BIOGEOCHEMISTRY OF URBAN, SUBURBAN, AND RURAL PONDS AND LAKES IN SOUTH-CENTRAL TEXAS

A Thesis

by

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ABSTRACT

Urban lotic surface waters have been extensively studied due to reported increases in their alkalization and dissolved organic carbon (DOC). However, urban lentic surface waters, which are subject to the same United States Environmental Protection Agency and Texas Commission on Environmental Quality (TCEQ) standards and present opportunities for human recreation and interaction, have received less attention. This study analyzed 24 urban, suburban, and rural lakes and ponds in South-Central Texas for *Escherichia coli* (*E. coli*), biogeochemical parameters, and a variety of metals within sediment. Additionally, potential relationships between seasonality, land cover classifications, and the analyzed constituents were explored. Seven of the 24 sampling sites had annual *E. coli* geometric means that exceeded the TCEQ's Primary Contact Recreation Standard of 126 most probable number (MPN) 100 mL^{-1} but none exceeded the Secondary Contact Recreation I Standard of 630 MPN 100 $mL^{-1.}$ Seasonally, the fall and spring had the highest number of sites that exceeded both of these standards. The biogeochemical parameters analyzed included pH, electrical conductivity, NO_3-N, NH_4-N, dissolved organic nitrogen, PO_4-P, total suspended solids, DOC, $SUVA_{254}$, and BOD_5. All of the parameters, except BOD_5, were found to have statistically significant relationships with seasonality. None of the metals analyzed exceeded the TCEQ Texas Risk Reduction Program Tier 1 Sediment Protective Concentration Levels. Select biogeochemical parameters and metals were found to be significantly correlated with four land cover classifications, including grassland, forest, developed, and water. *E. coli* concentrations were not found to be significant correlated with any land cover. The findings from this study emphasize the importance of monitoring lentic surface waters, especially due to the increased *E. coli* concentrations and the impact of seasonality on water quality conditions.

DEDICATION

For my family, both here on Earth and those in Heaven: Dad, Aunt Kim, Pop-Pop, and Granddaddy Young. I miss and love you all more than words can say!

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NOMENCLATURE

Ag	Silver
ANOVA	Analysis of variance
As	Arsenic
B/CS	Bryan/College Station
Ba	Barium
BOD_5	Five-day biochemical oxygen demand
°C	Degrees Celsius
C	Carbon
Ca	Calcium
Cd	Cadmium
CFU	Colony forming unit
Cl	Chlorine
cm	centimeter
Co	Cobalt
COC	Chemical of concern
Cr	Chromium
Cu	Copper
d	days
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DON	Dissolved organic nitrogen

DOP	Dissolved organic phosphorus
DST	Defined substrate technology
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
Fe	Iron
FPXRF	Field portable x-ray fluorescence
g	gram
g/cm^3	gram per cubic centimeter
HDPE	High-density polyethylene
Hg	Mercury
HOA	Homeowner Association
K	Potassium
LU/LC	Land use/land cover
m	Meter
mm	Millimeter
Mn	Manganese
Mo	Molybdenum
MPN	Most probable number
N	Nitrogen
Na	Sodium
NAIP	National Agriculture Imagery Program
NaWA	Nutrient and Water Analysis Laboratory

NC\CIR	Natural Color/Color Infrared
ND	non-detectable
NH_4-N	Ammonium
Ni	Nickel
NLCD	National Land Cover Database
nm	Nanometer
NO_3-N	Nitrate
OSSF	On-site sewage facility
P	Phosphorus
Pb	Lead
PBS	Phosphate-buffered saline
PCL	Protective concentration level
PEC	Probable effect concentration
PO_4-P	Orthophosphate
PTE	Potentially toxic elements
QA/QC	Quality assurance and quality control
Rb	Rubidium
RBEL	Risk-based exposure limit
S	Sulfur
SAML	Soil and Aquatic Microbiology Laboratory
Sb	Antimony
Se	Selenium

Sn	Tin
SOP	Standard operating procedure
Sr	Strontium
$SUVA_{254}$	Specific Ultraviolet Absorbance at 254 nanometers
TAMU	Texas A&M University
TCEQ	Texas Commission on Environmental Quality
Ti	Titanium
TMDL	Total Maximum Daily Load
TNRCC	Texas Natural Resource Conservation Commission
TNRIS	Texas Natural Resources Information System
TPDES	Texas Pollutant Discharge Elimination System
TRRP	Texas Risk Reduction Program
TSS	Total suspended solids
TWRI	Texas Water Resources Institute
UV	Ultraviolet
WHO	World Health Organization
WWTF	Wastewater treatment facility
XRF	X-ray Fluorescence
Zn	Zinc
Zr	Zirconium

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

General Overview of Water Quality in the United States

Since the Industrial Revolution in the eighteenth century, urbanization has been an omnipresent trend throughout the United States of America (Miller and Mooney-Melvin 1987). The effects of urbanization have not all been positive for the country however, with there being well-documented negative effects on surface water (Meyer et al. 2005; Walsh et al. 2005). In attempts to combat the increasing number of contaminated surface waters throughout the United States, the Clean Water Act (CWA) was developed as an amendment in 1977 to the Federal Water Pollution Control Act of 1972 as Congress' attempt to regulate pollutant discharges and subsequently improve surface water quality throughout the United States (Foster and Matlock 2001). The CWA gave the United States Environmental Protection Agency (EPA) the authority to set water quality standards for all potential contaminants in surface waters and to assist in achieving the objective of the CWA, "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Foster and Matlock 2001).

In 2000, the EPA suggested that over 218 million Americans, the majority of the American population at that time, lived within ten miles of a contaminated waterbody (Foster and Matlock 2001). Although the majority of surface water contamination was initially attributed to runoff from agricultural lands and urban or industrial areas, each waterbody is unique geographically, hydrologically, and geologically.

With this in mind, there is no guarantee that measures taken to improve the water quality of one surface waterbody will work for another, even if they are seemingly similar in their nature. This complexity led to the CWA requiring states to begin establishing their own EPA-approved natural resource programs (Sapat 2004). In Texas, the Texas Natural Resource Conservation Commission was created in 1993 as a comprehensive environmental protection agency for the State of Texas and was eventually renamed the Texas Commission on Environmental Quality (TCEQ).

As a requirement of the Federal CWA Sections 305(b), the National Water Quality Inventory Report to Congress, and 303(d), Impaired Waters and Total Maximum Daily Loads (TMDLs), the TCEQ must maintain and provide the Texas Integrated Report of Surface Water Quality (Texas Integrated Report) as a tool to evaluate the quality of surface waters in Texas and inform decisions regarding the directions of agency programs (TCEQ 2012). The Texas Integrated Report, formerly referred to as the Texas Water Quality Inventory and 303(d) List, provides a historical view of water quality data for surface waterbodies throughout the State of Texas and critically assigns these waterbodies to differing categories of use, based on their ability to attain the Texas Surface Water Quality Standards (TCEQ 2012). The Texas Surface Water Quality Standards define specific goals for surface water quality throughout Texas with the hopes of maintaining healthy waters according to their appropriate uses: aquatic life, recreation, and sources of public water supply/drinking water (TCEQ 2012).

To be deemed suitable to support one of the aforementioned uses of surface waterbodies, various water quality standards must be met, including, but not limited to, dissolved oxygen (DO), temperature, toxic substances, pH, dissolved minerals, and bacteria. If these standards are not met, waterbodies can be listed on the Texas Integrated Report as impaired or as having a concern for future impairment. Subsequently, if a waterbody is listed on the Texas Integrated Report as impaired, numerous involved processes must be initiated and carried out to get it delisted. One of these processes is the development of TMDLs, which identify the maximum amount of a particular pollutant that a waterbody can receive daily while still being able to meet water quality standards (Paul 2003).

While the trend of urbanization throughout the country is also present in the State of Texas, greater attention has been paid to lotic surface waters when compared to lentic surface waters. This discrepancy in attention can be attributed to urban lotic surface waters experiencing increases in their alkalization, dissolved organic carbon (DOC), and bacteria, specifically *Escherichia coli* (*E. coli*) (Aitkenhead-Peterson et al. 2009; McCrary et al. 2013; Harclerode et al. 2013; Steele and Aitkenhead-Peterson 2011; Kaushal et al. 2018), which is currently the leading cause of impairment for waterbodies listed on the Texas Integrated Report. While data supports that lotic surface waters in Texas experience these water quality issues, lentic surface waters are monitored much less frequently, yet still provide an ample amount of opportunities for human recreation and interaction and potential subsequent health risks.

Urbanization, Land Use/Land Cover, and the Effects on Surface Waters

Urbanization is a significant trend in the United States, with more than 50 million people moving to urban areas between the years of 1980 to 2000; urban land use follows this same trend, with a 34% increase in urban land usage from 1980 to 2000 (Alig et al. 2004). By the year 2030, estimates show that 60% of the Earth's population will live in urban areas (Faulkner 2004). The effects of urbanization are not equally distributed across the land however, due to 75% of the Earth's population living on approximately only 20% of the total land area (Harrison and Pearce 2001). Urbanization can significantly affect the surrounding environment and the resources that humans need and utilize to survive. Air, soil, and water are some of the environmental resources that are most negatively affected in areas that experience intense urbanization (Faulkner 2004). Common causes of impairment in the United States include sediment, nutrients, and bacteria typically contributed by agriculture, atmospheric deposition, and hydromodification (EPA 2000). Urbanization has the potential to affect the majority of the aforementioned common causes of impairment. Research has shown that natural erosion accounts for approximately 30% of the total sediment in the United States, while the remaining 70% can be attributed to accelerated erosion caused by humans and urbanization (Spellman 2016).

As urbanization and its pertinent research progress, a better understanding of how the process of urbanization affects the surrounding environment and its critical resources can be gained. The relationship between urbanization and surface waterbodies has been relatively well-studied, with urban runoff contributing greatly to surface water impairments in the United States (Meyer et al. 2005; Walsh et al. 2005; Aitkenhead-Peterson et al. 2011; Kaushal et al. 2018). Another impact of urbanization is its tendency to increase both point and nonpoint sources of pollution throughout developing areas, primarily to accommodate humans' needs (Carle et al. 2005).

Urbanization has also led to expedited changes in land use/land cover (LU/LC). In many areas, new urban growth often results in previously existing rangeland areas being cleared for some type of urban development; these changes lead to an increase in the number of impervious surfaces throughout an area that subsequently do not allow for any water infiltration into the soil to occur (Aitkenhead-Peterson et al. 2011). When the number of impervious surfaces throughout an area increases, adverse natural effects, such as flooding, can become more prevalent in an area. As soil infiltration decreases, water must find another destination other than back into the ground; inevitably, decreased infiltration leads to increased amounts of runoff. As runoff occurs, it can collect various pollutants along the way from both undeveloped and developed surfaces (Gobel et al. 2007). The pollutants that are found in runoff are typically related to the type of LU/LC where it occurred (Paule et al. 2014). For instance, runoff that occurs in predominantly agricultural areas may have greater nutrient concentrations from increased fertilizer usage, while urban runoff may have greater concentrations of metals from sources like automobiles, which can contribute through emissions and the wearing of vehicle parts such as tires and brakes, among other sources (Reddy et al. 2014). No matter the pollutants, lotic and lentic surface waters are often the ultimate destination for these types of runoff, making them responsible for collecting not only the water, but also the pollutants that have been collected along the way. Three of the aspects of surface water quality that are most greatly affected by LU/LC change and urbanization are surface waterbodies' chemistry, microbiology, and sediment (Carle et al. 2005; EPA 2000; Stea et al. 2015; Wang et al. 2008).

It has been proven difficult to determine exactly what aspects of LU/LC change causes observable alterations in surface water quality, particularly in urban areas where there can be numerous potential contributing factors. With this in mind, a broader understanding of all of the potential factors is being pursued, keeping in mind that no two waterbodies are exactly the same. While LU/LC is one significant factor that can affect surface water quality both bacteriologically and geochemically, there are numerous other potential factors as well. These include, but are not limited to, underlying geology, season, climate, topography, vegetation, and surrounding waste treatment systems (Aitkenhead-Peterson et al. 2005; Aitkenhead-Peterson et al. 2011; Carpenter et al. 1998; Walsh et al. 2005).

Urbanization and Surface Waters: Carbon, Nitrogen, and Phosphorus

One aspect of surface waters that urbanization can significantly affect is the chemistry of surface waters. Particularly, essential elements including carbon, nitrogen, and phosphorus concentrations in surface waters can be increased. Excess nutrients within surface waterbodies can cause a broad array of problems, including toxic algal blooms, decreased oxygen levels, decreased biodiversity, fish kills, and decreased aquatic plants (Carpenter et al. 1998). Additionally, nutrient enrichment of carbon, nitrogen, and phosphorus can degrade entire ecosystems and eventually result in a surface waterbody being listed by the TCEQ and EPA as a concern or as impaired.

For surface waterbodies, sources of dissolved organic carbon (DOC) can be allochthonous or autochthonous. Potential natural sources of allochthonous DOC include rainouts of pollens and dusts, throughfall, and throughflow through watershed soil (Aitkenhead-Peterson et al. 2003). Potential anthropogenic sources of DOC to surface waterbodies include runoff from impervious urban surfaces and wastewater treatment facility (WWTF) effluent that can be enriched in DOC after it has been treated (Reungoat et al. 2010); although the WWTF may only contribute small DOC loading depending upon its system of treatment (Aitkenhead-Peterson and Steele 2016). Carbon plays a critical role in the chemical interactions within a surface waterbody and helps increase the efficiency of nitrogen and phosphorus cycling in sediments (Kritzberg 2004).

Nitrogen has numerous natural sources including rock weathering, atmospheric deposition, animal waste, decomposing organic material, and N_2 fixation (Robinson and Robbins 1970). Anthropogenic sources include fertilizers, sewage effluent, landfill leachate, soaps, detergents, and stormwater, among other potential sources (Vitousek et al. 1997). Nitrogen is present in the environment in several forms and can be found in surface waters as nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), and dissolved organic nitrogen (DON).

Phosphorus tends to be adsorbed to soil minerals and is transported primarily through erosion by wind or water. Phosphorus can be present within surface waterbodies in dissolved forms, including orthophosphate (PO_4^{3-}) and dissolved organic phosphorus (DOP). Natural sources of phosphorus originate in the two major phosphorus cycles, including a slower geological cycle and a faster ecological cycle. The slower geological cycle tends to produce inorganic forms from soil and rock erosion that are later transported to surface waterbodies. Meanwhile, the ecological cycle tends to produce organic forms from animal feces and decomposition of plants and animals. Anthropogenic sources of phosphorus include fertilizers (Cheng et al. 2014; Liang et al. 2013), agriculture runoff and erosion, and forestry processes that increase erosion (Carpenter et al. 1998). WWTFs can also act as a source of phosphorus if it is not effectively removed from effluent during the secondary treatment processes (Aitkenhead-Peterson et al. 2011; Morse et al. 1998).

Urbanization, *E. coli* in Surface Waters, and Potential Effects on Humans

Escherichia coli (*E. coli*) is often used as an indicator for fecal pollution due to its prevalence and the lower costs that are associated with its detection and enumeration when compared to other types of pathogens (Meays et al. 2004). It is a direct indicator that fecal contamination has occurred in waterbodies where it is present. In Texas, elevated bacterial concentrations are the leading cause of surface water impairment throughout the state. Understanding the relationship between *E. coli* and its presence within surface waterbodies is critical for humans. Waterbodies that are contaminated with fecal bacteria, as indicated by high *E. coli* concentrations, can cause infections, gastrointestinal illnesses, reproductive problems, and neurological disorders in humans that are potentially completely unaware of these risks (Calderon et al. 1991; Copeland 2002; Soller et al. 2010). *E. coli* is introduced into both lotic and lentic waterbodies primarily through non-point source pollution, which is one reason as to why it can be so challenging to identify and eliminate potential sources (Meays et al. 2004). Numerous studies conducted have focused on identifying potential sources of *E. coli* in surface water over time (Sapkota et al. 2007; Harmel et al. 2010; McCrary et al. 2013; Brinkmeyer et al. 2015; Borel et al. 2012).

Sources of *E. coli* include, but are not limited to, wildlife (both avian and non-avian), livestock, domesticated animals, humans, and subsequent systems that deal with managing human fecal waste, such as on-site sewage facilities (OSSFs) and WWTFs. Bacterial loading in surface waterbodies can occur directly or indirectly. For example, direct bacterial loading can occur through WWTFs that discharge effluent with concentrations of *E. coli* that violate the concentration in wastewater discharge permits. Conversely, indirect loading can occur through processes like runoff, which can collect fecal waste that remains on the land surface and eventually deposit it into nearby surface waterbodies that are often times the ultimate destination for runoff. Past studies have postulated that surface runoff represents the most significant risk for surface water contamination (Jamieson et al. 2003).

The fate of *E. coli* can vary greatly once it is introduced into surface waterbodies. Dependent upon environmental conditions, *E. coli* can die-off, multiply, or bind to sediment and live along the moist and warmer bottom of a waterbody. Several studies have explored the relationships between *E. coli* and sediment in surface waterbodies. Brinkmeyer et al. (2015) established through a study in Houston, Texas, that sediment can be a source of *E. coli* to surface waterbodies and that there is a significant correlation between *E. coli* survival and sediment size. A relationship has been observed between *E.*

coli prevalence and survival and organic matter and nutrients within a surface waterbody (Duan et al. 2014; Garzio-Hadzick et al. 2010; McCrary et al. 2013). Lastly, anthropogenic events, such as swimming, or natural events, such as rainfall, can lead to higher counts of *E. coli* in surface waterbodies. Increased counts can also be attributed to turbulence, which disturbs the sediment and subsequently re-suspends it, and whatever may be bound to it, back in the water column (Charcklis et al. 2005; Peterson et al. 2009; Wu et al. 2009).

Metals in Lentic Waters' Sediment and Potential Effects on Humans

Metals that are found in urban runoff are commonly derived from sources such as motor vehicle operation, building siding and roofs, wet and dry atmospheric fallout and deposition, and road surface materials (Campbell 1994; Characklis and Wiesner 1997; Garnaud et al. 1999; Davis et al. 2001). Sources associated with motor vehicle operation can include brakes, tires, and oil leakage. Metals that are commonly associated with urban runoff include, but are not limited to, arsenic (As), barium (Ba), calcium (Ca), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), potassium (K), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), rubidium (Rb), strontium (Sr), titanium (Ti), zinc (Zn), and zirconium (Zr); these metals are prominent in urban watersheds and can have potential implications on human health (Campbell 1994; Characklis and Wiesner 1997; Davis et al. 2001; Garnaud et al. 1999). The majority of the metals found to be prominent in urban sediment that have the highest potential for causing harm to humans are heavy metals, which are defined as naturally occurring elements that have densities of at least five times greater than that of water (1 g/cm^3) and high atomic weights (Tchounwou et al. 2014). They can cause both acute and chronic health effects including cancer, disturbance of the reproductive, neurological, dermatologic, nervous, hepatobiliary, renal, cardiovascular, gastro-intestinal, and hematologic systems, and damage to critical organs such as the kidneys, liver, and lungs (Mulligan et al. 2001; Jarup 2003; Tchounwou et al. 2014). Each metal has its own potential health risks associated with it and the amount of exposure that occurs. Therefore, understanding the relationship between various types of metals and their potential presence in the sediment of surface waterbodies where human interaction and subsequent exposure can occur is critical.

No matter their original source, metals that are deposited onto the surface of the Earth await various fates. For instance, after deposition, metals can accumulate in the underlying soil over time. Alternatively, if deposited in an impervious area, they can become constituents of runoff during storm events. Lotic and lentic waterbodies that are destinations for runoff process sediment differently, due to the influence of streamflow. Lotic waters have the ability to flush metal-laden sediment downstream. Conversely, due to lack of flow, lentic waters do not have this ability. This can cause sediment accumulation to occur and increase over time without a natural method to flush it out. This effect is particularly prevalent in urban watersheds that experience significant amounts of sedimentation (Paul and Meyer 2001).

Lentic waters' inability to naturally flush out metals and other constituents that accumulate in sediment becomes critical when considering the effects that metals can have on both aquatic and human health. Human exposure to metals can lead to health effects that are dependent on the particular types of metals that are present and may include cancer, disturbance of the reproductive, neurological, cardiovascular, and hematologic systems, and damage to critical organs such as the kidneys, liver, and lungs (Jarup 2003). Therefore, understanding the relationship between various types of metals and their potential presence in the sediment of lentic waters where human interaction and subsequent exposure can occur is critical. Heavy metals can be especially harmful to humans due to their high levels of toxicity, mobility, and solubility (Mulligan et al. 2001).

Bioaccumulation and biomagnification are two processes that are important when considering metals in sediment. Fish studies focusing on bioaccumulation and biomagnification have shown that metals are not only toxic to fish, but also to humans who later consume the fish (Campbell et al. 2005; Akan et al. 2012). Mercury, when methylated, has been found to be readily bioaccumulated and biomagnified through plants and smaller organisms, like plankton, that ingest it through food intake or passive surface absorption (Monteiro et al. 1996). Biomagnification and bioaccumulation then occur as fish consume the plants and smaller organisms, and humans then consume the fish. Mercury originates from both natural and anthropogenic sources and has high levels of mobility, toxicity, and availability in the environment, making it particularly dangerous for aquatic life and humans. With these risks in mind, bioaccumulation and biomagnification must be considered for urban lentic waters, particularly those where fishing is encouraged.

Objectives for Study

The primary objective of this study was to compare the annual and seasonal concentrations of various biological and chemical constituents in the water and sediment of urban lentic waters to the State of Texas' standards according to their designated uses. The secondary objective was to assess the potential effects of land cover on the annual and seasonal water and sediment chemistry of these lentic waters through a 100 m land cover buffer around each waterbody.

This study provides a unique dataset that enables the seasonal and annual water quality of various types of lentic waterbodies throughout the predominantly urban cities of Bryan and College Station, Texas, to be better understood. While the majority of the waterbodies in this study are surrounded by urban lands, a few of the sampling sites are surrounded by a significant amount of rural lands, enabling a contrasting dataset to be available for comparison.

As an initial examination of a wide variety of urban, suburban, and rural lakes and ponds located within a region of Texas characterized by rapid growth, this study increases awareness in regards to the overall water quality of lentic waterbodies that are not as commonly monitored, yet still provide opportunities for recreation and interaction. The datasets that were obtained during this study enable the appropriate entities to be made aware of the current conditions of various lentic waterbodies throughout the area with the hopes of the future implementation of mitigation efforts, the pursuit of closer examinations of lentic surface water health, and the avoidance of potential health risks associated with human interaction. Optimally, this study will be able to be used as an analog to other areas throughout the state and the country that can be characterized similarly with the hopes of more attention eventually being paid to the overall water quality of lentic waterbodies that were previously primarily disregarded.

CHAPTER II

URBANIZATION AND THE BIOGEOCHEMISTRY OF URBAN LENTIC WATERS

Introduction

Urbanization and Lentic Waters

The term urbanization describes not only an increase in human habitation throughout an area, but also increased consumption of energy and resources and expedited LU/LC change (McDonnell and Pickett 1990). Land cover is defined as the physical characteristics of the earth's surface like vegetation, water, soil, anthropogenic structures, etc. while land use is defined to how humans utilize the land, primarily for economic activity (Hua 2017). In many areas, new urban growth often results in an increase in the number of impervious surfaces throughout an area that subsequently do not allow for any infiltration of precipitation or irrigation to occur (Aitkenhead-Peterson et al. 2011). Decreased infiltration may lead to increased runoff and adverse effects from natural events, like flooding. As runoff occurs, it can collect various pollutants along the way from both undeveloped and developed surfaces (Gobel et al. 2007). This potentially contaminated runoff can ultimately end up in nearby lotic and lentic waterbodies.

In urban areas in particular, urban runoff can greatly contribute to surface water impairments (Meyer et al. 2005; Walsh et al. 2005; Aitkenhead-Peterson et al. 2011; Kaushal et al. 2018).The pollutants that are found in runoff are typically related to the types of LU/LC that are associated with where it occurred (Paule et al. 2014). For instance, runoff that occurs in predominantly agricultural areas may have increased nutrient concentrations from fertilizer usage, while urban runoff may have greater concentrations of metals from sources like automobiles or industrial operations (Lee and Bang 2000; Jamieson et al. 2004; Reddy et al. 2014). Three of the aspects of surface water quality that are most greatly affected by LU/LC change and urbanization are surface waterbodies' chemistry, microbiology, and sediment (EPA 2000; Carle et al. 2005; Wang et al. 2008; Stea et al. 2015).

Urbanization also has the tendency to increase both point and nonpoint sources of pollution throughout developing areas, primarily to accommodate humans' needs as populations rapidly expand (Carle et al. 2005). For instance, consider humans' consistent need for food. As populations increase throughout urban areas, the demand for food does as well. Increased demands for food can lead to farmers implementing agricultural practices that utilize excessive amounts of fertilizers to expedite and supplement growth and production in order to increase supply; however, this is not always the case and farmers have the ability to increase food production to meet demands while also minimizing the associated pollution. Another example of this tendency of urbanization is humans' need for waste management. Neighborhoods throughout urban areas are typically connected to waste management infrastructure that transports waste to WWTFs, which manage help to sewage and can produce nutrient-enriched effluent that is discharged to nearby surface waters. Areas that are unable to connect to municipal infrastructure typically have OSSFs installed for waste management. If not properly managed, these systems can lead the introduction of high concentrations of nutrients and enteric human pathogens, such as *E. coli*, to nearby surface waters. These potential sources of pollution can become more prevalent as populations continue to increase around urban areas and more waste management is necessary.

Nutrients in Urban Lentic Waters

Surface water chemistry, specifically carbon, nitrogen, and phosphorus, can be significantly affected by both natural and anthropogenic sources in both rural and urban settings (Walsh et al. 2005). Carbon plays a critical role in the chemical interactions within a surface waterbody and helps increase the efficiency of nitrogen and phosphorus cycling in the water and sediments (McCrary et al. 2013). Organic carbon is typically derived from photosynthesis and sources of DOC can be allochthonous or autochthonous in surface waterbodies. Carbon can be introduced to urban waterbodies in the form of DOC through allochthonous anthropogenic sources, including WWTF effluent that can be enriched in DOC after treatment and runoff from impervious surfaces around cities (Westerhoff and Anning 2000; Reungoat et al. 2010). Natural sources of allochthonous carbon can result from throughflow through surrounding soils in watersheds, throughfall, and the rainout of pollens and dusts (Aitkenhead-Peterson et al. 2003). The primary autochthonous sources of DOC for surface waterbodies are derived from algal cell leakage, and autochthonous DOC has been found to be more labile than allochthonous DOC and subsequently help to efficiently cycle N and P in surface waters (Kritzberg 2004). Labile DOC is primarily produced by aquatic organisms like algae and is subsequently found closer to the surface of waterbodies (Aluwihare et al. 1997). It typically consists of compounds that can be consumed by bacteria. Conversely, refractory carbon is more difficult for aquatic organisms to utilize and is more evenly distributed throughout the water columns of surface waterbodies as a result.

Nitrogen is present in the environment in several forms and can be found in surface waters as nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), and dissolved organic nitrogen (DON). Fertilizers that contain nitrogen are utilized in both rural and urban settings, whether it be for agriculture or aesthetic purposes in neighborhoods or parks. With this in mind, both rural and urban runoff containing nitrogen can lead to increased nitrogen concentrations in surface waterbodies. Natural sources of nitrogen include N_2 fixation, rock weathering, animal waste, and decomposing organic material, while anthropogenic sources can include concentrated animal feeding operations (CAFOs) in rural areas, fertilizers, soaps and detergents, wastewater effluent, landfill leachate, and stormwater (Vitousek et al. 1997; Driscoll et al. 2003;).

Phosphorus typically adsorbs to minerals within soil particles and is transported primarily through wind or water after erosion occurs, and reducing conditions within waterbodies can cause PO_4^{3-} to desorb from sediments that they typically would adsorb (Pant et al. 2001). Erosion is a commonality among potential sources of nitrogen, whether it be through agricultural runoff and erosion or forestry processes that can expedite and increase erosion (Carpenter et al. 1998). Fertilizers are another common source of phosphorus to the environment (Liang et al. 2013; Cheng et al. 2014). If not removed completely during secondary treatment processes, WWTFs can also be sources of phosphorus (Aitkenhead-Peterson et al. 2011; Morse et al. 1998).

Nutrients are becoming an increasing problem throughout lotic waters in the State of Texas, with more lotic surface waters throughout the state showing increases in C, N, and P concentrations (TCEQ 2014). Excess amounts of nutrients, particularly nitrogen and phosphorus, can lead to increased algal production that can overload entire ecosystems. Often times, organisms that would typically utilize nutrients are overwhelmed by excessive amounts of algae that are actually caused by the excess nutrients (Walsh et al. 2005). These types of algae can degrade water quality, diminish oxygen supplies in the waterbodies that various types of aquatic life need to survive, and significantly harm food resources and habitats (EPA 2017). According to the EPA, excessive amounts of nutrients can lead to large algal blooms, which can have detrimental effects on entire ecosystems, including fish kills, the elimination of oxygen in the water, and illnesses that can affect both fish and humans (EPA 2017). For humans in particular, algal blooms can produce elevated concentrations of toxins in the water that can make humans sick if they come in contact with or drink the polluted water or consume fish or shellfish that have been affected (EPA 2017). NO_3-N and PO_4-P concentrations can be as low as 0.05 mg L^{-1} and still produce significant observable increases in toxic dinoflagellate concentrations and phytoplankton biomass in various ecosystems, including freshwater (Burkholder et al. 1992; Mallin and Wheeler 2000; Qin et al. 2013).

To gain more control on nutrients throughout the United States, the EPA mandated that all states include nutrient criteria in their water quality standards (TCEQ 2014). Subsequently, the TCEQ adopted new numerical nutrient criteria for various reservoirs throughout the state that are based on chlorophyll-a concentrations, due to the costs of analyzing every nutrient separately (TCEQ 2014). Chlorophyll-a is the primary photosynthetic pigment in phytoplankton and is frequently utilized as an indicator for nutrient concentrations in aquatic ecosystems, with past studies proving significant correlations between chlorophyll-a and nitrate, nitrite, and ammonium concentrations in water (Balali et al. 2013). In 2010, the TCEQ adopted site-specific chlorophyll-a nutrient criteria for 75 reservoirs around the state, with the EPA approving these criteria in 2013. These chlorophyll-a criteria provide measurements for which various types of waterbodies' chlorophyll-a concentrations can be compared to determine if there are pollution issues or not. Subsequently, the State of Texas and the affected cities can gain a better understanding of what the nutrient concentrations are in the waterbodies in which they interact.

Currently, the TCEQ is in the process of continuing to develop nutrient criteria that are based on waterbody type. For instance, reservoirs will have different nutrient criteria than wetlands. The five types of waterbodies that will currently have nutrient criteria developed for them by the TCEQ are: reservoirs, freshwater streams and rivers, estuaries and tidal streams, wetlands, and boundary waters (TCEQ 2014). Besides reservoirs, there are no other criteria that will be developed for lentic waterbodies. Considering that reservoirs are typically lentic waterbodies that are much greater in size, smaller lentic waters, such as lakes and ponds, represent a group in which there will be no chlorophyll-a criteria for comparison. With no criteria for comparison, there is a knowledge gap when it comes to understanding what nutrient concentrations are like in these types of lentic waterbodies across the state, and what potential health effects could be associated with these concentrations.

Bacteria in Urban Lentic Waters

In 2012, approximately 48% of the 568 waterbodies that were listed on the Texas Integrated Report were impaired for high bacteria levels, making bacterial impairment the most common reason for listing waterbodies (Gregory et al. 2014). According to the 2014 Texas Integrated Report, 255 Category 5 waterbodies were listed for failing to meet bacteria standards (TCEQ 2015). Category 5 waters are those that do not currently have a Total Maximum Daily Load (TMDL) Document or other management strategies underway. *Escherichia coli* (*E. coli*) is the bacterium that is used as an indicator for harmful pathogens, or disease-causing microorganisms, for freshwater throughout the State of Texas. *E. coli* was selected as the indicator for fecal pollution throughout the state because of its prevalence and lower associated costs for both detection and enumeration when compared to other types of microorganisms (Meays et al. 2004). It is a direct indicator that fecal contamination has occurred in waterbodies where it is present.

The TCEQ has established primary, secondary, and noncontact recreation standards for *E. coli* within surface waters, which are based on the risk of ingestion of water that could occur with a particular activity. Primary contact recreation includes activities that could potentially involve a significant risk of ingestion of water such as wading by children, swimming, water skiing, diving, tubing, and surfing, in addition to whitewater canoeing, kayaking, and rafting (TCEQ 2014). The Primary Contract

Recreation Standard for *E. coli* is a geometric mean of 126 100 mL^{-1} of water. The number of bacteria can be expressed as colony forming units (CFU) or most probable number (MPN); the units are determined by the method of analysis. Secondary contact recreation includes activities that do not involve a significant risk of water ingestion such as fishing, boating, and interactions along the shoreline (TCEQ 2014). The Secondary Contact Recreation Standard I for *E. coli* is a geometric mean of 630 100 mL^{-1} of water. Noncontact recreation includes any activities that do not involve a significant risk of ingesting water and occur in areas where primary and secondary recreation should not, due to unsafe conditions (TCEQ 2014). Noncontact recreation includes activities such as birding and hiking or biking near a waterbody. The Noncontact Recreation Standard for *E. coli* is a geometric mean of 2,060 100 mL^{-1} of water. Lastly, the TCEQ has established a standard for any single sample that is collected at any point in time. The Single Sample Criterion is 399 100 mL^{-1} of water.

Considering the widespread issue of bacterial contamination in surface waters throughout the country, particularly in the State of Texas, understanding the relationship between *E. coli* and its presence within surface waterbodies is critical for humans. Waterbodies that are contaminated with *E. coli* can cause infections, gastrointestinal illnesses, reproductive problems, and neurological disorders in humans that are potentially completely unaware of these risks (Calderon et al. 1991; Copeland 2002; Soller et al. 2010). Non-point source pollution is the primary source of *E. coli* for both lotic and lentic waterbodies, which helps to explain why it can be so difficult to identify and eliminate potential sources (Meays et al. 2004). Point sources of pollution can be traced back to their origins and are typically permitted discharges of effluent that can be rich in nutrients from WWTFs for surface waters. Despite the challenge, numerous studies have focused on identifying potential point and non-point sources of *E. coli* in surface waterbodies over time (Sapkota et al. 2007; Harmel et al. 2010; McCrary et al. 2013; Brinkmeyer et al. 2015; Borel et al. 2012).

Direct bacterial loading in urban ecosystems can occur through WWTFs that could potentially discharge effluent with bacteria levels of *E. coli* that exceed their permitted discharge limit. Septic systems are a primary example of indirect loading and are relied upon for sewage treatment by areas that do not have access to municipal pipe systems. If leakage occurs, surrounding soils can become saturated with nutrients from the waste and subsequently become available for runoff that ends up in nearby surface waters (Driscoll et al. 2003). Runoff is another potential source of indirect bacterial loading because it can collect fecal waste and eventually deposited in nearby surface waterbodies. Surface runoff represents the most significant risk for surface water contamination (Jamieson et al. 2003) and a study in Wisconsin on eight beaches in the area found significant associations between *E. coli* concentrations in beach waters and rainfall (Kleinheinz et al. 2009).

Once fecal microorganisms, such as *E. coli*, are introduced into surface waters, they can die-off, multiply, or bind to sediment and live along the moist and warmer bottom of a waterbody. The ultimate fate of bacteria within a waterbody is dependent upon environmental conditions. Anthropogenic events, such as swimming, or natural events, such as rainfall, can lead to higher counts of *E. coli* in surface waterbodies because they can increase turbulence; turbulence can unsettle and re-suspend sediment, which can also re-suspend bacteria back into the water column that may have previously been bound to it (Charcklis et al. 2005; Peterson et al. 2009; Wu et al. 2009). Brinkmeyer et al. (2015) conducted a study in Houston, Texas, that established that sediment can be a source of *E. coli* to surface waterbodies and that there is a significant correlation between *E. coli* survival and sediment size.

Relationships between Biogeochemistry and E. coli Concentrations

Relationships have been identified between *E. coli* prevalence, survival, organic matter, and nutrients within a surface waterbody (Garzio-Hadzick et al. 2010; Duan et al. 2014). Shiloach and Fass (2005) determined that limited amounts of nutrients such as carbon, nitrogen, phosphorus, zinc, copper, magnesium, potassium, iron, and sulfur can limit the growth of *E. coli* due to the microorganisms' nutritional requirements. However, another study conducted in South-Central Texas found no significant relationship between nutrients and *E. coli* concentrations (Harclerode et al. 2013).

Objectives and Hypotheses

There were several objectives for this study. Firstly, it aimed to determine if the lentic waterbodies' geometric mean *E. coli* concentrations would meet the State of Texas' Primary and Secondary Contact Recreation Standards of 126 and 630 MPN 100 mL^{-1} of water, respectively, at seasonal and annual time scales. *E. coli* concentrations were also compared to the Single Sample Standard of 399 MPN 100 mL^{-1} of water. The second objective was to examine the changes in biogeochemistry of the lentic waterbodies at seasonal time scales. The third objective was to determine if there are relationships between *E. coli* concentrations and the urban lentic waterbodies' biogeochemical parameters at seasonal and annual temporal scales. The final objective was to identify any potentially significant correlations between the predominant surrounding land cover classifications and the concentrations of *E. coli* or biogeochemical constituents within the lentic surface waters.

The second and third objectives had associated hypotheses that were as follows:

H_{O2}: There will be no significant differences in DOC, DON, $SUVA_{254}$, NO_3-N, NH_4-N, PO_4-P, BOD_5, and TSS when comparing seasonal averages for each individual lentic waterbody.

H_2: The average concentrations of biogeochemical parameters including DOC, DON, $SUVA_{254}$, NO_3-N, NH_4-N, PO_4-P, BOD_5, and TSS for the lentic waters will be the highest during the fall season, due to potential increased rainfall and subsequent runoff.

H_{O3}: There will be no relationships between *E. coli* concentrations and the urban lentic waterbodies' biogeochemical parameters at seasonal and annual temporal scales.

H_3: Significant relationships between *E. coli* concentrations and the urban lentic waterbodies' biogeochemical parameters will be observable using multiple regression analysis at seasonal and annual temporal scales

Materials and Methods

Experimental Design: Site Selection and Descriptions

This study commenced in March of 2017 and concluded in February of 2018 and included 24 unique lentic waterbodies throughout the Bryan/College Station, Texas, USA region. The sites were determined based on geographic location and subsequent surrounding land cover, primary and secondary purposes, recreational viability, and safety/accessibility (Figure 1; Table 1). The majority of the study sites varied greatly in their physical characteristics. For example, Lake Bryan, a power plant cooling reservoir has recreational boating, swimming, and fishing. Two sites were sampled on the lake due to its relatively large size when compared to the other sampling sites. Lake Bryan 1 (Site 1) was located near a designated swimming area near numerous camping sites, while Lake Bryan 2 (Site 2) was located near the boat ramp where fishing commonly takes place off the nearby dock. Another site, by the Wahlberg Golf Learning Center, directly receives treated wastewater effluent from the Carters Creek WWTF that is enriched in nitrogen and phosphorus. Other sites included city ponds for fishing and ponds that are little more than stormwater retention/detention ponds with hiking trails for aesthetic value in the cities' growing sub-divisions.

All of the sampling sites were located in either the Gibbons Creek-Navasota River Watershed or the Old River-Brazos River Watershed (Figure 2; Table 1). More generally, they were all located within the Lower Brazos River Basin. The Lower Brazos River Basin includes the cities of Bryan and College Station. The Lower Brazos River Basin is classified as having a subtropical humid climate and receives approximately 104.1 mm of average rainfall per year; average temperatures for the area include average annual lows of 14.9° C, average annual highs of 26.3° C, and an average annual temperature of 20.6° C (United States Climate Data: College Station Weather Averages).

Table 1: Detailed characteristics for each sampling site. Data from the Texas Natural Resources Information System.

Site Number	Site Name	Aerated	Fishing	Boating	Swimming	Type	Purpose	Watershed
1	Lake Bryan 1	N	Y	Y	Y	Lake	Power Plant Cooling	Old River – Brazos River
2	Lake Bryan 2	N	Y	Y	Y	Lake	Power Plant Cooling	Old River – Brazos River
3	Country Club	Y	N	N	N	Lake	Golf Course	Gibbons Creek – Navasota River
4	Allen Ridge Park	N	N	N	N	Pond	Stormwater	Gibbons Creek – Navasota River
5	Cy Miller Park	Y	Y	N	N	Pond	City Pond	Gibbons Creek – Navasota River
6	Lochinvar	N	N	N	N	Pond	Golf Course	Gibbons Creek – Navasota River
7	Central Park 2	Y	Y	N	N	Pond	City Pond	Gibbons Creek – Navasota River
8	Central Park 1	Y	Y	N	N	Pond	City Pond	Gibbons Creek – Navasota River
9	Castlegate 1	Y	N	N	N	Pond	Neighborhood	Gibbons Creek – Navasota River
10	Castlegate 2	Y	N	N	N	Pond	Neighborhood	Gibbons Creek – Navasota River
11	Amber Lake 1	Y	Y	N	N	Pond	Neighborhood	Gibbons Creek – Navasota River
12	Amber Lake 2	Y	Y	N	N	Pond	Neighborhood	Gibbons Creek – Navasota River
13	Carter Lake	N	Y	Y	Y	Lake	Private Lake	Gibbons Creek – Navasota River
14	Gabbard Park	Y	Y	N	N	Pond	City Pond	Gibbons Creek – Navasota River
15	John Crompton Park	Y	N	N	N	Pond	City Pond	Gibbons Creek – Navasota River
16	Wolf Pen	N	N	N	N	Pond	City Pond	Gibbons Creek – Navasota River
17	Museum	N	Y	N	N	Pond	Stormwater	Gibbons Creek – Navasota River
18	Lake Placid	N	Y	Y	Y	Lake	Private Lake	Gibbons Creek – Navasota River
19	Symphony Park	N	N	N	N	Pond	Neighborhood	Gibbons Creek – Navasota River
20	Research Park	N	N	N	N	Pond	Commercial	Old River – Brazos River
21	Wahlberg Lake	N	N	N	N	Lake	Commercial	Old River – Brazos River
22	Atlas Lake	Y	N	N	N	Lake	Commercial	Old River – Brazos River
23	Traditions Golf	N	N	N	N	Pond	Golf Course	Old River – Brazos River
24	Nantucket Lake	N	Y	Y	Y	Lake	Neighborhood	Gibbons Creek – Navasota River

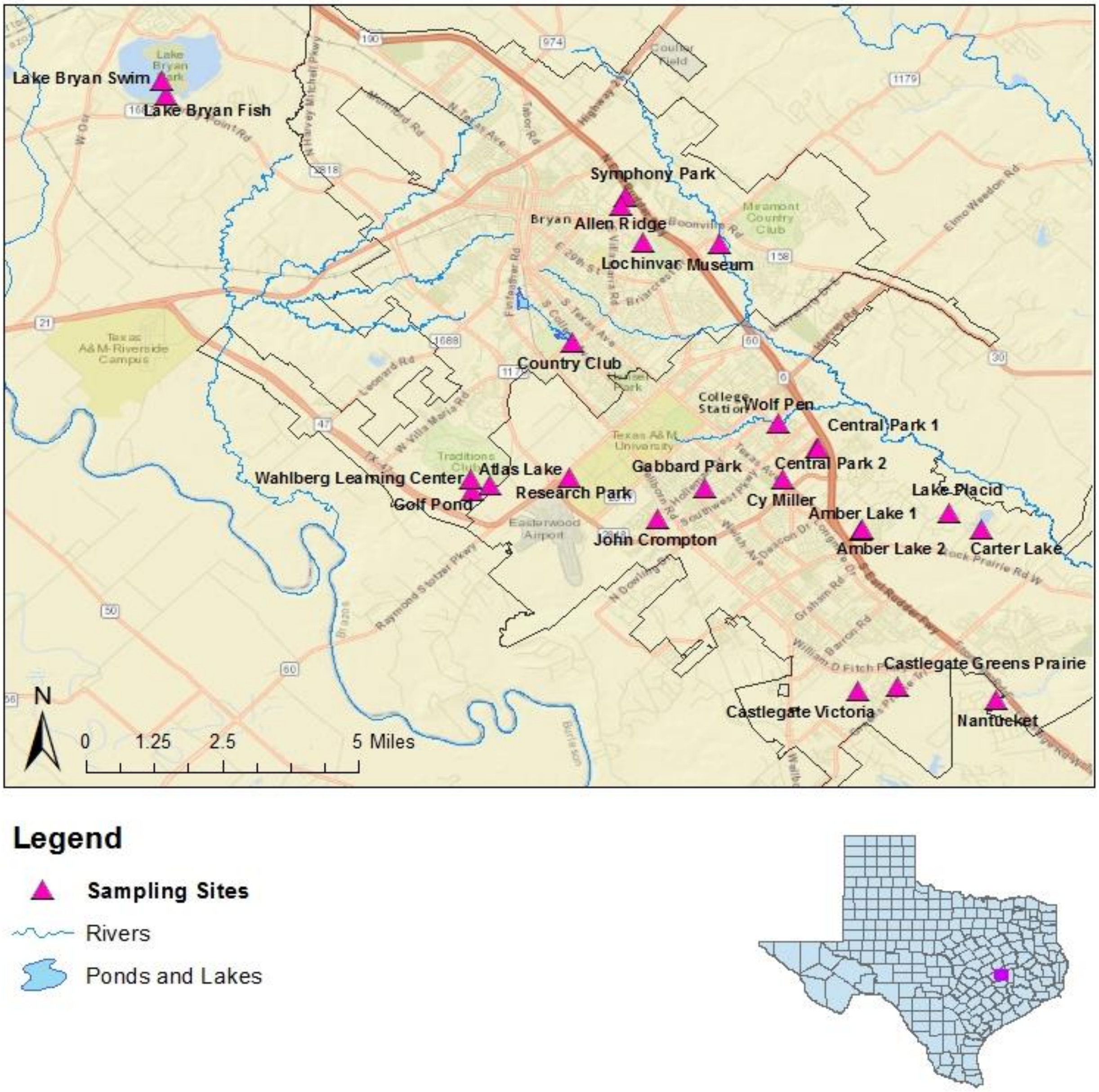

Figure 1: Sampling sites throughout the Bryan/College Station area. Sample collections occurred twice a month for a total of one year. Data from the Texas Natural Resources Information System and Texas Commission on Environmental Quality Databases, map created by Kirby Young.

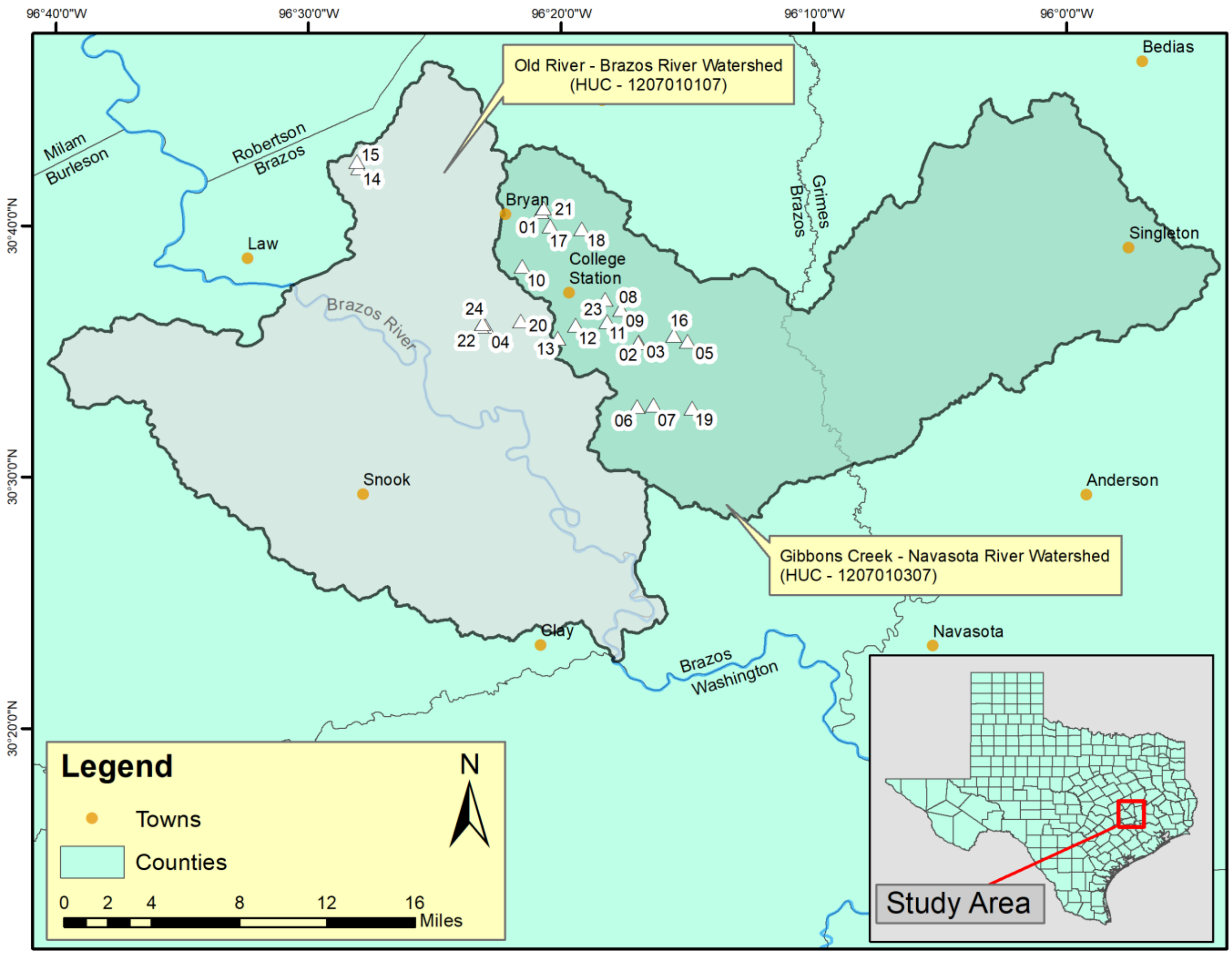

Figure 2: Locations of sampling sites within the Old River - Brazos River Watershed and the Gibbons Creek - Navasota River Watershed. Site numbers correlate with those in Table 1. Data from the Texas Natural Resources Information System and the National Land Cover Database, map created by Shubham Jain.

Surface Water Quality Sampling

Water samples were collected from each lentic waterbody twice each month. The sampling sites that were monitored followed a strict standard operating protocol (SOP) set forth by project leaders. Safety and accessibility were always a priority over sample collection, and if any site was considered unsafe or inaccessible on any particular day, sampling was not conducted. Samples in the field were collected directly into sterile 500 mL HDPE bottles and were collected from the banks of each of the lentic waterbodies and monthly bacteria samples were collected in sterile 120 mL IDEXX sample bottles that contained sodium thiosulfate to remove any potential chlorine. The samples were collected from the banks in areas that were as clear as possible in order to minimize any potential interference with algae, leaves, sticks, or any other debris that could have affected results. Once all 24 samples were collected, they were transported back to Texas A&M University (TAMU) to the appropriate laboratories. Bacteriological analyses utilized the IDEXX method and were conducted in the Soil and Aquatic Microbiology Laboratory (SAML) at TAMU, while biogeochemical analyses were conducted in the Nutrient and Water Analysis (NaWA) Laboratory at Texas A&M University. Samples intended for bacteriological analyses were immediately placed in a cooler with ice for preservation after collection. Sample collection and delivery to TAMU took no more than four hours from the time that the first sample was collected to the time that the samples were delivered. Analyses began immediately upon arrival to the laboratories.

Biogeochemical Analyses

pH and electrical conductivity were quantified on unfiltered samples utilizing a bench pH meter and EC probe. Up to 200 mL of each sample were filtered through pre-weighed Whatman GF/F filters, oven dried (60° C for 3 days), and then weighed to determine total suspended solids (TSS). Portions of each sample were transferred to biological oxygen demand (BOD) bottles and dissolved oxygen (DO) at t=0 d and t=5 d were recorded utilizing a YSI DO Meter to assess sample BOD_5. Dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) were measured using high-temperature Pt-catalyzed combustion with a Shimadzu TOC-VCSH and Shimadzu total measuring unit TNM-1 (Shimadzu Corp. Houston, TX, USA). Dissolved organic carbon (DOC) was measured as non-purgeable carbon using EPA Method 415.1, which entails acidifying the sample (2 M HCl to pH 2) and sparging it for 4 minutes with carbon-free air. Ammonium-N was analyzed using the phenate hypochlorite method with sodium nitroprusside enhancement (EPA Method 350.1). Nitrate-N was analyzed using Cadmium-Copper (Cd-Cu) reduction (EPA Method 353.3). Orthophosphate-P was quantified using the ascorbic acid, molybdate blue method. Colorimetric methods were performed with a Smartchem Discrete Analyzer (Model 200 Westco Scientific Instruments Inc. Brookfield, CT, USA). Dissolved organic nitrogen (DON) is the difference of total dissolved nitrogen minus the sum of ammonium-N and nitrate-N [TDN – (NH_4-N + NO_3-N)]. For all chemical analyses, NIST traceable laboratory standards and replicate samples were included in instrument runs after every 10 samples to monitor instrument precision. Specific Absorbance at 254 nm ($SUVA_{254}$) was used as an optical measure of refractory C and was analyzed using a Shimadzu Spectrophotometer Model UV-1280.

***E. coli* Analyses**

Bacteriological analyses were conducted according to the EPA-approved Colilert Method. Samples in the field were collected directly into sterile 120 mL IDEXX sample bottles that contained sodium thiosulfate to remove any potential chlorine. To obtain the most accurate measurement of *E. coli* in the lentic waterbodies' samples, the samples were diluted 1:10 with premade phosphate-buffered saline (PBS). 10 mL of each field sample were measured out with an adjustable volume pipette set to 10 mL. The sample, along with 90 mL of PBS, were inserted into another sterile 120 mL IDEXX sample bottle that also contained sodium thiosulfate. One package of Colilert was added to each IDEXX bottle that contained 10 mL of sample and 90 mL of PBS. Once the Colilert was added, the bottles were capped and then shaken until all of the Colilert was completely dissolved. The sample/reagent mixture was then poured into an IDEXX Quanti-Tray/2000 and fully sealed using an IDEXX Quanti-Tray Sealer. After the sample/reagent mixtures were fully sealed in the Quanti-Trays, they were placed in an incubator at 35 ± 0.5º C for 24 h. After 24 h had passed, the trays were removed from the incubator and results were read according to the IDEXX Quanti-Tray/2000 Most Probable Number (MPN) Table (Appendix A).

The Colilert that was added to the samples contained a DST nutrient-indicator, 4-methylumbeilliferyl-beta-D-glucuronide (MUG), which the *E. coli* metabolized. This process subsequently caused the samples to fluoresce in the trays under UV light.

Positive and negative wells were counted by identifying the number of large and small wells that fluoresced under a 6-watt, 365-nm ultraviolet (UV) light that was within 5 inches of the samples in a dark environment. The wells that fluoresced were considered positive, while those that did not were considered negative. The MPNs of *E. coli* were determined by first counting the number of small and large wells on the tray that fluoresced under ultraviolet light. Then, the MPN from the table that correlated with the number of positive wells was identified, producing the MPN of *E. coli* 100 mL^{-1} of water for each sample. Due to the initial 1:10 dilutions that each of the samples underwent when they were initially being processed, the MPNs that were identified were multiplied by 10 to obtain the final MPN values.

Land Cover Buffers

The Supervised Classification Method was used to prepare land cover maps for the Bryan/College Station Area using 1 m Natural Color/Color Infrared (NC\CIR) Orthoimagery from 2016 that was obtained from the NAIP. Land cover was classified into four major classifications: developed, water, grassland, and forest, which are the predominant land cover classifications throughout the study area. Shapefiles for the lentic waterbodies were either imported from the City of College Station (City of College Station GIS 2015) or Brazos County's (Brazos Central Appraisal District GIS Data) Online Open Data Files or were delineated using the 2016 1 m NC\CIR Orthoimagery from NAIP (Figure 3). 100 m buffers were created around each lentic waterbody and the land cover raster was clipped over the buffer to identify the specific land cover percentages that were present in each waterbody's buffer (Figure 4). The land cover data that was gathered from these buffers was utilized to determine potential relationships between land cover classifications and concentrations of biogeochemical and microbial constituents within the waterbodies' water and various metals within the waterbodies' sediment.

Figure 3: Aerial photograph of John Crompton Park (Site 15) before the 100 m buffer was created. Image from Google Earth.

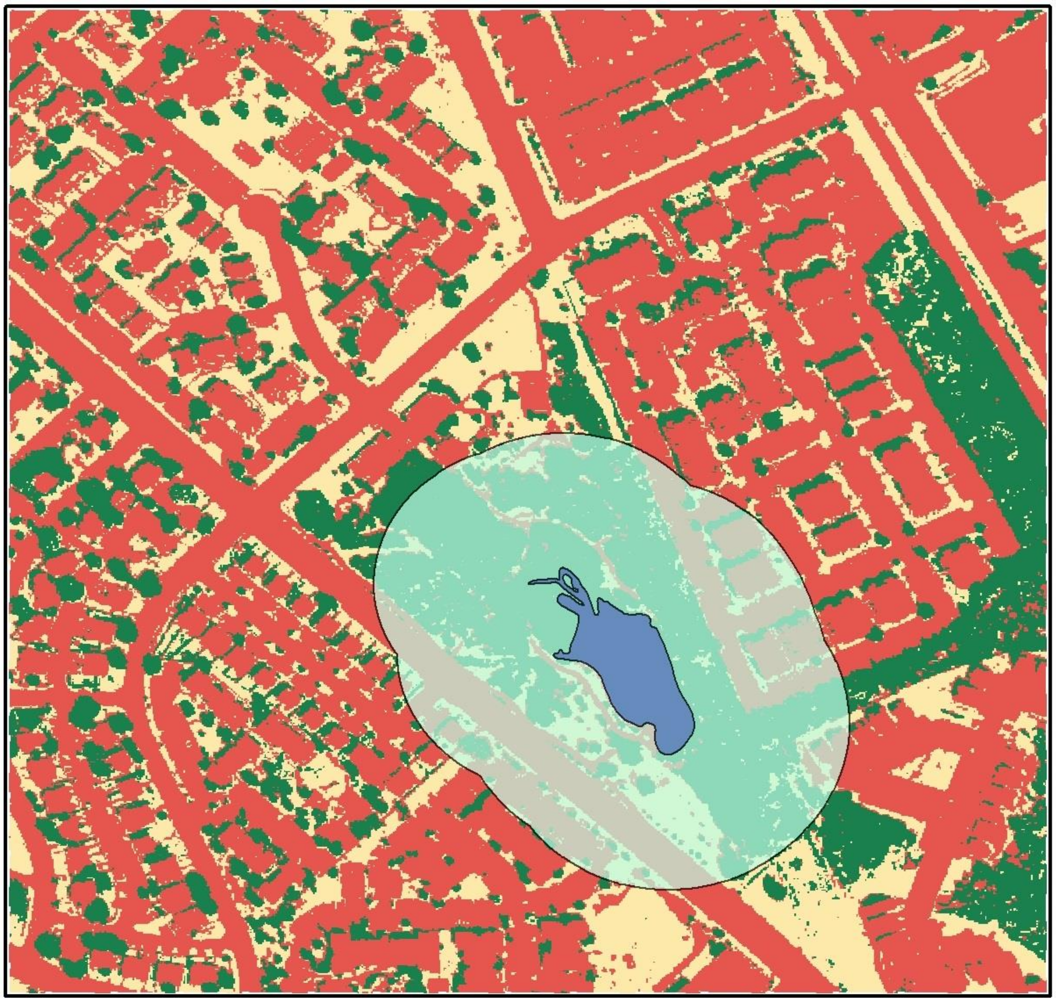

Figure 4: Aerial photograph of John Crompton Park (Site 15) with LU/LC data layer applied and a 100-meter buffer shown around the pond. Data from the National Agriculture Imagery Program (NAIP) and Google Earth, image created by Shubham Jain. Blue represents water, yellow represents grassland, red represents developed, and green represents forested land cover.

Land Cover Analyses

The majority of the sampling sites for this study are located within the Gibbons Creek – Navasota River Watershed, namely 18 out of the 24 total sites (Table 1).

Pasture/hay land cover dominates the land cover distribution for the Gibbons Creek – Navasota River Watershed by covering over 34% of the total area (Table 2). Developed land covers 19% of this watershed, which includes developed open space and developed at low, medium, and high intensities. Out of these four developed classifications, developed open space has the most coverage throughout the watershed with 7%. This developed area is primarily concentrated around the cities of Bryan and College Station, with the majority of both cities located in the Gibbons Creek – Navasota River Watershed (Figure 5). Deciduous forest covers 11% of the total watershed area, while cultivated crops and emergent herbaceous wetlands represent the land cover classifications with the least area, each with 0% area. Additionally, there is an area located near the center of the watershed that has a concentration of woody wetlands land cover (Figure 5).

The remaining six sampling sites that are not located within the Gibbons Creek – Navasota River Watershed are located within the Old River – Brazos River Watershed (Table 1). Pasture/hay land cover also dominates the Old River – Brazos River Watershed, with over 35% of the watershed included under that classification (Table 3). This watershed includes a much greater amount of cultivated cropland cover when compared to the Gibbons Creek – Navasota River Watershed, with it covering 21% of the watershed. The cultivated crop land cover is concentrated along an area that is adjacent to the town of Snook (Figure 5). Developed land cover encompasses 9% of the total watershed area. High intensity developed land and barren land covers were the least abundant land covers throughout the watershed, each with 0% area. The majority of

Bryan and College Station are both located within the Gibbons Creek – Navasota River Watershed, with only the western portion of Bryan located within the Old River – Brazos River Watershed; however, it is important to note that both Bryan and College Station are growing rapidly and expanding geographically as well. Pasture/hay land cover dominates both watersheds that contain sampling sites for this study, but the Gibbons Creek – Navasota River Watershed has more than two times the amount of developed area when compared to the Old River – Brazos River Watershed and contains the majority of the sampling sites.

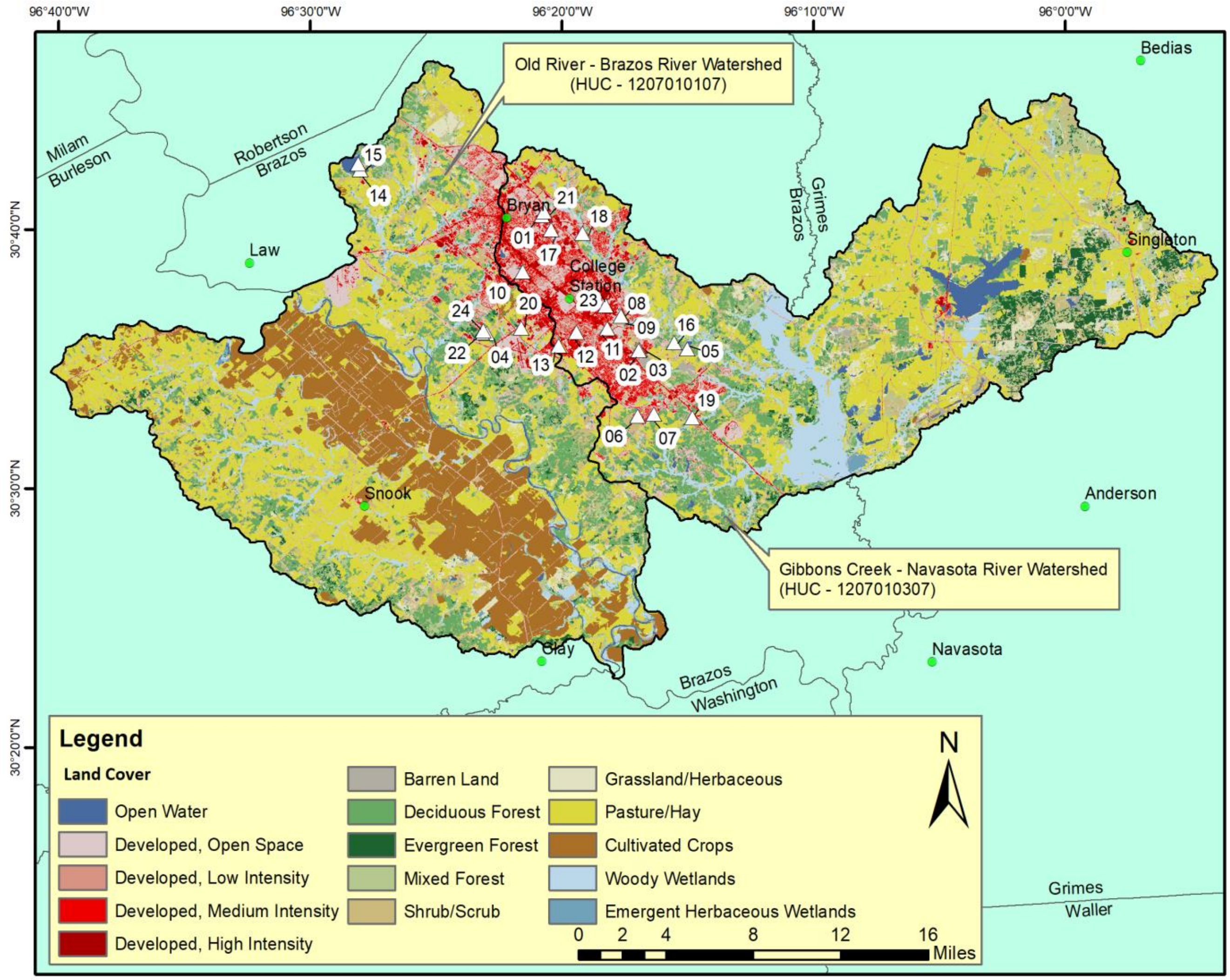

Figure 5: Land cover distribution for the study area, including both the Gibbons Creek-Navasota River and the Old River-Brazos River watersheds. Site numbers are shown according to Table 1. Data from the 2011 National Land Cover Database, map created by Shubham Jain.

Table 2: Land cover distribution for the Gibbons Creek-Navasota River Watershed. Data from the 2011 National Land Cover Database.

Gibbons Creek - Navasota River Watershed Land Cover Distribution

ID	Land Cover	Area (Acres)	Percentage of Total Area
11	Open Water	4289	3
21	Developed Open Space	12244	7
22	Developed, Low Intensity	10537	6
23	Developed, Medium Intensity	7988	5
24	Developed, High Intensity	2202	1
31	Barren Land	1273	1
41	Deciduous Forest	19522	11
42	Evergreen Forest	7235	4
43	Mixed Forest	10281	6
52	Shrub/ Scrub	12592	7
71	Grassland/Herbaceous	8143	5
81	Pasture/Hay	57437	34
82	Cultivated Crops	693	0
90	Woody Wetlands	15450	9
95	Emergent Herbaceous Wetlands	820	0
	All land covers combined	170707	100

Table 3: Land cover distribution for the Old River-Brazos River Watershed. Data from the 2011 National Land Cover Database.

Old River - Brazos River Watershed Land Cover Distribution

ID	Land Cover	Area (Acres)	Percentage of Total Area
11	Open Water	2857	1
21	Developed Open Space	11839	6
22	Developed, Low Intensity	4631	2
23	Developed, Medium Intensity	2770	1
24	Developed, High Intensity	787	0
31	Barren Land	739	0
41	Deciduous Forest	21595	11
42	Evergreen Forest	2314	1
43	Mixed Forest	5131	3
52	Shrub/ Scrub	15757	8
71	Grassland/Herbaceous	6632	3
81	Pasture/Hay	65767	35
82	Cultivated Crops	39957	21
90	Woody Wetlands	8632	5
95	Emergent Herbaceous Wetlands	1061	1
	All land covers combined	190468	100

The percentage of each of the four main land cover classifications that were calculated by the creation of a 100 m buffer around each lentic waterbody vary by site and are unique for each waterbody, with no two sites having the exact same percentages. The land cover classification that is least prevalent in the 100 m buffer around each of the lentic waterbodies is water (Table 4). The sampling site with the greatest amount of water land cover (12%) surrounding it is a pond at a city park in College Station referred to as Central Park 2 (Site 7), which is located adjacent to another larger pond at the same park that is referred to as Central Park 1 (Site 8). There were 10 sampling sites that have no water land cover within their 100 m buffers; those that do are in close proximity to other small lentic waterbodies. The concentrations of developed land cover surrounding each waterbody range from 9% at Lake Placid (Site 18), a private lake in a rural area of College Station, to 48% at Symphony Park (Site 19), a pond within an urban neighborhood in Bryan. Grassland and forest land cover classifications were the most abundant within the 100 m buffers around the lentic waterbodies, which could be attributed to the fact that many of the sampling sites are located at parks or in neighborhoods that were purposefully designed to be surrounded with vegetated land. The most abundant amount of grassland land cover (79%) is located around the Traditions Golf sampling site (Site 23), which is a small pond located on a large golf course in Bryan. The least abundant amount of grassland (14%) is located around Amber Lake 1 (Site 11), a pond located within an urban neighborhood in College Station, and Carter Lake (Site 13), a private lake that is located within a more rural area of College Station that is surrounded by abundant large trees. Coinciding with this data is the amount of forested land cover surrounding Carter Lake (69%), which is the second largest amount out of all of the sampling sites. Lake Placid, which is geographically close to Carter Lake, has the greatest amount of forested land cover with 75%. The least amount of forested land cover is located around the pond at Site 23, Traditions Golf, which has abundant grassland land cover due to its location on a large golf course, but minimal forested area surrounding it.

Table 4: Land cover data for each sampling site within the 100 m buffers. Buffers were created around each sampling site to calculate the immediate land cover percentages.

Site Number	Site Name	Land Cover Classification (%)			
		Water	Grassland	Developed	Forest
1 and 2	Lake Bryan 1 and 2	0	41	10	49
3	Country Club	1	53	20	26
4	Allen Ridge Park	0	27	41	32
5	Cy Miller Park	1	35	43	21
6	Lochinvar	4	46	21	29
7	Central 2	12	45	24	19
8	Central 1	7	38	17	38
9	Castlegate 1	0	35	35	30
10	Castlegate 2	0	34	36	30
11	Amber Lake 1	6	14	29	51
12	Amber Lake 2	4	20	39	38
13	Carter Lake	3	14	13	69
14	Gabbard Park	0	43	19	38
15	John Crompton Park	0	21	31	48
16	Wolf Pen	2	37	18	42
17	Museum	0	21	19	60
18	Lake Placid	0	16	9	75
19	Symphony Park	0	25	48	26
20	Research Park	9	38	22	31
21	Wahlberg Lake	8	67	10	14
22	Atlas Lake	7	39	46	8
23	Traditions Golf	0	79	18	3
24	Nantucket Lake	1	33	22	45

Statistical Analyses

Average concentrations and standard deviations were calculated for all biogeochemical and microbial data. In addition, the geometric mean was calculated for seasonal and annual *E. coli* values. For Objective 1, geometric mean seasonal and annual data were compared to standards for recreational use. For Objective 2, an analysis of variance (ANOVA) was performed using seasons as the independent variables and biogeochemical data as the dependent variables for each of the 24 sites ($\alpha = 0.05$). Both simple linear regression analyses and backward, stepwise multiple regression analyses were used to determine if and which nutrients might have a significant relationship with *E. coli* concentrations for Objective 3. Pearson bivariate correlation analyses were employed using the land cover classifications in the 100 m buffer around each waterbody to determine if land cover had any significant correlations with the biogeochemical or microbial seasonal concentrations.

Results

Biogeochemistry of Urban Lentic Waters

The null hypothesis that the biogeochemistry of the urban ponds and lakes would not be significantly different between seasons was rejected. The alternative hypothesis that concentrations would be higher in the fall was also rejected. Each site was examined individually and it was obvious that each site was unique from the others.

pH and Electrical Conductivity

Nine of the 24 sites had significant relationships between seasonality and pH (Tables 5-10). The highest seasonal pH was found in Traditions Golf (Site 23) in the spring (10.2±0.2) and the lowest pH was in John Crompton Park (Site 15) and Wolf Pen (Site 16) in the summer and winter, respectively (7.7±0.2 and 7.7±0.6). There were large variations in pH for some of the sites (Figure 6). For EC, eight of the 24 sites had significant relationships between seasonality and EC. Highest electrical conductivity was in Lake Bryan 1 (Site 1) (1798±83 μS cm^{-1}) in the fall and the lowest was in Gabbard Park (Site 14) (84±19 μS cm^{-1}) in the summer; neither of these sites had significant relationships with seasonality (Tables 5-10).

Nitrogen: NO_3-N, NH_4-N, and DON

Seven of the 24 sites had a significant relationship between seasonality and NO_3-N (Tables 5-10). Highest seasonal NO_3-N concentrations were found in Wahlberg Lake (Site 21) (16.3±2.5 mg L^{-1}) in the spring. Cy Miller Park (Site 5) and Central Park 1 (Site 8) had non-detectable NO_3-N in the fall. For NH_4-N, six of the 24 sites had a significant relationship with seasonality (Tables 5-10). The highest NH_4-N was in Amber Lake 1 (Site 11) (0.58±0.28 mg L^{-1}) and non-detectable NH_4-N was found in Lake Bryan 2 (Site 2), Lochinvar (Site 6), Central Park 2 (Site 7), Amber Lake 2 (Site 12), and Atlas Lake (Site 22). Eight of the 24 sites had a significant seasonal relationship with DON (Tables 5-10). Highest DON was in Lake Placid (Site 18) (1.7±1.9 mg L^{-1}) during the spring and a non-detectable DON concentration was found in Wahlberg Lake (Site 21) in the spring.

PO_4-P and TSS

Half of the sites had a significant relationship between seasonality and PO_4-P (Tables 5-10). The highest PO_4-P was in Wahlberg Lake (Site 21) (14.1±20.9 mg L^{-1}) during the winter and several sites displayed low PO_4-P (0.01 mg L^{-1}) during different seasons including Lake Bryan 2 (Site 2), Carter Lake (Site 13), Lake Placid (Site 18), and Nantucket Lake (Site 24). Total suspended solids ranged from 3-646 mg L^{-1} across sites. Only five of the sites showed a significant relationship between seasonality and TSS. The lowest TSS was in John Crompton Park (Site 15) (3.0±2 mg L^{-1}) in the fall and the highest TSS was in Lochinvar (Site 6) during the winter (646±1411 mg L^{-1}) (Tables 5-10).

DOC, $SUVA_{254}$, and BOD_5

DOC was the parameter most affected by seasonality, with fifteen of the 24 sites having a significant relationship between seasonality and DOC (Tables 5-10) for DOC. The highest DOC concentration was in Lake Bryan 1 (Site 1) (65±23 mg L^{-1}) during the summer and the lowest DOC concentrations were in Carter Lake (Site 13) (6±2 and 6±0 mg L^{-1}) during the fall and winter seasons.

$SUVA_{254}$ is an optical measure of DOC aromaticity that was used as a surrogate for determining allochthonous versus autochthonous inputs of DOC. Nine of the 24 sites had a significant relationship between seasonality and $SUVA_{254}$ and all nine also had a significant relationship between seasonality and DOC. The highest $SUVA_{254}$ was in Nantucket Lake (Site 24) (7.7±7.1 L mg-C^{-1} m^{-1}) during the spring and the lowest $SUVA_{254}$ values were in Lake Bryan 1 (Site 1) and Wahlberg Lake (Site 21) (0.9±0.6

and 0.9±0.5 L mg-C^{-1} m^{-1}) during the summer. All of the sites sampled had lower $SUVA_{254}$ values in the summer than they did during any other season over the course of the year.

There was no significant relationship between seasonality and BOD_5 at any of the sites that were examined. The highest BOD_5 was in Lake Placid (Site 18) (22.6±39.7 mg L^{-1}) during the spring and lowest observed BOD_5 was in Carter Lake (Site 13) (0.8±1.2 mg L^{-1}) during the summer (Tables 5-10).

Table 5: Seasonal biogeochemical data for sites 1-5. Differences in lowercase letters indicate a significant difference at $p < 0.05$.

		pH	EC	NO_3-N	NH_4-N	PO_4-P	DOC	DON	$SUVA_{254}$	TSS	BOD_5
			μS cm^{-1}			mg L^{-1}			L mg-$C^{-1}m^{-1}$	mg L^{-1}	
Site 1	Spring	9.4±0.2b	1676±223	0.05±0.03	0.01±0.03	0.02±0.02	11±2a	0.7±0.1	5.8±2.4c	127±33	1.9±1.7
	Summer	9.3±0.1ab	1568±183	0.06±0.06	0.01±0.02	0.02±0.01	65±23b	0.7±0.2	0.9±0.6a	78±41	3.4±4.2
	Fall	9.2±0.4ab	1798±83	0.02±0.00	0.01±0.01	0.02±0.03	24±23a	0.6±0.2	2.8±1.1ab	73±21	2.6±1.6
	Winter	9.0±0.1a	1627±215	0.05±0.02	0.04±0.03	0.03±0.01	15±1a	0.7±0.1	3.6±0.4bc	122±43	1.6±1.3
Site 2	Spring	9.4±0.2b	1677±220	0.05±0.05ab	0.00±0.00	0.02±0.01	12±2a	0.7±0.1	6.1±3.0b	33±64	3.3±4.2
	Summer	9.3±0.0b	1579±134	0.03±0.02ab	0.00±0.01	0.01±0.01	49±35b	16±0.1	1.7±1.5a	20±13	6.5±8.8
	Fall	9.4±0.1b	1821±71	0.02±0.01a	0.02±0.0.02	0.02±0.01	22±22ab	0.6±0.2	3.0±1.3ab	19±28	6.6±2.8
	Winter	9.1±0.1a	1658±227	0.07±0.03b	0.21±0.30	0.01±0.01	14±4a	0.6±0.3	4.1±0.8ab	34±26	7.3±3.8
Site 3	Spring	9.5±0.4b	313±90	0.02±0.02	0.01±0.01a	0.33±0.09b	11±1	0.9±0.2	4.6±3.2	33±64	3.3±4.2
	Summer	7.7±0.1a	276±77	0.25±0.56	0.07±0.10ab	0.09±0.08a	24±12	1.0±0.4	2.4±0.9	20±13	6.5±8.8
	Fall	7.7±0.2a	367±62	0.02±0.04	0.12±0.15ab	0.13±0.07a	23±19	1.0±0.4	2.6±1.0	19±28	6.6±2.8
	Winter	7.9±0.1a	392±84	0.07±0.06	0.24±0.21b	0.13±0.06a	12±3	1.0±0.3	3.7±0.7	34±26	7.3±3.8
Site 4	Spring	7.9±0.3ab	147±22a	0.03±0.01	0.04±0.04	0.51±0.07b	10±4	1.0±0.3	4.9±2.7	9±11	3.7±2.6
	Summer	7.6±0.2a	136±31a	0.18±0.41	0.16±0.23	0.32±0.17ab	17±6	0.8±0.4	2.6±1.0	142±223	13.6±16.2
	Fall	7.9±0.2ab	155±28ab	0.03±0.04	0.11±0.11	0.44±0.08ab	13±6	0.7±0.1	3.9±1.3	17±9	7.7±4.2
	Winter	8.1±0.1b	208±49b	0.08±0.10	0.05±0.06	0.30±0.12a	13±1	0.6±0.1	3.6±0.7	12±13	8.2±9.2
Site 5	Spring	8.4±0.4	291±39	0.07±0.10	0.08±0.09	0.04±0.02	10±2a	0.8±0.1c	3.9±2.8	9±3	3.0±1.2
	Summer	8.1±0.5	284±33	0.01±0.01	0.01±0.03	0.04±0.02	19±5b	0.7±0.1bc	1.4±0.3	11±5	4.2±1.6
	Fall	7.9±0.2	239±27	0.00±0.01	0.01±0.02	0.08±0.04	8±2a	0.5±0.2ab	3.2±0.8	5±4	2.9±1.8
	Winter	8.2±0.3	272±48	0.01±0.01	0.07±0.05	0.06±0.04	8±0a	0.5±0.1a	3.1±0.3	7±3	1.8±1.3

Table 6: Seasonal biogeochemical data for sites 6-10. Differences in lowercase letters indicate a significant difference at $p < 0.05$.

		pH	EC	NO_3-N	NH_4-N	PO_4-P	DOC	DON	$SUVA_{254}$	TSS	BOD_5
			μS cm^{-1}			mg L^{-1}			L mg-$C^{-1}m^{-1}$	mg L^{-1}	
Site 6	Spring	8.8±0.3c	651±39	0.03±0.04	0.00±0.00a	0.20±0.02	7±5	0.4±0.2a	4.5±5.7	16±7	4.1±3.2
	Summer	8.4±0.3bc	705±472	0.18±0.25	0.01±0.01a	0.28±0.08	50±38	1.1±0.4b	2.6±1.2	23±16	4.5±3.6
	Fall	8.2±0.2ab	771±273	0.07±0.10	0.01±0.01a	0.21±0.05	37±46	1.1±0.5b	3.6±1.6	8±5	3.9±2.1
	Winter	8.0±0.2a	622±325	0.15±0.19	0.22±0.20b	0.19±0.14	14±4	0.5±0.2ab	3.9±0.8	646±1411	12.4±21.0
Site 7	Spring	8.5±0.2	257±32b	0.02±0.02ab	0.00±0.00a	0.25±0.02b	15±4a	1.2±0.1c	6.9±4.7	51±18	3.8±1.5
	Summer	8.2±0.2	243±39b	0.03±0.02ab	0.00±0.01a	0.14±0.06a	23±6b	0.9±0.1b	3.1±1.3	49±24	2.6±2.0
	Fall	8.4±0.2	139±343a	0.01±0.01a	0.01±0.03a	0.06±0.03a	9±2a	0.5±0.2a	4.0±0.7	41±8	4.0±2.0
	Winter	8.3±0.3	262±50b	0.05±0.03b	0.21±0.20b	0.14±0.09a	13±1a	0.7±0.2ab	5.0±0.3	44±11	3.4±2.0
Site 8	Spring	8.2±0.3	248±32b	0.03±0.02	0.03±0.04	0.28±0.04c	16±4b	1.3±0.2c	6.9±4.9	34±11	5.8±3.0
	Summer	8.0±0.3	231±44b	0.02±0.01	0.15±0.23	0.15±0.07b	21±4c	0.8±0.3b	3.1±0.8	28±13	4.9±2.1
	Fall	8.4±0.3	133±32a	0.00±0.01	0.01±0.01	0.04±0.03a	8±1a	0.5±0.2a	4.1±0.5	24±4	5.2±3.3
	Winter	8.3±0.3	260±66n	0.03±0.03	0.15±0.06	0.13±0.11ab	13±1b	0.8±0.1ab	4.5±0.4	30±6	4.0±2.7
Site 9	Spring	8.3±0.6	371±70	0.08±0.09a	0.02±0.04	0.05±0.02a	11±2a	0.8±0.1b	5.9±3.6	85±20	4.7±2.9
	Summer	8.3±0.3	333±109	0.05±0.04a	0.02±0.03	0.11±0.05ab	22±11b	0.6±0.1ab	3.3±1.6	72±22	3.0±0.9
	Fall	8.1±0.2	377±136	0.03±0.04a	0.12±0.19	0.11±0.07a	14±7ab	0.4±0.3a	4.1±1.8	60±24	3.0±2.1
	Winter	8.1±0.2	433±75	0.33±0.09b	0.12±0.09	0.19±0.04b	14±1ab	0.7±0.1ab	5.3±0.5	78±15	2.9±2.0
Site 10	Spring	8.8±0.2c	436±109	0.07±0.09	0.05±0.05	0.10±0.02a	14±3	1.0±0.2b	6.3±3.3	35±36	1.8±1.5
	Summer	8.7±0.2bc	508±93	0.05±0.03	0.03±0.03	0.25±0.11b	25±9	0.5±0.1a	3.0±1.3	28±10	1.2±1.4
	Fall	8.5±0.1ab	486±190	0.01±0.01	0.03±0.03	0.08±0.02a	16±20	0.4±0.2a	4.3±2.0	14±4	1.6±1.5
	Winter	8.4±0.1a	556±101	0.06±0.02	0.08±0.05	0.08±0.01a	11±1	0.6±0.0a	5.5±0.5	37±28	1.4±0.9

Table 7: Seasonal biogeochemical data for sites 11-15. Differences in lowercase letters indicate a significant difference at $p < 0.05$.

		pH	EC	NO_3-N	NH_4-N	PO_4-P	DOC	DON	$SUVA_{254}$	TSS	BOD_5
			µS cm^{-1}			mg L^{-1}			L mg-$C^{-1}m^{-1}$	mg L^{-1}	
Site 11	Spring	8.5±0.3	344±162	0.13±0.20	0.22±0.17	0.16±0.05	13±4	1.2±0.7	7.1±4.8	20±11	5.5±2.6
	Summer	8.6±0.5	559±201	0.12±0.11	0.05±0.07	0.22±0.09	47±22	1.3±0.3	3.0±1.5	18±14	4.8±3.2
	Fall	8.3±0.2	583±327	0.21±0.33	0.04±0.04	0.27±0.22	17±6	1.0±0.3	4.9±0.8	21±13	6.5±3.7
	Winter	8.5±0.1	308±46	0.18±0.10	0.58±0.28	0.09±0.03	14±1	0.9±0.2	5.5±0.3	57±26	7.3±5.2
Site 12	Spring	8.9±0.6	243±61	0.02±0.02	0.00±0.00a	0.10±0.09	15±3a	1.2±0.3	5.8±5.7	13±6a	8.1±3.9
	Summer	9.0±0.4	296±66	0.02±0.02	0.05±0.08ab	0.04±0.03	29±7b	1.4±0.2	2.3±1.1	16±8a	8.9±5.8
	Fall	9.0±0.8	205±54	0.02±0.01	0.09±0.15ab	0.04±0.01	11±2a	0.9±0.7	4.2±0.4	7±4a	3.9±3.6
	Winter	8.4±0.2	289±44	0.04±0.01	0.19±0.13b	0.04±0.01	13±2a	0.9±0.1	5.3±0.6	35±20b	9.6±2.9
Site 13	Spring	8.7±0.5	182±46	0.03±0.04a	0.05±0.08	0.06±0.10	9±4ab	0.6±0.3	3.4±2.0ab	37±35	6.4±7.4
	Summer	8.5±0.4	209±24	0.01±0.01a	0.04±0.09	0.01±0.00	12±4b	0.4±0.1	2.2±0.9a	44±52	0.8±1.2
	Fall	8.4±0.3	198±10	0.04±0.03a	0.05±0.04	0.02±0.02	6±2a	0.3±0.2	4.9±1.2b	32±10	1.8±1.0
	Winter	8.4±0.2	212±35	0.10±0.05b	0.06±0.02	0.01±0.01	6±0a	0.4±0.1	7.4±0.5c	56±6	1.5±0.9
Site 14	Spring	8.3±0.6	198±179	0.06±0.10	0.04±0.04ab	0.48±0.13c	12±5	0.8±0.3	5.1±2.6	15±10ab	5.0±2.0
	Summer	8.1±0.2	84±19	0.02±0.03	0.01±0.02a	0.24±0.08b	12±3	0.7±0.2	3.1±0.9	12±6ab	4.2±3.0
	Fall	8.3±0.3	203±59	0.04±0.03	0.13±0.11b	0.14±0.10ab	14±10	0.5±0.3	3.3±1.1	9±4a	5.0±4.5
	Winter	8.3±0.1	172±33	0.09±0.09	0.11±0.07ab	0.04±0.01a	10±1	0.5±0.1	4.2±0.4	24±9b	4.1±2.5
Site 15	Spring	8.0±0.4	174±68	0.12±0.08	0.41±0.69	0.32±0.08	9±3	0.5±0.3	4.5±1.7	6±3ab	2.0±1.7
	Summer	7.7±0.2	140±53	0.15±0.10	0.09±0.14	0.26±0.08	15±6	0.6±0.2	2.7±1.1	10±6b	1.4±2.2
	Fall	8.0±0.2	228±60	0.06±0.02	0.04±0.05	0.19±0.08	13±10	0.6±0.3	3.4±1.1	3±2a	4.1±3.7
	Winter	8.1±0.1	225±74	0.20±0.25	0.12±0.11	0.38±0.25	11±4	0.7±0.4	4.3±0.6	7±4ab	3.3±2.1

Table 8: Seasonal biogeochemical data for sites 16-20. Differences in lowercase letters indicate a significant difference at $p < 0.05$.

		pH	EC	NO_3-N	NH_4-N	PO_4-P	DOC	DON	$SUVA_{254}$	TSS	BOD_5
			μS cm^{-1}			mg L^{-1}			L mg-$C^{-1}m^{-1}$	mg L^{-1}	
Site 16	Spring	8.2±0.3	511±183	0.04±0.05	0.06±0.09	0.08±0.01	13±4ab	0.9±0.3	5.5±2.5b	119±59b	6.4±1.0
	Summer	8.2±0.6	403±182	0.05±0.08	0.01±0.03	0.12±0.10	25±13b	0.9±0.4	2.4±1.4a	44±10a	6.4±4.3
	Fall	7.8±0.1	351±83	0.02±0.01	0.08±0.12	0.04±0.03	13±11ab	0.4±0.2	2.9±1.0ab	54±18a	4.7±3.4
	Winter	7.7±0.6	417±73	0.09±0.02	0.07±0.04	0.10±0.09	10±2a	0.5±0.3	4.8±1.1ab	50±15a	2.9±2.1
Site 17	Spring	8.8±0.6b	269±32ab	0.01±0.01	0.01±0.02	0.04±0.03	9±1	0.5±0.1	4.1±1.9	18±11ab	4.9±1.6
	Summer	8.5±0.4ab	237±51a	0.01±0.01	0.14±0.22	0.04±0.06	15±6	0.4±0.2	2.4±1.2	14±5a	3.3±1.6
	Fall	7.9±0.1a	201±53a	0.01±0.00	0.01±0.01	0.08±0.04	12±8	0.4±0.2	3.5±1.3	9±3a	3.7±2.5
	Winter	8.0±0.1a	281±55b	0.17±0.24	0.11±0.09	0.03±0.02	9±2	0.6±0.3	3.9±0.8	33±16b	4.6±2.8
Site 18	Spring	8.6±0.7	551±122b	0.02±0.02ab	0.02±0.02a	0.06±0.05b	22±21	1.7±1.9	4.7±4.7	404±917	22.6±39.7
	Summer	8.6±0.5	670±96b	0.01±0.01a	0.13±0.18a	0.01±0.01a	24±8	1.0±0.2	2.1±1.1	178±151	15.1±6.8
	Fall	8.0±0.1	285±81a	0.01±0.01a	0.02±0.02a	0.02±0.02ab	15±7	0.7±0.2	3.0±0.8	57±71	17.3±26.4
	Winter	8.0±0.2	563±121b	0.04±0.02b	0.43±0.19b	0.01±0.01a	10±1	0.3±0.3	3.0±0.3	15±25	6.1±6.6
Site 19	Spring	8.0±0.2	382±90a	0.04±0.05	0.04±0.08	0.07±0.06	10±4a	0.8±0.4ab	3.9±2.1	27±16	5.8±2.4
	Summer	7.9±0.2	493±183ab	0.02±0.03	0.01±0.02	0.05±0.06	33±17b	0.9±0.1b	1.8±1.2	25±14	5.4±4.9
	Fall	7.9±0.2	724±252b	0.01±0.01	0.02±0.03	0.04±0.02	19±15ab	0.6±0.1ab	2.8±1.3	21±10	3.7±3.0
	Winter	7.9±0.2	438±100ab	0.05±0.10	0.17±0.22	0.03±0.06	9±7a	0.4±0.2a	3.7±0.6	29±25	6.8±7.7
Site 20	Spring	8.4±0.2	642±171	0.03±0.04	0.03±0.05	0.74±0.22b	9±3a	0.6±0.1	4.9±2.0b	17±7	2.8±1.8
	Summer	8.4±0.2	763±290	0.08±0.13	0.06±0.13	0.32±0.14a	29±21b	0.5±0.1	1.9±1.5a	32±23	1.7±1.9
	Fall	8.3±0.2	981±132	0.03±0.02	0.01±0.02	0.30±0.14a	8±6a	0.3±0.2	3.8±1.4ab	27±14	1.7±2.3
	Winter	8.2±0.4	658±207	0.09±0.07	0.11±0.07	0.37±0.14a	9±4a	0.9±1.1	3.8±1.3ab	36±28	1.9±1.5

Table 9: Seasonal biogeochemical data for sites 21-24. Differences in lowercase letters indicate a significant difference at $p < 0.05$.

		pH	EC	NO_3-N	NH_4-N	PO_4-P	DOC	DON	$SUVA_{254}$	TSS	BOD_5
			µS cm^{-1}			mg L^{-1}			L mg-$C^{-1}m^{-1}$	mg L^{-1}	
Site 21	Spring	9.0±0.3	1130±143	16.3±2.5b	0.04±0.08	5.0±0.3	9±2a	0.0±0.0	4.3±3.3b	323±541	4.9±4.1
	Summer	9.1±0.3	1078±117	8.2±3.9a	0.07±0.10	3.4±1.5	39±14b	0.5±0.3	0.9±0.5a	55±32	10.3±4.1
	Fall	9.4±0.4	1244±264	9.1±5.5a	0.03±0.07	4.3±1.4	13±11a	1.1±0.9	3.1±1.0ab	45±23	10.2±3.6
	Winter	9.4±0.3	1238±174	4.4±2.2a	0.05±0.06	14.1±20.9	11±2a	1.3±1.8	4.7±1.3b	65±16	8.9±3.6
Site 22	Spring	9.1±0.3b	666±64b	1.1±0.9b	0.05±0.07	0.79±0.26b	8±1a	0.6±0.2	5.4±1.1b	53±23	2.2±1.8
	Summer	8.9±0.2b	621±82ab	0.1±0.1a	0.00±0.00	0.36±0.11a	22±10b	0.6±0.2	1.5±1.4a	17±11	2.0±1.3
	Fall	8.7±0.2ab	516±46a	0.5±0.5ab	0.03±0.04	0.38±0.17a	9±4a	0.7±0.3	3.9±1.3a	41±36	3.1±2.7
	Winter	8.3±0.6a	526±82a	0.2±0.2ab	0.04±0.02	0.25±0.10a	8±4a	0.7±0.3	3.8±1.1a	46±9	2.5±1.5
Site 23	Spring	10.2±0.2b	879±130	0.26±0.31	0.04±0.06	0.58±0.06b	12±2a	1.1±0.1a	6.4±3.4c	133±148	6.9±2.2
	Summer	10.1±0.4b	846±148	0.03±0.02	0.01±0.01	0.06±0.07a	38±11b	1.7±0.2b	1.4±0.5a	374±19	10.2±7.5
	Fall	9.3±0.2a	873±67	0.03±0.02	0.01±0.02	0.08±0.09a	18±10a	1.1±0.2a	3.0±0.7ab	16±7	5.8±5.4
	Winter	8.9±0.2a	824±127	0.06±0.03	0.05±0.04	0.23±0.36a	17±7a	1.3±0.5ab	4.4±1.1bc	30±12	2.3±1.5
Site 24	Spring	9.1±0.2	203±41b	0.01±0.00	0.09±0.08	0.05±0.07b	10±4a	0.7±0.1	7.7±7.1b	30±11	9.2±1.9
	Summer	9.0±0.5	141±21a	0.01±0.01	0.04±0.06	0.01±0.01a	17±4b	0.9±0.1	2.2±0.9a	17±7	8.5±3.2
	Fall	8.8±0.1	105±18ab	0.02±0.01	0.02±0.02	0.01±0.01ab	9±2a	0.5±0.1	3.2±0.4a	15±8	6.6±5.2
	Winter	8.1±1.0	147±26ab	0.02±0.01	0.04±0.02	0.01±0.00ab	9±0a	0.5±0.1	3.0±0.4a	21±10	3.4±1.9

Table 10: Maximum and minimum seasonal biogeochemical data ($\alpha = 0.05$).

Parameter	Maximum	Site Detected	Season	Minimum	Site Detected	Season	Sites Affected by Seasonality
pH	10.2±0.2	Site 23	Spring	7.7±0.2	Site 15	Summer	9
EC (µs cm^{-1})	1798±83	Site 1	Fall	84±19	Site 14	Summer	8
NO_3-N (mg L^{-1})	16.3±2.5	Site 21	Spring	ND	Sites 5 and 8	Fall	7
NH_4-N (mg L^{-1})	0.58±0.28	Site 11	Winter	ND	Sites 2, 6, 7, 12, and 22	Spring	6
PO_4-P (mg L^{-1})	14.1±20.9	Site 21	Winter	0.01	Sites 2, 13, 18, and 24	Various	12
DON (mg L^{-1})	1.7±1.9	Site 18	Spring	ND	Site 21	Spring	8
DOC (mg L^{-1})	65±23	Site 1	Summer	6±0	Site 13	Winter	15
TSS (mg L^{-1})	646±1411	Site 6	Winter	0±2	Site 15	Fall	5
$SUVA_{254}$ (L mg-C^{-1} m^{-1})	7.7±7.1	Site 24	Spring	0.9±0.5	Site 21	Summer	9
BOD_5 (mg L^{-1})	22.6±39.7	Site 18	Spring	0.8±1.2	Site 13	Summer	0

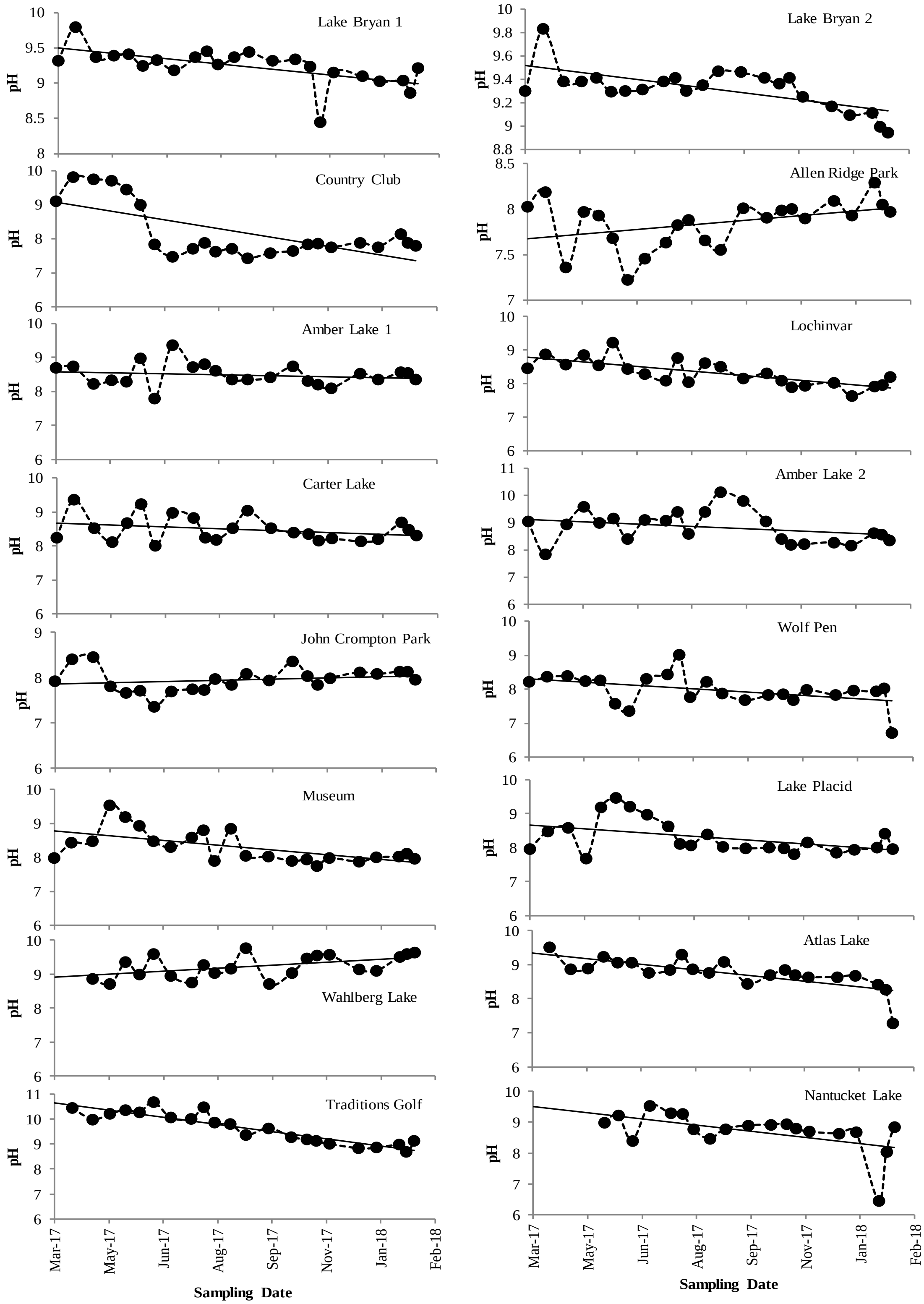

Figure 6: Annual time series of pH for sites with the most annual variation.

E. coli in Urban Lentic Waters

Annual arithmetic and geometric means were calculated for each lentic waterbody. Arithmetic means ranged from 128 MPN 100 mL^{-1} in Lake Bryan 1 (Site 1) to 1485 MPN 100 mL^{-1} in Amber Lake 1 (Site 11) (Figure 7). Geometric mean *E. coli* concentrations are the specific criterion that the TCEQ uses for comparison to Texas' Surface Water Quality Standards. Seven sampling sites had annual geometrics means of *E. coli* concentrations that exceeded the Primary Contact Recreation Standard. These sites included Country Club (Site 3), Lochinvar (Site 6), Central Park 2 (Site 7), Central Park 1 (Site 8), Amber Lake 1 (Site 11), Amber Lake 2 (Site 12), and Gabbard Park (Site 14) (Figure 8). These values ranged from 129 MPN 100 mL^{-1} at Central Park 2 (Site 7) to 456 MPN 100 mL^{-1} at Amber Lake 1 (Site 11). None of the lentic waterbodies had geometric mean *E. coli* concentrations that exceeded the Secondary Contact Recreation I Standard.

Seasonal arithmetic and geometric means were also calculated for each lentic waterbody. For the Spring, arithmetic mean *E. coli* concentrations ranged from 1 MPN 100 mL^{-1} of water in Nantucket Lake (Site 24) to 1,417 MPN 100 mL^{-1} in Amber Lake 1 (Site 11) (Figure 9). Geometric mean *E. coli* concentrations for the spring ranged from 1 MPN 100 mL^{-1} in Nantucket Lake (Site 24) to 769 MPN 100 mL^{-1} in Amber Lake 1 (Site 11). Seven sampling sites had geometric means that exceeded the Primary Contract Recreation Standard and only one site, Amber Lake 1 (Site 11), that exceeded the Secondary Contact Recreation I Standard with a seasonal geometric mean of 769 MPN 100 mL^{-1} (Figure 10). The sites with geometric means that exceeded the Primary Contact

Recreation Standard were Country Club (Site 3), Allen Ridge Park (Site 4), Central Park 1 (Site 8), Amber Lake 1 (Site 11), Gabbard Park (Site 14), Wolf Pen (Site 16), and Symphony Park (Site 19) (Figure 10).

For the summer season, arithmetic mean *E. coli* concentrations ranged from 1 MPN 100 mL^{-1} in Lake Bryan 1 (Site 1), Lake Bryan 2 (Site 2), and Museum (Site 17), to 500 MPN 100 mL^{-1} at Country Club (Site 3) (Figure 9). Geometric mean *E. coli* concentrations for the summer ranged from 1 MPN 100 mL^{-1} in Lake Bryan 1 (Site 1), Lake Bryan 2 (Site 2), and Museum (Site 17), to 400 MPN 100 mL^{-1} in Gabbard Park (Site 14) (Table 11). Four sampling sites exceeded the Primary Contract Recreation Standard including Country Club (Site 3), Lochinvar (Site 6), Central Park Park 1 (Site 8), and Gabbard Park (Site 14) (Figure 10; Table 11). No sites had geometric means for *E. coli* concentrations that exceeded the Secondary Contact Recreation I Standard.

For the fall season, arithmetic mean *E. coli* concentrations ranged from 1 MPN 100 mL^{-1} of water in Lake Bryan 2 (Site 2) and Castlegate 2 (Site 10) to 3155 MPN 100 mL^{-1} in Amber Lake 1 (Site 11) (Table 11). Geometric means *E. coli* concentrations for the fall ranged from 1 MPN 100 mL^{-1} in Lake Bryan 2 (Site 2) and Castlegate 2 (Site 10) to 1079 MPN 100 mL^{-1} in Amber Lake 1 (Site 11) (Table 11). Nine sampling sites exceeded the Primary Contact Recreation Standard including Country Club (Site 3), Allen Ridge Park (Site 4), Lochinvar (Site 6), Central Park 2 (Site 7), Central Park 1 (Site 8), Amber Lake 1 (Site 11), Amber Lake 2 (Site 12), Gabbard Park (Site 14), and Lake Placid (Site 18) (Figure 8). Amber Lake 1 (Site 11) was the only lentic waterbody that exceeded the Secondary Contact Recreation I Standard with a geometric mean of 1079 MPN 100 mL^{-1} (Figure 10).

For the winter season, arithmetic mean *E. coli* concentrations ranged from 11 MPN 100 mL^{-1} of water in Lake Bryan 2 (Site 2) to 1012 MPN 100 mL^{-1} in Amber Lake 1 (Site 11) (Table 11). Geometric means for the winter ranged from 3 MPN 100 mL^{-1} in Lake Bryan 2 (Site 2) to 863 MPN 100 mL^{-1} in Amber Lake 1 (Site 11). There were 8 sampling sites with geometric mean *E. coli* concentrations that exceeded the Primary Contact Recreation Standard including Lochinvar (Site 6), Central Park 2 (Site 7), Central Park 1 (Site 8), Amber Lake 1 (Site 11), Amber Lake 1 (Site 12), Gabbard Park (Site 14), John Crompton Park (Site 15), and Research Park (Site 20) (Figure 10). Two sites exceeded the Secondary Contract Recreation Standard including Amber Lake 1 (Site 11), with 863 MPN 100 mL^{-1}, and Gabbard Park (Site 14), with 744 MPN 100 mL^{-1} (Table 11).

There were 52 individual samples collected over the course of the year that had *E. coli* concentrations that exceeded the Single Sample Standard of 399 MPN 100 mL^{-1} (Appendix C). There were 13 exceedances in the spring, 8 in the summer, 11 in the fall, and 20 in the winter. The greatest single sample concentration was 8,664 MPN 100 mL^{-1} during the fall in Amber Lake 1 (Site 11), which is more than 21 times the Single Sample Standard. Amber Lake 1 (Site 11) exceeded this standard during eight of the 12 sampling events over the course of the year. The other sites that exceeded the Single Sample Standard included Lake Bryan 1 (Site 1), Country Club Lake (Site 3), Allen Ridge Park (Site 4), Lochinvar (Site 6), Central Park 1 (Site 7), Central Park 2 (Site 8), Castlegate 1 (Site 9), Amber Lake 2 (Site 12), Gabbard Park (Site 14), John Crompton Park (Site 15), Wolf Pen (Site 16), Lake Placid (Site 18), Symphony Park (Site 19), and Research Park (Site 20).

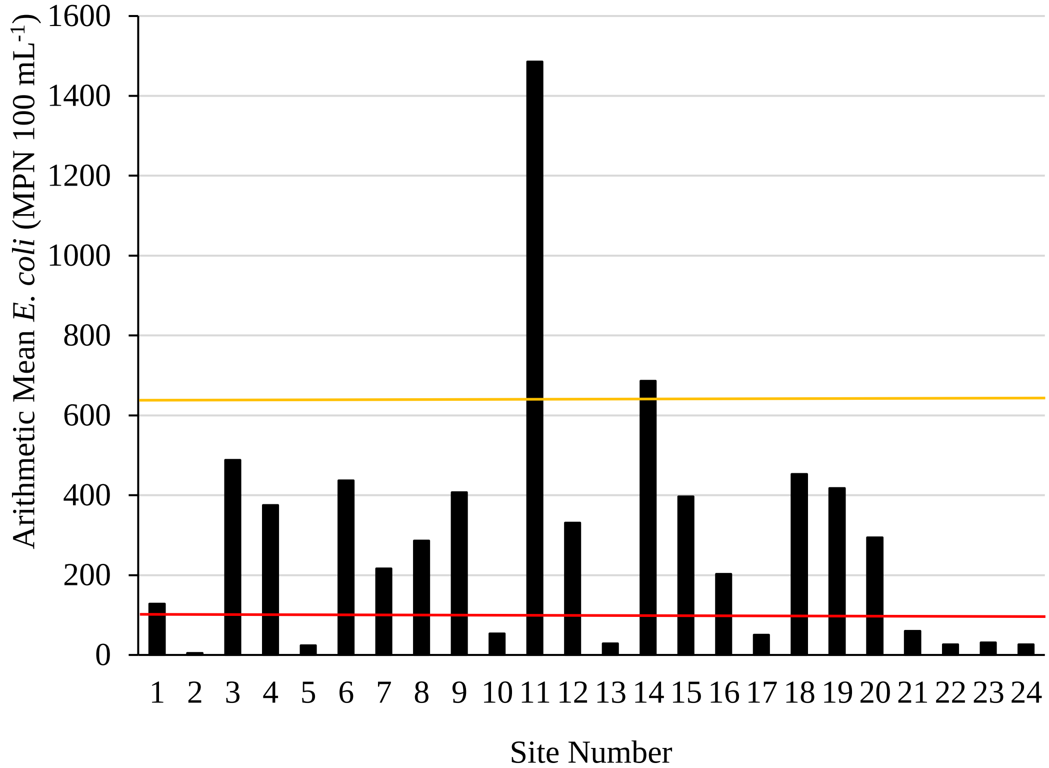

Figure 7: Annual arithmetic mean *E. coli* concentrations at each sampling site. The red line represents the State of Texas' Primary Contact Recreation Standard of 126 MPN 100 mL^{-1} of water. The yellow line represents the State of Texas' Secondary Contact Recreation I Standard of 630 MPN 100 mL^{-1} of water.

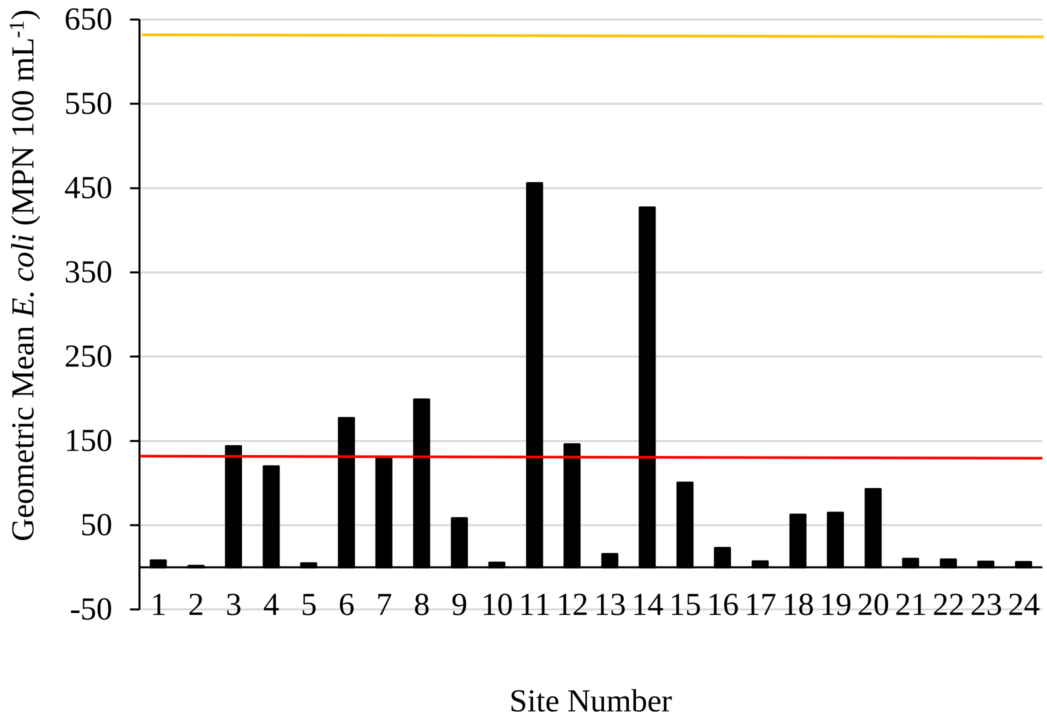

Figure 8: Annual geometric mean *E. coli* concentrations at each sampling site. The red line represents the State of Texas' Primary Contact Recreation Standard of 126 MPN 100 mL^{-1} of water.

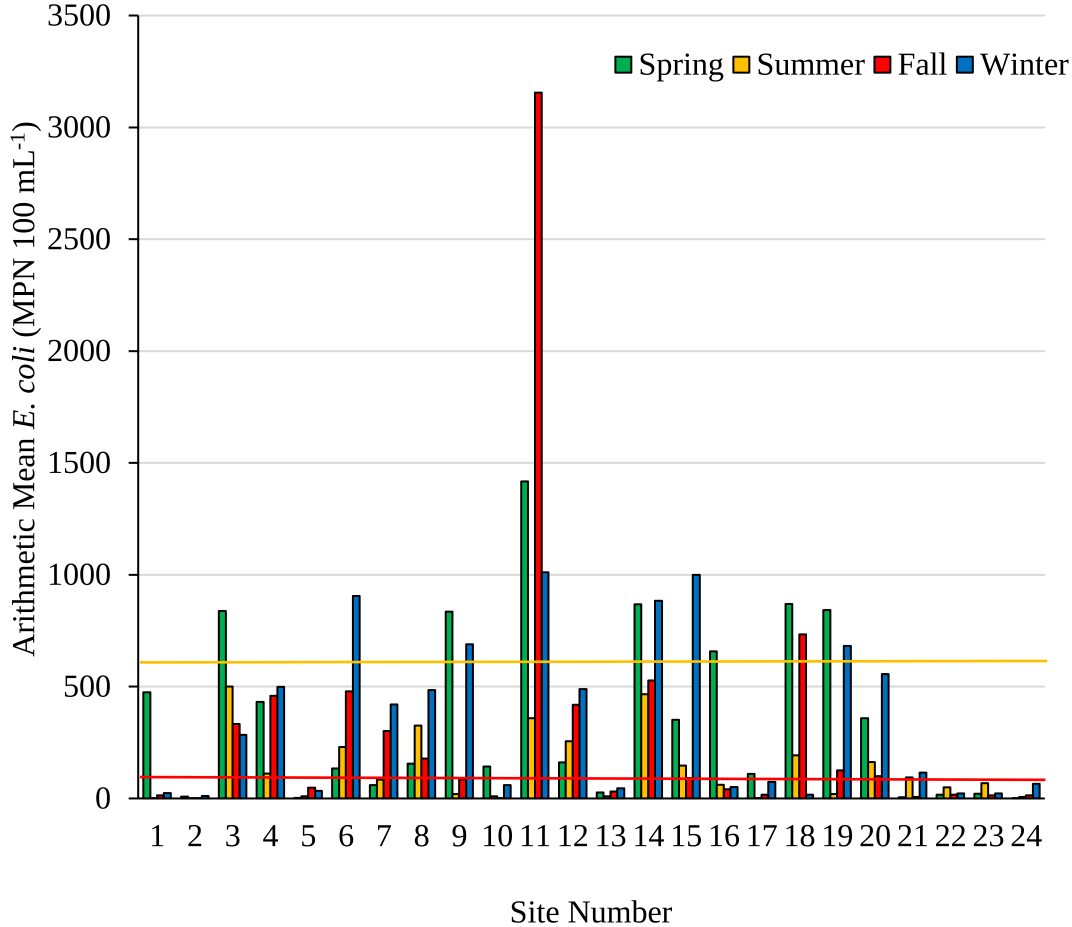

Figure 9: Seasonal arithmetic mean *E. coli* concentrations at each sampling site. The red line represents the State of Texas' Primary Contact Recreation Standard of 126 MPN 100 mL^{-1} of water. The yellow line represents the State of Texas' Secondary Contact Recreation I Standard of 630 MPN 100 mL^{-1} of water.

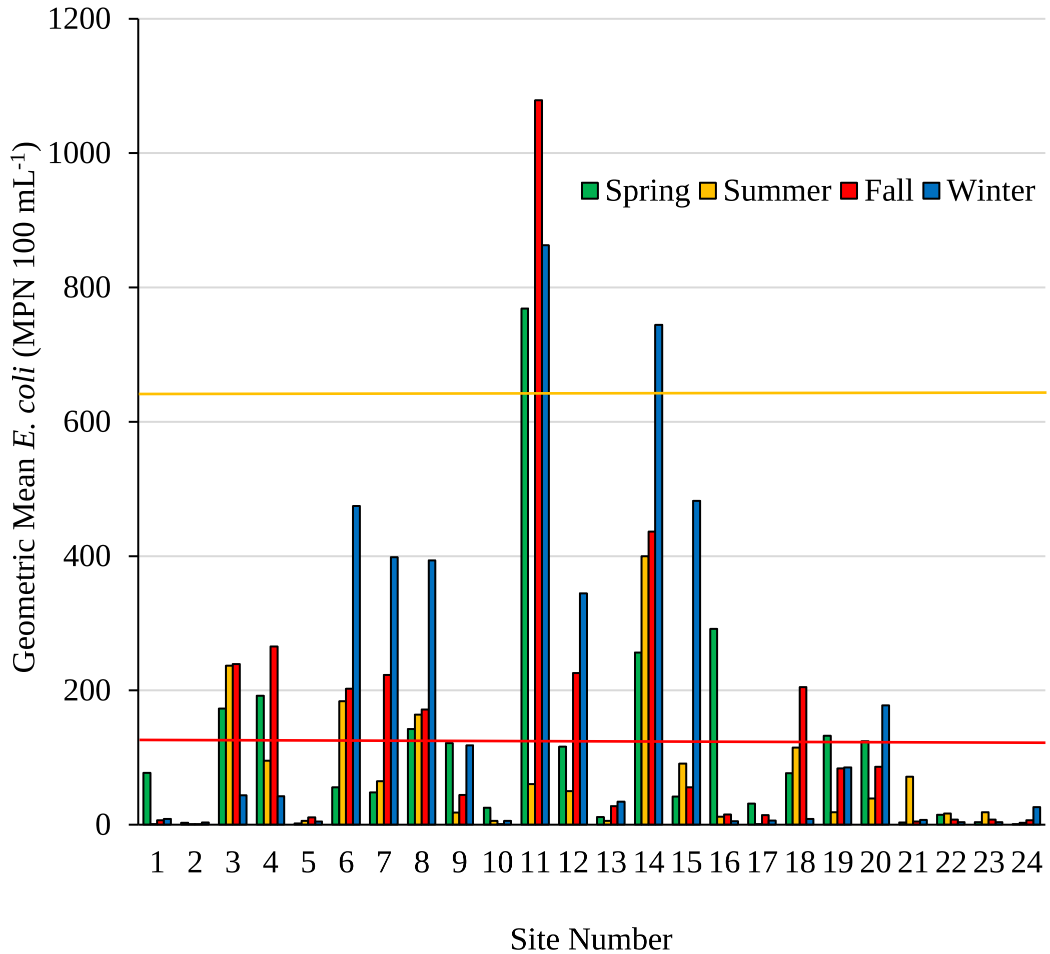

Figure 10: Seasonal geometric mean *E. coli* concentrations at each sampling site. The red line represents the State of Texas' Primary Contact Recreation Standard of 126 MPN 100 mL^{-1} of water. The yellow line represents the State of Texas’ Secondary Contact Recreation I Standard of 630 MPN 100 mL^{-1} of water.

Table 11: Annual and seasonal arithmetic (A) and geometric (G) mean *E. coli* concentrations (MPN 100 mL^{-1}) at each sampling site.

Site	Annual		Spring		Summer		Fall		Winter	
#	A	G	A	G	A	G	A	G	A	G
1	128	8	474	77	1	1	14	7	25	9
2	5	2	8	3	1	1	1	1	11	3
3	489	144	838	173	500	237	334	239	284	44
4	376	120	432	192	112	95	459	266	499	42
5	24	5	3	2	10	6	48	11	34	5
6	437	177	134	56	231	184	479	203	906	475
7	216	129	60	48	84	65	301	223	421	398
8	286	199	156	142	326	164	179	171	485	394
9	407	58	835	121	20	18	86	44	689	118
10	54	5	143	25	10	6	1	1	60	6
11	1485	456	1417	769	358	60	3155	1079	1012	863
12	331	146	161	116	256	50	419	226	489	345
13	28	16	27	11	10	6	31	28	46	34
14	687	427	869	256	467	400	528	436	884	744
15	397	101	352	42	147	91	91	56	999	482
16	203	23	658	292	61	12	41	15	51	5
17	50	7	109	31	1	1	17	14	75	6
18	453	62	869	77	193	115	734	205	17	8
19	418	65	842	132	20	18	126	84	682	85
20	294	93	358	124	163	39	99	86	556	178
21	60	10	6	3	94	71	7	5	115	7
22	27	9	18	15	50	16	17	7	22	4
23	31	7	22	4	68	19	14	7	22	4
24	26	6	1	1	7	3	14	7	66	26

The arithmetic and geometric mean *E. coli* concentrations for each site were compared to the number of days since the last rainfall event in the study area (Figure 11) and the amount of rainfall that was received during the last rainfall event (Figure 12). *E. coli* concentrations tended to decrease as the days since the last rainfall event in the study area increased for both arithmetic and geometric means ($R^2 = 0.14$ and $R^2 = 0.08$, respectively) (Figure 11). The R^2 values reflect a stronger relationship between days since last rainfall event and arithmetic mean *E. coli* concentrations rather than geometric means. *E. coli* concentrations tended to increase as the amount of rainfall received during the last rainfall event in the study area increased for both arithmetic and geometric means ($R^2 = 0.11$ and $R^2 = 0.29$, respectively) (Figure 12). The R^2 values reflect a stronger relationship between the last amount of rainfall received and geometric mean *E. coli* concentrations rather than arithmetic means. The only p-value that was found to be significant was between the geometric mean *E. coli* concentrations and the amount of rainfall that was received during the last rainfall event when $\alpha = 0.10$ ($p = 0.07$).

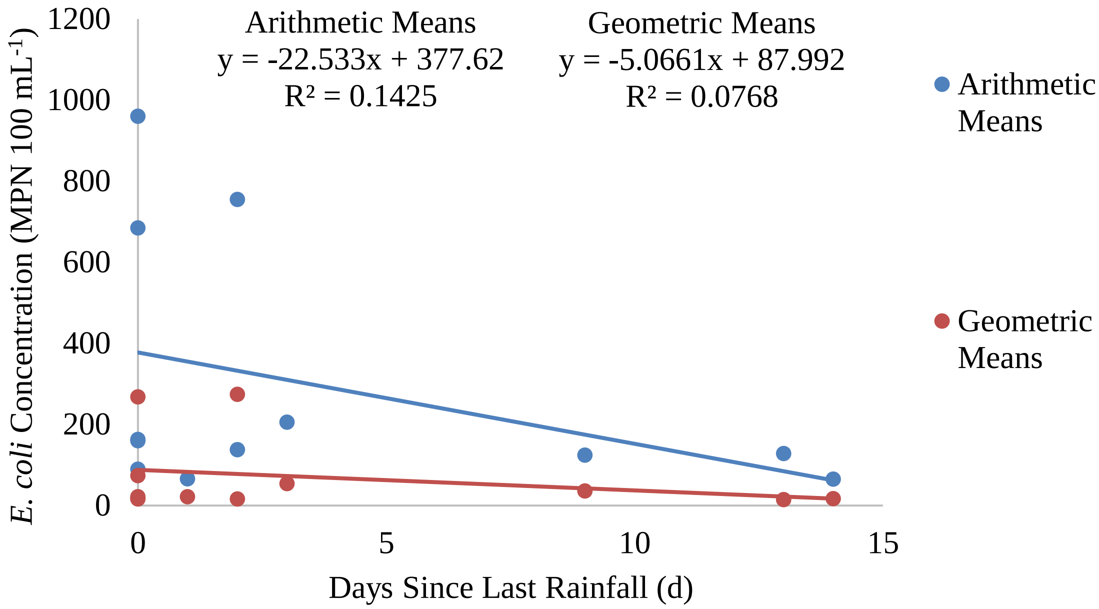

Figure 11: Arithmetic and geometric mean *E. coli* concentrations versus days since last rainfall event in the study area. Weather data from Weather Underground.

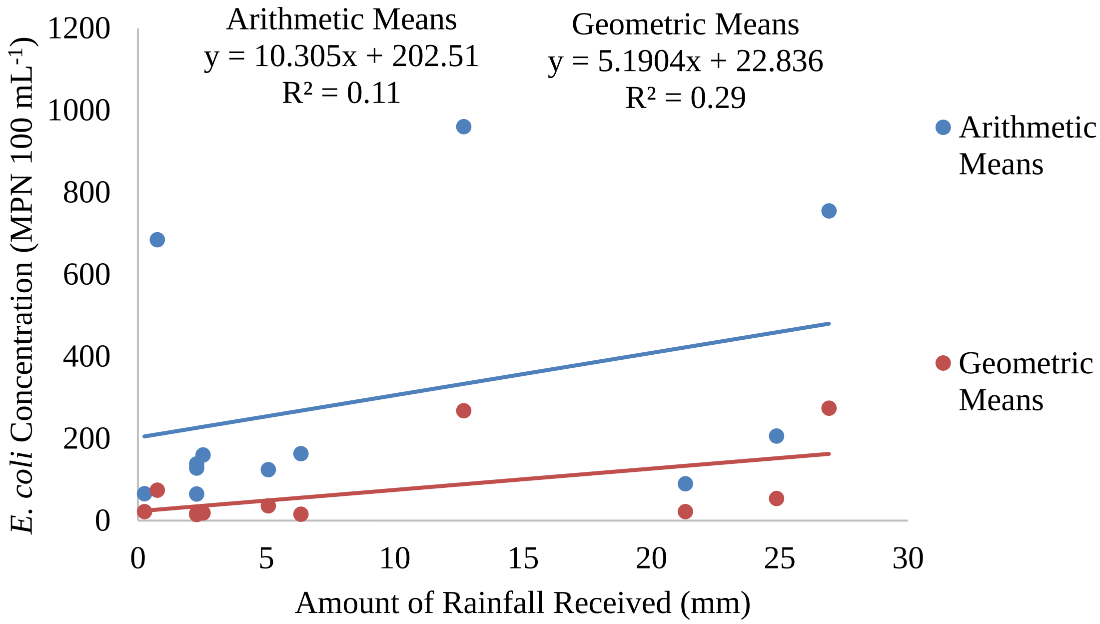

Figure 12: Arithmetic and geometric mean *E. coli* concentrations versus last amount of rainfall received in the study area. Weather data from Weather Underground.

Relationships between Biogeochemistry and E. coli Concentrations

The null hypothesis that there would be no significant relationship between *E. coli* concentrations and the urban lentic waterbodies' biogeochemical parameters at seasonal and annual temporal scales was rejected for all seasons except the spring. The alternative hypothesis that there would be a significant relationship between *E. coli* concentrations and the urban lentic waterbodies' biogeochemical parameters was accepted for all seasons except the spring (Table 12).

A backward stepwise multiple regression analysis was performed to determine which biogeochemical parameters, if any, had significant relationships with *E. coli* arithmetic means. This analysis generated several models; the model with the lowest standard error of the estimate was selected. During the spring season, none of the nutrients had significant relationships with *E. coli* numbers (R^2 = 0.26; p = 0.17). In the summer, $SUVA_{254}$, TSS, pH, EC, and biological oxygen demand were important for explaining 51% of the variance in *E. coli* arithmetic mean values (R^2 = 0.51; p = 0.02). In the fall, 66% of the variance in values (R^2 = 0.66; p = 0.007) was explained by $SUVA_{254}$, pH, BOD, TSS, and PO_4-P. During the winter season, 44% of the variance in *E. coli* was described by TSS, EC, DOC, and NH_4-N (R^2 = 0.44; p = 0.02).

Table 12: Regression coefficients for models describing *E. coli* arithmetic means.

	R^2	p	Equation Coefficients
Annual	0.23	0.001	570.4 * NH_4-N – 189 * pH + 278.7 * DON + 19.4 * BOD_5 + 74.8 * $SUVA_{254}$ + 1253.7
Spring	0.22	0.17	28.15 * BOD_5 - 241.23 * pH + 80.37 * $SUVA_{254}$ + 1912
Summer	0.51	0.02	0.28 * EC - 139.4 * pH + 30.5 * BOD_5 - 2.71 * TSS + 144.5 * $SUVA_{254}$ + 803.8
Fall	0.66	0.007	0.86 * EC – 727 * pH - 253.7 * PO_4-P - 27.8 * DOC+1709.1 * DON + 81.1 * BOD_5 + 760.9 * $SUVA_{254}$ + 2197.5
Winter	0.44	0.02	674.9 * NH_4-N - 0.44 * EC + 41.9 * DOC + 0.79 * TSS - 52.04

Land Cover Effects on Seasonal Biogeochemical and Microbial Data

Grassland land cover in the 100 m buffer surrounding the lentic waterbodies typically had a significant positive correlation with the biogeochemical constituents for all four seasons. During the spring, grassland cover had a significant positive correlation with pH ($p < 0.01$), EC ($p < 0.05$), NO_3-N ($p < 0.05$), and PO_4-P ($p < 0.05$) (Table 13). Grassland land cover had a significant positive correlation with pH, NO_3-N and PO_4-P in the summer ($p < 0.05$) (Table 13). In the fall, there were positive correlations with pH, EC, NO_3-N, PO_4-P and DON ($p < 0.05$) and a negative correlation with $SUVA_{254}$ ($p < 0.05$) (Table 13). During the winter, there were significant positive correlations that were observed between grassland land cover and pH, EC, NO_3-N, PO_4-P and DOC ($p < 0.05$) and DON ($p < 0.01$) (Table 13).

When developed land cover occurred within the 100 m buffer around each waterbody, significant negative correlations tended to be observed. There were negative correlations for TSS in the spring and fall ($p < 0.01$ and < 0.05 respectively) (Table 13). Additionally, there were negative correlations observed in both the winter and summer for EC ($p < 0.05$) (Table 13). The only significant positive correlation that was observed with surrounding water land cover within the 100 m buffers was with PO_4-P during the spring (Table 13).

The inclusion of forest land cover or small woodlands within the 100 m buffers had minimal significant correlations on the biogeochemical constituents in the waterbodies that were examined. There was a significant positive correlation between forest land cover and BOD_5 in the spring ($p < 0.05$) while there was a negative correlation observed in the winter between forest land cover and DON ($p < 0.01$) (Table 13).

For the microbial data that was gathered from each of the lentic waterbodies, there were no significant observed correlations of land cover on *E. coli* concentrations when examining seasonal arithmetic means using Pearson bivariate correlation analyses ($p > 0.05$).

Table 13: Pearson bivariate correlation analyses (R-values) and significance *$p < 0.05$ and **$p < 0.01$.

	Land Cover	pH	EC	NO_3-N	NH_4-N	PO_4-P	DOC	DON	BOD_5	TSS	$SUVA_{254}$
Spring	Grassland	**0.58****	**0.45***	**0.44***	-0.30	**0.50***	-0.17	-0.27	-0.27	0.23	0.16
	Developed	-0.39	**-0.47***	-0.23	0.19	-0.21	-0.25	0.06	-0.29	**-0.53****	-0.08
	Forest	-0.23	-0.08	-0.30	0.16	-0.38	0.32	0.20	**0.46***	0.15	-0.12
	Water	-0.09	-0.02	0.35	-0.10	**0.41***	0.00	-0.04	-0.15	0.00	0.18
Summer	Grassland	**0.43***	0.38	**0.43***	-0.35	**0.43***	0.31	0.21	0.13	-0.12	-0.37
	Developed	-0.35	**-0.43***	-0.25	-0.11	-0.19	-0.29	0.08	-0.13	-0.29	0.17
	Forest	-0.14	-0.05	-0.28	0.39	-0.33	-0.09	-0.23	0.01	0.35	0.20
	Water	0.00	0.03	0.34	-0.05	0.39	0.08	-0.02	-0.18	-0.20	0.02
Fall	Grassland	**0.44***	**0.41***	**0.42***	-0.05	**0.42***	0.27	**0.50***	0.00	0.12	**-0.45***
	Developed	-0.34	-0.37	-0.24	0.20	-0.20	-0.20	-0.11	-0.32	**-0.43***	0.25
	Forest	-0.19	-0.11	-0.28	-0.04	-0.31	-0.04	-0.37	0.23	0.18	0.15
	Water	0.16	0.00	0.35	-0.28	0.36	-0.30	0.04	-0.06	0.06	0.38
Winter	Grassland	**0.47***	**0.45***	**0.41***	-0.37	**0.43***	**0.43***	**0.61****	-0.02	0.17	-0.16
	Developed	-0.40	**-0.46***	-0.24	-0.10	-0.25	-0.13	-0.09	0.08	-0.16	-0.06
	Forest	-0.17	-0.07	-0.27	0.37	-0.28	-0.28	**-0.55****	-0.07	-0.07	0.14
	Water	0.16	-0.03	0.33	0.14	0.34	-0.05	0.37	0.13	0.10	0.21

Discussion

This study examined the biogeochemistry and *E. coli* concentrations in a variety of urban, suburban, and rural lentic ponds and lakes throughout the predominantly urban area of Bryan/College Station, TX, USA. Lotic surface waters have historically received more attention than lentic waters due to report increases in alkalization and DOC; in Texas in particular, increases in bacterial concentrations have also been prevalent. While efforts are being made towards improving lotic water quality, there is minimal knowledge on the overall health of lentic waters, despite them being subject to the same EPA and TCEQ standards and presenting opportunities for human recreation and interaction. This study sought to gain a better understanding of the overall water quality of a variety of lentic waterbodies and the subsequent risks they could present to humans and aquatic life.

Biogeochemistry of Urban Lentic Waters

Urbanization potentially alters the biogeochemistry of receiving freshwaters (McEnroe et al. 2013). Forty-five urban ponds in Ontario, Canada were examined to determine if their optical characteristics differed from other freshwater systems; results showed that DOC concentrations ranged from 2 – 16 mg L^{-1} for two summer-time sampling events (McEnroe et al. 2013). These values were lower than observed concentrations in this study, which ranged from 12.4 – 65.2 mg L^{-1} during the summer. These relatively higher values could be due to the surrounding LU/LC (Erlandsson et al. 2011), climate, or increased inputs of allochthonous DOC (Erlandsson et al. 2010), among other potential causes. A novel study in Ohio examined the effect of thousands of students jumping into a campus lake and found that DOC concentrations increased from 3.6 to 18 mg L^{-1} (Welch et al. 2017), providing some justification that human contact with lentic waters can change their biogeochemistry.

A study conducted on a lake in an urban area of Beijing utilized multivariate statistical methods to determine that temperature, secchi disk depth, chemical oxygen demand, total suspended solids, and chlorophyll-a were more significantly affected by seasonality than total nitrogen, total phosphates, NH_4-N, and BOD_5 (Jiang-Qi et al. 2013). This study determined that pH, EC, NO_3-N, NH_4-N, DON, PO_4-P, $SUVA_{254}$, and DOC were all significantly affected by seasonality in a number of the lentic waterbodies, but BOD_5 and *E. coli* were found to not be significantly affected. These findings highlight the unique biogeochemical interactions that occur within and between different types of lentic waterbodies and their surroundings.

Use of reclaimed water to replenish urban ponds used for aesthetic value may be relatively new. A study in China aroused public concern about the water quality of these ponds (Chen et al. 2017). Pairs of ponds were replenished with either surface water (SW) or reclaimed wastewater (RW) from nearby WWTFs and the most significant risks were found to be significantly higher algal growth and pathogenic risk, particularly the growth of pathogenic viruses in the RW group of ponds. This study in Bryan/College Station did not observe significantly higher *E. coli* in Wahlberg Lake (Site 21), which is replenished with reclaimed wastewater, but the concentrations of NO_3-N and PO_4-P were significantly higher. Potential sources of water to surface waterbodies other than runoff should be considered because alternative sources can contain contaminants that are not necessarily common constituents of the surrounding area's runoff; this is particularly critical for lentic waters, which cannot naturally flush their systems out over time. For example, despite Wahlberg Lake's (Site 21) close geographic relation to Traditions Golf (Site 23), their observed concentrations of NO3-N and PO_4-P were very different (16.3 mg L^{-1} (Site 21) versus 0.26 mg L^{-1} (Site 23) in the spring). This data highlights the influence of the wastewater effluent in Wahlberg Lake (Site 21).

BOD_5 and TSS are two biogeochemical parameters that are included in Texas WWTFs' Texas Pollutant Discharge Elimination System (TPDES) permits. In order to legally discharge treated wastewater effluent to its predefined and preapproved destination, WWTFs must not exceed the discharge limitations of each parameter as outlined on their TPDES permits, which can change periodically. According to a past TPDES Permit for a WWTF that is local to the study area, the single grab discharge limitations for BOD_5 and TSS have both historically been 65 mg L^{-1} (TCEQ 2013). This study found BOD_5 concentrations that ranged from 0.8 to 22.6 mg L^{-1}, which are all below the single grab discharge limitation that was specified on the local WWTF's TPDES Permit; however, TSS for this study ranged from 3 to 646 mg L^{-1}. Elevated TSS within surface waters could be caused by high concentrations of bacteria, nutrients, metals, and sediment and can lead to overall water quality deterioration of waterbody (Bilotta and Brazier 2008).

E. coli in Urban Lentic Waters

This study determined that *E. coli* concentrations can vary greatly between different types of lentic waterbodies that cannot consequently be assumed as safe for recreation, with seasonal geometric means ranging from 1 to 1079 MPN 100 mL^{-1}. A study conducted on five urban beaches around Lake Michigan found that water and weather parameters could be utilized to predict *E. coli* concentrations within a waterbody, particularly when determining whether a waterbody may exceed the EPA's standard for primary contact recreation (Nevers and Whitman 2005). These predictions could be applied towards other types of lentic waterbodies that are prevalent throughout urban areas but currently have little known about the potential risks they present for humans and aquatic life.

Potential sources of bacteria that surround each waterbody should be considered for observed *E. coli* concentrations. For example, Amber Lake 1 (Site 11) is a neighborhood pond that allows fishing for residents only. Amber Lake 1 (Site 11) and the adjacent Amber Lake 2 (Site 12) are home to various types of animals, including ducks and other aquatic birds, among other species, that neighborhood residents provide food and help care for. While aquatic birds and other wildlife are likely not the sole contributors of *E. coli* to these waterbodies, their potential for bacterial loading does need to be considered. Amber Lake 1 (Site 11) was found to have the highest *E. coli* concentrations for the entire year and every season except the summer. Conversely, if obvious potential sources are not present or within plain sight, there could be unidentified sources contributing bacteria into lentic waters such as failing OSSFs.

Relationships between Biogeochemistry and E. coli Concentrations

The seasonal relationships between *E. coli* and biogeochemical parameters that were analyzed in this study could account for the potential effects of the weather and seasonal changes in land cover on these relationships as well. Significant relationships were found in this study in all seasons except the spring, with the strongest correlation in the fall season. Hein (2015) suggested that the interactions between nutrients and *E. coli* vary by site and observed relationships could be attributed to the *E. coli* and nutrients coming from the same source, rather than being cause and effect of one another.

These relationships has been attributed to various causes, including a study conducted by Brinkmeyer et al. (2015) that found that there was a high correlation between *E. coli* concentrations and the grain size of the sediment within waterbodies. Analyses of the sediment characteristics within each the lentic waterbodies could help to better explain the potential effects of sediment size on nutrients and *E. coli* concentrations within urban lentic waterbodies. The effect of sediment size was further explained when an experimental watershed was created by Cho et al. (2010) that showed that the number of *E. coli* attached to sediment was related to the size of the sediment. Analyzing the concentrations of *E. coli* and nutrients within the sediment could help to further explain relationships and the impact that resuspension could have on what is seen in the water columns for each lentic waterbody.

Land Cover Effects on Seasonal Biogeochemical and Microbial Data

Grassland land cover was determined to be the most significantly correlated with biogeochemical parameters in this study and best management practices (BMPs) such as infiltration trenches, permeable pavement systems, vegetated filter strips, and native landscaping in urban neighborhoods could be implemented in predominantly urban areas to increase the amount of vegetated areas around lentic waterbodies (WDEQ 2013).

Structural BMPs such as wetlands, dry ponds, wet ponds, and sand filters can be implemented to reduce concentrations of microbes and nutrients within stormwater (James and Joyce 2004), but a study in Detroit found that these types of BMPs diminish in their effectiveness as impervious cover throughout an area increases (Pennington et al. 2003).

Conclusions

All of the biogeochemical constituents analyzed in this study were affected by seasonality to some degree. Additionally, *E. coli* concentrations were found throughout the lentic waterbodies that exceeded both the State of Texas' Primary and Secondary Contact Recreation I Standards according to their arithmetic and geometric means. Significant relationships were found between biogeochemistry and *E. coli* concentrations in each season except for the spring. Lastly, grassland land cover was found to have a significant positive correlation with the analyzed biogeochemical parameters in all four seasons, while no relationships were found between land cover classifications and *E. coli* concentrations.

While the majority of the lentic ponds and lakes in this study were not initially created for recreational activities, there is a presumed risk for human recreation and interaction associated with any type of waterbody that is accessible by the public. Many, but not all, of the lentic waters in this study had signs posted that stated that swimming or fishing, or both, were prohibited; however, there is no guarantee that people will obey these rules.

The findings from this study support the need for more attention to be paid to lentic surface waters, particularly due to the increased *E. coli* concentrations found throughout the sampling sites. Furthermore, future studies could include analyses of sources for bacterial and nutrient loading for different types of lentic waterbodies and best management practices that could be implemented to minimize the effects from urban stormwater runoff and other potential sources of contaminants to these lentic waters.

CHAPTER III

URBANIZATION, LAND USE/LAND COVER CHANGE, AND METALS IN URBAN LENTIC WATERS' SEDIMENT

Introduction

The Effects of Urbanization and Land Use/Land Cover Change

As urbanization continues to be a trend across the United States, the effects on the surrounding environment and the resources that humans need and utilize to survive must be considered. According to Leopold (1968), hydrologically, urbanization can affect peak flow characteristics, total runoff, water quality, and hydrologic geomorphology. Urbanization has led to expedited changes in land uses and land cover. Land cover is defined as the physical characteristics of the earth's surface like vegetation, water, soil, anthropogenic structures, etc. while land use is defined to how humans utilize the land, primarily for economic activity (Hua 2017).

When the area of impervious surfaces throughout a watershed increases as with urbanization, decreased infiltration of precipitation and irrigation water occurs and natural events, such as flooding, can become a more prevalent occurrence. Sedimentation also increases with urbanization, due to the removal of natural root systems that help keep sediment in place (Leopold 1968). Natural erosion accounts for approximately 30% of the total sediment in the United States, while the remaining 70% can be attributed to accelerated erosion caused by humans and urbanization (Spellman

2016). Additionally, sediment yields can range from 1,000 to greater than 100,000 tons per square mile per year (Leopold 1968).

Sediment, like other pollutants, gets removed by runoff when storm events occur and there are no longer structures in place to retain it. Lotic and lentic surface waterbodies are often the ultimate destination for this type of runoff, making them responsible for collecting not only the water, but also the pollutants that can come along with it.

It has been proven difficult to determine exactly what aspects of LU/LC change cause observable alterations in surface water sediments, particularly in urban areas where there can be numerous potential contributing factors occurring simultaneously. Steele et al. (2010) found that most sediment buildup in surface waters occurs during the construction phase in urban ecosystems; after construction, sediment transfer drops significantly. One of the most critical impacts of urbanization on sediment is the potential for the accumulation of metals within the sediment that are derived from anthropogenic sources and are typically found in greater concentrations near urban areas (Characklis and Wiesner 1997). Sediments are often carriers of potentially toxic elements (PTEs) of which metals are included. These metals can ultimately end up in surface waterbodies and contaminate them with potentially harmful substances that humans could encounter if any interaction or recreation occurs.

Metals in Lentic Waters and Potential Effects on Humans

The majority of the metals that are present on the Earth today have undergone biogeochemical cycles over time (Garrett 2000). Anthropogenic, industrial, domestic, technological, medical, and agricultural processes tend to utilize these metals for various applications and subsequently redistribute them widely across the environment (Tchounwou et al. 2014). Whether it be in commonly used products or in metal-based industrial operations like smelters, humans tend to rely heavily upon metals. Urban areas tend to have even higher concentrations of metals, due to abundant amounts of sources that are commonly found in urban settings such as motor vehicle brakes, tires, and oil leakage, building siding and roofs, wet and dry atmospheric fallout and deposition, and road surface materials that are commonly applied in urban settings (Campbell 1994; Characklis and Wiesner 1997; Garnaud et al. 1999; Davis et al. 2001). According to past studies, a wide variety of metals have been found to be present in surrounding surface waterbodies' sediment in predominantly urban areas, such as As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mn, Mo, Ni, Pb, Rb, Sr, Ti, Zn, and Zr (Campbell 1994; Characklis and Wiesner 1997; Garnaud et al. 1999; Davis et al. 2001).

Lotic waters have the ability to wash the metals downstream that become part of the waterbodies' sediment, while lentic waters do not. Without flow to naturally flush the system, sediment accumulation can occur and increases over time. This effect is particularly prevalent in urban watersheds that experience significant amounts of sedimentation (Paul and Meyer 2001). Lentic waters' inability to naturally flush out metals and other constituents that accumulate in sediment becomes critical when considering the effects that metals can have on both aquatic and human health. They can cause both acute and chronic health effects including cancer, disturbance of the reproductive, neurological, dermatologic, nervous, hepatobiliary, renal, cardiovascular, gastro-intestinal, and hematologic systems, and damage to critical organs such as the kidneys, liver, and lungs (Mulligan et al. 2001; Jarup 2003; Tchounwou et al. 2014). Only Ag, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Pb, Ni, Sb, Sn, Zn, and Zr have densities greater than 5 g/cm^3 and are formally considered heavy metals according to the definition by Tchounwou et al. (2014); however, other metals such as Ba, Ca, K, Rb, Sr, and Ti can still be potentially harmful to humans and should still be analyzed. Each individual metal has its own potential health risks associated with it and the amount of exposure that occurs. Therefore, understanding the relationship between various types of metals and their potential presence in the sediment of lentic waterbodies where human interaction and subsequent exposure can occur is critical.

Standards for Metals in Sediment

The TCEQ has not established specific standards for metals within surface waterbodies' sediment; however, the Texas Risk Reduction Program (TRRP) began in September 1999 and sets forth the procedures and requirements for areas that must undergo remediation for various reasons. The TRRP is the State of Texas' Program that provides critical information regarding protective concentration levels (PCLs), which is the "…regulatory standard for a concentration of a chemical of concern (COC) that must be achieved in the source medium (e.g. soil, groundwater, sediment) in order to protect a receptor at the point(s) of exposure to a COC" (TCEQ 2013). PCLs aim to protect human health and the environment from any type of release for any type of COC. They are based on the risk-based exposure limits (RBEL), or the protective level that must be met at the point of exposure, in addition to the particular COC's toxicity, exposure dose, and mobility, and the acceptable risk and hazard levels (TCEQ 2013). Tier 1 PCLs are the default cleanup standards in the TRRP, while Tier 2 PCLs are site-specific and are determined by inputting information into particular Tier 2 equations (TCEQ 2013). Tier 1 PCLs include values for both soil, water, and sediment, and depend upon on the human activities that take place at each individual site. For instance, there are stricter Tier 1 PCLs for areas where there is a much greater chance of human interaction than those that were developed for commercial use and subsequently do not present much opportunity for human interaction and potential exposure to any COCs that might be present.

In 2006, the TCEQ established the TRRP Tier 1 Direct Human Contact Sediment PCLs (TRRP Tier 1 Sediment PCLs). The TRRP Tier 1 Sediment PCLs assume that incidental ingestion of sediment, dermal contact with sediment, and the transfer of COCs to humans from the tissue of aquatic organisms, such as finfish/shellfish, are the human health exposure pathways that are assumed to be applicable (Table 14; TCEQ 2006). Due to the fact that the TCEQ has not established specific standards for various COCs in the sediment of surface waters before an environmental incident occurs that requires remediation, the TRRP Tier 1 Sediment PCLs provided a sufficient set of data for comparison for this study. These PCLs represented appropriate goals for concentrations of COCs that the State of Texas has deemed to be acceptable by approving these values.

By comparing the concentrations of various metals that were present within the sediment of the lotic waterbodies in this study to the Tier 1 PCLs, a better understanding of the general composition of the sediment within them could be gained. Additionally, there would be data that would reflect whether or not there should be concern towards the sediment compositions of each of these waterbodies where human interaction could occur. If the concentrations of particular metals that were known to have adverse effects on humans exceeded the PCLs, the responsible entities could be made aware and the appropriate steps could be taken towards improving the overall quality of the sediment within these lentic waters. It is also important to note that according to the Texas Natural Resource Conservation Commission (TNRCC), some metals that are found within the sediment are not necessarily a concern from a human health standpoint because they are essential in certain dosages; no PCLs were calculated by the TCEQ for metals that fall under this category (TCEQ 2009). Additionally, some of the metals that were included in this study have not yet had TRRP Tier 1 Sediment PCLs calculated for them at the time of this study.

Table 14: Applicable Texas Commission on Environmental Quality Texas Risk Reduction Program Tier 1 Direct Human Contact Sediment Protective Concentration Levels (mg kg^{-1}). Data is from 2006 Tier 1 Direct Human Contact Sediment Protective Concentration Levels Table (TCEQ 2006). [1]Metals that are considered to not be of necessary concern from a human health standpoint by the Texas Natural Resource Conservation Commission and therefore have no calculated human health-based values. [2]Metals that currently have no calculated Tier 1 Direct Human Contact Sediment Protective Concentration Levels.

Metal	TCEQ TRRP Tier 1 Total Residential Soil Combined PCLs (mg kg^{-1})
As	110
Ba	23000
Ca[1]	No Standard
Cd	1100
Co	32000
Cr (total)	36000
Cu	21000
Fe[1]	No Standard
Hg	34
K[1]	No Standard
Mn	14000
Mo	1800
Ni	1400
Pb	500
Rb[2]	No Standard
Sr	150000
Ti	1000000
Zn	76000
Zr[2]	No Standard

Objectives

The major objective of this study was to determine if the concentrations of a group of metals in the lentic waterbodies' sediment would meet the TCEQ's TRRP Tier 1 Sediment PCLS. The metals that were analyzed were selected due to their association with urban runoff, potential danger to humans and aquatic organisms, and instrument capability included: As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mn, Mo, Ni, Pb, Rb, Sr, Ti, Zn, and Zr. An additional objective of this study was to identify any potential significant correlations the between predominant surrounding land cover classifications and the metal concentrations found throughout the sediment of the various lentic surface waters.

Materials and Methods

Experimental Design: Site Selection and Descriptions

This study included 24 sites throughout the Bryan/College Station area that each contain a unique type of lentic waterbody. The sites were determined based on geographic location and subsequent surrounding land cover, primary and secondary purposes, recreational viability, and safety/accessibility (Chapter II: Figure 1; Table 1**).** The majority of the study sites varied greatly in their physical characteristics and no two were the same. For example, Wolf Pen Creek Park contains a small waterbody that surrounds an amphitheater in the middle of the City of College Station and acts as a potential flood mitigation structure when significant storm events. Lake Placid however, is a private lake surrounded by homes that rely on OSSFs in South College Station and is surrounded by more rural land. The variety of sampling sites and their corresponding LU/LC classifications within this study enabled a broad array of lentic waterbodies and their sediment to be analyzed, better understood, and subsequently potentially used as analogs to similar lentic waterbodies that are located around the State of Texas and nationally.

All of the sampling sites were located in either the Gibbons Creek-Navasota River Watershed or the Old River-Brazos River Watershed (Chapter II: Figure 2; Table 1). More generally, they were all located within the Lower Brazos River Basin. The Lower Brazos River Basin includes the cities of Bryan and College Station. The Lower Brazos River Basin is classified as having a subtropical humid climate and receives approximately 104.1 mm of average rainfall per year; average temperatures for the area include average annual lows of 14.9° C, average annual highs of 26.3° C, and an average annual temperature of 20.6° C (United States Climate Data: College Station Weather Averages).

For sediment sampling in particular, three sampling locations were chosen at each of the lentic waterbodies, equating to 72 sediment samples being collected total. Sediment samples were collected once throughout the project period from the banks of the lentic waterbodies, initially near the area where the bi-monthly water samples were collected. To document any heterogeneity that may occur between sampling locations at each particular waterbody, the distribution of sampling locations varied by site and was dependent on the individual characteristics of each waterbody and its surroundings. For instance, the sampling sites with clear inlets and outlets were sampled near these areas, in addition to where the bi-monthly water sample was collected. Sampling near the inlets and outlets of the waterbodies when possible enabled the change in sediment composition throughout the waterbodies, if any, to be captured. Alternatively, the waterbodies that did not have clear inlets and outlets were sampled once at the location where the bi-monthly water samples were collected in addition to two other samples that were collected approximately 20 meters on either side of the first sampling location (Table 15). Sample Location 1 represents the location where bi-monthly water samples are collected. Sample Location 2 is the location located to the left of Sample Location 1, when facing the waterbody from the bank. Sample Location 3 is the location located to the right of Sample Location 1, when facing the waterbody from the bank.

Table 15: Sediment sampling locations for each lentic waterbody.

Site No.	Site Name	Sample Location 1	Sample Location 2	Sample Location 3
1	Lake Bryan 1	30.709191, -96.467794	30.708922, -96.467801	30.709517, -96.468206
2	Lake Bryan 2	30.705548, -96.466494	30.705139, -96.466817	30.705871, -96.466188
3	Country Club	30.639589, -96.359112	30.642448, -96.362269	30.643357, -96.363729
4	Allen Ridge Park	30.675981, -96.346385	30.675859, -96.346525	30.676054, -96.346276
5	Cy Miller Park	30.603282, -96.303087	30.603409, -96.302949	30.603122, -96.303234
6	Lochinvar	30.666696, -96.340177	30.666473, -96.340009	30.666713, -96.340520
7	Central 2	30.611198, -96.293927	30.611065, -96.294115	30.611320, -96.294039
8	Central 1	30.611141, -96.293619	30.611166, -96.293327	30.611124, -96.293887
9	Castlegate 1	30.546697, -96.282980	30.546573, -96.282743	30.546524, -96.283242
10	Castlegate 2	30.548029, -96.272406	30.548128, -96.272582	30.547977, -96.272251
11	Amber Lake 1	50.589878, -96.282097	30.590062, -96.282023	30.589894, -96.281979
12	Amber Lake 2	30.589060, -96.282320	30.589227, -96.282441	30.588899, -96.282230
13	Carter Lake	30.590535, -96.249663	30.590059, -96.250107	30.590923, -96.249251
14	Gabbard Park	30.600280, -96.323616	30.600701, -96.323721	30.599789, -96.323719
15	John Crompton	30.591959, -96.335229	30.591693, -96.335095	30.592024, -96.335260
16	Wolf Pen	30.618153, -96.303873	30.618082, -96.303961	30.618246, -96.303772
17	Museum	30.664357, -96.319714	30.664522, -96.319706	30.664205, -96.319763
18	Lake Placid	30.594253, -96.259050	30.594306, -96.258931	30.594160, -96.259162
19	Symphony Park	30.678316, -96.344768	30.678401, -96.344664	30.678260, -96.344873
20	Research Park	30.603543, -96.359985	30.603536, -96.359756	30.603457, -96.360089
21	Wahlberg Lake	30.601907, -96.385184	30.602215, -96.385545	30.601568, -96.385098
22	Atlas Lake	30.600060, -96.383129	30.599990, -96.383494	30.600160, -96.382950
23	Traditions Golf	30.600329, -96.386269	30.600400, -96.386153	30.600219, -96.386298
24	Nantucket Lake	30.542843, -96.247964	30.542803, -96.248452	30.542526, -96.247738

Sediment Sampling in the Field

The annual sediment-sampling event took place on December 31, 2017. Three sediment sampling locations were chosen for each lentic waterbody (Table 15). Samples were collected in 100 mL sterile plastic containers with a gardening hand trowel and a dust pan. Utilizing waders and latex gloves, the samples were collected along the banks of each waterbody. The trowel was inserted vertically into the sediment where the water was no greater than 0.3 meters deep. After scooping up the top 10 to 15 cm of sediment, which was dependent upon the compactness of the sediment layer for each waterbody, the dust pan was placed underneath the sample in the trowel so avoid losing sediment as water drained from it. The amount of sample that was collected from each site was dependent upon various conditions including the hardness of the layer of sediment along the bank and the depth of organic matter on top of the sediment. Sites that had an abundant amount of organic material on top of the sediment were more difficult to sample and subsequently had a resulting smaller sample size, but were still sufficient. No matter the sample size, the collected sediment sample was then placed in the 100-mL sterile plastic container and labeled with the sampling location prior to storage in a cooler for transport. This process was repeated at all 24 waterbodies, with three replicate samples collected at each site. Global Positioning System (GPS) coordinates were recorded at all three sampling locations for each site. There were 72 sediment samples collected in total.

Sediment Analyses in the Laboratory

Metals selected for analyses were those that are associated with urban runoff, are potentially dangerous to humans and aquatic organisms, and were capable of being analyzed by instruments in the laboratory. The approximate sediment sample size from each waterbody was between 20 and 100 mL. Each sediment sample was homogenized, dried, and ground before analysis. To reduce the potential physical matrix effects from physical variations in the samples, each sample was homogenized. Homogenization included grinding and sieving of all of the sediment samples to a uniform particle size to reduce variability between samples. First, the sediment samples were dried with a convection oven; approximately 10 to 20 g of each sample was placed in the oven at a temperature no greater than 150º C to dry completely. The drying process was considered sufficiently complete when a constant weight for each sample could be obtained. After the sediment samples were dried, they underwent homogenization, were ground with a mortar and pestle for approximately 10 minutes each, and were then sieved with a 60-mesh sieve to ensure uniform particle size. After the samples were sieved, an aliquot of each sample was placed in 31.0-mm polyethylene sample cups for analysis, with each cup being 50-75% full. Then, the samples cups were covered with 2.5 µm Mylar film.

A Delta Premium Geochem Analyzer (Olympus Corp., Houston, TX, USA) was utilized for the sediment analyses for each of the prepared sediment samples. The Innov-X Delta Advance Pro software program was utilized to run the analyses in Soil Mode. The predefined constituents that were included in the software program’s Soil Mode included: Ag, As, Ba, Ca, Cd, Cl, Co, Cr, Cu, Fe, Hg, K, Mn, Mo, Ni, P, Pb, Rb, S, Sb, Se, Sn, Sr, Ti, Zn, and Zr. Since this study was primarily focused on the concentrations of potentially harmful metals within the lentic waterbodies' sediment, the group of metals that were focused on for this study were As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mn, Mo, Ni, Pb, Rb, Sr, Ti, Zn, and Zr. A NIST 2710a Standard Reference Material Montana I Soil was analyzed first to verify the XRF was working correctly. Calibration checks were performed after every 20 samples to maintain quality assurance and quality control (QA/QC). After all of the samples were run, the data was exported into a Microsoft Excel Worksheet for data management, analysis, comparison to the Tier 1 Sediment PCLs, and statistics to be performed.

Statistical Analyses

Means and standard deviations were calculated for each of the metals that were analyzed. These concentrations were compared with those of the TRRP Tier 1 Sediment PCLs. Pearson bivariate correlation analyses were used to determine if any specific land cover within the 100 m buffer zone around the waterbodies had a significant ($\alpha = 0.05$ or $\alpha = 0.10$) effect of metals in sediment.

Results

Metals in Urban Lentic Waters' Sediment: Do They Meet Standards?

None of the sampling sites had concentrations of As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mn, Mo, Ni, Pb, Rb, Sr, Ti, Zn, and Zr that exceeded the TRRP Tier 1 Sediment PCLs.

Ba concentrations in sediment ranged from 118±10 mg kg^{-1} in Lake Bryan 2 (Site 2) to 542±16 mg kg^{-1} in Wahlberg Lake (Site 24). Concentrations of Ba in these urban waterbody sediments did not exceed the TRRP Tier 1 Sediment PCL of 23,000 mg kg^{-1} for Ba (Table 16). Ca concentrations in sediment ranged from 1,443±45 in Lake Bryan 1 (Site 1) to 13,568±140 mg kg^{-1} in Amber Lake 2; there is no TRRP Tier 1 Sediment PCL for Ca in sediment (Table 16). K concentrations in sediment ranged from 2,693±53 in Lake Bryan 2 (Site 2) to 10,694±118 mg kg^{-1} in Museum (Site 17), which collects runoff from a shopping center; there is no TRRP Tier 1 Sediment PCL for K in sediment (Table 16). Rb concentrations ranged from 13 mg kg^{-1} in Lake Bryan 2 (Site 2) to 50±1 mg kg^{-1} in Museum (Site 17); there is no TRRP Tier 1 Sediment PCL for Rb in sediment (Table 16). Sr concentrations ranged from 23±1 mg kg^{-1} in Lake Bryan 2 (Site 2) to 151±3 mg kg^{-1} in Museum (Site 17). Concentrations of Sr found within each of the sampling sites did not exceed the TRRP Tier 1 Sediment PCL of 150,000 mg kg^{-1} for Sr (Table 16). Ti concentrations ranged from 1,116±23 mg kg^{-1} in Central 2 (Site 8) to 3,123±45 mg kg^{-1} in Carter Lake (Site 13). Concentrations of Ti did not exceed the TRRIP Tier 1 PCL of 1,000,000 mg kg^{-1} for Ti (Table 16).

All of the heavy metals that were analyzed in the urban lentic waterbodies' sediment were also all below the TRRP Tier 1 Sediment PCLs for those constituents. As concentrations ranged from non-detectable (ND) in 10 of the sampling sites, to 6±1 mg kg^{-1} in Country Club (Site 3), Carter Lake (Site 13), and Wolf Pen (Site 16) ; concentrations of As did not exceed the TRRP Tier 1 Sediment PCL of 110 mg kg^{-1} for As (Table 17). The concentrations of Cd in each of the sampling sites were all non-detectable and did not exceed the TRRP Tier 1 Sediment PCL of 1,100 mg kg^{-1} for Cd (Table 17). The concentrations of Co in each of the sampling sites were also all non-detectable and did not exceed the TRRP Tier 1 Sediment PCL of 32,000 mg kg^{-1} for Co (Table 17). The concentrations of Cr ranged from 18±2 mg kg^{-1} in Central 2 (Site 8) to 60±4 mg kg^{-1} in Amber Lake 2 (Site 12); concentrations of Cr did not exceed the TRRP Tier 1 Sediment PCL of 36,000 mg kg^{-1} for Cr (Table 17). The concentrations of Cu ranged from non-detectable in 13 of the sampling sites to 239±6 mg kg^{-1} in Atlas Lake (Site 22). These concentrations did not exceed the TRRP Tier 1 Sediment PCL of 21,000 mg kg^{-1} for Cu. Concentrations of Fe ranged from 2,350±30 mg kg^{-1} in Central 2 (Site 8) to 23,422±153 mg kg^{-1} in Amber Lake 2 (Site 12); there is no TRRP Tier 1 Sediment PCL for Fe in sediment (Table 17). The concentrations of Hg in each lentic waterbody were all non-detectable and did not exceed the TRRP Tier 1 Sediment PCL of 34 mg kg^{-1} for Hg (Table 17). Concentrations of Mn ranged from 18±4 mg kg^{-1} in Lake Bryan 2 (Site 2) to 165±5 mg kg^{-1} in Wahlberg Lake (Site 21); concentrations of Mn did not exceed the TRRP Tier 1 Sediment PCL of 14,000 mg kg^{-1} for Mn (Table 18). Concentrations of Mo ranged from non-detectable for 14 of the sampling sites to 15±2 mg kg^{-1} in Lake Bryan 1 (Site 1). The concentrations of Mo found at each sampling site did not exceed the TRRP Tier 1 Sediment PCL of 1,800 mg kg^{-1} for Mo (Table 18). Concentrations of Ni ranged from non-detectable for 22 of the urban lentic waterbodies to 20±6 mg kg^{-1} at Wahlberg Lake (Site 21), but did not exceed the TRRP Tier 1 Sediment PCL of 1,400 mg kg^{-1} for Ni (Table 18). Concentrations of Pb ranged from 8±1 mg kg^{-1} in Lake Bryan 1 (Site 1) and Amber Lake 1 (Site 11) to 24±2 mg kg^{-1} in

Country Club (Site 3); none of the concentrations exceed the TRRP Tier 1 Sediment PCL of 500 mg kg^{-1} for Pb (Table 18). Concentrations of Zn ranged from 7±1 mg kg^{-1} in Central 2 (Site 8) to 50±2 mg kg^{-1} in Cy Miller Park (Site 5). These concentrations did not exceed the TRRP Tier 1 Sediment PCL of 76,000 mg kg^{-1} for Zn (Table 18). Lastly, concentrations of Zr ranged from 331±6 mg kg^{-1} in Gabbard Park (Site 14) to 1696±23 mg kg^{-1} in Lake Bryan 1 (Site 1); there is no TRRP Tier 1 Sediment PCL for Zr in sediment (Table 18).

Table 16: Mean concentrations of Ba, Ca, K, Rb, Sr, and Ti (mg kg^{-1}) with standard deviations. The applicable Texas Risk Reduction Program Tier 1 Direct Human Contact Sediment Protective Concentration Levels are listed below each metal.

Site Number	Ba 23000 mg kg^{-1}	Ca No Standard	K No Standard	Rb No Standard	Sr 150000 mg kg^{-1}	Ti 1000000 mg kg^{-1}
1	118 ± 10	1511 ± 35	2693 ± 53	13 ± 0.70	23 ± 1	3039 ± 38
2	313 ± 12	1433 ± 45	4504 ± 73	20 ± 0.83	80 ± 2	2176 ± 38
3	203 ± 11	41402 ± 302	6625 ± 92	30 ± 1	67 ± 2	2213 ± 36
4	238 ± 11	6260 ± 74	9848 ± 111	46 ± 1	137 ± 3	2110 ± 34
5	206 ± 10	10124 ± 95	8592 ± 99	36 ± 0.97	98 ± 2	2105 ± 33
6	187 ± 9	10089 ± 94	8337 ± 96	34 ± 1	110 ± 3	1601 ± 28
7	216 ± 11	1797 ± 43	7608 ± 95	37 ± 1	81 ± 2	2617 ± 38
8	133 ± 8	2163 ± 40	6821 ± 85	27 ± 0.90	67 ± 2	1116 ± 23
9	180 ± 9	7619 ± 80	7592 ± 94	32 ± 1	77 ± 2	1602 ± 29
10	184 ± 9	3474 ± 54	8459 ± 101	40 ± 1	61 ± 2	1467 ± 28
11	139 ± 9	3846 ± 54	6422 ± 83	29 ± 0.90	46 ± 2	1667 ± 28
12	247 ± 14	13568 ± 140	7312 ± 105	49 ± 1	66 ± 2	2876 ± 47
13	208 ± 13	2638 ± 58	7306 ± 99	39 ± 1	60 ± 1	3123 ± 45
14	154 ± 8	4915 ± 60	5661 ± 77	27 ± 0.90	76 ± 1	1283 ± 26
15	200 ± 10	5562 ± 68	8610 ± 101	37 ± 1	112 ± 3	1966 ± 33
16	223 ± 11	6048 ± 74	10446 ± 116	49 ± 1	131 ± 3	2325 ± 36
17	288 ± 11	4562 ± 65	10694 ± 118	50 ± 1	151 ± 3	2500 ± 38
18	217 ± 10	5494 ± 68	6628 ± 87	36 ± 1	83 ± 2	2403 ± 36
19	222 ± 11	11235 ± 106	5684 ± 81	32 ± 0.97	104 ± 3	2321 ± 36
20	180 ± 9	6502 ± 71	6889 ± 85	31 ± 0.90	76 ± 2	2095 ± 31
21	542 ± 16	3518 ± 65	8205 ± 109	47 ± 1	178 ± 4	2849 ± 47
22	147 ± 10	1492 ± 37	4829 ± 73	25 ± 0.90	44 ± 2	2819 ± 38
23	338 ± 11	5261 ± 65	7889 ± 94	37 ± 1	111 ± 2	1962 ± 33
24	176 ± 10	3354 ± 53	7322 ± 91	35 ± 1	57 ± 2	2230 ± 34

Table 17: Mean concentrations of As, Cd, Co, Cr, Cu, Fe, and Hg (mg kg^{-1}) with standard deviations. The applicable Texas Risk Reduction Program Tier 1 Direct Human Contact Sediment Protective Concentration Levels are listed below each metal.

Site Number	As 110 mg kg^{-1}	Cd 1100 mg kg^{-1}	Co 32000 mg kg^{-1}	Cr 36000 mg kg^{-1}	Cu 21000 mg kg^{-1}	Fe No Standard	Hg 34 mg kg^{-1}
1	4 ± 1	nd	nd	34 ± 3	nd	4118 ± 42	nd
2	5 ± 1	nd	nd	55 ± 3	nd	13317 ± 94	nd
3	6 ± 1	nd	nd	44 ± 3	nd	8647 ± 72	nd
4	nd	nd	nd	35 ± 3	nd	5371 ± 51	nd
5	nd	nd	nd	29 ± 3	10 ± 3	5345 ± 50	nd
6	nd	nd	nd	26 ± 3	8 ± 3	3441 ± 38	nd
7	4 ± 1	nd	nd	34 ± 3	9 ± 3	6366 ± 57	nd
8	nd	nd	nd	18 ± 2	nd	2350 ± 30	nd
9	4 ± 1	nd	nd	28 ± 3	nd	3193 ± 37	nd
10	nd	nd	nd	31 ± 3	nd	4280 ± 45	nd
11	3 ± 1	nd	nd	37 ± 3	8 ± 2	5158 ± 48	nd
12	5 ± 1	nd	nd	60 ± 4	nd	23422 ± 153	nd
13	6 ± 1	nd	nd	49 ± 3	nd	14369 ± 102	nd
14	nd	nd	nd	20 ± 2	11 ± 2	3194 ± 36	nd
15	4 ± 1	nd	nd	30 ± 3	nd	4779 ± 47	nd
16	6 ± 1	nd	nd	46 ± 3	10 ± 3	7314 ± 63	nd
17	4 ± 1	nd	nd	50 ± 3	9 ± 2	7847 ± 65	nd
18	nd	nd	nd	50 ± 3	nd	7351 ± 61	nd
19	4 ± 1	nd	nd	39 ± 3	8 ± 2	7404 ± 62	nd
20	nd	nd	nd	31 ± 3	nd	4293 ± 43	nd
21	4 ± 1	nd	nd	68 ± 4	11 ± 3	12953 ± 98	nd
22	nd	nd	nd	38 ± 3	239 ± 6	4588 ± 47	nd
23	3 ± 1	nd	nd	33 ± 3	9 ± 3	5518 ± 51	nd
24	nd	nd	nd	28 ± 3	nd	4786 ± 47	nd

Table 18: Mean concentrations of Mn, Mo, Ni, Pb, Zn, and Zr (mg kg^{-1}) with standard deviations. The applicable Texas Risk Reduction Program Tier 1 Direct Human Contact Sediment Protective Concentration Levels are listed below each metal.

Site Number	Mn 14000 mg kg^{-1}	Mo 1800 mg kg^{-1}	Ni 1400 mg kg^{-1}	Pb 500 mg kg^{-1}	Zn 76000 mg kg^{-1}	Zr No Standard
1	41 ± 3	15 ± 2	nd	8 ± 1	12 ± 2	1696 ± 23
2	18 ± 4	5 ± 2	nd	13 ± 2	27 ± 2	479 ± 8
3	84 ± 4	nd	19 ± 6	24 ± 2	33 ± 2	662 ± 11
4	47 ± 4	nd	nd	14 ± 2	32 ± 2	897 ± 13
5	108 ± 4	5 ± 2	nd	19 ± 2	50 ± 2	571 ± 9
6	40 ± 3	5 ± 2	nd	14 ± 1	21 ± 2	626 ± 10
7	70 ± 4	nd	nd	15 ± 2	19 ± 2	651 ± 10
8	30 ± 3	5 ± 2	nd	10 ± 1	7 ± 1	579 ± 9
9	31 ± 3	nd	nd	9 ± 1	9 ± 2	645 ± 10
10	39 ± 4	nd	nd	11 ± 1	13 ± 2	422 ± 7
11	42 ± 3	nd	nd	8 ± 1	23 ± 2	388 ± 6
12	52 ± 5	7 ± 2	nd	14 ± 2	46 ± 3	488 ± 8
13	45 ± 4	nd	nd	13 ± 2	27 ± 2	728 ± 11
14	52 ± 3	nd	nd	11 ± 1	28 ± 2	331 ± 6
15	72 ± 4	5 ± 2	nd	16 ± 2	23 ± 2	634 ± 10
16	157 ± 5	nd	nd	18 ± 2	42 ± 2	590 ± 9
17	101 ± 4	nd	nd	16 ± 2	24 ± 2	507 ± 8
18	58 ± 4	nd	nd	11 ± 1	26 ± 2	808 ± 12
19	99 ± 4	nd	nd	15 ± 2	31 ± 2	486 ± 8
20	93 ± 4	7 ± 2	nd	12 ± 1	25 ± 2	594 ± 9
21	165 ± 5	nd	20 ± 6	17 ± 2	27 ± 2	583 ± 10
22	47 ± 4	10 ± 2	nd	12 ± 1	15 ± 2	1626 ± 22
23	94 ± 4	nd	nd	10 ± 1	15 ± 2	701 ± 10
24	65 ± 4	7 ± 2	nd	17 ± 2	16 ± 2	968 ± 14

Land Cover Effects on Metals within Urban Lentic Waterbodies' Sediment

A 100 m buffer was created around each of the urban lentic waterbodies in order to quantify the land cover that immediately surrounds each site and determine potential relationships between four major land cover types (Chapter II: Table 4) and concentrations of metals within the waterbodies (Tables 15-17).

Pearson bivariate correlation analyses were utilized to determine any potential correlations between land cover and metal concentrations within the lentic waterbodies' sediment. There was a significant positive correlation observed between grassland land cover in the 100 m buffer and Ba ($p < 0.05$) (Table 19). Additionally, Cu was observed to have a positive significant correlation with developed land and a negative significant correlation with forest land cover ($p < 0.10$) (Table 19). There were no other significant correlations observed between other metals within the sediment and land cover data from each waterbodies' 100 m buffer.

Table 19: Pearson bivariate correlation (R) values used to determine significant land cover correlations with metals in the sampling sites' sediment. *p < 0.10 and **p < 0.05

Land Cover	S	Cl	K	Ca	Ti	Cr	Mn	Fe	Cu
Grassland	-0.33	-0.12	-0.08	0.14	-0.08	-0.04	0.33	-0.15	0.08
Developed	0.05	-0.12	0.15	0.13	-0.11	-0.25	-0.07	-0.08	**0.37***
Forest	0.33	0.19	-0.03	-0.17	0.12	0.20	-0.28	0.18	**-0.37***
Water	-0.34	-0.05	-0.04	-0.17	0.15	0.06	0.15	0.04	0.26
	Zn	As	Rb	Sr	Zr	Mo	Ba	Pb	
Grassland	-0.20	0.04	-0.13	0.24	0.09	0.01	**0.46****	0.13	
Developed	0.22	-0.25	0.16	-0.05	-0.01	0.01	-0.26	0.08	
Forest	0.05	0.16	0.01	-0.17	-0.07	-0.03	-0.25	-0.16	
Water	-0.11	-0.09	0.01	-0.03	0.01	0.10	0.09	-0.02	

Discussion

This study analyzed the concentrations of a variety of metals that are commonly associated with urban runoff within 24 lentic waterbodies throughout the Bryan/College Station, TX, area. Specifically, the concentrations of As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mn, Mo, Ni, Pb, Rb, Sr, Ti, Zn, and Zr were compared to the TRRP Tier 1 Sediment PCLs for these metals. Additionally, relationships between the metals' concentrations and four major land cover classifications were explored.

Metals in Urban Lentic Waters' Sediment: Do They Meet Standards?

A study conducted in the Experimental Lakes Area in northwestern Ontario found that sediment are commonly the major sinks for isotopes, such as Se, Hg, Cs, Fe, and Co, which are initially deposited within the water column of a lentic waterbody (Hesslein et al. 2011). Hesslein et al. (2011) also found that thermoclines can potentially interfere with deposition and adsorption to sediment (Hesslein et al. 2011). Urban runoff is a common source of metals, heavy metals, and other contaminants that are deposited into lentic waterbodies. Metals associated with urban runoff are typically derived from the anthropogenic activities that take place on the surrounding land area; For example, a study that was conducted in the Chattahoochee River Basin found correlations among population and traffic density and the river basin's sediment concentrations of Pb and Zn (Callender and Rice 2000).

The majority of the studies conducted on the concentrations of urban runoff-derived metals found within surface waterbodies' sediment have typically been focused on lotic waters, however, a study in Southern California focused on the concentrations of a group of metals found in urban wetlands (Brown et al. 2010). These concentrations were compared to freshwater probable effects concentrations (PECs) (MacDonald et al. 2000), or concentrations above which harmful effects can be experienced by aquatic, sediment-dwelling organisms; they found that Cd, Ni, Zn, Pb, and Cu were the metals that exceeded the PECs most frequently throughout 21 urban wetland sites, respectively (Brown et al. 2010). Brown et al. (2010) collected the top 10 cm of sediment from each of the sampling locations and combined the grab samples from each site to form a composite sample; while this study in Bryan/College Station sampled sediment to similar depths, ranging from 10-15 cm depending upon how compact the sediment layer was. Additionally, this study in Bryan/College Station compared the detected concentrations to the TRRP Tier 1 Sediment PCLs, which are based on each metal's associated risks if human exposure occurs. None of the metals in this study exceeded the TRRP Tier 1 Sediment PCLs, but As came closest to exceedance with concentrations ranging from non-detectable to 6.1 ± 1.4 mg kg^{-1} throughout the 24 sites with a PCL of 24.0 mg kg^{-1}.

Land Cover Effects on Metals within Urban Lentic Waterbodies' Sediment

The study conducted by Brown et al. (2010) found a positive significant correlation between Cu, Pb, and Zn and the percentage of the surrounding impervious land cover. A significant positive correlation between grassland land cover in the 100 m buffer and Ba and another significant positive correlation between developed land cover in the 100 m buffer and Cu were identified in this study in Bryan/College Station. There was also a negative significant correlation identified between forest land cover in the 100 m buffer and Cu. According to the World Health Organization (WHO), anthropogenic sources of Ba are primarily industrial and include burning coal, fossil fuels, and waste, wastewater discharge from metallurgical and industrial processes, and the disposal of fly ash and sludge in landfills (WHO 2001). Barium has also been used in insecticides and rodenticides (WHO 2001), which could potentially be one possible explanation for the significant positive correlation between Ba and grassland land cover.

While copper is considered an essential trace mineral for the human body that must be ingested through dietary sources, health risks can occur when excessive exposure occurs. Anthropogenic sources of Cu include particulate matter from smokestack emissions, motor-vehicle brake-component and tire wear, and combustion of gasoline, lubricating, and diesel oils (Rice et al. 2002). These sources could explain the significant positive correlation between Cu and developed land cover. Lastly, a study conducted in Central Japan determined that various plant species had the ability to absorb and accumulate copper (Memon et al. 2012), which could explain the negative significant correlation between Cu and forest land cover. Alternatively, if a greater amount of forest land cover is present within the 100 m buffer, there could be a decreased chance of Cu contamination from anthropogenic sources such as vehicles. A more in-depth analysis of the surrounding vegetation for each lentic waterbody could help to confirm whether or not this could be a potential explanation for the results seen in this study and could also explore other potential relationships around some of the other lentic waterbodies that had vegetation present in their 100 m buffer areas.

Conclusions

None of the metals that were analyzed in this study exceeded their respective TRRP Tier 1 Sediment PCLs. Additionally, significant correlations were identified between the amount of forest land cover within the 100 m buffer around each lentic waterbody and the concentration of Cu in the sediment (negative), developed land cover and Cu (positive), and grassland land cover and Ba (positive). This study confirms that while there are currently minimal potential health risks for humans associated with the sediment within this study's 24 lentic waterbodies, more attention does need to be paid to the compositions of lentic waters' sediment due to the potential for the accumulation of metals and heavy metals from urban runoff. While As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mn, Mo, Ni, Pb, Rb, Sr, Ti, Zn, and Zr were not detected in excess of their standards, all of the contaminants except Cd, Co, and Hg were detected to some degree. As impervious cover, continuous construction activities, and the associated runoff continue to increase with urbanization, contaminants, like metals and heavy metals, can accumulate in lentic waterbodies that do not have the ability to flush them out as lotic systems do. Increasing concentrations of these contaminants can lead to increased risks for not only humans who recreate and interact with these waterbodies, but the aquatic life as well.

Alternative options for future research could include analyses of macrophytes and benthic organisms, due to their tendency to obviously reflect any potential metal pollution, particularly that caused by heavy metals (Linnik and Zubenko, 2000). Additionally, increasing the frequency of sediment sampling of each lentic waterbody from a one-time sampling event to seasonally could allow for any seasonal trends to be identified and for modifications in the composition of the sediment, if any, to be identified. Lastly, sediment sampling could be conducted not only more frequently, but also at more locations around each of the waterbodies in order to better document any potential heterogeneity that may be present. This could include conducting profile sampling, which could help identify any depositional trends, or sampling deeper areas of the waterbodies rather than just off the banks.

CHAPTER IV

CONCLUSIONS

Chapter II examined the biogeochemistry and *E. coli* concentrations in a variety of urban, suburban, and rural lentic ponds and lakes throughout the study area. There were multiple components to this study, including analyses of the annual and seasonal biogeochemistry and microbiology of the lentic waters, in addition to the potential relationships between the observed biogeochemistry, microbiology, and land cover classifications within a 100 m buffer of each site. The results of this study regarding the observed biogeochemistry and microbiology in each waterbody highlighted the unique nature of each site and the inability to generalize findings when it comes lentic waterbodies with differing surroundings. The null hypothesis that there would be no significant relationship seasonally and annually between *E. coli* concentrations and the urban lentic waterbodies' biogeochemical parameters was rejected for the summer, fall, and winter, while the alternative hypothesis was accepted for the spring. Grassland land cover was determined to have a significant positive correlation with the analyzed biogeochemical parameters in all four seasons, while no significant correlations were identified between land cover classifications and *E. coli* concentrations.

Chapter III analyzed and compared the concentrations of As, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mn, Mo, Ni, Pb, Rb, Sr, Ti, Zn, and Zr within each of the lentic waterbodies' sediment to their respective TRRP Tier 1 Sediment PCLs. All of the metals were detected in concentrations that did not exceed these standards. Additionally, relationships between the metals' concentrations and four major land cover classifications were explored and significant correlations were found between grassland land cover and Ba and forest and developed land covers and Cu.

This study took a holistic approach towards gaining a better understanding of the overall health of variety of lentic waterbodies throughout a predominantly urban that is experiencing continually rapid development and urbanization. All of the biogeochemical, microbial, sediment, and land cover analyses that were conducted enabled a broad picture of these waterbodies to be captured and the potential associated risks for humans and aquatic life to be acknowledged. There is no guarantee that recreation or interaction by humans will not occur in lentic waterbodies, even when preventative measures such as the installment of signs warning against primary and secondary contact recreational activities are taken. This study's findings support the notion that more attention needs to be paid to lentic waterbodies, particularly because of the *E. coli* concentrations that were found both seasonally and annually. City managers and homeowner association (HOA) boards, among other people, can utilize the data gathered during this study to make informed decisions as to which BMPs can be implemented to potentially improve water quality of these lentic waterbodies. Lastly, the sites focused on during this study and their associated data could potentially be used as analogs to similar lentic waterbodies that are located around the State of Texas and nationally.

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APPENDIX A

IDEXX QUANTI-TRAY®/2000 MPN TABLE (PER 100 ML)

IDEXX Quanti-Tray®/2000 MPN Table *(per 100ml)*

# Large Wells Positive	# Small Wells Positive																								
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	<1	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.1	15.1	16.1	17.1	18.1	19.1	20.2	21.2	22.2	23.3	24.3
1	1.0	2.0	3.0	4.0	5.0	6.0	7.1	8.1	9.1	10.1	11.1	12.1	13.2	14.2	15.2	16.2	17.3	18.3	19.3	20.4	21.4	22.4	23.5	24.5	25.6
2	2.0	3.0	4.1	5.1	6.1	7.1	8.1	9.2	10.2	11.2	12.2	13.3	14.3	15.4	16.4	17.4	18.5	19.5	20.6	21.6	22.7	23.7	24.8	25.8	26.9
3	3.1	4.1	5.1	6.1	7.2	8.2	9.2	10.3	11.3	12.4	13.4	14.5	15.5	16.5	17.6	18.6	19.7	20.8	21.8	22.9	23.9	25.0	26.1	27.1	28.2
4	4.1	5.2	6.2	7.2	8.3	9.3	10.4	11.4	12.5	13.5	14.6	15.6	16.7	17.8	18.8	19.9	21.0	22.0	23.1	24.2	25.3	26.3	27.4	28.5	29.6
5	5.2	6.3	7.3	8.4	9.4	10.5	11.5	12.6	13.7	14.7	15.8	16.9	17.9	19.0	20.1	21.2	22.2	23.3	24.4	25.5	26.6	27.7	28.8	29.9	31.0
6	6.3	7.4	8.4	9.5	10.6	11.6	12.7	13.8	14.9	16.0	17.0	18.1	19.2	20.3	21.4	22.5	23.6	24.7	25.8	26.9	28.0	29.1	30.2	31.3	32.4
7	7.5	8.5	9.6	10.7	11.8	12.8	13.9	15.0	16.1	17.2	18.3	19.4	20.5	21.6	22.7	23.8	24.9	26.0	27.1	28.3	29.4	30.5	31.6	32.8	33.9
8	8.6	9.7	10.8	11.9	13.0	14.1	15.2	16.3	17.4	18.5	19.6	20.7	21.8	22.9	24.1	25.2	26.3	27.4	28.6	29.7	30.8	32.0	33.1	34.3	35.4
9	9.8	10.9	12.0	13.1	14.2	15.3	16.4	17.6	18.7	19.8	20.9	22.0	23.2	24.3	25.4	26.6	27.7	28.9	30.0	31.2	32.3	33.5	34.6	35.8	37.0
10	11.0	12.1	13.2	14.4	15.5	16.6	17.7	18.9	20.0	21.1	22.3	23.4	24.6	25.7	26.9	28.0	29.2	30.3	31.5	32.7	33.8	35.0	36.2	37.4	38.6
11	12.2	13.4	14.5	15.6	16.8	17.9	19.1	20.2	21.4	22.5	23.7	24.8	26.0	27.2	28.3	29.5	30.7	31.9	33.0	34.2	35.4	36.6	37.8	39.0	40.2
12	13.5	14.6	15.8	16.9	18.1	19.3	20.4	21.6	22.8	23.9	25.1	26.3	27.5	28.6	29.8	31.0	32.2	33.4	34.6	35.8	37.0	38.2	39.5	40.7	41.9
13	14.8	16.0	17.1	18.3	19.5	20.6	21.8	23.0	24.2	25.4	26.6	27.8	29.0	30.2	31.4	32.6	33.8	35.0	36.2	37.5	38.7	39.9	41.2	42.4	43.6
14	16.1	17.3	18.5	19.7	20.9	22.1	23.3	24.5	25.7	26.9	28.1	29.3	30.5	31.7	33.0	34.2	35.4	36.7	37.9	39.1	40.4	41.6	42.9	44.2	45.4
15	17.5	18.7	19.9	21.1	22.3	23.5	24.7	25.9	27.2	28.4	29.6	30.9	32.1	33.3	34.6	35.8	37.1	38.4	39.6	40.9	42.2	43.4	44.7	46.0	47.3
16	18.9	20.1	21.3	22.6	23.8	25.0	26.2	27.5	28.7	30.0	31.2	32.5	33.7	35.0	36.3	37.5	38.8	40.1	41.4	42.7	44.0	45.3	46.6	47.9	49.2
17	20.3	21.6	22.8	24.1	25.3	26.6	27.8	29.1	30.3	31.6	32.9	34.1	35.4	36.7	38.0	39.3	40.6	41.9	43.2	44.5	45.9	47.2	48.5	49.8	51.2
18	21.8	23.1	24.3	25.6	26.9	28.1	29.4	30.7	32.0	33.3	34.6	35.9	37.2	38.5	39.8	41.1	42.4	43.8	45.1	46.5	47.8	49.2	50.5	51.9	53.2
19	23.3	24.6	25.9	27.2	28.5	29.8	31.1	32.4	33.7	35.0	36.3	37.6	39.0	40.3	41.6	43.0	44.3	45.7	47.1	48.4	49.8	51.2	52.6	54.0	55.4
20	24.9	26.2	27.5	28.8	30.1	31.5	32.8	34.1	35.4	36.8	38.1	39.5	40.8	42.2	43.6	44.9	46.3	47.7	49.1	50.5	51.9	53.3	54.7	56.1	57.6
21	26.5	27.9	29.2	30.5	31.8	33.2	34.5	35.9	37.3	38.6	40.0	41.4	42.8	44.1	45.5	46.9	48.4	49.8	51.2	52.6	54.1	55.5	56.9	58.4	59.9
22	28.2	29.5	30.9	32.3	33.6	35.0	36.4	37.7	39.1	40.5	41.9	43.3	44.8	46.2	47.6	49.0	50.5	51.9	53.4	54.8	56.3	57.8	59.3	60.8	62.3
23	29.9	31.3	32.7	34.1	35.5	36.8	38.3	39.7	41.1	42.5	43.9	45.4	46.8	48.3	49.7	51.2	52.7	54.2	55.6	57.1	58.6	60.2	61.7	63.2	64.7
24	31.7	33.1	34.5	35.9	37.3	38.8	40.2	41.7	43.1	44.6	46.0	47.5	49.0	50.5	52.0	53.5	55.0	56.5	58.0	59.5	61.1	62.6	64.2	65.8	67.3
25	33.6	35.0	36.4	37.9	39.3	40.8	42.2	43.7	45.2	46.7	48.2	49.7	51.2	52.7	54.3	55.8	57.3	58.9	60.5	62.0	63.6	65.2	66.8	68.4	70.0
26	35.5	36.9	38.4	39.9	41.4	42.8	44.3	45.9	47.4	48.9	50.4	52.0	53.5	55.1	56.7	58.2	59.8	61.4	63.0	64.7	66.3	67.9	69.6	71.2	72.9
27	37.4	38.9	40.4	42.0	43.5	45.0	46.5	48.1	49.6	51.2	52.8	54.4	56.0	57.6	59.2	60.8	62.4	64.1	65.7	67.4	69.1	70.8	72.5	74.2	75.9
28	39.5	41.0	42.6	44.1	45.7	47.3	48.8	50.4	52.0	53.6	55.2	56.9	58.5	60.2	61.8	63.5	65.2	66.9	68.6	70.3	72.0	73.7	75.5	77.3	79.0
29	41.7	43.2	44.8	46.4	48.0	49.6	51.2	52.8	54.5	56.1	57.8	59.5	61.2	62.9	64.6	66.3	68.0	69.8	71.5	73.3	75.1	76.9	78.7	80.5	82.4
30	43.9	45.5	47.1	48.7	50.4	52.0	53.7	55.4	57.1	58.8	60.5	62.2	64.0	65.7	67.5	69.3	71.0	72.9	74.7	76.5	78.3	80.2	82.1	84.0	85.9
31	46.2	47.9	49.5	51.2	52.9	54.6	56.3	58.1	59.8	61.6	63.3	65.1	66.9	68.7	70.5	72.4	74.2	76.1	78.0	79.9	81.8	83.7	85.7	87.6	89.6
32	48.7	50.4	52.1	53.8	55.6	57.3	59.1	60.9	62.7	64.5	66.3	68.2	70.0	71.9	73.8	75.7	77.6	79.5	81.5	83.5	85.4	87.5	89.5	91.5	93.6
33	51.2	53.0	54.8	56.5	58.3	60.2	62.0	63.8	65.7	67.6	69.5	71.4	73.3	75.2	77.2	79.2	81.2	83.2	85.2	87.3	89.3	91.4	93.6	95.7	97.8
34	53.9	55.7	57.6	59.4	61.3	63.1	65.0	67.0	68.9	70.8	72.8	74.8	76.8	78.8	80.8	82.9	85.0	87.1	89.2	91.4	93.5	95.7	97.9	100.2	102.4
35	56.8	58.6	60.5	62.4	64.4	66.3	68.3	70.3	72.3	74.3	76.3	78.4	80.5	82.6	84.7	86.9	89.1	91.3	93.5	95.7	98.0	100.3	102.6	105.0	107.3
36	59.8	61.7	63.7	65.7	67.7	69.7	71.7	73.8	75.9	78.0	80.1	82.3	84.5	86.7	88.9	91.2	93.5	95.8	98.1	100.5	102.9	105.3	107.7	110.2	112.7
37	62.9	65.0	67.0	69.1	71.2	73.3	75.4	77.6	79.8	82.0	84.2	86.5	88.8	91.1	93.4	95.8	98.2	100.6	103.1	105.6	108.1	110.7	113.3	115.9	118.6
38	66.3	68.4	70.6	72.7	74.9	77.1	79.4	81.6	83.9	86.2	88.6	91.0	93.4	95.8	98.3	100.8	103.4	105.9	108.6	111.2	113.9	116.6	119.4	122.2	125.0
39	70.0	72.2	74.4	76.7	78.9	81.3	83.6	86.0	88.4	90.9	93.4	95.9	98.4	101.0	103.6	106.3	109.0	111.8	114.6	117.4	120.3	123.2	126.1	129.2	132.2
40	73.8	76.2	78.5	80.9	83.3	85.7	88.2	90.8	93.3	95.9	98.5	101.2	103.9	106.7	109.5	112.4	115.3	118.2	121.2	124.3	127.4	130.5	133.7	137.0	140.3
41	78.0	80.5	83.0	85.5	88.0	90.6	93.3	95.9	98.7	101.4	104.3	107.1	110.0	113.0	116.0	119.1	122.2	125.4	128.7	132.0	135.4	138.8	142.3	145.9	149.5
42	82.6	85.2	87.8	90.5	93.2	96.0	98.8	101.7	104.6	107.6	110.6	113.7	116.9	120.1	123.4	126.7	130.1	133.6	137.2	140.8	144.5	148.3	152.2	156.1	160.2
43	87.6	90.4	93.2	96.0	99.0	101.9	105.0	108.1	111.2	114.5	117.8	121.1	124.6	128.1	131.7	135.4	139.1	143.0	147.0	151.0	155.2	159.4	163.8	168.2	172.8
44	93.1	96.1	99.1	102.2	105.4	108.6	111.9	115.3	118.7	122.3	125.9	129.6	133.4	137.4	141.4	145.5	149.7	154.1	158.5	163.1	167.9	172.7	177.7	182.9	188.2
45	99.3	102.5	105.8	109.2	112.6	116.2	119.8	123.6	127.4	131.4	135.4	139.6	143.9	148.3	152.9	157.6	162.4	167.4	172.6	178.0	183.5	189.2	195.1	201.2	207.5
46	106.3	109.8	113.4	117.2	121.0	125.0	129.1	133.3	137.6	142.1	146.7	151.5	156.5	161.6	167.0	172.5	178.2	184.2	190.4	196.8	203.5	210.5	217.8	225.4	233.3
47	114.3	118.3	122.4	126.6	130.9	135.4	140.1	145.0	150.0	155.3	160.7	166.4	172.3	178.5	185.0	191.8	198.9	206.4	214.2	222.4	231.0	240.0	249.5	259.5	270.0
48	123.9	128.4	133.1	137.9	143.0	148.3	153.9	159.7	165.8	172.2	178.9	186.0	193.5	201.4	209.8	218.7	228.2	238.2	248.9	260.3	272.3	285.1	298.7	313.0	328.2
49	135.5	140.8	146.4	152.3	158.5	165.0	172.0	179.3	187.2	195.6	204.6	214.3	224.7	235.9	248.1	261.3	275.5	290.9	307.6	325.5	344.8	365.4	387.3	410.6	435.2

09-63235-01

IDEXX Quanti-Tray®/2000 MPN Table *(per 100ml)*

# Large Wells Positive	# Small Wells Positive																							
	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
0	25.3	26.4	27.4	28.4	29.5	30.5	31.5	32.6	33.6	34.7	35.7	36.8	37.8	38.9	40.0	41.0	42.1	43.1	44.2	45.3	46.3	47.4	48.5	49.5
1	26.6	27.7	28.7	29.8	30.8	31.9	32.9	34.0	35.0	36.1	37.2	38.2	39.3	40.4	41.4	42.5	43.6	44.7	45.7	46.8	47.9	49.0	50.1	51.2
2	27.9	29.0	30.0	31.1	32.2	33.2	34.3	35.4	36.5	37.5	38.6	39.7	40.8	41.9	43.0	44.0	45.1	46.2	47.3	48.4	49.5	50.6	51.7	52.8
3	29.3	30.4	31.4	32.5	33.6	34.7	35.8	36.8	37.9	39.0	40.1	41.2	42.3	43.4	44.5	45.6	46.7	47.8	48.9	50.0	51.2	52.3	53.4	54.5
4	30.7	31.8	32.8	33.9	35.0	36.1	37.2	38.3	39.4	40.5	41.6	42.8	43.9	45.0	46.1	47.2	48.3	49.5	50.6	51.7	52.9	54.0	55.1	56.3
5	32.1	33.2	34.3	35.4	36.5	37.6	38.7	39.9	41.0	42.1	43.2	44.4	45.5	46.6	47.7	48.9	50.0	51.2	52.3	53.5	54.6	55.8	56.9	58.1
6	33.5	34.7	35.8	36.9	38.0	39.2	40.3	41.4	42.6	43.7	44.8	46.0	47.1	48.3	49.4	50.6	51.7	52.9	54.1	55.2	56.4	57.6	58.7	59.9
7	35.0	36.2	37.3	38.4	39.6	40.7	41.9	43.0	44.2	45.3	46.5	47.7	48.8	50.0	51.2	52.3	53.5	54.7	55.9	57.1	58.3	59.4	60.6	61.8
8	36.6	37.7	38.9	40.0	41.2	42.3	43.5	44.7	45.9	47.0	48.2	49.4	50.6	51.8	53.0	54.1	55.3	56.5	57.7	59.0	60.2	61.4	62.6	63.8
9	38.1	39.3	40.5	41.6	42.8	44.0	45.2	46.4	47.6	48.8	50.0	51.2	52.4	53.6	54.8	56.0	57.2	58.4	59.7	60.9	62.1	63.4	64.6	65.8
10	39.7	40.9	42.1	43.3	44.5	45.7	46.9	48.1	49.3	50.6	51.8	53.0	54.2	55.5	56.7	57.9	59.2	60.4	61.7	62.9	64.2	65.4	66.7	67.9
11	41.4	42.6	43.8	45.0	46.3	47.5	48.7	49.9	51.2	52.4	53.7	54.9	56.1	57.4	58.6	59.9	61.2	62.4	63.7	65.0	66.3	67.5	68.8	70.1
12	43.1	44.3	45.6	46.8	48.1	49.3	50.6	51.8	53.1	54.3	55.6	56.8	58.1	59.4	60.7	62.0	63.2	64.5	65.8	67.1	68.4	69.7	71.0	72.4
13	44.9	46.1	47.4	48.6	49.9	51.2	52.5	53.7	55.0	56.3	57.6	58.9	60.2	61.5	62.8	64.1	65.4	66.7	68.0	69.3	70.7	72.0	73.3	74.7
14	46.7	48.0	49.3	50.5	51.8	53.1	54.4	55.7	57.0	58.3	59.6	60.9	62.3	63.6	64.9	66.3	67.6	68.9	70.3	71.6	73.0	74.4	75.7	77.1
15	48.6	49.9	51.2	52.5	53.8	55.1	56.4	57.8	59.1	60.4	61.8	63.1	64.5	65.8	67.2	68.5	69.9	71.3	72.6	74.0	75.4	76.8	78.2	79.6
16	50.5	51.8	53.2	54.5	55.8	57.2	58.5	59.9	61.2	62.6	64.0	65.3	66.7	68.1	69.5	70.9	72.3	73.7	75.1	76.5	77.9	79.3	80.8	82.2
17	52.5	53.9	55.2	56.6	58.0	59.3	60.7	62.1	63.5	64.9	66.3	67.7	69.1	70.5	71.9	73.3	74.8	76.2	77.6	79.1	80.5	82.0	83.5	84.9
18	54.6	56.0	57.4	58.8	60.2	61.6	63.0	64.4	65.8	67.2	68.6	70.1	71.5	73.0	74.4	75.9	77.3	78.8	80.3	81.8	83.3	84.8	86.3	87.8
19	56.8	58.2	59.6	61.0	62.4	63.9	65.3	66.8	68.2	69.7	71.1	72.6	74.1	75.5	77.0	78.5	80.0	81.5	83.1	84.6	86.1	87.6	89.2	90.7
20	59.0	60.4	61.9	63.3	64.8	66.3	67.7	69.2	70.7	72.2	73.7	75.2	76.7	78.2	79.8	81.3	82.8	84.4	85.9	87.5	89.1	90.7	92.2	93.8
21	61.3	62.8	64.3	65.8	67.3	68.8	70.3	71.8	73.3	74.9	76.4	77.9	79.5	81.1	82.6	84.2	85.8	87.4	89.0	90.6	92.2	93.8	95.4	97.1
22	63.8	65.3	66.8	68.3	69.8	71.4	72.9	74.5	76.1	77.6	79.2	80.8	82.4	84.0	85.6	87.2	88.9	90.5	92.1	93.8	95.5	97.1	98.8	100.5
23	66.3	67.8	69.4	71.0	72.5	74.1	75.7	77.3	78.9	80.5	82.2	83.8	85.4	87.1	88.7	90.4	92.1	93.8	95.5	97.2	98.9	100.6	102.4	104.1
24	68.9	70.5	72.1	73.7	75.3	77.0	78.6	80.3	81.9	83.6	85.2	86.9	88.6	90.3	92.0	93.8	95.5	97.2	99.0	100.7	102.5	104.3	106.1	107.9
25	71.7	73.3	75.0	76.6	78.3	80.0	81.7	83.3	85.1	86.8	88.5	90.2	92.0	93.7	95.5	97.3	99.1	100.9	102.7	104.5	106.3	108.2	110.0	111.9
26	74.6	76.3	78.0	79.7	81.4	83.1	84.8	86.6	88.4	90.1	91.9	93.7	95.5	97.3	99.2	101.0	102.9	104.7	106.6	108.5	110.4	112.3	114.2	116.2
27	77.6	79.4	81.1	82.9	84.6	86.4	88.2	90.0	91.9	93.7	95.5	97.4	99.3	101.2	103.1	105.0	106.9	108.8	110.8	112.7	114.7	116.7	118.7	120.7
28	80.8	82.6	84.4	86.3	88.1	89.9	91.8	93.7	95.6	97.5	99.4	101.3	103.3	105.2	107.2	109.2	111.2	113.2	115.2	117.3	119.3	121.4	123.5	125.6
29	84.2	86.1	87.9	89.8	91.7	93.7	95.6	97.5	99.5	101.5	103.5	105.5	107.5	109.5	111.6	113.7	115.7	117.8	120.0	122.1	124.2	126.4	128.6	130.8
30	87.8	89.7	91.7	93.6	95.6	97.6	99.6	101.6	103.7	105.7	107.8	109.9	112.0	114.2	116.3	118.5	120.6	122.8	125.1	127.3	129.5	131.8	134.1	136.4
31	91.6	93.6	95.6	97.7	99.7	101.8	103.9	106.0	108.2	110.3	112.5	114.7	116.9	119.1	121.4	123.6	125.9	128.2	130.5	132.9	135.3	137.7	140.1	142.5
32	95.7	97.8	99.9	102.0	104.2	106.3	108.5	110.7	113.0	115.2	117.5	119.8	122.1	124.5	126.8	129.2	131.6	134.0	136.5	139.0	141.5	144.0	146.6	149.1
33	100.0	102.2	104.4	106.6	108.9	111.2	113.5	115.8	118.2	120.5	122.9	125.4	127.8	130.3	132.8	135.3	137.8	140.4	143.0	145.6	148.3	150.9	153.7	156.4
34	104.7	107.0	109.3	111.7	114.0	116.4	118.9	121.3	123.8	126.3	128.8	131.4	134.0	136.6	139.2	141.9	144.6	147.4	150.1	152.9	155.7	158.6	161.5	164.4
35	109.7	112.2	114.6	117.1	119.6	122.2	124.7	127.3	129.9	132.6	135.3	138.0	140.8	143.6	146.4	149.2	152.1	155.0	158.0	161.0	164.0	167.1	170.2	173.3
36	115.2	117.8	120.4	123.0	125.7	128.4	131.1	133.9	136.7	139.5	142.4	145.3	148.3	151.3	154.3	157.3	160.5	163.6	166.8	170.0	173.3	176.6	179.9	183.3
37	121.3	124.0	126.8	129.6	132.4	135.3	138.2	141.2	144.2	147.3	150.3	153.5	156.7	159.9	163.1	166.5	169.8	173.2	176.7	180.2	183.7	187.3	191.0	194.7
38	127.9	130.8	133.8	136.8	139.9	143.0	146.2	149.4	152.6	155.9	159.2	162.6	166.1	169.6	173.2	176.8	180.4	184.2	188.0	191.8	195.7	199.7	203.7	207.7
39	135.3	138.5	141.7	145.0	148.3	151.7	155.1	158.6	162.1	165.7	169.4	173.1	176.9	180.7	184.7	188.7	192.7	196.8	201.0	205.3	209.6	214.0	218.5	223.0
40	143.7	147.1	150.6	154.2	157.8	161.5	165.3	169.1	173.0	177.0	181.1	185.2	189.4	193.7	198.1	202.5	207.1	211.7	216.4	221.1	226.0	231.0	236.0	241.1
41	153.2	157.0	160.9	164.8	168.9	173.0	177.2	181.5	185.8	190.3	194.8	199.5	204.2	209.1	214.0	219.1	224.2	229.4	234.8	240.2	245.8	251.5	257.2	263.1
42	164.3	168.6	172.9	177.3	181.9	186.5	191.3	196.1	201.1	206.2	211.4	216.7	222.2	227.7	233.4	239.2	245.2	251.3	257.5	263.8	270.3	276.9	283.6	290.5
43	177.5	182.3	187.3	192.4	197.6	202.9	208.4	214.0	219.8	225.8	231.8	238.1	244.5	251.0	257.7	264.6	271.7	278.9	286.3	293.8	301.5	309.4	317.4	325.7
44	193.6	199.3	205.1	211.0	217.2	223.5	230.0	236.7	243.6	250.8	258.1	265.6	273.3	281.2	289.4	297.8	306.3	315.1	324.1	333.3	342.8	352.4	362.3	372.4
45	214.1	220.9	227.9	235.2	242.7	250.4	258.4	266.7	275.3	284.1	293.3	302.6	312.3	322.3	332.5	343.0	353.8	364.9	376.2	387.9	399.8	412.0	424.5	437.4
46	241.5	250.0	258.9	268.2	277.8	287.8	298.1	308.8	319.9	331.4	343.3	355.5	368.1	381.1	394.5	408.3	422.5	437.1	452.0	467.4	483.3	499.6	516.3	533.5
47	280.9	292.4	304.4	316.9	330.0	343.6	357.8	372.5	387.7	403.4	419.8	436.6	454.1	472.1	490.7	509.9	529.8	550.4	571.7	593.8	616.7	640.5	665.3	691.0
48	344.1	360.9	378.4	396.8	416.0	436.0	456.9	478.6	501.2	524.7	549.3	574.8	601.5	629.4	658.6	689.3	721.5	755.6	791.5	829.7	870.4	913.9	960.6	1011.2
49	461.1	488.4	517.2	547.5	579.4	613.1	648.8	686.7	727.0	770.1	816.4	866.4	920.8	980.4	1046.2	1119.9	1203.3	1299.7	1413.6	1553.1	1732.9	1986.3	2419.6	>2419.6

09-63235-01

APPENDIX B

SITE, SAMPLE, AND RAIN DATA

Collection	Site	ID	Season	Last Rain	Rain Date	Days since Rain Event	Amount of Rain Received	Site Number
				d		Days	mm	
3/13/17	Lake Bryan 1	6576	1	21	2/20/17	2	6.096	1
3/13/17	Lake Bryan 2	6577	1	21	2/20/17	2	6.096	2
3/13/17	Country Club	6578	1	21	2/20/17	2	6.096	3
3/13/17	Allen Ridge Park	6579	1	21	2/20/17	2	6.096	4
3/13/17	Cy Miller Park	6580	1	21	2/20/17	2	6.096	5
3/13/17	Lochinvar	6581	1	21	2/20/17	2	6.096	6
3/13/17	Central Park 2	6582	1	21	2/20/17	2	6.096	7
3/13/17	Central Park 1	6583	1	21	2/20/17	2	6.096	8
3/13/17	Castlegate 1	6584	1	21	2/20/17	2	6.096	9
3/13/17	Castlegate 2	6585	1	21	2/20/17	2	6.096	10
3/13/17	Amber Lake 1	6586	1	21	2/20/17	2	6.096	11
3/13/17	Amber Lake 2	6587	1	21	2/20/17	2	6.096	12
3/13/17	Carter Lake	6588	1	21	2/20/17	2	6.096	13
3/13/17	Gabbard Park	6589	1	21	2/20/17	2	6.096	14
3/13/17	John Crompton Park	6590	1	21	2/20/17	2	6.096	15
3/13/17	Wolf Pen	6591	1	21	2/20/17	2	6.096	16
3/13/17	Museum	6592	1	21	2/20/17	2	6.096	17
3/13/17	Lake Placid	6593	1	21	2/20/17	2	6.096	18
3/13/17	Symphony Park	6594	1	21	2/20/17	2	6.096	19
3/13/17	Research Park	6595	1	21	2/20/17	2	6.096	20
3/13/17	Wahlberg Lake	-	1	21	2/20/17	2	6.096	21
3/13/17	Atlas Lake	-	1	21	2/20/17	2	6.096	22
3/13/17	Traditions Golf	-	1	21	2/20/17	2	6.096	23

3/13/17	Nantucket Lake		1	21	2/20/17	2	6.096	24
3/29/17	Lake Bryan 1	6596	1	1	3/29/17	0	12.7	1
3/29/17	Lake Bryan 2	6597	1	1	3/29/17	0	12.7	2
3/29/17	Country Club	6598	1	1	3/29/17	0	12.7	3
3/29/17	Allen Ridge Park	6599	1	1	3/29/17	0	12.7	4
3/29/17	Cy Miller Park	6600	1	1	3/29/17	0	12.7	5
3/29/17	Lochinvar	6601	1	1	3/29/17	0	12.7	6
3/29/17	Central Park 2	6602	1	1	3/29/17	0	12.7	7
3/29/17	Central Park 1	6603	1	1	3/29/17	0	12.7	8
3/29/17	Castlegate 1	6604	1	1	3/29/17	0	12.7	9
3/29/17	Castlegate 2	6605	1	1	3/29/17	0	12.7	10
3/29/17	Amber Lake 1	6606	1	1	3/29/17	0	12.7	11
3/29/17	Amber Lake 2	6607	1	1	3/29/17	0	12.7	12
3/29/17	Carter Lake	6608	1	1	3/29/17	0	12.7	13
3/29/17	Gabbard Park	6609	1	1	3/29/17	0	12.7	14
3/29/17	John Crompton Park	6610	1	1	3/29/17	0	12.7	15
3/29/17	Wolf Pen	6611	1	1	3/29/17	0	12.7	16
3/29/17	Museum	6612	1	1	3/29/17	0	12.7	17
3/29/17	Lake Placid	6613	1	1	3/29/17	0	12.7	18
3/29/17	Symphony Park	6614	1	1	3/29/17	0	12.7	19
3/29/17	Research Park	6615	1	1	3/29/17	0	12.7	20
3/29/17	Wahlberg Lake	-	1	1	3/29/17	0	12.7	21
3/29/17	Atlas Lake	6617	1	1	3/29/17	0	12.7	22
3/29/17	Traditions Golf	6616	1	1	3/29/17	0	12.7	23
3/29/17	Nantucket Lake	-	1	1	3/29/17	0	12.7	24
4/17/17	Lake Bryan 1	6685	1	6	4/11/17	0	11.43	1
4/17/17	Lake Bryan 2	6686	1	6	4/11/17	0	11.43	2

4/17/17	Country Club	6687	1	6	4/11/17	0	11.43	3
4/17/17	Allen Ridge Park	6688	1	6	4/11/17	0	11.43	4
4/17/17	Cy Miller Park	6689	1	6	4/11/17	0	11.43	5
4/17/17	Lochinvar	6690	1	6	4/11/17	0	11.43	6
4/17/17	Central Park 2	6691	1	6	4/11/17	0	11.43	7
4/17/17	Central Park 1	6692	1	6	4/11/17	0	11.43	8
4/17/17	Castlegate 1	6693	1	6	4/11/17	0	11.43	9
4/17/17	Castlegate 2	6694	1	6	4/11/17	0	11.43	10
4/17/17	Amber Lake 1	6695	1	6	4/11/17	0	11.43	11
4/17/17	Amber Lake 2	6696	1	6	4/11/17	0	11.43	12
4/17/17	Carter Lake	6697	1	6	4/11/17	0	11.43	13
4/17/17	Gabbard Park	6698	1	6	4/11/17	0	11.43	14
4/17/17	John Crompton Park	6699	1	6	4/11/17	0	11.43	15
4/17/17	Wolf Pen	6700	1	6	4/11/17	0	11.43	16
4/17/17	Museum	6701	1	6	4/11/17	0	11.43	17
4/17/17	Lake Placid	6702	1	6	4/11/17	0	11.43	18
4/17/17	Symphony Park	6703	1	6	4/11/17	0	11.43	19
4/17/17	Research Park	6704	1	6	4/11/17	0	11.43	20
4/17/17	Wahlberg Lake	6705	1	6	4/11/17	0	11.43	21
4/17/17	Atlas Lake	6706	1	6	4/11/17	0	11.43	22
4/17/17	Traditions Golf	6707	1	6	4/11/17	0	11.43	23
4/17/17	Nantucket Lake	-	1	6	4/11/17	0	11.43	24
5/3/17	Lake Bryan 1	6708	1	22	4/11/17	0	2.54	1
5/3/17	Lake Bryan 2	6709	1	22	4/11/17	0	2.54	2
5/3/17	Country Club	6710	1	22	4/11/17	0	2.54	3
5/3/17	Allen Ridge Park	6711	1	22	4/11/17	0	2.54	4
5/3/17	Cy Miller Park	6712	1	22	4/11/17	0	2.54	5

5/3/17	Lochinvar	6713	1	22	4/11/17	0	2.54	6
5/3/17	Central Park 2	6714	1	22	4/11/17	0	2.54	7
5/3/17	Central Park 1	6715	1	22	4/11/17	0	2.54	8
5/3/17	Castlegate 1	6716	1	22	4/11/17	0	2.54	9
5/3/17	Castlegate 2	6717	1	22	4/11/17	0	2.54	10
5/3/17	Amber Lake 1	6718	1	22	4/11/17	0	2.54	11
5/3/17	Amber Lake 2	6719	1	22	4/11/17	0	2.54	12
5/3/17	Carter Lake	6720	1	22	4/11/17	0	2.54	13
5/3/17	Gabbard Park	6721	1	22	4/11/17	0	2.54	14
5/3/17	John Crompton Park	6722	1	22	4/11/17	0	2.54	15
5/3/17	Wolf Pen	6723	1	22	4/11/17	0	2.54	16
5/3/17	Museum	6724	1	22	4/11/17	0	2.54	17
5/3/17	Lake Placid	6725	1	22	4/11/17	0	2.54	18
5/3/17	Symphony Park	6726	1	22	4/11/17	0	2.54	19
5/3/17	Research Park	6727	1	22	4/11/17	0	2.54	20
5/3/17	Wahlberg Lake	6728	1	22	4/11/17	0	2.54	21
5/3/17	Atlas Lake	6729	1	22	4/11/17	0	2.54	22
5/3/17	Traditions Golf	6730	1	22	4/11/17	0	2.54	23
5/3/17	Nantucket Lake	-	1	22	4/11/17	0	2.54	24
5/17/17	Lake Bryan 1	6731	1	6	5/11/17	0	1.524	1
5/17/17	Lake Bryan 2	6732	1	6	5/11/17	0	1.524	2
5/17/17	Country Club	6733	1	6	5/11/17	0	1.524	3
5/17/17	Allen Ridge Park	6734	1	6	5/11/17	0	1.524	4
5/17/17	Cy Miller Park	6735	1	6	5/11/17	0	1.524	5
5/17/17	Lochinvar	6736	1	6	5/11/17	0	1.524	6
5/17/17	Central Park 2	6737	1	6	5/11/17	0	1.524	7
5/17/17	Central Park 1	6738	1	6	5/11/17	0	1.524	8

5/17/17	Castlegate 1	6739	1	6	5/11/17	0	1.524	9
5/17/17	Castlegate 2	6740	1	6	5/11/17	0	1.524	10
5/17/17	Amber Lake 1	6741	1	6	5/11/17	0	1.524	11
5/17/17	Amber Lake 2	6742	1	6	5/11/17	0	1.524	12
5/17/17	Carter Lake	6743	1	6	5/11/17	0	1.524	13
5/17/17	Gabbard Park	6744	1	6	5/11/17	0	1.524	14
5/17/17	John Crompton Park	6745	1	6	5/11/17	0	1.524	15
5/17/17	Wolf Pen	6746	1	6	5/11/17	0	1.524	16
5/17/17	Museum	6747	1	6	5/11/17	0	1.524	17
5/17/17	Lake Placid	6748	1	6	5/11/17	0	1.524	18
5/17/17	Symphony Park	6749	1	6	5/11/17	0	1.524	19
5/17/17	Research Park	6750	1	6	5/11/17	0	1.524	20
5/17/17	Wahlberg Lake	6751	1	6	5/11/17	0	1.524	21
5/17/17	Atlas Lake	6752	1	6	5/11/17	0	1.524	22
5/17/17	Traditions Golf	6753	1	6	5/11/17	0	1.524	23
5/17/17	Nantucket Lake	6754	1	6	5/11/17	0	1.524	24
5/30/17	Lake Bryan 1	6755	1	8	5/22/17	1	0.254	1
5/30/17	Lake Bryan 2	6756	1	8	5/22/17	1	0.254	2
5/30/17	Country Club	6757	1	8	5/22/17	1	0.254	3
5/30/17	Allen Ridge Park	6758	1	8	5/22/17	1	0.254	4
5/30/17	Cy Miller Park	6759	1	8	5/22/17	1	0.254	5
5/30/17	Lochinvar	6760	1	8	5/22/17	1	0.254	6
5/30/17	Central Park 2	6761	1	8	5/22/17	1	0.254	7
5/30/17	Central Park 1	6762	1	8	5/22/17	1	0.254	8
5/30/17	Castlegate 1	6763	1	8	5/22/17	1	0.254	9
5/30/17	Castlegate 2	6764	1	8	5/22/17	1	0.254	10
5/30/17	Amber Lake 1	6765	1	8	5/22/17	1	0.254	11

5/30/17	Amber Lake 2	6766	1	8	5/22/17	1	0.254	12
5/30/17	Carter Lake	6767	1	8	5/22/17	1	0.254	13
5/30/17	Gabbard Park	6768	1	8	5/22/17	1	0.254	14
5/30/17	John Crompton Park	6769	1	8	5/22/17	1	0.254	15
5/30/17	Wolf Pen	6770	1	8	5/22/17	1	0.254	16
5/30/17	Museum	6771	1	8	5/22/17	1	0.254	17
5/30/17	Lake Placid	6772	1	8	5/22/17	1	0.254	18
5/30/17	Symphony Park	6773	1	8	5/22/17	1	0.254	19
5/30/17	Research Park	6774	1	8	5/22/17	1	0.254	20
5/30/17	Wahlberg Lake	6775	1	8	5/22/17	1	0.254	21
5/30/17	Atlas Lake	6776	1	8	5/22/17	1	0.254	22
5/30/17	Traditions Golf	6777	1	8	5/22/17	1	0.254	23
5/30/17	Nantucket Lake	6778	1	8	5/22/17	1	0.254	24
6/12/17	Lake Bryan 1	6779	2	8	6/4/17	3	0.254	1
6/12/17	Lake Bryan 2	6780	2	8	6/4/17	3	0.254	2
6/12/17	Country Club	6781	2	8	6/4/17	3	0.254	3
6/12/17	Allen Ridge Park	6782	2	8	6/4/17	3	0.254	4
6/12/17	Cy Miller Park	6783	2	8	6/4/17	3	0.254	5
6/12/17	Lochinvar	6784	2	8	6/4/17	3	0.254	6
6/12/17	Central Park 2	6785	2	8	6/4/17	3	0.254	7
6/12/17	Central Park 1	6786	2	8	6/4/17	3	0.254	8
6/12/17	Castlegate 1	6787	2	8	6/4/17	3	0.254	9
6/12/17	Castlegate 2	6788	2	8	6/4/17	3	0.254	10
6/12/17	Amber Lake 1	6789	2	8	6/4/17	3	0.254	11
6/12/17	Amber Lake 2	6790	2	8	6/4/17	3	0.254	12
6/12/17	Carter Lake	6791	2	8	6/4/17	3	0.254	13
6/12/17	Gabbard Park	6792	2	8	6/4/17	3	0.254	14

6/12/17	John Crompton Park	6793	2	8	6/4/17	3	0.254	15
6/12/17	Wolf Pen	6794	2	8	6/4/17	3	0.254	16
6/12/17	Museum	6795	2	8	6/4/17	3	0.254	17
6/12/17	Lake Placid	6796	2	8	6/4/17	3	0.254	18
6/12/17	Symphony Park	6797	2	8	6/4/17	3	0.254	19
6/12/17	Research Park	6798	2	8	6/4/17	3	0.254	20
6/12/17	Wahlberg Lake	6799	2	8	6/4/17	3	0.254	21
6/12/17	Atlas Lake	6800	2	8	6/4/17	3	0.254	22
6/12/17	Traditions Golf	6801	2	8	6/4/17	3	0.254	23
6/13/17	Nantucket Lake	6802	2	8	6/4/17	3	0.254	24
6/28/17	Lake Bryan 1	6803	2	3	6/25/17	3	24.89	1
6/28/17	Lake Bryan 2	6804	2	3	6/25/17	3	24.89	2
6/28/17	Country Club	6805	2	3	6/25/17	3	24.89	3
6/28/17	Allen Ridge Park	6806	2	3	6/25/17	3	24.89	4
6/28/17	Cy Miller Park	6807	2	3	6/25/17	3	24.89	5
6/28/17	Lochinvar	6808	2	3	6/25/17	3	24.89	6
6/28/17	Central Park 2	6809	2	3	6/25/17	3	24.89	7
6/28/17	Central Park 1	6810	2	3	6/25/17	3	24.89	8
6/28/17	Castlegate 1	6811	2	3	6/25/17	3	24.89	9
6/28/17	Castlegate 2	6812	2	3	6/25/17	3	24.89	10
6/28/17	Amber Lake 1	6813	2	3	6/25/17	3	24.89	11
6/28/17	Amber Lake 2	6814	2	3	6/25/17	3	24.89	12
6/28/17	Carter Lake	6815	2	3	6/25/17	3	24.89	13
6/28/17	Gabbard Park	6816	2	3	6/25/17	3	24.89	14
6/28/17	John Crompton Park	6817	2	3	6/25/17	3	24.89	15
6/28/17	Wolf Pen	6818	2	3	6/25/17	3	24.89	16

6/28/17	Museum	6819	2	3	6/25/17	3	24.89	17
6/28/17	Lake Placid	6820	2	3	6/25/17	3	24.89	18
6/28/17	Symphony Park	6821	2	3	6/25/17	3	24.89	19
6/28/17	Research Park	6822	2	3	6/25/17	3	24.89	20
6/28/17	Wahlberg Lake	6823	2	3	6/25/17	3	24.89	21
6/28/17	Atlas Lake	6824	2	3	6/25/17	3	24.89	22
6/28/17	Traditions Golf	6825	2	3	6/25/17	3	24.89	23
6/28/17	Nantucket Lake	6826	2	3	6/25/17	3	24.89	24
7/17/17	Lake Bryan 1	6827	2	13	7/4/17	2	2.286	1
7/17/17	Lake Bryan 2	6828	2	13	7/4/17	2	2.286	2
7/17/17	Country Club	6829	2	13	7/4/17	2	2.286	3
7/17/17	Allen Ridge Park	6830	2	13	7/4/17	2	2.286	4
7/17/17	Cy Miller Park	6831	2	13	7/4/17	2	2.286	5
7/17/17	Lochinvar	6832	2	13	7/4/17	2	2.286	6
7/17/17	Central Park 2	6833	2	13	7/4/17	2	2.286	7
7/17/17	Central Park 1	6834	2	13	7/4/17	2	2.286	8
7/17/17	Castlegate 1	6835	2	13	7/4/17	2	2.286	9
7/17/17	Castlegate 2	6836	2	13	7/4/17	2	2.286	10
7/17/17	Amber Lake 1	6837	2	13	7/4/17	2	2.286	11
7/17/17	Amber Lake 2	6838	2	13	7/4/17	2	2.286	12
7/17/17	Carter Lake	6839	2	13	7/4/17	2	2.286	13
7/17/17	Gabbard Park	6840	2	13	7/4/17	2	2.286	14
7/17/17	John Crompton Park	6841	2	13	7/4/17	2	2.286	15
7/17/17	Wolf Pen	6842	2	13	7/4/17	2	2.286	16
7/17/17	Museum	6843	2	13	7/4/17	2	2.286	17
7/17/17	Lake Placid	6844	2	13	7/4/17	2	2.286	18
7/17/17	Symphony Park	6845	2	13	7/4/17	2	2.286	19

7/17/17	Research Park	6846	2	13	7/4/17	2	2.286	20
7/17/17	Wahlberg Lake	6847	2	13	7/4/17	2	2.286	21
7/17/17	Atlas Lake	6848	2	13	7/4/17	2	2.286	22
7/17/17	Traditions Golf	6849	2	13	7/4/17	2	2.286	23
7/17/17	Nantucket Lake	6850	2	13	7/4/17	2	2.286	24
7/28/17	Lake Bryan 1	6851	2	24	7/4/17	13	2.286	1
7/28/17	Lake Bryan 2	6852	2	24	7/4/17	13	2.286	2
7/28/17	Country Club	6853	2	24	7/4/17	13	2.286	3
7/28/17	Allen Ridge Park	6854	2	24	7/4/17	13	2.286	4
7/28/17	Cy Miller Park	6855	2	24	7/4/17	13	2.286	5
7/28/17	Lochinvar	6856	2	24	7/4/17	13	2.286	6
7/28/17	Central Park 2	6857	2	24	7/4/17	13	2.286	7
7/28/17	Central Park 1	6858	2	24	7/4/17	13	2.286	8
7/28/17	Castlegate 1	6859	2	24	7/4/17	13	2.286	9
7/28/17	Castlegate 2	6860	2	24	7/4/17	13	2.286	10
7/28/17	Amber Lake 1	6861	2	24	7/4/17	13	2.286	11
7/28/17	Amber Lake 2	6862	2	24	7/4/17	13	2.286	12
7/28/17	Carter Lake	6863	2	24	7/4/17	13	2.286	13
7/28/17	Gabbard Park	6864	2	24	7/4/17	13	2.286	14
7/28/17	John Crompton Park	6865	2	24	7/4/17	13	2.286	15
7/28/17	Wolf Pen	6866	2	24	7/4/17	13	2.286	16
7/28/17	Museum	6867	2	24	7/4/17	13	2.286	17
7/28/17	Lake Placid	6868	2	24	7/4/17	13	2.286	18
7/28/17	Symphony Park	6869	2	24	7/4/17	13	2.286	19
7/28/17	Research Park	6870	2	24	7/4/17	13	2.286	20
7/28/17	Wahlberg Lake	6871	2	24	7/4/17	13	2.286	21
7/28/17	Atlas Lake	6872	2	24	7/4/17	13	2.286	22

7/28/17	Traditions Golf	6873	2	24	7/4/17	13	2.286	23
7/28/17	Nantucket Lake	6874	2	24	7/4/17	13	2.286	24
8/7/17	Lake Bryan 1	6875	2	34	7/4/17	0	66.04	1
8/7/17	Lake Bryan 2	6876	2	34	7/4/17	0	66.04	2
8/7/17	Country Club	6877	2	34	7/4/17	0	66.04	3
8/7/17	Allen Ridge Park	6878	2	34	7/4/17	0	66.04	4
8/7/17	Cy Miller Park	6879	2	34	7/4/17	0	66.04	5
8/7/17	Lochinvar	6880	2	34	7/4/17	0	66.04	6
8/7/17	Central Park 2	6881	2	34	7/4/17	0	66.04	7
8/7/17	Central Park 1	6882	2	34	7/4/17	0	66.04	8
8/7/17	Castlegate 1	6883	2	34	7/4/17	0	66.04	9
8/7/17	Castlegate 2	6884	2	34	7/4/17	0	66.04	10
8/7/17	Amber Lake 1	6885	2	34	7/4/17	0	66.04	11
8/7/17	Amber Lake 2	6886	2	34	7/4/17	0	66.04	12
8/7/17	Carter Lake	6887	2	34	7/4/17	0	66.04	13
8/7/17	Gabbard Park	6888	2	34	7/4/17	0	66.04	14
8/7/17	John Crompton Park	6889	2	34	7/4/17	0	66.04	15
8/7/17	Wolf Pen	6890	2	34	7/4/17	0	66.04	16
8/7/17	Museum	6891	2	34	7/4/17	0	66.04	17
8/7/17	Lake Placid	6892	2	34	7/4/17	0	66.04	18
8/7/17	Symphony Park	6893	2	34	7/4/17	0	66.04	19
8/7/17	Research Park	6894	2	34	7/4/17	0	66.04	20
8/7/17	Wahlberg Lake	6895	2	34	7/4/17	0	66.04	21
8/7/17	Atlas Lake	6896	2	34	7/4/17	0	66.04	22
8/7/17	Traditions Golf	6897	2	34	7/4/17	0	66.04	23
8/7/17	Nantucket Lake	6898	2	34	7/4/17	0	66.04	24
8/22/17	Lake Bryan 1	6901	2	15	8/7/17	14	2.286	1

8/22/17	Lake Bryan 2	6902	2	15	8/7/17	14	2.286	2
8/22/17	Country Club	6903	2	15	8/7/17	14	2.286	3
8/22/17	Allen Ridge Park	6904	2	15	8/7/17	14	2.286	4
8/22/17	Cy Miller Park	6905	2	15	8/7/17	14	2.286	5
8/22/17	Lochinvar	6906	2	15	8/7/17	14	2.286	6
8/22/17	Central Park 2	6907	2	15	8/7/17	14	2.286	7
8/22/17	Central Park 1	6908	2	15	8/7/17	14	2.286	8
8/22/17	Castlegate 1	6909	2	15	8/7/17	14	2.286	9
8/22/17	Castlegate 2	6910	2	15	8/7/17	14	2.286	10
8/22/17	Amber Lake 1	6911	2	15	8/7/17	14	2.286	11
8/22/17	Amber Lake 2	6912	2	15	8/7/17	14	2.286	12
8/22/17	Carter Lake	6913	2	15	8/7/17	14	2.286	13
8/22/17	Gabbard Park	6914	2	15	8/7/17	14	2.286	14
8/22/17	John Crompton Park	6915	2	15	8/7/17	14	2.286	15
8/22/17	Wolf Pen	6916	2	15	8/7/17	14	2.286	16
8/22/17	Museum	6917	2	15	8/7/17	14	2.286	17
8/22/17	Lake Placid	6918	2	15	8/7/17	14	2.286	18
8/22/17	Symphony Park	6919	2	15	8/7/17	14	2.286	19
8/22/17	Research Park	6920	2	15	8/7/17	14	2.286	20
8/22/17	Wahlberg Lake	6921	2	15	8/7/17	14	2.286	21
8/22/17	Atlas Lake	6922	2	15	8/7/17	14	2.286	22
8/22/17	Traditions Golf	6923	2	15	8/7/17	14	2.286	23
8/22/17	Nantucket Lake	6924	2	15	8/7/17	14	2.286	24
9/5/17	Lake Bryan 1	6933	3	8	8/27/17	7	0.508	1
9/5/17	Lake Bryan 2	6934	3	8	8/27/17	7	0.508	2
9/5/17	Country Club	6935	3	8	8/27/17	7	0.508	3
9/5/17	Allen Ridge Park	6936	3	8	8/27/17	7	0.508	4

9/5/17	Cy Miller Park	6937	3	8	8/27/17	7	0.508	5
9/5/17	Lochinvar	6938	3	8	8/27/17	7	0.508	6
9/5/17	Central Park 2	6939	3	8	8/27/17	7	0.508	7
9/5/17	Central Park 1	6940	3	8	8/27/17	7	0.508	8
9/5/17	Castlegate 1	6941	3	8	8/27/17	7	0.508	9
9/5/17	Castlegate 2	6942	3	8	8/27/17	7	0.508	10
9/5/17	Amber Lake 1	6943	3	8	8/27/17	7	0.508	11
9/5/17	Amber Lake 2	6944	3	8	8/27/17	7	0.508	12
9/5/17	Carter Lake	6945	3	8	8/27/17	7	0.508	13
9/5/17	Gabbard Park	6946	3	8	8/27/17	7	0.508	14
9/5/17	John Crompton Park	6947	3	8	8/27/17	7	0.508	15
9/5/17	Wolf Pen	6948	3	8	8/27/17	7	0.508	16
9/5/17	Museum	6949	3	8	8/27/17	7	0.508	17
9/5/17	Lake Placid	6950	3	8	8/27/17	7	0.508	18
9/5/17	Symphony Park	6951	3	8	8/27/17	7	0.508	19
9/5/17	Research Park	6952	3	8	8/27/17	7	0.508	20
9/5/17	Wahlberg Lake	6953	3	8	8/27/17	7	0.508	21
9/5/17	Atlas Lake	6954	3	8	8/27/17	7	0.508	22
9/5/17	Traditions Golf	6955	3	8	8/27/17	7	0.508	23
9/5/17	Nantucket Lake	6956	3	8	8/27/17	7	0.508	24
9/26/17	Lake Bryan 1	6957	3	30	8/27/17	9	5.08	1
9/26/17	Lake Bryan 2	6958	3	30	8/27/17	9	5.08	2
9/26/17	Country Club	6959	3	30	8/27/17	9	5.08	3
9/26/17	Allen Ridge Park	6960	3	30	8/27/17	9	5.08	4
9/26/17	Cy Miller Park	6961	3	30	8/27/17	9	5.08	5
9/26/17	Lochinvar	6962	3	30	8/27/17	9	5.08	6
9/26/17	Central Park 2	6963	3	30	8/27/17	9	5.08	7

9/26/17	Central Park 1	6964	3	30	8/27/17	9	5.08	8
9/26/17	Castlegate 1	6965	3	30	8/27/17	9	5.08	9
9/26/17	Castlegate 2	6966	3	30	8/27/17	9	5.08	10
9/26/17	Amber Lake 1	6967	3	30	8/27/17	9	5.08	11
9/26/17	Amber Lake 2	6968	3	30	8/27/17	9	5.08	12
9/26/17	Carter Lake	6969	3	30	8/27/17	9	5.08	13
9/26/17	Gabbard Park	6970	3	30	8/27/17	9	5.08	14
9/26/17	John Crompton Park	6971	3	30	8/27/17	9	5.08	15
9/26/17	Wolf Pen	6972	3	30	8/27/17	9	5.08	16
9/26/17	Museum	6973	3	30	8/27/17	9	5.08	17
9/26/17	Lake Placid	6974	3	30	8/27/17	9	5.08	18
9/26/17	Symphony Park	6975	3	30	8/27/17	9	5.08	19
9/26/17	Research Park	6976	3	30	8/27/17	9	5.08	20
9/26/17	Wahlberg Lake	6977	3	30	8/27/17	9	5.08	21
9/26/17	Atlas Lake	6978	3	30	8/27/17	9	5.08	22
9/26/17	Traditions Golf	6979	3	30	8/27/17	9	5.08	23
9/26/17	Nantucket Lake	6980	3	30	8/27/17	9	5.08	24
10/17/17	Lake Bryan 1	6981	3	14	10/3/17	14	13.208	1
10/17/17	Lake Bryan 2	6982	3	14	10/3/17	14	13.208	2
10/17/17	Country Club	6983	3	14	10/3/17	14	13.208	3
10/17/17	Allen Ridge Park	6984	3	14	10/3/17	14	13.208	4
10/17/17	Cy Miller Park	6985	3	14	10/3/17	14	13.208	5
10/17/17	Lochinvar	6986	3	14	10/3/17	14	13.208	6
10/17/17	Central Park 2	6987	3	14	10/3/17	14	13.208	7
10/17/17	Central Park 1	6988	3	14	10/3/17	14	13.208	8
10/17/17	Castlegate 1	6989	3	14	10/3/17	14	13.208	9
10/17/17	Castlegate 2	6990	3	14	10/3/17	14	13.208	10

10/17/17	Amber Lake 1	6991	3	14	10/3/17	14	13.208	11
10/17/17	Amber Lake 2	6992	3	14	10/3/17	14	13.208	12
10/17/17	Carter Lake	6993	3	14	10/3/17	14	13.208	13
10/17/17	Gabbard Park	6994	3	14	10/3/17	14	13.208	14
10/17/17	John Crompton Park	6995	3	14	10/3/17	14	13.208	15
10/17/17	Wolf Pen	6996	3	14	10/3/17	14	13.208	16
10/17/17	Museum	6997	3	14	10/3/17	14	13.208	17
10/17/17	Lake Placid	6998	3	14	10/3/17	14	13.208	18
10/17/17	Symphony Park	6999	3	14	10/3/17	14	13.208	19
10/17/17	Research Park	7000	3	14	10/3/17	14	13.208	20
10/17/17	Wahlberg Lake	7001	3	14	10/3/17	14	13.208	21
10/17/17	Atlas Lake	7002	3	14	10/3/17	14	13.208	22
10/17/17	Traditions Golf	7003	3	14	10/3/17	14	13.208	23
10/17/17	Nantucket Lake	7004	3	14	10/3/17	14	13.208	24
10/31/17	Lake Bryan 1	7005	3	9	10/22/17	0	21.336	1
10/31/17	Lake Bryan 2	7006	3	9	10/22/17	0	21.336	2
10/31/17	Country Club	7007	3	9	10/22/17	0	21.336	3
10/31/17	Allen Ridge Park	7008	3	9	10/22/17	0	21.336	4
10/31/17	Cy Miller Park	7009	3	9	10/22/17	0	21.336	5
10/31/17	Lochinvar	7010	3	9	10/22/17	0	21.336	6
10/31/17	Central Park 2	7011	3	9	10/22/17	0	21.336	7
10/31/17	Central Park 1	7012	3	9	10/22/17	0	21.336	8
10/31/17	Castlegate 1	7013	3	9	10/22/17	0	21.336	9
10/31/17	Castlegate 2	7014	3	9	10/22/17	0	21.336	10
10/31/17	Amber Lake 1	7015	3	9	10/22/17	0	21.336	11
10/31/17	Amber Lake 2	7016	3	9	10/22/17	0	21.336	12
10/31/17	Carter Lake	7017	3	9	10/22/17	0	21.336	13

10/31/17	Gabbard Park	7018	3	9	10/22/17	0	21.336	14
10/31/17	John Crompton Park	7019	3	9	10/22/17	0	21.336	15
10/31/17	Wolf Pen	7020	3	9	10/22/17	0	21.336	16
10/31/17	Museum	7021	3	9	10/22/17	0	21.336	17
10/31/17	Lake Placid	7022	3	9	10/22/17	0	21.336	18
10/31/17	Symphony Park	7023	3	9	10/22/17	0	21.336	19
10/31/17	Research Park	7024	3	9	10/22/17	0	21.336	20
10/31/17	Wahlberg Lake	7025	3	9	10/22/17	0	21.336	21
10/31/17	Atlas Lake	7026	3	9	10/22/17	0	21.336	22
10/31/17	Traditions Golf	7027	3	9	10/22/17	0	21.336	23
10/31/17	Nantucket Lake	7028	3	9	10/22/17	0	21.336	24
11/9/17	Lake Bryan 1	7029	3	9	10/31/17	0	0.762	1
11/9/17	Lake Bryan 2	7030	3	9	10/31/17	0	0.762	2
11/9/17	Country Club	7031	3	9	10/31/17	0	0.762	3
11/9/17	Allen Ridge Park	7032	3	9	10/31/17	0	0.762	4
11/9/17	Cy Miller Park	7033	3	9	10/31/17	0	0.762	5
11/9/17	Lochinvar	7034	3	9	10/31/17	0	0.762	6
11/9/17	Central Park 2	7035	3	9	10/31/17	0	0.762	7
11/9/17	Central Park 1	7036	3	9	10/31/17	0	0.762	8
11/9/17	Castlegate 1	7037	3	9	10/31/17	0	0.762	9
11/9/17	Castlegate 2	7038	3	9	10/31/17	0	0.762	10
11/9/17	Amber Lake 1	7039	3	9	10/31/17	0	0.762	11
11/9/17	Amber Lake 2	7040	3	9	10/31/17	0	0.762	12
11/9/17	Carter Lake	7041	3	9	10/31/17	0	0.762	13
11/9/17	Gabbard Park	7042	3	9	10/31/17	0	0.762	14
11/9/17	John Crompton Park	7043	3	9	10/31/17	0	0.762	15
11/9/17	Wolf Pen	7044	3	9	10/31/17	0	0.762	16

11/9/17	Museum	7045	3	9	10/31/17	0	0.762	17
11/9/17	Lake Placid	7046	3	9	10/31/17	0	0.762	18
11/9/17	Symphony Park	7047	3	9	10/31/17	0	0.762	19
11/9/17	Research Park	7048	3	9	10/31/17	0	0.762	20
11/9/17	Wahlberg Lake	7049	3	9	10/31/17	0	0.762	21
11/9/17	Atlas Lake	7050	3	9	10/31/17	0	0.762	22
11/9/17	Traditions Golf	7051	3	9	10/31/17	0	0.762	23
11/9/17	Nantucket Lake	7052	3	9	10/31/17	0	0.762	24
11/21/17	Lake Bryan 1	7053	3	21	10/31/17	5	1.016	1
11/21/17	Lake Bryan 2	7054	3	21	10/31/17	5	1.016	2
11/21/17	Country Club	7055	3	21	10/31/17	5	1.016	3
11/21/17	Allen Ridge Park	7056	3	21	10/31/17	5	1.016	4
11/21/17	Cy Miller Park	7057	3	21	10/31/17	5	1.016	5
11/21/17	Lochinvar	7058	3	21	10/31/17	5	1.016	6
11/21/17	Central Park 2	7059	3	21	10/31/17	5	1.016	7
11/21/17	Central Park 1	7060	3	21	10/31/17	5	1.016	8
11/21/17	Castlegate 1	7061	3	21	10/31/17	5	1.016	9
11/21/17	Castlegate 2	7062	3	21	10/31/17	5	1.016	10
11/21/17	Amber Lake 1	7063	3	21	10/31/17	5	1.016	11
11/21/17	Amber Lake 2	7064	3	21	10/31/17	5	1.016	12
11/21/17	Carter Lake	7065	3	21	10/31/17	5	1.016	13
11/21/17	Gabbard Park	7066	3	21	10/31/17	5	1.016	14
11/21/17	John Crompton Park	7067	3	21	10/31/17	5	1.016	15
11/21/17	Wolf Pen	7068	3	21	10/31/17	5	1.016	16
11/21/17	Museum	7069	3	21	10/31/17	5	1.016	17
11/21/17	Lake Placid	7070	3	21	10/31/17	5	1.016	18
11/21/17	Symphony Park	7071	3	21	10/31/17	5	1.016	19

11/21/17	Research Park	7072	3	21	10/31/17	5	1.016	20
11/21/17	Wahlberg Lake	7073	3	21	10/31/17	5	1.016	21
11/21/17	Atlas Lake	7074	3	21	10/31/17	5	1.016	22
11/21/17	Traditions Golf	7075	3	21	10/31/17	5	1.016	23
11/21/17	Nantucket Lake	7076	3	21	10/31/17	5	1.016	24
12/18/17	Lake Bryan 1	7077	4	2	12/16/17	2	26.924	1
12/18/17	Lake Bryan 2	7078	4	2	12/16/17	2	26.924	2
12/18/17	Country Club	7079	4	2	12/16/17	2	26.924	3
12/18/17	Allen Ridge Park	7080	4	2	12/16/17	2	26.924	4
12/18/17	Cy Miller Park	7081	4	2	12/16/17	2	26.924	5
12/18/17	Lochinvar	7082	4	2	12/16/17	2	26.924	6
12/18/17	Central Park 2	7083	4	2	12/16/17	2	26.924	7
12/18/17	Central Park 1	7084	4	2	12/16/17	2	26.924	8
12/18/17	Castlegate 1	7085	4	2	12/16/17	2	26.924	9
12/18/17	Castlegate 2	7086	4	2	12/16/17	2	26.924	10
12/18/17	Amber Lake 1	7087	4	2	12/16/17	2	26.924	11
12/18/17	Amber Lake 2	7088	4	2	12/16/17	2	26.924	12
12/18/17	Carter Lake	7089	4	2	12/16/17	2	26.924	13
12/18/17	Gabbard Park	7090	4	2	12/16/17	2	26.924	14
12/18/17	John Crompton Park	7091	4	2	12/16/17	2	26.924	15
12/18/17	Wolf Pen	7092	4	2	12/16/17	2	26.924	16
12/18/17	Museum	7093	4	2	12/16/17	2	26.924	17
12/18/17	Lake Placid	7094	4	2	12/16/17	2	26.924	18
12/18/17	Symphony Park	7095	4	2	12/16/17	2	26.924	19
12/18/17	Research Park	7096	4	2	12/16/17	2	26.924	20
12/18/17	Wahlberg Lake	7097	4	2	12/16/17	2	26.924	21
12/18/17	Atlas Lake	7098	4	2	12/16/17	2	26.924	22

12/18/17	Traditions Golf	7099	4	2	12/16/17	2	26.924	23
12/18/17	Nantucket Lake	7100	4	2	12/16/17	2	26.924	24
1/3/18	Lake Bryan 1	7101	4	15	12/30/17	4	0.254	1
1/3/18	Lake Bryan 2	7102	4	15	12/30/17	4	0.254	2
1/3/18	Country Club	7103	4	15	12/30/17	4	0.254	3
1/3/18	Allen Ridge Park	7104	4	15	12/30/17	4	0.254	4
1/3/18	Cy Miller Park	7105	4	15	12/30/17	4	0.254	5
1/3/18	Lochinvar	7106	4	15	12/30/17	4	0.254	6
1/3/18	Central Park 2	7107	4	15	12/30/17	4	0.254	7
1/3/18	Central Park 1	7108	4	15	12/30/17	4	0.254	8
1/3/18	Castlegate 1	7109	4	15	12/30/17	4	0.254	9
1/3/18	Castlegate 2	7110	4	15	12/30/17	4	0.254	10
1/3/18	Amber Lake 1	7111	4	15	12/30/17	4	0.254	11
1/3/18	Amber Lake 2	7112	4	15	12/30/17	4	0.254	12
1/3/18	Carter Lake	7113	4	15	12/30/17	4	0.254	13
1/3/18	Gabbard Park	7114	4	15	12/30/17	4	0.254	14
1/3/18	John Crompton Park	7115	4	15	12/30/17	4	0.254	15
1/3/18	Wolf Pen	7116	4	15	12/30/17	4	0.254	16
1/3/18	Museum	7117	4	15	12/30/17	4	0.254	17
1/3/18	Lake Placid	7118	4	15	12/30/17	4	0.254	18
1/3/18	Symphony Park	7119	4	15	12/30/17	4	0.254	19
1/3/18	Research Park	7120	4	15	12/30/17	4	0.254	20
1/3/18	Wahlberg Lake	7121	4	15	12/30/17	4	0.254	21
1/3/18	Atlas Lake	7122	4	15	12/30/17	4	0.254	22
1/3/18	Traditions Golf	7123	4	15	12/30/17	4	0.254	23
1/3/18	Nantucket Lake	7124	4	15	12/30/17	4	0.254	24
1/24/18	Lake Bryan 1	7125	4	9	1/22/18	2	2.286	1

1/24/18	Lake Bryan 2	7126	4	9	1/22/18	2	2.286	2
1/24/18	Country Club	7127	4	9	1/22/18	2	2.286	3
1/24/18	Allen Ridge Park	7128	4	9	1/22/18	2	2.286	4
1/24/18	Cy Miller Park	7129	4	9	1/22/18	2	2.286	5
1/24/18	Lochinvar	7130	4	9	1/22/18	2	2.286	6
1/24/18	Central Park 2	7131	4	9	1/22/18	2	2.286	7
1/24/18	Central Park 1	7132	4	9	1/22/18	2	2.286	8
1/24/18	Castlegate 1	7133	4	9	1/22/18	2	2.286	9
1/24/18	Castlegate 2	7134	4	9	1/22/18	2	2.286	10
1/24/18	Amber Lake 1	7135	4	9	1/22/18	2	2.286	11
1/24/18	Amber Lake 2	7136	4	9	1/22/18	2	2.286	12
1/24/18	Carter Lake	7137	4	9	1/22/18	2	2.286	13
1/24/18	Gabbard Park	7138	4	9	1/22/18	2	2.286	14
1/24/18	John Crompton Park	7139	4	9	1/22/18	2	2.286	15
1/24/18	Wolf Pen	7140	4	9	1/22/18	2	2.286	16
1/24/18	Museum	7141	4	9	1/22/18	2	2.286	17
1/24/18	Lake Placid	7142	4	9	1/22/18	2	2.286	18
1/24/18	Symphony Park	7143	4	9	1/22/18	2	2.286	19
1/24/18	Research Park	7144	4	9	1/22/18	2	2.286	20
1/24/18	Wahlberg Lake	7145	4	9	1/22/18	2	2.286	21
1/24/18	Atlas Lake	7146	4	9	1/22/18	2	2.286	22
1/24/18	Traditions Golf	7147	4	9	1/22/18	2	2.286	23
1/24/18	Nantucket Lake	7148	4	9	1/22/18	2	2.286	24
1/31/18	Lake Bryan 1	7149	4	0	1/31/18	0	2.54	1
1/31/18	Lake Bryan 2	7150	4	0	1/31/18	0	2.54	2
1/31/18	Country Club	7151	4	0	1/31/18	0	2.54	3
1/31/18	Allen Ridge Park	7152	4	0	1/31/18	0	2.54	4

1/31/18	Cy Miller Park	7153	4	0	1/31/18	0	2.54	5
1/31/18	Lochinvar	7154	4	0	1/31/18	0	2.54	6
1/31/18	Central Park 2	7155	4	0	1/31/18	0	2.54	7
1/31/18	Central Park 1	7156	4	0	1/31/18	0	2.54	8
1/31/18	Castlegate 1	7157	4	0	1/31/18	0	2.54	9
1/31/18	Castlegate 2	7158	4	0	1/31/18	0	2.54	10
1/31/18	Amber Lake 1	7159	4	0	1/31/18	0	2.54	11
1/31/18	Amber Lake 2	7160	4	0	1/31/18	0	2.54	12
1/31/18	Carter Lake	7161	4	0	1/31/18	0	2.54	13
1/31/18	Gabbard Park	7162	4	0	1/31/18	0	2.54	14
1/31/18	John Crompton Park	7163	4	0	1/31/18	0	2.54	15
1/31/18	Wolf Pen	7164	4	0	1/31/18	0	2.54	16
1/31/18	Museum	7165	4	0	1/31/18	0	2.54	17
1/31/18	Lake Placid	7166	4	0	1/31/18	0	2.54	18
1/31/18	Symphony Park	7167	4	0	1/31/18	0	2.54	19
1/31/18	Research Park	7168	4	0	1/31/18	0	2.54	20
1/31/18	Wahlberg Lake	7169	4	0	1/31/18	0	2.54	21
1/31/18	Atlas Lake	7170	4	0	1/31/18	0	2.54	22
1/31/18	Traditions Golf	7171	4	0	1/31/18	0	2.54	23
1/31/18	Nantucket Lake	7172	4	0	1/31/18	0	2.54	24
2/7/18	Lake Bryan 1	7173	4	0	2/7/18	0	6.35	1
2/7/18	Lake Bryan 2	7174	4	0	2/7/18	0	6.35	2
2/7/18	Country Club	7175	4	0	2/7/18	0	6.35	3
2/7/18	Allen Ridge Park	7176	4	0	2/7/18	0	6.35	4
2/7/18	Cy Miller Park	7177	4	0	2/7/18	0	6.35	5
2/7/18	Lochinvar	7178	4	0	2/7/18	0	6.35	6
2/7/18	Central Park 2	7179	4	0	2/7/18	0	6.35	7

2/7/18	Central Park 1	7180	4	0	2/7/18	0	6.35	8
2/7/18	Castlegate 1	7181	4	0	2/7/18	0	6.35	9
2/7/18	Castlegate 2	7182	4	0	2/7/18	0	6.35	10
2/7/18	Amber Lake 1	7183	4	0	2/7/18	0	6.35	11
2/7/18	Amber Lake 2	7184	4	0	2/7/18	0	6.35	12
2/7/18	Carter Lake	7185	4	0	2/7/18	0	6.35	13
2/7/18	Gabbard Park	7186	4	0	2/7/18	0	6.35	14
2/7/18	John Crompton Park	7187	4	0	2/7/18	0	6.35	15
2/7/18	Wolf Pen	7188	4	0	2/7/18	0	6.35	16
2/7/18	Museum	7189	4	0	2/7/18	0	6.35	17
2/7/18	Lake Placid	7190	4	0	2/7/18	0	6.35	18
2/7/18	Symphony Park	7191	4	0	2/7/18	0	6.35	19
2/7/18	Research Park	7192	4	0	2/7/18	0	6.35	20
2/7/18	Wahlberg Lake	7193	4	0	2/7/18	0	6.35	21
2/7/18	Atlas Lake	7194	4	0	2/7/18	0	6.35	22
2/7/18	Traditions Golf	7195	4	0	2/7/18	0	6.35	23
2/7/18	Nantucket Lake	7196	4	0	2/7/18	0	6.35	24

APPENDIX C

BIOGEOCHEMICAL AND MICROBIAL DATA

pH	EC	NO_3-N	NH_4-N	PO_4-P	DOC	TDN	DON	BOD_5	TSS	$SUVA_{254}$	DOC;DON	*E.coli*	Site Number
	μS/cm	mg/L								L mg^{-1} m^{-1}	mg L^{-1}	MPN/100mL	
9.31	1504	0.12	0.01	0.03	11.04	0.75	0.62	0.6	137	6.93	17.7	-	1
9.3	1528	0.14	0.01	0.02	14.26	0.82	0.66	0.0	129	5.95	21.5	-	2
9.1	266	0.05	0.01	0.28	10.61	0.71	0.65	0.0	6	4.89	16.2	-	3
8.03	125	0.02	0.01	0.56	12.31	1.08	1.04	4.2	11	5.48	11.8	-	4
7.99	252	0.18	0.22	0.03	11.92	1.43	1.03	4.2	8	3.71	11.6	-	5
8.47	630	0.08	0.01	0.18	5.35	0.51	0.42	0.0	5	1.20	12.7	-	6
8.4	230	0.06	0.01	0.25	19.32	1.47	1.41	3.3	67	5.52	13.7	-	7
8.37	222	0.07	0.01	0.27	19.42	1.58	1.50	2.2	47	5.48	13.0	-	8
8.84	303	0.25	0.01	0.06	9.54	1.02	0.75	2.6	111	6.32	12.7	-	9
8.71	343	0.25	0.01	0.13	16.83	1.50	1.23	0.0	22	5.80	13.6	-	10
8.69	194	0.14	0.33	0.15	14.17	1.72	1.26	1.6	27	6.70	11.3	-	11
9.03	190	0.05	0.01	0.07	14.27	0.99	0.93	6.0	9	5.24	15.3	-	12
8.24	176	0.11	0.20	0.26	10.74	0.98	0.66	1.0	42	5.63	16.2	-	13
7.99	122	0.26	0.03	0.52	18.27	1.57	1.28	2.9	31	7.81	14.3	-	14
7.92	293	0.07	0.10	0.16	11.82	0.93	0.77	0.0	11	5.29	15.4	-	15
8.21	384	0.14	0.01	0.08	14.29	1.06	0.91	5.9	46	7.00	15.7	-	16
7.99	229	0.01	0.01	0.08	10.73	0.55	0.53	2.5	11	5.42	20.2	-	17
7.96	444	0.02	0.04	0.12	16.72	1.19	1.13	3.8	73	2.17	14.8	-	18
7.66	413	0.04	0.01	0.05	12.65	0.76	0.71	1.5	16	4.55	17.9	-	19
8.3	569	0.08	0.01	0.87	9.40	0.75	0.66	1.2	14	5.60	14.2	-	20
-	-	-	-	-	-	-	-	-	-	-	-	-	21
-	-	-	-	-	-	-	-	-	-	-	-	-	22
-	-	-	-	-	-	-	-	-	-	-	-	-	23

-	-	-	-	-	-	-	-	-	-	-	-	-	24
9.79	1504	0.05	0.00	0.03	13.14	0.69	0.63	0.8	105	4.12	20.8	488	1
9.83	1560	0.02	0.00	0.02	13.12	0.60	0.57	2.7	121	4.10	23.2	21	2
9.81	295	0.02	0.02	0.38	12.45	0.96	0.93	1.8	8	3.68	13.4	2420	3
8.19	132	0.02	0.07	0.41	11.25	0.88	0.78	0.6	0	4.41	14.4	1046	4
8.02	275	0.22	0.13	0.04	10.48	1.18	0.83	1.5	14	3.02	12.6	7	5
8.89	655	0.02	0.00	0.20	4.98	0.43	0.41	4.3	18	4.12	12.2	10	6
8.82	242	0.01	0.00	0.24	17.15	1.25	1.24	5.2	78	4.89	13.9	107	7
8.85	237	0.01	0.00	0.24	17.30	1.32	1.32	7.9	43	5.07	13.1	192	8
8.84	356	0.07	0.00	0.06	11.01	1.02	0.96	5.6	79	4.26	11.5	2420	9
9.16	384	0.07	0.06	0.09	15.88	1.23	1.11	2.7	16	5.47	14.3	387	10
8.72	224	0.53	0.39	0.16	15.42	3.36	2.44	9.4	27	5.13	6.3	2420	11
7.82	208	0.02	0.00	0.06	14.88	1.05	1.03	7.2	17	3.82	14.4	249	12
9.35	187	0.01	0.00	0.01	6.44	0.47	0.46	2.4	62	2.97	13.9	49	13
9.32	134	0.10	0.02	0.48	13.31	1.01	0.89	6.1	14	4.66	15.0	2420	14
8.4	111	0.09	0.11	0.36	10.55	1.02	0.81	2.7	3	4.23	13.0	980	15
8.36	477	0.01	0.01	0.09	13.84	0.93	0.91	5.4	130	4.18	15.3	1733	16
8.43	286	0.02	0.00	0.06	10.60	0.60	0.58	4.1	15	3.64	18.2	308	17
8.47	481	0.02	0.03	0.07	14.76	0.98	0.93	11.7	38	4.25	15.8	2420	18
8.11	326	0.14	0.00	0.09	11.94	0.97	0.82	6.3	40	3.53	14.5	2420	19
8.56	469	0.08	0.00	0.66	8.36	0.61	0.53	4.5	31	3.91	15.8	980	20
-	-	-	-	-	-	-	-	-	-	-	-	-	21
9.52	672	1.69	0.00	0.80	7.05	2.31	0.62	2.9	79	4.76	11.4	33	22
10.42	821	0.64	0.13	0.37	13.28	1.93	1.16	8.4	68	6.46	11.5	1	23
-	-	-	-	-	-	-	-	-	-	-	-	-	24
9.36	1445	0.03	0.00	0.01	10.28	0.77	0.74	3.2	163	4.57	13.9	-	1
9.38	1414	0.03	0.00	0.03	12.67	0.86	0.83	2.4	106	5.25	15.3	-	2

9.74	211	0.01	0.02	0.41	9.75	0.77	0.74	1.3	10	2.92	13.2	-	3
7.36	129	0.03	0.07	0.62	11.53	0.99	0.88	3.3	0	3.68	13.0	-	4
8.83	263	0.00	0.13	0.01	10.45	0.86	0.73	3.9	11	2.10	14.4	-	5
8.58	643	0.01	0.00	0.23	4.93	0.44	0.43	4.9	21	1.70	11.4	-	6
8.42	233	0.02	0.00	0.27	15.23	1.25	1.22	5.1	43	4.58	12.4	-	7
7.92	216	0.02	0.00	0.29	16.43	1.36	1.34	6.4	20	4.42	12.2	-	8
7.13	306	0.11	0.00	0.03	10.37	0.90	0.79	10.0	100	3.95	13.1	-	9
8.72	346	0.06	0.06	0.11	14.29	1.22	1.10	3.6	109	4.62	13.0	-	10
8.22	282	0.04	0.39	0.12	12.83	0.91	0.48	5.1	0	5.21	26.6	-	11
8.92	193	0.01	0.00	0.06	14.71	1.09	1.08	8.4	9	2.77	13.6	-	12
8.53	171	0.01	0.00	0.00	6.59	0.55	0.54	2.5	4	1.26	12.2	-	13
8.55	107	0.01	0.02	0.56	11.26	0.80	0.77	6.3	3	3.53	14.6	-	14
8.46	110	0.13	0.11	0.38	8.20	0.74	0.50	1.5	5	3.22	16.3	-	15
8.38	461	0.02	0.01	0.07	13.66	0.97	0.94	6.6	138	4.01	14.5	-	16
8.47	233	0.01	0.00	0.04	8.92	0.63	0.62	4.3	3	2.79	14.5	-	17
8.57	476	0.01	0.03	0.05	13.39	0.88	0.85	3.8	5	3.11	15.8	-	18
8.02	271	0.01	0.00	0.06	9.91	0.71	0.70	8.1	4	2.93	14.2	-	19
8.17	443	0.01	0.00	1.10	8.91	0.67	0.66	3.3	10	3.97	13.5	-	20
8.87	965	14.46	0.00	5.10	7.29	14.29	0.00	4.1	1134	2.74	-	-	21
8.87	579	1.22	0.00	0.92	7.87	2.07	0.85	2.1	48	4.06	9.3	-	22
9.98	742	0.56	0.01	0.72	12.52	1.65	1.07	5.5	395	4.81	11.7	-	23
-	-	-	-	-	-	-	-	-	-	-	-	-	24
9.38	1890	0.03	0.00	0.05	14.62	0.87	0.83	0.0	165	4.37	17.5	934	1
9.38	1876	0.02	0.00	0.02	11.40	0.85	0.83	0.0	153	5.76	13.7	1	2
9.7	263	0.00	0.00	0.37	11.66	0.98	0.98	0.0	1	2.96	11.9	52	3
7.97	153	0.04	0.00	0.51	14.23	1.59	1.55	2.1	7	3.19	9.2	218	4
8.63	279	0.00	0.00	0.03	9.91	0.94	0.94	1.5	6	2.86	10.6	1	5

8.86	647	0.00	0.00	0.22	3.78	0.38	0.38	0.9	10	3.25	10.0	52	6
8.46	251	0.01	0.00	0.26	15.61	1.19	1.18	1.2	41	5.12	13.2	52	7
8.03	245	0.04	0.04	0.34	18.56	1.60	1.51	10.2	23	5.09	12.3	75	8
8.43	387	0.00	0.00	0.04	12.00	0.74	0.74	1.8	63	3.93	16.2	10	9
8.7	405	0.01	0.00	0.09	15.53	1.02	1.00	0.0	23	4.92	15.5	1	10
8.31	319	0.00	0.00	0.14	13.15	0.96	0.96	3.9	15	4.51	13.7	1723	11
9.57	232	0.00	0.00	0.01	16.34	1.39	1.39	15.6	22	3.07	11.8	31	12
8.11	105	0.00	0.05	0.06	15.88	1.19	1.14	20.1	9	3.10	13.9	1	13
8.03	563	0.00	0.00	0.23	13.11	0.66	0.66	2.4	6	3.05	20.0	52	14
7.81	182	0.00	0.00	0.34	10.66	0.83	0.83	0.6	5	3.40	12.8	1	15
8.23	607	0.02	0.00	0.06	17.73	1.02	1.01	7.8	208	4.00	17.6	134	16
9.53	272	0.00	0.00	0.02	10.51	0.57	0.57	6.0	34	3.16	18.5	10	17
7.67	533	0.05	0.00	0.11	64.34	5.58	5.54	103.5	2275	2.20	11.6	187	18
7.99	454	0.02	0.00	0.02	15.59	1.46	1.44	7.5	19	2.29	10.8	96	19
8.67	851	0.00	0.00	0.72	13.53	0.83	0.82	0.3	18	3.58	16.5	31	20
8.71	1074	19.04	0.00	5.43	9.02	18.30	0.00	1.2	48	3.60	-	1	21
8.88	642	2.27	0.05	1.16	8.71	2.94	0.62	0.0	37	5.34	14.1	10	22
10.19	821	0.04	0.00	0.60	15.05	1.17	1.13	4.8	57	4.22	13.3	1	23
-	-	-	-	-	-	-	-	-	-	-	-	-	24
9.41	1740	0.05	0.07	0.00	8.90	0.74	0.62	4.2	95	4.40	14.4	-	1
9.41	1696	0.03	0.00	0.00	8.6	0.61	0.58	2.6	81	3.51	14.7	-	2
9.44	450	0.03	0.00	0.36	10.6	1.33	1.29	6.0	7	2.31	8.2	-	3
7.93	178	0.04	0.08	0.49	3.5	0.98	0.87	3.6	6	2.76	4.0	-	4
8.29	318	0.01	0.00	0.04	6.8	0.77	0.76	3.3	7	2.10	8.9	-	5
8.55	724	0.01	0.00	0.20	9	0.18	0.17	8.4	15	0.95	53.0	-	6
8.44	272	0.01	0.00	0.21	7	1.19	1.17	3.9	49	4.57	6.0	-	7
8.25	267	0.02	0.00	0.24	7.4	1.26	1.24	4.5	41	4.47	6.0	-	8

8.53	495	0.02	0.11	0.03	7.5	1.03	0.90	4.2	93	4.02	8.3	-	9
8.79	526	0.02	0.03	0.07	8.7	0.92	0.87	2.4	18	4.06	10.0	-	10
8.28	635	0.04	0.08	0.14	5.5	1.02	0.90	6.6	30	4.03	6.1	-	11
8.97	295	0.01	0.00	0.28	9.6	1.72	1.71	4.5	7	2.61	5.6	-	12
8.66	208	0.01	0.00	0.00	8.6	0.42	0.42	2.4	14	1.58	20.7	-	13
7.82	150	0.00	0.05	0.59	4.9	0.80	0.76	4.8	11	2.58	6.5	-	14
7.66	193	0.16	1.79	0.33	3.2	0.99	0.00	4.8	7	3.48	-	-	15
8.25	824	0.04	0.10	0.09	5.85	1.43	1.29	7.2	135	4.02	4.5	-	16
9.19	308	0.01	0.04	0.00	8.2	0.51	0.47	7.2	20	2.35	17.5	-	17
9.18	599	0.01	0.04	0.01	7.9	0.89	0.85	4.5	11	2.24	9.3	-	18
7.97	506	0.01	0.00	0.00	4.1	0.74	0.73	6.6	41	2.24	5.6	-	19
8.36	752	0.01	0.10	0.58	5.7	0.79	0.67	4.8	14	3.54	8.5	-	20
9.36	1186	17.68	0.00	4.87	12.1	16.61	0.00	10.8	44	1.77	-	-	21
9.24	679	0.38	0.16	0.60	10.5	0.89	0.35	4.8	74	5.50	30.0	-	22
10.36	939	0.04	0.00	0.62	8.3	1.09	1.05	5.7	44	4.31	7.9	-	23
8.99	174	0.01	0.03	0.00	7.8	0.78	0.74	7.8	22	2.72	10.5	-	24
9.24	1971	0.03	0.00	0.02	10.28	0.65	0.62	2.7	95	10.28	16.7	1	1
9.29	1988	0.04	0.00	0.02	11.98	0.65	0.61	1.8	95	11.98	19.6	1	2
8.98	390	0.01	0.03	0.18	11.00	0.81	0.77	10.7	163	11.00	14.4	41	3
7.68	165	0.01	0.01	0.47	10.05	0.63	0.61	8.4	30	10.05	16.5	31	4
8.75	357	0.01	0.02	0.07	9.49	0.68	0.65	3.6	5	9.49	14.7	1	5
9.23	609	0.08	0.00	0.19	15.77	0.92	0.85	6.2	25	15.77	18.6	341	6
8.19	316	0.02	0.00	0.28	16.45	1.24	1.22	3.9	28	16.45	13.5	20	7
7.99	302	0.02	0.10	0.28	16.80	1.22	1.10	3.6	28	16.80	15.3	201	8
8.04	376	0.04	0.02	0.09	13.04	0.86	0.81	4.2	62	13.04	16.2	74	9
8.59	611	0.03	0.15	0.11	12.90	0.95	0.78	2.1	22	12.90	16.6	41	10
8.96	412	0.03	0.13	0.26	16.72	1.09	0.94	6.3	18	16.72	17.8	109	11

9.14	339	0.01	0.00	0.09	17.26	1.20	1.19	6.9	12	17.26	14.5	203	12
9.22	242	0.02	0.06	0.04	5.88	0.34	0.26	9.9	92	5.88	22.6	31	13
8.11	112	0.01	0.11	0.50	8.74	0.50	0.38	7.5	22	8.74	23.1	134	14
7.71	157	0.24	0.37	0.32	7.58	0.88	0.27	2.4	5	7.58	27.9	75	15
7.58	311	0.02	0.22	0.08	9.98	0.54	0.30	5.4	59	9.98	33.7	107	16
8.93	286	0.01	0.00	0.02	7.40	0.40	0.39	5	26	7.40	19.0	10	17
9.46	774	0.01	0.00	0.01	14.25	0.83	0.82	8.4	23	14.25	17.3	1	18
8.21	321	0.02	0.20	0.18	7.86	0.50	0.28	4.5	41	7.86	27.9	10	19
8.5	766	0.01	0.08	0.50	8.71	0.48	0.39	2.9	16	8.71	22.5	63	20
9	1296	13.93	0.16	4.79	9.22	13.26	0.00	3.6	67	9.22	-	10	21
9.07	756	0.07	0.02	0.49	7.09	0.60	0.51	1.2	27	7.09	14.0	10	22
10.27	1074	0.02	0.08	0.59	12.27	1.04	0.95	9.9	102	12.27	13.0	63	23
9.22	232	0.01	0.14	0.10	12.77	0.77	0.62	10.5	37	12.77	20.5	1	24
9.32	1412	0.04	0.00	0.02	78.09	0.70	0.66	1.8	38	0.75	118.0	-	1
9.3	1460	0.02	0.00	0.02	14.59	0.62	0.60	0.9	68	3.80	24.2	-	2
7.83	220	0.02	0.00	0.17	9.18	0.69	0.67	5.4	39	3.89	13.8	-	3
7.22	98	0.01	0.12	0.56	10.60	0.79	0.66	8.4	0	4.31	16.1	-	4
7.33	251	0.00	0.00	0.07	18.54	0.62	0.62	1.4	3	1.54	30.0	-	5
8.45	624	0.02	0.00	0.28	18.94	1.16	1.13	2.4	7	4.63	16.8	-	6
7.9	217	0.01	0.00	0.25	12.85	0.93	0.92	4.2	21	5.47	14.0	-	7
7.87	208	0.01	0.00	0.25	15.53	1.06	1.05	6.3	19	4.53	14.8	-	8
7.88	162	0.01	0.00	0.09	7.83	0.48	0.48	4.2	37	6.04	16.5	-	9
8.55	391	0.03	0.00	0.14	11.59	0.76	0.74	3.0	12	4.95	15.8	-	10
7.79	318	0.02	0.00	0.13	13.91	0.82	0.80	5.4	0	5.64	17.4	-	11
8.4	201	0.01	0.00	0.09	15.43	1.01	1.00	5.4	16	4.47	15.4	-	12
8.01	197	0.01	0.00	0.01	5.92	0.38	0.38	0.3	12	3.97	15.7	-	13
7.75	62	0.00	0.00	0.37	8.61	0.53	0.53	0.0	11	4.54	16.1	-	14

7.36	93	0.19	0.01	0.34	8.15	0.87	0.67	3.0	4	4.86	12.2	-	15
7.36	213	0.01	0.00	0.07	7.75	0.43	0.42	4.5	40	5.06	18.4	-	16
8.48	173	0.01	0.52	0.16	7.54	0.41	0.00	5.2	14	4.73	-	-	17
9.2	567	0.00	0.00	0.01	10.75	0.64	0.64	8.3	152	4.31	16.8	-	18
7.51	234	0.01	0.00	0.17	15.49	0.99	0.99	10.8	21	3.92	15.7	-	19
8.6	626	0.01	0.00	0.60	6.90	0.44	0.43	3.9	10	4.51	16.1	-	20
9.61	947	9.89	0.10	4.21	32.55	9.27	0.00	9.3	100	1.45	-	-	21
9.06	524	0.02	0.00	0.45	5.78	0.40	0.38	3.6	6	4.20	15.3	-	22
10.66	808	0.01	0.00	0.18	19.14	1.38	1.37	23.7	45	2.36	13.9	-	23
8.4	121	0.00	0.09	0.02	11.33	0.74	0.65	13.2	15	3.93	17.5	-	24
9.18	1545	0.02	0.00	0.02	23.94	0.75	0.72	2.4	74	2.03	33.1	1	1
9.31	1542	0.03	0.00	0.01	11.72	0.70	0.66	0	80	3.56	17.7	1	2
7.47	198	0.02	0.01	0.1	12.84	0.89	0.86	3	24	2.84	14.9	1296	3
7.46	129	0.02	0.00	0.19	25.19	1.50	1.48	42	530	1.60	17.1	199	4
8.52	258	0	0.00	0.06	9.96	0.66	0.66	4.5	10	1.92	15.1	10	5
8.29	334	0.04	0.00	0.17	31.32	0.91	0.87	0	9	1.95	36.2	84	6
8.13	208	0.02	0.00	0.17	23.41	1.02	1.00	3.3	25	2.47	23.5	169	7
8	196	0.01	0.01	0.17	18.68	0.99	0.97	3.9	22	2.96	19.2	759	8
8.16	251	0.02	0.00	0.06	11.66	0.62	0.60	2.4	78	3.72	19.4	10	9
8.57	418	0.02	0.01	0.17	25.72	0.53	0.50	0	25	2.14	51.3	20	10
9.35	541	0.06	0.00	0.32	50.40	1.75	1.69	4.8	12	2.18	29.9	275	11
9.1	258	0.05	0.00	0.02	35.18	1.45	1.40	7.5	7	1.42	25.1	238	12
8.97	183	0.01	0.00	0.002	10.96	0.39	0.38	0	20	1.71	29.0	20	13
8.27	66	0	0.00	0.27	9.58	0.57	0.57	3.3	9	3.00	16.8	594	14
7.69	108	0.09	0.03	0.27	10.73	0.68	0.56	0	18	2.59	19.3	75	15
8.31	261	0.02	0.00	0.19	20.08	0.74	0.72	7.5	60	2.05	27.9	171	16

8.3	193	0.01	0.00	0.01	13.51	0.53	0.52	2.7	22	1.89	26.1	1	17
8.96	606	0	0.00	0.01	24.15	1.02	1.02	21	79	1.62	23.7	464	18
8.1	323	0	0.00	0.05	15.28	0.69	0.69	11.7	49	2.40	22.2	10	19
8.22	794	0.02	0.00	0.27	17.90	0.37	0.35	0.3	35	1.27	51.2	246	20
8.95	1022	9.9	0.27	4.26	58.96	10.69	0.52	10.2	19	0.29	113.8	187	21
8.77	545	0.24	0.00	0.49	29.14	0.84	0.60	1.5	27	0.59	48.6	41	22
10.04	809	0.01	0.00	0.09	47.63	1.80	1.78	10.2	27	0.72	26.7	41	23
9.53	113	0.01	0.00	0.01	15.16	0.93	0.92	11.4	11	2.06	16.5	20	24
9.36	1585	0.05	0.00	0.04	63.16	1.00	0.95	11.7	155	0.70	66.3	-	1
9.38	1582	0.03	0.00	0.01	33.22	0.58	0.55	2.1	65	1.42	60.8	-	2
7.69	274	0.01	0.00	0.03	21.82	0.99	0.98	2.4	8	2.02	22.3	-	3
7.63	138	0.04	0.60	0.26	11.97	1.53	0.89	0	19	3.22	13.5	-	4
8	282	0.00	0.07	0.01	24.83	0.64	0.57	4.5	11	1.09	43.6	-	5
8.1	436	0.22	0.00	0.20	45.70	1.01	0.79	1.5	10	1.23	57.6	-	6
8.26	229	0.03	0.00	0.10	28.20	1.21	1.18	0	52	2.29	23.8	-	7
7.79	214	0.04	0.37	0.19	25.74	1.22	0.82	8.4	49	2.91	31.6	-	8
8.64	331	0.07	0.07	0.06	30.41	0.85	0.71	2.1	56	1.83	43.1	-	9
8.85	504	0.06	0.05	0.19	35.24	0.43	0.32	0	27	1.69	111.0	-	10
8.71	572	0.03	0.11	0.19	64.77	1.51	1.37	2.7	11	1.70	47.2	-	11
9.06	282	0.02	0.17	0.03	35.32	1.45	1.27	6	21	1.70	27.8	-	12
8.83	196	0.01	0.22	0.00	19.49	0.48	0.25	0	20	1.49	76.5	-	13
8.38	83	0.01	0.01	0.19	10.32	0.59	0.56	3.6	8	3.72	18.3	-	14
7.74	203	0.21	0.37	0.32	22.22	1.43	0.86	0	3	1.86	25.8	-	15
8.44	320	0.02	0.00	0.02	21.67	0.53	0.51	0	42	1.36	42.2	-	16
8.58	233	0.01	0.31	0.02	10.97	0.81	0.49	2.4	7	2.94	22.3	-	17
8.62	642	0.01	0.06	0.00	18.75	1.00	0.93	21.9	75	2.24	20.2	-	18
8.09	519	0.06	0.00	0.00	23.82	0.87	0.81	3.6	10	1.80	29.4	-	19

8.46	906	0.03	0.33	0.22	64.85	1.00	0.64	1.2	23	0.49	101.1	-	20
8.77	1070	0.36	0.00	0.41	15.57	0.79	0.43	11.1	82	1.58	35.9	-	21
8.85	607	0.09	0.00	0.18	16.25	1.05	0.96	0	15	1.60	16.9	-	22
10	865	0.04	0.00	0.01	31.21	1.80	1.76	4.8	11	1.43	17.7	-	23
9.28	134	0.01	0.15	0.00	20.96	1.02	0.85	8.7	8	1.66	24.6	-	24
9.45	1610	0.04	0.00	0.01	90.56	0.79	0.76	3	58	0.53	119.9	1	1
9.41	1555	0.03	0.00	0.01	80.93	0.72	0.69	2.1	62	0.55	116.7	1	2
7.88	362	0.00	0.00	0.01	40.92	1.70	1.70	24	27	1.36	24.0	108	3
7.83	174	0.01	0.23	0.30	21.36	1.15	0.91	4.8	2	1.97	23.4	84	4
8.34	290	0.01	0.00	0.04	22.25	0.90	0.90	3.6	8	1.21	24.8	1	5
8.76	1169	0.12	0.00	0.36	122.91	1.96	1.85	9	29	1.76	66.5	439	6
8.45	248	0.02	0.00	0.11	26.15	0.81	0.80	4.2	52	2.73	32.9	52	7
8.49	224	0.01	0.51	0.09	22.52	0.89	0.36	4.5	11	2.76	62.1	187	8
8.23	404	0.04	0.00	0.12	35.08	0.73	0.69	3	100	1.86	50.9	30	9
8.95	554	0.05	0.00	0.27	35.21	0.50	0.45	2.4	27	1.89	78.4	1	10
8.8	842	0.29	0.00	0.28	76.38	1.78	1.48	9.3	35	1.74	51.5	799	11
9.38	324	0.01	0.00	0.02	29.87	1.45	1.44	15.9	22	1.98	20.8	529	12
8.24	207	0.00	0.00	0.01	11.66	0.50	0.50	1.2	18	1.92	23.5	1	13
7.91	96	0.00	0.00	0.27	15.11	0.86	0.86	4.2	6	2.44	17.7	637	14
7.73	180	0.05	0.00	0.21	20.24	0.84	0.79	0	11	1.79	25.7	30	15
9.02	365	0.00	0.00	0.03	27.61	0.91	0.91	8.7	31	1.24	30.4	10	16
8.8	250	0.00	0.00	0.02	19.24	0.62	0.62	1.5	12	1.64	31.1	1	17
8.11	684	0.01	0.48	0.02	31.86	1.89	1.40	21	220	1.35	22.7	63	18
7.94	578	0.00	0.05	0.01	45.40	1.05	1.00	0	16	0.98	45.3	31	19
8.83	943	0.01	0.00	0.21	44.03	0.46	0.45	0.6	20	0.61	97.8	1	20
9.28	1104	9.49	0.00	3.78	45.57	10.50	1.01	5.4	25	0.61	45.1	63	21
9.3	647	0.18	0.00	0.35	33.52	0.82	0.63	1.2	9	0.64	53.0	1	22

10.45	641	0.03	0.00	0.02	41.93	1.96	1.93	4.2	14	1.32	21.8	1	23
9.27	152	0.00	0.00	0.01	22.04	1.00	1.00	6.6	25	1.57	22.0	1	24
9.26	1370	0.18	0.05	0.02	74.2	0.6	0.35	1.2	81	0.81	214.2	-	1
9.3	1494	0.08	0.01	0.01	97.8	0.6	0.47	1.5	39	0.47	209.3	-	2
7.62	223	1.39	0.17	0.20	27.6	2.0	0.44	4.2	17	2.50	63.2	-	3
7.88	108	1.01	0.01	0.10	15.7	1.2	0.13	3	5	2.02	117.7	-	4
7.83	282	0.03	0.00	0.02	23.0	0.7	0.66	6.3	17	1.12	34.7	-	5
8.05	261	0.66	0.00	0.27	24.0	1.3	0.65	7.2	34	3.02	36.9	-	6
8.15	237	0.06	0.01	0.10	29.1	1.0	0.98	3.6	87	2.14	29.7	-	7
7.97	223	0.02	0.01	0.07	26.3	1.0	1.00	4	32	2.23	26.4	-	8
8.32	391	0.12	0.02	0.15	24.6	0.7	0.60	4	77	2.76	40.8	-	9
8.77	532	0.11	0.05	0.30	20.2	0.6	0.40	1.8	38	3.56	50.0	-	10
8.6	363	0.20	0.02	0.10	38.7	1.4	1.15	6.4	34	3.41	33.5	-	11
8.58	310	0.01	0.01	0.01	29.9	1.5	1.44	16.2	24	2.19	20.7	-	12
8.17	217	0.00	0.00	0.01	14.3	0.5	0.52	3	148	1.70	27.6	-	13
8.13	80	0.07	0.00	0.16	16.8	0.8	0.74	9.3	23	2.29	22.7	-	14
7.97	78	0.31	0.05	0.12	11.9	0.7	0.32	5.1	13	2.15	37.0	-	15
7.76	639	0.21	0.01	0.28	48.6	1.8	1.57	12.6	51	2.60	31.0	-	16
7.89	256	0.02	0.00	0.01	22.4	0.5	0.48	2.4	10	1.55	46.6	-	17
8.05	678	0.01	0.07	0.01	31.1	1.0	0.92	10.4	78	1.34	33.6	-	18
7.94	572	0.04	0.01	0.04	53.0	0.9	0.88	4.8	21	0.88	60.4	-	19
8.23	252	0.35	0.02	0.34	20.1	0.8	0.45	4.2	76	2.73	45.2	-	20
9.04	1033	9.86	0.01	3.51	37.7	10.3	0.41	8.1	46	0.79	91.6	-	21
8.86	653	0.20	0.00	0.35	23.9	0.8	0.60	3	10	0.90	39.6	-	22
9.84	852	0.07	0.01	0.03	46.2	1.7	1.66	12.9	51	1.21	27.9	-	23
8.76	165	0.01	0.00	0.00	17.9	0.9	0.87	6.6	23	1.88	20.6	-	24
9.36	1887	0.01	0.02	0.01	61.57	0.54	0.51	0.3	62	0.69	120.2	1	1

9.35	1838	0.01	0.01	0.02	57.69	0.54	0.52	10.2	299	0.63	110.2	1	2
7.70	378	0.08	0.21	0.02	31.19	1.46	1.17	0.0	5	1.50	26.7	95	3
7.66	169	0.01	0.02	0.48	15.83	1.01	0.98	23.4	298	2.54	16.1	52	4
8.76	343	0.00	0.01	0.03	17.41	0.79	0.78	4.8	17	1.59	22.2	20	5
8.62	1403	0.04	0.03	0.37	58.07	1.42	1.35	6.7	46	3.23	42.9	169	6
8.23	318	0.01	0.01	0.12	20.81	0.83	0.80	0.0	58	3.51	25.9	31	7
8.17	318	0.00	0.01	0.12	19.67	0.84	0.83	2.4	32	3.32	23.7	31	8
8.45	457	0.02	0.04	0.19	21.95	0.69	0.63	2.4	85	3.59	34.9	20	9
8.75	646	0.05	0.07	0.44	24.04	0.57	0.45	0.0	40	3.49	53.3	10	10
8.33	720	0.14	0.15	0.29	37.35	1.41	1.13	0.0	17	3.40	33.1	1	11
9.39	398	0.04	0.12	0.05	28.49	1.85	1.70	2.4	7	2.30	16.8	1	12
8.53	253	0.01	0.02	0.01	11.78	0.32	0.30	0.0	44	2.28	39.5	10	13
8.18	114	0.01	0.05	0.15	14.08	0.93	0.88	4.5	14	2.63	16.0	169	14
7.84	179	0.05	0.10	0.3	14.14	0.84	0.69	0.0	11	2.75	20.4	336	15
8.21	618	0.01	0.07	0.1	24.59	1.21	1.13	4.8	41	2.07	21.7	1	16
8.84	316	0.01	0.00	0.01	18.51	0.59	0.58	5.4	16	1.85	32.0	1	17
8.39	844	0.00	0.16	0.03	28.01	1.04	0.88	8.0	462	1.52	31.9	52	18
8.06	734	0.00	0.00	0.01	44.69	0.98	0.97	1.2	32	1.09	46.0	20	19
8.24	1059	0.04	0.03	0.3	22.99	0.60	0.53	0.0	26	1.63	43.4	243	20
9.17	1290	9.85	0.05	4.13	40.77	10.31	0.40	17.7	59	0.69	102.1	31	21
8.76	749	0.07	0.01	0.35	25.08	0.53	0.46	2.4	33	0.89	54.9	108	22
9.78	1101	0.02	0.02	0.02	42.02	1.70	1.66	5.4	53	1.57	25.3	161	23
8.46	160	0.01	0.01	0.01	15.60	0.95	0.93	4.8	20	2.08	16.7	1	24
9.44	1830	0.02	0.01	0.02	71.06	0.59	0.56	2.4	75	0.6	126.6	-	1
9.47	1866	0.02	0.02	0.01	66.49	0.71	0.67	6.6	122	0.6	99.3	-	2
7.42	273	0.00	0.00	0.16	19.36	0.88	0.87	7.2	25	2.0	22.2	-	3
7.55	109	0.00	0.02	0.55	11.23	0.57	0.55	0	4	3.5	20.3	-	4

7.59	195	0.00	0.01	0.10	11.96	0.52	0.51	0	11	2.1	23.4	-	5
8.5	798	0.01	0.01	0.14	24.76	1.36	1.34	0.6	9	2.4	18.5	-	6
8.7	86	0.00	0.00	0.06	10.13	0.45	0.44	0	36	3.0	23.0	-	7
8.86	87	0.00	0.01	0.06	7.63	0.42	0.40	0.9	19	3.8	19.0	-	8
8.48	141	0.00	0.00	0.05	8.65	0.35	0.35	0	37	3.0	25.0	-	9
8.59	106	0.01	0.05	0.11	10.52	0.47	0.41	0	13	3.7	25.8	-	10
8.33	172	0.05	0.01	0.09	13.10	0.68	0.62	3	8	3.6	21.1	-	11
10.1	122	0.02	0.38	0.05	14.95	2.66	2.25	0	11	3.6	6.6	-	12
9.03	184	0.01	0.08	0.01	9.75	0.47	0.38	1.5	22	3.2	25.4	-	13
8.93	88	0.00	0.03	0.33	10.98	0.49	0.46	0	6	3.0	23.8	-	14
8.09	162	0.05	0.13	0.23	10.70	0.69	0.52	0	3	3.0	20.6	-	15
7.88	200	0.01	0.02	0.10	10.98	0.40	0.38	0	32	2.9	29.2	-	16
8.05	109	0.01	0.01	0.14	11.82	0.44	0.42	0.3	13	3.1	28.1	-	17
8.02	179	0.01	0.05	0.06	12.42	0.55	0.49	0	10	3.6	25.2	-	18
8.3	821	0.01	0.02	0.03	23.83	0.49	0.46	0	12	1.5	51.4	-	19
8.4	781	0.01	0.01	0.56	18.96	0.34	0.32	0	53	1.5	59.3	-	20
9.78	720	1.04	0.02	1.99	35.73	1.83	0.78	6	36	1.4	45.9	-	21
9.09	436	0.02	0.00	0.25	17.01	0.58	0.55	0	8	1.4	30.9	-	22
9.35	748	0.02	0.04	0.26	38.69	1.18	1.12	0	16	1.7	34.5	-	23
8.78	75	0.01	0.01	0.03	12.18	0.48	0.46	0	11	3.4	26.6	-	24
9.31	1731	0.02	0.00	0.02	13.99	0.85	0.83	2.1	68	3.9	16.9	10	1
9.46	1709	0.01	0.00	0.03	10.25	0.81	0.79	1.8	54	4.6	12.9	1	2
7.57	429	0.00	0.07	0.25	62.54	1.86	1.80	6	5	1.0	34.8	667	3
8.01	140	0.00	0.00	0.52	24.79	0.89	0.89	10.8	33	1.8	28.0	104	4
7.84	218	0.00	0.00	0.10	6.77	0.63	0.63	4.8	9	4.4	10.7	132	5
8.17	992	0.04	0.00	0.18	129.48	2.02	1.98	6	10	0.9	65.4	92	6
8.35	114	0.00	0.00	0.04	5.88	0.44	0.44	4.2	36	5.2	13.4	63	7

8.2	104	0.00	0.00	0.03	5.85	0.43	0.43	10.2	31	5.0	13.7	152	8
7.9	285	0.00	0.00	0.06	27.80	0.37	0.37	3.6	26	0.9	74.3	20	9
8.62	543	0.01	0.00	0.10	57.53	0.36	0.35	2.4	6	0.5	162.5	1	10
8.4	873	0.20	0.00	0.54	24.32	1.61	1.41	7.2	37	5.0	17.2	523	11
9.79	166	0.01	0.00	0.04	8.29	0.57	0.56	4.2	8	4.4	14.8	91	12
8.53	189	0.01	0.00	0.01	5.95	0.40	0.39	2.1	19	4.3	15.2	20	13
8.06	207	0.02	0.30	0.13	10.35	1.35	1.04	13.2	13	3.4	10.0	228	14
7.94	166	0.03	0.00	0.12	7.88	0.65	0.62	3.6	3	3.9	12.7	211	15
7.68	318	0.01	0.00	0.03	7.23	0.59	0.58	6.3	44	3.4	12.5	1	16
8.03	165	0.01	0.00	0.03	7.16	0.57	0.56	3.6	7	4.7	12.8	10	17
7.97	209	0.02	0.00	0.02	12.92	0.83	0.81	69.6	180	3.2	15.9	512	18
7.76	995	0.01	0.00	0.04	11.12	0.66	0.65	4.8	12	3.3	17.1	20	19
8.38	1024	0.02	0.00	0.27	7.81	0.43	0.40	1.8	27	3.9	19.4	41	20
8.71	1264	15.91	0.00	4.65	5.96	18.66	2.75	15.3	90	3.9	2.2	10	21
8.45	487	1.50	0.03	0.72	6.79	2.65	1.11	2.7	18	4.5	6.1	10	22
9.63	851	0.03	0.00	0.02	15.88	1.56	1.53	15.9	30	3.0	10.4	20	23
8.89	94	0.01	0.00	0.01	7.97	0.51	0.50	5.1	7	3.9	16.0	30	24
9.33	1920	0.02	0.00	0.01	12.45	0.42	0.40	2.4	48	3.3	31.1	-	1
9.41	1895	0.01	0.00	0.01	13.05	0.42	0.41	2.4	46	3.5	32.0	-	2
7.64	416	0.00	0.32	0.06	16.52	1.37	1.05	9.6	5	2.4	15.7	-	3
7.91	189	0.02	0.26	0.41	9.35	0.90	0.61	7.2	18	5.9	15.2	-	4
7.94	256	0.00	0.00	0.06	7.05	0.29	0.29	3.3	5	3.3	24.1	-	5
8.32	1128	0.02	0.00	0.24	17.04	0.64	0.62	3	6	5.1	27.5	-	6
8.56	146	0.01	0.00	0.04	7.98	0.27	0.27	4.8	37	4.2	30.1	-	7
8.46	137	0.00	0.00	0.02	7.53	0.24	0.24	5.4	22	4.0	31.7	-	8
8.09	456	0.03	0.02	0.07	9.11	0.31	0.26	3	87	4.6	35.3	-	9
8.45	507	0.01	0.01	0.07	7.79	0.24	0.22	2.4	17	4.9	35.4	-	10

8.72	1065	0.88	0.04	0.53	23.58	1.89	0.96	3.3	9	5.2	24.5	-	11
9.03	203	0.04	0.00	0.03	9.75	0.42	0.38	4.2	3	3.8	25.5	-	12
8.39	210	0.03	0.00	0.05	5.59	0.10	0.07	1.8	29	4.7	75.2	-	13
8.19	248	0.06	0.00	0.10	10.27	0.43	0.37	3.9	14	3.5	27.9	-	14
8.36	206	0.04	0.04	0.10	8.29	0.31	0.24	0.6	0	3.9	34.2	-	15
7.82	374	0.02	0.00	0.03	7.79	0.30	0.28	4.2	68	3.1	27.9	-	16
7.9	225	0.01	0.00	0.09	8.12	0.20	0.19	3.6	6	4.1	43.0	-	17
7.99	275	0.02	0.01	0.01	10.36	0.43	0.40	4.8	11	3.4	25.8	-	18
7.78	1003	0.02	0.00	0.02	11.92	0.46	0.45	4.8	29	3.7	26.6	-	19
8.37	1128	0.07	0.00	0.23	5.97	0.14	0.07	1.8	27	4.4	87.0	-	20
9.05	1434	14.38	0.00	4.49	8.92	14.97	0.59	11.4	39	2.5	15.1	-	21
8.69	534	0.51	0.00	0.38	7.43	0.95	0.43	2.7	30	4.2	17.2	-	22
9.27	921	0.03	0.00	0.05	14.35	1.00	0.96	5.1	15	3.3	14.9	-	23
8.92	111	0.02	0.00	0.01	9.42	0.32	0.31	15	24	3.0	30.5	-	24
9.23	1793	0.02	0.00	0.01	14.96	0.61	0.58	4.5	112	2.9	25.6	30	1
9.36	1807	0.02	0.05	0.01	14.28	0.54	0.46	1.8	60	3.2	30.9	1	2
7.82	366	0.11	0.32	0.05	13.12	1.28	0.84	2.4	73	3.1	15.6	81	3
7.99	170	0.11	0.23	0.35	9.85	0.87	0.53	5.4	18	4.0	18.6	162	4
7.89	254	0.00	0.00	0.03	7.17	0.39	0.39	2.7	3	3.1	18.5	1	5
8.09	784	0.04	0.02	0.21	16.33	0.78	0.71	3	5	4.5	22.9	71	6
8.4	148	0.01	0.00	0.04	9.31	0.43	0.43	4.5	42	3.7	21.8	405	7
8.35	142	0.01	0.00	0.02	8.27	0.43	0.42	3.9	27	4.1	19.5	253	8
8.05	474	0.01	0.50	0.10	11.45	0.53	0.03	3.3	71	4.8	396.5	20	9
8.54	548	0.01	0.01	0.05	7.67	0.37	0.36	1.2	18	5.3	21.6	1	10
8.3	484	0.05	0.03	0.11	11.31	0.72	0.65	4.2	14	5.9	17.4	277	11
8.4	228	0.01	0.00	0.02	9.24	0.51	0.50	2.1	1	4.7	18.6	121	12
8.35	205	0.06	0.11	0.01	5.92	0.25	0.09	3	36	4.8	65.6	20	13

8.37	239	0.09	0.22	0.10	9.71	0.70	0.39	5.1	4	4.2	24.7	369	14
8.03	304	0.05	0.02	0.17	9.26	0.55	0.48	4.2	2	3.7	19.3	20	15
7.86	398	0.01	0.31	0.03	8.42	0.37	0.06	8.1	77	3.4	138.6	70	16
7.93	227	0.00	0.00	0.07	8.28	0.35	0.35	7.5	11	3.8	23.6	10	17
7.98	305	0.00	0.00	0.01	11.69	0.59	0.59	8.1	28	3.2	19.9	10	18
7.82	612	0.00	0.07	0.02	9.89	0.49	0.42	7.5	36	3.8	23.7	130	19
8.44	1012	0.02	0.00	0.20	6.40	0.19	0.17	0.6	19	3.4	37.9	101	20
9.47	1370	9.88	0.00	4.15	7.13	10.99	1.11	10.8	29	3.5	6.4	1	21
8.85	543	0.33	0.00	0.33	7.48	0.81	0.48	7.8	110	4.1	15.5	1	22
9.19	916	0.03	0.00	0.04	10.94	0.97	0.94	6	12	3.7	11.6	1	23
8.94	113	0.03	0.00	0.01	9.23	0.47	0.45	8.4	26	3.1	20.6	10	24
8.44	1684	0.01	0.02	0.08	14.37	0.91	0.87	0	69	3.1	16.5	1	1
9.41	1777	0.01	0.02	0.02	13.93	0.90	0.87	0.9	65	3.2	16.1	1	2
7.84	313	0.01	0.03	0.10	13.89	0.96	0.93	4.8	7	3.5	15.0	253	3
8	151	0.01	0.08	0.38	9.68	0.84	0.75	7.2	17	4.3	12.9	1112	4
7.97	249	0.01	0.04	0.14	6.86	0.78	0.73	1.8	3	3.4	9.4	10	5
7.91	424	0.26	0.03	0.19	17.42	1.24	0.95	5.1	14	3.8	18.3	1274	6
8.12	164	0.02	0.07	0.11	10.25	0.94	0.85	4.5	35	4.0	12.0	435	7
8.09	160	0.00	0.03	0.08	8.49	0.79	0.76	3	21	4.5	11.2	131	8
7.88	429	0.06	0.15	0.23	12.99	1.20	1.00	1.8	63	5.4	13.0	218	9
8.43	589	0.02	0.07	0.08	6.85	0.81	0.71	0	14	6.0	9.6	1	10
8.18	493	0.06	0.03	0.26	20.67	1.39	1.29	8.4	21	4.5	16.0	8664	11
8.18	236	0.01	0.12	0.05	10.96	1.03	0.90	2.4	11	4.4	12.2	1046	12
8.15	193	0.05	0.05	0.01	5.60	0.65	0.54	0	43	5.8	10.3	52	13
8.14	230	0.05	0.12	0.14	34.06	1.11	0.94	2.4	11	1.3	36.2	987	14
7.84	249	0.08	0.04	0.32	33.60	1.13	1.01	6	7	1.4	33.2	41	15
7.68	386	0.03	0.11	0.06	34.88	0.88	0.75	1.5	65	1.0	46.5	52	16

7.75	230	0.01	0.02	0.09	27.07	0.69	0.66	2.1	9	1.2	41.1	30	17
7.8	351	0.00	0.05	0.01	29.47	0.99	0.94	3	8	1.3	31.5	1679	18
7.65	435	0.01	0.03	0.08	47.37	0.81	0.77	0	15	0.8	61.8	228	19
7.95	866	0.04	0.05	0.30	5.49	0.56	0.47	0	27	4.0	11.8	156	20
9.55	1292	7.12	0.17	4.20	9.66	8.36	1.07	6	27	3.1	9.0	10	21
8.69	534	0.12	0.10	0.27	6.57	1.12	0.89	1.2	36	4.8	7.4	41	22
9.11	882	0.00	0.01	0.06	12.41	1.18	1.16	2.4	10	3.3	10.7	20	23
8.79	116	0.01	0.02	0.01	7.98	0.70	0.67	3	7	3.1	12.0	1	24
9.15	1829	0.02	0.02	0.00	14.22	0.69	0.65	4.2	65	3.19	21.9	-	1
9.25	1874	0.02	0.02	0.01	14.95	0.71	0.67	3.9	76	3.02	22.2	-	2
7.74	406	0.01	0.00	0.14	15.42	0.68	0.67	9.6	1	3.79	22.8	-	3
7.9	168	0.01	0.05	0.42	11.54	0.77	0.70	16.8	13	3.87	16.4	-	4
8.08	264	0.01	0.03	0.05	8.41	0.65	0.62	4.5	1	2.74	13.7	-	5
7.95	498	0.03	0.00	0.28	14.96	0.88	0.85	5.7	1	4.65	17.5	-	6
8.19	177	0.01	0.00	0.05	9.93	0.70	0.69	5.7	57	3.99	14.4	-	7
8.26	168	0.01	0.02	0.02	10.41	0.70	0.66	7.5	22	3.44	15.7	-	8
8.18	478	0.09	0.05	0.13	11.41	0.80	0.66	6.3	75	5.73	17.3	-	9
8.47	620	0.02	0.06	0.07	7.12	0.44	0.35	3.6	13	5.69	20.1	-	10
8.08	409	0.04	0.12	0.06	10.51	1.11	0.95	12.6	36	5.20	11.1	-	11
8.2	274	0.01	0.01	0.03	10.56	0.64	0.62	10.5	8	4.25	16.9	-	12
8.21	205	0.09	0.03	0.00	5.37	0.45	0.32	2.4	43	6.78	16.7	-	13
8.18	208	0.02	0.13	0.06	9.37	0.85	0.69	5.1	5	4.19	13.6	-	14
7.99	282	0.08	0.02	0.19	9.85	0.68	0.57	10.2	3	4.67	17.3	-	15
7.98	432	0.02	0.01	0.01	7.86	0.50	0.47	7.8	39	3.72	16.9	-	16
7.98	249	0.01	0.02	0.08	7.69	0.38	0.35	5.1	5	4.21	22.0	-	17
8.15	389	0.02	0.00	0.02	12.72	0.81	0.78	18.3	106	3.06	16.2	-	18
7.92	479	0.01	0.00	0.03	9.59	0.58	0.57	5.1	19	3.67	16.9	-	19

8.24	1075	0.03	0.00	0.21	3.11	0.24	0.20	6	11	5.72	15.5	-	20
9.57	1384	6.39	0.00	6.36	7.74	5.02	0.00	11.4	46	3.90	-	-	21
8.63	562	0.28	0.06	0.32	7.25	0.99	0.65	4.2	46	4.52	11.2	-	22
9	920	0.05	0.01	0.03	13.21	1.16	1.09	5.4	15	3.16	12.1	-	23
8.69	123	0.02	0.06	0.00	9.02	0.52	0.45	7.8	14	2.93	20.0	-	24
9.09	1704	0.02	0.00	0.01	13.48	0.68	0.65	3.6	113	3.23	20.7	10	1
9.17	1774	0.03	0.00	0.00	10.31	0.64	0.61	2.1	99	4.54	16.9	31	2
7.88	378	0.13	0.09	0.12	9.00	0.60	0.38	4.8	27	4.22	23.6	831	3
8.09	165	0.15	0.02	0.47	12.72	0.87	0.71	10.2	11	4.58	18.0	1445	4
8.07	275	0.01	0.02	0.14	9.16	0.58	0.54	3.6	5	3.59	16.8	99	5
8.02	317	0.48	0.50	0.38	14.11	1.25	0.26	3.6	20	5.12	53.5	2005	6
8.17	230	0.10	0.29	0.14	12.78	0.93	0.54	4.5	37	4.58	23.5	406	7
8.13	216	0.01	0.17	0.07	11.92	0.79	0.60	4.8	25	4.09	20.0	531	8
7.97	406	0.20	0.00	0.23	13.59	0.97	0.76	5.4	62	4.94	17.8	2005	9
8.28	554	0.08	0.00	0.08	10.02	0.64	0.55	2.4	24	5.27	18.1	178	10
8.52	290	0.08	0.18	0.05	12.41	0.97	0.72	7.8	22	5.14	17.3	1652	11
8.27	282	0.04	0.15	0.02	13.35	1.00	0.81	7.2	13	4.40	16.6	1013	12
8.13	206	0.14	0.07	0.00	5.16	0.49	0.27	2.4	59	7.22	18.8	53	13
8.17	168	0.03	0.02	0.05	9.44	0.54	0.48	5.4	17	4.60	19.5	1652	14
8.12	146	0.63	0.07	0.44	8.16	1.16	0.47	4.5	11	5.17	17.5	2005	15
7.84	395	0.10	0.00	0.26	9.77	0.70	0.60	6	45	4.85	16.1	150	16
7.88	282	0.10	0.21	0.05	7.38	0.77	0.46	3.9	30	4.71	15.9	222	17
7.84	478	0.02	0.32	0.00	10.87	0.75	0.42	3.6	5	3.00	26.0	1	18
7.87	325	0.24	0.54	0.14	9.81	0.97	0.19	20.1	71	4.60	51.9	2005	19
7.91	375	0.21	0.15	0.36	8.48	0.74	0.38	4.2	77	5.27	22.2	1184	20
9.15	1320	5.70	0.16	51.51	12.92	10.25	4.39	15	64	3.57	2.9	344	21
8.64	576	0.43	0.07	0.31	7.16	1.03	0.52	3.6	60	4.08	13.7	64	22

8.83	715	0.10	0.01	0.88	28.58	2.11	1.99	3	10	4.39	14.4	64	23
8.63	151	0.02	0.05	0.02	8.97	0.50	0.43	4.5	19	3.73	20.8	178	24
9.02	1251	0.06	0.06	0.03	16.64	0.92	0.80	0.3	83	3.43	20.9	-	1
9.09	1255	0.06	0.05	0.02	14.73	0.81	0.70	2.1	90	3.50	21.1	-	2
7.75	257	0.08	0.45	0.12	10.99	1.42	0.89	4.8	79	4.50	12.4	-	3
7.93	146	0.01	0.02	0.35	14.63	0.84	0.81	10.8	34	3.87	18.0	-	4
7.9	192	0.02	0.15	0.05	8.28	0.55	0.38	2.4	9	2.91	21.6	-	5
7.64	598	0.03	0.35	0.09	18.44	1.01	0.64	49.8	3171	2.98	28.9	-	6
8	191	0.05	0.51	0.09	11.67	1.15	0.59	3.9	61	5.12	19.7	-	7
8	180	0.04	0.22	0.08	14.07	1.04	0.77	3.9	28	4.25	18.2	-	8
7.87	315	0.32	0.15	0.16	11.97	1.18	0.71	3	78	6.20	16.8	-	9
8.26	381	0.08	0.09	0.08	9.70	0.71	0.54	1.5	16	6.31	18.0	-	10
8.35	238	0.15	0.61	0.09	13.39	1.71	0.95	15	63	5.97	14.1	-	11
8.15	216	0.06	0.31	0.03	10.81	1.18	0.81	6.3	17	6.06	13.3	-	12
8.19	156	0.16	0.05	0.02	5.70	0.56	0.35	1.8	49	7.85	16.3	-	13
8.26	122	0.18	0.16	0.03	10.09	0.99	0.65	6.6	40	4.26	15.5	-	14
8.08	155	0.15	0.19	0.18	9.25	0.77	0.43	2.7	3	4.51	21.3	-	15
7.96	300	0.07	0.10	0.07	12.28	0.98	0.81	2.7	39	3.93	15.2	-	16
8.01	191	0.58	0.11	0.05	8.95	1.02	0.33	6.6	48	4.07	27.2	-	17
7.94	400	0.04	0.70	0.01	10.65	0.95	0.21	4.8	3	2.97	50.3	-	18
7.83	336	0.01	0.18	0.01	10.33	0.65	0.46	5.4	9	3.51	22.4	-	19
7.96	572	0.05	0.22	0.30	4.74	0.41	0.14	1.8	8	4.87	34.1	-	20
9.11	929	7.30	0.01	4.76	12.55	8.13	0.81	8.1	50	3.49	15.5	-	21
8.67	383	0.50	0.03	0.34	7.61	1.11	0.59	2.4	40	4.26	12.9	-	22
8.85	665	0.07	0.11	0.09	14.83	1.33	1.15	2.7	37	3.63	12.8	-	23
8.68	108	0.03	0.06	0.01	8.60	0.59	0.51	1.8	13	3.07	17.0	-	24
9.03	1657	0.03	0.03	0.03	15.65	0.81	0.75	0.9	195	3.37	20.9	63	1

9.11	1726	0.07	0.71	0.02	15.42	0.80	0.03	0	95	3.74	536.3	1	2
8.12	404	0.12	0.03	0.04	11.30	1.30	1.15	8.4	26	3.66	9.8	10	3
8.29	247	0.00	0.02	0.21	11.36	0.58	0.56	0.6	3	3.65	20.2	52	4
8.22	281	0.00	0.04	0.04	7.89	0.51	0.47	0	3	3.02	16.8	1	5
7.93	1165	0.07	0.15	0.04	8.18	0.57	0.35	0	3	3.44	23.3	627	6
8.73	283	0.01	0.03	0.02	10.82	0.71	0.67	0	32	5.30	16.0	594	7
8.7	258	0.00	0.07	0.02	13.36	0.86	0.79	0.3	26	4.30	16.9	776	8
8.39	466	0.45	0.24	0.13	14.44	1.30	0.61	0	68	5.03	23.6	20	9
8.48	611	0.06	0.12	0.07	11.40	0.72	0.54	0	87	5.12	21.0	1	10
8.56	341	0.16	0.97	0.10	13.98	2.17	1.04	1.2	41	5.57	13.5	393	11
8.61	305	0.02	0.06	0.04	12.28	1.04	0.96	13.5	43	5.66	12.8	122	12
8.7	218	0.11	0.06	0.02	6.33	0.59	0.43	0	65	6.78	14.8	10	13
8.39	170	0.20	0.21	0.02	9.65	0.85	0.44	0	19	4.15	22.0	512	14
8.14	241	0.02	0.04	0.09	10.02	0.54	0.49	0	2	3.56	20.5	60	15
7.93	447	0.08	0.09	0.03	10.89	0.84	0.67	0	45	3.57	16.2	1	16
8.03	283	0.17	0.03	0.01	7.33	0.63	0.43	1.2	17	4.68	17.0	1	17
8	607	0.05	0.25	0.01	11.72	1.04	0.73	0	3	2.64	16.0	30	18
7.9	514	0.00	0.03	0.00	9.60	0.52	0.48	0	14	2.99	19.8	10	19
8.21	828	0.03	0.06	0.19	6.72	0.39	0.30	0	13	3.27	22.1	10	20
9.52	1290	4.57	0.01	4.53	8.51	5.03	0.45	5.4	49	5.47	18.9	1	21
8.41	547	0.13	0.04	0.16	7.59	0.79	0.62	0	37	4.11	12.2	1	22
8.96	922	0.02	0.04	0.06	16.36	1.42	1.36	0	32	3.32	12.0	1	23
6.45	135	0.04	0.07	0.01	8.62	0.59	0.48	0.9	12	2.70	18.1	10	24
8.86	1786	0.07	0.026	0.04	13.90	0.76	0.66	1.8	98	3.81	21.2	-	1
8.99	1799	0.08	0.029	0.02	10.88	0.68	0.57	2.1	93	5.27	19.0	-	2
7.87	477	0.01	0.170	0.14	12.98	0.99	0.81	4.8	14	3.43	16.1	-	3
8.05	253	0.01	0.047	0.30	13.83	0.60	0.54	7.2	7	3.32	25.4	-	4

8.02	292	0.01	0.064	0.04	8.51	0.55	0.48	1.8	10	2.97	17.7	-	5
7.96	436	0.06	0.028	0.28	15.77	0.78	0.69	5.7	21	3.97	22.9	-	6
8.18	301	0.05	0.032	0.19	14.36	0.95	0.86	5.1	50	4.84	16.6	-	7
8.52	348	0.06	0.091	0.23	13.98	1.02	0.87	7.8	39	4.89	16.1	-	8
8.29	482	0.36	0.093	0.22	14.23	1.21	0.75	3.6	80	5.21	18.8	-	9
8.5	612	0.03	0.097	0.09	12.33	0.75	0.63	2.1	31	5.02	19.6	-	10
8.54	356	0.19	0.622	0.14	15.40	1.91	1.09	4.2	91	5.55	14.1	-	11
8.56	321	0.04	0.077	0.06	15.62	1.22	1.11	10.2	44	5.11	14.1	-	12
8.48	248	0.06	0.037	0.02	5.30	0.39	0.29	1.5	54	7.90	18.6	-	13
8.35	213	0.04	0.071	0.05	10.17	0.62	0.51	4.8	25	4.50	19.9	-	14
8.13	269	0.16	0.282	0.71	17.22	1.79	1.35	3.9	11	4.10	12.8	-	15
8.03	458	0.12	0.086	0.11	7.63	0.37	0.17	3.3	77	6.41	46.0	-	16
8.1	316	0.00	0.206	0.02	10.81	1.21	1.00	8.1	52	3.09	10.8	-	17
8.41	632	0.02	0.540	0.01	9.92	0.53	0.00	17.4	60	3.29	-	-	18
8.28	479	0.01	0.075	0.01	9.51	0.78	0.69	4.8	27	3.26	13.7	-	19
8.81	627	0.10	0.045	0.57	12.12	0.89	0.74	2.1	42	3.74	16.4	-	20
9.6	1306	2.85	0.047	4.37	11.86	3.66	0.76	7.5	81	4.45	15.6	-	21
8.27	546	0.03	0.022	0.12	6.70	0.52	0.47	3	47	4.52	14.4	-	22
8.67	869	0.08	0.054	0.07	16.08	1.45	1.32	3.9	40	4.58	12.1	-	23
8.03	163	0.01	0.033	0.01	9.08	0.45	0.41	4.2	35	2.92	22.2	-	24
9.21	1736	0.07	0.08	0.04	14.37	0.90	0.76	1.2	122	4.09	19.0	1	1
8.94	1738	0.10	0.26	0.01	16.38	1.25	0.89	2.1	78	3.63	18.5	1	2
7.78	442	0.01	0.47	0.21	17.22	1.78	1.31	13.5	25	2.79	13.2	10	3
7.97	231	0.22	0.15	0.17	14.38	0.82	0.45	9.6	6	2.69	31.7	1	4
8.55	321	0.01	0.09	0.04	8.53	0.62	0.53	1.2	7	2.90	16.1	1	5
8.21	596	0.09	0.07	0.15	13.06	0.76	0.60	2.7	16	3.92	21.6	85	6
8.46	305	0.05	0.18	0.24	13.56	1.15	0.91	3.3	41	5.04	14.9	262	7

8.35	299	0.06	0.18	0.26	14.13	1.22	0.98	3.3	34	4.86	14.5	148	8
8.17	498	0.31	0.13	0.21	13.87	1.33	0.89	2.4	102	5.28	15.5	41	9
8.46	620	0.04	0.11	0.10	10.88	0.73	0.58	1.2	29	5.68	18.8	1	10
8.34	313	0.34	0.53	0.08	12.91	1.70	0.83	8.1	66	5.24	15.6	990	11
8.34	320	0.05	0.33	0.04	14.06	1.37	0.99	10.8	59	5.38	14.2	331	12
8.3	231	0.04	0.08	0.01	6.09	0.56	0.44	1.8	51	7.10	13.8	75	13
8.36	187	0.02	0.10	0.04	13.10	0.78	0.66	3.6	20	3.50	19.9	487	14
7.96	316	0.02	0.01	0.48	12.83	0.94	0.92	5.4	6	4.00	13.9	933	15
6.71	484	0.09	0.07	0.04	8.53	0.54	0.38	2.7	45	5.02	22.3	1	16
7.96	335	0.02	0.01	0.00	10.78	1.04	1.01	3	18	2.98	10.7	1	17
7.96	698	0.06	0.34	0.00	9.21	0.49	0.09	4.5	6	3.27	108.1	20	18
7.79	535	0.01	0.01	0.00	7.13	0.44	0.42	3.6	22	3.94	16.9	31	19
7.96	890	0.04	0.09	0.41	13.63	2.93	2.79	1.5	38	2.00	4.9	473	20
9.65	1345	1.67	0.01	5.49	7.68	0.73	0.00	8.7	83	6.64	-	1	21
7.27	580	0.10	0.05	0.31	16.60	1.41	1.26	3.6	44	1.85	13.2	1	22
9.11	950	0.03	0.02	0.06	9.89	0.56	0.52	1.8	32	6.25	19.1	1	23
8.84	176	0.01	0.01	0.01	9.72	0.77	0.75	5.4	27	2.77	13.0	10	24

APPENDIX D

PROPERTIES OF SEDIMENT ANALYSES

Date	Time	Reading	Sample ID	Sediment Label	Mode	Instrument SN	Model	Tube Anode	Unit	Elapsed Time 1	Elapsed Time 2	Elapsed Time 3
2/6/18	10:48:20	#1			Cal Check	512124	Delta Premium	Rh	%	14.83		
2/6/18	10:52:33	#2	Standard NIST 2710a		Soil	512124	Delta Premium	Rh	PPM	14.77	14.6	14.57
2/6/18	10:57:53	#3	CG GP 1	S07793	Soil	512124	Delta Premium	Rh	PPM	14.7	14.52	14.86
2/6/18	11:05:04	#4	Wolf Pen 2	S07812	Soil	512124	Delta Premium	Rh	PPM	14.71	14.53	14.84
2/6/18	11:06:24	#5	CG GP 3	S07795	Soil	512124	Delta Premium	Rh	PPM	14.74	14.58	14.87
2/6/18	11:07:32	#6	Lochinvar 2	S07782	Soil	512124	Delta Premium	Rh	PPM	14.71	14.48	14.87
2/6/18	11:08:57	#7	LB Fish 2	S07770	Soil	512124	Delta Premium	Rh	PPM	14.7	14.51	14.8
2/6/18	11:10:29	#8	Wolf Pen 3	S07813	Soil	512124	Delta Premium	Rh	PPM	14.92	14.54	14.84
2/6/18	11:11:41	#9	CG Vic 1	S07790	Soil	512124	Delta Premium	Rh	PPM	14.74	14.5	14.87
2/6/18	11:12:55	#10	Wolf Pen 1	S07811	Soil	512124	Delta Premium	Rh	PPM	14.72	14.51	14.83
2/6/18	11:14:10	#11	LB Fish 1	S07769	Soil	512124	Delta Premium	Rh	PPM	14.74	14.52	14.81
2/6/18	11:15:09	#12	Symphony 2	S07821	Soil	512124	Delta Premium	Rh	PPM	14.76	14.58	14.86
2/6/18	11:16:18	#13	LB Fish 3	S07771	Soil	512124	Delta Premium	Rh	PPM	14.9	14.53	14.77

2/6/18	11:17:29	#14	Lochinvar 1	S07781	Soil	512124	Delta Premium	Rh	PPM	14.69	14.8	14.86
2/6/18	11:18:32	#15	Cy Miller 3	S07780	Soil	512124	Delta Premium	Rh	PPM	14.74	14.5	14.84
2/6/18	11:19:41	#16	Allen Ridge 3	S07777	Soil	512124	Delta Premium	Rh	PPM	14.72	14.52	14.98
2/6/18	11:20:48	#17	Central Park 2-3	S07786	Soil	512124	Delta Premium	Rh	PPM	14.73	14.52	14.85
2/6/18	11:21:49	#18	Wahlberg 3	S07828	Soil	512124	Delta Premium	Rh	PPM	14.77	14.62	14.91
2/6/18	11:22:52	#19	Cy Miller 2	S07779	Soil	512124	Delta Premium	Rh	PPM	14.72	14.53	14.85
2/6/18	11:23:58	#20	Lochinvar 3	S07783	Soil	512124	Delta Premium	Rh	PPM	14.7	14.52	14.85
2/6/18	11:24:59	#21	CG GP 2	S07794	Soil	512124	Delta Premium	Rh	PPM	14.76	14.59	14.88
2/6/18	11:26:04	#22	Lake Placid 1	S07817	Soil	512124	Delta Premium	Rh	PPM	14.74	14.56	14.81
2/6/18	11:27:08	#23	Central Park 2-2	S07785	Soil	512124	Delta Premium	Rh	PPM	14.72	14.52	14.81
2/6/18	11:28:44	#24	Allen Ridge 2	S07776	Soil	512124	Delta Premium	Rh	PPM	14.77	14.52	14.86
2/6/18	11:29:10	#25			Cal Check	512124	Delta Premium	Rh	%	14.83		
2/6/18	11:30:17	#26	Symphony 3	S07822	Soil	512124	Delta Premium	Rh	PPM	14.75	14.57	14.85
2/6/18	11:31:31	#27	Lake Placid 3	S07819	Soil	512124	Delta Premium	Rh	PPM	14.73	14.51	14.81
2/6/18	11:32:34	#28	Wahlberg 2	S07827	Soil	512124	Delta Premium	Rh	PPM	14.75	14.83	14.81

2/6/18	11:33:35	#29	Nantucket 1	S07835	Soil	512124	Delta Premium	Rh	PPM	14.73	14.56	14.86
2/6/18	11:34:37	#30	Amber 1-1	S07796	Soil	512124	Delta Premium	Rh	PPM	14.73	14.59	14.87
2/6/18	11:35:34	#31	Wahlberg 1	S07826	Soil	512124	Delta Premium	Rh	PPM	14.76	14.59	14.84
2/6/18	11:36:34	#32	Amber 2-1	S07799	Soil	512124	Delta Premium	Rh	PPM	14.75	14.56	14.73
2/6/18	11:37:38	#33	Central Park 1-3	S07789	Soil	512124	Delta Premium	Rh	PPM	14.7	14.51	14.87
2/6/18	11:38:36	#34	Carter Lake 1	S07802	Soil	512124	Delta Premium	Rh	PPM	14.75	14.82	14.81
2/6/18	11:39:34	#35	Allen Ridge 1	S07775	Soil	512124	Delta Premium	Rh	PPM	14.75	14.6	14.85
2/6/18	11:40:38	#36	Carter Lake 2	S07803	Soil	512124	Delta Premium	Rh	PPM	14.74	14.54	14.82
2/6/18	11:41:45	#37	Museum 1	S07814	Soil	512124	Delta Premium	Rh	PPM	14.71	14.71	14.85
2/6/18	11:43:26	#38	Traditions Golf 2	S07833	Soil	512124	Delta Premium	Rh	PPM	14.69	14.74	14.86
2/6/18	11:45:19	#39	John Crompton 1	S07808	Soil	512124	Delta Premium	Rh	PPM	14.72	14.59	14.88
2/6/18	11:46:23	#40	Research 2	S07824	Soil	512124	Delta Premium	Rh	PPM	14.72	14.51	14.86
2/6/18	11:47:25	#41	John Crompton 3	S07810	Soil	512124	Delta Premium	Rh	PPM	14.73	14.59	14.98
2/6/18	11:48:26	#42	Traditions Golf 1	S07832	Soil	512124	Delta Premium	Rh	PPM	14.69	14.73	14.87

2/6/18	11:49:31	#43	John Crompton 2	S07809	Soil	512124	Delta Premium	Rh	PPM	14.7	14.52	14.86
2/6/18	11:50:33	#44	Traditions Golf 3	S07834	Soil	512124	Delta Premium	Rh	PPM	14.72	14.55	14.82
2/6/18	11:51:58	#45	Research 3	S07825	Soil	512124	Delta Premium	Rh	PPM	14.72	14.71	14.89
2/6/18	11:53:02	#46	Research 1	S07823	Soil	512124	Delta Premium	Rh	PPM	14.7	14.5	15.14
2/6/18	11:54:03	#47	Museum 2	S07815	Soil	512124	Delta Premium	Rh	PPM	14.76	14.57	14.87
2/6/18	11:55:09	#48	Country Club 2	S07773	Soil	512124	Delta Premium	Rh	PPM	14.73	14.62	14.85
2/6/18	11:55:35	#49			Cal Check	512124	Delta Premium	Rh	%	14.84		
2/6/18	11:56:41	#50	Amber 1-2	S07797	Soil	512124	Delta Premium	Rh	PPM	14.74	14.52	15.18
2/6/18	11:57:46	#51	Nantucket 2	S07836	Soil	512124	Delta Premium	Rh	PPM	14.72	14.51	14.86
2/6/18	11:58:48	#52	Atlas 3	S07831	Soil	512124	Delta Premium	Rh	PPM	14.7	14.54	14.87
2/6/18	11:59:52	#53	Amber 2-3	S07801	Soil	512124	Delta Premium	Rh	PPM	14.77	14.61	14.77
2/6/18	12:00:51	#54	Country Club 1	S07772	Soil	512124	Delta Premium	Rh	PPM	14.74	14.56	14.82
2/6/18	12:01:49	#55	Central Park 1-2	S07788	Soil	512124	Delta Premium	Rh	PPM	14.7	15.04	14.86
2/6/18	12:02:49	#56	Museum 3	S07816	Soil	512124	Delta Premium	Rh	PPM	14.72	14.53	14.83

2/6/18	12:04:00	#57	Atlas 1	S07829	Soil	512124	Delta Premium	Rh	PPM	14.7	14.51	14.87
2/6/18	12:04:57	#58	Amber 1-3	S07798	Soil	512124	Delta Premium	Rh	PPM	14.92	14.53	15.3
2/6/18	12:08:54	#59	Country Club 3	S07774	Soil	512124	Delta Premium	Rh	PPM	14.76	14.56	14.85
2/6/18	12:09:53	#60	Nantucket 3	S07837	Soil	512124	Delta Premium	Rh	PPM	14.74	14.53	14.85
2/6/18	12:10:51	#61	Amber 2-2	S07800	Soil	512124	Delta Premium	Rh	PPM	14.72	14.57	14.77
2/6/18	12:11:53	#62	Central Park 1-1	S07787	Soil	512124	Delta Premium	Rh	PPM	15.35	15.07	14.88
2/6/18	12:12:56	#63	CG Vic 3	S07792	Soil	512124	Delta Premium	Rh	PPM	14.73	14.55	15.06
2/6/18	12:13:56	#64	LB Swim 1	S07766	Soil	512124	Delta Premium	Rh	PPM	14.73	14.68	15.37
2/6/18	12:14:54	#65	LB Swim 2	S07767	Soil	512124	Delta Premium	Rh	PPM	14.7	14.49	14.85
2/6/18	12:15:57	#66	CG Vic 2	S07791	Soil	512124	Delta Premium	Rh	PPM	14.71	14.54	14.9
2/6/18	12:17:01	#67	Cy Miller 1	S07778	Soil	512124	Delta Premium	Rh	PPM	14.69	14.47	14.84
2/6/18	12:18:06	#68	Gabbard 2	S07806	Soil	512124	Delta Premium	Rh	PPM	14.76	14.55	14.93
2/6/18	12:19:14	#69	Lake Placid 2	S07818	Soil	512124	Delta Premium	Rh	PPM	14.75	14.51	14.87
2/6/18	12:20:14	#70	Gabbard 1	S07805	Soil	512124	Delta Premium	Rh	PPM	14.71	14.52	14.87
2/6/18	12:21:23	#71	Carter Lake 3	S07804	Soil	512124	Delta Premium	Rh	PPM	14.72	14.68	14.79

2/6/18	12:22:45	#72	LB Swim 3	S07768	Soil	512124	Delta Premium	Rh	PPM	14.72	14.54	14.88
2/6/18	12:24:31	#73	Central Park 2-1	S07784	Soil	512124	Delta Premium	Rh	PPM	14.76	14.54	14.86
2/6/18	12:25:44	#74	Gabbard 3	S07807	Soil	512124	Delta Premium	Rh	PPM	14.71	14.51	14.85
2/6/18	12:26:21	#75			Cal Check	512124	Delta Premium	Rh	%	14.86		
2/6/18	12:27:37	#76	Symphony 1	S07820	Soil	512124	Delta Premium	Rh	PPM	14.72	14.51	14.83
2/6/18	12:29:20	#77	Atlas 2	S07830	Soil	512124	Delta Premium	Rh	PPM	14.7	14.5	14.89

APPENDIX E

METAL CONCENTRATIONS WITHIN SEDIMENT

K	K +/-	Ca	Ca +/-	Ti	Ti +/-	Cr	Cr +/-	Mn	Mn +/-	Fe	Fe +/-	Co	Co +/-
23898	259	5894	112	3195	60	78	5	2197	23	47499	330	ND	
8385	97	3222	50	882	22	18	2	37	3	3018	36	ND	
10404	115	6166	75	2325	36	43	3	158	5	7315	63	ND	
9290	109	3348	55	1964	33	37	3	42	4	5548	53	ND	
8069	94	11194	100	1855	30	31	3	48	3	3439	38	ND	
4274	69	1362	42	2010	35	43	3	ND		10981	81	ND	
10364	116	6182	76	2104	35	45	3	166	5	7823	66	ND	
8107	96	8481	85	1554	29	29	3	39	3	3329	38	ND	
10569	116	5795	72	2545	37	49	3	147	4	6804	59	ND	
4092	69	1149	41	2026	36	58	3	ND		12016	88	ND	
5492	81	10548	103	2359	37	39	3	91	4	7365	63	ND	
5145	81	1788	52	2493	42	65	4	18	4	16953	114	ND	
8670	97	8522	83	1410	27	24	3	33	3	3542	38	ND	
9107	102	11208	102	2300	34	37	3	112	4	5932	53	ND	
9496	107	6412	74	2312	35	36	3	46	4	5562	52	ND	
7459	94	1663	42	2604	38	33	3	65	4	5875	55	ND	
8531	113	3595	67	2992	49	61	4	148	5	13099	101	ND	
8686	102	10446	100	2507	37	30	3	114	4	5829	54	ND	
8272	97	10552	98	1537	28	24	3	38	3	3341	38	ND	
7702	98	3851	58	1555	30	38	3	38	4	4273	46	ND	
6569	88	6237	75	2360	37	52	3	62	4	8315	67	ND	
7789	95	2051	46	2579	37	37	3	86	4	8022	65	ND	
9897	112	6100	73	1854	33	32	3	46	4	5097	50	ND	

5617	82	12307	114	2348	36	35	3	95	4	7361	63	ND	
6496	85	5357	66	2212	34	54	3	60	4	7198	60	ND	
8033	104	3278	61	2687	44	64	4	256	6	12399	91	ND	
7344	91	3431	53	1623	29	26	3	70	4	4414	45	ND	
5610	77	2599	45	1419	26	54	3	18	3	3471	38	ND	
8052	109	3681	67	2868	49	79	4	90	5	13360	101	ND	
7759	112	21001	195	2877	48	62	4	67	5	27485	177	ND	
6190	80	1503	34	876	21	18	2	19	3	1903	27	ND	
6807	97	2441	57	2978	44	47	3	37	4	14045	102	ND	
10150	114	6268	74	2165	35	38	3	49	4	5453	52	ND	
7749	102	2764	57	3285	45	50	3	44	4	12792	94	ND	
10067	109	4201	58	1534	29	28	3	98	4	3734	40	ND	
7848	92	4133	57	1836	32	34	3	90	4	4986	47	ND	
8656	101	5785	70	2111	34	34	3	95	4	5651	52	ND	
6905	85	6477	70	2048	31	35	3	96	4	4403	43	ND	
8283	100	4507	61	2019	33	28	3	59	4	4235	45	ND	
7398	90	4229	57	1787	31	31	3	83	4	4797	46	ND	
8890	103	6395	74	1767	31	28	3	62	4	4450	45	ND	
8420	99	7421	81	2262	37	34	3	110	4	6770	59	ND	
6554	83	5689	66	1750	29	27	3	80	4	3449	38	ND	
7209	87	7339	76	2487	34	32	3	102	4	5026	47	ND	
12994	138	5038	73	2728	42	63	4	114	5	11852	88	ND	
6352	90	18161	155	2372	38	48	3	70	4	7961	68	ND	

6529	85	3517	53	1815	30	31	3	44	3	5222	50	ND	
7313	90	2605	47	2690	37	26	3	69	4	4694	46	ND	
4804	73	1446	38	3007	39	40	3	45	4	5987	55	ND	
7113	105	4343	79	3022	49	57	4	42	5	24516	159	ND	
6505	92	72937	501	2223	36	44	3	100	4	10682	83	ND	
7075	87	2432	43	1107	24	18	2	32	3	2635	32	ND	
9022	107	4447	64	3237	43	59	3	91	4	7956	66	ND	
4917	73	1465	37	2280	34	30	3	48	3	3799	42	ND	
7128	87	5421	65	1766	29	25	3	63	4	6781	56	ND	
7019	95	33109	250	2043	35	39	3	81	4	7298	64	ND	
7309	92	4026	58	2377	35	32	3	55	4	5250	50	ND	
7064	99	15359	145	2728	43	60	4	47	4	18265	122	ND	
7198	88	2553	44	1366	25	19	2	38	3	2511	31	ND	
7472	94	5586	67	1373	27	26	3	28	3	2725	34	ND	
1873	42	1126	27	2213	29	17	2	36	3	1613	24	ND	
3937	66	947	36	4088	47	45	3	58	4	8005	66	ND	
7196	92	8791	89	1879	32	29	3	27	3	3525	40	ND	
7982	92	8719	84	1507	27	19	2	97	4	4273	42	ND	
5785	81	5084	64	1322	27	21	3	50	4	3103	37	ND	
6819	87	4888	63	2638	37	43	3	53	4	6539	56	ND	
5500	75	4451	56	1030	23	18	2	46	3	2799	33	ND	
7362	99	2709	59	3107	45	51	4	55	4	16271	111	ND	
2270	51	2461	43	2815	37	39	3	30	3	2737	35	ND	
7577	96	1676	42	2668	38	32	3	60	4	5200	50	ND	
5698	76	5211	61	1497	27	21	2	61	3	3681	38	ND	

5943	81	10849	101	2256	35	42	3	110	4	7487	61	ND	
4767	72	1564	37	3169	40	43	3	48	4	3977	43	ND	
7843	96	8844	89	1485	28	19	3	46	3	3588	40	ND	

Ni	Ni +/-	Cu	Cu +/-	Zn	Zn +/-	As	As +/-	Rb	Rb +/-	Sr	Sr +/-	Zr	Zr +/-
27	8	3351	33	4251	36	1494	23	116	2	256	6	348	8
ND		ND		12.6	1.6	ND		35.7	1	53.5	1.7	257	5
ND		10	3	47	2	ND		47.4	1.2	131	3	621	10
ND		ND		12.4	1.7	ND		45.7	1.1	70	2	498	8
ND		ND		19.1	1.8	ND		33.6	1	112	3	736	11
ND		ND		21.9	1.9	4	1.1	18.3	0.8	69	2	480	8
ND		ND		46	2	5.6	1.2	51.4	1.2	127	3	585	9
ND		ND		9.6	1.5	ND		31.6	1	81	2	576	9
ND		ND		34	2	ND		47.8	1.1	134	3	565	9
ND		ND		27	2	ND		17.3	0.8	80	2	474	8
ND		ND		28	2	3.6	1.2	31	1	104	3	466	8
ND		ND		33	2	6	1.2	23.3	0.9	92	2	482	8
ND		ND		23.5	1.9	ND		36.5	1	112	3	567	9
ND		10	3	43	2	ND		35.8	1	104	3	770	11
ND		ND		30	2	ND		45.5	1.1	136	3	864	13
ND		ND		20.2	1.9	3.7	1.1	35.5	1	77	2	648	10
18	6	ND		26	2	ND		46.7	1.2	173	4	626	10
ND		11	3	61	3	ND		37.7	1	97	2	557	9
ND		8	3	19.2	1.8	ND		31.6	1	107	3	575	9

ND		ND		13.8	1.7	ND		37.6	1.1	59.4	1.9	511	8
ND		ND		29	2	ND		35	1	83	2	818	12
ND		9	3	21.7	1.9	ND		39.2	1	89	2	594	9
ND		ND		30	2	ND		44.2	1.1	135	3	923	14
ND		ND		32	2	ND		32.3	1	104	3	507	8
ND		ND		24.7	1.9	ND		35.8	1	84	2	709	10
ND		12	3	26	2	4.4	1.2	46.8	1.2	175	4	573	9
ND		ND		17.9	1.8	ND		33.8	1	56.4	1.8	834	12
ND		ND		12.7	1.6	ND		25.7	0.9	41.4	1.5	358	6
22	6	10	3	30	2	ND		46.2	1.2	187	4	550	10
ND		ND		48	3	4.4	1.3	48.7	1.2	71	2	486	8
ND		ND		6.9	1.4	ND		24.8	0.9	65.8	1.9	552	8
ND		ND		26	2	5.1	1.2	37.6	1.1	55.3	1.9	708	11
ND		ND		36	2	ND		48.1	1.2	140	3	904	13
ND		ND		24	2	5.6	1.2	38.2	1.1	61.7	2	707	11
ND		9	2	9.8	1.5	ND		39	1	140	3	456	7
ND		ND		16.6	1.7	3.3	1	37.1	1	102	2	714	10
ND		ND		24.5	1.9	3.9	1.1	38.5	1	107	3	701	10
ND		ND		26.4	1.9	ND		30.9	0.9	75.1	2	613	9
ND		ND		20.2	1.9	ND		34.8	1	113	3	666	10
ND		ND		12.5	1.6	ND		33	1	102	2	688	10
ND		ND		25.7	2	ND		37.1	1	116	3	536	9
ND		9	3	16.4	1.7	ND		41.7	1.1	129	3	701	10
ND		ND		18.7	1.7	ND		28.7	0.9	70.5	2	565	9

ND		ND		28.7	2	ND		33	0.9	82	2	603	9
ND		ND		33	2	ND		64.6	1.3	197	4	433	8
ND		ND		32	2	ND		28.7	1	60.5	1.9	609	10
ND		ND		24.7	1.9	ND		29.5	0.9	45.5	1.6	341	6
ND		ND		17.9	1.8	ND		35	1	61.5	1.9	1125	16
ND		156	5	17	2	ND		30.9	1	48.2	1.7	1604	22
ND		ND		50	3	6.7	1.3	51.8	1.2	61.2	2	458	8
19	6	ND		31	2	6.1	1.4	32	1	78	2	748	12
ND		ND		4.5	1.3	ND		28.9	0.9	70.1	2	514	8
ND		ND		30	2	4.2	1.2	47.2	1.1	117	3	632	10
ND		308	7	11.7	2	ND		20	0.8	40.3	1.5	1674	23
ND		8	2	31.5	2	3	1	32.1	0.9	50.2	1.6	466	7
ND		ND		35	2	ND		29	1	62	2	628	10
ND		ND		12.9	1.6	ND		35.3	1	52.4	1.7	946	13
ND		ND		39	2	3.9	1.1	47.4	1.2	66	2	521	8
ND		ND		8.3	1.4	ND		26.6	0.9	65.1	1.8	672	10
ND		ND		9	1.5	4.2	1	30.9	1	71	2	595	9
ND		ND		ND		ND		7.8	0.6	17.7	1	1457	19
ND		ND		16.9	1.8	4.3	1.1	20.4	0.8	31	1.3	1965	26
ND		ND		9.8	1.6	ND		33.3	1	78	2	763	11
ND		8	2	46	2	ND		34.7	0.9	92	2	386	6
ND		ND		28	2	ND		27.7	0.9	76	2	307	6
ND		ND		23.7	1.9	ND		36	1	83	2	897	13
ND		ND		24.7	1.9	ND		26.1	0.9	79	2	359	6

ND		ND		32	2	7.5	1.2	42.2	1.1	64.3	2	769	12
ND		ND		7.2	1.5	ND		9.4	0.7	20.3	1.2	1667	23
ND		ND		14.7	1.7	ND		35.2	1	77	2	710	11
ND		11	2	30.7	2	ND		27.9	0.9	71.6	1.9	328	6
ND		8	2	33	2	ND		32.4	0.9	105	2	485	8
ND		252	6	16	2	ND		23.1	0.9	42.5	1.6	1599	22
ND		ND		8.8	1.5	ND		32.9	1	79	2	548	9

Mo	Mo +/-	Cd	Cd +/-	Ba	Ba +/-	Hg	Hg +/-	Pb	Pb +/-
5.7	1.7	22	7	466	20	64	5	5488	41
ND		ND		151	8	ND		6.9	1.3
ND		ND		232	11	ND		19.8	1.7
ND		ND		206	10	ND		13.8	1.5
ND		ND		186	9	ND		12.4	1.4
4.6	1.5	ND		288	11	ND		13.3	1.5
ND		ND		229	11	ND		13.2	1.5
ND		ND		190	9	ND		9.4	1.4
ND		ND		208	11	ND		19.8	1.7
ND		ND		298	12	ND		13.4	1.5
ND		ND		225	11	ND		14.9	1.5
ND		ND		354	13	ND		12.4	1.5
5.2	1.5	ND		189	9	ND		13.7	1.4
ND		ND		223	10	ND		20	1.6
ND		ND		236	11	ND		14.9	1.6

ND		ND		210	11	ND		11.7	1.5
ND		ND		543	16	ND		18.4	1.8
4.6	1.5	ND		209	11	ND		17.3	1.6
ND		ND		186	9	ND		15.6	1.5
ND		ND		194	10	ND		11.4	1.5
ND		ND		242	11	ND		11.3	1.4
ND		ND		225	11	ND		15.4	1.5
ND		ND		252	10	ND		13.7	1.5
ND		ND		214	11	ND		14.7	1.5
ND		ND		200	10	ND		11.4	1.4
ND		ND		505	15	ND		15.8	1.6
6.4	1.7	ND		165	9	ND		14.4	1.5
ND		ND		108	8	ND		6.9	1.3
ND		ND		578	16	ND		16.2	1.7
ND		ND		259	15	ND		16.4	1.7
ND		ND		125	7	ND		9.4	1.4
ND		ND		182	12	ND		12	1.5
ND		ND		227	11	ND		13.3	1.5
ND		ND		202	13	ND		12.8	1.5
ND		ND		216	9	ND		12.9	1.4
ND		ND		319	11	ND		8.3	1.3
ND		ND		228	10	ND		15	1.5
ND		ND		180	9	ND		11.6	1.4
ND		ND		195	10	ND		18.5	1.6

ND		ND		285	10	ND		9.7	1.4
4.6	1.5	ND		176	9	ND		15.1	1.5
ND		ND		410	12	ND		13.2	1.5
5.2	1.5	ND		167	9	ND		11.1	1.4
8.2	1.5	ND		193	10	ND		14	1.4
ND		ND		362	13	ND		17.6	1.6
ND		ND		204	11	ND		24.5	1.8
ND		ND		149	9	ND		9.5	1.4
5.7	1.9	ND		196	10	ND		16.4	1.5
ND		ND		139	10	ND		13.8	1.5
6.6	1.6	ND		262	15	ND		14.4	1.7
ND		ND		177	11	ND		26.7	1.8
4.6	1.5	ND		144	8	ND		11.8	1.4
ND		ND		286	12	ND		16.2	1.6
10	2	ND		142	10	ND		10	1.4
ND		ND		159	9	ND		8.8	1.3
ND		ND		228	11	ND		20.3	1.7
8.2	1.8	ND		166	10	ND		19.8	1.6
ND		ND		219	13	ND		11.2	1.5
ND		ND		129	8	ND		9.6	1.3
ND		ND		167	9	ND		6.6	1.3
15	2	ND		54	8	ND		4.8	1.2
ND		ND		189	12	ND		10.8	1.4
ND		ND		182	10	ND		9.9	1.4

ND		ND		187	9	ND		18.6	1.5
ND		ND		163	9	ND		12.1	1.4
ND		ND		208	11	ND		10.9	1.4
ND		ND		152	8	ND		10.4	1.3
ND		ND		239	13	ND		13.5	1.5
ND		ND		112	10	ND		8.5	1.4
ND		ND		214	11	ND		17.4	1.6
ND		ND		146	8	ND		10.4	1.3
ND		ND		227	11	ND		15.7	1.5
ND		ND		161	11	ND		12	1.5
ND		ND		186	9	ND		11	1.4