evenness Score	Intol. Taxa (TV≤ 4)	Percent Chironomidae	Dominant 1 Taxa / 3 Taxa	Dominant FFG**	B-IBI Score & ALU
2004	--	--	--	--	--	--	--	--
2005	--	--	--	--	--	--	--	--
2014	12272	42	0.667	8	26%	20%	CG 31%	39 H

H = High, -- Site not sampled.

Bear Creek

BCC: At County Line Road (32.83264, -97.03021)

The furthest downstream site on Bear Creek is just outside (1.5 km) of airport property. From this point, Bear Creek flows for 13 km before flowing into the West Fork of the Trinity River.

Habitat Quality. The downstream site of Bear Creek received a total habitat quality index score of 19, resulting in an intermediate HQI classification. This score and classification are based on several habitat parameters observed within the 400 m reach surveyed. The available instream cover index score of 4 was based upon a 69% average instream cover and a diverse array of cover types. Instream cover types included abundant algae and macrophytes, overhanging vegetation, some boulders and cobble, undercut banks, and some urban debris like tires and cement fragments. Bottom substrate stability was determined to be moderately stable, with an index score of 3, based upon an average of 44% of the substrate being gravel sized or larger. There were 3 riffle habitats observed within the surveyed reach, resulting in an index score of 3. No pools were observed (dimensions of largest pool index score of 1). Channel flow status was moderate, receiving an index score of 2. Bank stability was determined to be moderately stable, with a score of 2, based upon an average erosion potential of 25% and an average bank slope of 45.2 degrees. Channel sinuosity was determined to be low (channel sinuosity index score of 1) based on two poorly defined bends observed within the surveyed reach. The extent of the riparian vegetation buffer averaged between 10 m and greater than 20 m for all transects, and is therefore classified as wide, receiving a riparian buffer vegetation index score of 2. The aesthetics of the stream were determined to be common, an index score of 1, based on the presence of a head cut dam upstream of the reach, the urban debris found within the stream channel, and the urban setting in which the stream resides. A habitat index score of 19 assigns this stream to the upper end of the "intermediate" HQI classification. No significant change was noted between the habitat quality index scores of past surveys (Table 25).

Table 25. BCC HQI score, ALU classification, and flow conditions over sampling years.

Survey Year	HQI Score	ALU Classification	Flow (cfs)
2004	--	--	--
2005	--	--	--
2008	19	Intermediate	17.02
2014	19	Intermediate	0.80

-- Site not sampled.

Benthic Macroinvertebrates. Cobble, gravel and sand are the major the substrate types at the Bear Creek at County Line Road site. Macrophytes and algae are abundant and can serve as an additional types of instream habitat. Taxa richness is around the average, 34, in relation to other study sites. Furthermore, the benthic macroinvertebrate population at this site is the most evenly distributed among the sites sampled (Evenness is 0.764). The family Chironomidae (Diptera) make up only 22% of the overall abundance (13,866). The next most abundant taxa group is *Stenelmis sp.* (Coleoptera: Elmidae) at 14%. The composition of FFG's are better distributed than other study sites. One group does not overly dominate the population and the proportion of predators is within the expected range (18%). This suggest a more balanced trophic structure relative to other sites. Overall, this high evenness of taxa and FFG's boosted this site to an IBI score of 41, resulting in the only non-reference site to receive a classification of "Exceptional."

Table 26. Bear Creek at County Line Road (BCC) Benthic Macroinvertebrate Metrics

Study Year	Abundance	Richness	Evenness	Intol. Taxa (TV≤ 4)	Percent Chironomidae	Dominant 1 Taxa / 3 Taxa	Dominant FFG	B-IBI Scores & ALU
2004	--	--	--	--	--	--	--	--
2005	--	--	--	--	--	--	--	--
2014	13866	34	0.764	5	22%	14% / 38%	CG 37%	41 E

E = Exceptional, -- Site not sampled.

Grapevine Creek

GVC: Downstream of Bridge at Railroad Tracks (32.93799, -97.02183)

Grapevine Creek is located on the northeast side of airport property and flows in a northeast direction into the Elm Fork of the Trinity River. The 150 m reach is located near a railroad crossing in a warehouse district. During this sampling event, the stream was not flowing and only pools were present. The most upstream transect was bounded by a beaver dam, slowing the flow of water downstream.

Habitat Quality. The surveyed reach on Grapevine Creek received a total habitat quality index score of 13, classifying this site has having limited HQI classification. Available instream cover received an index score of 1 and was considered absent. This was based upon a 17% average instream cover and the lack of diversity of stable instream cover types, which included: algae, woody debris, overhanging vegetation, and few macrophytes. Bottom substrate stability was characterized has having minimal (1%) gravel sized or larger substrate, as silt was the observed dominant substrate type. This resulted in a bottom substrate stability index score of 1. Riffle areas were determined to be absent, receiving an index score of 1. Most of the reach was one large pool and was therefore determined to be moderate in size (dimensions of largest pool index score of 3). Low to moderate flow conditions were observed within the reach, resulting in a channel flow status index score of 1.5. Bank stability was determined to be moderately unstable, with an index score of 1, based upon an average bank erosion potential of 51% and steep average bank slopes of 49 degrees. Channel sinuosity was determined to be moderate due to the presence of one well-defined bend and one poorly defined bend. This resulted in a channel sinuosity index score of 2. The extent of the riparian vegetation buffer varied throughout the reach and was determined to be between moderate and wide, with an index score of 1.5. The overall aesthetics of this site were considered to be common, an index score of 1, based on the observed stream uses (urban runoff), channel modifications and obstructions (old bridge pilings), channelization of the main stream channel. A habitat quality index score of 13 assigns a limited habitat quality index classification to this stream, which was consistent given the stream uses, channel modifications and obstructions.

Table 27. GVC HQI score, ALU classification, and flow conditions over sampling years.

Survey Year	HQI Score	ALU Classification	Flow (cfs)
2004	12.0	Limited	0.21
2005	--	--	--
2008	8.0	Limited	0.17
2014	13.0	Limited	No Flow

-- Site not sampled.

This stream was surveyed in 2005, 2008 as well as 2014 (Table 27). While the stream has remained at the “limited” classification, there were some observed changes within the reach over the years. Flow conditions were different between the surveys due to the observance of pool areas in the 2004 and 2014 surveys but a lack of pool areas in the 2008 survey. The 2008 study also noted a lack of tree canopy cover and a shorter riparian vegetated buffer throughout the reach compared to the 2014 survey. Further, because this site is located within a warehouse district area with known human impacts, and overall low flow status, the “limited” classification is representative of the stream’s location.

Benthic Macroinvertebrates. The substrate at this site was primarily silt. Other types of instream cover were rare and/or of poor quality (woody debris, algae, etc.). While, abundance and taxa richness was the highest at this site (13,867 individuals representing 47 taxa), evenness (0.606) was near the site wide average. *Hylella azteca* (Amphipoda) was the dominant taxa present (35%) and *Caenis sp*. (Ephemeroptera: Caenidae) was the next most common (16%). Both taxa contributed to collector gatherers being the most abundant FFG (38%). The shift from the Elmid beetle *Stenelmis sp.* to *Dubiraphia sp*. was also noted here. (See TLT site discussion.) Despite the limited HQI score (Table 28), taxa richness contributed to the ALU classification of “High” at Grapevine Creek (score 37).

Table 28. Grapevine Creek (GVC) Benthic Macroinvertebrate Metrics

Study Year	Abundance	Richness	Evenness	Intol. Taxa (TV≤ 4)	Percent Chironomidae	Dominant 1 Taxa / 3 Taxa	Dominant FFG	B-IBI Score & ALU
2004	1267	13	0.642	2	46%	39% / 80%	CG 46%	31 H
2005	--	--	--	--	--	--	--	--
2014	13867	47	0.606	7	12%	34% / 62%	CG 38%	37 H

H = High, -- Site not sampled.

Hackberry Creek

HBC: Next to runway (32.90813, -97.01000)

Hackberry Creek is also located on the northeast side of airport property. It receives some groundwater input and flows southeast into the Elm Fork of the Trinity River. The study site is located in the headwater region of the small stream and is adjacent to the airport runway.

Habitat Quality. The 150 m surveyed reach on Hackberry Creek received a total habitat quality index score of 16, classifying this site as having an intermediate habitat HQI classification. Available instream cover was classified as rare (available instream cover index score of 2) based upon a 42% average instream cover and consisted of unstable instream cover types like algae, gravel, overhanging vegetation, undercut banks, and woody debris. Bottom substrate stability was classified as unstable, resulting in an index score of 1, and was characterized by eroding mudstone and bedrock, which make for poor quality habitat, as dominant substrate types and an average of 21% gravel sized or larger substrate composition. Riffle habitats were common (number of riffles index score of 3) as 3 riffle areas were observed within the surveyed reach. Two small pool habitats were observed, receiving an index score of 2 for the dimensions of largest pool. Moderate flow conditions (channel flow status index score of 2) were observed. Bank stability was determined to be moderately stable, index score of 2, based upon bank angles of 32.5 degrees and moderate bank erosion potential (44%). Channel sinuosity received an index score of 1 due to the three poorly defined bends observed within the surveyed reach. The extent of the riparian vegetation buffer was approximately 10 m in the downstream portions and greater than 20 m in the upstream transects. It was therefore determined to be wide, with an index score of 2, for this reach. The overall aesthetics of the surveyed reach was concluded to be common, resulting in an index score of 1, based on the observed stream uses (urban and airport runoff) and the presence of channel obstructions or modifications (culverts). A habitat quality index score of 16 assigns an "intermediate" HQI classification to this stream. Compared to the three previous surveys (2004, 2005, 2008) the habitat index score has decreased slightly (Table 29), but remains within the intermediate habitat quality index classification.

Table 29. HBC HQI score, ALU classification, and flow conditions over sampling years.

Survey Year	HQI Score	ALU Classification	Flow (cfs)
2004	18.0	Intermediate	0.08
2005	18.0	Intermediate	0.27
2008	17.0	Intermediate	0.19
2014	16.0	Intermediate	0.01

Benthic Macroinvertebrates. At Hackberry Creek, the substrate consists of bedrock and eroding mudstone, which are not particularly good quality habitat for benthic macroinvertebrates. Overhanging vegetation and undercut banks were the main sources of instream cover observed. Hackberry Creek had the lowest abundance of all stream sites (3,129) and while taxa richness was good, at 30 taxa, it was the second lowest among sites. Conversely, evenness was comparatively high at 0.702. The dominant taxa present at this site were *Stenelmis sp*. (Coleoptera: Elmidae) and Chironomidae (Diptera) at 29% and 25%, respectively. Hackberry Creek had the fewest representatives from intolerant taxa groups (4 taxa). However, low abundance could have confounded many of these variables. As seen in table 30, low flow is commonplace at Hackberry Creek. It is possible that drought conditions reduced water levels to the point of decreasing the number of macroinvertebrates present. Nevertheless, with moderate taxa richness and high evenness this site remained "High" in its ALU classification.

Table 30. Hackberry Creek (HBC) Benthic Macroinvertebrate Metrics

Study Year	Abundance	Richness	Evenness	Intol. Taxa (TV≤ 4)	Percent Chironomidae	Dominant 1 Taxa / 3 Taxa	Dominant FFG	B-IBI Score & ALU
2004	4189	19	0.603	5	27%	44% / 71%	CG 30%	35 H
2005	7909	32	0.645	5	55%	24% / 55%	CG 31%	37 H
2014	3219	30	0.702	4	25%	29% / 51%	CG 39%	35 H

H = High

Reference Sites

Elm Fork of the Trinity River

EFT: Downstream of Lake Ray Roberts (33.33704, -97.03105)

The first reference site is a larger order stream than many of the study streams. It is approximately 3 km downstream of the Lake Ray Robert Dam and runs north to south. The site is located within Denton County, Texas and flows through a large greenbelt that runs from Lake Ray Roberts to Lake Lewisville. The sub-watershed surrounding the study site is dominated by agricultural practices.

Habitat Quality. A 500 m reach on the Elm Fork of the Trinity River was surveyed on 14 July 2014. The site received a habitat quality index score of 21, classifying this site as having a "high" HQI classification. Several habitat parameters contributed to this score and classification. Available instream cover was determined to be common, resulting in an index score of 3, based upon an average percent instream cover of 30.8% and the following instream cover types: overhanging vegetation, woody debris, undercut banks, and some large cobble and boulders. Bottom substrate stability was determined to be moderately stable, receiving an index score of 3, based upon 32.5% of the substrate composition being gravel sized or larger. There were a few types of dominant substrates present throughout this reach, including: gravel, cobble, sand, and bedrock. Riffle areas were abundant (number of riffles index score of 4) as 5 riffle areas were observed at this site. No true pool habitats were observed in the reach and, therefore, received an index score of 1. High flow conditions were observed (channel flow status index score of 3). Stream banks were classified as being moderately unstable, receiving an index score of 1, due to an average stream bank erosion potential of 41.6% and an average stream bank slope of 48.3 degrees. Channel sinuosity (see Table 4) was determined to be low, with an index score of 1. This was based on only observing two poorly defined stream bends. The riparian buffer was measured to be an average of greater than 20 m classifying it as extensive (riparian vegetation buffer index score of 3). The site aesthetics were determined to be a natural area, index score of 2, based upon the surrounding land use (nature park, trails, and pastures) and a lack of channel obstructions or modifications. A habitat index score of 21 assigns a "high" HQI classification, which was consistent for a stream of this type in a rural setting, which receives minimal urban anthropogenic impacts. Moreover, flow in this stream is consistent and maintained by continuous releases from the dam at Lake Ray Roberts. Finally, this is the first survey conducted on this reference stream by the University of North Texas for this study, thus no comparisons can be made across a temporal scale at this time.

Benthic Macroinvertebrates. Cobble, gravel, and sand dominated the bottom substrates. Macrophytes and algae were absent or rarely observed while woody debris and large logs were more common. The tree canopy covered, on average, 71% of the stream channel within the study reach, limiting plant growth. Of the 6,018 individuals sampled at the Elm Fork of the Trinity River, representing 38 taxa, *Cheumatopsyche sp.* and *Hydropsyche sp.* (Trichoptera: Hydropsychidae) made up 22% and 12%, respectively, of the sampled population. These taxa contribute to the dominance of the filter feeding FFG (40%). Filter feeders are commonly found downstream of dams and in streams located near heavy agricultural land use. Suspended organic materials, the main food source for filter feeders, are discharged from dams during water release. Additionally, agriculture practices can contribute to organic enrichment much like that of urban land uses mentioned at other sites. The next most abundant groups are the Baetidae mayflies (Ephemeroptera) *Baetis sp*. (11%) and *Fallceon sp.* (10%). Despite the dominance of the Hydropsychidae family of Caddisflies, the evenness metric is one of the highest among sampling sites (0.708). The mayfly order, Ephemeroptera, had the highest richness at this site with 8 different genera. In addition, the intolerant taxa (tolerance value ≤ 4) were represented by 10 different taxa, the most of any site within the study. These metrics allowed the Elm Fork of the Trinity River to receive the highest IBI score of 47 and a classification of "Exceptional."

South Bear Creek

SBC: At Highway 377 (32.580961, -97.598735)

South Bear Creek is located in the southeast corner of Parker County and serves as a reference site. The surveyed reach is near highway 377. Its watershed consists of rural (agriculture, pasture, etc.) and some residential land uses.

Habitat Quality. A 175 m reach of South Bear Creek was surveyed and received a total habitat quality index score of 23, classifying this site as having a high HQI classification. Several habitat parameters contributed to this score and classification. Available instream cover was determined to be common, receiving an index score of 3, based on a 68% average instream cover and following cover types: cobble and gravel, some woody debris, few macrophytes, and a common presence of algae. Bottom substrate stability was determined to be moderately stable, resulting in an index score of 3. The streambed substrate was characterized as having 66% gravel sized or larger substrate composition with a majority of the transects containing gravel as the dominant substrate type. Riffle habitats were determined to be common (number of riffles index score of 3) as three riffle habitats were observed within the surveyed reach. Two large pool habitats, over one meter in depth, were observed within this reach. This results in a “dimensions of largest pool” index score of 4. Flow conditions were considered low, resulting in a channel flow status index score of 1. Stream banks were determined to be moderately stable, resulting in an index score of 2, based upon an average bank erosion potential of 49% and an average bank slope of 22.1 degrees. One moderately defined bend and two poorly defined bends were observed within the reach, indicating moderate channel sinuosity (channel sinuosity index score of 2). The extent of the riparian vegetation buffer was determined to be extensive (riparian buffer vegetation score of 2) based upon an average tree canopy of 74.8% and a buffer width that was greater than 20 m. The overall aesthetics was determined to be a natural setting, an aesthetics of reach index score of 2, based on the observed stream uses (little development, farm houses, rural pastures, and clear water). A habitat quality index score of 23 assigns a “high” HQI classification for this stream. This is the first survey conducted on this reference stream for this study, thus no comparisons can be made across a temporal scale at this time.

Benthic Macroinvertebrates. The substrate of South Bear Creek consisted of gravel, sand and cobble. Macrophytes and woody debris were also present but in small amounts. These types of substrates can provide quality habitat for benthic macroinvertebrates. Average tree canopy cover for this reach was 75% allowing little light through for instream plant growth. Abundance at this site was 4,258, represented by 34 different taxa. Of those taxa, *Fallceon sp.* (Ephemeroptera: Baetidae) and Chironominae (Chironomidae: Diptera) made up 40% and 20% of the population collected, respectively. Evenness at South Bear Creek (0.579) was lower than average. This site was the only location that Stoneflies (Plecoptera) were collected. Overall, South Bear Creek was classified as an “High” aquatic life use with a score of 37.

Lentic Habitats

Trigg Lake was constructed on Airport property to collect stormwater runoff and provide aquatic habitat to the surrounding greenspace. A pond, constructed in 1987 as part of the University of North Texas Water Research Field Station, was surveyed as a non-urbanized reference site for

Trigg Lake. Habitat and benthic macroinvertebrate assessments are conducted differently in lentic systems due to the fundamental differences between lentic and lotic systems. These differences are why they are treated separately here.

Water Quality. Physico-chemical parameters collected at the time of sampling at located in Table 31. All water quality parameters were within normal ranges. Table 32 contains information on the depth profiles of each lake site. A detailed discussion of these results can be found in the site-by-site discussions below.

Table 31. Water quality parameters of lake sites.

Site ID*	Time	Max depth (m)	Surface Water Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH
TL	9:00 AM	3.87	28.9	7.30	500	8.49
WRFS	3:00 PM	1.52	34.2	18.5	900	9.88

* Refer to Table 3 for Site ID descriptions.

Table 32. Dissolved oxygen and temperature profile of the lentic habitats.

Trigg Lake (TL)			Water Research Field Station (WRFS)		
Depth (m)	**DO (mg/L)**	**Temperature (C°)**	**Depth (m)**	**DO (mg/L)**	**Temperature (C°)**
Surface	7.45	29.0	Surface	18.50	34.2
1.0	7.34	28.9	0.61	8.50	28.4
2.0	7.07	28.9	0.76	4.50	27.9
3.0	6.99	28.9	0.91	0.32	27.4
3.8	6.77	28.8	1.22	0.34	25.5
			1.52	0.31	24.2

Trigg Lake

TL: (32.855314, -97.045320)

Habitat Quality. The presence of many aerators within the lake contributed to the mixing of oxygenated water and a lack of a hypolimnion layer (Table 32). At the northern end of Trigg Lake where water is shallow and macrophytes are abundant, the surface water dissolved oxygen readings were consistent with mid-lake readings. The habitat survey began at the dock, located on the west side of the lake. Six stations were established at equal distances around the shoreline. The riparian zone vegetation varied by station, with some areas having more tree canopy coverage than others. Some sites were maintained by regular mowing. The substrate along the shoreline was dominated by sand and fine sediments and was heavily vegetated. The only site that varied from this pattern was at the dam where vegetative cover consisted of low grass and the bank substrate was concrete. Little human influence was evident except for the presence of the dam, nearby roads, and the occasional litter and urban debris. The littoral zone was predominately sands and silts and was anoxic in nature (i.e. was black in color and had a sulphur dioxide odor). The dominant macrophytes were cattails (*Typha spp.)*, American pondweed (*Potamogeton nodosus*), southern naiad (*Najas guadalupensis*), the non-native eurasion watermilfoil (*Myriophyllum spicatum*), and watermeal (*Wolffia spp*.) These macrophytes were the major, and sometimes only, source for fish cover. Towards the north end of the lake the water was shallow enough for light to penetrate to the benthic zone. This results in a section of the lake that is very dense with macrophytes like cattails (*Typha spp.)*, southern naiad (*Najas guadalupensis*), and the non-native eurasion watermilfoil (*Myriophyllum spicatum*). These dense cattails restricted our view of the riparian and littoral zones on the northern end of the lake, therefore, habitat characteristics could not be assessed in this region of the lake.

Benthic Macroinvertebrates. Benthic samples taken at Trigg lake contained 2307 individuals representing 16 different taxa. Oligochaeta (Annelidae), Chironominae (Diptera: Chironomidae), and *Chaoborus sp.* (Diptera: Chaoboridae) made up 40.3%, 24% and 13.4%, respectively, of the total population collected (Table 33).

Table 33. Trigg Lake and the Water Research Field Station Benthic Macroinvertebrate Metrics

Site ID* & Year	Abundance	Richness	Evenness	Percent Oligochaeta	Percent Chironomidae	Dominant Taxon	Dominant 3 Taxa
TL 2014	2307	16	0.605	40%	30%	40%	78%
WRFS 2014	1114	4	0.603	34%	4%	61%	69%

* Refer to Table 3 for Site ID descriptions.

University of North Texas Water Research Field Station Pond

WRFS: (33.20027, -97.21513)

Habitat Quality. The Water Research Field Station showed strong thermal stratification and a hypolimnetic zone with lower dissolved oxygen and temperature developed at approximately 1 meter (Table 32). The habitat survey was performed at five stations around the shoreline. The riparian zone vegetation varied by station, consisting of mostly grasses and forbs, with most sites lacking a canopy layer of trees. The substrate along the shoreline was dominated by fine sediments and was not heavily vegetated. Surrounding human influences included one home with outbuildings, associated lawns, and nearby roads. The littoral zone sediments were predominately silt with organic debris and an anoxic appearance (i.e. was black in color and had a sulphur dioxide odor). Emergent macrophytes were sparse along the shoreline and fish cover visible at the water's surface was lacking. These characteristics are typical of a small pond in a rural setting where shorelines are semi maintained. This is the first time a habitat survey was conducted at this site.

Benthic Macroinvertebrates. Of the 1114 organisms collected at the Water Research Field Station pond, only 4 taxa were represented. *Chaoborus sp*. (Diptera: Chaoboridae) accounted for 61% of the individuals and Oligochaeta (Annelidae) made up 34%. Chironominae (Diptera: Chironomidae) and Ceratopogonidae (Diptera) made up there other two taxa groups (Table 33).

Overall, Trigg Lake is in good ecological health. High dissolved oxygen levels throughout the benthic zone, well established and diverse riparian vegetation, and a comparatively diverse benthic macroinvertebrate community sets this lake apart from the reference site at the Water Research Field Station.

Conclusion

Habitat Quality. The majority of the study sites were classified as having an intermediate HQI classification. Little Bear Creek, upstream of the golf course and outside of the Airport's influence, was one exception. This urbanized site, along with both reference sites, scored high for habitat quality. The benthic substrate in this reach of Little Bear Creek was stabilized with riprap during the construction of a nearby bridge. This improves the ecological condition of the substrate habitat for aquatic organisms; increased macroinvertebrate diversity is associated with more stable substrates. Reductions in the shifting of the substrates also enabled the establishment of rooted aquatic plants observed at this station. This provides additional desirable habitat for benthic macroinvertebrates. However, the riprap is an artificial habitat that is not representative of the range of substrates expected in this ecoregion. This should be kept in mind when making comparisons between sites.

A few patterns associated with changes observed among sample years were evident in the individual components of the HQI score. In sites where the HQI score was reduced relative to previous years it was common to see a reduction in the channel flow status parameter of the HQI (BBC and BCT14). TCEQ defines channel flow status as *the degree to which water covers the entire available channel substrate from bank to bank ((TCEQ), 2014)*. Prevailing supra-seasonal drought conditions would certainly influence the flow status. (Flow data at each site between years is provided in Table 1B of Appendix 1.) Reduced flow in some sites left a large portion of the channel substrate exposed and not available for use by aquatic organisms. The available instream cover component of the assessment was also responsible for differences among years. Loose algal mats represent an unstable cover type and were common or abundant in many of the sites. The general instability of this type of cover had a negative effect on the instream cover index score and reduced the overall score for some sites despite the comparatively high amount of cover available. Reduced water levels can also influence the number of riffles and pools that are present.

HQI values for Bear Creek at County Line Road (BCC), Hackberry Creek, and the Trigg Lake Tributary were similar to values reported in previous years. Two sites, Big Bear Creek at Grapevine-Euless Rd (BBC) and Bear Creek Tributary 14 showed declines in their HQI scores relative to previous years. Four sites, Bear Creek below the golf course, Little Bear Creek above the golf course, Grapevine Creek, and Bear Creek Tributary 19 showed increases in their HQI scores (Table 34).

Increases in HQI scores could be attributed to changes in various habitat components and revealed few definitive patterns across sites (Table 1B: Appendix 1). For example, the HQI score for Grapevine Creek increased from 8 in 2008 to 13 in this survey. The increase appears to be related primarily to an increase in the width of the riparian buffer along the stream. The value calculated for this sampling event was also in line with the value of 12 calculated for this stream in the first assessment in 2004. The HQI calculated for the Bear Creek site below the golf course (BCB) also appears to have benefitted from an increase in the riparian buffer vegetation. Urban runoff from a residential area, which can maintain flow in urban streams during dry periods, may have aided the HQI score for Little Bear Creek where channel flow status was classified as high (water filled > 75% of the channel and < 5% of the substrate was exposed). Normal flow status and the presence of multiple riffles in the reach helped to increase the HQI score for Little Bear Creek.

Table 34. Habitat Quality Index (HQI) scores for 2004, 2005, 2008, 2014 survey events.

Site ID*	2004 HQI	2005 HQI	2008 HQI	2014 HQI	Classification
BBC	16.0	17.0	21.0	18.0	Intermediate
BCT14	--	18.0	21.0	14.5	Intermediate
BCT19	--	24.0	17.5	19.0	Intermediate
LBA	--	--	16.0	20.5	High
BCB	19.0	16.0	15.5	18.0	Intermediate
TLT	--	--	14.5	14.5	Intermediate
BCC	--	--	19.0	19.0	Intermediate
GVC	12.0	--	8.0	13.0	Limited
HBC	18.0	18.0	17.0	16.0	Intermediate
EFT*	--	--	--	21.0	High
SBC*	--	--	--	23.0	High

* Refer to Table 3 for Site ID descriptions. --, site not sampled
^ Denotes Reference Site.

Benthic macroinvertebrate community. Taxa richness and evenness scores at all sites reveal a healthy benthic community of receiving waters, especially in consideration of the urban setting in which these waters reside.

The IBI scores based on benthic macroinvertebrate samples resulted in a ALU classification of “high” or better in all sites but one. The urbanized reference site at Little Bear Creek (LBA) received a score of 29, or “Intermediate”, which is just below the threshold of “high” classification. As mentioned in earlier sections, this site had a discrepancy between scores (HQI of High) and serves as a prime example as to why well rounded surveys are needed to characterize aquatic ecosystems. Either of these assessments alone would provide a false picture of the stream’s health. However, when considered together, a clearer image of aquatic life can be obtained.

Overall, IBI scores increased, or remained similar, in comparison to previous surveys (Appendix 1A). This improvement can be attributed to high macroinvertebrate taxa richness and improved evenness across many sites during the 2014 study (Table 33). Only Hackberry Creek had a reduction of the IBI score, however, remained classified as “high” ALU. This occurrence could be attributed to the low abundance detected here as discussed in the previous section. Abundance of benthic macroinvertebrates can be influenced by any number of things; however, reduced flow conditions are likely to have played a role.

To summarize the entire watershed at DFW Airport, habitat and aquatic life, are in good condition especially when considering the urbanized watershed in which it resides. The DFW Airport covers approximately 17,000 acres, of that 1,785 acres consist of a large riparian forest that does not exist elsewhere within the watershed of Big Bear Creek or Little Bear Creek. This unique aspect of the DFW Airport has the potential to improve water quality by behaving as a protected riparian cross-timbers forest habitat in a heavily urbanized region. Dense residential neighborhoods encompass the upper reaches of these watershed and this tract of riparian forest would be subject to development or other changes in land use if not for the DFW Airport’s ownership.

Furthermore, the most downstream site, Bear Creek at County Line Road, despite receiving much of the runoff from airport property, had the highest B-IBI score (41) and was the only DFW site classified as "exceptional." This site had the highest evenness (0.764) and was unique in its lack of dominance by any one taxa group (Elmidae 14%, *Tricorythodes sp.* 12%). The HQI score at this BCC was "intermediate" (19). The main factors lowering this score were a result of the urban setting in which it was found and a lack of pool habitats. Overall, conditions were improved at this site compared to its upstream counterparts, supporting the idea that the DFW Airport, and its protected riparian forest, have the potential to improve water quality. Additional bioassessments at this site could further support or disprove this notion.

Bioassessments completed at Trigg Lake and the UNT Water Research Field Station revealed that Trigg Lake is in good ecological health. High dissolved oxygen levels throughout the benthic zone, well established and diverse riparian vegetation, and a comparatively diverse benthic macroinvertebrate community sets this lake apart from the reference site at the Water Research Field Station.

Land use analysis revealed little changes in land use between 2008 and 2014 on DFW Airport Property. Percent impervious surface (a combination of percent transportation land use and buildings land use) increased slightly from 27.2% in 2008 to 29.1% in 2014. The most abundant land use classification within the DFW Airport Property was the Mowed/Grazed/Herbaceous class at 46.1%. Overall, land use results in the study area were as expected in this rapidly growing urban region. Results of this study and its comparison to previous studies performed under different flow conditions point out the value of conducting bioassessments over a long time period to better separate changes in community structure due anthropogenic influences from expected natural variability caused by changes in factors such as flow, drought, etc.

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Appendix 1. Summary of Biological and Habitat Data

Table 1A. Comparisons of benthic macroinvertebrate metrics from 2004, 2005, 2014 studies.

Site ID and Stream Site	Parameter	2004	2005	2014
BBC: Big Bear Creek Grapeview-Euless Rd Bridge	Abundance	1224	3303	7837
	Taxa Richness	17	22	29
	Evenness	0.589	0.533	0.668
	B-IBI Score	32	29	39
	B-IBI Classification	High	Intermediate	High
BCT14: Bear Creek Tributary 14	Abundance	--	6539	5688
	Taxa Richness	--	30	36
	Evenness	--	0.566	0.730
	B-IBI Score	--	33	37
	B-IBI Classification	--	High	High
BCT19: Bear Creek Tributary 19	Abundance	--	9225	6293
	Taxa Richness	--	28	43
	Evenness	--	0.545	0.567
	B-IBI Score	--	35	39
	B-IBI Classification	--	High	High
LBA: Little Bear Creek	Abundance	--	--	10032
	Taxa Richness	--	--	44
	Evenness	--	--	0.547
	B-IBI Score	--	--	29
	B-IBI Classification	--	--	Intermediate
BCB: Bear Creek downstream of golf course	Abundance	1015	9046	3244
	Taxa Richness	13	24	35
	Evenness	0.623	0.646	0.672
	B-IBI Score	21	33	37
	B-IBI Classification	Intermediate	High	High
TLT: Trigg Lake Tributary	Abundance	--	--	12272
	Taxa Richness	--	--	42
	Evenness	--	--	0.667
	B-IBI Score	--	--	39
	B-IBI Classification	--	--	High
BCC: Bear Creek at County Line Rd.	Abundance	--	--	13866
	Taxa Richness	--	--	34
	Evenness	--	--	0.764
	B-IBI Score	--	--	41
	B-IBI Classification	--	--	Exceptional
GVC: Grapevine Creek	Abundance	1267	--	13867
	Taxa Richness	13	--	47
	Evenness	0.642	--	0.606
	B-IBI Score	31	--	37
	B-IBI Classification	High	--	High
HBC: Hackberry Creek	Abundance	4189	7909	3129
	Taxa Richness	19	32	30
	Evenness	0.603	0.645	0.702
	B-IBI Score	35	37	35
	B-IBI Classification	High	High	High

--, site not sampled

Appendix 1. Summary of Biological and Habitat Data – Continued.

Table 1B. Comparisons of physiochemical measurements taken during 2004, 2005, 2008, 2014 studies.

Site ID and Stream Site	Parameter	2004	2005	2008	2014
BBC: Big Bear Creek Grapeview-Euless Rd Bridge	Water Temperature C °	24.2	21.8	25.5	30.4
	D.O. (mg/L)	6.8	4.5	5.7	8.1
	pH	7.5	7.7	7.9	7.9
	Conductivity (uS/cm)	859	854	856	500
	Flow (CFS)	10.90	3.42	21.42	0.16
BCT14: Bear Creek Tributary 14	Water Temperature C °	--	19.9	26.2	22.7
	D.O. (mg/L)	--	8.0	7.0	5.6
	pH	--	8.1	8.4	7.9
	Conductivity (uS/cm)	--	1569	1484	1750
	Flow (CFS)	--	0.08	0.28	No flow
BCT19: Bear Creek Tributary 19	Water Temperature C °	--	22.4	29.3	27.5
	D.O. (mg/L)	--	8.0	8.7	5.3
	pH	--	7.6	8.6	7.8
	Conductivity (u/S)	--	1271	699	850
	Flow (CFS)	--	0.99	0.14	0.06
LBA: Little Bear Creek	Water Temperature C °	--	--	23.9	29.9
	D.O. (mg/L)	--	--	7.5	7.5
	pH	--	--	8.2	8.2
	Conductivity (uS/cm)	--	--	566	600
	Flow (CFS)	--	--	5.60	0.79
BCB: Bear Creek downstream of golf course	Water Temperature C °	24.9	21.7	27.1	27.1
	D.O. (mg/L)	8.1	5.0	7.1	7.2
	pH	7.6	7.9	8.2	7.7
	Conductivity (uS/cm)	570	812	805	600
	Flow (CFS)	42.68	6.80	12.17	0.93
TLT: Trigg Lake Tributary	Water Temperature C °	--	--	24.3	32.2
	D.O. (mg/L)	--	--	4.5	17.7
	pH	--	--	7.9	9.0
	Conductivity (uS/cm)	--	--	280	610
	Flow (CFS)	--	--	0.15	No flow
BCC: Bear Creek at County Line Rd.	Water Temperature C °	--	--	28.3	27.4
	D.O. (mg/L)	--	--	8.1	8.4
	pH	--	--	8.2	8.2
	Conductivity (uS/cm)	--	--	732	990
	Flow (CFS)	--	--	17.02	0.80
HBC: Hackberry Creek	Water Temperature C °	30.5	21.7	25.4	26.4
	D.O. (mg/L)	7.8	5.8	4.0	5.3
	pH	7.6	7.6	7.9	7.7
	Conductivity (uS/cm)	983	891	792	700
	Flow (CFS)	0.08	0.27	0.19	0.01
GVC: Grapevine Creek	Water Temperature C °	27.3	--	27.4	29.2
	D.O. (mg/L)	10.0	--	6.0	4.2
	pH	7.7	--	8.1	7.5
	Conductivity (uS/cm)	929.5	--	784	800
	Flow (CFS)	0.21	--	0.17	No flow

--, site not sampled.

Appendix 1. Summary of Biological and Habitat Data – Continued.

Table 1C. Taxa List and Site Abundances for 2014 DFW Airport Bioassessment.

Taxa	*FFG*	*TV*	*BBC*	*BCB*	*BCC*	*LBA*	*TLO*	*GVC*	*HBC*	*BCT14*	*BCT19*	*EFT*	*SBC*	*TL*	*WRFS*
Kingdom: Animalia															
Phylum: Annelida (Aquatic Worms)	CG	8	67	32	329	245	273	273	87	327	205	355	26	929	378
Subclass: Hirudinae (Leeches)	P	8	79	12	206	159	1	28	6		4	3	19	2	
Phylum: Nematoda	P	5			32			1			3				
Phylum: Platyhelminthes **Genus:** *Dugesia sp*. (Dugesiidae)	P	7.5	93	424	465	130	79	32	231	31	87	457		1	
Phylum: Mollusca (Mussels and Snails)															
Class: Gastropoda	SCR	7	7	13	1171	218	2054	274	12	87	4	1	10	50	
Class: Gastropoda **Tribe:** Ancylini (Limpets)	SCR	7	4	2	8	34	5	287		44	2	1			
Class: Bivalvia	FC	6	438	334	923	134	78	92		801		79		72	
Phylum: Arthropoda															
Class: Arachnida **Subclass:** Acari (Water Mites)	P	6	24		15	48	977	185	19	542	4	1	18	15	
SubPhylum: Crustacea **Order:** Amphipoda (Hyalella azteca)	CG/SHR	8	86	84	426	1810	1588	4806	19	817	1	2	9	201	
Class: Insecta															
Order: Collembola	CG			27		10		7		2	3	1	1		
Order: Ephemeroptera															
Baetis sp. (Baetidae)	SCR/CG	4	483	3	10							667			
Callibaetis sp. (Baetidae)	CG	4					301	798		112	10				
Fallceon sp. (Baetidae)	SCR/CG	4	1502	283	619	230			58		561	612	1699		
Caenis sp. (Caenidae)	SCR/CG	7	146	7	26	171	292	2283	391	508	683	103	85	6	
Leucrocuta sp. (Heptageniidae)	SCR/CG											69			
Maccaffertium sp. (Heptageniidae)	SCR/CG												184		
Stenacron sp. (Heptageniidae)	SCR/CG	4	30	1				24			7	30			
Isonychia sp. (Isonychiidae)	FC	3										123			
Tricorythodes sp. (Leptohypidae)	CG	5	80	18	1694	300	16		2		44	309	3		
Leptophlebidae (early instar)		2										6			
Order: Odonata															
Anisoptera (early instar)	P				4	8	221	577	3		1	7	9		
Basiaeschna sp. (Aeshnidae)	P	2				1	4								
Nasiaeschna sp. (Aeshnidae)	P	8				1		29		4					
Epitheca sp. (Corduliidae)	P	4					255	39		190				1	
Hetaerina sp. (Calopterygidae)	P	6		3	40	88			8						
Argia sp. (Coenagrionidae)	P	6	51	15	773	500	38	434	177	191	551	12	269		
Enallagma sp. (Coenagrionidae)	P	6			18	87	123	1037		468	4				
Ischnura sp. (Coenagrionidae)	P	9				21	92	34		2					
Gomphidae (early instar)	P	1	8			1		27		29	3		134		
Erpetogomphus sp. (Gomphidae)	P	1					11		21			21			
Libellulidae (early instar)	P									58					

Appendix 1. Summary of Biological and Habitat Data – Continued.

Table 1C. Taxa List and Site Abundances for 2014 DFW Airport Bioassessment. - Continued

Taxa	FFG	TV	BBC	BCB	BCC	LBA	TLO	GVC	HBC	BCT14	BCT19	EFT	SBC	TL	WRFS
Order: Plecoptera															
Perlidae (early instar)	P												3		
Order: Orthoptera															
Ellipes sp. *(*Tridactylidae)	SHR					1			1	1					
***Order:** Hemiptera*															
Belostomatidae	P					1		6			3				
Corixidae	P/CG	9						7							
Trepobates sp. (Gerridae)	P	5	5	1	4	2	27	254		138	14		1		
Rheumatobates sp. (Gerridae)	P	5				5		61		25	1				
*Hydrometra sp. (*Hydrometridae)	P						2	4							
*Mesovelia sp. (*Mesoveliidae*)*	P						6	1		9	1			1	
Naucoridae	P	5					2								
Ranatra sp. *(*Nepidae)	P	7					1								
Neoplea sp. (Pleidae)	P						14					1			
Saldidae	P			2											
Microvelia sp. (Veliidae)	P		5	16		9	4	3	2	2	9		11		
Rhagovelia sp. (Veliidae)	P		1	4	9	5					38	1			
Order: Megaloptera															
Corydalus sp. (Corydalidae)	P	6	5	87	18	6			2			236			
Order: Neuroptera															
Climacia sp. (Sisyridae)				2		17	2								
Order: Trichoptera															
Helicopsyche sp. (Helicopsychidae)	SCR	2										219	1		
Cheumatopsyche sp. (Hydropsychidae)	FC	6	1845	442	1206	222		2	34	1	207	1334	436		
Hydropsyche sp. (Hydropsychidae)	FC	5										698			
Hydroptila sp. (Hydroptilidae)	SCR	2	13	33	268	204	21	4	104	1	22	3	54		
Ochotrichia sp. (Hydroptilidae)	CG	4					299			1					
Oxyethira sp. (Hydroptilidae)	CG/SCR	2					51	2					6		
Ceraclea sp. (Leptoceridae)	P/CG/SHR			6	9	4									
Oecetis sp. (Leptoceridae)	P/SHR	5		1	37	29	87			1		59	1	4	
Chimarra sp. (Philopotamidae)	FC	2	1180	159	221	15			1		383		70		
Cernotina sp. (Polycentropodidae)	P	6	1					15							
Neuroeclipsis sp. (Polycentropodidae)	FC/SHR/P	4										5			
Order: Lepidoptera															
Petrophila sp. (Crambidae)	SCR	5	24	4	160	47			9		14	21	3		
Synclita sp. (Crambidae)	SHR							12							

Appendix 1. Summary of Biological and Habitat Data – Continued.

Appendix 1C. Taxa List and Site Abundances for 2014 DFW Airport Bioassessment. - Continued

Taxa	FFG	TV	BBC	BCB	BCC	LBA	TLO	GVC	HBC	BCT14	BCT19	EFT	SBC	TL	WRFS
Order: Coleoptera															
Celina sp. (Dytiscidae)	P	5		1				1							
Hydrovatus sp. (Dytiscidae)	P	5						1							
Uvarus sp. (Dytiscidae)	P	5							3						
Dubiraphia sp. (Elmidae)	SCR/CG	5					1492	209		4					
Stenelmis sp. (Elmidae)	SCR/CG	7	109	116	2002	88		12	895		34	21	37		
Dineutus sp. (Gyrinidae)	P	5									7				
Peltodytes sp. (Haliplidae)	SHR/P	8			1		1	8			4				
Berosus sp. (Hydrophilidae)	CG	9		1	91	8	10	45	183	31	91		2		
Enochrus sp. (Hydrophilidae)	CG	8						2			2		1	1	
Hydrobius sp. (Hydrophilidae)				1		2	2								
Tropisternus sp. (Hydrophilidae)	CG	10											5		
Paracymus sp. (Hydrophilidae)											1				
Order: Diptera															
Ceratopogonidae	P/CG	5	8	29	5	74	593	283	43	218	52	1	33	25	11
Chaoborus sp. (Chaoboridae)	P	4					1	4						308	682
Chironomidae (Pupae)		6	76	22	168	88	156	87	58	79	97	17	46	3	1
Chironominae (Chironomidae)	CG/FC/P	6	1039	858	1624	4630	2418	1025	296	601	2477	346	831	553	42
Orthocladinae (Chironomidae)	CG	6	68	64	898	83	87	11	117	3	133	76	55		
Tanypodinae (Chironomidae)	P	6	360	137	382	285	566	530	314	356	496	78	124	135	
Anopheles sp. (Culicidae)	FC	9					9	2		1	2				
Culex sp. (Culicidae)	FC/CG	8					11			1	16				
Morphotype 1 (Empididae)	P	8							13						
Hemerodromia sp. (Empididae)	P/CG	6									7	3			
Psychodidae						1									
Simulium sp. (Simuliidae)	FC	4			4						4	38	65		
Stratiomyidae	CG	7				3	2	6	19	1	1				
Tabanidae	P	7								1		2	6		
Tipulidae	SHR/CG					7		3	1				1		
Total Abundance			7837	3244	13866	10032	12272	13867	3129	5688	6293	6018	4258	2307	1114

Appendix 1. Summary of Biological and Habitat Data – Continued.

Table 1D. Land Use Analysis Results for 2014 and 2008.

2014 Land Cover Classifications by Watershed within DFW International Airport Boundary																
Watersheds	Bare Ground		Buildings		Manicured		Mowed/Grazed/Herbaceous		Transportation		Water		Wooded		Total	% Impervious
Cottonwood Branch N.	60.0	4.5%	12.2	0.9%	0.0	0.0%	736.3	55.8%	102.3	7.8%	16.5	1.3%	289.0	21.9%	1,216.3	9.4%
Cottonwood Branch S.	0.0	0.0%	0.0	0.0%	0.0	0.0%	93.9	62.8%	9.4	6.3%	1.6	1.1%	29.3	19.6%	134.2	7.0%
Denton Creek	0.1	0.1%	0.0	0.0%	0.0	0.0%	100.2	63.2%	4.0	2.5%	1.2	0.8%	52.2	32.9%	157.7	2.5%
Estelle Creek	0.8	0.1%	0.8	0.1%	0.0	0.0%	549.6	78.7%	36.0	5.2%	6.5	0.9%	104.2	14.9%	697.9	5.3%
Grapevine Creek	4.8	0.2%	235.8	8.6%	0.0	0.0%	1,300.9	47.6%	1,044.6	38.3%	11.0	0.4%	100.9	3.7%	2,698.0	47.5%
Hackbery Creek	2.2	0.3%	8.2	1.0%	0.0	0.0%	398.5	50.0%	265.3	33.3%	4.8	0.6%	118.0	14.8%	797.0	34.3%
Mud Springs Creek	2.9	0.1%	19.8	0.9%	0.0	0.0%	1,329.6	61.5%	729.9	33.8%	11.9	0.6%	70.7	3.3%	2,164.8	34.6%
S. Fork Hackberry Creek	0.0	0.0%	3.4	0.5%	0.0	0.0%	393.5	52.9%	62.2	8.4%	9.5	1.3%	275.1	37.0%	743.7	8.8%
Upper Bear Creek	29.2	0.4%	247.4	3.0%	162.5	2.0%	3,148.6	38.1%	2,226.6	26.9%	108.2	1.3%	2,324.2	28.1%	8,246.7	30.0%
Unspecified Watershed															331.6	
Total Class for DFW	100.0	0.6%	527.6	3.1%	162.5	0.9%	8,051.1	46.8%	4,480.3	26.1%	171.2	1.0%	3,363.6	19.6%	17,187.9	29.1%

2008 Land Cover Classifications by Watershed within DFW International Airport Boundary																					
Watersheds	**Bare Ground**		**Buildings**		**Herbaceous**		**Manicured**		**Mowed or Grazed**		**Transportation**		**Water**		**Wooded**		**Unclassified**		**Total**	**% Impervious**
Cottonwood Branch N.	8.7	0.7%	9.5	0.7%	481.3	36.5%	0.7	0.1%	417.4	31.6%	60.6	4.6%	9.0	0.7%	332.3	25.2%	0.0	0.0%	1,319.6	5.3%
Cottonwood Branch S.	0.0	0.0%	1.1	0.7%	18.4	12.3%	0.0	0.0%	108.7	72.7%	14.9	10.0%	0.0	0.0%	6.4	4.3%	0.0	0.0%	149.5	10.7%
Denton Creek	0.0	0.0%	0.1	0.1%	29.9	18.4%	0.0	0.0%	40.0	24.6%	4.3	2.7%	0.7	0.4%	87.5	53.9%	0.0	0.0%	162.5	2.7%
Estelle Creek	0.0	0.0%	1.3	0.2%	262.1	37.5%	0.1	0.0%	317.7	45.5%	32.8	4.7%	0.5	0.1%	84.2	12.0%	0.0	0.0%	698.7	4.9%
Grapevine Creek	105.8	3.9%	210.0	7.7%	183.5	6.7%	1.5	0.1%	1,196.1	43.8%	919.2	33.7%	4.2	0.2%	110.2	4.0%	0.1	0.0%	2,730.5	41.4%
Hackbery Creek	0.3	0.0%	6.9	0.9%	76.7	9.6%	0.0	0.0%	378.3	47.5%	226.0	28.4%	0.0	0.0%	108.9	13.7%	0.0	0.0%	797.0	29.2%
Mud Springs Creek	0.0	0.0%	12.8	0.6%	145.1	6.7%	0.3	0.0%	1,226.7	56.7%	694.5	32.1%	0.0	0.0%	83.3	3.9%	0.0	0.0%	2,162.6	32.7%
S. Fork Hackberry Creek	0.0	0.0%	3.7	0.5%	272.8	36.7%	0.2	0.0%	278.6	37.4%	44.9	6.0%	0.0	0.0%	144.2	19.4%	0.0	0.0%	744.4	6.5%
Upper Bear Creek	77.4	0.9%	281.7	3.4%	1,773.4	21.5%	189.4	2.3%	1,444.1	17.5%	2,112.0	25.5%	60.5	0.7%	2,325.6	28.1%	2.7	0.0%	8,266.8	29.0%
Unspecified Watershed																			33.5	
Total Class for DFW	192.1	1.1%	527.2	3.1%	3,243.2	19.0%	192.1	1.1%	5,407.6	31.7%	4,109.3	24.1%	74.9	0.4%	3,282.5	19.2%	2.8	0.0%	17,065.1	27.2%

Appendix 1. Summary of Biological and Habitat Data – Continued.

Table 1D. Land Use Analysis Results for 2014 and 2008 – Continued.

2014 Land cover acreage totals for Cities within Study Area																		
Jurisdictions	Bare Ground		Buildings		Manicured		Mowed/Grazed/ Herbaceous		Transportation		Water		Wooded		Total Acres within City	% of total Study Area	Total Impervious Surface % (Buildings + Transportation)
	Acres	% of City	Acres	% of City	Acres	% of City	Acres	% of City	Acres	% of City	Acres	% of City	Acres	% of City			
Bedford	5.2	0.35%	314.1	21.34%	0.0	0.00%	593.6	40.33%	324.3	22.03%	11.4	0.77%	223.2	15.17%	1471.8	1.5%	43.4%
Carrollton	0.2	0.04%	0.2	0.04%	0.0	0.00%	117.2	26.24%	15.6	3.49%	13.5	3.02%	300.0	67.16%	446.7	0.5%	3.5%
Colleyville	97.2	1.16%	1023.9	12.24%	61.0	47.03%	3459.2	41.36%	1262.1	15.09%	129.7	1.55%	2331.0	27.87%	8364.1	8.5%	27.3%
Coppell	96.1	1.14%	1543.1	18.23%	52.4	34.34%	3743.9	44.23%	1749.1	20.66%	152.6	1.80%	1127.0	13.31%	8464.2	8.6%	38.9%
Dallas	182.7	11.26%	13.4	0.83%	0.0	0.00%	499.0	30.76%	194.5	11.99%	460.3	28.38%	272.1	16.78%	1622.0	1.7%	12.8%
DFW Airport	105.8	0.62%	528.1	3.10%	164.7	95.70%	8146.6	47.86%	4541.6	26.68%	172.1	1.01%	3364.2	19.76%	17023.1	17.3%	29.8%
Euless	108.3	2.82%	626.3	16.33%	0.8	2.28%	1460.0	38.06%	873.1	22.76%	35.1	0.92%	732.1	19.09%	3835.7	3.9%	39.1%
Flower Mound	92.1	6.62%	146.8	10.55%	11.3	83.70%	529.7	38.08%	301.5	21.67%	13.5	0.97%	296.3	21.30%	1391.2	1.4%	32.2%
Fort Worth	70.3	2.03%	435.0	12.59%	2.4	5.61%	1947.4	56.36%	862.4	24.96%	42.8	1.24%	94.9	2.75%	3455.2	3.5%	37.5%
Grand Prairie	86.8	3.12%	206.4	7.43%	12.3	18.41%	1119.8	40.31%	530.6	19.10%	66.8	2.40%	755.0	27.18%	2777.7	2.8%	26.5%
Grapevine	86.1	1.15%	935.2	12.44%	186.6	191.19%	2403.2	31.97%	2205.5	29.34%	97.6	1.30%	1601.9	21.31%	7516.1	7.7%	41.8%
Haslet	1.1	1.29%	1.1	1.29%	0.0	0.00%	78.2	91.68%	4.6	5.39%	0.1	0.12%	0.2	0.23%	85.3	0.1%	6.7%
Hurst	0.2	0.03%	137.2	20.73%	0.0	0.00%	246.6	37.27%	144.0	21.76%	4.5	0.68%	129.2	19.53%	661.7	0.7%	42.5%
Irving	356.1	1.79%	2793.5	14.06%	408.4	89.70%	7848.6	39.51%	5457.0	27.47%	455.3	2.29%	2547.2	12.82%	19866.1	20.2%	41.5%
Keller	130.9	1.41%	1203.8	12.96%	158.6	144.58%	4821.9	51.90%	1524.8	16.41%	109.7	1.18%	1341.9	14.44%	9291.6	9.5%	29.4%
Lewisville	58.7	3.07%	238.5	12.47%	0.0	0.00%	834.9	43.66%	532.7	27.86%	25.0	1.31%	222.5	11.64%	1912.3	1.9%	40.3%
North Richland Hills	76.4	2.71%	427.3	15.14%	0.0	0.00%	1373.3	48.65%	524.9	18.59%	26.5	0.94%	394.7	13.98%	2823.1	2.9%	33.7%
Southlake	95.1	1.62%	703.1	11.96%	85.1	95.62%	2570.3	43.71%	979.0	16.65%	89.0	1.51%	1359.0	23.11%	5880.6	6.0%	28.6%
Tarrant County	19.7	1.47%	105.8	7.89%	2.0	17.39%	885.9	66.10%	233.2	17.40%	11.5	0.86%	82.1	6.13%	1340.2	1.4%	25.3%
Total acres by Class	1669.0		11382.8		1145.6		42679.3		22260.5		1917.0		17174.5		98228.7		
% of total Study Area		1.7%		11.6%		1.2%		43.4%		22.7%		2.0%		17.5%			34.2%

2008 Land cover acreage totals for Cities within Study Area																					
Jurisdictions	Bare Ground		Buildings		Herbaceous		Manicured		Mowed or Grazed		Transportation		Water		Wooded		Unclassified		Total Acres within City	% of total Study Area	Total Impervious Surface % (Buildings + Transportation)
	Acres	% of City	Acres	% of City	Acres	% of City	Acres	% of City	Acres	% of City	Acres	% of City	Acres	% of City	Acres	% of City	Acres	% of City			
Bedford	11.9	0.81	324.0	22.01	200.5	13.62	22.1	1.50	283.1	19.23	239.3	16.26	7.2	0.49	332.2	22.57	51.4	3.49	1471.5	1.5%	38.3%
Carrollton	0.0	0.00	0.7	0.16	20.7	4.64	2.1	0.48	64.3	14.40	1.4	0.32	19.3	4.32	210.8	47.20	0.0	0.00	446.6	0.5%	0.5%
Colleyville	74.4	0.89	1416.6	16.94	1215.1	14.53	134.6	1.61	2323.1	27.78	995.1	11.90	107.9	1.29	2030.4	24.28	64.4	0.77	8362.6	8.5%	28.8%
Coppell	284.3	3.36	1003.5	11.86	182.8	2.16	98.2	1.16	3024.1	35.74	1577.2	18.64	131.2	1.55	1952.9	23.08	0.8	0.01	8461.4	8.6%	30.5%
Dallas	0.0	0.00	6.3	0.39	190.8	11.77	1.9	0.12	527.1	32.51	36.0	2.22	792.7	48.89	65.8	4.06	0.0	0.00	1621.4	1.7%	2.6%
DFW Airport	191.0	1.12	526.9	3.09	3236.4	18.98	191.0	1.12	5396.9	31.65	4104.4	24.07	75.0	0.44	3279.1	19.23	35.8	0.21	17051.8	17.4%	27.2%
Euless	24.9	0.65	807.1	21.05	607.0	15.83	37.2	0.97	740.0	19.30	659.9	17.21	23.0	0.60	929.1	24.23	6.9	0.18	3834.4	3.9%	38.3%
Flower Mound	28.2	2.03	96.0	6.90	220.6	15.86	1.0	0.07	412.0	29.62	244.6	17.59	9.0	0.65	377.9	27.17	0.0	0.00	1390.8	1.4%	24.5%
Fort Worth	236.0	6.83	497.5	14.40	1078.9	31.23	9.0	0.26	683.0	19.77	697.8	20.20	24.9	0.72	223.9	6.48	4.1	0.12	3454.7	3.5%	34.6%
Grand Prairie	81.1	2.92	154.4	5.56	582.6	20.98	0.0	0.00	397.7	14.32	347.7	12.52	125.8	4.53	1092.4	39.34	0.3	0.01	2776.9	2.8%	18.1%
Grapevine	6.8	0.09	1337.5	17.80	831.8	11.07	175.8	2.34	1755.3	23.36	1692.2	22.52	64.6	0.86	1569.0	20.88	4.5	0.06	7514.2	7.6%	40.3%
Haslet	1.0	1.18	2.0	2.35	60.1	70.59	0.0	0.00	17.0	19.99	4.3	5.06	0.0	0.02	0.4	0.48	0.0	0.02	85.2	0.1%	7.4%
Hurst	1.1	0.17	150.4	22.73	85.9	12.99	4.7	0.71	164.7	24.89	76.9	11.62	2.0	0.30	174.9	26.43	0.7	0.10	661.6	0.7%	34.4%
Irving	391.2	1.97	1916.5	9.65	1138.0	5.73	258.2	1.30	5846.7	29.44	4671.0	23.52	419.0	2.11	4458.5	22.45	2.0	0.01	19859.6	20.2%	33.2%
Keller	123.6	1.33	1525.5	16.42	1657.4	17.84	68.7	0.74	2527.0	27.20	1207.8	13.00	55.7	0.60	2033.7	21.89	91.0	0.98	9290.5	9.5%	29.4%
Lewisville	1.3	0.07	160.0	8.37	213.5	11.17	11.9	0.62	779.9	40.80	385.6	20.17	20.8	1.09	332.8	17.41	0.0	0.00	1911.6	1.9%	28.5%
North Richland Hills	42.1	1.49	516.3	18.29	421.1	14.92	14.7	0.52	773.1	27.39	399.7	14.16	9.0	0.32	624.4	22.12	22.0	0.78	2822.7	2.9%	32.5%
Southlake	35.3	0.60	1108.3	18.85	759.0	12.91	65.9	1.12	1802.1	30.65	767.9	13.06	78.2	1.33	1197.1	20.36	6.5	0.11	5879.5	6.0%	31.9%
Tarrant County	53.2	3.97	148.0	11.04	593.0	44.25	2.8	0.21	265.1	19.78	159.1	11.87	4.8	0.36	114.1	8.51	0.0	0.00	1340.2	1.4%	22.9%
Total acres by Class	1587.4		11697.4		13295.4		1099.7		27782.2		18267.9		1970.3		20999.2		290.4		98237.2		30.5%
% of total Study Area		1.6%		11.9%		13.5%		1.1%		28.3%		18.6%		2.0%		21.4%		0.3%			

Appendix 1. Summary of Biological and Habitat Data – Continued.

Table 1D. Land Use Analysis Results for 2014 and 2008 – Continued.

2014 Land Cover Classifications by Watershed																	% of Total Area	% Impervious (Buildings + Transportation)
Watershed	Bare Ground		Buildings		Manicured		Mowed/Grazed/Herbaceous		Transportation		Water		Wooded		Total			
Cottonwood Branch N	86.42	2.0%	462.29	10.7%	35.10	0.8%	1895.15	43.7%	1131.45	26.1%	45.08	1.0%	679.15	15.7%	4334.64		4.41%	36.77%
Cottonwood Branch S	11.07	0.3%	477.52	15.1%	274.92	8.7%	1246.22	39.3%	757.22	23.9%	53.48	1.7%	350.72	11.1%	3171.15		3.23%	38.94%
Denton Creek	250.24	2.8%	1138.54	12.7%	184.94	2.1%	3616.66	40.2%	1804.89	20.1%	211.78	2.4%	1790.78	19.9%	8997.83		9.16%	32.71%
Estelle Creek	17.00	0.9%	136.21	7.2%	0.00	0.0%	1086.38	57.1%	479.62	25.2%	17.56	0.9%	164.52	8.7%	1901.29		1.94%	32.39%
Grapevine Creek	192.74	2.2%	1030.20	12.0%	11.08	0.1%	3599.78	42.0%	2357.79	27.5%	507.75	5.9%	870.87	10.2%	8570.21		8.73%	39.53%
Hackberry Creek	239.48	3.9%	663.45	10.7%	120.61	1.9%	2562.97	41.2%	1934.85	31.1%	116.25	1.9%	578.68	9.3%	6216.29		6.33%	41.80%
Lower Bear Creek	180.63	1.6%	1474.30	13.3%	24.27	0.2%	4371.47	39.6%	2428.89	22.0%	315.08	2.9%	2255.42	20.4%	11050.06		11.25%	35.32%
Mud Springs Creek	2.97	0.1%	27.18	1.2%	0.00	0.0%	1347.08	60.8%	750.39	33.9%	11.95	0.5%	75.86	3.4%	2215.43		2.26%	35.10%
S. Fork Hackberry Creek	0.14	0.0%	88.32	4.9%	0.00	0.0%	872.19	48.5%	425.65	23.6%	30.07	1.7%	383.52	21.3%	1799.89		1.83%	28.56%
Upper Bear Creek	688.13	1.4%	5883.62	11.8%	494.54	1.0%	22075.37	44.2%	10187.70	20.4%	607.83	1.2%	10022.99	20.1%	49960.18		50.87%	32.17%
															98216.97		100.00%	

2008 Land Cover Classifications by Watershed																				
Watershed	Bare Ground		Buildings		Herbaceous		Manicured		Mowed or Grazed		Transportation		Water		Wooded		Unclassified		Total	% of Total Area
Cottonwood Branch N	65	1.5%	351	8.1%	550	12.7%	52	1.2%	1,547	35.7%	841	19.4%	22	0.5%	910	21.0%	0	0.0%	4,337	4.4%
Cottonwood Branch S	3	0.1%	304	9.6%	89	2.8%	92	2.9%	1,303	41.1%	698	22.0%	51	1.6%	631	19.9%	1	0.0%	3,172	3.2%
Denton Creek	36	0.4%	774	8.6%	648	7.2%	171	1.9%	3,158	35.1%	1,511	16.8%	225	2.5%	2,483	27.6%	1	0.0%	9,006	9.2%
Estelle Creek	53	2.8%	86	4.5%	310	16.3%	4	0.2%	835	43.9%	407	21.4%	10	0.5%	200	10.5%	0	0.0%	1,903	1.9%
Grapevine Creek	300	3.5%	788	9.2%	437	5.1%	43	0.5%	3,170	37.0%	1,979	23.1%	797	9.3%	1,054	12.3%	1	0.0%	8,569	8.7%
Hackberry Creek	149	2.4%	578	9.3%	354	5.7%	99	1.6%	2,318	37.3%	1,796	28.9%	106	1.7%	820	13.2%	1	0.0%	6,222	6.3%
Lower Bear Creek	276	2.5%	994	9.0%	1,348	12.2%	33	0.3%	1,978	17.9%	1,934	17.5%	376	3.4%	4,099	37.1%	1	0.0%	11,039	11.2%
Mud Springs Creek	49	2.2%	13	0.6%	146	6.6%	0	0.0%	1,229	55.5%	696	31.4%	0	0.0%	82	3.7%	0	0.0%	2,215	2.3%
S. Fork Hackberry Creek	0	0.0%	81	4.5%	315	17.5%	23	1.3%	736	40.9%	385	21.4%	13	0.7%	246	13.7%	0	0.0%	1,799	1.8%
Upper Bear Creek	699	1.4%	7,843	15.7%	9,242	18.5%	599	1.2%	11,840	23.7%	8,243	16.5%	400	0.8%	10,840	21.7%	250	0.5%	49,956	50.9%
																			98,218	100.0%

Appendix 2. Data and Calculating Worksheets Sheets.

Table 2A. Habitat Quality Assessment Worksheets ((TCEQ), 2014)

Streamflow (Discharge) Measurement Form

Streamflow (Discharge) Measurement Form

Stream:____Date:_______________
Station ____
Description:____
Time Began:_____________ Time Ended: _____________Meter Type:_______________
Observers: _______________Total Stream Width: _________Section Width (W):________
Observations:____

Section Midpoint (ft)	Section Depth (ft) (D)	Sensor Depth (ft)	Velocity (V)		Flow (Q) (ft^3/s) Q = (W)(D)(V)
			At Point (ft/s)	**Average (ft/s)**	
$m^3/s \times 35.3 = ft^3/s$			**Total Flow (Discharge)**		

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Appendix 2. Data and Calculating Worksheets Sheets.

Table 2A. Habitat Quality Assessment Worksheets ((TCEQ), 2014) – Continued

<table>
<tr><td colspan="2">Page 1 of ___</td><td colspan="4">Part I—Stream Physical-Characteristics Worksheet</td><td></td></tr>
<tr><td colspan="3">Observers:</td><td colspan="2">Date:</td><td colspan="2">Time:</td></tr>
<tr><td colspan="7">Weather conditions:</td></tr>
<tr><td colspan="3">Stream:</td><td colspan="4">Stream segment no.</td></tr>
<tr><td colspan="3">Location of site:</td><td>Length of reach:</td><td colspan="3"></td></tr>
<tr><td>Observed stream uses:</td><td colspan="6"></td></tr>
<tr><td colspan="7">Stream type (circle one): perennial or intermittent with perennial pools</td></tr>
<tr><td>Stream bends:</td><td>No. well defined</td><td></td><td>No. moderately defined</td><td></td><td>No. poorly defined</td><td></td></tr>
<tr><td colspan="7">Aesthetics (circle one): (1) wilderness (2) natural (3) common (4) offensive</td></tr>
<tr><td colspan="4">Channel obstructions or modifications:</td><td colspan="2">No. of riffles</td><td></td></tr>
<tr><td colspan="7">Channel flow status (circle one): high moderate low no flow</td></tr>
<tr><td>Riparian vegetation (%):</td><td>Left Bank</td><td>Right Bank</td><td colspan="4">Maximum pool depth:</td></tr>
<tr><td>Trees</td><td></td><td></td><td colspan="4">Maximum pool width:</td></tr>
<tr><td>Shrubs</td><td></td><td></td><td colspan="4" rowspan="6">Notes:</td></tr>
<tr><td>Grasses or forbs</td><td></td><td></td></tr>
<tr><td>Cultivated fields</td><td></td><td></td></tr>
<tr><td>Other</td><td></td><td></td></tr>
<tr><td colspan="3">Site map:</td></tr>
</table>

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Appendix 2. Data and Calculating Worksheets Sheets.

Table 2A. Habitat Quality Assessment Worksheets ((TCEQ), 2014) – Continued

Page 2 of ___ **Part I—Stream Physical-Characteristics Worksheet (continued)**

Date: **Stream Name:**

Location of transect	Stream width (m)	Left-bank slope (°)	Left-bank erosion potential (%)	Stream depths (m) at points across transect Thalweg Depth:		Right-bank slope (°)	Right-bank erosion potential (%)	Tree canopy (%)
								Total
	Habitat type (circle one) **Riffle** **Run** **Glide** **Pool**	Dominant substrate type		Dominant types riparian vegetation Left bank: Right bank:			% Gravel or larger	CL CR
Macrophytes (circle one) **Abundant** **Common** **Rare** **Absent**	Algae (circle one) **Abundant** **Common** **Rare** **Absent**	Width of natural buffer vegetation (m) LB:	RB:	Instream cover types			% Instream cover	LB RB

Location of Transect	Stream width (m)	Left-bank slope (°)	Left-bank erosion potential (%)	Stream depths (m) at points across transect Thalweg depth:		Right-bank slope (°)	Right-bank erosion potential (%)	Tree canopy (%)
								Total
	Habitat type (circle one) **Riffle** **Run** **Glide** **Pool**	Dominant substrate type		Dominant types riparian vegetation Left bank: Right bank:			% Gravel or larger	CL CR
Macrophytes (circle one) **Abundant** **Common** **Rare** **Absent**	Algae (circle one) **Abundant** **Common** **Rare** **Absent**	Width of natural buffer vegetation (m) LB:	RB:	Instream cover types			% Instream cover	LB RB

Location of transect	Stream width (m)	Left-bank slope (°)	Left-bank erosion potential (%)	Stream depths (m) at points across transect Thalweg depth:		Right-bank slope (°)	Right-bank erosion potential (%)	Tree canopy (%)
								Total
	Habitat type (circle one) **Riffle** **Run** **Glide** **Pool**	Dominant substrate type		Dominant types riparian vegetation Left bank: Right bank:			% Gravel or larger	CL CR
Macrophytes (circle one) **Abundant** **Common** **Rare** **Absent**	Algae (circle one) **Abundant** **Common** **Rare** **Absent**	Width of natural buffer vegetation (m) LB:	RB:	Instream cover types			% Instream cover	LB RB

Appendix 2. Data and Calculating Worksheets Sheets.

Table 2A. Habitat Quality Assessment Worksheets ((TCEQ), 2014) – Continued

Page 3 of ___ **Part I—Stream Physical-Characteristics Worksheet (continued)**

Date: **Stream Name:**

Location of transect	Stream width (m)	Left-bank slope (°)	Left-bank erosion potential (%)	Stream depths (m) at points across transect Thalweg Depth:											Right-bank slope (°)	Right-bank erosion potential (%)	Tree canopy (%)
																	Total
	Habitat type (circle one) **Riffle** **Run** **Glide** **Pool**		Dominant substrate type			Dominant types riparian vegetation Left bank: Right bank:										% Gravel or larger	CL CR
Macrophytes (circle one) **Abundant** **Common** **Rare** **Absent**	Algae (circle one) **Abundant** **Common** **Rare** **Absent**		Width of natural buffer vegetation (m) LB:	RB:		Instream cover types										% Instream cover	LB RB

Location of Transect	Stream width (m)	Left-bank slope (°)	Left-bank erosion potential (%)	Stream depths (m) at points across transect Thalweg depth:											Right-bank slope (°)	Right-bank erosion potential (%)	Tree canopy (%)
																	Total
	Habitat type (circle one) **Riffle** **Run** **Glide** **Pool**		Dominant substrate type			Dominant types riparian vegetation Left bank: Right bank:										% Gravel or larger	CL CR
Macrophytes (circle one) **Abundant** **Common** **Rare** **Absent**	Algae (circle one) **Abundant** **Common** **Rare** **Absent**		Width of natural buffer vegetation (m) LB:	RB:		Instream cover types										% Instream cover	LB RB

Location of transect	Stream width (m)	Left-bank slope (°)	Left-bank erosion potential (%)	Stream depths (m) at points across transect Thalweg depth:											Right-bank slope (°)	Right-bank erosion potential (%)	Tree canopy (%)
																	Total
	Habitat type (circle one) **Riffle** **Run** **Glide** **Pool**		Dominant substrate type			Dominant types riparian vegetation Left bank: Right bank:										% Gravel or larger	CL CR
Macrophytes (circle one) **Abundant** **Common** **Rare** **Absent**	Algae (circle one) **Abundant** **Common** **Rare** **Absent**		Width of natural buffer vegetation (m) LB:	RB:		Instream cover types										% Instream cover	LB RB

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Appendix 2. Data and Calculating Worksheets Sheets.

Table 2A. Habitat Quality Assessment Worksheets ((TCEQ), 2014) – Continued

Part II—Summary of Physical Characteristics of Water Body

Using information from all of the transects and measurements in Part I and other sources, report the following general characteristics or averages for the entire reach:

Stream Name:	**Date:**
Physical Characteristics	**Value**
Stream bed slope over evaluated reach (from USGS map; elevation change in meters / reach length in kilometers)	
Approximate drainage area above the transect furthest downstream (from USGS or county highway map in km^2)	
Stream order	
Length of stream evaluated (meters or kilometers)	
Number of lateral transects made	
Average stream width (meters)	
Average stream depth (meters)	
Stream discharge (ft^3/sec)	
Flow measurement method	
Channel flow status (high, moderate, low, or no flow)	
Maximum pool width (meters)	
Maximum pool depth (meters)	
Total number of stream bends	
Number of well-defined bends	
Number of moderately defined bends	
Number of poorly defined bends	
Total number of riffles	
Dominant substrate type	
Average percent of substrate gravel-sized or larger	
Average percent instream cover	
Number of stream cover types	
Average percent stream-bank erosion potential	
Average stream-bank slope (degrees)	
Average width of natural buffer vegetation (meters)	
Average percent composition of riparian vegetation by: (total to equal 100%)	
Trees	
Shrubs	
Grasses and forbs	
Cultivated fields	
Other	
Average percent of tree-canopy coverage	
Overall aesthetic appraisal of the stream	

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Appendix 2. Data and Calculating Worksheets Sheets.

Table 2A. Habitat Quality Assessment Worksheets ((TCEQ), 2014) – Continued

Part III—Habitat-Quality Index

Habitat Parameter		Scoring Category		
Available Instream Cover	**Abundant** > 50% of substrate favorable for colonization and fish cover; good mix of several stable (not new fall or transient) cover types such as snags, cobble, undercut banks, macrophytes	**Common** 30–50% of substrate supports stable habitat; adequate habitat for maintenance of populations; may be limited in the number of different habitat types	**Rare** 10–29.9% of substrate supports stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed	**Absent** < 10% of substrate supports stable habitat; lack of habitat is obvious; substrate unstable or lacking
Score_________	4	3	2	1
Bottom Substrate Stability	**Stable** > 50% gravel or larger substrate; gravel, cobble, boulders; dominant substrate type is gravel or larger	**Moderately Stable** 30–50% gravel or larger substrate; dominant substrate type is mix of gravel with some finer sediments	**Moderately Unstable** 10–29.9% gravel or larger substrate; dominant substrate type is finer than gravel, but may still be a mix of sizes	**Unstable** < 10% gravel or larger substrate; substrate is uniform sand, silt, clay, or bedrock
Score_________	4	3	2	1
Number of Riffles To be counted, riffles must extend >50% the width of the channel and be at least as long as the channel width	**Abundant** $\geq$ 5 riffles	**Common** 2–4 riffles	**Rare** 1 riffle	**Absent** No riffles
Score_________	4	3	2	1
Dimensions of Largest Pool	**Large** Pool covers more than 50% of the channel width; maximum depth is > 1 meter	**Moderate** Pool covers approximately 50% or slightly less of the channel width; maximum depth is 0.5–1 meter	**Small** Pool covers approximately 25% of the channel width; maximum depth is < 0.5 meter	**Absent** No existing pools, only shallow auxiliary pockets
Score_________	4	3	2	1
Water Level	**High** Water reaches the base of both lower banks; < 5% of channel substrate is exposed	**Moderate** Water fills >75% of the channel; or < 25% of channel substrate is exposed	**Low** Water fills 25–75% of the available channel or riffle substrates are mostly exposed	**No Flow** Very little water in the channel and mostly present in standing pools, or stream is dry
Score_________	3	2	1	0

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Appendix 2. Data and Calculating Worksheets Sheets.

Table 2A. Habitat Quality Assessment Worksheets ((TCEQ), 2014) – Continued

Part III—Habitat-Quality Index (continued)

Habitat Parameter	**Scoring Category**			
Bank Stability	**Stable** Little evidence (< 10%) of erosion or bank failure; bank angles average < 30º	**Moderately Stable** Some evidence (10–29.9%) of erosion or bank failure; small areas of erosion mostly healed over; bank angles average 30–39.9°	**Moderately Unstable** Evidence of erosion or bank failure is common (30–50%); high potential of erosion during flooding; bank angles average 40–60°	**Unstable** Large and frequent evidence (> 50%) of erosion or bank failure; raw areas frequent along steep banks; bank angles average > 60°
Score_______	3	2	1	0
Channel Sinuosity	**High** ≥ 2 well-defined bends with deep outside areas (cut banks) and shallow inside areas (point bars) present	**Moderate** 1 well-defined bend **or** ≥ 3 moderately-defined bends present	**Low** < 3 moderately-defined bends **or** only poorly-defined bends present	**None** Straight channel; may be channelized
Score_______	3	2	1	0
Riparian Buffer Vegetation	**Extensive** Width of natural buffer is > 20 meters	**Wide** Width of natural buffer is 10.1–20 meters	**Moderate** Width of natural buffer is 5–10 meters	**Narrow** Width of natural buffer is < 5 meters
Score________	3	2	1	0
Aesthetics of Reach	**Wilderness** Outstanding natural beauty; usually wooded or unpastured area; no obvious indications of human activity	**Natural Area** Trees or native vegetation is common; some development evident (from fields, pastures, rural dwellings) little evidence of human activity	**Common Setting** Not offensive; area is developed, but uncluttered such as in an urban park	**Offensive** Stream does not enhance the aesthetics of the area; cluttered; highly developed; may be a dumping area
Score_________	3	2	1	0
Total Score_____________				

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Habitat-Quality Index

26–31	**Exceptional**
20–25	**High**
14–19	**Intermediate**
≤ 13	**Limited**

Appendix 2. Data and Calculating Worksheets Sheets.

Table 2B. B-IBI metrics, criteria, and worksheet ((TCEQ), 2014).

Table F.1. Metrics and scoring criteria for Surber samples—Benthic Index of Biotic Integrity. (Davis, 1997.) (Footnotes appear on following page.)

	Metric	Scoring Criteria		
		5	**3**	**1**
Central bioregion **(Ecoregions: 23, 24, 27, 29, 30, 31, and 32)**	1. Total taxa	> 32	32–18	< 18
	2. Diptera taxa	> 7	7–4	< 4
	3. Ephemeroptera taxa	> 4	4–2	< 2
	4. Intolerant taxa	> 8	8–4	< 4
	5. % EPT taxa	> 30	30.0–17.4	< 17.4
	6. % Chironomidae	[a]	< 22.3	≥ 22.3
	7. % Tolerant taxa	[a]	< 10.0	≥ 10.0
	8. % Grazers	> 14.9	14.9–8.7	< 8.7
	9. % Gatherers	> 15.2	15.2–8.8	< 8.8
	10. % Filterers	[a]	> 11.9	≤ 11.9
	11. % Dominance (3 taxa)	< 54.6	54.6–67.8	> 67.8
East bioregion **(Ecoregions: 33, 34, and 35)**	1. Total taxa	> 30	30–17	< 17
	2. Diptera taxa	> 10	10–6	< 6
	3. Ephemeroptera taxa	[b]	> 3	≤ 3
	4. Intolerant taxa	> 4	4–2	< 2
	5. % EPT taxa	> 18.9	18.9–10.8	< 10.8
	6. % Chironomidae	[a]	< 40.2	≥ 40.2
	7. % Tolerant taxa	< 16.0	16.0–24.3	> 24.3
	8. % Grazers	> 9.0	9.0–5.2	< 5.2
	9. % Gatherers	> 12.5	12.5–7.3	< 7.3
	10. % Filterers	[a]	> 16.3	≤ 16.3
	11. % Dominance (3 taxa)	< 57.7	57.7–71.6	> 71.6

Appendix 2. Data and Calculating Worksheets Sheets.

Table 2B. B-IBI metrics, criteria, and worksheet ((TCEQ), 2014). – Continued

	Metric	Scoring Criteria		
		5	**3**	**1**
North bioregion (Ecoregions: 25 and 26)	1. Total taxa	> 33	33–19	< 19
	2. Diptera taxa	> 14	14–8	< 8
	3. Ephemeroptera taxa	[b]	> 2	[illegible]
	4. Intolerant taxa	> 3	3–2	< 2
	5. % EPT taxa	> 14.4	14.4–8.2	< 8.2
	6. % Chironomidae	< 36.9	36.9–56.2	> 56.2
	7. % Tolerant taxa	< 14.1	14.1–21.5	> 21.5
	8. % Grazers	[b]	> 5.4	[illegible]
	9. % Gatherers	[a]	> 14.9	[illegible]
	10. % Filterers	> 12.2	12.2–7.1	< 7.1
	11. % Dominance (3 taxa)	< 68.1	68.1–84.5	> 84.5

[a] The discriminatory power was less than optimal for this bioregion, so the metric was assigned only two scoring categories.

[b] The median value for this bioregion was less than the metric-selection criterion (< 5.5 for taxa richness metrics; < 12 for percentage metrics expected to decrease with disturbance), so the metric was assigned only two categories.

Appendix 2. Data and Calculating Worksheets Sheets.

Table 2B. B-IBI metrics, criteria, and worksheet ((TCEQ), 2014). – Continued

Metrics and Scoring for Surber Samples for Benthic Macroinvertebrates by Bioregion: Central, East, or North

Stream Name:					
Date:		**Collectors:**			
Location:					
County:		**Ecoregion #:**			
Type of assessment:		UAA	ALA	ALM	RWA

Metric	**Value**	**Score**
1. Total taxa		
2. Diptera taxa		
3. Ephemeroptera taxa		
4. Intolerant taxa		
5. % EPT taxa		
6. % Chironomidae		
7. % Tolerant taxa		
8. % Grazers		
9. % Gatherers		
10. % Filterers		
11. % Dominance (3 taxa)		
Aquatic life use point score ranges:	Exceptional: High: Intermediate: Limited:	> 40 31–40 21–30 < 21
Total Score:		
Aquatic-Life Use:		

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Note: This form should be used as part of the biological monitoring packet. If you chose to use another format, all information must be included.

Appendix 3. Abbreviations used in the Report

Acronym	**Definition**
ALU	Aquatic Life Use
B-IBI	Benthic - Index of Biotic Integrity
BBC	Big Bear Creek at Grapevine Euless Road
BCB	Bear Creek below the golf course
BCC	Bear Creek at County Line Road
BCT14	Bear Creek Tributary 14
BCT19	Bear Creek Tributary 19 at Airfield Road
CG	Collector Gatherer
DFW	Dallas/Fort Worth International Airport
DO	Dissolved Oxygen
EFT	Elm Fork of the Trinity River
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency
FC	Filtering Collectors
FFG	Functional Feeding Group
GVC	Grapevine Creek
HBC	Hackberry Creek
HQI	Habitat Quality Index
ISC	Impervious Surface Cover
LBA	Little Bear Creek
NCTCOG	North Central Texas Council of Governments
P	Predator
SBC	South Bear Creek
SCR	Scraper
SHR	Shredder
TCEQ	Texas Commission on Environmental Quality
TL	Trigg Lake
TLT	Trigg Lake Tributary
TV	Tolerance Value
UNT	University of North Texas
WRFS	Water Research Field Station

Appendix 4. Glossary of Terms used in the Report

Abundance
The total number of individual organism collected in a sample.

Aesthetics of Reach
The overall visual quality of the river study area.

Amphipoda
Scud; An invertebrate order of crustacean with no carapace and generally laterally compressed.

Aquatic-life use (ALU)
A beneficial-use designation (in state water quality standards) in which the water body provides suitable habitat for survival and reproduction of desirable fish, benthic macroinvertebrates, shellfish, and other aquatic organisms.

Bank
The portion of the channel that tends to restrict lateral movement of water. It often has a slope less than 90º and exhibits a distinct break in slope from the stream bottom. Also, a distinct change in the substrate materials or vegetation may delineate the bank.

Bank Stability
Potential for bank erosion

Bare Ground (Land Use Class)
Land cover that lacks vegetation to hold soil in place but allows infiltration of rain water.

Benthic Macroinvertebrates/Organisms
Aquatic, bottom-dwelling organisms that lack a backbone and are large enough to see with the naked eye when they are mature. Including worms, leeches, snails, flatworms, burrowing mayflies, clams, and various insects.

Bioassessment/Biomonitoring
Use of living organisms to determine the quality of the environment.

Biological diversity
The variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequencies. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, and genes.

Appendix 4. Glossary of Terms used in the Report - continued

Biological integrity

The ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region.

Bivalvia

Mussel (Molluscs); Class of aquatic invertebrates that have laterally compressed bodies covered by a shell consisting of two hinged parts.

Buildings (Land Use Class)

Land cover that consists of built structures. Impervious to rain water infiltration.

Channel

That portion of the landscape that contains the bank and the stream bottom. It is distinct from the surrounding area due to breaks in the general slope of the land, lack of terrestrial vegetation, and changes in the composition of substrate materials.

Channelization

Straightening and deepening streams so water will move faster, a method of flood control that disturbs fish and wildlife habitats and can interfere with a water body's ability to assimilate waste.

Chironomidae (Diptera)

Midge; Family of small, delicate flies (Diptera) with an aquatic larval life stage. Minute two-winged mosquito-like fly lacking biting mouth parts; appear in dancing swarms especial near water.

Coleoptera

Beetle; Order of insects with hardened fore-wings (elytra) as adults. Larva are variable in form but commonly contain a hardened head capsule and jointed legs. Many aquatic species are known.

Community

An assemblage of populations of two or more different species occupying the same geographical area at a particular time.

Conductivity (Specific Conductance)

A measurement of waters ability to conduct electricity. A way of measuring ionic content of a water body.

Cut bank

The outside (concave) bank of a stream-channel bend characterized by high erosion. Streamflow usually increases along the cut-bank side of the channel.

Appendix 4. Glossary of Terms used in the Report - continued

Diptera

Fly; A large order of insects that have two wings. The hind wings are reduced to form balancing organs (halteres).

Discharge

Flow; The volume of water moving past a point over time.

Dissolved oxygen

The oxygen freely available in water. Dissolved oxygen is vital to fish and other aquatic life and for the prevention of odors. Traditionally, the level of dissolved oxygen has been accepted as the single most important indicator of a water body's ability to support desirable aquatic life.

Ecoregion (Bioregion)

A relatively homogeneous ecological area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.

Emergent vegetation

Aquatic macrophytes (plants), such as cattails, that are rooted in the sediment, near shore or in marshes, with nearly all of the leaves above the water surface.

Ephemeroptera

Mayfly. Aquatic insect that is generally associated with good water quality.

Evenness

The relative abundance of different taxa in a sample. Ranges from 0 to 1. One being the most even, or evenly distributed, between the different taxa present. No one taxa dominates the sample.

Family

A group of related plants or animals forming a category ranking above a genus and below an order and usually comprising several to many genera.

Filamentous Algae

Single cells of algae that form long visible chains that intertwine to form large mats.

Filterers (Filtering-Collectors)

A functional feeding group that is described as collectors of suspended fine particulate organic matter.

Floating vegetation

Rooted plants (some free floating) with leaves floating on the surface (for example, water lily, water shield, duckweed, and water hyacinths).

Appendix 4. Glossary of Terms used in the Report - continued

Flow (Channel flow status)
The degree to which water covers the entire available channel substrate from bank to bank.

Functional Feeding Group
A classification system based on behavioral mechanisms of food acquisition rather than type of food the organism ingests.

Gastropoda
Snails.

Gatherers (Collector-Gatherers)
A functional feeding group that is described as collectors of deposited fine particulate organic matter.

Genus
A category of biological classification ranking between family and species, comprising structurally or phylogenetically (evolutionarily) related species and designated by a Latin or Latinized capitalized singular noun.

Glide
Portion of the water column in which the flow is characterized by slow moving laminar flow, similar to that which would be found in a shallow canal. Water-surface gradient over a glide is nearly zero, so velocity is slow, but flow is from shore to shore without eddy development. A glide is too shallow to be a pool but has too little water velocity to be a run.

Habitat
The area in which an organism lives.

Habitat Quality Index
A tool that is used to measure nine different habitat parameters to generate a habitat quality index score.

Hemiptera
True Bug; A order of insects that have piercing-sucking mouthparts.

Hypolimnion
The dense cold bottom layer of water in a lake that is thermally stratified.

Impervious Surface Cover
Land cover that prevents the infiltration of rainwater. Roads, parking lots, buildings, etc.

Index of biotic integrity (IBI)
A composite index of the overall condition of a fish or benthic community based on the cumulative score of separate metrics.

Indicator organism
An organism, species, or community that indicates the presence of a certain environmental condition or conditions.

Instream Cover
Amount of suitable habitat for aquatic organisms.

Intolerant organism
An organism that is sensitive to degradation in water quality and habitat. Sensitive organisms are usually driven from an area or killed as the result of some contaminant, especially organic pollution (for example, sewage, feedlot runoff, food waste).

Invertebrate
Animal lacking a backbone.

Land Use
How the land is used by humans. Typically involves the management of modification of the natural environment into a built environment.

Lentic
Of, relating to, or living in non-moving fresh water.

Lotic
Of, relating to, or living in moving fresh water.

Macroinvertebrate
An organism lacking a backbone that is large enough to be seen with the naked eye when mature.

Macrophyte
Any large vascular plant that can be seen without the aid of a microscope or magnifying device (cattails, rushes, arrowhead, water lily, and other aquatic species).

Manicured (Land Use Class)
Land cover type that consists of short, mowed grass that is heavily managed with fertilizers. Typical of golf courses and affluent residential areas.

Mowed/Herbaceous (Land Use Class)
Land cover type that consists of pasture or slightly managed grassland or shrub land.

Appendix 4. Glossary of Terms used in the Report - continued

Natural vegetative buffer

An area of either natural or native vegetation that buffers the water body from terrestrial runoff and the activities of man. In natural areas, it may be much greater than the riparian zone width. In human-altered settings, the natural vegetative buffer limit is at the point of human influence in the riparian zone such as a road, parking lot, pasture, or crop field. It is the width of this buffer that we are most interested in measuring for quantifying potential stream impairments.

Nutrient

Any substance used by living things to promote growth. The term is generally applied to nitrogen and phosphorus in water and wastewater, but is also applied to other essential and trace elements.

Odonata

Dragonfly/Damselfly

Oligochaeta (Annelida)

Aquatic worms

Overhanging vegetation

Vegetation that overhangs the water column and provides food or cover for fish and benthic macroinvertebrates or shades the water from solar radiation.

pH

The hydrogen-ion activity of water caused by the breakdown of water molecules and presence of dissolved acids and bases.

Photosynthesis

The manufacture by plants of carbohydrates and oxygen from carbon dioxide and water in the presence of chlorophyll using sunlight as an energy source.

Plecoptera

Stonefly. An aquatic insect order that is generally associated with good water quality.

Pool

A portion of a stream where water velocity is low and the depth is greater than the riffle, run, or glide. Pools often contain large eddies with widely varying directions of flow compared to riffles and runs, where flow is nearly exclusively downstream. The water-surface gradient of pools is very close to zero and their channel profile is usually concave.

Population

All of the organisms of the same species living in the same geographical area.

Appendix 4. Glossary of Terms used in the Report - continued

Predators

A functional feeding group that is described as organism that consumes other organisms.

Reach

A length of a stream. Portion of the stream that is assessed during a habitat quality assessment.

Receiving water

A river, stream, lake, or other body of surface water into which wastewater or treated effluent is discharged.

Reference Site

A minimally impacted stream in similar geographic regions as the study streams. Used to compare ecology between impacted and minimally impacted conditions.

Riffle

A shallow portion of the stream extending across a stream bed characterized by relatively fast moving turbulent water. The water column in a riffle is usually constricted and water velocity is fast due to a change in surface gradient. The channel profile in a riffle is usually straight to convex.

Riparian zone

Generally includes the area of the stream bank and out onto the floodplain that is periodically inundated by floodwaters from the stream. The limit of the zone depends on many factors including the makeup of the native plant community, soil moisture levels, and distance from the stream (or the limit of interaction between land and stream processes). Interaction between this terrestrial zone and the stream is vital for the health of the stream.

Run

A relatively shallow portion of a stream characterized by relatively fast moving non-turbulent flow. A run is usually too deep to be considered a riffle and too shallow to be considered a pool. The channel profile under a run is usually a uniform flat plane.

Scrapers/Grazers

A functional feeding group that is described as grazers of attached algae; Piercers of plant tissues.

Sinuosity

How a stream bends or meanders along its length.

Sediment

Particles or clumps of particles of sand, clay, silt, and plant or animal matter carried in water, which are deposited in reservoirs and slow-moving areas of streams and rivers.

Sentinels (Biological)

See indicator species.

Shredders

A functional feeding group that is described as consuming living plant tissues or decomposing coarse particulate organic matter.

Species

A category of biological classification ranking immediately below genus, comprising related organisms potentially capable of interbreeding. A species is identified by a two-part name—the name of the genus followed by a Latin or Latinized uncapitalized noun agreeing grammatically with the genus name.

Stream bend

The curved part of a stream. A well-defined bend has a deep outside area (cut bank) and a shallow inside area accentuated by point-bar development. Due to sharp bending, streamflow is forced to the cut-bank side, and eddies develop on the inside of the bend. A moderately developed bend forces some flow to the outside and has only a slight change in depth across the channel. A poorly defined bend has no noticeable change in water depth across the channel, and streamflow is generally not forced to one side.

Stream order

A scheme for classifying stream sizes in which the smallest, unbranched tributaries in a watershed are designated first-order streams. Where two first-order streams join, a second-order stream is formed; where two second order streams join, a third-order stream is formed, and so on.

Submerged vegetation

Rooted plants with almost all leaves below the water surface (for example, alligator weed, hydrilla or elodea).

Substrate

The surface or material on which on organism lives.

Substrate Stability

Measurement of how stable the bottom substrate is so that it can support life. Larger substrate particles are more stable.

Taxa

A group of organisms of the same classification. Usually genus or family.

Taxonomic (Taxa) richness

The number of different taxa groups present at a site.

Appendix 4. Glossary of Terms used in the Report - continued

Tolerant organism
An organism that has the capacity to grow and thrive when subjected to unfavorable environmental factors.

Transect line
A straight line, perpendicular to the streamflow, between two points on opposite stream banks.

Transportation (Land Use Class)
A land cover type consisting of paved roads, parking lots, etc. Considered impervious to water infiltration.

Tributary
A stream or river that flows into a larger stream or river.

Trichoptera
Caddisfly. An diverse group of aquatic insects.

Turbidity
The measure of the relative clarity of water.

Urbanization
The change from natural, or rural, areas to more densely populated, man-made, unnatural areas.

Water (Land Use Class)
A land cover type that consists water. Streams, lakes, ponds, etc.

Watershed
The area of land from which precipitation drains to a single point. Sometimes referred to as a drainage basin, drainage area, or catchment basin.

Wooded (Land Use Class)
Land cover type that consists of forested, wooded area.

Unclassified (Land Use Class)
Land cover that was not classified due to its location outside of the study area.