STRAIGHT PIPES AND HOUSEHOLD WASTEWATER DISCHARGES INTO THE RURAL ALABAMA AND IMPACT ON WATERSHED WATER QUALITY WITH WETLAND LAND-USES

by

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ABSTRACT

In rural areas, untreated wastewater discharged from homes (commonly called “straight pipes”) can cause harmful effects on the region’s rivers, streams and lead to negative impacts on water quality and potentially ecological and human health. Determining and addressing the water quality and health of these aquatic ecosystems requires identification of the source of contamination. Surface water quality in Hale County was evaluated at least once a month at twenty sites in wet and dry seasons. Samples were analyzed for physical (turbidity), chemical (pH, conductivity, chloride, sulfate, calcium, iron, magnesium, potassium, sodium, ammonium, ortho-phosphorus, nitrite, nitrate, dissolved organic carbon, optical indices), and microbiological (*E. coli*) water quality parameters. Excitation-emission matrixes (EEMs) Parallel Factor Analysis (PARAFAC) was used to identify and classify fluorescence emitting organic substances based on fluorescence peak location. Three fluorescence components, terrestrial humic-like, microbial humic-like, and protein-like fluorophores were identified using the EEM-PARAFAC model. Principal component analysis (PCA) was used to identify analyte signatures associated with sewage contamination. The PCA (varimax rotation) identified three primary components (Eigenvalue >1), accounting for 40.4%, 19.0% and 8.7% of total variance respectively. In order to detect straight pipe wastewater impacts on water quality, three main sites were sampled upstream, midstream and downstream of the town of Newbern, Alabama over the three months of the drought period (i.e., from September to November 28th, 2016). Over 20 water quality parameters were analyzed and compared with the WHO, EPA, and ADEM standards. The results showed that *E. coli* values highly exceed water quality standards, particularly after the drought when peak *E. coli* concentrations downstream exceeded 100,000 per 100 mL. This study also investigated the impacts of wetland land use on stream water quality response at eight main sites. The results showed that potassium (R square 0.78), C3 (R square 0.58) and optical brighteners (R square 0.53) correlated positively with percent wetland in the draining watersheds. This study is one of the first to document the adverse impacts of straight pipe discharges on water quality in the United States.

LIST OF ABBREVIATIONS AND SYMBOLS

ADEM	Alabama Department of Environmental Management
AU	Arbitrary Unit
A&I	Agricultural and Industrial Water Supply
Br	Bridge
Ca	Calcium
cfu	colony-forming unit
Chl-a	chlorophyll a
Cl	Chlorine
cm	centimeter
Cr	Creek
Ctr	Center
CWA	Clean Water Act
^{0}C	Degree Celsius
C1	Component One
C2	Component Two
C3	Component Three

C1%	Proportion of Component One
C2%	Proportion of Component Two
C3%	Proportion of Component Three
DEM	Digital Elevation Model
DOC	Dissolved Organic Carbon
DOM	Dissolved Organic Matter
DX	Dionex
E. Coli	Escherichia Coli
EEM	Excitation Emission Matrices
EPA	Environmental Protection Agency
E2/E3	Absorbance Ratios
Fe	Iron
FI	Fluorescence Index
F&W	Fish and Wildlife
GIS	Geographic Information System
GPS	Global Positioning System
HCl	Hydrogen Chloride
IC	Ion Chromatography

Jul	July
Jun	June
K	Potassium
km	kilometer
l	liter
LWF	Limited Warmwater Fishery
m	meter
mg	milligram
ml	milliliter
μS	microsecond
Mar	March
MATLAB	Matrix Laboratory
Mg	Magnesium
MPN	Most Probable Number
n	Sample Size
NA	no available
Na	Sodium
NAD	North American Datum

NH_4	Ammonium
nm	nanometer
Nov	November
NTUs	Nephelometric Turbidty Units
OAW	Outstanding Alabama Water
Oct	October
OB	Optical Brightener
ortho-p	ortho-phosphate
OSTSD	On-site Sewage Treatment and Disposal Systems
PARAFAC	Parallel factor analysis
PBS	Phosphate Buffered Saline
PCA	Principal Component Analysis
pH	Potential of Hydrogen
Pr	Prairie
PWS	Public Water Supply
Rd	Road
Recy	Recycle
RU	Raman Unit

R^2	R-square
S	Swimming and Other Whole-Body Water-Contact Sports
SE	Standard Error
SH	Selfish Harvesting
SPR	Soluble Reactive Phosphorous
S_R	Spectral Slope Ratios
$SUVA_{254}$	Specific Ultraviolet absorbance at 254nm
TDN	Total Dissolved Nitrogen
UA	University of Alabama
Upst	Upstream
US	United States
UV	Ultraviolet
UV-VIS	Ultraviolet Visible absorbance
WHO	World Health Organization

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1. INTRODUCTION

1.1.Onsite Wastewater

About 75% of the US population has access to municipal systems with public sewers for wastewater treatment. The remaining 25%, 80 million people, treat their wastewater on site, mostly using conventional septic systems (U.S. EPA,2013). The purpose of a septic system, on-site wastewater treatment system, is to assimilate the effluent into the environment. It is recognized that these systems can fail and, when they do, inadequately treated effluent can have serious environmental effects. Since failing systems pose public health and environmental risks, strategies need to be adopted to control these risks. Additionally, some soil conditions are unsuitable for septic systems. In rural areas with these soil conditions and no access to sewers, many poor residents are left with no affordable, safe and legal options for onsite waste water management.

In the Black Belt region of Alabama (Figure 1), many communities struggle with wastewater management. Soil and geology type of Black Belt causes most of the region unsuitable for the conventional septic system (He et al., 2011). In addition to failing septic systems, household raw sewage is often discharged directly into the wooded area by using a pipe, so called “straight pipe” (Figure 2) in the rural Black Belt. The prevalence of straight pipe and septic tank failures in rural areas can cause environmental and human health problems when associated pollutants are discharge to nearby waterways.

White and Jones (2006) reported that in Bibb County in Alabama, 15% of homes not connected to sewers were directly discharging raw sewage (White and Jones, 2006; Figure 3).

While the impacts of raw sewage discharges on our waterways and ecosystems are expected to be substantial, the greatest concern is their threat to human health. Based on these results and Bibb County water use report by Littlepage et al. (2005), we estimate that homes with straight pipes account for over 150,000 gallons of raw sewage discharged into the land surface and streams each day in Bibb County alone. Based on average pathogen concentrations in wastewater (Payment and Locas, 2011; Robertson et al., 2006), we estimate that straight pipes in Bibb County potentially discharge billions of infectious pathogens per day. Representative pathogen loads from these straight pipes per day in Bibb County are >3 billion enteric viruses, >5 billion Giardia cysts, and >1 billion Cryptosporidium oocysts. These pathogens have very low infectious doses and survive much longer in the environment than indicator bacteria like *E. coli* —the absence of *E. coli* may indicate the absence of viable pathogenic bacteria while these more robust pathogens are still present.

1.2. Dissolved Organic Matter (DOM)

Dissolved organic matter (DOM) is an assemblage of heterogeneous compounds present in all natural waters and is a massive carbon pool in aquatic ecosystems (Purves et al., 2001). DOM is becoming highly recognized for the role it plays in moderating the environmental and ecological processes, such as transforming carbon into the microbial food web, protecting aquatic biota through buffering pH, complexing metals, transporting organic pollutants and absorbing ultraviolet radiation (Martell et al. 1988; Williamson et al. 1994; Findlay 2003; Clements et al.,2008). Although a complex mixture, DOM composition can be characterized by optical properties including using UV-VIS (visible) and fluorescence spectroscopy methods. Relative to molecular methods (e.g., Lu et al., 2015), optical measurements provide a more rapid and economic means for characterizing DOM compositions and distinguishing biological sources. Using UV spectroscopy, a large number of useful proxies can be obtained, such as $SUVA_{254}$ (specific UV absorbance at 254nm) that indicate aromaticity, E2/E3 ratios (absorbance at 254 nm divided by absorbance at 365 nm) and spectral slopes ratio (S_R=S275–295nm/S350–400nm) that measure molecuar weight (Helms et al. 2008; Shang et al. 2017). Using fluorescence spectroscopy, fulvic-like, humic-like and protein-like fluorescence components can be detected by gathering emission spectra over a range of excitation wavelengths, generating three-dimensional spectra referred to as excitation-emission matrices (EEM) (Coble, 1996). PARAFAC analysis of EEM creates a model to determine primary components in DOM. This method has been widely applied to DOM studies including evaluating photochemical and microbial modifications (Stedmon and Marker 2005; Lu et al., 2013) and discerning primary sources (Lu et al., 2014; Hu et al., 2016). Using DOM to identify pollution from wastewater in rural streams was one of the focuses of this investigation.

Land use is a significant driver mediating the amount, composition, and fate of DOM in streams and rivers (Williams et al., 2010; Lu et al. 2013, 2014, 2015b). Wetlands has been found to be a primary source of DOM to aquatic ecosystems, and runoff from wetland soils often lead to enhanced DOC concentration and DOM aromaticity in receiving streams and rivers, while this effects often depends on flow paths and antecedent hydrological conditions ((Eckhardt and Moore 1990, Gorham et al. 1998). This study will evaluate the watershed-scale effects of wetland on stream water DOM and other water quality parameters

The detection of optical brighteners (OBs), also known as fluorescent whitening agents, is a chemically based microbial source tracking method. OBs comprise of several classes of compounds including water soluble dyes that act as brightening agents by absorbing light in the ultraviolet range and fluorescing in the visible region. They are added not only to the manufacture of paper but also to laundry detergents solid in the United States and other countries (Waye 2003). OBs may appear in surface waters adjacent to a failing on-site sewage treatment system, since laundry effluents are estimated to be a significant part of total on-site wastewater treatment system (US. Environmental Protection Agency 1990). The main advantage of OBs as an effluent tracing technique is that sources of OBs are exclusively anthropogenic, which provides indisputable evidence of human impacts on surface waters (Dates 1999). Besides, OBs are relatively persistent under environmental conditions and resistant to microbial degradation as a tracer (Poiger et al. 1998).

1.3. Objectives

This study aims to identify a water quality signature that can be used to identify the presence of wastewater contamination in rural streams. It also serves as a baseline study for our ongoing investigation of stream water quality conditions of the Hale County in Alabama. The specific objectives of the thesis threefold. First, we focus on stream water samples taken upstream, midstream and downstream of a potential source, before (drought condition) and after (Post-drought condition) precipitation, to determine if these samples contain wastewater signals from septic effluent or straight pipes. Second, we compared and classify four types of water, wastewater, dry (drought), wet, and post-drought samples. Third, we assess stream water quality in relation to land use pattern. The assessment comprises analyzing multiple geochemical and microbiological stream water quality parameters and comparing them against local and international water quality standards, performing correlation analysis between selected water quality parameters and correlating them to land use type, and asseding the effects of wetlands based on Geographic Information System (GIS) land use analysis and evaluating wetland vs. the stream water quality relationship .

2. LITERATURE REVIEW

The first national law to regulate water pollution was the Federal Water Pollution Control Act in the United States in 1948. The Act became known as a Clean Water Act (CWA) after amendment in 1977. The CWA aims to restore or maintain the quality standards as a chemical, physical and biological integrity of the nation’s water. Today the U.S. Environmental Protection Agency (EPA) works to keep the goals and regulations set forth by the CWA along with other federal and state agencies in the United States (EPA, 2014). According to the Alabama Department of Environmental Management (ADEM), water quality standards consist of three parts: designated uses, numeric and narrative criteria, and an antidegradation policy (ADEM 2016). Designated uses describe the best reasonably expected of waters among these three quality standards. In Alabama, waters can be attributed one or more of seven designated uses according to ADEM Administrative Code r. 335-6-11. These applications are: Outstanding Alabama Water (OAW), Public Water Supply (PWS), Shellfish Harvesting (SH), Swimming and Other Whole Body Water-Contact Sports (S), Fish and Wildlife (F&W), Limited Warmwater Fishery (LWF) and Agricultural and Industrial Water Supply (A&I). The first five of the seven designated uses are considered by EPA to be consistent with the fishable/swimmable goal and thus provide for the protection of aquatic life and human health (ADEM 2016).

Septic tank systems, called on-site sewage treatment and disposal systems (OSTDS), are an often-used system of wastewater treatment and disposal in areas without centralized waste treatment infrastructure. If on-site wastewater treatment and disposal systems are well designed and maintained, they can be efficient in eliminating organic matter, bacteria, and nutrients from wastewater (USEPA 1990). Conversely, unsuitable soils, high water tables, system under-design, and improper installation and management can lead to malfunctions. When certain conditions occur, and water tables intersect nearby surface waters, the level of waste treatment might be inadequate to protect the water quality of receiving water bodies (USEPA 1990). There are many pollutants and indicators of pollution that can be used to identify the presence of wastewater including microorganisms, inorganic chemicals and organic chemicals.

One of the most important sampling techniques for determining wastewater pollution in surface waters depends on the use bacteria like fecal coliform (including *E. coli*). Fecal coliform bacteria can be found in human sewage and the guts of warm-blooded animals. Conversely, there are abundant non-human sources of fecal coliform in both urbanized and rural watersheds. There are many animals that produce a high amount of fecal more than humans (Trial et al., 1993). Further parameters such as nutrients that co-occur in minimally treated domestic wastes, and also, they have natural sources (Aley et al., 1985). Consequently, if there are high amounts of nutrient and fecal coliform bacteria in the water bodies, that means not always the presence of domestic waste in waterways.

The EPA describes a pathogenic microbe as one that leads to disease in humans, animals, plants, or other microorganisms and can be classified as bacteria, protozoans, viruses, or fungi (EPA, 2006). Streams as a surface water can be contaminated and polluted by a variety of sources. These sources can be nutrients and chemicals from agricultural runoff, sewage contamination comes from the septic system, and straight pipe in rural areas, particularly mixed pollutants discharge from storm water and some possible chemical discharge from industries. The most recent survey of soil-transmitted helminthiasis in Alabama was a University of Alabama at Birmingham master's thesis conducted in Wilcox County in 1993; it showed that 33

% of children who are under ten years old tested positive for one or more helminths (Badham, 1993). Furthermore, *E. coli* O157: H7 has been increasingly used by certain researchers as a reliable indicator of a bacterial pathogen. *E. coli* O157: H7 has reached epidemic proportions and resulted here at seven people killed, and more than 2300 people became sick in May 2000, Ontario in Canada (O'Connor 2002). Recently, published data from the The American Journal of Tropical Medicine and Hygiene, collected and published by researchers from Lowndes County, reported that more than 42% of adults with inadequate sanitation are infected with hookworm (McKenna et al., 2017). Not only Lowndes but also other counties in Alabama's Black Belt are at higher risk due to poorly draining clay soils and region's notorious humidity (Walton, 2015).

Sources for sodium and chloride ions associated with human activities include leachate from municipal landfills, effluent from private and municipal septic systems, general agricultural and road runoff, and certain agricultural chemicals. Although the identification and quantification of Na^+ and Cl^- in water is an essential issue, the determination of the sources of Na^+ and Cl^- as contaminants in surface water and groundwater are challenging and hence needs further research attention (Triska et al., 1989).

Fluorescence spectroscopy is a quick, highly sensitive and noninvasive method to studying fluorescent organic substances (Bro et al., 2005). Fluorescing compounds are frequently mentioned as fluorophores in the literature. Excitation emission matrix (EEM) fluorescence spectroscopy has been used since the 1990s for studying fluorescent matter in marine environments (Coble et al., 1990; Coble et al., 1993, Mopper et al., 1993). The process includes exciting a sample over a range of wavelengths and recording the fluorescence emission over another range of wavelengths. The resulting excitation-emission matrix produces a contoured map demonstrating fluorescent 'hotspot', which can be linked to specific fluorescent substances, such as polycyclic aromatic hydrocarbons (Nahorniak et al., 2006) and pesticides (Jiji et al., 1999). Natural waters include two main fluorescing groups derived from dissolved organic matter (DOM): humic-like and protein-like, and they often interfere with the identification of anthropogenic, pollutant-related fluorescence.

Various studies accomplished and successfully identified humic-like and protein-like fluorescent groups using excitation-emission matrices (Coble et al., 1990; Coble et al., 1993, Mopper et al., 1993). Stedmon et al. (2003) were one of the first groups combining fluorescence EEM with PARAFAC in order to classify consistent present in a DOM sample. Humic-like substances produce fluorescent peaks at emission wavelengths of 420-450 nm from excitation wavelengths of 230-260 nm and 320-350 nm. Protein-like substances are identified as fluorescent peaks at emission wavelengths of 300- 305 nm and 340-350 nm from excitation wavelengths of 220 nm and 275 nm, respectively.

More recent studies have examined DOM fluorescing properties from rivers (Yan et al., 2000; Hu et al., 2016), municipal wastewater (Saadi et al., 2006), landfill leachate and industrial discharge (Baker et al., 2004; Baker et al., 2002). This has led to the identification of many organic constituents using EEM fluorescence spectroscopy including terrestrial humic acid, fulvic acid, microbial humic substance, tryptophan, tyrosine, photodegraded and microbially degraded products. It is important to note that they are often referred to as ‘humic acid-like’, ‘tyrosine-like’ etc. This is because additional chemical analysis is needed to validate it was indeed that class of compounds producing the fluorescence signal.

The fluorescence characteristics of surface water vary as a function of sources of river input. For instance, sewage (Baker et al., 2001) has been positively traced in river waters using fluorescence spectroscopy. They observed a sharp rise in the tryptophan/fulvic fluorescence intensity ratio in sewage impacted rivers when associated with non-effected waters upstream. It is interesting to mention that those humic substances found in river systems might be connected with decaying plant and microbes overall, it is presumed that river water with limited impacts from anthropogenic activity derives is dominated by humic fluorescence.

EEM fluorescence spectroscopy has been also successfully coupled with Parallel Factor Analysis (PARAFAC) to effectively model fluorescence spectra (Hua et al., 2005). They used an expanded data set with 1,276 EEM samples collected over one-year, allowing the researchers to account for seasonal variation. Four components described humic groups, two components described as fulvic acids, one was associated to tyrosine, and one was associated to tryptophan. Holbrook et al. (2006) used 55 EEM samples and were capable of validating three PARAFAC components. The first component was similar to a humic-like component identified in Stedmon et al. (2003). The second component was similar to fulvic-like material. The third component was related to the protein fluorophore identified as component 5 in Stedmon et al., 2005.

Anthropogenic impacts of the paved runoff and sanitary sewage on DOM quality of wet weather overflow (WWF) has also been studied using EEM-PARAFAC (Chen et al., 2017). EEM–PARAFAC yielded terrestrial humic-like, anthropogenic humic-like, tryptophan-like, and tyrosine-like DOM components as indicators to identify the types of sewage overflows and the illegal contact status of drainage systems. Additionally, a short emission wavelength (em: 302–313 nm) peak of the tyrosine-like component occurred in the reserved sanitary sewage, while a sort of longer emission wavelength (em: 321–325 nm) peak came from the sump deposit (Chen et al., 2017).

Optical brightener compounds are defined as isoindoline compounds. The optical activity of isoindoline compounds can be employed to advantage in the optical brightening of a diverse range of natural and artificial materials. They are suitable in the brightening of fabrics and find application in the preparation of laundry detergent compositions and hypochlorite bleach-containing compositions (Hamilton et al., 1972). As laundry effluent is estimated to be a substantial fraction of total on-site sewage treatment and disposal effluent (USEPA 1990), optical brighteners have the possible for appearing in surface waters adjacent to improperly functioning on-site sewage treatment and disposal.

Optical brighteners can be detected by tracking methods. This detection is a chemically based microbial source tracking method. Optical Brighteners involve some classes of compounds, water-soluble dyes, which absorb onto textiles and act as brightening agents by absorbing light in the UV range and fluorescing in the visible (blue) region. One of many great advantages of optical brighteners as a microbial tracking method is that sources of optical brighteners are distinctively anthropogenic and serve as an unquestionable signal of human activities or wastewater in surface waters (Dates et al., 1999). Secondly, optical brighteners have the benefit of being persistent under environmental conditions and resistant to microbial degradation (Poiger et al., 1998).

A wetland can be defined as an ecosystem in which the existence of water determines its formation process and characteristics. Ramsar (1971) uses a wide definition of wetlands, including a wide variety of habitats such as marshes, peatlands, floodplains, lakes and rivers, and coastal areas such as saltmarshes, seagrass beds and mangroves but also coral reefs and marine areas no deeper than six metres at low tide, along with human-made sites such as, rice paddies, fish ponds, waste-water treatment ponds and reservoirs (Ramsar, 1971). Wetlands comprise only about 6% of the earth's land surface, but ecologically they are disproportionately important. For instance, 25% of the plant species occur only in one wetland type, peat swamps in Malaysia

(Anderson 1983). Approximately 10% of the world's fish fauna occurs in the Amazon basin (Groombridge and Jenkins 1998). Wetlands support both aquatic and terrestrial biota; they are very diverse (Gopal et al. 2000). In addition, wetlands are important in the landscape that provide plentiful beneficial services such as contain protecting and improving water quality. Those taxa unique to wetlands will contribute significantly to the overall diversity of regions containing numerous wetlands.

Wetlands are natural filters and environmentally friend, serving to improve water quality from urban, agricultural lands into the streams by trapping pollutants. Wetlands are principally beneficial because they are mostly located between land and open water. This condition allows wetlands to capture many pollutants before they enter into the stream, river and other water body systems. Wetlands are incredibly substantial for the treatment of both point-source wastewaters and non-point source pollution (Hammer, 1986). However, wetlands are not often managed well, endangering their existence and decreasing their ecological balance/services contribution.

Land use and water quality are inter-related in some way, and this can be explained by their potential relationship with each other. Land use attributes (e.g., wetland, agricultural, residential can influence water quality in that region. Different water quality parameters are analyzed and used to evaluate water quality for different purposes such as for regulatory standards or international organization guidelines. Examples of the standards contain *E. coli*, and total coliform must not be detected in a 100 ml of the water sample for WHO drinking water standards, and <260/100 ml for aesthetic standards. Water quality standards have regulated the purpose of protecting water quality for human purposes, recreation uses and the ecological health and freshwater ecosystem.

3. MATERIALS AND METHODS

3.1. Site Descriptions and Experimental Design

This study was conducted in and around Hale County in the west-central part of Alabama. Samples were collected each month for nine months (March 2016 to December 2016) from twenty sampling points selected along the course of the Hale County (Figure 4). The stream samples were taken as grab samples, and all were stored in 500 ml polypropylene bottles. These bottles were cleaned by soaking in HCl and then rinsed with tap water and deionized water. The bottles were kept in an ice-packed cooler while they were transported and then kept in the refrigerator for analysis. Some sample analyses were performed within five days of collection and frozen samples analyzed in a month. A portable dissolved oxygen meter and a HACH model portable pH meter were used to make in-situ measurements.

3.2. Water Quality Measurements

Water samples were tested for chemical, physical and microbiological parameters. Chemical parameters included anions, cations, DOM, DOC, nutrients, pH and conductivity. Turbidity was analyzed as a physical measure of particles in the water. *E. coli* and coliform bacteria were analyzed as microbial indicators.

For microbiological parameters, the IDEXX Quanti-Tray 2000 system with Colilert media (IDEXX Laboratories, Inc., Westbrook, ME) was used for detection of *E. coli* and coliform bacteria. Dilutions were carried out in sterile phosphate buffered saline (PBS) when high bacterial concentrations were anticipated to ensure a readable quantitative result. The standard analysis procedure was used, as follows: the Colilert media snap pack was opened, and the reagent was added to 100 ml of water sample in a sterile 120 ml vessel and allowed to dissolve. The Quanti-Tray was held upright, the foil tab was pulled without touching the inside of the foil, and the sample was poured into the tray. The Quanti-Tray was sealed with the sealer and incubated 24 and 48 hours at 35 °C. After incubation, wells positive for total coliform turned yellow, and a negative sample looked the same visually as when the sample was collected. Each tray was placed under long-wave, 365-nm ultraviolet (UV) light and wells positive for *E. coli* fluoresced blue. The most probable number (MPN) of coliforms and *E. coli* in each 100-mL sample was obtained by counting the positive wells and using appropriate Quanti-Tray table to find the MPN (USEPA 2007).

Turbidity measurements were obtained by the nephelometric method using a HACH 2100Q Portable Turbidimeter with turbidity units (NTUs). The method is based on a comparison of the intensity of light scattered by the sample under defined conditions as compared to the intensity of light scattered by standard reference suspensions under the same circumstances. The standards were used to reference and calibrate the turbidity meter. The higher the intensity of scattered light, the higher the turbidity. Results were reported as nephelometer turbidity units or NTUs.

For chemical analysis, all samples were filtered to 30-ml bottles as anions, cations, nutrients, DOM, DOC separately through a glass-fiber filtration unit in the geology lab. For the DOC and nutrient concentration analyses were stored at −20℃ in the dark. We preserved samples for anion, cation and DOM quality analysis at 4□ in the dark to avoid any potential interferences. Duplicate samples (A & B) were analyzed for 20 locations.

Fluorescence excitation-emission matrix (EEM) measurements were conducted using a Horiba Jobin Yvon Flouromax-3 spectrofluorometer. To attain fluorescence EEMs, excitation wavelengths increased from 240 to 500 nm at step intervals of 5nm, yielding 53 excitation wavelength data points (240nm, 245nm…. 500nm). Emission and fluorescence were measured at emission wavelengths of 280 to 538 nm at step intervals of 3nm resulted in 87 emission wavelength data points. The excitation and emission slits were set to a 5-nm bandpass. A flow-through water bath was used to keep a constant temperature of 20°C. UV-visible absorbance measurements were conducted with a UV-VIS Spectrophotometer. Dissolved organic carbon (DOC) concentrations were measured as non-purgeable organic carbon and total dissolved N (TDN) using Shimadzu TOC-VCSH analyzer with lower detection limits of 0.4 mg C L-1 for DOC and 0.1 mg N L-1 for TDN using high-temperature catalytic oxidation. Glucose was used to construct standard curves, and a consensus seawater reference standard (Hansell laboratory, http://yyy.rsmas.miami.edu/groups/biogeochem/CRM.html) was used to confirm analytical accuracy. Specific ultraviolet absorbance at 254 nm ($SUVA_{254}$) was determined by dividing the UV absorbance measured at 254nm by the DOC concentration and are reported in units of liter per milligram of carbon (Weishaar et al., 2003). E2/E3 ratios were calculated (Dahlen, 1996) and specific UV absorbance at 280 nm ($SUVA_{280}$) was obtained by normalizing the absorbance at 280 nm to dissolved organic carbon concentration (Chin et al., 1994; Chin et al., 1998). We also conducted S_R for molecular weight, biological indices, humification indices, and percentage contributions of different fluorescence component, etc. Yang et al., 2015, Lu et al., 2013); we also looked for the optical brighteners used in detergent.

Several post-acquisition steps were used to adjust the EEM data. First, the excitation and emission data were corrected for the instrument-specific response. Second, the EEM response of

Milli-Q water was subtracted from sample EEMs. Third, the UV-visible absorption spectra were used to correct the EEM data for inner filter effects (McKnight et al., 2001). And finally, the fluorescence intensities of the EEMs were normalized to the area under the Raman peak, thereby converting the arbitrary units (AU) into Raman units (RU). Following the creation of EEMs, they were then exported into Excel files and MATLAB files for further interpretation and modeling, including removing portions of the EEMs at which there was interference from Raleigh scattering, converting the data into vectors, and selecting characteristic peak signals based on documented key excitation/emission pairings (McKnight et al., 2001, Coble, 1996) and also plotting the data into contour and surface maps. The fluorescence index (FI), which is the ratio of emissions at 470 nm to 520 nm at an excitation of 370 nm, was calculated for all samples.

Analysis of the cations for this research (most notably Ca, Mg, K, Na) in the stream water samples was made by spectrometer PerkinElmer Inc. - Optima 4300 DV ICP-OES with Perkin Elmer AS□93 Plus Autosampler. This setup uses inductively coupled plasma mass spectrometry for detecting metals and several non-metals. Calibration and Quality Control Standards: 0.25, 0.5, 1.0, 5.0, 10.0 and 20.0 mg/L (prepared from multi□ element standards (100 mg/L) from CPI International and High Purity Inc.). Concentrations measured in mg/L. Each cation measured in three replicates and averaged. Before running analysis, if required, samples were diluted by 2% HNO3 Blank Solution.

Analysis of the anions for this research (most notably chloride and sulfate) in the stream water samples were made by Ion Chromatography (IC). Ion Chromatograph to measure concentrations of inorganic anions in aqueous samples. In ion chromatography, separation of a mixture of compounds into its components is achieved based on their relative interactions with an inert matrix. The detection of ions separated through the ion chromatographic column is done with a conductivity detector.

Concentrations of chloride and sulfate (Cl^-, $SO_4{}^{2-}$) in aqueous samples were measured using a Dionex (now acquired by Thermo Scientific) DX 600 Ion Chromatograph (IC) instrument. Aqueous samples collected for the analysis of inorganic anions were filtered through 0.45-micron or lower syringe filter and collected in clean HDPE bottles. At least 20 ml of sample was required for analysis with the IC. Samples were kept frozen and thawed on the day of analysis. When analyses were done, concentrations were calculated by using the Dionex PeakNet software.

Nutrient samples were analyzed for nitrate, nitrite, ammonium (NH_4), and orthophosphate with Lachat Quikchem 8500 series 2 Flow Injection Analyzer. The method used was for Ammonia (Phenolate) in Waters, Lachat method # 10-107-06-1-F.

3.3. Parallel Factor Analysis (PARAFAC)

PARAFAC can statistically decompose EEMs into fluorescent groups or components (Stedmon et al., 2003). PARAFAC modeling can be obtained by either creating or validating the model using the complete data set of EEMs or by fitting the EEMs to an already established PARAFAC model. The data consisted of 98 samples, each analyzed for 87 emissions and 53 excitation wavelengths. Resulting excitation and emission matrices were processed for PARAFAC in MATLAB using the DOMFluor toolbox according to (Stedmon and Bro 2008; http://www.models.life.ku.dk/). The data were evaluated by split-half analysis where it was split randomly into two halves, a calibration and validation array, each consisting of 49 samples. The PARAFAC algorithm was then applied stepwise to both arrays for 2-10 components. The three-component model was determined to be the best fit for those datasets after validation using four approaches: residual analysis, examination of spectral properties, split-half analysis and random initialization (Stedmon and Bro 2008). We described fluorescence components in this study as “humic-like” or “protein-like” since these components are likely a mixture of similar fluorophores rather than pure fluorophores.

3.3.1. Wastewater Dilution

Wastewater samples that were too concentrated for analysis were diluted with deionized (DI) water. Dilutions were carried out at the following ratios to enable analysis: 1:2, 1:5, 1:10, 1:20.

3.4. Principal Component Analysis (PCA)

Principal components analyses (PCA) were made with varimax factor rotation on the drought/post-drought, wet/dry and wastewater data sets, individually. PCA helped us to identify promising parameters for inexpensive and robust detection of wastewater contamination. Variables incorporated in the two PCAs were: Ca, Fe, Mg, K, Na, Chloride, Sulfate, DOC, $SUVA_{254}$, S_R, E2/E3, NH_4, Ortho-P, Nitrate, Nitrite, *E. coli*, FI, Optical Brighteners and the percent contribution of each of the three PARAFAC components.

3.5. Geographical Information System (GIS)

The land use characteristics and geology type of the watershed were determined by using Arc GIS. A projected coordinate system was set up the data frame to the North American (NAD) 83 UTM Zone 16N. The shapefiles were added to the table of contents layers window of

ArcGIS. The land use layers of Hale County were first clipped using the “Clip Analysis” tool of the Geoprocessing drop-down menu on the ArcMap toolbar, to extract the area of interest defined by the boundary GIS layer of the watershed. The 2016 existing GIS layers for land use types of Hale County watershed was used to create a map for the six land use types. Wetland land use type of these land use was studied for our study. Table 1 summaries the land use types assigned to each of the six land use types.

For watershed areas of each sampling, the station was delineated by using a digital elevation model (DEM). The DEM, land cover and ESRI shapefile data were downloaded from the USDA’s Geospatial Gateway. Hale County and select the ESRI shapefile format & UTM Zone 16 NAD 83 projection were ordered. National Land Cover Dataset was downloaded to quantify, determine geology type and land use the land cover class in a watershed. For catchment delineation, the procedures contain the use of ArcHydro-DEM- Flow direction- Flow accumulation. Special analyst tools were used for this analysis. Using the ArcView topology of the ArcGIS toolbar, proportions (%) of each land use type were determined. For determine geology type, the Geology shapefile to the sub watershed shapefile was clipped. The Tabulate Area tool (in the Spatial Analyst toolbox) was run. The output table was found by clicking on the List by Source icon in the Table of Contents, and finally, geology type of each sampling station was determined.

4. RESULTS

Surface water quality results are presented in this section, organized based on precipitation conditions. Figure 5 shows daily precipitation for the sampling period with precipitation on sampling dates indicated by blue dots and the corresponding precipitation categories (e.g., Wet, Post-Drought) specified for each sampling date. Household wastewater is the pollution source of interest; therefore, wastewater samples were also analyzed.

4.1. Water Quality Parameters

Water samples were collected and analyzed regularly throughout nine months for these parameters: Nutrients (most notably ammonium, nitrate, nitrite, and orthophosphate), cations (most notably Ca^{2+}, Mg^{2+}, K^+, Na^+ and Fe^{2+}), anions (most notably chloride and sulfate), *E. coli*, conductivity, pH, and turbidity. We also conducted extensive dissolved organic matter (DOM) characterization parameters including total organic carbon-total nitrogen and composition information of DOM from EEM-PARAFAC (excitation emission matrix-parallel factor analysis) that yield a suite of organic proxies including $SUVA_{254}$ for aromaticity, S_R for molecular weight, freshness indices and percentage contributions of different fluorescence components etc.(Yang et al., 2015, Lu et al., 2013); we also examined the optical brighteners used in detergent. Results were compared based on four categories: wastewater, post-drought, wet and dry conditions. Data from the extended drought in fall 2016 were grouped with other dry weather points; water sample data collected in late-November 2016 were categorized as post-drought and grouped separately from other wet weather sampling data.

4.1.1. Wastewater Conditions

Figure 6 shows cation concentrations. Firstly, Ca^{2+} averaged 2.58 ± 0.33; 2 mg/L (mean ± SE; n) and ranged between 2.25 and 2.91 mg/L. Secondly, Fe^{2+} values averaged 0.55 ± 0.43; 2 mg/L and ranged between 0.12 and 0.97 mg/L. Thirdly, Mg^{2+} values averaged 0.86 ± 0.11; 2 mg/L and ranged between 0.74 and 0.97 mg/L. Finally, K^+ and Na^+ values ranged from 6.56 to 8.62 (7.59 ± 1.03; 2) and from 8.08 to 14.64 (11.36 ± 3.28; 2) mg/L, respectively.

Anions concentrations for chloride averaged 107.62 ± 9.29; 4 mg/L (mean ± SE; n) and ranged between 96.93 and 135.42 mg/L. Sulfate values averaged 17.93 ± 1.80; 4 mg/L and ranged between 14.18 and 22.83 mg/L (Figure7).

Nutrients concentrations for ammonium averaged 22200 ± 9357.19; 4 ug/L (mean ± SE; n) and ranged between 5800 and 39800 ug/L. Orthophosphate values averaged 5017 ± 1372.80; 4 ugP/L and ranged between 2620 and 7440 ugP/L. Nitrite and nitrate values ranged from 4.21 to 19.3 (11.8 ± 4.33; 4) and from 1.39 to 3.45 (2.43 ± 0.82; 4) ugN/L, respectively (Figure 8)

E. coli concentrations were not calculated for the wastewater samples. Concentrations of *E. coli* in domestic sewage are high (1000-100,000 per mL) but are documented to vary widely based on the extent to which the fecal matter that contribute the *E. coli* are diluted by other water sources (e.g., washing machine, industrial sources, rainwater infiltration).

DOC concentrations averaged 22 ± 5.71; 25 mg/L (mean ± SE; n) and ranged between 1.45 and 101 mg/L. E2/E3 values averaged 3.65 ± 0.18; 25 and ranged between 1.12 and 5.33. $SUVA_{254}$ and S_R values ranged from 0.65 to 3.19 (1.89 ± 0.18; 25) L/(mg m) and from 0.99 to 2.14 (1.45 ± 0.07; 25) L/(mg m), respectively (Figure 10).

DOM sources can be determined by fluorescence-property-based indices (Jaffé et al. 2008). Our samples had FI values ranging from 1.83 to 2.65 (2.31 ± 0.04; 27) and Optical Brightener values ranging from 2.65 to 51.56 (11.87 ± 2.17; 27) (Figure 11).

4.1.2. Post-Drought Conditions

Cation concentrations for Ca^{2+} averaged 21.35 ± 4.56; 11 mg/L (mean ± SE; n) and ranged between 3.69 and 47.4 mg/L. Fe^{2+} values averaged 0.28 ± 0.12; 11 mg/L and ranged between 0.03 and 1.12 mg/L. Mg^{2+} values averaged 2.57 ± 0.41; 11 mg/L and ranged between 1.04 and 4.99 mg/L. K^+ and Na^+ values ranged from 1.53 to 9.37 (4.54 ± 0.64; 11) and from 1.71 to 16.18 (6.07 ± 1.58; 11) mg/L, respectively (Figure6).

Anion concentrations for chloride averaged 5.03 ± 0.50; 11 mg/L (mean ± SE; n) and ranged between 2.74 and 7.98 mg/L. Sulfate values averaged 9.40 ± 2.13; 11 mg/L and ranged between 1.64 and 24.02 mg/L (Figure7).

There are no available data for nutrients.

E. coli concentrations averaged 28256.23 ± 13312.71; 11 cfu/100 mL (mean ± SE; n) and ranged between 329.35and 116160 cfu/100 mL (Figure 9).

DOC concentrations averaged 20.41 ± 4.73; 11 mg/L (mean ± SE; n) and ranged between 5.96 and 49.42 mg/L. E2/E3 values averaged 4.33 ± 0.14; 11 and ranged between 3.71 and 5.07. $SUVA_{254}$ and S_R values ranged from 1.90 to 4.58 (3.17 ± 0.26; 11) L/(mg m) and from 0.77 to 1.03 (0 .87 ± 0.02; 11) L/(mg m), respectively (Figure 10).

DOM sources can be determined by fluorescence-property-based indices (Jaffé et al. 2008). Our samples had FI values ranging from 1.56 to 2.22 (1.84 ± 0.07; 11) and Optical Brightener values ranging from 3.02 to 11.72 (7.28 ± 1.00; 11) (Figure 11).

4.1.3. Wet Conditions

Cations concentrations for Ca^{2+} averaged 38.49 ± 7.00; 26 mg/L (mean ± SE; n) and ranged between 1.52 and 121.7 mg/L. Fe^{2+} values averaged 0.3 ± 0.05; 26 mg/L and ranged between 0.01 and 0.8 mg/L. Mg^{2+} values averaged 2.11 ± 0.23; 26 mg/L and ranged between 0.61 and 4.61 mg/L. K^+ and Na^+ values ranged from 0.69 to 9.84 (3.41 ± 0.52; 26) and from 1.11 to 31.7 (10.36 ± 2.00; 26) mg/L, respectively (Figure 6).

Anions concentrations for Chloride averaged 13.65 ± 3.38; 10 mg/L (mean ± SE; n) and ranged between 2.14 and 28.95 mg/L. Sulfate values averaged 47.42 ± 12.76; 10 mg/L and ranged between 1.05 and 97.75 mg/L (Figure 7).

Nutrients concentrations for ammonium averaged 45.3 ± 8.27; 24 ug/L (mean ± SE; n) and ranged between 5.9 and 130 ug/L. Orthophosphate values averaged 19.85 ± 3.91; 24 ugP/L and ranged between 1.71 and 55.2 ugP/L. Nitrite and nitrate values ranged from 1.03 to 173.2 (28.57 ± 10.36; 24) and from 8.9 to 369.6 (100.63 ± 22.22; 24) ugN/L, respectively (Figure 8).

E. coli concentrations averaged 303 ± 52.60; 24 cfu/100 mL (mean ± SE; n) and ranged between 3.05 and 831.5 cfu/100 mL (Figure 9).

DOC concentrations averaged 4.59 ± 0.49; 24 mg/L (mean ± SE; n) and ranged between 1.89 and 9.07 mg/L. E2/E3 values averaged 4.40 ± 0.26; 24 and ranged between 3.35 and 7.76. $SUVA_{254}$ and S_R values ranged from 1.81 to 6.47 (4.27 ± 0.29; 24) L/ (mg m) and from 0.75 to 1.33 (1.00 ± 0.04; 24) L/ (mg m), respectively (Figure 10).

DOM sources can be determined by fluorescence-property-based indices (Jaffé et al. 2008). Our samples had FI values ranging from 1.55 to 2.05 (1.75 ± 0.03; 24) and Optical Brightener values ranging from 0.84 to 5.24 (2.10 ± 0.26; 24) (Figure 11).

4.1.4. Dry Conditions

Cation concentrations for Ca^{2+} averaged 40.41 ± 5.08; 57 mg/L (mean ± SE; n) and ranged between 1.02 and 132.8 mg/L. Fe^{2+} values averaged 0.27 ± 0.04; 57 mg/L and ranged between 0.004 and 0.84 mg/L. Mg^{2+} values averaged 2.36 ± 0.19; 57 mg/L and ranged between 0.54 and 5.7 mg/L. K^+ and Na^+ values ranged from 0.38 to 9.89 (4.004 ± 0.35; 57) and from 1.57 to 35.44 (8.97 ± 1.21; 57) mg/L, respectively (Figure 6).

Anion concentrations for chloride averaged 14.97 ± 2.00; 53 mg/L (mean ± SE; n) and ranged between 2.43 and 53.36 mg/L. Sulfate values averaged 36.52 ± 6.15; 53 mg/L and ranged between 1.13 and 140.68 mg/L (Figure 7).

Nutrients concentrations for ammonium averaged 51.9 ± 6.31; 66 ug/L (mean ± SE; n) and ranged between 2.3 and 204 ug/L. Orthophosphate values averaged 26.8 ± 2.32; 66 ugP/L and ranged between 3.35 and 66.4 ugP/L. Nitrite and nitrate values ranged from 0.9 to 296.8 (100.3 ± 13.42; 66) and from 0.3 to 382.9 (86.4 ± 12.09; 66) ugN/L, respectively (Figure 8).

E. coli concentrations averaged 287.5 ± 35.89; 66 cfu/100 mL (mean ± SE; n) and ranged between 31.6 and 1241 cfu/100 mL (Figure 9).

DOC concentrations averaged 4.65 ± 0.23; 70 mg/L (mean ± SE; n) and ranged between 1.91 and 9.98 mg/L. E2/E3 values averaged 4.63 ± 0.19; 70 and ranged between 0.375 and 7.85. $SUVA_{254}$ and S_R values ranged from 1.92 to 8.83 (3.96 ± 0.20; 70) L/(mg m) and from 0.00 to 1.72 (0.93 ± 0.04; 70) L/(mg m), respectively (Figure 10).

DOM sources can be determined by fluorescence-property-based indices (Jaffé et al. 2008). Our samples had FI values ranging from 1.01 to 2.44 (1.82 ± 0.20; 70) and Optical Brightener values ranging from 0.95 to 6.33 (2.20 ± 0.13; 70) (Figure 11).

4.1.5. pH, Conductivity, Turbidity and Geology Type of Watershed

In Lindsay Ponds, the pH for October was 7.29 and November was 6.92 (Table 2). The conductivity for October was 37.8 µS/cm and November was 42.3 µS/cm (Table 3). The turbidity for October was 14.5 NTU and November was 180 NTU (Table 4). Unit age was Cretaceous, and rock type was Sand/Clay or Mud (Table 5).

Rd16 Bridge 1 Upstream: The pH for October was 7.19 and November was 7.22 (Table 2). The conductivity for October was 429 µS/cm and November was N/A (Table 3). The turbidity for October was 7.66 NTU and November was N/A (Table 4). The geological unit age was Holocene, and rock type was Beach sand/Alluvium (Table 5)

Rd16 Bridge 2: The pH for October was 7.24 and November was 7.28 (Table 2). The conductivity for October was N/A and November was 451 µS/cm (Table 3). The turbidity for October was N/A and November was 38.3 NTU (Table 4). The geological unit age was Holocene, and rock type was Beach sand/Alluvium (Table 5)

Rd16 Bridge 4: The pH for October was 6.93 and November was 7.05 (Table 2). The conductivity for October was 108 µS/cm and November was 137.3 µS/cm (Table 3). The turbidity for October was 9.16 NTU and November was 74.9 NTU (Table 4). The geological unit age was Holocene, and rock type was Beach sand/Alluvium (Table 5)

Recycling Center: The geological unit age was Cretaceous, and rock type was Sand/Clay or Mud (Table 5). No data are available for pH, conductivity and turbidity.

Big Prairie Creek Rd61: The pH for October was 7.05 and November was 7.19 (Table 2). The conductivity for October was 148.4 µS/cm and November was 375.05 µS/cm (Table 3). The turbidity for October was 2.8 NTU and November was 27.65 NTU (Table 4). The geological unit age was Cretaceous, and rock type was Carbonate/Mixed clastic (Table 5).

Big Prairie Creek Windmill: The pH for October was 7.01 and November was 7.01 (Table 2). The conductivity for October was 111.35 µS/cm and November was 202.25 µS/cm (Table 3). The turbidity for October was 2.15 NTU and November was 119.05 NTU (Table 4). The geological unit age was Holocene, and rock type was Beach sand/Alluvium (Table 5)

Big Prairie Creek Rd48: The pH for October was 7.08 and November was 6.92 (Table 2). The conductivity for October was N/A and November was 46.8 µS/cm (Table 3). The turbidity for October was N/A and November was 10.6 NTU (Table 4). The geological unit age was Holocene, and rock type was Beach sand/Alluvium (Table 5).

4.1.6. EEM-PARAFAC Factor Identification

In our study area in Hale County, most of May samples analyzed used different wavelength ranges from March, June, July, August, October, November. Excitation-Emission Matrices (EEM) analysis yielded three fluorescence components for both C1, C2, and C3 (Figure 12,13; Table 6,7). For May samples, C1 represented Microbial humic-like DOM (excitation maximum wavelength <240 (340) nm, emission maximum wavelength 392 nm) that has been observed widely within the nutrient-rich environment (Murphy et al. 2013). C2 was assigned as terrestrial humic-like component (excitation maximum wavelength 280 (<240) nm, maximum emission wavelength 340 nm) within wetland and forest environment (Murphy et al. 2013), and C3 was identified as protein-like compounds (excitation maximum wavelength <270 (352) nm, emission maximum wavelength 472 nm; Youhei Yamashita2013, 2015). For other months, C1 and C2 represented protein-like components (excitation maximum wavelength 280 (<240) nm, maximum emission wavelength 322 nm and excitation maximum wavelength 280 (<240) nm, emission maximum wavelength <280 (340) nm; D.N.Kothawala 2014; K.R. Murphy 2013; Chris

Osburn 2014; Adam Hambly 2015). C3 was identified humic-like components (excitation maximum wavelength 340 (<245) nm, maximum emission wavelength 424 nm).

4.2. Watershed Land Use and Wetland Effect

The land use in Hale County is currently dominated by forest and planted/cultivated lands. Wetland has accounts for a small percentage at our research site. Table 1 summarizes the extent of different land use in Hale County. Figure 14 shows that location of study sites in Hale County Watershed, Alabama, USA.

4.2.1. Watershed Land Use

Sample site Lindsay Ponds are located near Road 19 in Greensboro, Newbern (NW). The Lindsay Ponds part of the Watershed has a land use that is characterized by 0.87 percent wetland, 5.8 percent planted/cultivated crops and 16.48 percent scrublands.

Sample site Road16 Bridge 1 Upstream is located at Road 16 in Greensboro, NW. The Road16 Bridge 1 Upstream part of the Watershed has a land use that is characterized by 2.88 percent wetland, 4.08 percent planted/cultivated crops, and 2.58 percent scrublands.

Sample site Road16 Bridge 2 is located at Road 16 in Greensboro, NW. The Road16 Bridge 2 part of the Watershed has a land use that is characterized by 6.79 percent wetland, 58.54 percent planted/cultivated crops, and 3.21 percent scrublands.

Sample site Road16 Bridge 4 is located at Road 16 in Greensboro, NW. The Road16 Bridge 4 part of the Watershed has a land use that is characterized by 4.95 percent wetland, 36.43 percent planted/cultivated crops, and 12.11 percent scrublands.

Sample site Recycling Center is located at Road 19 in Greensboro, NW. The Recycling Center part of the Watershed has a land use that is characterized by 3.29 percent Herbaceous, 2.38 percent developed, and 27.28 percent scrublands.

Sample site Big Prairie Creek is located at Road 61 in Newbern, NW. The Big Prairie Creek part of the Watershed has a land use that is characterized by 6.65 percent wetland, 14.60 percent planted/cultivated crops, and 16.06 percent scrublands.

Sample site Big Prairie Creek Windmill is located at Windmill in Newbern, NW. The Big Prairie Creek Windmill part of the Watershed has a land use that is characterized by 6.64 percent wetland, 12.40 percent planted/cultivated crops, and 16.67 percent scrublands.

Sample site Big Prairie Creek Road 48 is located at Road 48 in Newbern, NW. The Big Prairie Creek Road 48 part of the Watershed has a land use that is characterized by 6.52 percent wetland, 4.43 percent planted/cultivated crops, and 16.08 percent scrublands.

4.2.2. Impact of Wetland on Water Quality

To assess the water quality of stream waters and determine if increases in wetland land use change the water quality parameters, Stream water samples were collected during times with and without rainfall over the period of several months and analyzed for cations (calcium, magnesium, sodium, iron, and potassium), anions (chloride and sulfate), DOM components (C1, C2, C3, and percentages C1%, C2% C3%), DOC, $SUVA_{254}$, S_R, E2/E3, nutrients (ammonium, ortho-p, nitrite, nitrate), *E. coli*, Optical Brightener and FI.

4.2.3. Cations

In Figure 15e, the scatter plot of Potassium on the y-axis and wetland percentages on x-axis demonstrates a slope of 0.96 and a y-intercept= 0.38. R^2 is 0.78, meaning that 78% of the variation in potassium values can be explained by wetland land use. Figure 15e shows a positive slope= 0.96, which means that potassium went up with increasing amounts of wetland land use. R-square values for calcium, magnesium, sodium and iron were 0.07, 0.46, 0.08 and 0.04, respectively in wetlands (Figure 15).

4.2.4. Anions

Figure 16b shows that the slope is negative 2.56 and the y intercept is 25.65. R^2 of 0.08 can be interpreted as 8% of the change in Sulfate values was explained by the amount of wetland. The negative slope shows that sulfate goes down with an increase in wetland percentage. The R-square value was 0.07 for chloride versus wetlands (Figure 16).

4.2.5. DOM Components and Percentages

Figure 17c shows the slope of 0.88 and y-intercept=1.1. R^2 of 0.58 means that 58% of the variation in component C3 values can be explained by wetland land use. Also, R-square values for C1 and C2 were 0.3 and 0.5, respectively versus wetlands (Figure 17). Lastly, R-square values for C1%, C2% and C3% were 0.01, 0.03 and 0.2, respectively versus wetlands (Figure 18).

4.2.6. DOC, $SUVA_{254}$, S_R, and E2/E3

The scatter plot of DOC vs. wetlands shows a slope of 1.35, a y-intercept=1.72 and R-square value 0.49 (Figure19a). R^2 of 0.49 can be interpreted as 49% of the variation in DOC values was explained by the percentage of wetlands. R-square values for $SUVA_{254}$, S_R and E2/E3 were 0.29, 0.16 and 0.01 respectively in wetlands (Figure19).

4.2.7. Nutrients

Figure 20 shows the R-square values for ammonium, ortho-p, nitrite, and nitrate versus %wetland was 0.15, 0.21, 0.25 and 0.05 respectively. While ammonium, ortho-p, and nitrate have positive slopes, nitrite has a negative slope.

4.2.8. *E. coli*, Optical Brightener and FI

Figure 21 shows the R-square values for *E. coli*, Optical Brightener and FI versus %wetland was 0.16, 0.53 and 0.43 respectively. Figure 15b illustrates the slope of 0.55 and y-intercept of 0.89. R^2 of Optical Brighteners (0.53) can be explained by wetland land use. Figure 21c shows the slope is 0.03, which is consistent with the fact that the FI did not change much with increasing wetland percentage.

4.3. Comparison of Sampling Concentrations between Sites for Newbern

For this section, we chose Newbern a town where many homes discharge untreated wastewater onto the ground. We separated our sampling sites as upstream, adjacent (midstream) and downstream of Newbern. Clustered column graphs are displayed for the parameters of: Nutrients (most notably ammonium, nitrate, nitrite and orthophosphate), cations (mostly Ca^{2+},

Mg^{2+}, K^{+}, Na^{+} and Fe), anions (mostly chloride and sulfate), *E. coli*, C1, C2, C3 components and their percentiles C1%, C2%, C3%, DOC, S_R, $SUVA_{254}$, E2/E3, FI, Biological Indices (Chl-a), Optical Brighteners. These parameters were shown to be above the criteria and recommendations for Alabama streams. The results were intended to be used as an essential means for differentiating water quality between the three sampling sites.

4.3.1. Cations

Cations water quality results do provide a useful means for comparing characteristic water quality from the sources. The results for drought testing and post-drought testing are displayed in figure 2. The minimum Ca^{2+}measurements were 11.63, 13.94, 11.58 mg/L, maximum Ca^{2+}measurements were 12.15, 48.73, 22.40 mg/l and concentrations averaged 11.89 ± 0.26; 2, 26.51 ± 6.88; 6, 18.72 ± 3.57; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum Ca^{2+}measurements were 3.70, 12.44, 8.67 mg/L, maximum Ca^{2+}measurements were 3.70, 29.67, 47.41 mg/l and concentrations averaged 3.70 ± 0.00; 2, 23.65 ± 3.83; 4, 33.75 ± 12.56; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 22a).

The minimum Mg^{2+} measurements were 2.41, 2.03, 1.93 mg/L, maximum Mg^{2+} measurements were 2.42, 4.97, 2.71 mg/l and concentrations averaged 2.42 ± 0.01; 2, 3.10 ± 0.55; 6, 2.45 ± 0.26; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum Mg^{2+} measurements were 1.26, 1.58, 1.05 mg/L, maximum Mg^{2+} measurements were 1.29, 3.36, 4.99 mg/l and concentrations averaged 1.27 ± 0.02; 2, 2.63 ± 0.38; 4, 3.64 ± 1.30; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 22b).

The minimum Na^+ measurements were 2.47, 2.17, 1.58 mg/L, maximum Na^+ measurements were 2.56, 4.73, 3.36 mg/l and concentrations averaged 2.51 ± 0.05; 2, 3.20 ± 0.47; 6, 2.76 ± 0.59; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum Na^+ measurements were 1.72, 2.47, 3.18 mg/L, maximum Na^+ measurements were 1.83, 6.89, 16.18 mg/l and concentrations averaged 1.77 ± 0.05; 2, 5.43 ± 1.00; 4, 11.77 ± 4.29; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 22c).

The minimum Fe^{2+} measurements were 0.26, 0.09, 0.07 mg/L, maximum Fe^{2+} measurements were 0.43, 0.26, 0.22 mg/l and concentrations averaged 0.34 ± 0.09; 2, 0.16 ± 0.03; 6, 0.12 ± 0.05; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum Fe^{2+} measurements were 1.06, 0.07, 0.04 mg/L, maximum Fe^{2+} measurements were 1.12, 0.32, 0.12 mg/l and concentrations averaged 1.09 ± 0.03; 2, 0.13 ± 0.06; 4, 0.09± 0.03; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 22d).

The minimum K^+ measurements were 6.19, 6.44, 6.38 mg/L, maximum K^+ measurements were 6.24, 6.86, 6.51 mg/l and concentrations averaged 6.22 ± 0.03; 2, 6.62 ± 0.08; 6, 6.47 ± 0.04; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum K^+ measurements were 5.74, 2.50, 1.54 mg/L maximum K^+ measurements were 5.77, 9.37, 3.87 mg/l and concentrations averaged 5.76 ± 0.01; 2, 4.74 ± 1.62; 4, 3.08 ± 0.77; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 22e).

4.3.2. Anions

The minimum Chloride measurements were 4.75, 2.45, 2.81 mg/L, maximum Chloride measurements were 5.01, 6.00, 3.30 mg/l and concentrations averaged 4.88 ± 0.13; 2, 4.12 ± 0.62; 6, 3.08 ± 0.14; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum Chloride measurements were 2.91, 4.69, 2.74 mg/L, maximum Chloride measurements were 3.96, 6.89, 7.98 mg/l and concentrations averaged 3.44 ± 0.52; 2, 6.06 ± 0.48; 4, 5.15 ± 1.53; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 23a).

The minimum Sulfate measurements were 3.66, 2.06, 1.97 mg/L, maximum Sulfate measurements were 3.78, 4.62, 2.56 mg/l and concentrations averaged 3.72 ± 0.06; 2, 2.99 ± 0.39; 6, 2.34 ± 0.19; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum Sulfate measurements were 1.64, 5.82, 3.97 mg/L, maximum Sulfate measurements were 2.21, 24.02, 13.73 mg/l and concentrations averaged 1.92 ± 0.28; 2, 14.36 ± 4.41; 4, 8.39 ± 2.86; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 23b).

4.3.3. DOM Components and Percentiles

The minimum C1 measurements were 1.92, 2.65, 1.98, maximum C1 measurements were 2.00, 6.51, 3.61 and concentrations averaged 1.96 ± 0.04; 2, 4.16 ± 0.74; 6, 3.05 ± 0.53; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum C1 measurements were 1.27, 7.73, 3.18, maximum C1 measurements were

1.32, 11.48, 24.94 and concentrations averaged 1.29 ± 0.02; 2, 9.57 ± 1.06; 4, 17.66 ± 7.24; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 24a).

The minimum C2 measurements were 2.00, 0.47, 0.44, maximum C2 measurements were 2.06, 2.54, 1.28 and concentrations averaged 2.03 ± 0.03; 2, 1.20 ± 0.42; 6, 0.74 ± 0.27; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum C2 measurements were 2.95, 1.24, 2.17, maximum C2 measurements were 2.99, 6.30, 6.53 and concentrations averaged 2.97 ± 0.02; 2, 3.78 ± 1.44; 4, 5.05 ± 1.44; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 24b).

The minimum C3 measurements were 4.52, 5.03, 5.10, maximum C3 measurements were 4.52, 8.87, 6.05 and concentrations averaged 4.52 ± 0.00; 2, 6.60 ± 0.73; 6, 5.72 ± 0.31; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum C3 measurements were 4.81, 11.49, 6.48, maximum C3 measurements were 4.82, 17.18, 14.42 and concentrations averaged 4.82 ± 0.00; 2, 14.33 ± 1.63; 4, 11.76 ± 2.64; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 24c).

The minimum C1% measurements were 22.55, 31.95, 23.73, maximum C1% measurements were 23.41, 36.31, 35.71 and concentrations averaged 22.98 ± 0.43; 2, 34.29 ± 0.76; 6, 31.61 ± 3.94; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum C1% measurements were 14.02, 32.61, 26.89, maximum C1% measurements were 14.49, 37.78, 54.40 and concentrations averaged 14.26 ±

0.23; 2, 35.23 ± 1.45; 4, 45.21 ± 9.16; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 25a).

The minimum C2% measurements were 23.51, 4.77, 4.40, maximum C2% measurements were 24.25, 14.15, 15.33 and concentrations averaged 23.88 ± 0.37; 2, 8.79 ± 1.74; 6, 8.19 ± 3.57; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum C2% measurements were 32.49, 6.08, 14.09, maximum C2% measurements were 32.92, 18.04, 18.35 and concentrations averaged 32.70 ± 0.22; 2, 12.12 ± 3.41; 4, 15.56 ± 1.40; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 25b).

The minimum C3% measurements were 53.08, 49.53, 59.77, maximum C3% measurements were 53.20, 60.67, 60.95 and concentrations averaged 53.14 ± 0.06; 2, 56.92 ± 2.29; 6, 60.20 ± 0.37; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum C3% measurements were 53.03, 49.15, 31.41, maximum C3% measurements were 53.05, 56.14, 54.76 and concentrations averaged 53.04 ± 0.01; 2, 52.65 ± 1.96; 4, 39.23 ± 7.77; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 25c).

4.3.4. DOC and Optical Indices

The minimum DOC measurements were 4.79, 5.54, 2.99 mg/L, maximum DOC measurements were 4.90, 9.98, 7.13 mg/l and concentrations averaged 4.85 ± 0.05; 2, 7.30 ± 0.83; 6, 5.75 ± 1.38; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum DOC measurements were 5.96, 16.21, 7.90 mg/L, maximum DOC measurements were 6.02, 24.95, 49.42 mg/l and concentrations averaged 5.99 ± 0.03; 2, 20.53 ± 2.42; 4, 35.55 ± 13.83; 3 mg/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 26a).

The minimum $SUVA_{254}$ measurements were 3.88, 2.95, 2.96 L/(mg m), maximum $SUVA_{254}$ measurements were 3.98, 3.35, 5.42 L/(mg m)and concentrations averaged 3.93 ± 0.05; 2, 3.12 ± 0.07; 6, 3.78 ± 0.82; 3 L/(mg m) (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum $SUVA_{254}$ measurements were 4.17, 2.73, 1.90 L/(mg m), maximum $SUVA_{254}$ measurements were 4.19, 3.22, 4.59 L/(mg m)and concentrations averaged 4.18 ± 0.01; 2, 2.97 ± 0.13; 4, 2.80 ± 0.89; 3 L/(mg m) (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 26b).

The minimum S_R measurements were 0.90, 0.90, 0.92 L/(mg m), maximum S_R measurements were 0.91, 0.99, 0.95 L/(mg m)and concentrations averaged 0.91 ± 0.01; 2, 0.95 ± 0.02; 6, 0.94 ± 0.01; 3 L/(mg m) (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum S_R measurements were 0.82, 0.83, 0.77 L/(mg m), maximum S_R measurements were 0.83, 0.85, 1.03 L/(mg m)and concentrations averaged 0.83 ± 0.00; 2, 0.83 ± 0.00; 4, 0.94 ± 0.09; 3 L/(mg m) (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 26c).

The minimum E2/E3 measurements were 3.96, 4.99, 5.06, maximum E2/E3 measurements were 4.02, 5.90, 5.48 and concentrations averaged 3.99 ± 0.03; 2, 5.38 ± 0.15; 6, 5.34 ± 0.14; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum E2/E3 measurements were 3.71, 4.46, 3.97, maximum E2/E3 measurements were 3.75, 5.08, 4.01 and concentrations averaged 3.73 ± 0.02;

2, 4.76 ± 0.16; 4, 3.98 ± 0.01; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 26d).

4.3.5. Nutrients

The minimum NH4 measurements were 4.55, 8.55, 3.39 ug/L, maximum NH4 measurements were 9.07, 107.00, 51.30 ug/L and concentrations averaged 6.81 ± 2.26; 2, 43.18 ± 19.13; 6, 34.83 ± 15.73; 3 ug/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. There is no NH4 data available at site Post-Drought condition (Figure 27a).

The minimum Ortho-P measurements were 10.20, 19.50, 35.70 ug/L, maximum Ortho-P measurements were 23.80, 66.30, 44.40 ug/L and concentrations averaged 17.00 ± 6.80; 2, 43.73 ± 8.01; 6, 39.87 ± 2.52; 3 ug/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. There is no Ortho-P data available at site Post-Drought condition (Figure 27b).

The minimum Nitrite measurements were 0.92, 1.20, 1.46 ug/L, maximum Nitrite measurements were 1.28, 2.30, 2.05 ug/L and concentrations averaged 1.10 ± 0.18; 2, 1.70 ± 0.16; 6, 1.85 ± 0.20; 3 ug/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. There is no Nitrite data available at site Post-Drought condition (Figure 27c).

The minimum Nitrate measurements were 2.47, 0.53, B.D. ug/L, maximum Nitrate measurements were 7.43 15.90, 122.96 ug/L and concentrations averaged 4.95 ± 2.48; 2, 6.54 ± 2.79; 6, 83.64 ± 41.84; 3 ug/L (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. There is no Nitrate data available at site Post-Drought condition (Figure 27d).

4.3.6. Bacteria

Figure 28. Shows that sampling during drought revealed average concentrations of *E. coli* bacteria around 50-100 per 100 mL; during the storm, at the end of November, the drought *E. coli* levels increased by about 10-times upstream of Newbern (this is expected because *E. coli* is in animal and bird feces and washes into rivers). Downstream of Newbern, average *E. coli* concentrations increased to nearly 100,000 *E. coli* per 100 mL. This indicates a primary source of *E. coli* in and around Newbern.

The minimum *E. coli* measurements were 50.20, 32.60, 51.80 cfu/100 mL, maximum *E. coli* measurements were 50.20, 46.13, 143.90 cfu/100 mL and concentrations averaged 50.20 ± 0.00; 2, 40.98 ± 2.67; 6, 82.50 ± 30.70; 3 cfu/100 mL (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum *E. coli* measurements were 329.25, 1139.95, 5800.00 cfu/100 mL, maximum *E. coli* measurements were 329.35, 20535.00, 116160.00 cfu/100 mL and concentrations averaged 329.30 ± 0.05; 2, 10837.48 ± 5598.87; 4, 79373.33 ± 36786.67; 3 cfu/100 mL (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 28).

4.3.7. Indices

The minimum Chl-a measurements were 0.08, 0.07, 0.09, maximum Chl-a measurements were 0.09, 0.13, 0.09 and concentrations averaged 0.09 ± 0.00; 2, 0.09 ± 0.01; 6, 0.09 ± 0.00; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum Chl-a measurements were 0.10, 0.18, 0.19, maximum Chl-a measurements were 0.10, 0.38, 0.26 and concentrations averaged 0.10 ± 0.00; 2, 0.28 ± 0.06; 4, 0.23 ± 0.02; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 29a).

The minimum FI measurements were 1.83, 1.85, 1.85, maximum FI measurements were 1.83, 2.24, 1.86 and concentrations averaged 1.83 ± 0.00; 2, 2.01 ± 0.07; 6, 1.86 ± 0.00; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum FI measurements were 1.79, 1.64, 1.57, maximum FI measurements were 1.79, 1.97, 2.22 and concentrations averaged 1.79 ± 0.00; 2, 1.80 ± 0.09; 4, 2.00 ± 0.22; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 29b).

The minimum OPT (Optical Brighteners) measurements were 2.83, 3.20, 3.21, maximum OPT measurements were 2.84, 6.34, 3.87 and concentrations averaged 2.84 ± 0.00; 2, 4.45 ± 0.60; 6, 3.63 ± 0.21; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. And also, the minimum OPT measurements were 3.04, 7.67, 3.87, maximum OPT measurements were 3.03, 10.19, 11.72 and concentrations averaged 3.03 ± 0.01; 2, 8.93 ± 0.72; 4, 9.08 ± 2.61; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 29c).

4.3.8. Principal Component Analysis (PCA)

The PCA was run on 20 water quality samples. Graphical representation of PCA output enables us to visualize how samples are related to each other, which includes drought, post-drought, wet, and wastewater. Together, principal components 1 and 2 (PC1 and PC2, respectively) explained 59.4% of the total variance in the dataset (Figure 30). PC1, which explained 40.4% of the total variance, showed differences between wastewater and stream water. The wastewater end members are well separated from stream water and post-drought (first flush) water samples by PC1, which is dominated by soluble reactive phosphorous (SPR), dissolved organic carbon concentration (DOC), *E. coli*, Ammonium-N, protein fluorescence, and optical brighteners. All these indicators demonstrate that wastewater has a characteristic nutrient &microbial signal that can be used to trace water sources in natural waterways, which is well synthesized by PC1. The post-drought samples had a higher PC1 score than stream water samples, representing precipitation mobilizes sewage related chemicals into nearby streams. Using base-flow stream water and wastewater as end members, we estimated that post-drought stream water contains 6.7% of wastewater. PC2 and PC3 are associated more with hydrological flow paths and hence not discussed in detail my study.

5. DISCUSSION

The discussion is organized around the study objectives. The specific objectives of the thesis are first, to focus on stream water samples taken upstream, midstream and downstream, before (drought condition) and after (Post-drought condition) precipitation to determine if these samples have significant wastewater signals from septic effluent or straight pipes. Second, the comparison of the sampling concentration, the parameters were separated four types as wastewater, dry (drought), wet and post-drought. Third, to assesses the stream water quality concerning the wetland land use distribution pattern, and determine how they relate to each other within sampling locations.

We found in our study that there was a positive correlation between some cations (potassium and sodium), nutrients (nitrite), *E. coli*, DOC, Optical Brightener and FI in our basin. The source of contamination within the surface water in Hale County could be from runoff sources from roads, from straight pipes, or from septic systems as the water is brought to the surface through flushing of the soil.

5.1. Sampling at Newbern

Newbern was chosen as a potentially contaminated region because it includes many households using straight pipes. In order to detect wastewater signal in nearby Big Prairie Creek, water sampling sites were identified upstream, adjacent (midstream) and downstream of Newbern. During the drought under baseflow conditions, our sampling sites showed no notable change in concentrations from Upstream to Downstream. In contrast, during the post-drought condition, we observed large increases in key water quality parameters from Upstream to Downstream. In addition, both PCA and our EEM-PARAFAC model were used to verify these observations.

5.1.1. *E. coli*

E. coli and fecal coliform are measures of many enterobacteria, bacteria that live within the digestive system of mammals, within the water. This is measured as the number of colonies of bacteria per milliliter of the liter of water. This is a direct measure of the amount of human influence there is in the area as well as the amount of runoff or flushing of the groundwater to the surface (Withgott and Brennan, 2008; Wicklein, 2004). These organisms are used as indicators that human consumption or recreational activity will yield an acceptably low risk to health; guidelines and standards for *E. coli* are determined at both national and international levels as appropriate to the setting and use. They are also used as general indicators for the presence and magnitude of fecal contamination in research.

Around Newbern, *E. coli* concentrations were higher following precipitation (Figure 28). Additionally, the increase was greater the downstream of Newbern than upstream. *E. coli* value increased about 5 times in upstream, 250 times in midstream and almost 1000 times in downstream from drought through post-drought. This increase in *E. coli* was likely due to the large number of straight pipes in Newbern. Straight pipe discharge onto the ground surface led to stream contamination as the accumulated wastewater in Newbern was flushed into the nearby creek during precipitation.

In our study, *E. coli* concentrations from different sampling sites and the results find the *E. coli* counts varied between 40.98 ± 2.67 cfu/100 ml and 79373.33 ± 36786.67 cfu/100 ml

(Figure 28). In our study, RD 61 Bridge *E. coli* concentration (116160 cfu/100ml) single sampling location could be used as an example for comparison to the Alabama Bacteria's Criteria, so *E. coli* values (colonies/100 ml) categorized respectively; single sample maximum should be equal or less than 235 according to Outstanding Alabama Water (OAW), single sample maximum should be equal or less than 2507 October through May according to Public Water Supply (PWS), single sample maximum should be equal or less than 235 according to Swimming and Other Whole Body Water Contact Sports (S), single sample maximum should be equal or less than 235 according to Shellfish Harvesting (SH), single sample maximum should be equal or less than 2507 October through May according to Fish and Wildlife (F&W), single sample maximum should be equal or less than 2507 according to Limited Warmwater Fishery (LWF) and single sample maximum should be equal or less than 3200 according to Agricultural and Industrial Water Supply (A&I) for Non-Coastal Waters (ADEM, 2016). The range of variation of *E. coli* concentrations amongst sampling sites from upstream to downstream indicates a high level of fecal bacteria contamination during drought and post-drought. The maximum *E. coli* measurements were recorded 50.20, 46.13, 143.90 cfu/100 mL through upstream, midstream, downstream respectively at site Drought condition, while the maximum *E. coli* measurements were 329.35, 20535.00, 116160.00 cfu/100 mL through upstream, midstream, downstream respectively at site Post-Drought condition. The possible source of higher concentrations during the post-drought condition discharge of septic system and untreated wastewater discharge from the houses located at Newbern.

5.1.2. Optical Brighteners

The detection of optical brighteners is a chemically based microbial source tracking method. Optical brighteners act as brightening indicator by absorbing light in the UV range, and its fluorescing in the visible region. Optical Brighteners found in detergent and whiteners in toilet paper yield a robust absorbance emission signal that is straightforward and inexpensive to measure with a hand-held fluorometer for tracking of signals (Hagedorn and Weisberg, 2011). Many investigators have reached the same conclusion that these compounds have a high potential as a monitoring wastewater contamination in natural waters (Hagedorn and Weisberg, 2011; Cao et al., 2009; Tavares et al., 2008). These compounds demonstrate a real promise in our data to act as an indicator of human fecal contamination from onsite wastewater discharges into the streams. In our study, the optical brightener concentrations found at Newbern indicated that fecal bacterial contamination came from human wastewater in the form of sewage leaks or spills or septic system leakage. As noted above, Newbern has suffered for many years from problems with onsite wastewater management. We observed that maximum optical brightener values were 2.84, 6.34, 3.87 and concentrations averaged 2.84 ± 0.00; 2, 4.45 ± 0.60; 6, 3.63 ± 0.21; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Drought condition. After precipitation, we found maximum optical brightener values were 3.03, 10.19, 11.72 and concentrations averaged 3.03 ± 0.01; 2, 8.93 ± 0.72; 4, 9.08 ± 2.61; 3 (mean ± SE; n) through upstream, midstream, downstream respectively at site Post-Drought condition (Figure 29c). It is evident that optical brightener values at post-drought condition three times more than drought condition. Data at our pristine (no human influence) control site at Mayfield Creek showed an average optical brightener values 0.83 and 2.83 through drought and post-drought condition respectively. Therefore, a significant relationship was found between optical brightener values and precipitation at Newbern. This experiment showed that the value of using optical brighteners are promising as a supplement of fecal indicator bacteria, probably enabling differentiation of wastewater from animal fecal contamination in rural areas (Tavarese et al., 2008).

5.1.3. DOM, DOC and Indices

The organic matter detected in the stream has a distinct fluorescence signature and distinct characteristics that are different from in stream samples. The sample compositions show small $SUVA_{254}$ value with, high DOC concentrations indicating more labile and less aromatic carbon structures. The fluorescence index (FI), calculated as the ratio of intensity at 470nm/520nm emission and 370 nm excitation, has been commonly used to indicate the relative contributions of algal versus terrestrial derived DOM. While lower FI is related to more highly processed, terrestrial derived material that has greater aromatic content and higher molecular weight, higher FI is with algal derived material which has lower aromatic content and lower molecular weight (McKnight et al., 2001, Jaffe et al., 2008). In our study, stream samples all included an FI value bigger than 1.66, classifying the organic matter in those samples as having a more microbial derived structure (Figure 29b). Furthermore, our samples also consisted of higher DOC concentrations with a high FI values and a high $SUVA_{254}$ determinative of less changeable carbon and more aromatic structure (Figure 26). The downstream samples demonstrated characteristics in the mid-range for DOC, $SUVA_{254}$ and FI values supporting the idea that organic matter found at these sites is a highly complex structure with their sources that might have been adequately characterized by the stream samples.

5.1.4. Principal Component Analysis (PCA)

The principal component analyzes, and my figures show the high information content inherent to peak C1, C2 and C3 in the excitation-emission matrix to delineate the different sources of the variable organic matter in my study sampling set. The skill to use a model for predictive abilities requires that characteristic properties can be traceable in aquatic samples.

The PCA (varimax rotation) identified three primary components (Eigenvalue >1), accounting for 40.4%, 19.0% and 8.7% of total variance respectively. The wastewater and members have well separated from stream water and post-drought (first flush) water samples by PC1, which is dominated by soluble reactive phosphorous (SPR), dissolved organic carbon concentration (DOC), *E. coli*, Ammonium-N, protein fluorescence, and optical brighteners. All these indicators show that wastewater has a characteristic nutrient &microberich signal that can be used to trace water sources in natural waterways, which is well synthesized by PC1. The post-drought samples had a higher PC1 score than stream water samples, indicating precipitation mobilizes sewage associated with chemicals to nearby streams. Using base-flow stream water and wastewater as end members, we estimated that post-drought stream water contains 6.7% of wastewater. PC2 and PC3 are associated more with hydrological flow paths and hence not discussed in detail my study. The drought ensured a critical opportunity for multiple sampling trips before and then immediately following the first rain after two months. Newbern, Alabama, a small town with a conservative estimate of 50% straight pipes and very impermeable clay soil, provided an ideal setting to sample runoff containing untreated wastewater. Figure 28 displays how during the drought under baseflow conditions, sampling sites Upstream, adjacent (Midstream) and Downstream of Newbern show no change in *E. coli* concentration. In contrast, during the first rainstorm following the drought, median *E. coli* increased by less than one log unit upstream but by nearly 3 log10 (1000x) downstream. PCA results verified these observations by showing increasing PC1 scores from upstream to the downstream site (Figure 30).

5.1.5. EEM-PARAFAC Model

Finally, wastewater was detected in our study area in Newbern by using EEM-PARAFAC model. The EEM-PARAFAC model identified three fluorescence components, terrestrial humic-like compounds derived from soils, microbial humic-like compounds and protein-like humic compounds respectively. The fluorescence spectra obviously demonstrate that wastewater samples (Figure 31a) have higher amounts of microbially-produced, protein-like compounds than a regular stream water without an input of wastewater (Figure 31b). As it is known the upstream site of Newbern no input of wastewater to the downstream site collecting data from wide range of straight pipe discharges that lead to shifting what the dominant fluorescence region from indicating humic, soil-derived compounds to indicating microbially-derived compounds.

5.2. The Relationship of Water Quality Parameters Among Variables

The pH is a test of acidity or alkalinity of water soluble substance (Zeb et al. 2011). pH varied little among the sampling locations in our study, remaining near neutral. (Table 2).

Conductivity is a good method to measure the dissolved ions, and it is directly related to total soil solids (Bhatt, 1999). Conductivity can be impacted by the presence of inorganic dissolved solids such sodium, magnesium, nitrate, chloride, phosphate (Chergui et al., 2013). Conductivity is a good indicator of a range of natural and anthropogenic effects on water. It is impacted by geology, land use and groundwater inflows (Stevenson et al., 2010). In this study, conductivity values varied widely between sampling sites. The highest conductivity value was recorded at the Rd16 Br2 451 µS/cm in 30-November (Table 3). This highest conductivity may be explained by the anthropogenic activities and effects of residents. Another important indicator of high conductivity values can be explained by using straight pipes discharging wastewater into the stream due to the presence of chloride, phosphate, and nitrate. Although these variations of conductivity among the sampling sites, no sites exceeded the critical limit of 1000 µS/cm (Drinking Water Quality: WHO, 2010).

5.3 The Relationship Between Wetland Land-Use and Water Quality

We attempted to mine our data to evaluate whether there was a relationship between percentage wetlands and our water quality parameters. However, correlations between percent wetland and water quality parameters were difficult to identify in this study. Other factors, including precipitation and the differing influence of pollution sources on our sampling locations, made it hard to elucidate the effects of wetlands. Additionally, none of the sampling sites of basins were comprised of more than 10% wetlands. The sampling sites Rd 16 Bridge 2 and Big Prairie Creek Road 61 of basins include the most at 6.79% and 6.65% respectively. Some water quality parameters appeared to be positively correlated with wetlands: Figure 15e shows increases in Potassium (R square 0.78), Figure 17c shows C3 (R square 0.58) and Figure 21b shows Optical Brighteners (R square 0.53). The collecting of water samples from sites that has less than 10% wetland for identifying effects on water quality is not ideal. After many sampling events, most of the sampling sites were severely affected by the drought. Therefore, these relationships could be distinguished better by including watersheds with more wetland proportions and without being faced with drought in the analysis.

6. CONCLUSION

During the eight months investigation of wastewater signals in Hale County Alabama, a total of 20 water quality samples from twenty sites were collected and analyzed for physical (turbidity), chemical (anions, cations, DOM, DOC, nutrients, pH and conductivity) and microbiological (*E. coli* and coliform bacteria) parameters. The relationship between water quality parameters and wetland land use was determined by using GIS. These observed patterns led to the following conclusions:

1. This study analyzed water quality parameters during and immediately following the extended drought condition period from September to November 28th, 2016. The the maximum *E. coli* measurements were recorded 50.20, 46.13, 143.90 cfu/100 mL through upstream, midstream, downstream respectively during drought condition, while the maximum *E. coli* measurements were 329.35, 20535.00, 116160.00 cfu/100 mL through upstream, midstream, downstream respectively at site Post-Drought condition. The minimum *E. coli* concentrations averaged 50.20 ± 0.00; 2, 40.98 ± 2.67; 6, 82.50 ± 30.70; 3 cfu/100 mL (mean ± SE; n) through upstream, midstream, downstream respectively during drought condition. The minimum *E. coli* concentrations averaged 329.30 ± 0.05; 2, 10837.48 ± 5598.87; 4, 79373.33 ± 36786.67; 3 cfu/100 mL (mean ± SE; n) through upstream, midstream, downstream respectively during post-drought condition. The most likely source of higher concentrations during the post-drought condition is the discharge of septic system and untreated wastewater discharge from the houses located at Newbern. Although cows were observed near Big Prairie Creek, they were up gradient from the midstream and

downstream sampling sites. While it is likely that fecal contamination from cow waste were washed into the stream following rainfall, three major pieces of evidence indicate that *E. coli* contamination was primarily from sewage: (1) the increase in *E. coli* was greatest downstream of Newbern, (2) the cows have constant access to Big Prairie Creek and often defecate directly into the stream during both wet and dry conditions and (3) optical brighteners that are found in detergent and toilet paper also increased substantially downstream of Newbern.

2. We also found a link between optical brightener values and precipitation at Newbern as well. We observed that maximum optical brightener values were 2.84, 6.34, 3.87 through upstream, midstream, downstream respectively during drought condition. After precipitation, we found maximum optical brightener values were 3.03, 10.19, 11.72 through upstream, midstream, downstream respectively during post-drought condition. This experiment showed that using optical brighteners is promising as a supplement to fecal indicator bacteria, potentially enabling identification of wastewater from straight pipes.

3. The PCA (varimax rotation) identified three primary components (Eigenvalue >1), accounting for 40.4%, 19.0% and 8.7% of total variance respectively. The wastewater and members have well separated from stream water and post-drought (first flush) water samples by PC1. The post-drought samples had a higher PC1 score than stream water samples, indicating precipitation mobilizes sewage associated with chemicals to nearby streams. Using base-flow stream water and wastewater as end members, we estimated that post-drought stream water contains 6.7% of wastewater.

4. Finally, the EEM-PARAFAC model identified three fluorescence components, terrestrial humic-like compounds derived from soils, microbial humic-like compounds and protein-like

humic compounds respectively. The fluorescence spectra clearly demonstrate that wastewater samples (Figure 26a) have higher amounts of microbially-produced, protein-like compounds than a regular stream water sample.

5. Some water quality parameters appeared to be positively correlated with wetlands: Potassium (R square 0.78), C3 (R square 0.58) and Optical Brighteners (R square 0.53). The collection of water samples from sites with less than 10% wetland for identifying effects on water quality is not ideal. After many sampling events, most of the sampling sites were severely affected by the drought. Therefore, these relationships could be distinguished better by including watersheds with greater wetland proportions in the analysis

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Figure 1. Alabama Black Belt Counties (Source: UA Center for Economic & Business Research)

Figure 2. A Typical Straight Pipe Discharge (EPA Region 4, 2002).

Figure 3. A Map of Households with Direct Discharge (Straight Pipe) in Bibb County (from White and Jones, 2006).

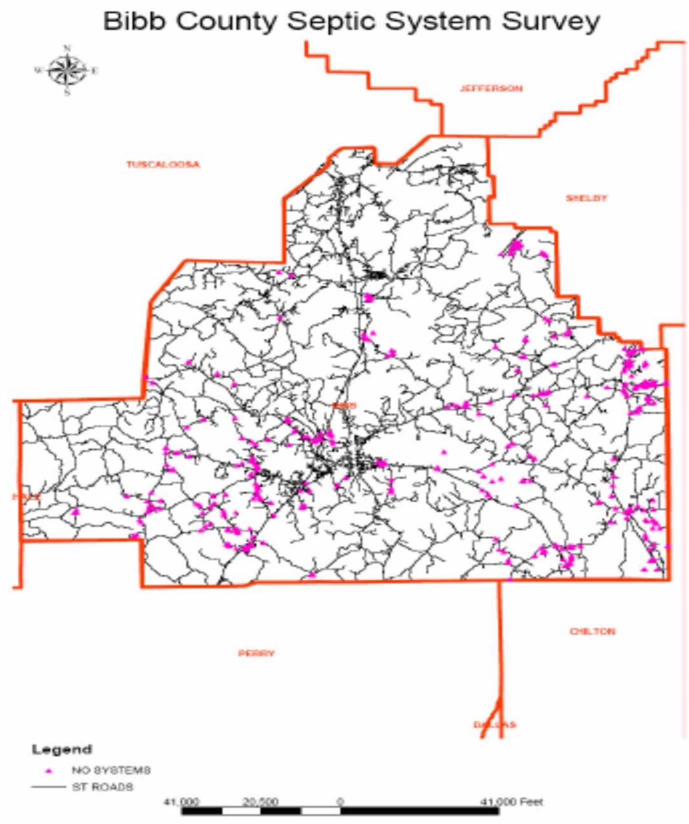
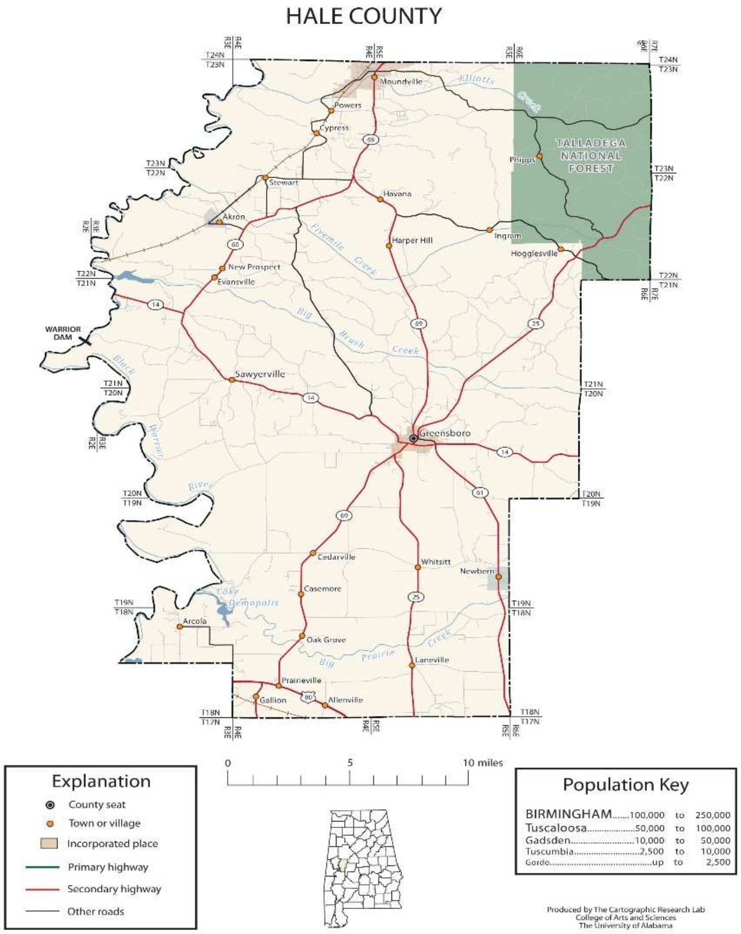


Figure 4. Hale County's Major Roads and Towns.



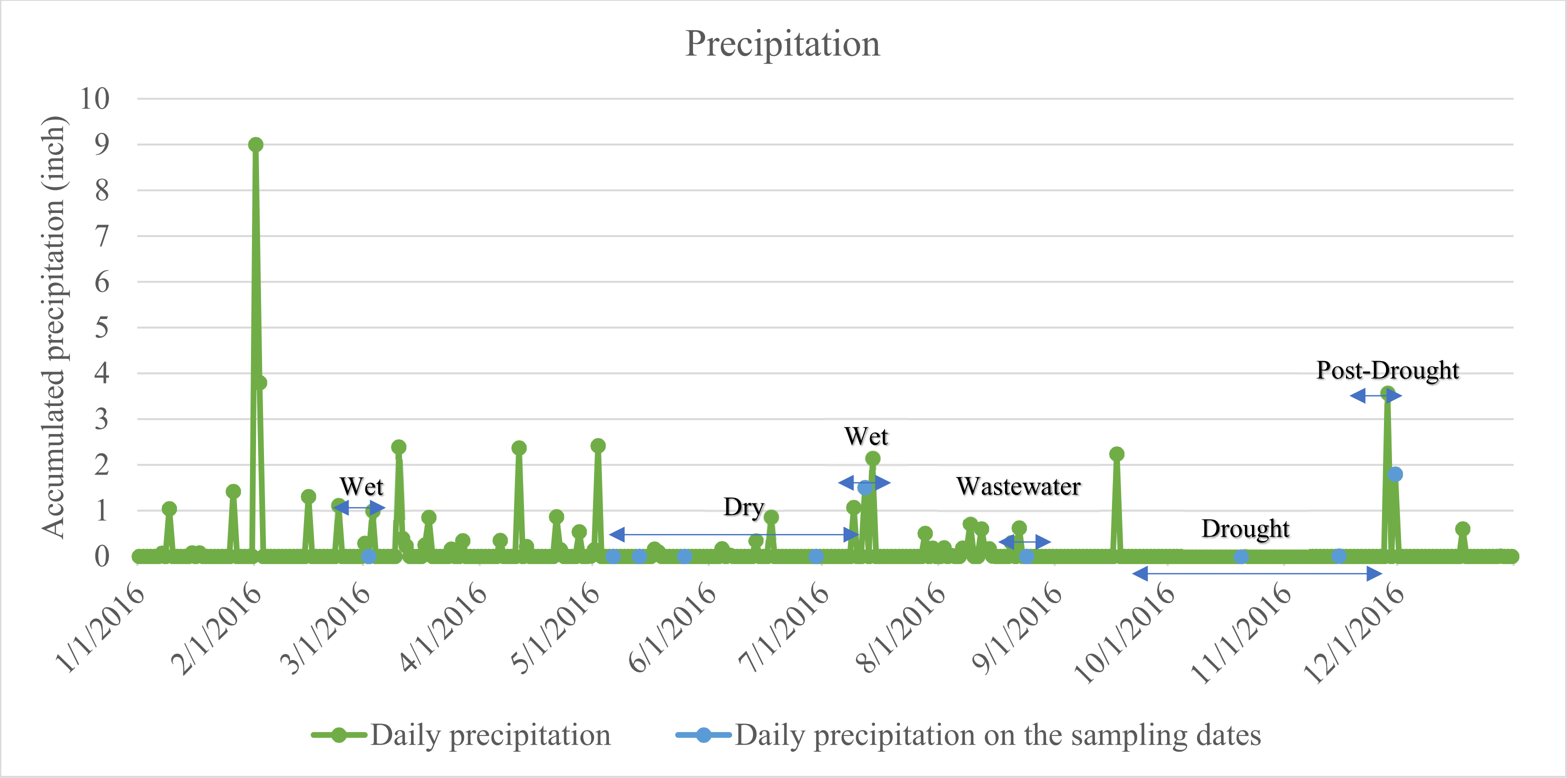


Figure 5. The Precipitation Data of the Sampling Area. Sampling Dates are 2-March, 6-May,13-May, 25-May, 29-June, 12-July, 24-August, 20-October, 15-November and 30-November.

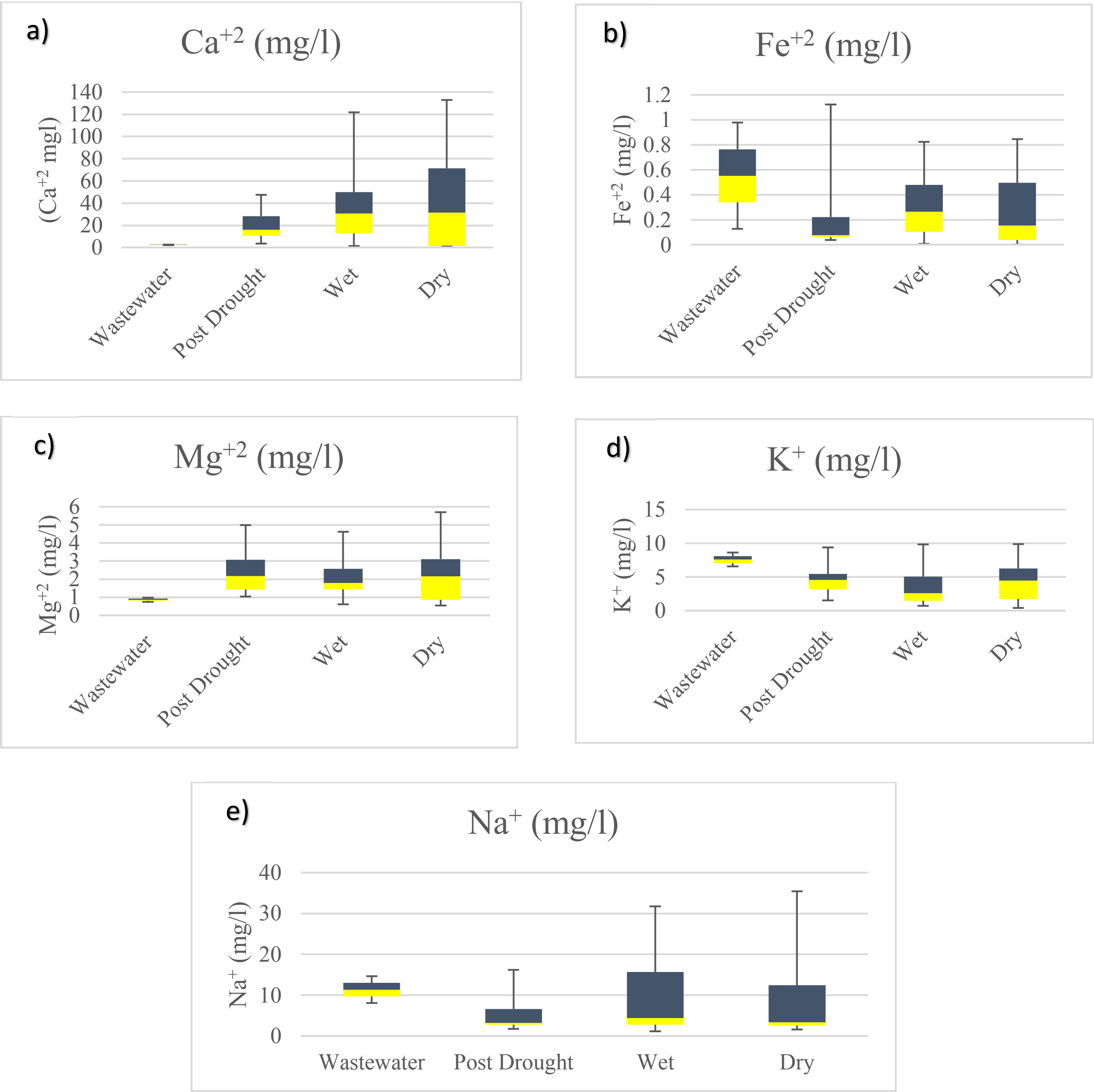
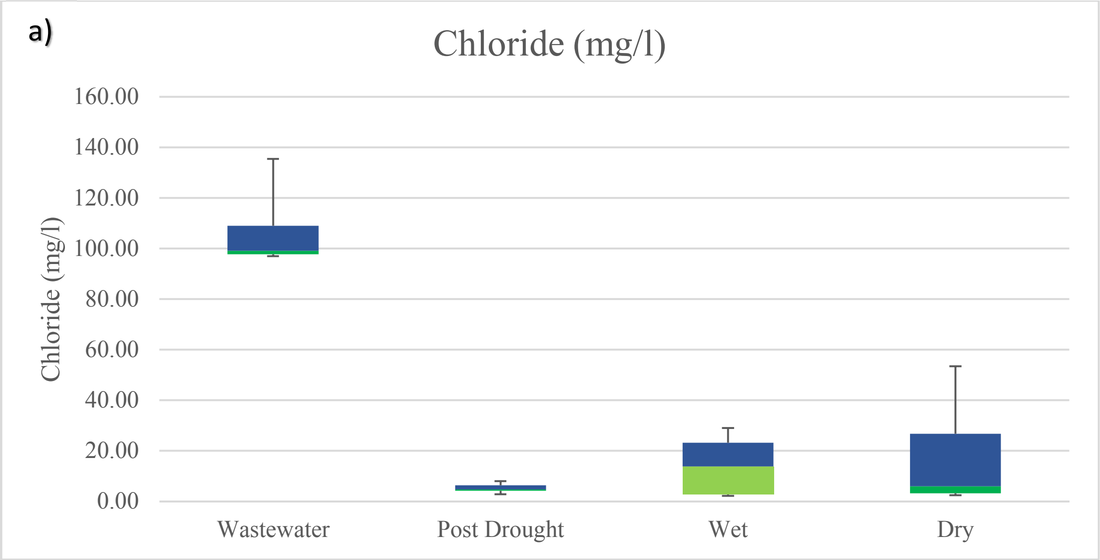


Figure 6. Water Quality Parameters for Cations According to Wastewater, Post-Drought, Wet and Dry Conditions.



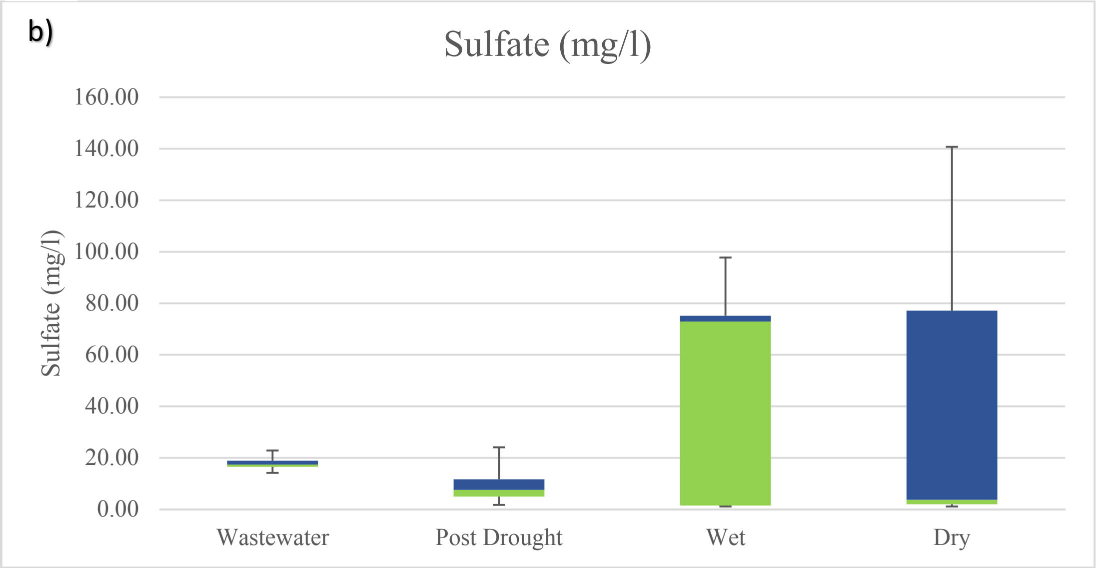


Figure 7. Water Quality Parameters for Anions According to Wastewater, Post-Drought, Wet and Dry Conditions.

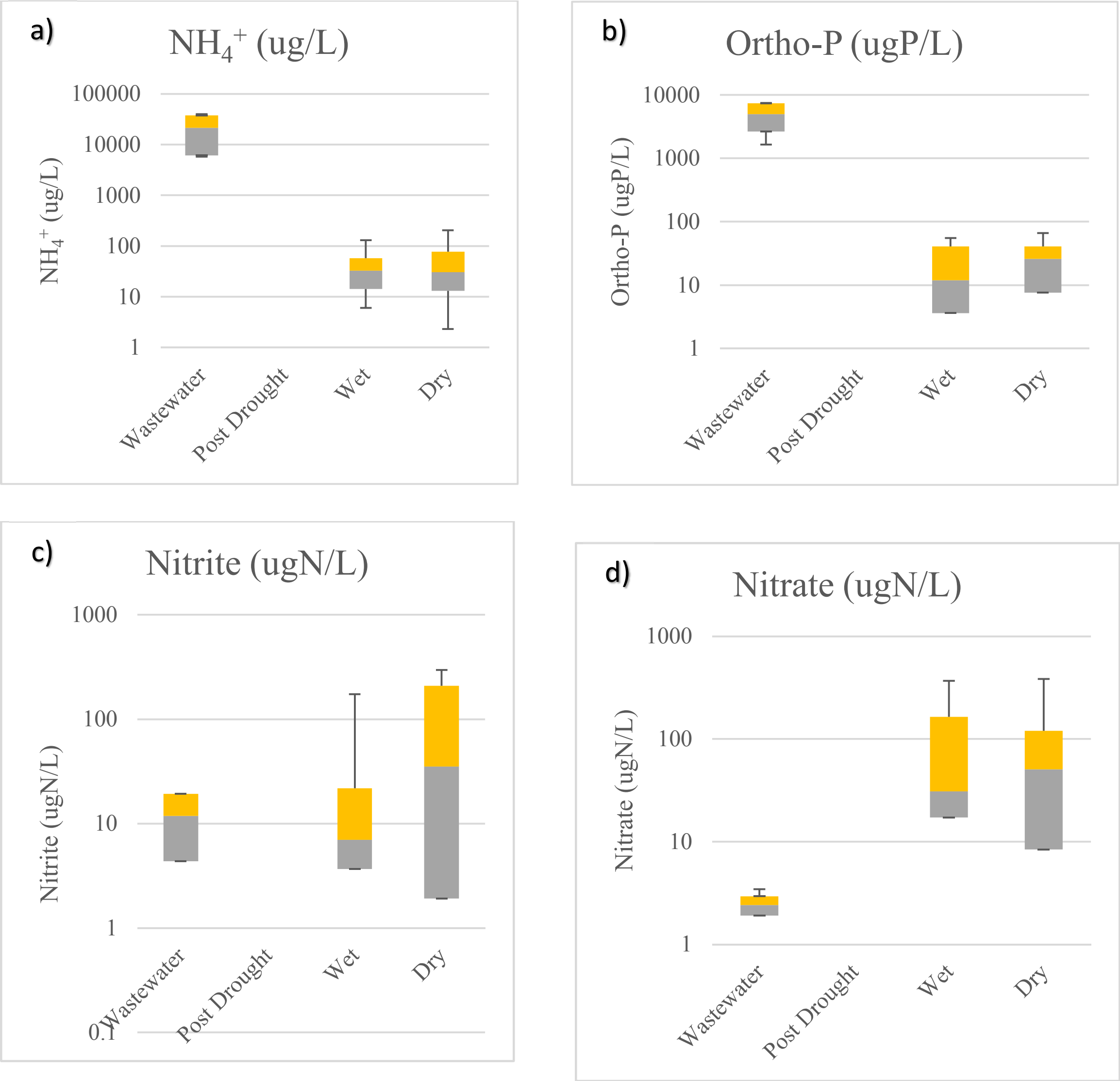


Figure 8. Semi-log Plots of Water Quality Parameters for Nutrients According to Wastewater, Wet and Dry conditions.

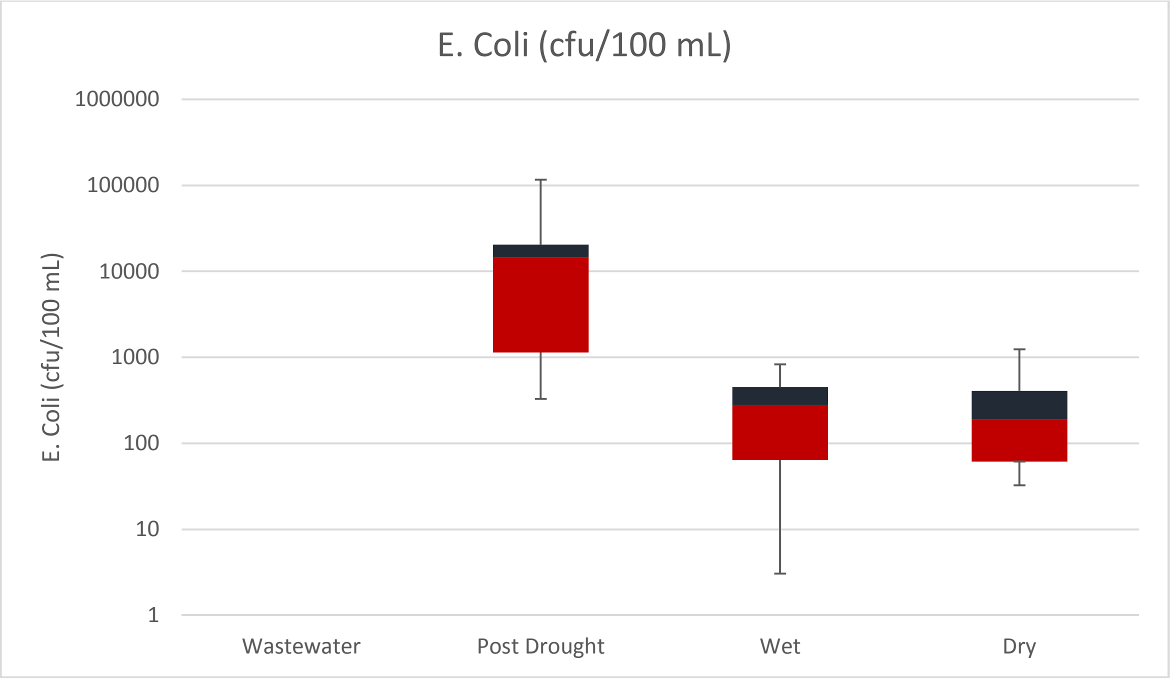


Figure 9. Semi-log Plot of *E. coli* Concentrations in Post-Drought, Wet and Dry Conditions.

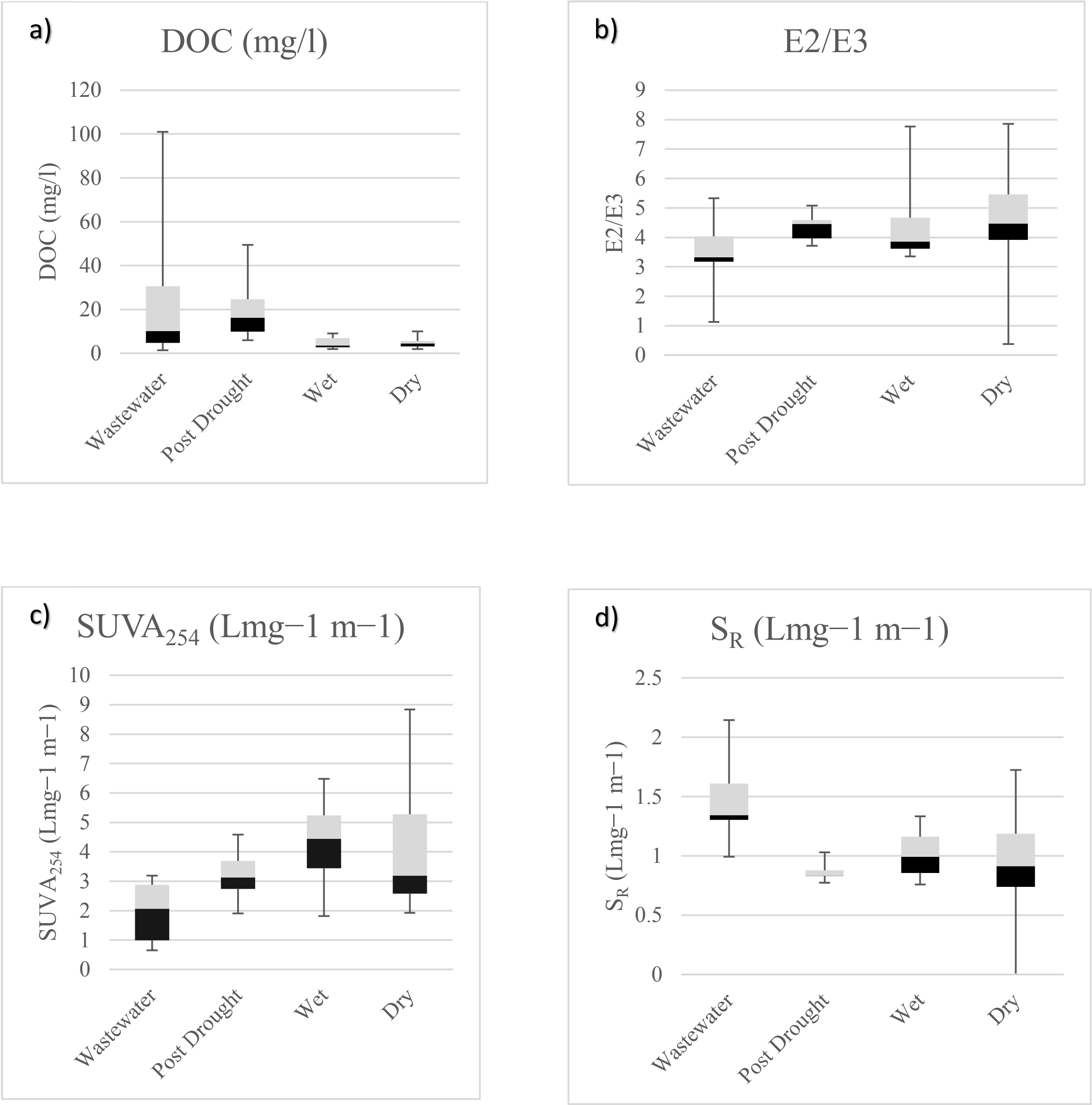


Figure 10. Water Quality Parameters for DOC, $SUVA_{254}$, S_R and E2/E3 According to Wastewater, Post-Drought, Wet and Dry Conditions.

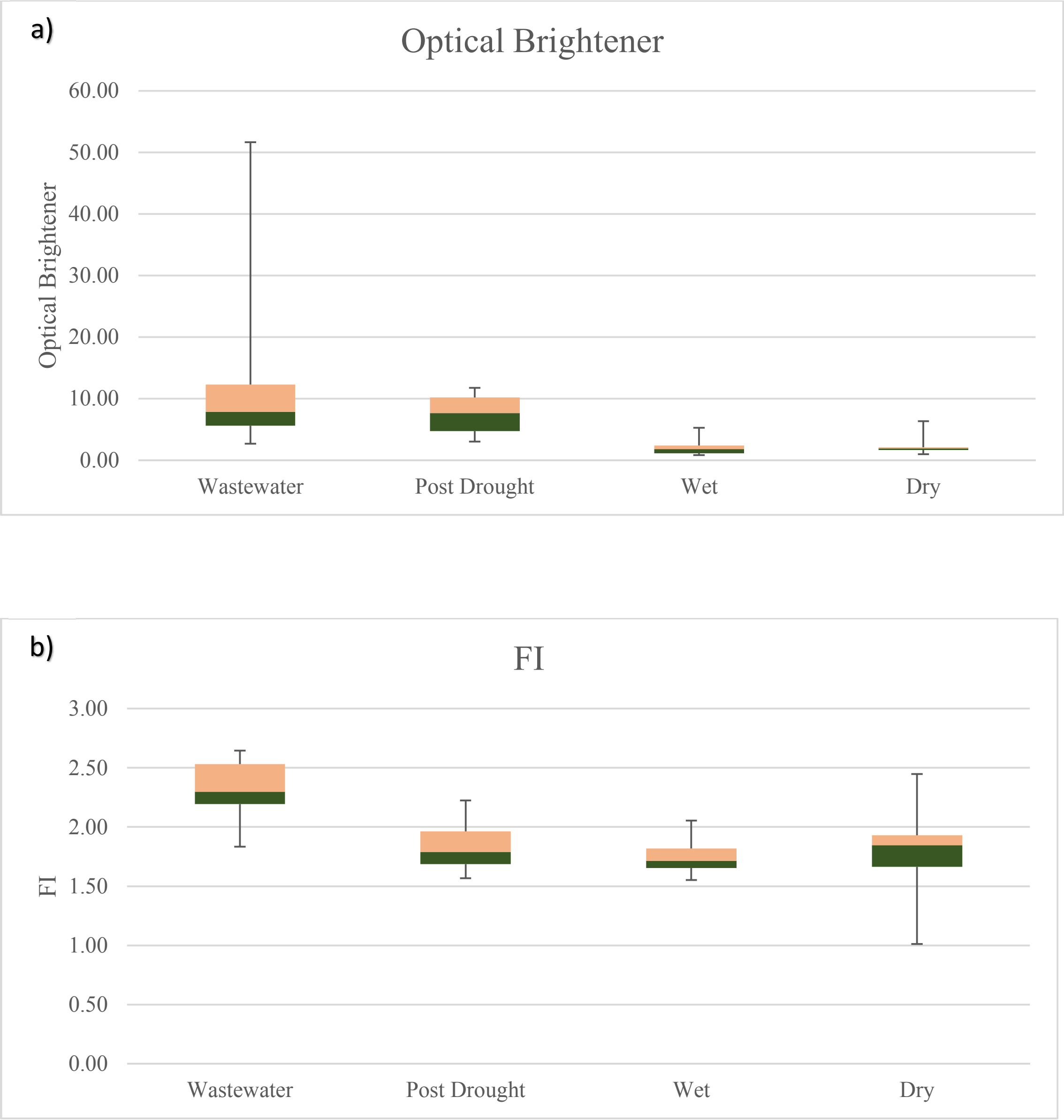


Figure 11. Fluorescence-property-based Indices for Optical Brightener and Fluorescence Indices According to Wastewater, Post-Drought, Wet and Dry Conditions.

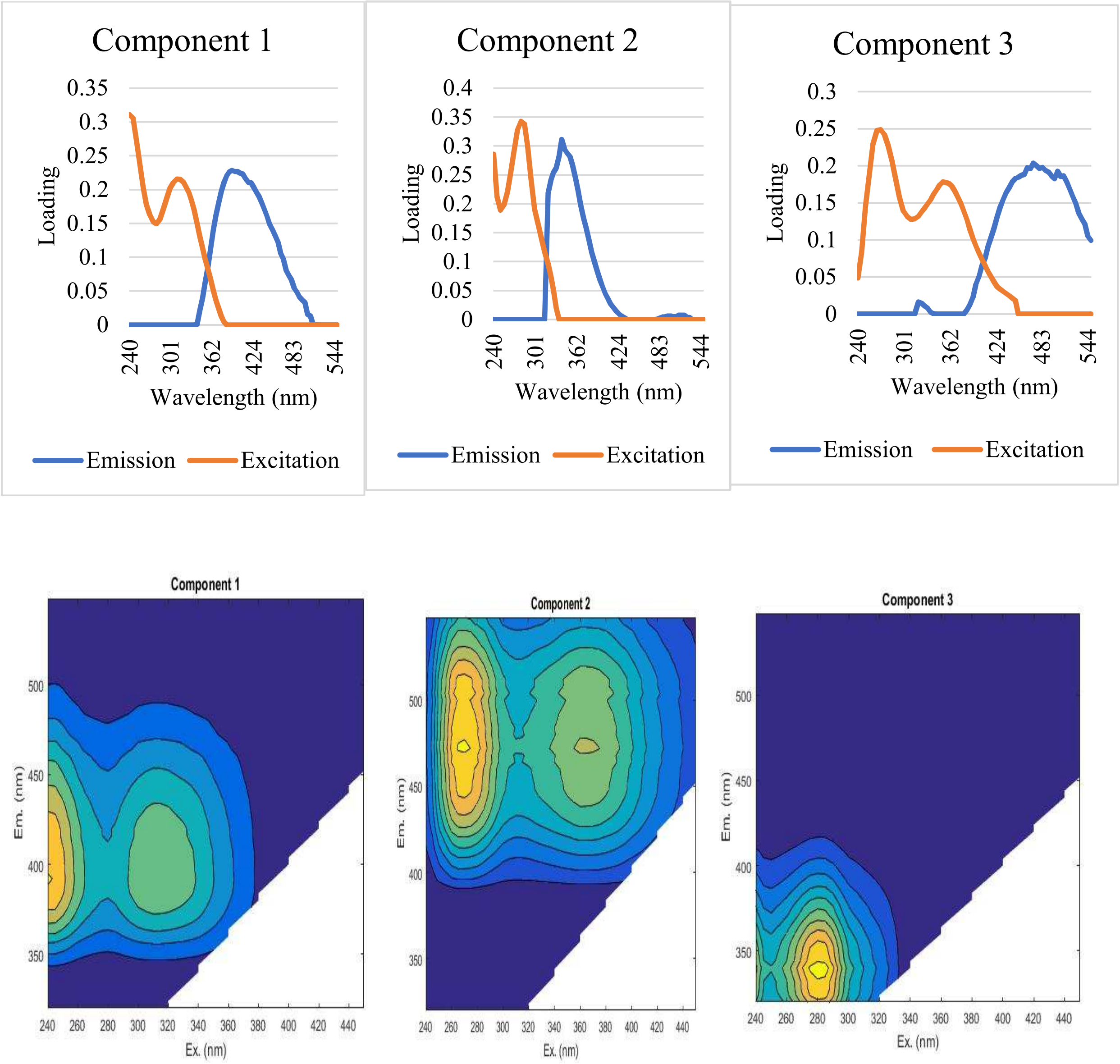


Figure 12. Excitation-emission Spectra and Loading of the Three Fluorescence Components (C1-C3) Identified by the Parallel Factor Analysis of DOM Samples for May from Hale County Watershed.

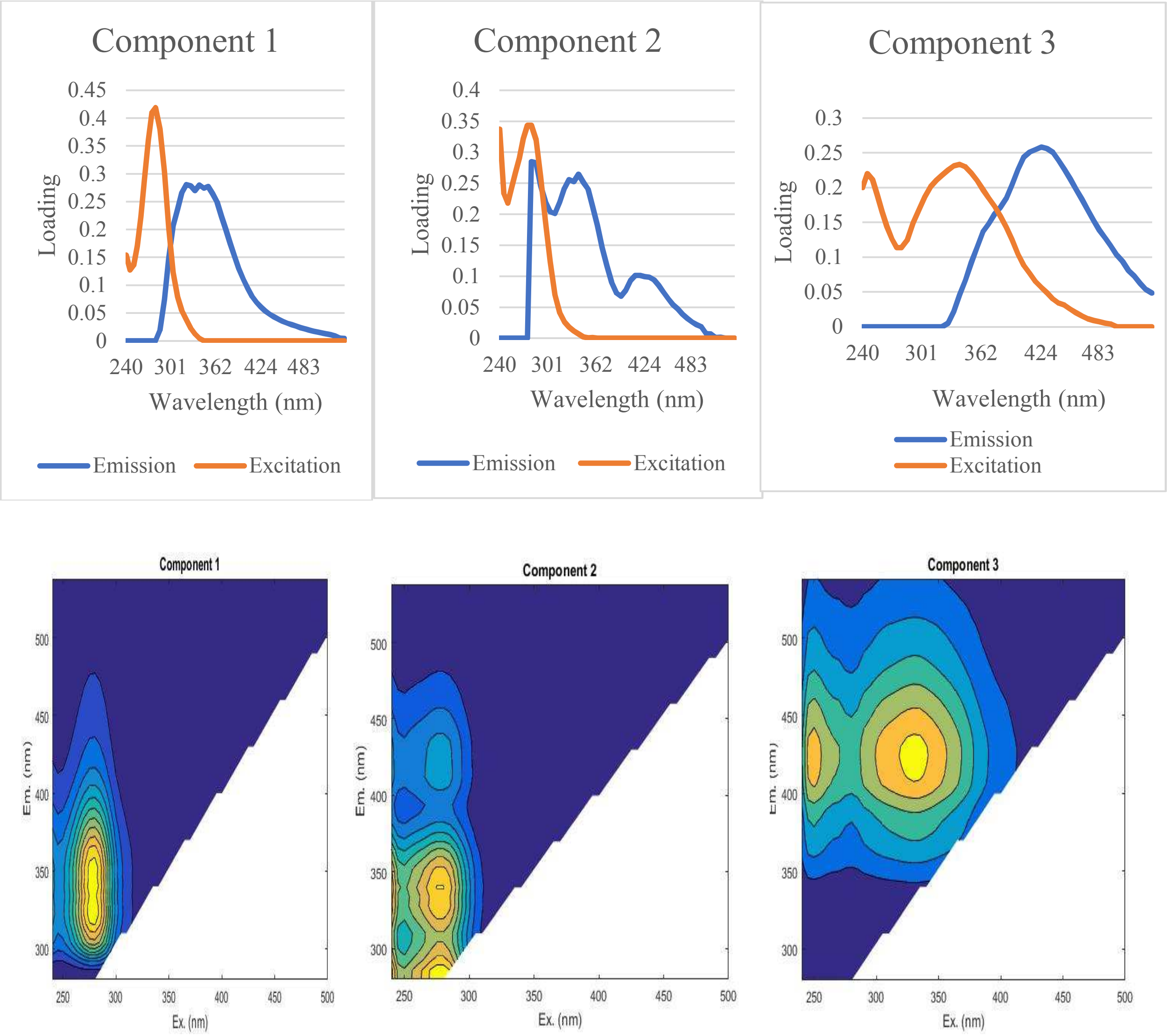


Figure 13. Excitation-emission Spectra and Loading of the Three Fluorescence Components (C1-C3) Identified by the Parallel Factor Analysis of DOM Samples for March, June, July, August, October, November from Hale County Watershed.

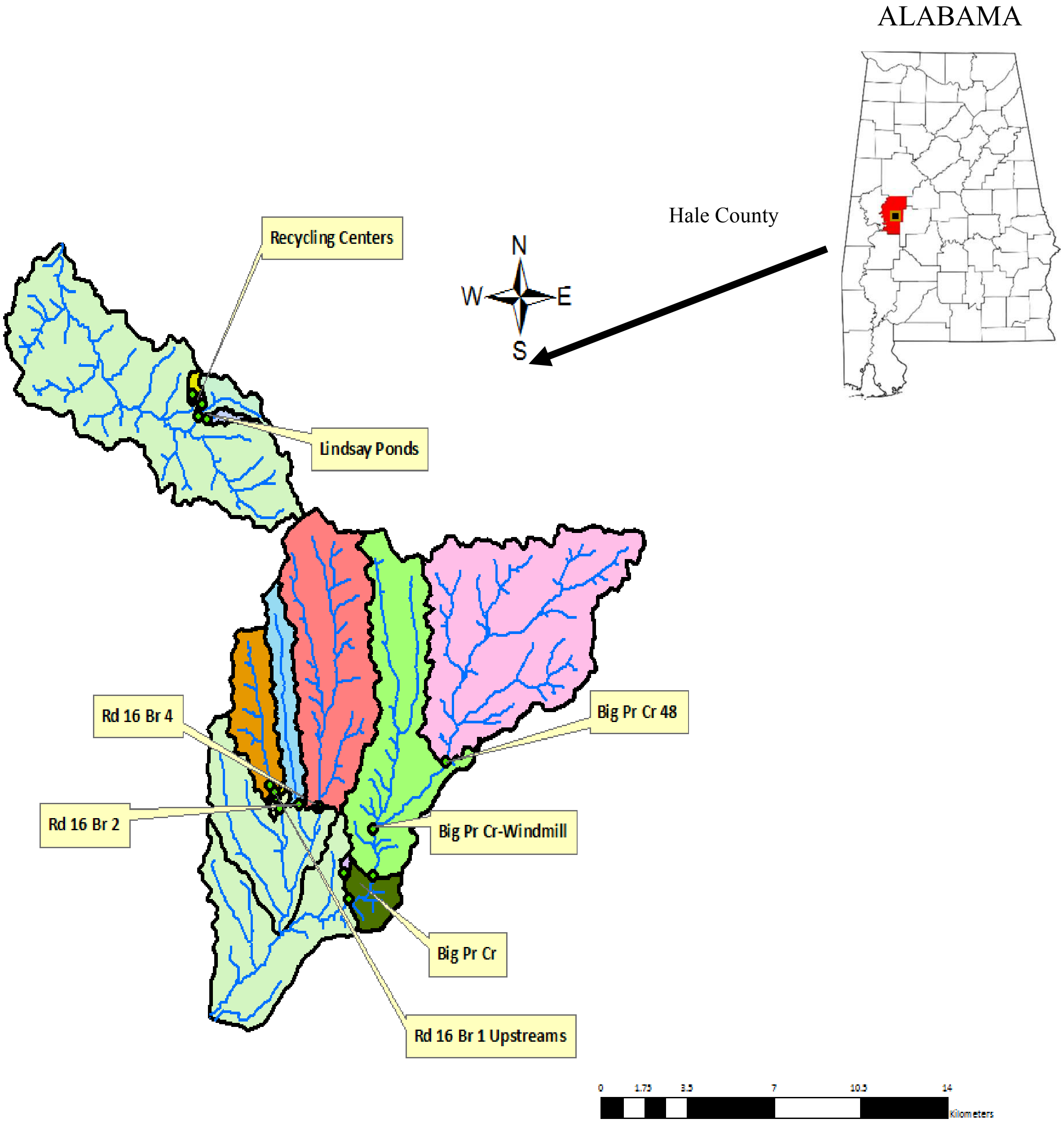


Figure 14. Locations of Study Sites in Hale County Watershed, Alabama, USA, Streams are Indicated by Blue Lines, Watershed Boundaries are Indicated by Black Lines, and Sampling Sites are Denoted by Black Dots.

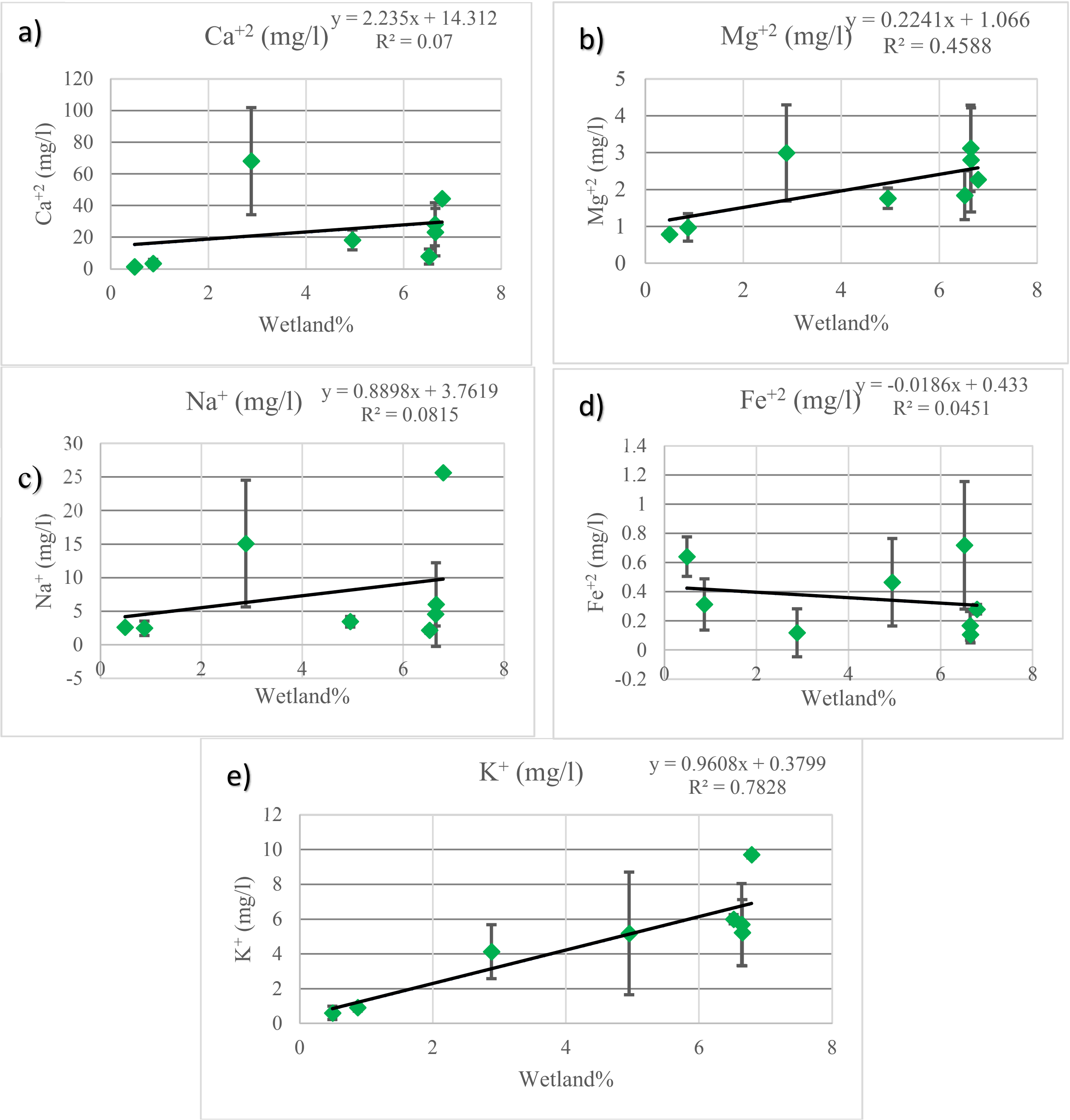


Figure 15. Wetland Effect on Surface Water Quality for Cations.

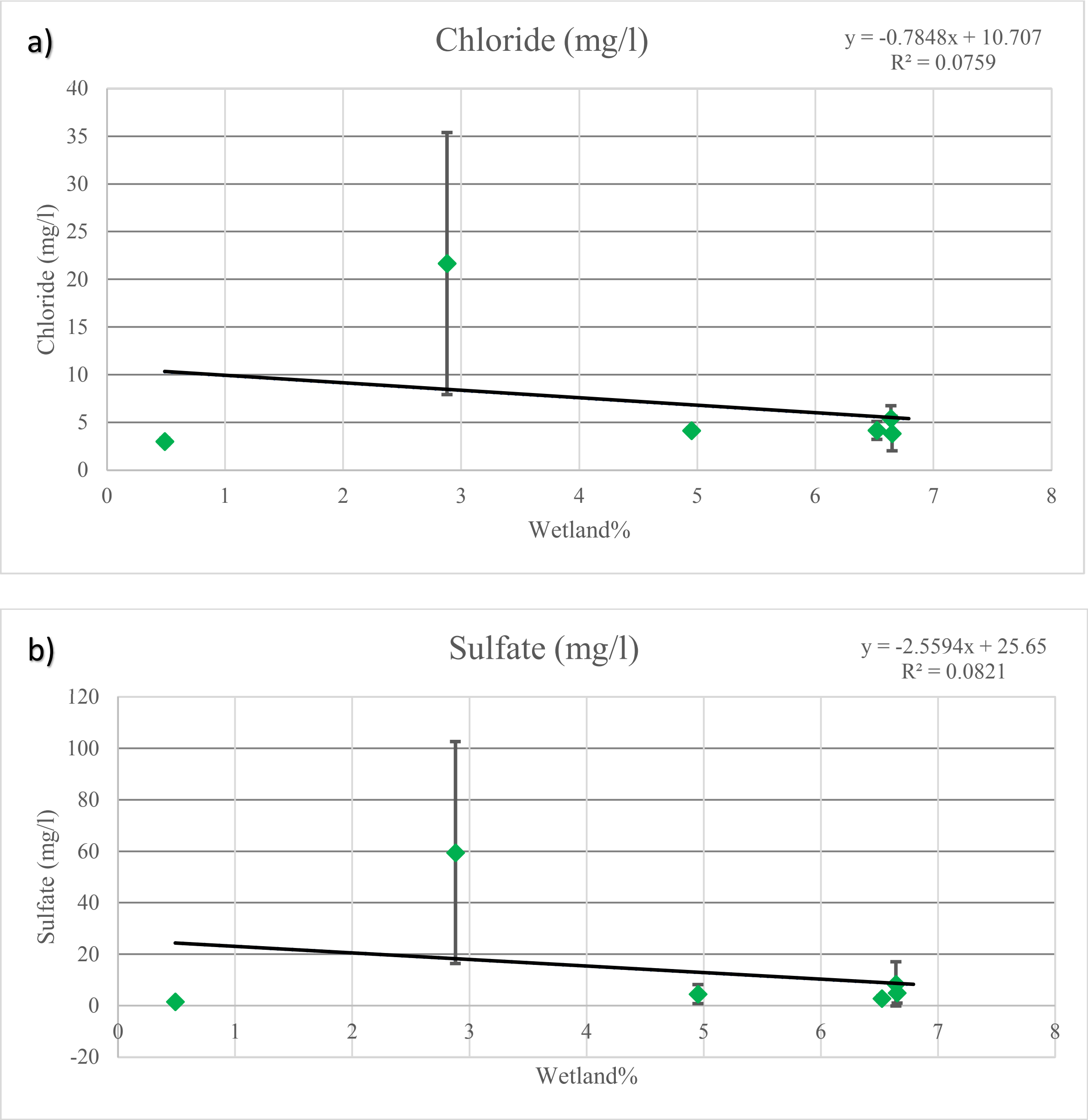


Figure 16. Wetland Effect on Surface Water Quality for Anions.

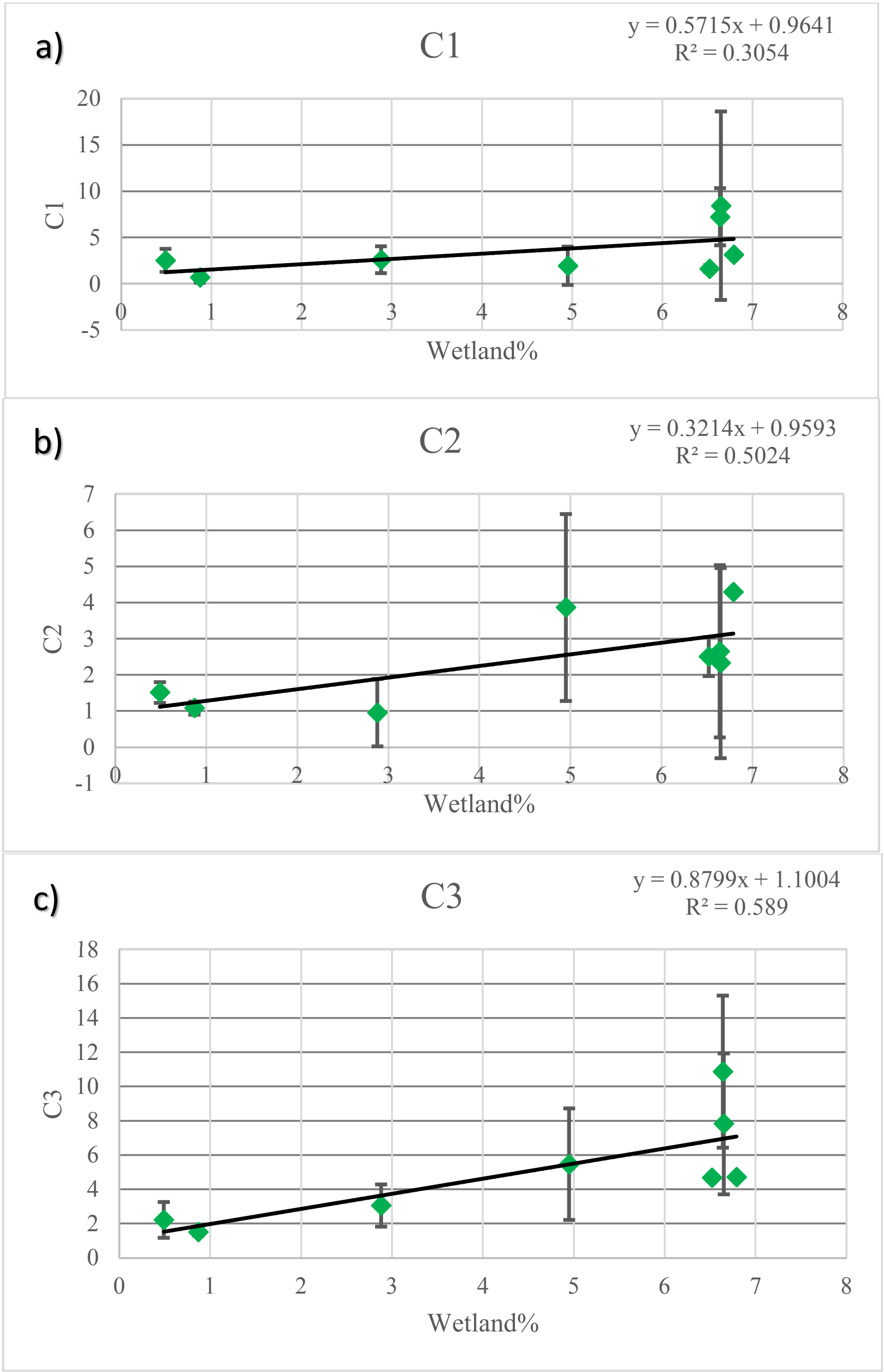


Figure 17. Wetland Effect on Surface Water Quality for DOM Components.

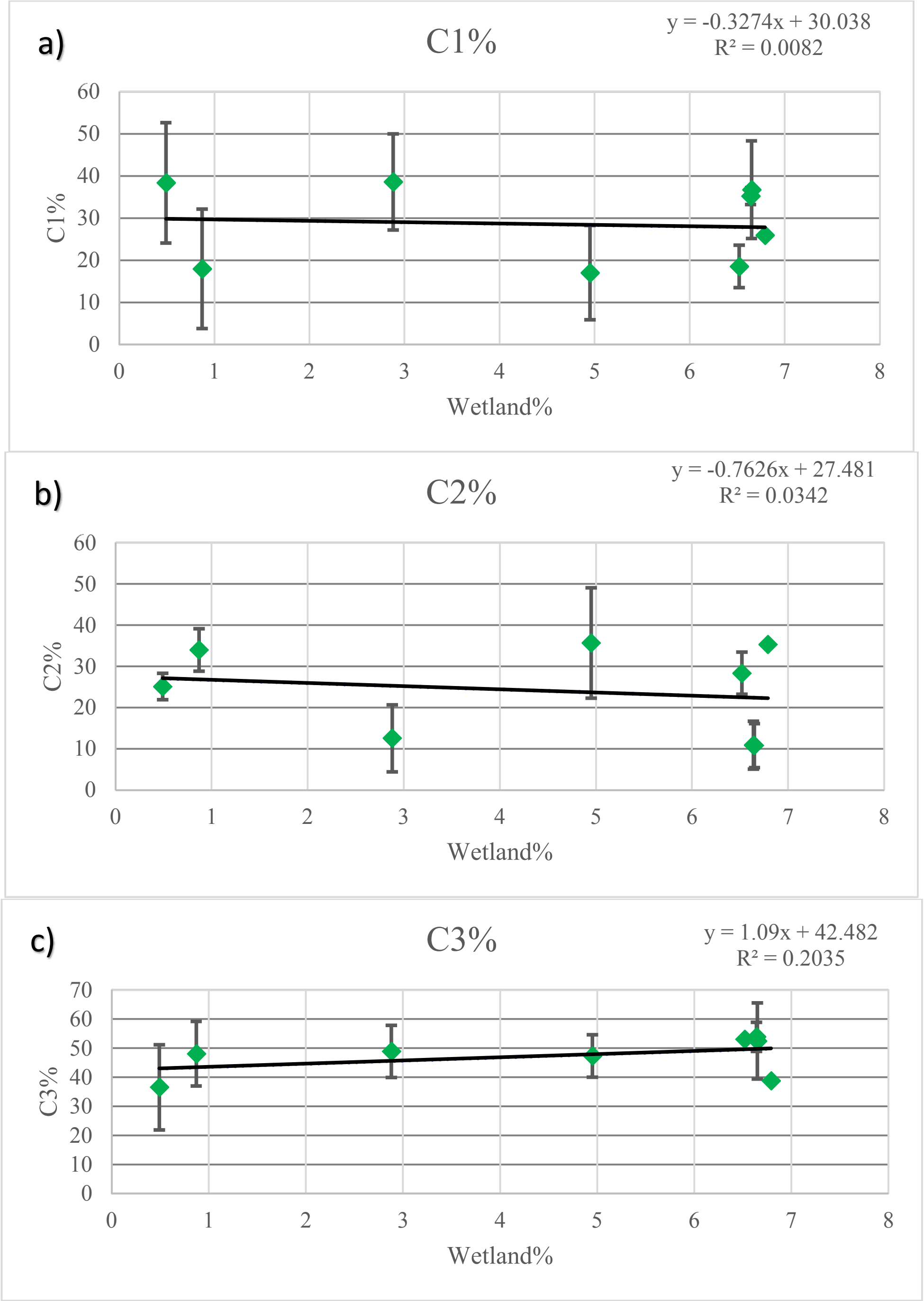


Figure 18. Wetland effect on Surface Water Quality for Percentage of DOM Components.

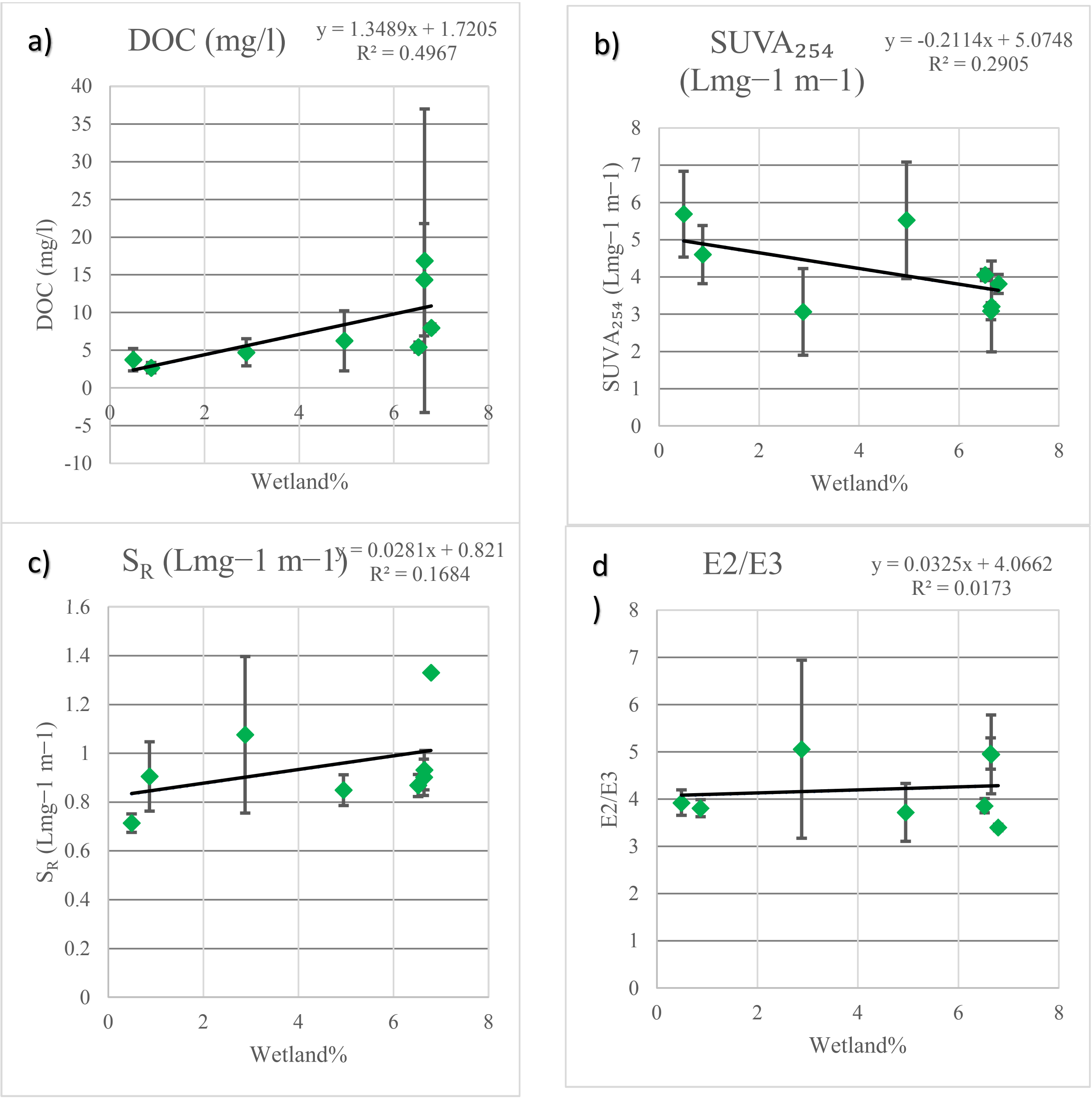


Figure 19. Wetland Effect on Surface Water Quality for DOC, $SUVA_{254}$, S_R and E2/E3.

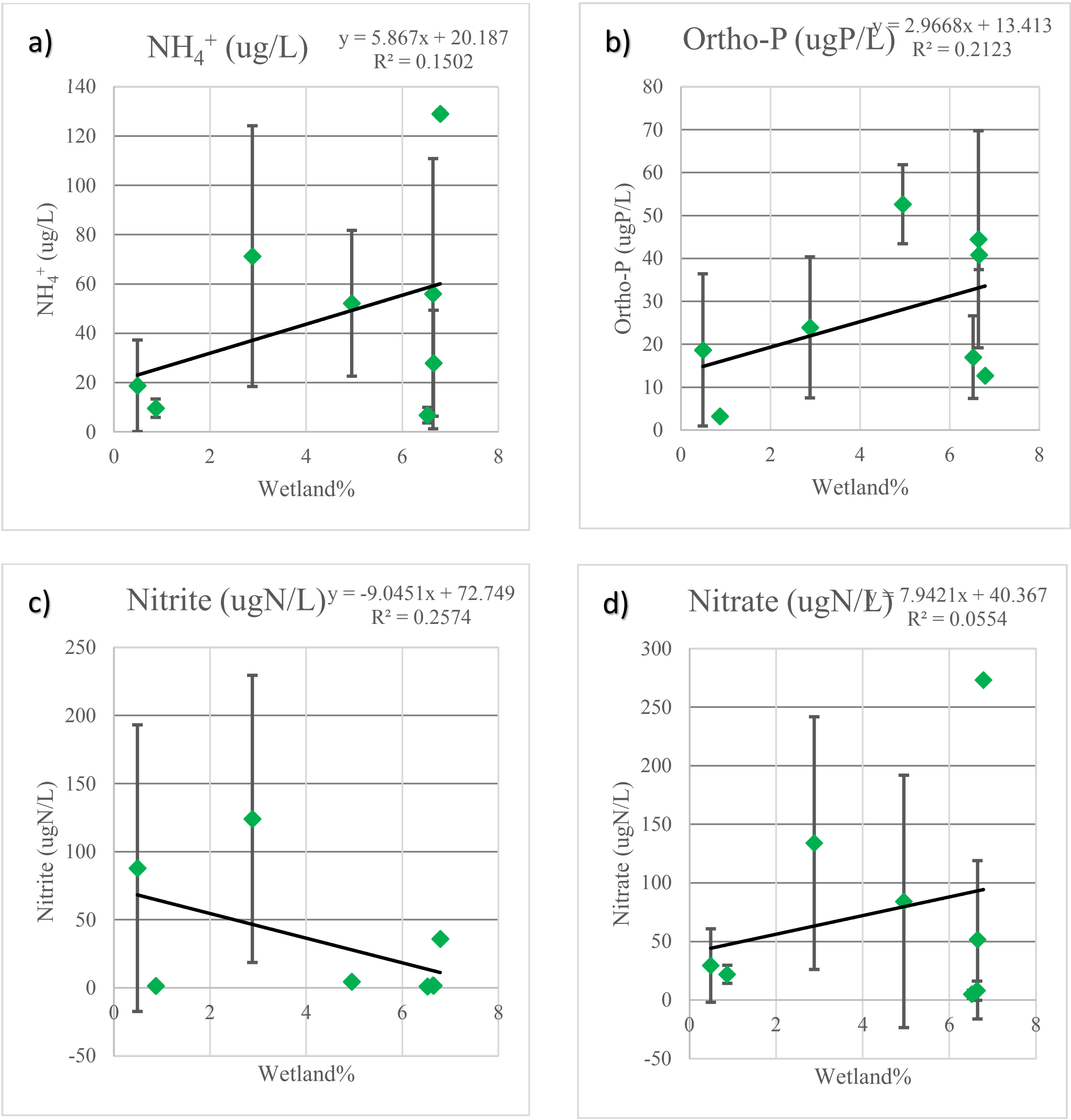


Figure 20. Wetland Effect on Surface Water Quality for Nutrients.

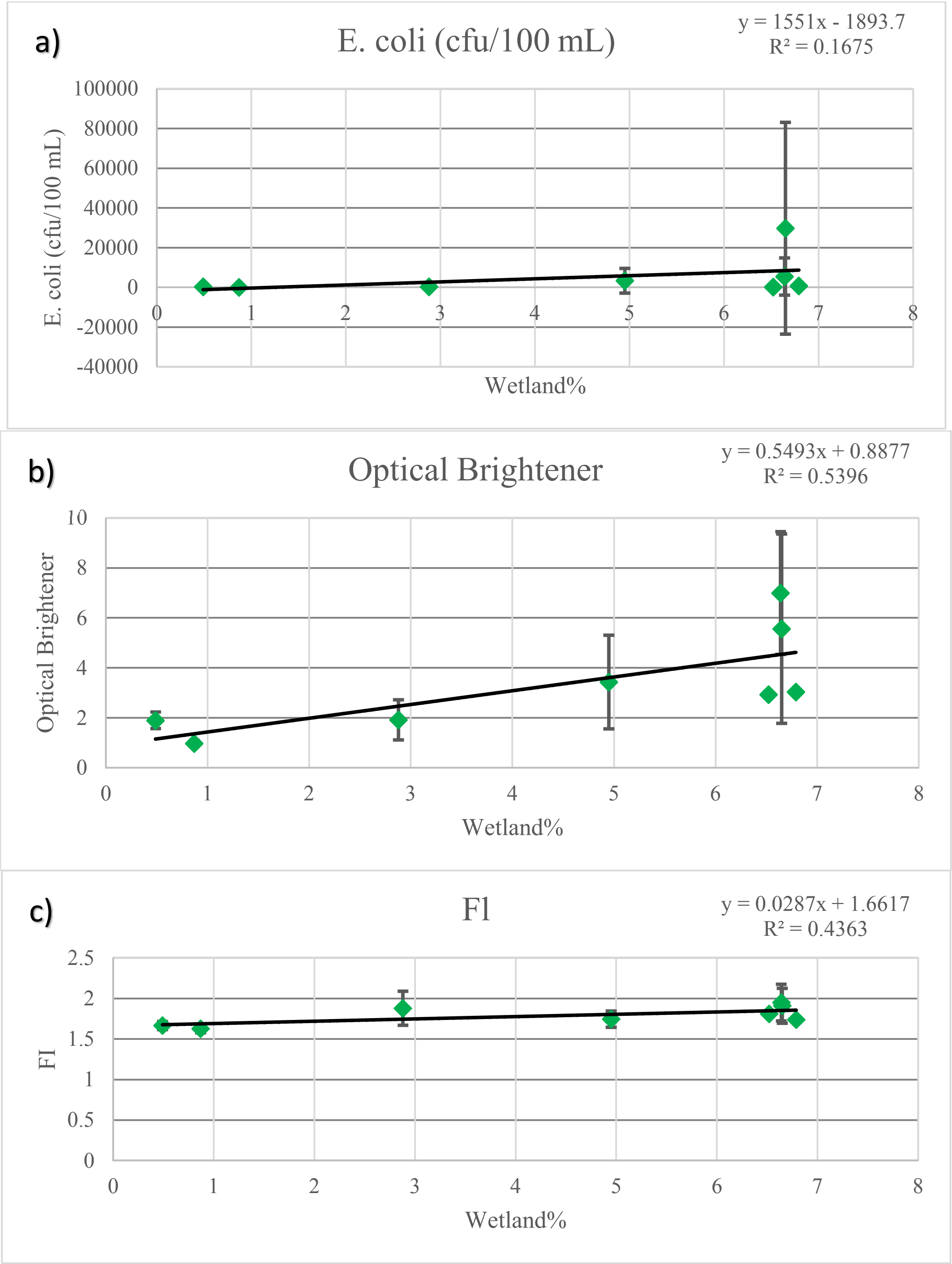


Figure 21. Wetland Effect on Surface Water Quality for *E. coli*. Optical Brightener and FI.

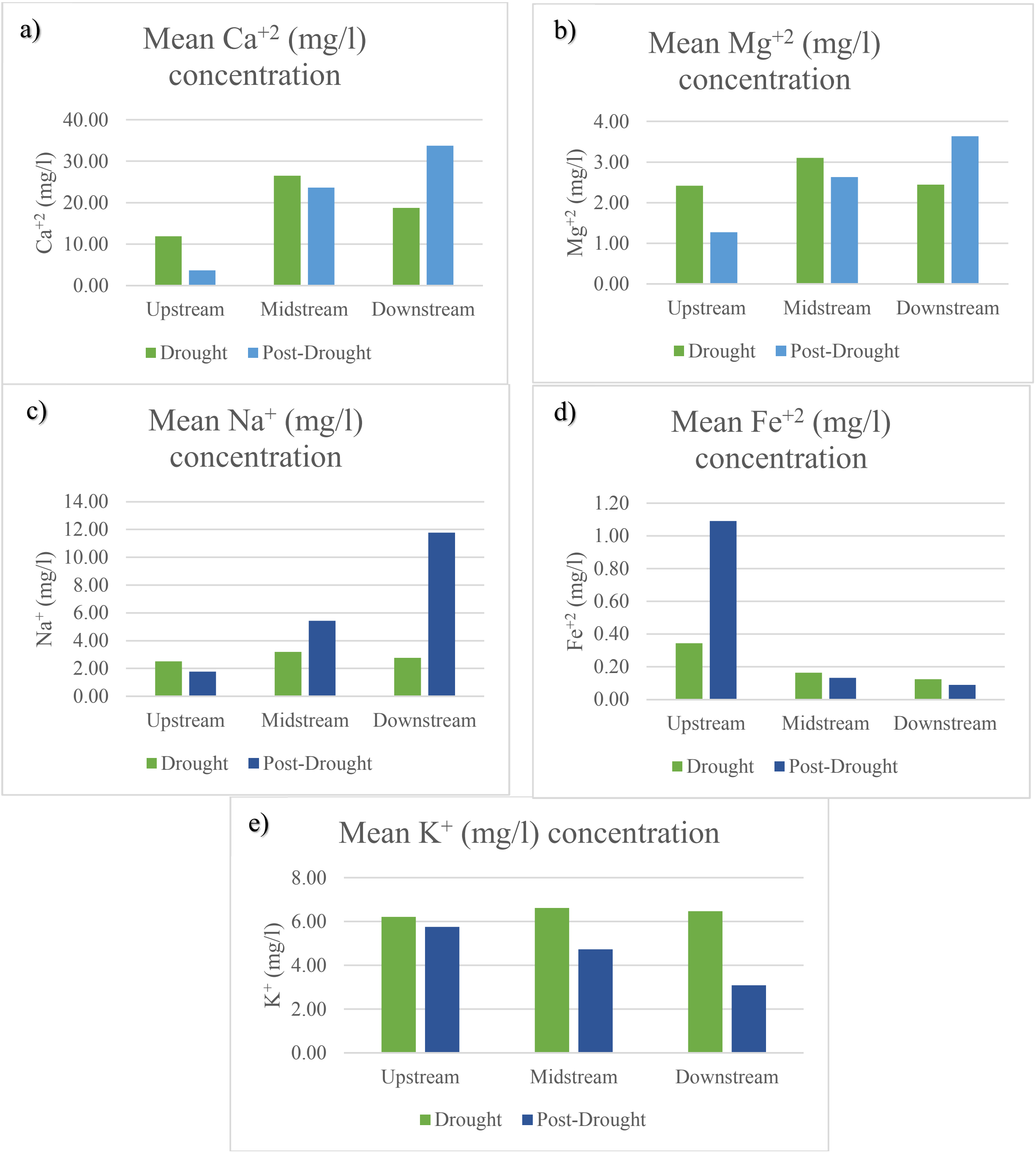


Figure 22. Mean Value of Cations for Stream Water Quality of Upstream, Midstream and Downstream.

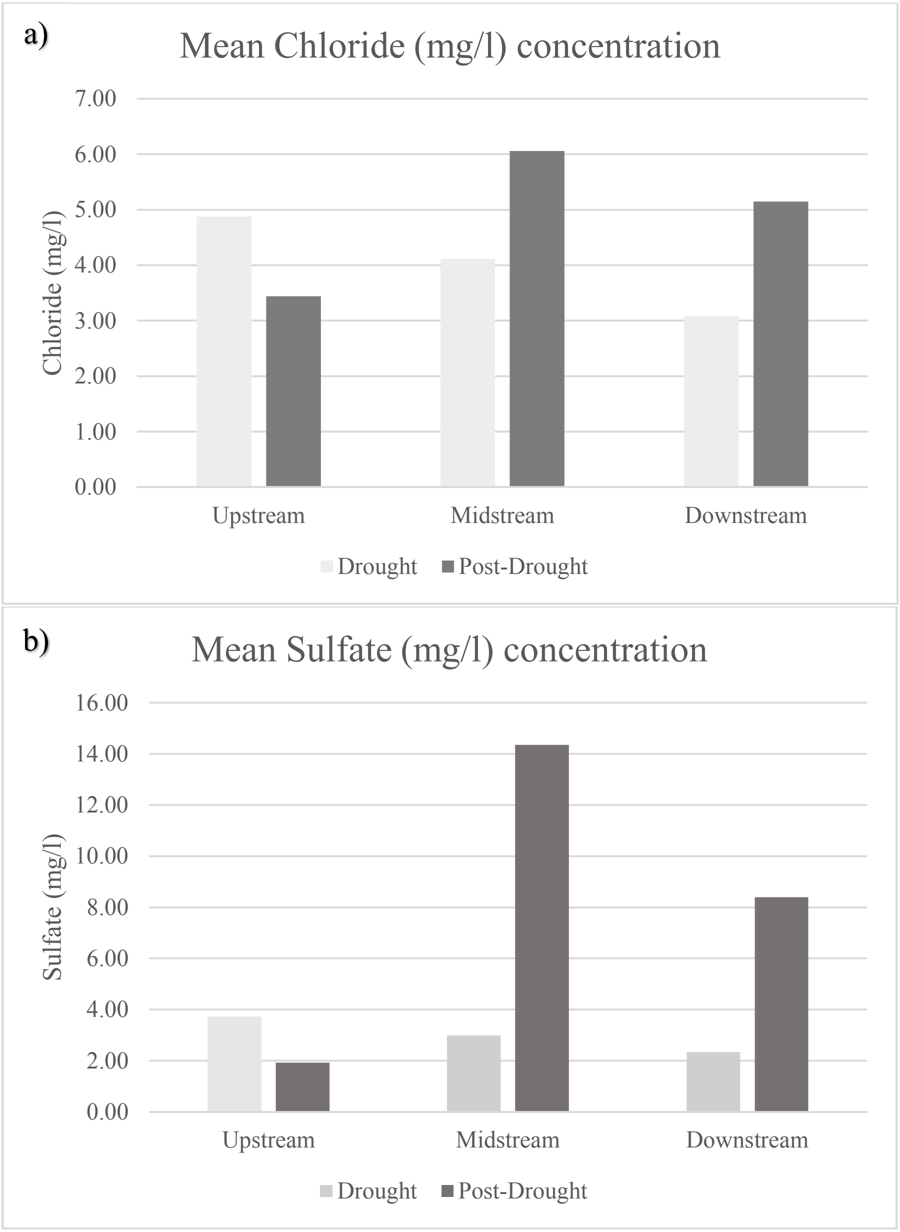


Figure 23. Mean Value of Anions for Stream Water Quality of Upstream, Midstream and Downstream.

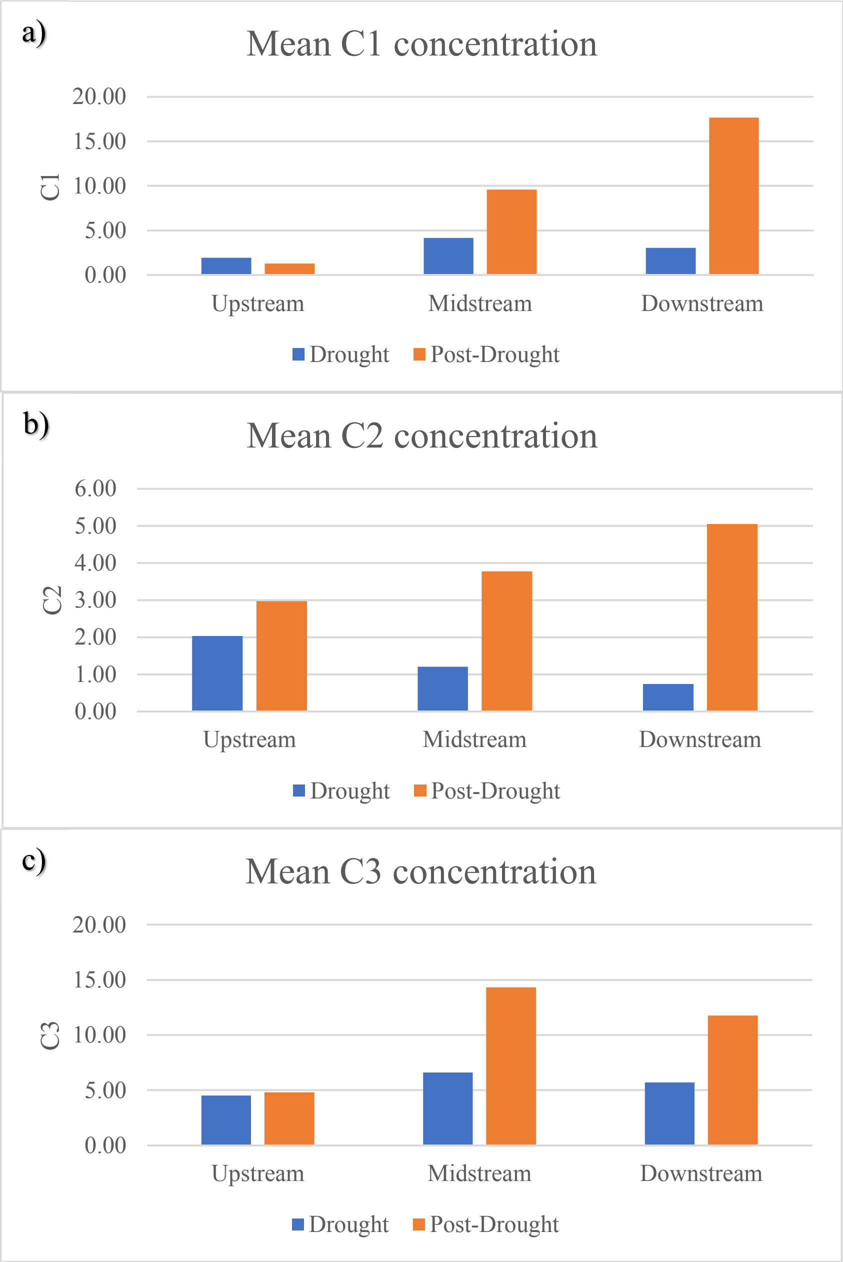


Figure 24. Mean Values of DOM Components for Stream Water Quality of Upstream, Midstream and Downstream.

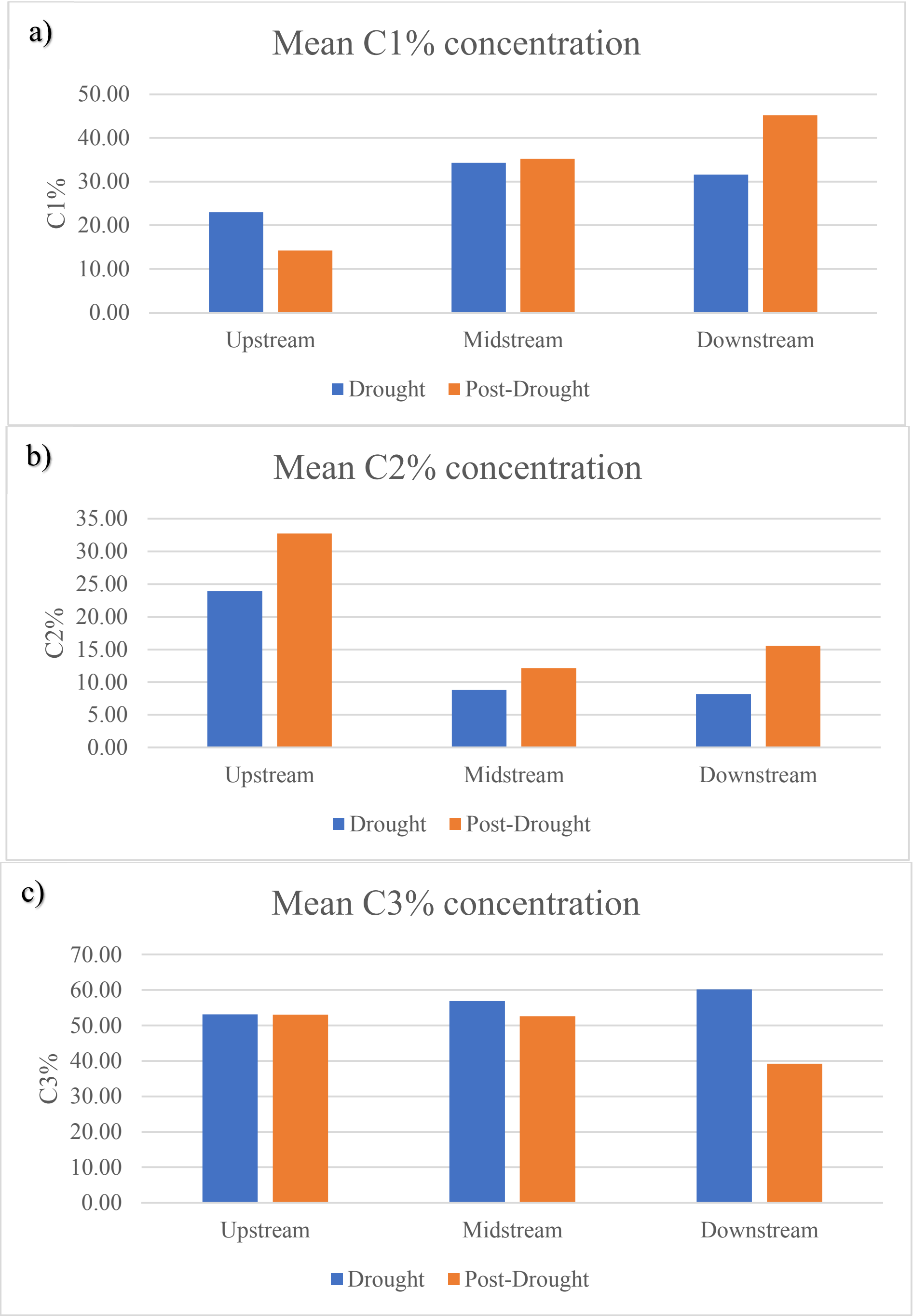


Figure 25. Percentage Mean Values of DOM Components for Stream Water Quality of Upstream, Midstream and Downstream.

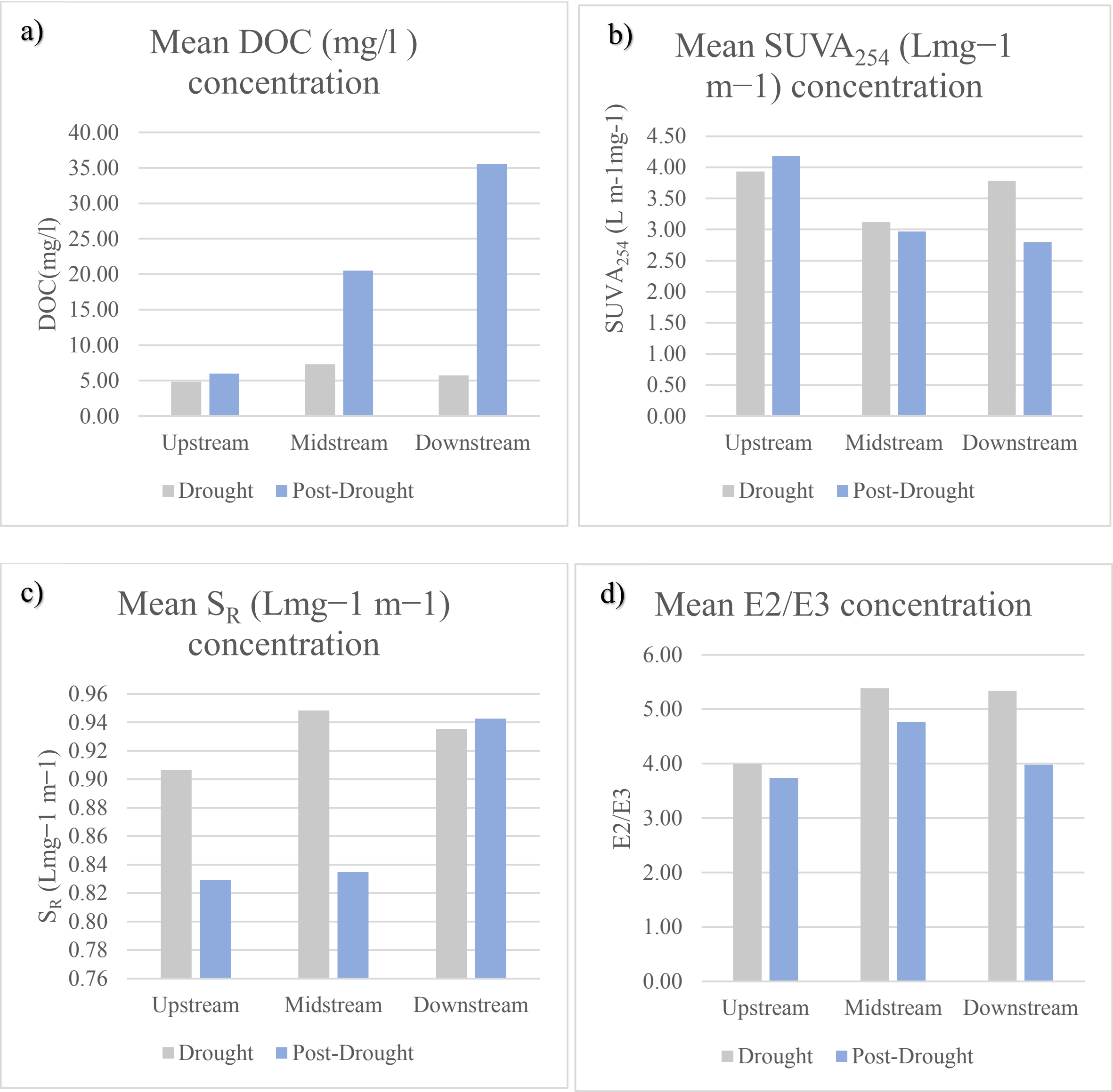


Figure 26. Mean of DOC, $SUVA_{254}$, S_R and E2/E3 Values for Stream Water Quality of Upstream, Midstream and Downstream.

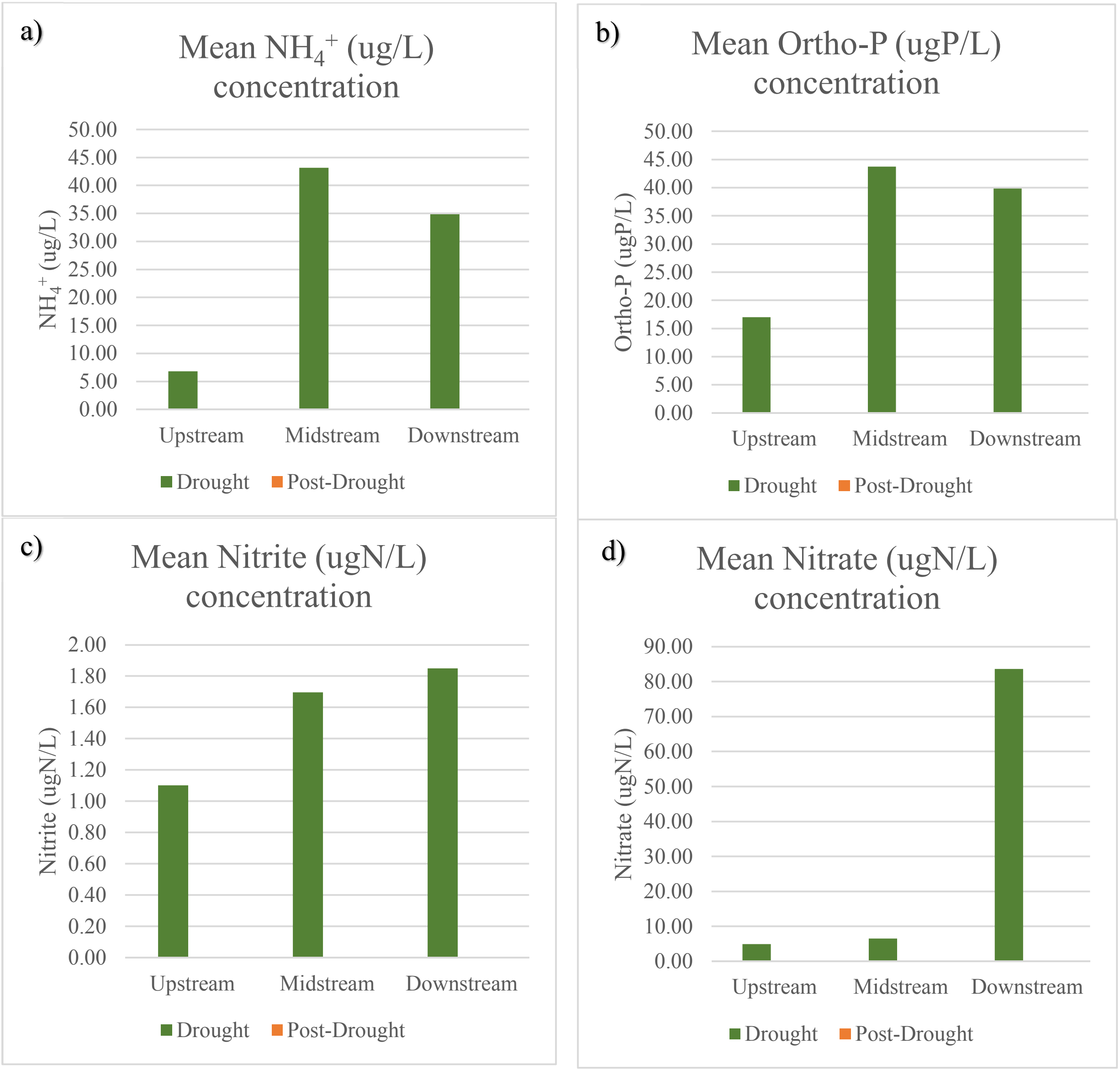


Figure 27. Mean of Nutrient Values for Stream Water Quality of Upstream, Midstream and Downstream.

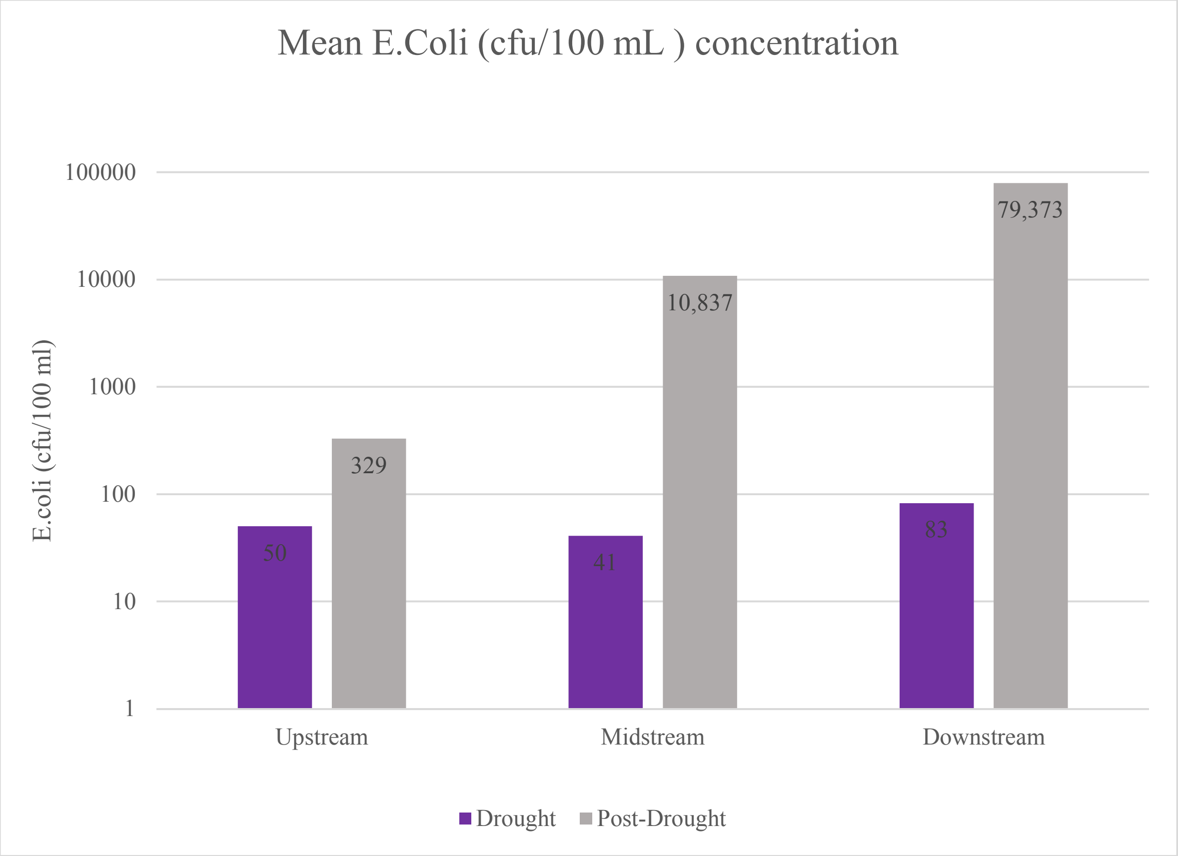


Figure 28. Mean of *E. coli* Values for Stream Water Quality of Upstream, Midstream and Downstream.

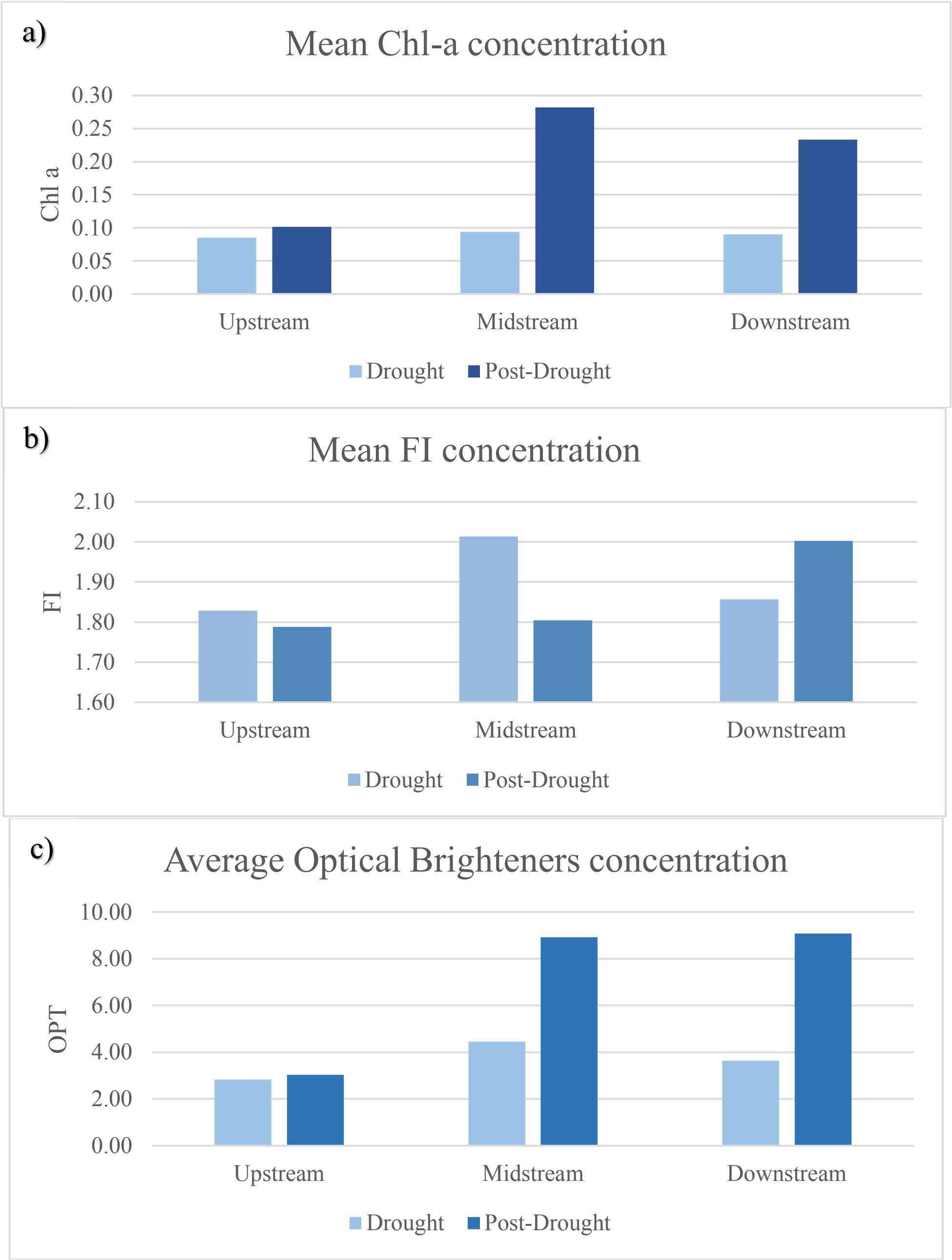


Figure 29. Mean of Chl-a, FI and Optical Brightener Values for Stream Water Quality of Upstream, Midstream and Downstream.

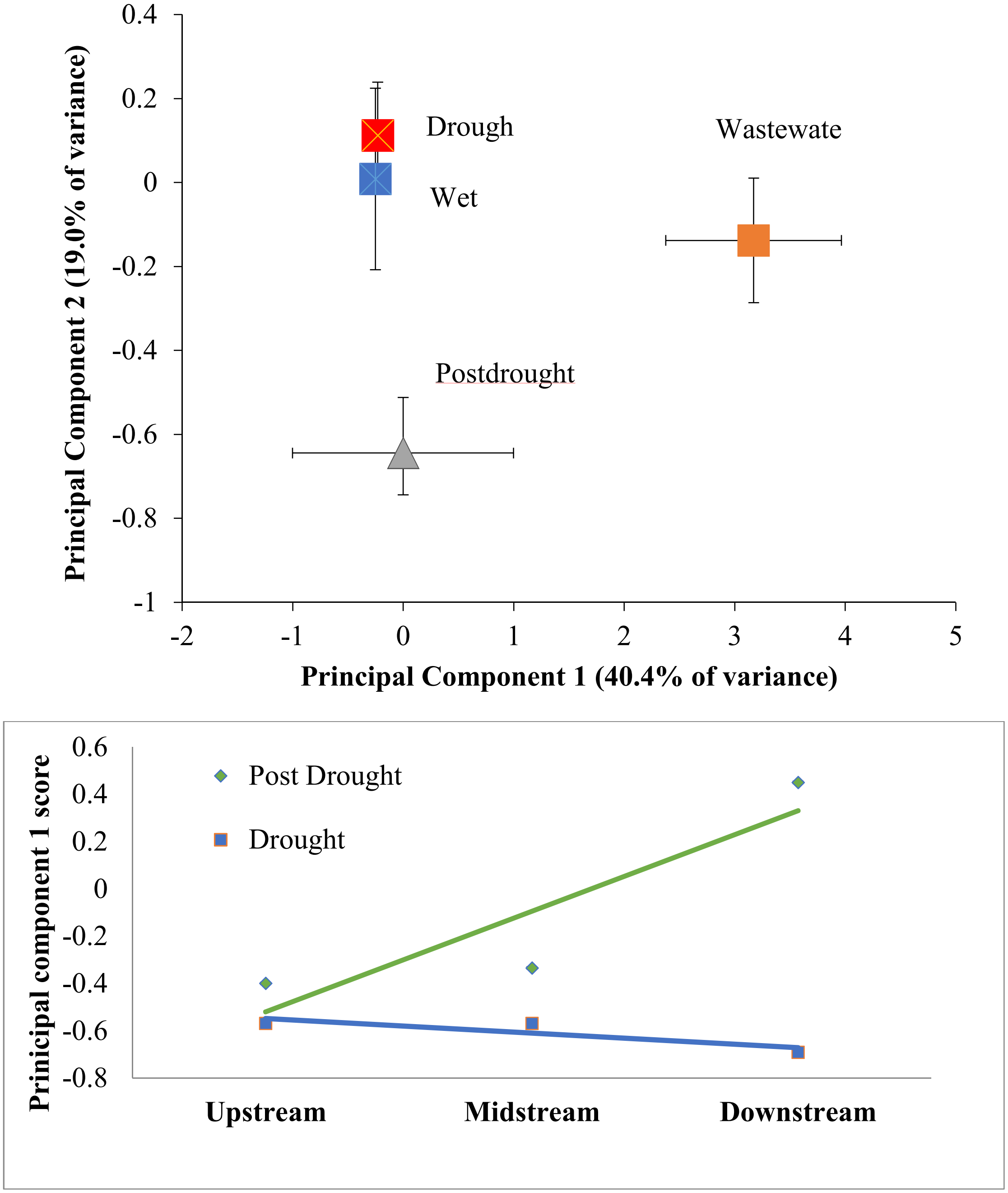


Figure 30. Median Loading Scores of PC1 (wastewater indicator) Increase Dramatically from the Upstream to Downstream Sites of Newbern after a Precipitation Event, Relative to a Decrease or Little Change During Drought.

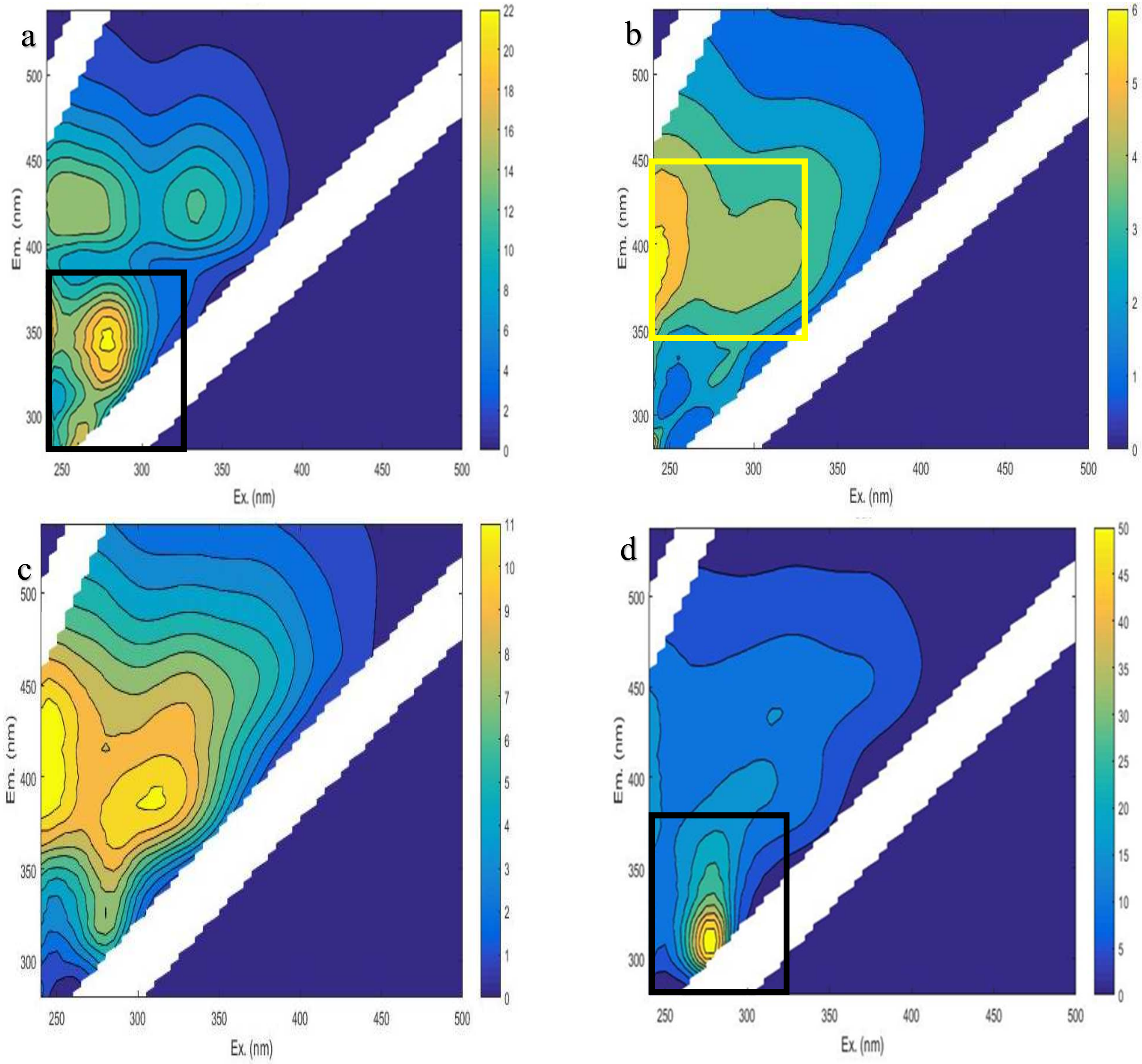


Figure 31. (a) Typical Wastewater DOM Fluorescence Results for Project Sample. Intensity is in Raman Units. The Black Rectangle Outlines the Fluorescence Region Indicative of Microbial-produced Compounds and the Yellow Rectangle Indicates Humic, Terrestrial Fluorescence. DOM Fluorescence Results for Samples Taken Post-Drought Upstream (b), Adjacent (c) and Downstream (d) of Known Straight Pipe Discharges in Newbern.

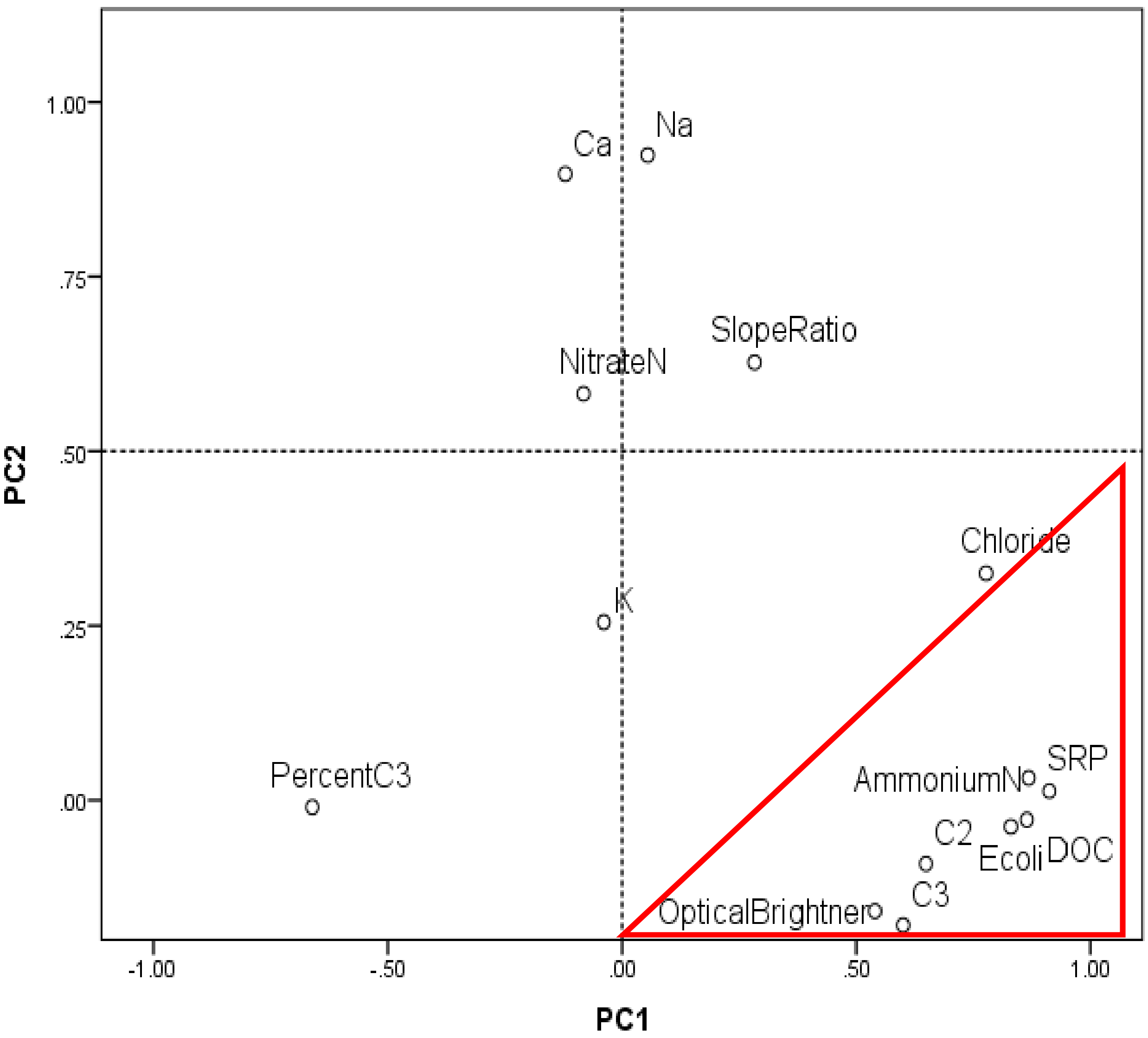


Figure 32. Principal component analysis of geochemical and microbiological indicators of stream water and wastewater samples. The upper panel shows the loading plot of different indicators with the wastewater associated analytes grouping in the bottom right (note highly-correlated indicators are removed to avoid collinearity), and the lower panel shows loading scores for different types of water samples.

Table 1. Watershed Land Use and Hydrological Parameters for the Sampling Streams in the Present Study.

Sampling sites	**Stream order**	**Sampling Dates**	**Watershed area(km2)**	**Wetland (%)**	**Planted/ Cultivated**	**Herbaceous (%)**	**Shrublands (%)**	**Developed (%)**	**Forest (%)**	**GPS Coordinates (°)**
Lindsay Ponds	2	2-Mar	3.55	0.87%	5.80%	3.97%	16.48%	6.52%	59.56%	N 32.73072 W 87.59648
Rd16 Br 1 Upst.	4	02-Mar 06-May 13-May 25-May 16-Jun 29-Jun 12-Jul 20-Oct	9.65	2.88%	4.08%	68.60%	2.58%	3.30%	7.47%	N 32.60448 W 87.5611
Rd16 Br 2	1	2-Mar	6.76	6.79%	58.54%	0.07%	3.21%	3.22%	9.63%	N 32.60581 W 87.55258
Rd16 Br 4	4	02-Mar 20-Oct 15-Nov 30-Nov	30.7	4.95%	36.43%	2.89%	12.11%	5.03%	35.78%	N 32.60497 W 87.54375
Recy. Ctr.	1	13-May 25-May 16-Jun	0.49	0.49%	NA	3.29%	27.28	2.38%	67.03%	N 32.73573 W 87.59934
BigPr- Cr Rd61	1	20-Oct 30-Nov	3.94	6.65%	14.60%	1.92%	16.06%	3.52%	55.21%	N 32.57567 W 87.53084
BigPr-Cr Windmill	3	20-Oct 15-Nov 30-Nov	30.06	6.64%	12.40%	2.01%	16.67%	3.49%	57.19%	N 32.58297 W 87.5206
BigPr-Cr-Rd48	5	20-Oct 15-Nov 30-Nov	48.39	6.52%	4.43%	1.90%	16.08%	3.23%	66.51%	N 32.6196 W 87.48964

1: Lindsay Ponds (Lindsay Ponds1, Lindsay Ponds2 and Lindsay Bridge), Rd16 Br1 Upst.(Upstream1, Upstream2, Upstream3 of Rd16 Bridge1), Rd16 Br4 (Rd16 Br3 and Rd16 Br4), Recy. Ctr. (Recycling Start, Recycling Center Site2, Recycling Center Site3 and RcUpstream), BigPr- Cr Rd61 (Culvert east side Rd61, Culvert west side Rd61, Big Prairie Creek-Jackson Sisters and Big Prairie Creek Rd61)

2: NA = data not available

Table 2. pH Parameters for the Sampling Streams in the Present Study.

Sampling sites	Sampling Dates	pH	Sampling Dates	pH	GPS Coordinates (°)
Lindsay Ponds	20-Oct	7.29	30-Nov	6.92	N 32.73072 W 87.59648
Rd16 Br 1 Upst.	20-Oct	7.19	30-Nov	7.22	N 32.60448 W 87.5611
Rd16 Br 2	20-Oct	7.24	30-Nov	7.28	N 32.60581 W 87.55258
Rd16 Br 4	20-Oct	6.93	30-Nov	7.05	N 32.60497 W 87.54375
Recy. Ctr.	20-Oct	N/A	30-Nov	N/A	N 32.73573 W 87.59934
BigPr- Cr Rd61	20-Oct	7.05	30-Nov	7.19	N 32.57567 W 87.53084
BigPr-Cr Windmill	20-Oct	7.01	30-Nov	7.01	N 32.58297 W 87.5206
BigPr-Cr-Rd48	20-Oct	7.08	30-Nov	6.92	N 32.6196 W 87.48964

1: Lindsay Ponds (Lindsay Ponds1, Lindsay Ponds2 and Lindsay Bridge), Rd16 Br1 Upst.(Upstream1, Upstream2, Upstream3 of Rd16 Bridge1), Rd16 Br4 (Rd16 Br3 and Rd16 Br4), Recy. Ctr. (Recycling Start, Recycling Center Site2, Recycling Center Site3 and RcUpstream), BigPr- Cr Rd61 (Culvert east side Rd61, Culvert west side Rd61, Big Prairie Creek-Jackson Sisters and Big Prairie Creek Rd61)

2: NA = data not available

Table 3. Conductivity Values for the Sampling Streams in the Present Study.

Sampling sites	Sampling Dates	Conductivity (µS/cm)	Sampling Dates	Conductivity (µS/cm)	GPS Coordinates (°)
Lindsay Ponds	20-Oct	37.8	30-Nov	42.3	N 32.73072 W 87.59648
Rd16 Br 1 Upst.	20-Oct	429	30-Nov	N/A	N 32.60448 W 87.5611
Rd16 Br 2	20-Oct	N/A	30-Nov	451	N 32.60581 W 87.55258
Rd16 Br 4	20-Oct	108	30-Nov	137.3	N 32.60497 W 87.54375
Recy. Ctr.	20-Oct	N/A	30-Nov	N/A	N 32.73573 W 87.59934
BigPr- Cr Rd61	20-Oct	148.4	30-Nov	375.05	N 32.57567 W 87.53084
BigPr-Cr Windmill	20-Oct	111.35	30-Nov	202.25	N 32.58297 W 87.5206
BigPr-Cr-Rd48	20-Oct	N/A	30-Nov	46.8	N 32.6196 W 87.48964

1: Lindsay Ponds (Lindsay Ponds1, Lindsay Ponds2 and Lindsay Bridge), Rd16 Br1 Upst.(Upstream1, Upstream2, Upstream3 of Rd16 Bridge1), Rd16 Br4 (Rd16 Br3 and Rd16 Br4), Recy. Ctr. (Recycling Start, Recycling Center Site2, Recycling Center Site3 and RcUpstream), BigPr- Cr Rd61 (Culvert east side Rd61, Culvert west side Rd61, Big Prairie Creek-Jackson Sisters and Big Prairie Creek Rd61)

2: NA = data not available

Table 4. Turbidity Values for the Sampling Streams in the Present Study.

Sampling sites	Sampling Dates	Turbidty (NTU)	Sampling Dates	Turbidty (NTU)	GPS Coordinates (°)
Lindsay Ponds	20-Oct	14.5	30-Nov	180	N 32.73072 W 87.59648
Rd16 Br 1 Upst.	20-Oct	7.66	30-Nov	N/A	N 32.60448 W 87.5611
Rd16 Br 2	20-Oct	N/A	30-Nov	38.3	N 32.60581 W 87.55258
Rd16 Br 4	20-Oct	9.16	30-Nov	74.9	N 32.60497 W 87.54375
Recy. Ctr.	20-Oct	N/A	30-Nov	N/A	N 32.73573 W 87.59934
BigPr- Cr Rd61	20-Oct	2.8	30-Nov	27.65	N 32.57567 W 87.53084
BigPr-Cr Windmill	20-Oct	2.15	30-Nov	119.05	N 32.58297 W 87.5206
BigPr-Cr-Rd48	20-Oct	N/A	30-Nov	10.6	N 32.6196 W 87.48964

1: Lindsay Ponds (Lindsay Ponds1, Lindsay Ponds2 and Lindsay Bridge), Rd16 Br1 Upst.(Upstream1, Upstream2, Upstream3 of Rd16 Bridge1), Rd16 Br4 (Rd16 Br3 and Rd16 Br4), Recy. Ctr. (Recycling Start, Recycling Center Site2, Recycling Center Site3 and RcUpstream), BigPr- Cr Rd61 (Culvert east side Rd61, Culvert west side Rd61, Big Prairie Creek-Jackson Sisters and Big Prairie Creek Rd61)
2: NA = data not available

Table 5. Geology Type of Watershed for the Sampling Streams in the Present Study.

Sampling sites	**Sampling Dates**	**Unit Age**	**Rock Type 1/2**	**GPS Coordinates (°)**
Lindsay Ponds	2-Mar	Cretaceous	Sand/Clay or Mud	N 32.73072 W 87.59648
Rd16 Br 1 Upst.	02-Mar 06-May 13-May 25-May 16-Jun 29-Jun 12-Jul 20-Oct	Holocene	Beach sand / Alluvium	N 32.60448 W 87.5611
Rd16 Br 2	2-Mar	Holocene	Beach sand / Alluvium	N 32.60581 W 87.55258
Rd16 Br 4	02-Mar 20-Oct 15-Nov 30-Nov	Holocene	Beach sand / Alluvium	N 32.60497 W 87.54375
Recy. Ctr.	13-May 25-May 16-Jun	Cretaceous	Sand/Clay or Mud	N 32.73573 W 87.59934
BigPr- Cr Rd61	20-Oct 30-Nov	Cretaceous	Carbonate / Mixed clastic	N 32.57567 W 87.53084
BigPr-Cr Windmill	20-Oct 15-Nov 30-Nov	Holocene	Beach sand / Alluvium	N 32.58297 W 87.5206
BigPr-Cr-Rd48	20-Oct 15-Nov 30-Nov	Holocene	Beach sand / Alluvium	N 32.6196 W 87.48964

1: Lindsay Ponds (Lindsay Ponds1, Lindsay Ponds2 and Lindsay Bridge), Rd16 Br1 Upst.(Upstream1, Upstream2, Upstream3 of Rd16 Bridge1), Rd16 Br4 (Rd16 Br3 and Rd16 Br4), Recy. Ctr. (Recycling Start, Recycling Center Site2, Recycling Center Site3 and RcUpstream), BigPr- Cr Rd61 (Culvert east side Rd61, Culvert west side Rd61, Big Prairie Creek-Jackson Sisters and Big Prairie Creek Rd61)

2: NA = data not available

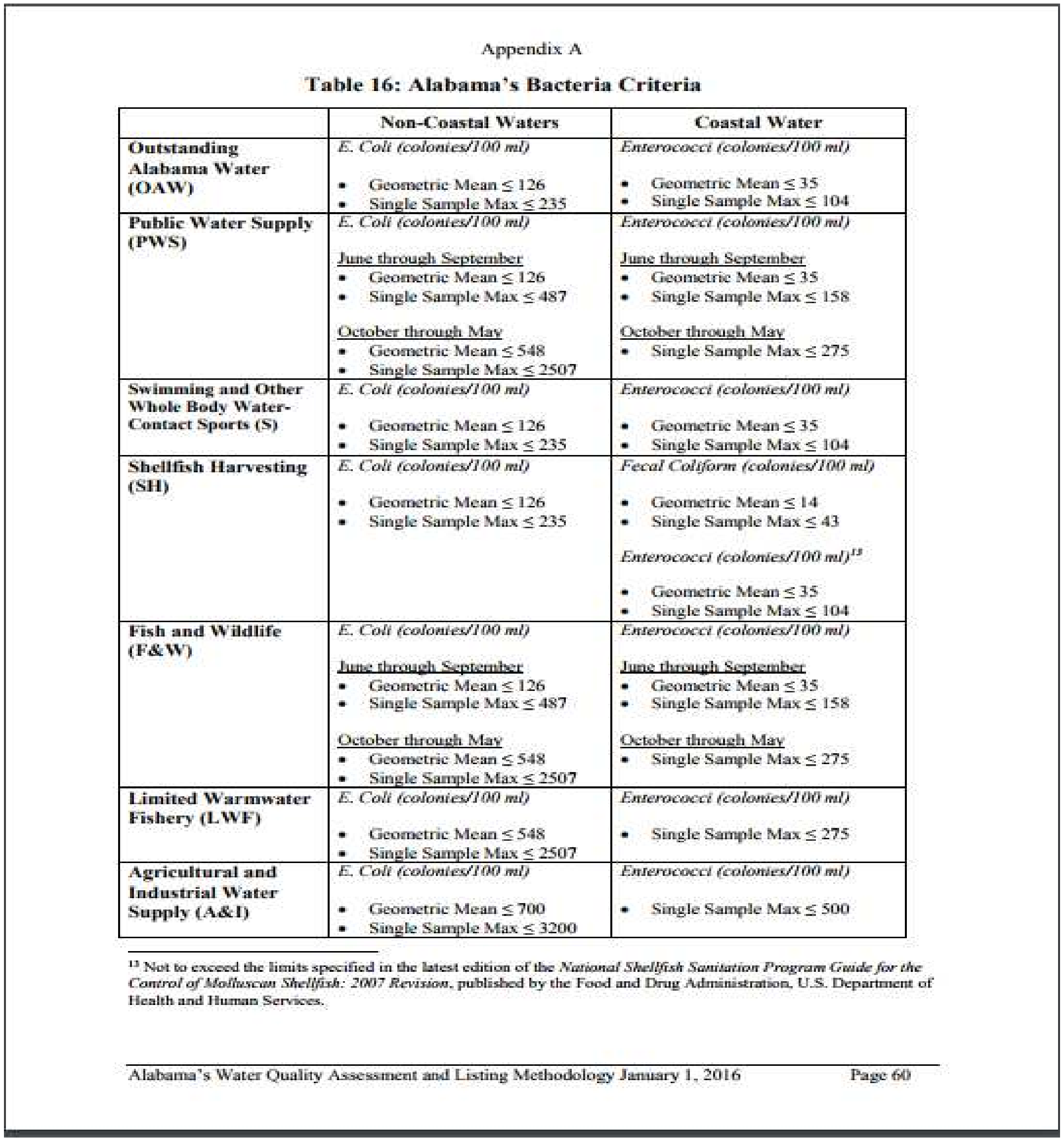
Table 6. Characteristics of the Three Fluorescence Components Identified by PARAFAC and the Attributed Sources for May.

Component	**Excitation maximum wavelength**	**Emission maximum wavelength**	**Similar fluorescence components identified in previous studies**				**Present study**
			Youhei Yamashita2013, 2015	Yulia Shutova 2014	Murphy et al. 2013	Osburn et al. 2016	
C1	<240 (340)	392	C2	C2	Nutrient-rich environment	C2	Microbial humic-like DOM
C2	280 (<240)	340	C3	C4	C5 Wetland, Forest	NA	Terrestrial humic-like DOM
C3	<270 (352)	472	C1	NA	C3	C1	Protein-like DOM from

Table 7. Characteristics of the Three Fluorescence Components Identified by PARAFAC and the Attributed Sources for Mar, Jun, Jul, Aug, Oct and Nov.

Component	**Excitation maximum wavelength**	**Emission maximum wavelength**	**Similar fluorescence components identified in previous studies**				**Present study**
			D.N.Kothawala 2014	K.R. Murphy 2013	Chris Osburn 2014	Adam Hambly 2015	
C1	280 (<240)	322	NA	C5	C5	C5	Protein-like DOM
C2	280 (<240)	<280 (340)	C6	C5	NA	C5	Protein-like DOM
C3	340 (<245)	424	NA	NA	NA	NA	Humic-like DOM

Table 8. Alabama’s Bacteria Criteria from (ADEM, 2016).



Appendix A

Table 16: Alabama’s Bacteria Criteria

	Non-Coastal Waters	**Coastal Water**
Outstanding Alabama Water (OAW)	*E. Coli (colonies/100 ml)* • Geometric Mean ≤ 126 • Single Sample Max ≤ 235	*Enterococci (colonies/100 ml)* • Geometric Mean ≤ 35 • Single Sample Max ≤ 104
Public Water Supply (PWS)	*E. Coli (colonies/100 ml)* June through September • Geometric Mean ≤ 126 • Single Sample Max ≤ 487 October through May • Geometric Mean ≤ 548 • Single Sample Max ≤ 2507	*Enterococci (colonies/100 ml)* June through September • Geometric Mean ≤ 35 • Single Sample Max ≤ 158 October through May • Single Sample Max ≤ 275
Swimming and Other Whole Body Water-Contact Sports (S)	*E. Coli (colonies/100 ml)* • Geometric Mean ≤ 126 • Single Sample Max ≤ 235	*Enterococci (colonies/100 ml)* • Geometric Mean ≤ 35 • Single Sample Max ≤ 104
Shellfish Harvesting (SH)	*E. Coli (colonies/100 ml)* • Geometric Mean ≤ 126 • Single Sample Max ≤ 235	*Fecal Coliform (colonies/100 ml)* • Geometric Mean ≤ 14 • Single Sample Max ≤ 43 *Enterococci (colonies/100 ml)*[13] • Geometric Mean ≤ 35 • Single Sample Max ≤ 104
Fish and Wildlife (F&W)	*E. Coli (colonies/100 ml)* June through September • Geometric Mean ≤ 126 • Single Sample Max ≤ 487 October through May • Geometric Mean ≤ 548 • Single Sample Max ≤ 2507	*Enterococci (colonies/100 ml)* June through September • Geometric Mean ≤ 35 • Single Sample Max ≤ 158 October through May • Single Sample Max ≤ 275
Limited Warmwater Fishery (LWF)	*E. Coli (colonies/100 ml)* • Geometric Mean ≤ 548 • Single Sample Max ≤ 2507	*Enterococci (colonies/100 ml)* • Single Sample Max ≤ 275
Agricultural and Industrial Water Supply (A&I)	*E. Coli (colonies/100 ml)* • Geometric Mean ≤ 700 • Single Sample Max ≤ 3200	*Enterococci (colonies/100 ml)* • Single Sample Max ≤ 500

[13] Not to exceed the limits specified in the latest edition of the *National Shellfish Sanitation Program Guide for the Control of Molluscan Shellfish: 2007 Revision*, published by the Food and Drug Administration, U.S. Department of Health and Human Services.

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Table 9. The precipitation data of the sampling area.

Month	January	February	March	April	May	June	July	August	Septembe	October	Novembe	December
Days	**Rainfall in inches**											
1	0	9	0.29	0	0.15	0	0	0	0	0	0	0
2	0	3.8	0	0	2.42	0	0	0.19	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	-
4	0	0	0	0	0	0.17	0	0.02	0	0	0	-
5	0	0	0	0	0	0	T	T	0	0	0	-
6	0	0	0	0.35	0	0.03	0	0	0	0	0	0
7	0.07	0	0	0	0	0	0	0.18	0	0	0	0
8	0	0	0	0	0	0	0	0.12	0	0	0	0
9	1.04	0	0	0	0	0	1.07	0.71	0	0	0	0
10	0	0	2.39	0	0	0	0	T	0	0	0	0
11	0	0	0.39	2.37	T	T	0	T	T	0	0	0
12	0	0	0.23	0	1.03	T	1.5	0.6	0	0	0	-
13	0	0	0	0.22	0	0.35	0	0.14	T	0	0	-
14	T	0	0	T	0	-	2.15	0.17	0	0	0	0
15	0.08	1.31	0	0	0	-	0	0.01	0	0	0.01	0
16	T	0	0	T	0	0	0	0	0	0	0	0
17	0.08	0	0.25	0	0.16	0.87	0	T	2.24	0	0	-
18	0	0	0.85	0	0.1	0	0	-	0	0	0	0.6
19	0	0	0	0	-	0	0	-	0	0	0	0
20	-	0	0	0	-	0	T	0.3	0	0	0	0
21	-	-	0	0.87	0	0	0	0	0	0.01	0	0
22	-	-	0	0.15	0	0	0	0.62	0	0	0	0
23	0	1.12	0	0	0	0	0	0	0	0	0	0
24	0	T	0.16	0	0	0	0	0	T	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
26	1.42	0	0	0	0	0	T	0	0	0	0	0
27	0	0	0.34	0.54	0	0	T	0	0	0	0	0
28	0	0	0	0	0	0	0.5	0	0	0	3.57	0.01
29	0	0	0	T	0	0	0	0	0	0	-	0
30	0	0	0	0.01	0	0	0.18	0	0	0	1.8	0
31	0	0	0	0	0	-	0	0		0	-	-

APPENDIX

				CATIONS					**ANIONS**	
Sample category	**Sample site**	**Sampling Date**	**Sample Name**	**Ca(mg/l)**	**Fe(mg/l)**	**Mg(mg/l)**	**K(mg/l)**	**Na(mg/l)**	**Chloride (mg/l)**	**Sulfate (mg/l)**
Wet	Lindsay Bridge	2-Mar-16	Lindsay_Bridge_Doma030216	1.56	0.28	0.87	0.71	1.92	N/A	N/A
Wet	Lindsay Bridge	2-Mar-16	Lindsay_Bridge_Domb030216	1.53	0.28	0.85	0.70	1.88	N/A	N/A
Wet	Lindsay Pond 1	2-Mar-16	Lindsay_Pond_1_Doma030216	6.74	0.53	1.43	0.87	2.77	N/A	N/A
Wet	Lindsay Pond 1	2-Mar-16	Lindsay_Pond_1_Domb030216	6.72	0.52	1.43	0.91	2.74	N/A	N/A
Wet	Lindsay Pond 2	2-Mar-16	Lindsay_Pond_2_Doma030216	1.78	0.13	0.61	1.10	4.29	N/A	N/A
Wet	Lindsay Pond 2	2-Mar-16	Lindsay_Pond_2_Domb030216	1.54	0.14	0.63	1.17	1.18	N/A	N/A
Wet	Road 16 Bridge 1	2-Mar-16	Rd16bridge1_Doma030216	44.94	0.32	2.00	5.27	10.46	N/A	N/A
Wet	Road 16 Bridge 1	2-Mar-16	Rd16bridge1_Domb030216	44.40	0.25	1.96	5.22	10.50	N/A	N/A
Wet	Road 16 Bridge 2	2-Mar-16	Rd16bridge2_Doma030216	43.95	0.26	2.26	9.58	25.51	N/A	N/A
Wet	Road 16 Bridge 2	2-Mar-16	Rd16bridge2_Domb030216	44.79	0.30	2.28	9.84	25.76	N/A	N/A
Wet	Road 16 Bridge 3	2-Mar-16	Rd16bridge3_Doma030216	28.66	0.82	1.70	1.55	3.76	N/A	N/A

Wet	Road 16 Bridge 3	2-Mar-16	Rd16bridge3_Domb030216	29.05	0.82	1.70	1.62	3.75	N/A	N/A
Wet	Road 16 Bridge 4	2-Mar-16	Rd16bridge4_Doma030216	16.42	0.68	1.49	2.30	4.60	N/A	N/A
Wet	Road 16 Bridge 4	2-Mar-16	Rd16bridge4_Domb030216	16.10	0.66	1.45	2.25	4.50	N/A	N/A
Wet	Road 16 Bridge 1	12-Jul-16	Cr_16bridge_1a071216	32.32	0.20	1.54	2.44	2.75	2.68	1.06
Wet	Road 16 Bridge 1	12-Jul-16	Cr_16bridge_1b071216	32.48	0.19	1.52	2.39	2.43	2.49	1.05
Wet	Road 16 Bridge 4	12-Jul-16	Cr_16bridge_4a071216	15.15	0.46	1.92	2.71	3.40	2.74	1.70
Wet	Road 16 Bridge 4	12-Jul-16	Cr_16bridge_4b071216	14.94	0.47	1.89	2.70	3.29	2.14	1.33
Wet	Upstream 1	12-Jul-16	Upstream_1a071216	121.63	0.01	4.61	2.98	31.37	24.04	75.29
Wet	Upstream 1	12-Jul-16	Upstream_1b071216	121.75	0.01	4.62	3.07	31.77	28.95	97.75
Wet	Upstream 2	12-Jul-16	Upstream_2a071216	65.31	0.03	3.46	5.01	13.80	12.72	74.06
Wet	Upstream 2	12-Jul-16	Upstream_2b071216	64.81	0.02	3.46	4.73	13.66	14.73	76.07
Wet	Upstream 3	12-Jul-16	Upstream_3a071216	83.61	0.01	3.47	6.51	21.23	25.54	74.39
Wet	Upstream 3	12-Jul-16	Upstream_3b071216	83.58	0.01	3.53	6.45	21.35	20.54	71.58

				DOM COMPONENTS								
Sample category	**Sample site**	**Sampling Date**	**Sample Name**	**C1**	**C2**	**C3**	**C1%**	**C2%**	**C3%**	**DOC mg/l**	**SUVA□□□ Lmg−1 m−1**	**S_R Lmg−1 m−1**

Wet	Lindsay Bridge	2-Mar-16	Lindsay_Bridge_Doma030216	0.00	0.87	1.41	0.00	37.99	62.01	1.90	5.74	0.76
Wet	Lindsay Bridge	2-Mar-16	Lindsay_Bridge_Domb030216	0.00	0.85	1.41	0.00	37.79	62.21	2.03	5.36	0.76
Wet	Lindsay Pond 1	2-Mar-16	Lindsay_Pond_1_Doma030216	1.34	1.19	1.78	31.19	27.56	41.25	3.46	3.90	0.89
Wet	Lindsay Pond 1	2-Mar-16	Lindsay_Pond_1_Domb030216	1.10	1.07	1.76	28.02	27.17	44.81	3.49	3.84	0.88
Wet	Lindsay Pond 2	2-Mar-16	Lindsay_Pond_2_Doma030216	0.86	1.27	1.35	24.69	36.58	38.73	2.67	4.31	1.09
Wet	Lindsay Pond 2	2-Mar-16	Lindsay_Pond_2_Domb030216	0.81	1.23	1.32	24.04	36.66	39.30	2.59	4.44	1.05
Wet	Road 16 Bridge 1	2-Mar-16	Rd16bridge1_Doma030216	2.52	4.53	5.89	19.49	35.00	45.52	7.96	4.44	1.18
Wet	Road 16 Bridge 1	2-Mar-16	Rd16bridge1_Domb030216	2.34	4.27	5.79	18.86	34.42	46.72	7.62	4.46	1.16
Wet	Road 16 Bridge 2	2-Mar-16	Rd16bridge2_Doma030216	3.11	4.32	4.73	25.61	35.55	38.85	7.64	3.99	1.33
Wet	Road 16 Bridge 2	2-Mar-16	Rd16bridge2_Domb030216	3.19	4.25	4.69	26.30	35.06	38.64	8.35	3.63	1.33
Wet	Road 16 Bridge 3	2-Mar-16	Rd16bridge3_Doma030216	0.47	8.57	8.76	2.62	48.15	49.23	9.07	5.85	0.95
Wet	Road 16 Bridge 3	2-Mar-16	Rd16bridge3_Domb030216	0.81	7.93	8.58	4.69	45.78	49.53	7.95	6.48	0.91
Wet	Road 16 Bridge 4	2-Mar-16	Rd16bridge4_Doma030216	0.61	2.77	3.21	9.30	41.98	48.72	3.67	6.32	0.85
Wet	Road 16 Bridge 4	2-Mar-16	Rd16bridge4_Domb030216	0.51	2.70	3.20	7.94	42.10	49.96	3.68	6.17	0.86
Wet	Road 16 Bridge 1	12-Jul-16	Cr_16bridge_1a071216	1.14	0.78	2.30	26.99	18.45	54.55	2.07	4.88	0.88
Wet	Road 16 Bridge 1	12-Jul-16	Cr_16bridge_1b071216	1.31	0.66	2.35	30.28	15.38	54.35	2.16	4.77	0.85

Wet	Road 16 Bridge 4	12-Jul-16	Cr_16bridge_4a071216	1.32	1.32	3.32	22.11	22.18	55.71	2.93	5.20	0.82
Wet	Road 16 Bridge 4	12-Jul-16	Cr_16bridge_4b071216	1.17	1.46	3.34	19.64	24.45	55.91	3.05	4.98	0.81
Wet	Upstream 1	12-Jul-16	Upstream_1a071216	1.68	0.10	1.76	47.39	2.86	49.75	2.80	2.25	1.07
Wet	Upstream 1	12-Jul-16	Upstream_1b071216	1.72	0.14	1.66	48.81	4.05	47.14	2.76	2.35	1.19
Wet	Upstream 2	12-Jul-16	Upstream_2a071216	2.34	0.60	2.64	41.95	10.70	47.36	4.60	2.65	1.04
Wet	Upstream 2	12-Jul-16	Upstream_2b071216	2.35	0.61	2.64	41.98	10.82	47.19	4.41	2.86	1.05
Wet	Upstream 3	12-Jul-16	Upstream_3a071216	2.95	0.37	2.86	47.71	6.02	46.27	6.72	1.82	1.20
Wet	Upstream 3	12-Jul-16	Upstream_3b071216	2.99	0.40	2.87	47.80	6.38	45.82	6.74	1.86	1.20

						NUTRIENTS				**BACTERIA**		
Sample category	**Sample site**	**Sampling Date**	**Sample Name**	**E2/E3**	**E4/E6**	**NH4 ug/L**	**Ortho-P ugP/L**	**nitrite ugN/L**	**Nitrate ugN/L**	**E. coli cfu/100 mL**	**Optical Brightener**	**FI**
Wet	Lindsay Bridge	2-Mar-16	Lindsay_Bridge_Doma030216	3.61	4.00	14.40	2.70	1.11	30.89	69.37	0.96	1.66
Wet	Lindsay Bridge	2-Mar-16	Lindsay_Bridge_Domb030216	3.61	8.00	14.20	3.60	1.43	31.07	69.37	0.96	1.62
Wet	Lindsay Pond 1	2-Mar-16	Lindsay_Pond_1_Doma030216	3.97	8.00	8.43	3.56	1.70	11.80	3.05	1.11	1.66
Wet	Lindsay Pond 1	2-Mar-16	Lindsay_Pond_1_Domb030216	3.97	8.00	8.25	3.93	1.73	17.37	3.05	1.10	1.67
Wet	Lindsay Pond 2	2-Mar-16	Lindsay_Pond_2_Doma030216	3.72	3.67	5.99	2.68	1.03	20.57	4.93	0.86	1.58

Wet	Lindsay Pond 2	2-Mar-16	Lindsay_Pond_2_Domb030216	3.97	3.33	6.37	3.13	1.46	20.24	4.93	0.84	1.55
Wet	Road 16 Bridge 1	2-Mar-16	Rd16bridge1_Doma030216	3.61	2.60	15.60	40.00	17.10	170.10	47.00	3.64	1.66
Wet	Road 16 Bridge 1	2-Mar-16	Rd16bridge1_Domb030216	3.76	2.92	17.20	29.40	14.40	151.80	47.00	3.59	1.65
Wet	Road 16 Bridge 2	2-Mar-16	Rd16bridge2_Doma030216	3.35	2.38	130.00	13.00	35.80	271.80	831.50	3.06	1.73
Wet	Road 16 Bridge 2	2-Mar-16	Rd16bridge2_Domb030216	3.45	2.47	128.00	12.40	36.00	274.40	831.50	3.01	1.74
Wet	Road 16 Bridge 3	2-Mar-16	Rd16bridge3_Doma030216	3.68	3.27	13.70	45.10	4.31	15.69	273.67	5.24	1.63
Wet	Road 16 Bridge 3	2-Mar-16	Rd16bridge3_Domb030216	3.89	3.50	15.80	50.00	5.02	14.68	273.67	5.14	1.62
Wet	Road 16 Bridge 4	2-Mar-16	Rd16bridge4_Doma030216	3.41	3.67	48.40	44.60	6.97	239.33	425.37	2.11	1.69
Wet	Road 16 Bridge 4	2-Mar-16	Rd16bridge4_Domb030216	3.36	3.67	49.60	43.20	7.01	243.49	425.37	2.09	1.69
Wet	Road 16 Bridge 1	12-Jul-16	Cr_16bridge_1a071216	4.33	5.00	35.50	5.33	5.88	13.72	283.43	1.46	1.74
Wet	Road 16 Bridge 1	12-Jul-16	Cr_16bridge_1b071216	4.46	6.00	37.60	7.26	8.18	16.52	283.43	1.50	1.77
Wet	Road 16 Bridge 4	12-Jul-16	Cr_16bridge_4a071216	3.83	5.50	82.60	55.20	7.08	122.92	634.65	2.15	1.76
Wet	Road 16 Bridge 4	12-Jul-16	Cr_16bridge_4b071216	3.76	5.50	100.00	52.30	9.52	369.68	634.65	2.16	1.78
Wet	Upstream 1	12-Jul-16	Upstream_1a071216	6.27	B.D.	114.00	17.30	169.60	162.80	210.03	1.19	2.05
Wet	Upstream 1	12-Jul-16	Upstream_1b071216	5.83	3.00	97.10	17.30	173.20	104.40	210.03	1.13	2.05
Wet	Upstream 2	12-Jul-16	Upstream_2a071216	5.33	6.00	43.70	3.37	6.65	18.85	525.80	1.82	1.94

Wet	Upstream 2	12-Jul-16	Upstream_2b071216	5.28	7.00	43.10	7.76	46.10	26.20	525.80	1.80	1.94
Wet	Upstream 3	12-Jul-16	Upstream_3a071216	7.53	B.D.	28.60	1.71	4.48	8.92	332.58	1.80	1.98
Wet	Upstream 3	12-Jul-16	Upstream_3b071216	7.76	3.00	29.90	11.50	120.00	57.80	332.58	1.79	1.98

				CATIONS					**ANIONS**	
Sample category	**Sample site**	**Sampling Date**	**Sample Name**	**Ca(mg/l)**	**Fe(mg/l)**	**Mg(mg/l)**	**K(mg/l)**	**Na(mg/l)**	**Chloride (mg/l)**	**Sulfate (mg/l)**
Dry	Road 16 Bridge 1	16-Jun-2016	Cr_16bridge_1b061616	31.60	0.30	1.48	2.78	3.61	4.33	4.01
Dry	Rec. center2	16-Jun-2016	Rc2_A061616	1.52	0.49	0.78	0.49	2.62	2.43	1.52
Dry	Rec. center2	16-Jun-2016	Rc2_B061616	1.19	0.51	0.78	0.41	2.51	3.23	1.99
Dry	Rec. center3	16-Jun-2016	Rc3_A061616	1.16	0.56	0.77	0.41	2.00	2.56	1.34
Dry	Rec. center3	16-Jun-2016	Rc3_B061616	1.21	0.57	0.77	0.39	2.06	3.17	1.70
Dry	Rec.center Upst	16-Jun-2016	Rcupstream_A061616	1.29	0.50	0.83	0.48	2.64	2.81	1.78
Dry	Upstream 1	16-Jun-2016	Upstream_1a061616	107.21	0.01	3.77	3.13	24.91	41.59	110.70
Dry	Upstream 1	16-Jun-2016	Upstream_1b061616	107.32	0.01	3.80	3.15	25.20	35.63	108.03
Dry	Upstream 2	16-Jun-2016	Upstream_2a061616	72.41	0.02	4.12	4.92	20.56	44.29	109.72
Dry	Upstream 2	16-Jun-2016	Upstream_2b061616	70.17	0.02	3.97	4.59	20.12	41.96	105.60
Dry	Upstream 3	16-Jun-2016	Upstream_3a061616	87.22	0.03	3.11	5.55	18.88	29.47	76.67

Dry	Upstream 3	16-Jun-2016	Upstream_3b061616	86.71	0.04	3.04	5.41	18.77	29.75	78.49
Dry	Road 16 Bridge 1	29-Jun-2016	Cr_16bridge_1a062916	32.26	0.25	1.54	2.34	1.78	15.09	2.61
Dry	Road 16 Bridge 1	29-Jun-2016	Cr_16bridge_1b062916	32.20	0.26	1.58	2.29	1.74	12.03	2.41
Dry	Upstream 1	29-Jun-2016	Upstream_1a062916	132.67	0.00	5.35	2.86	34.82	28.12	82.09
Dry	Upstream 1	29-Jun-2016	Upstream_1b062916	132.87	0.01	5.35	2.85	35.44	21.04	81.31
Dry	Upstream 2	29-Jun-2016	Upstream_2a062916	91.61	B.D.	5.70	5.33	26.56	39.08	104.98
Dry	Upstream 2	29-Jun-2016	Upstream_2b062916	90.62	B.D.	5.67	5.26	26.23	36.29	88.92
Dry	Upstream 3	29-Jun-2016	Upstream_3a062916	87.18	0.01	3.69	6.29	22.12	21.83	74.10
Dry	Upstream 3	29-Jun-2016	Upstream_3b062916	88.06	0.01	3.68	6.41	22.38	18.00	60.91
Dry (Drought)	Bpc Road 61 Brid	20-Oct-2016	Bpcrd.61bridgea102016	22.40	0.07	2.71	6.51	3.34	2.81	1.97
Dry (Drought)	Bpc Road 61 Brid	20-Oct-2016	Bpcrd.61bridgeb102016	22.19	0.07	2.71	6.50	3.36	3.30	2.56
Dry (Drought)	Bpc Road 61 Brid	20-Oct-2016	Bpcrd61bridgeb102016	11.58	0.22	1.93	6.38	1.58	3.14	2.49
Dry (Drought)	Bpctsa	20-Oct-2016	Bpctsa102016	14.11	0.11	2.16	6.58	2.17	2.45	3.14
Dry (Drought)	Bpctsa	20-Oct-2016	Bpctsb102016	13.94	0.09	2.03	6.52	2.21	3.41	4.62
Dry (Drought)	Bpc Windmill Rd	20-Oct-2016	Bpcwindmillrda102016	17.54	0.16	2.31	6.44	2.76	3.07	2.65

Dry (Drought)	Bpc Windmill Rd	20-Oct-2016	Bpcwindmillrdb102016	17.13	0.14	2.45	6.45	2.72	3.77	3.40
Dry (Drought)	Road 16 Bridge 1	20-Oct-2016	Rd16Bridge1A102016	71.48	0.05	3.31	6.01	8.91	7.61	9.18
Dry (Drought)	Road 16 Bridge 1	20-Oct-2016	Rd16Bridge1B102016	71.40	0.06	3.29	5.93	8.94	6.90	8.84
Dry (Drought)	Road 16 Bridge 4	20-Oct-2016	Rd16Bridge4A102016	17.37	0.30	2.01	9.90	3.26	3.95	1.68
Dry (Drought)	Bpc Rd 48 Bridge	15-Nov-2016	Bpcrd48bridgea111516	12.15	0.43	2.41	6.24	2.56	4.75	3.66
Dry (Drought)	Bpc Rd 48 Bridge	15-Nov-2016	Bpcrd48bridgeb111516	11.63	0.26	2.42	6.19	2.47	5.01	3.78
Dry (Drought)	Road 16 Bridge 4	15-Nov-2016	Rd16Bridge4A111516	12.09	0.45	1.60	9.30	2.41	3.97	1.93
Dry (Drought)	Road 16 Bridge 4	15-Nov-2016	Rd16Bridge4B111516	12.44	0.32	1.58	9.37	2.47	3.92	1.87
Dry (Drought)	Windmill Road	15-Nov-2016	Windmillrda111516	47.60	0.24	4.97	6.85	4.59	6.00	2.08
Dry (Drought)	Windmill Road	15-Nov-2016	Windmillrdb111516	48.73	0.26	4.68	6.86	4.73	5.99	2.06
Dry	Upstream 1	6-May-2016	Abridge105062016	45.38	0.05	1.81	3.98	9.16	26.92	60.64
Dry	Upstream 1	6-May-2016	Bridge1Upstream1B05062016	45.14	0.06	1.81	3.95	9.20	26.70	59.78
Dry	Upstream 2	6-May-2016	Bridge1upstream1A05062016	44.35	0.06	1.75	3.90	8.57	27.38	80.54
Dry	Upstream 2	6-May-2016	Bridge1Upstream1B05062016	44.26	0.05	1.72	3.88	8.68	53.36	140.68
Dry	Bridge 1	13-May-2016	B1a05132016	69.29	0.05	2.68	4.52	11.97	N/A	N/A
Dry	Bridge 2	13-May-2016	B1b05132016	69.07	0.04	2.66	4.53	11.86	N/A	N/A

Dry	Bridge 1 Upst2	13-May-2016	U2b1a05132016	74.64	0.03	2.73	4.30	12.93	N/A	N/A
Dry	Bridge 1 Upst2	13-May-2016	U2b1b05132016	75.83	0.03	2.79	4.45	13.28	N/A	N/A
Dry	Bridge 1 Upst1	13-May-2016	B1u1a05132016	71.07	0.03	2.88	4.53	12.47	N/A	N/A
Dry	Bridge 1 Upst1	13-May-2016	B1u1b05132016	70.90	0.03	2.87	4.58	12.45	N/A	N/A
Dry	Rec.center Brid2	13-May-2016	Rcb2a05132016	1.61	0.32	0.93	0.99	2.01	N/A	N/A
Dry	Rec.center J	13-May-2016	Rcjba05132016	1.03	0.84	0.55	1.72	2.63	N/A	N/A
Dry	Rec.center J	13-May-2016	Rcjbb05132016	1.05	0.85	0.58	1.72	2.64	N/A	N/A
Dry	Rec.center S2	13-May-2016	Rcs2a05132016	1.17	0.70	0.80	0.51	2.37	N/A	N/A
Dry	Rec.center S2	13-May-2016	Rcs2b05132016	1.18	0.71	0.83	0.48	2.37	N/A	N/A
Dry	Rec.center S3	13-May-2016	Rcs3a05132016	1.14	0.80	0.78	0.52	2.63	N/A	N/A
Dry	Rec.center S3	13-May-2016	Rcs3b05132016	1.12	0.80	0.79	0.50	2.63	N/A	N/A
Dry	Rec.center S	13-May-2016	Rcsa05132016	1.20	0.74	0.81	0.45	2.58	N/A	N/A
Dry	Rec.center S	13-May-2016	Rcsb05132016	1.18	0.73	0.85	0.48	2.68	N/A	N/A
Dry	Rec.center Upst	13-May-2016	Rcua05132016	1.24	0.73	0.83	0.47	2.55	N/A	N/A
Dry	Rec.center Upst	13-May-2016	Rcub05132016	1.23	0.73	0.80	0.44	2.64	N/A	N/A
Dry	Rec. center3	25-May-2016	Rc3_A052516	1.35	0.54	0.79	0.43	2.89	3.21	1.23

Dry	Rec. center3	25-May-2016	Rc3_B052516	1.49	0.55	0.79	0.47	2.89	3.16	1.19
Dry	Rec.center site2	25-May-2016	Rcsite2_A052516	2.66	0.57	0.82	0.54	3.25	3.48	2.42
Dry	Rec.center site2	25-May-2016	Rcsite2_B052516	2.38	0.56	0.81	0.46	3.19	2.90	2.02
Dry	Rec. center start	25-May-2016	Rcstart_A052516	1.29	0.58	0.78	0.46	2.87	2.75	B.D.
Dry	Rec. center start	25-May-2016	Rcstart_B052516	1.27	0.56	0.77	0.44	2.84	3.21	1.31
Dry	Rec.center Upst	25-May-2016	Rcupstream_A052516	1.45	0.56	0.79	0.41	2.96	3.20	1.17
Dry	Rec.center Upst	25-May-2016	Rcupstream_B052516	1.90	0.57	0.81	0.44	3.07	3.05	1.13
Dry	Upstream 1	25-May-2016	Upstream1_B052516	91.61	0.03	3.47	4.60	20.53	24.65	61.74
Dry	Upstream 2	25-May-2016	Upstream2_A052516	104.52	0.02	4.68	5.14	24.21	37.61	137.00
Dry	Upstream 2	25-May-2016	Upstream2_B052516	104.04	0.05	4.64	5.16	24.25	25.71	101.32
Dry	Upstream 3	25-May-2016	Upstream3_A052516	82.85	0.04	2.66	5.23	16.75	24.12	51.02
Dry	Upstream 3	25-May-2016	Upstream3_B052516	83.03	0.03	2.67	5.29	16.85	19.34	41.10

				DOM COMPONENTS										
Sample category	**Sample site**	**Sampling Date**	**Sample Name**	**C1**	**C2**	**C3**	**C1 %**	**C2 %**	**C3 %**	**Sample category**	**Sample Name**	**DOC mg/l**	**SUVA □□□ Lmg−1 m−1**	**S_R Lmg −1 m−1**

Dry	Road 16 Bridge 1	16-Jun-2016	Cr_16bridge_1b061616	1.11	0.81	2.78	23.63	17.31	59.07	Dry	CR_16BRIDGE_1B061616	2.69	4.65	0.87
Dry	Rec. center2	16-Jun-2016	Rc2_A061616	0.54	1.00	2.44	13.64	25.04	61.32	Dry	RC2_A061616	3.30	5.00	0.74
Dry	Rec. center2	16-Jun-2016	Rc2_B061616	0.51	1.00	2.48	12.81	24.97	62.21	Dry	RC2_B061616	3.27	5.17	0.76
Dry	Rec. center3	16-Jun-2016	Rc3_A061616	0.45	1.07	2.48	11.26	26.80	61.94	Dry	RC3_A061616	3.33	5.29	0.76
Dry	Rec. center3	16-Jun-2016	Rc3_B061616	0.43	1.11	2.51	10.68	27.42	61.90	Dry	RC3_B061616	3.28	5.36	0.76
Dry	Rec.center Upst	16-Jun-2016	Rcupstream_A061616	0.55	0.93	2.47	13.85	23.60	62.55	Dry	RCUPSTREAM_A061616	3.25	5.11	0.74
Dry	Upstream 1	16-Jun-2016	Upstream_1a061616	1.46	0.18	1.59	45.09	5.71	49.21	Dry	UPSTREAM_1A061616	2.79	2.58	1.26
Dry	Upstream 1	16-Jun-2016	Upstream_1b061616	1.57	0.14	1.74	45.41	4.18	50.41	Dry	UPSTREAM_1B061616	2.87	2.37	1.16
Dry	Upstream 2	16-Jun-2016	Upstream_2a061616	2.14	0.30	2.34	44.74	6.35	48.92	Dry	UPSTREAM_2A061616	4.52	2.17	1.40
Dry	Upstream 2	16-Jun-2016	Upstream_2b061616	2.12	0.33	2.34	44.30	6.83	48.86	Dry	UPSTREAM_2B061616	4.61	2.15	1.40

Dry	Upstream 3	16-Jun-2016	Upstream_3a061616	3.06	0.40	3.13	46.47	6.05	47.48	Dry	UPSTREAM_3A061616	5.82	2.11	1.24
Dry	Upstream 3	16-Jun-2016	Upstream_3b061616	3.20	0.39	3.16	47.40	5.72	46.88	Dry	UPSTREAM_3B061616	5.92	2.06	1.19
Dry	Road 16 Bridge 1	29-Jun-2016	Cr_16bridge_1a062916	1.16	0.36	2.06	32.30	10.11	57.59	Dry	CR_16BRIDGE_1A062916	1.91	4.87	0.81
Dry	Road 16 Bridge 1	29-Jun-2016	Cr_16bridge_1b062916	1.27	0.73	2.20	30.30	17.27	52.43	Dry	CR_16BRIDGE_1B062916	2.00	4.80	0.79
Dry	Upstream 1	29-Jun-2016	Upstream_1a062916	1.32	0.04	1.44	47.22	1.35	51.43	Dry	UPSTREAM_1A062916	2.47	2.10	0.95
Dry	Upstream 1	29-Jun-2016	Upstream_1b062916	1.59	0.04	1.46	51.52	1.14	47.34	Dry	UPSTREAM_1B062916	2.48	2.02	0.96
Dry	Upstream 2	29-Jun-2016	Upstream_2a062916	2.23	0.20	2.25	47.71	4.31	47.98	Dry	UPSTREAM_2A062916	4.62	1.93	1.20
Dry	Upstream 2	29-Jun-2016	Upstream_2b062916	2.28	0.21	2.31	47.57	4.35	48.08	Dry	UPSTREAM_2B062916	4.16	2.16	1.22
Dry	Upstream 3	29-Jun-2016	Upstream_3a062916	3.35	0.41	3.05	49.21	6.03	44.76	Dry	UPSTREAM_3A062916	6.67	1.94	1.41
Dry	Upstream 3	29-Jun-2016	Upstream_3b062916	3.82	0.47	3.06	51.94	6.43	41.64	Dry	UPSTREAM_3B062916	6.62	1.96	1.41

Dry (Drought)	Bpc Road 61 Brid	20-Oct-2016	Bpcrd.61bridgea102016	3.55	0.50	6.01	35.31	4.93	59.76	Dry	BPCRd.61BridgeA102016	7.13	2.96	0.94
Dry (Drought)	Bpc Road 61 Brid	20-Oct-2016	Bpcrd.61bridgeb102016	3.60	0.45	6.05	35.64	4.48	59.88	Dry	BPCRd.61BridgeB102016	7.13	2.96	0.95
Dry (Drought)	Bpc Road 61 Brid	20-Oct-2016	Bpcrd61bridgeb102016	1.98	1.29	5.10	23.66	15.40	60.94	Dry	BPCRd61BridgeB102016	2.99	5.42	0.92
Dry (Drought)	Bpctsa	20-Oct-2016	Bpctsa102016	2.65	0.62	5.04	31.87	7.48	60.64	Dry	BPCTSA102016	5.56	2.95	0.91
Dry (Drought)	Bpctsa	20-Oct-2016	Bpctsb102016	2.68	0.61	5.04	32.18	7.32	60.50	Dry	BPCTSB102016	5.54	2.98	0.90
Dry (Drought)	Bpc Windmill Rd	20-Oct-2016	Bpcwindmillrda102016	3.41	0.47	5.90	34.83	4.85	60.33	Dry	BPCwindmillRdA102016	6.47	3.09	0.98
Dry (Drought)	Bpc Windmill Rd	20-Oct-2016	Bpcwindmillrdb102016	3.31	0.50	5.88	34.17	5.18	60.66	Dry	BPCwindmillRdB102016	6.48	3.06	0.93
Dry (Drought)	Road 16 Bridge 1	20-Oct-2016	Rd16Bridge1A102016	7.41	1.69	5.40	51.14	11.63	37.22	Dry	Rd16Bridge1A102016	8.48	3.01	0.98
Dry (Drought)	Road 16 Bridge 1	20-Oct-2016	Rd16Bridge1B102016	7.37	1.66	5.43	50.96	11.51	37.53	Dry	Rd16Bridge1B102016	8.35	3.08	0.95
Dry (Drought)	Road 16 Bridge 4	20-Oct-2016	Rd16Bridge4A102016	1.43	0.99	3.04	26.27	18.07	55.67	Dry	Rd16Bridge4A102016	2.98	4.47	0.77

Dry (Drought)	Bpc Rd 48 Bridge	15-Nov-2016	Bpcrd48bridgea111516	1.99	2.01	4.53	23.36	23.56	53.08	Dry	BPCRd48BridgeA111516	4.90	3.88	0.90
Dry (Drought)	Bpc Rd 48 Bridge	15-Nov-2016	Bpcrd48bridgeb111516	1.91	2.07	4.52	22.49	24.30	53.20	Dry	BPCRd48BridgeB111516	4.79	3.98	0.91
Dry (Drought)	Road 16 Bridge 4	15-Nov-2016	Rd16Bridge4A111516	1.23	2.71	2.16	20.11	44.43	35.46	Dry	Rd16Bridge4A111516	2.59	6.95	0.77
Dry (Drought)	Road 16 Bridge 4	15-Nov-2016	Rd16Bridge4B111516	1.27	2.72	2.13	20.79	44.47	34.74	Dry	Rd16Bridge4B111516	2.51	7.21	0.79
Dry (Drought)	Windmill Road	15-Nov-2016	Windmillrda111516	6.42	2.51	8.87	36.06	14.10	49.84	Dry	windmillRdA111516	9.77	3.35	0.99
Dry (Drought)	Windmill Road	15-Nov-2016	Windmillrdb111516	6.50	2.54	8.88	36.28	14.17	49.55	Dry	windmillRdB111516	9.98	3.28	0.98
Dry	Upstream 1	6-May-2016	Abridge105062016	2.61	1.34	3.12	36.87	18.94	44.19	Dry	ABridge105062016	6.18	2.49	0.00
Dry	Upstream 1	6-May-2016	Bridge1Upstream1B05062016	2.70	1.30	3.14	37.79	18.21	44.00	Dry	Bridge1Upstream1B05062016	6.00	2.52	0.00
Dry	Upstream 2	6-May-2016	Bridge1upstream1A05062016	2.63	1.48	3.13	36.31	20.49	43.20	Dry	Bridge1upstream1A05062016	6.02	2.64	0.99
Dry	Upstream 2	6-May-2016	Bridge1Upstream1B05062016	2.42	1.63	3.19	33.38	22.53	44.10	Dry	Bridge1Upstream1B05062016	6.06	2.66	1.72

Dry	Bridge 1	13-May-2016	B1a05132016	4.03	1.60	4.30	40.58	16.14	43.28	Dry	B1A05132016	5.31	3.05	1.14
Dry	Bridge 2	13-May-2016	B1b05132016	4.03	1.59	4.29	40.65	16.05	43.30	Dry	B1B05132016	5.28	3.11	1.12
Dry	Bridge 1 Upst2	13-May-2016	U2b1a05132016	3.54	1.29	4.43	38.24	13.90	47.86	Dry	U2B1A05132016	5.63	2.57	1.20
Dry	Bridge 1 Upst2	13-May-2016	U2b1b05132016	3.54	1.29	4.40	38.37	13.95	47.68	Dry	U2B1B05132016	5.59	2.56	1.18
Dry	Bridge 1 Upst1	13-May-2016	B1u1a05132016	0.00	0.00	0.04	3.26	1.21	95.53	Dry	B1U1A05132016	5.49	2.58	1.24
Dry	Bridge 1 Upst1	13-May-2016	B1u1b05132016	3.40	1.28	4.74	36.11	13.55	50.34	Dry	B1U1B05132016	5.13	2.77	1.22
Dry	Rec.center Brid2	13-May-2016	Rcb2a05132016	N/A	N/A	N/A	N/A	N/A	N/A	Dry	RCB2A05132016	4.26	5.07	0.74
Dry	Rec.center J	13-May-2016	Rcjba05132016	4.80	1.99	4.86	41.22	17.06	41.71	Dry	RCJBA05132016	8.14	3.82	0.74
Dry	Rec.center J	13-May-2016	Rcjbb05132016	4.83	1.98	4.91	41.20	16.91	41.89	Dry	RCJBb05132016	8.04	3.85	0.71
Dry	Rec.center S2	13-May-2016	Rcs2a05132016	2.76	1.57	1.38	48.41	27.46	24.13	Dry	RCS2A05132016	3.53	5.83	0.66
Dry	Rec.center S2	13-May-2016	Rcs2b05132016	2.80	1.57	1.51	47.60	26.73	25.67	Dry	RCS2B05132016	3.52	5.87	0.65

Dry	Rec.center S3	13-May-2016	Rcs3a05132016	2.85	1.61	1.76	45.78	25.91	28.30	Dry	RCS3A05132016	3.42	6.67	0.68
Dry	Rec.center S3	13-May-2016	Rcs3b05132016	2.82	1.61	1.72	45.87	26.13	28.01	Dry	RCS3B05132016	2.57	8.84	0.69
Dry	Rec.center S	13-May-2016	Rcsa05132016	2.81	1.61	1.57	47.01	26.83	26.16	Dry	RCSA05132016	3.51	6.18	0.66
Dry	Rec.center S	13-May-2016	Rcsb05132016	2.79	1.60	1.59	46.69	26.70	26.61	Dry	RCSB05132016	3.54	6.08	0.67
Dry	Rec.center Upst	13-May-2016	Rcua05132016	3.02	1.73	1.65	47.16	27.08	25.77	Dry	RCUA05132016	3.17	7.16	0.68
Dry	Rec.center Upst	13-May-2016	Rcub05132016	3.04	1.73	1.60	47.72	27.16	25.12	Dry	RCUB05132016	2.95	7.62	0.67
Dry	Rec. center3	25-May-2016	Rc3_A052516	2.64	1.51	2.59	39.12	22.43	38.45	Dry	RC3_A052516	3.12	5.33	0.76
Dry	Rec. center3	25-May-2016	Rc3_B052516	2.57	1.48	2.48	39.31	22.65	38.04	Dry	RC3_B052516	3.12	5.20	0.75
Dry	Rec.center site2	25-May-2016	Rcsite2_A052516	2.73	1.52	1.51	47.47	26.38	26.15	Dry	RCSITE2_A052516	3.08	5.23	0.74
Dry	Rec.center site2	25-May-2016	Rcsite2_B052516	2.73	1.52	1.45	47.91	26.70	25.40	Dry	RCSITE2_B052516	3.11	5.28	0.73
Dry	Rec. center start	25-May-2016	Rcstart_A052516	2.74	1.51	1.43	48.25	26.57	25.19	Dry	RCSTART_A052516	3.12	5.33	0.73

Dry	Rec. center start	25-May-2016	Rcstart_B052516	N/A	N/A	N/A	N/A	N/A	N/A	Dry	RCSTART_B052516	3.13	5.27	0.72
Dry	Rec.center Upst	25-May-2016	Rcupstream_A052516	N/A	N/A	N/A	N/A	N/A	N/A	Dry	RCUPSTREAM_A052516	3.03	5.51	0.74
Dry	Rec.center Upst	25-May-2016	Rcupstream_B052516	N/A	N/A	N/A	N/A	N/A	N/A	Dry	RCUPSTREAM_B052516	3.05	5.54	0.73
Dry	Upstream 1	25-May-2016	Upstream1_B052516	N/A	N/A	N/A	N/A	N/A	N/A	Dry	UPSTREAM1_B052516	4.64	2.26	1.30
Dry	Upstream 2	25-May-2016	Upstream2_A052516	3.23	1.05	3.27	42.76	13.93	43.31	Dry	UPSTREAM2_A052516	5.10	2.32	1.39
Dry	Upstream 2	25-May-2016	Upstream2_B052516	3.23	1.04	3.16	43.47	14.01	42.52	Dry	UPSTREAM2_B052516	4.62	2.51	1.39
Dry	Upstream 3	25-May-2016	Upstream3_A052516	3.90	1.27	3.89	43.04	14.03	42.93	Dry	UPSTREAM3_A052516	5.51	2.65	1.44
Dry	Upstream 3	25-May-2016	Upstream3_B052516	3.93	1.28	3.80	43.60	14.24	42.16	Dry	UPSTREAM3_B052516	5.61	2.60	1.39

						NUTRIENTS				**BACTERIA**		
Sample category	**Sample site**	**Sampling Date**	**Sample Name**	**E2/E3**	**E4/E6**	**NH4 ug/L**	**Ortho-P ugP/L**	**nitrite ugN/L**	**Nitrate ugN/L**	**E. coli cfu/100 mL**	**Optical Brightener**	**FI**
Dry	Road 16 Bridge 1	16-Jun-2016	Cr_16bridge_1b061616	4.33	8.00	66.40	52.60	286.20	131.40	234.98	1.78	1.72

Dry	Rec. center2	16-Jun-2016	Rc2_A061616	4.07	5.00	11.80	24.00	125.20	32.60	883.20	1.64	1.64
Dry	Rec. center2	16-Jun-2016	Rc2_B061616	3.98	5.50	10.90	18.50	104.80	27.80	883.20	1.67	1.65
Dry	Rec. center3	16-Jun-2016	Rc3_A061616	3.87	3.25	20.80	36.00	197.60	90.40	675.78	1.67	1.66
Dry	Rec. center3	16-Jun-2016	Rc3_B061616	3.87	3.25	14.50	26.70	154.40	44.40	675.78	1.70	1.65
Dry	Rec.center Upst	16-Jun-2016	Rcupstream_A061616	4.10	3.33	13.30	29.70	168.80	61.20	360.53	1.67	1.67
Dry	Upstream 1	16-Jun-2016	Upstream_1a061616	4.81	2.00	160.00	20.50	188.40	198.00	53.90	1.09	2.00
Dry	Upstream 1	16-Jun-2016	Upstream_1b061616	5.14	1.67	171.60	23.80	225.20	290.80	53.90	1.16	2.03
Dry	Upstream 2	16-Jun-2016	Upstream_2a061616	5.72	2.00	116.00	36.50	210.00	110.40	487.78	1.53	1.94
Dry	Upstream 2	16-Jun-2016	Upstream_2b061616	5.42	2.33	121.00	46.80	280.00	156.00	487.78	1.55	1.96
Dry	Upstream 3	16-Jun-2016	Upstream_3a061616	7.22	4.00	71.10	37.60	296.40	123.60	46.10	1.94	1.91
Dry	Upstream 3	16-Jun-2016	Upstream_3b061616	7.59	B.D.	78.60	34.00	265.20	131.40	46.10	1.96	1.93
Dry	Road 16 Bridge 1	29-Jun-2016	Cr_16bridge_1a062916	4.36	B.D.	59.50	32.40	222.00	75.60	1241.13	1.37	1.72
Dry	Road 16 Bridge 1	29-Jun-2016	Cr_16bridge_1b062916	4.35	B.D.	58.50	11.30	47.00	37.60	1241.13	1.44	1.75
Dry	Upstream 1	29-Jun-2016	Upstream_1a062916	7.13	B.D.	161.40	8.55	78.00	155.20	682.73	0.96	2.02
Dry	Upstream 1	29-Jun-2016	Upstream_1b062916	7.86	B.D.	160.40	19.50	228.40	199.60	682.73	0.99	2.05
Dry	Upstream 2	29-Jun-2016	Upstream_2a062916	7.83	B.D.	93.50	26.30	160.00	105.60	320.83	1.45	1.98

Dry	Upstream 2	29-Jun-2016	Upstream_2b062916	7.31	B.D.	85.40	26.20	184.80	98.00	320.83	1.49	1.96
Dry	Upstream 3	29-Jun-2016	Upstream_3a062916	6.80	3.00	56.30	11.60	98.90	29.10	168.55	1.93	2.01
Dry	Upstream 3	29-Jun-2016	Upstream_3b062916	6.85	3.00	60.20	3.80	68.80	21.00	168.55	1.97	2.04
Dry (Drought)	Bpc Road 61 Brid	20-Oct-2016	Bpcrd.61bridgea102016	5.48	B.D.	49.80	39.50	2.04	122.96	51.80	3.83	1.86
Dry (Drought)	Bpc Road 61 Brid	20-Oct-2016	Bpcrd.61bridgeb102016	5.48	B.D.	51.30	35.70	2.05	127.95	51.80	3.87	1.86
Dry (Drought)	Bpc Road 61 Brid	20-Oct-2016	Bpcrd61bridgeb102016	5.06	B.D.	3.39	44.40	1.46	B.D.	143.90	3.21	1.85
Dry (Drought)	Bpctsa	20-Oct-2016	Bpctsa102016	5.90	B.D.	17.10	41.40	1.32	4.41	32.60	3.21	1.85
Dry (Drought)	Bpctsa	20-Oct-2016	Bpctsb102016	5.73	B.D.	17.80	43.10	1.71	2.79	32.60	3.20	1.86
Dry (Drought)	Bpc Windmill Rd	20-Oct-2016	Bpcwindmillrda102016	5.31	9.00	8.81	66.30	1.20	1.18	46.13	3.83	1.94
Dry (Drought)	Bpc Windmill Rd	20-Oct-2016	Bpcwindmillrdb102016	5.39	B.D.	8.55	66.20	1.76	0.53	46.13	3.82	1.95
Dry (Drought)	Road 16 Bridge 1	20-Oct-2016	Rd16Bridge1A102016	4.57	14.00	6.96	49.00	2.66	0.32	61.50	4.80	2.41
Dry (Drought)	Road 16 Bridge 1	20-Oct-2016	Rd16Bridge1B102016	4.60	14.00	7.33	48.50	2.51	B.D.	61.50	4.89	2.45

Dry (Drought)	Road 16 Bridge 4	20-Oct-2016	Rd16Bridge4A102016	4.03	B.D.	91.00	57.60	3.57	36.73	119.15	2.09	1.91
Dry (Drought)	Bpc Rd 48 Bridge	15-Nov-2016	Bpcrd48bridgea111516	4.02	4.00	9.07	23.80	0.92	7.43	50.20	2.84	1.83
Dry (Drought)	Bpc Rd 48 Bridge	15-Nov-2016	Bpcrd48bridgeb111516	3.96	4.33	4.55	10.20	1.28	2.47	50.20	2.83	1.83
Dry (Drought)	Road 16 Bridge 4	15-Nov-2016	Rd16Bridge4A111516	2.98	4.00	75.70	66.40	2.37	24.03	84.30	1.53	1.85
Dry (Drought)	Road 16 Bridge 4	15-Nov-2016	Rd16Bridge4B111516	2.95	3.33	70.90	61.40	1.89	15.41	84.30	1.51	1.84
Dry (Drought)	Windmill Road	15-Nov-2016	Windmillrda111516	4.99	5.33	107.00	25.90	2.30	15.90	44.20	6.30	2.24
Dry (Drought)	Windmill Road	15-Nov-2016	Windmillrdb111516	4.99	5.00	99.80	19.50	1.89	14.41	44.20	6.34	2.24
Dry	Upstream 1	6-May-2016	Abridge105062016	0.43	0.02	N/A	N/A	N/A	N/A	202.40	1.94	1.85
Dry	Upstream 1	6-May-2016	Bridge1Upstream1B05062016	0.38	0.02	N/A	N/A	N/A	N/A	202.40	1.97	1.86
Dry	Upstream 2	6-May-2016	Bridge1upstream1A05062016	0.44	0.03	N/A	N/A	N/A	N/A	152.40	1.95	1.82
Dry	Upstream 2	6-May-2016	Bridge1Upstream1B05062016	0.44	0.03	N/A	N/A	N/A	N/A	152.40	1.97	1.82
Dry	Bridge 1	13-May-2016	B1a05132016	4.62	4.00	178.60	7.24	12.80	199.20	234.50	2.23	1.85
Dry	Bridge 2	13-May-2016	B1b05132016	4.53	4.00	204.00	9.52	15.40	249.60	234.50	2.33	1.86

Dry	Bridge 1 Upst2	13-May-2016	U2b1a05132016	5.28	4.50	15.90	6.89	11.10	185.90	110.20	1.96	1.95
Dry	Bridge 1 Upst2	13-May-2016	U2b1b05132016	5.39	4.00	16.70	4.37	23.20	378.80	110.20	1.90	1.90
Dry	Bridge 1 Upst1	13-May-2016	B1u1a05132016	5.14	3.00	20.70	3.96	13.90	363.10	208.20	1.84	1.01
Dry	Bridge 1 Upst1	13-May-2016	B1u1b05132016	5.36	4.00	22.70	3.77	13.10	382.90	208.20	1.87	1.89
Dry	Rec.center Brid2	13-May-2016	Rcb2a05132016	4.52	5.50	4.54	3.40	1.53	8.44	298.20	1.86	1.81
Dry	Rec.center J	13-May-2016	Rcjba05132016	4.41	8.00	2.31	3.35	1.83	6.11	207.50	2.84	1.73
Dry	Rec.center J	13-May-2016	Rcjbb05132016	4.42	5.33	6.28	4.14	2.00	7.42	207.50	2.85	1.75
Dry	Rec.center S2	13-May-2016	Rcs2a05132016	3.82	6.50	4.54	3.40	1.53	8.44	405.60	1.86	1.60
Dry	Rec.center S2	13-May-2016	Rcs2b05132016	3.86	6.50	6.15	5.32	2.20	8.50	405.60	1.84	1.62
Dry	Rec.center S3	13-May-2016	Rcs3a05132016	3.49	4.50	15.40	7.06	1.69	5.76	104.40	1.89	1.66
Dry	Rec.center S3	13-May-2016	Rcs3b05132016	3.47	4.50	17.60	3.75	1.31	5.59	104.40	1.88	1.67
Dry	Rec.center S	13-May-2016	Rcsa05132016	3.70	7.00	13.00	5.81	1.59	3.24	515.40	1.87	1.73
Dry	Rec.center S	13-May-2016	Rcsb05132016	3.73	7.00	12.00	4.75	1.69	4.84	515.40	1.92	1.65
Dry	Rec.center Upst	13-May-2016	Rcua05132016	3.75	7.50	11.70	4.64	2.73	3.16	190.60	2.01	1.63
Dry	Rec.center Upst	13-May-2016	Rcub05132016	3.77	7.50	13.10	3.63	1.60	5.72	190.60	2.01	1.70
Dry	Rec. center3	25-May-2016	Rc3_A052516	3.91	4.00	30.90	46.00	276.80	53.20	52.60	1.72	1.64

Dry	Rec. center3	25-May-2016	Rc3_B052516	3.91	3.67	31.50	49.30	255.20	87.20	52.60	1.68	1.65
Dry	Rec.center site2	25-May-2016	Rcsite2_A052516	3.98	5.00	90.50	39.30	161.60	46.40	302.53	1.75	1.65
Dry	Rec.center site2	25-May-2016	Rcsite2_B052516	3.95	5.00	20.80	14.20	71.20	17.40	302.53	1.75	1.64
Dry	Rec. center start	25-May-2016	Rcstart_A052516	4.00	5.50	30.50	54.60	296.80	98.80	413.13	1.77	1.63
Dry	Rec. center start	25-May-2016	Rcstart_B052516	3.98	5.00	24.00	34.20	182.40	53.60	413.13	1.77	1.63
Dry	Rec.center Upst	25-May-2016	Rcupstream_A052516	3.93	5.50	21.00	44.30	240.40	67.20	170.50	1.74	1.64
Dry	Rec.center Upst	25-May-2016	Rcupstream_B052516	4.00	5.50	103.00	47.90	205.20	77.20	170.50	1.73	1.63
Dry	Upstream 1	25-May-2016	Upstream1_B052516	6.11	2.50	115.00	34.90	261.60	315.00	213.90	1.65	1.92
Dry	Upstream 2	25-May-2016	Upstream2_A052516	6.15	3.00	57.70	28.00	222.80	97.20	97.00	1.64	1.90
Dry	Upstream 2	25-May-2016	Upstream2_B052516	6.37	3.00	51.60	23.40	248.40	96.80	97.00	1.64	1.86
Dry	Upstream 3	25-May-2016	Upstream3_A052516	5.63	3.00	35.00	26.70	238.00	107.60	860.90	1.92	1.83
Dry	Upstream 3	25-May-2016	Upstream3_B052516	5.85	2.67	30.70	21.50	231.20	93.20	860.90	1.94	1.85

				CATIONS					**ANIONS**	
Sample category	**Sample site**	**Sampling Date**	**Sample Name**	**Ca(mg/l)**	**Fe(mg/l)**	**Mg(mg/l)**	**K(mg/l)**	**Na(mg/l)**	**Chloride (mg/l)**	**Sulfate (mg/l)**
Wet (Post drought)	Road 16 Bridge 4	30-Nov-2016	Rd16_Bridge4_Doma120316	16.06	0.06	2.17	5.14	3.20	4.38	9.45

Wet (Post drought)	Road 16 Bridge 4	30-Nov-2016	Rd16_Bridge4_Domb120316	15.63	0.05	2.15	5.14	3.06	4.51	7.53
Wet (Post drought)	Road 48 BCP	30-Nov-2016	Rd48_Bcp_Dom_A120316	3.70	1.06	1.29	5.74	1.72	3.96	2.21
Wet (Post drought)	Road 48 BCP	30-Nov-2016	Rd48_Bcp_Dom_B120316	3.70	1.12	1.26	5.77	1.83	2.91	1.64
Wet (Post drought)	Road 61 Bridge	30-Nov-2016	Rd61_Bridge_Dom_A120316	47.41	0.12	4.87	3.87	16.18	4.73	7.47
Wet (Post drought)	Road 61 Bridge	30-Nov-2016	Rd61_Bridge_Dom_B120316	45.19	0.11	4.99	3.85	15.93	7.98	13.73
Wet (Post drought)	Road 61 Cul. W.	30-Nov-2016	Rd61_Culvert_W_Dom_A120316	8.67	0.04	1.05	1.54	3.18	2.74	3.97
Wet (Post drought)	Trench	30-Nov-2016	Trench_Dom_A120316	26.75	0.08	2.79	2.52	6.28	6.45	19.57
Wet (Post drought)	Trench	30-Nov-2016	Trench_Dom_B120316	25.74	0.07	2.79	2.50	6.07	6.89	24.02
Wet (Post drought)	Windmill Road	30-Nov-2016	Windmillrd_Dom_A120316	12.44	0.32	1.58	9.37	2.47	6.19	8.02
Wet (Post drought)	Windmill Road	30-Nov-2016	Windmillrd_Dom_B120316	29.67	0.07	3.36	4.55	6.89	4.69	5.82

				DOM COMPONENTS								
Sample category			**Sample Name**	**C1**	**C2**	**C3**	**C1%**	**C2%**	**C3%**	**DOC mg/l**	**SUVA□ □□ Lmg−1 m−1**	**SR Lmg−1 m−1**
Wet (Post drought)	Road 16 Bridge 4	30-Nov-2016	Rd16_Bridge4_Doma120316	5.02	2.85	9.04	29.67	16.87	53.46	11.89	3.13	0.88

Wet (Post drought)	Road 16 Bridge 4	30-Nov-2016	Rd16_Bridge4_Domb120316	6.00	3.54	9.06	32.26	19.02	48.73	11.95	3.12	0.88
Wet (Post drought)	Road 48 BCP	30-Nov-2016	Rd48_Bcp_Dom_A120316	1.31	2.95	4.82	14.44	32.53	53.03	5.96	4.19	0.82
Wet (Post drought)	Road 48 BCP	30-Nov-2016	Rd48_Bcp_Dom_B120316	1.27	3.00	4.82	13.98	32.96	53.06	6.02	4.17	0.83
Wet (Post drought)	Road 61 Bridge	30-Nov-2016	Rd61_Bridge_Dom_A120316	24.95	6.52	14.43	54.36	14.21	31.44	49.42	1.91	1.03
Wet (Post drought)	Road 61 Bridge	30-Nov-2016	Rd61_Bridge_Dom_B120316	24.87	6.43	14.41	54.41	14.06	31.53	49.33	1.90	1.03
Wet (Post drought)	Road 61 Cul. W.	30-Nov-2016	Rd61_Culvert_W_Dom_A120316	3.18	2.18	6.48	26.82	18.43	54.75	7.90	4.59	0.77
Wet (Post drought)	Trench	30-Nov-2016	Trench_Dom_A120316	11.47	6.32	17.19	32.79	18.06	49.15	24.95	3.18	0.83
Wet (Post drought)	Trench	30-Nov-2016	Trench_Dom_B120316	11.31	6.28	17.15	32.55	18.09	49.36	24.47	3.22	0.83
Wet (Post drought)	Windmill Road	30-Nov-2016	Windmillrd_Dom_A120316	7.73	1.26	11.50	37.73	6.14	56.14	16.21	2.76	0.83
Wet (Post drought)	Windmill Road	30-Nov-2016	Windmillrd_Dom_B120316	7.74	1.32	11.52	37.62	6.41	55.97	16.47	2.73	0.85

						NUTRIENTS				**BACTERIA**		
Sample category			**Sample Name**	**E2/E3**	**E4/E6**	**NH4 ug/L**	**Ortho-P ugP/L**	**nitrite ugN/L**	**Nitrate ugN/L**	**E. coli cfu/100 mL**	**Optical Brightner**	**FI**
Wet (Post drought)	Road 16 Bridge 4	30-Nov-2016	Rd16_Bridge4_Doma120316	4.61	4.40	N/A	N/A	N/A	N/A	14345.00	5.56	1.73
Wet (Post drought)	Road 16 Bridge 4	30-Nov-2016	Rd16_Bridge4_Domb120316	4.56	4.40	N/A	N/A	N/A	N/A	14345.00	5.60	1.75

Wet (Post drought)	Road 48 BCP	30-Nov-2016	Rd48_Bcp_Dom_A120316	3.75	8.00	N/A	N/A	N/A	N/A	329.35	3.04	1.79
Wet (Post drought)	Road 48 BCP	30-Nov-2016	Rd48_Bcp_Dom_B120316	3.71	5.67	N/A	N/A	N/A	N/A	329.25	3.03	1.79
Wet (Post drought)	Road 61 Bridge	30-Nov-2016	Rd61_Bridge_Dom_A120316	3.97	3.94	N/A	N/A	N/A	N/A	116160.00	11.64	2.22
Wet (Post drought)	Road 61 Bridge	30-Nov-2016	Rd61_Bridge_Dom_B120316	3.96	3.94	N/A	N/A	N/A	N/A	116160.00	11.72	2.22
Wet (Post drought)	Road 61 Cul. W.	30-Nov-2016	Rd61_Culvert_W_Dom_A120316	4.01	6.00	N/A	N/A	N/A	N/A	5800.00	3.87	1.57
Wet (Post drought)	Trench	30-Nov-2016	Trench_Dom_A120316	4.46	3.85	N/A	N/A	N/A	N/A	20535.00	10.16	1.65
Wet (Post drought)	Trench	30-Nov-2016	Trench_Dom_B120316	4.52	4.27	N/A	N/A	N/A	N/A	20535.00	10.19	1.64
Wet (Post drought)	Windmill Road	30-Nov-2016	Windmillrd_Dom_A120316	5.08	9.50	N/A	N/A	N/A	N/A	1139.95	7.68	1.96
Wet (Post drought)	Windmill Road	30-Nov-2016	Windmillrd_Dom_B120316	5.00	5.25	N/A	N/A	N/A	N/A	1139.95	7.67	1.97

				CATIONS					**ANIONS**	
Sample category	**Sample site**	**Sampling Date**	**Sample Name**	**Ca(mg/l)**	**Fe(mg/l)**	**Mg(mg/l)**	**K(mg/l)**	**Na(mg/l)**	**Chloride (mg/l)**	**Sulfate (mg/l)**
Wastewater	RidoniaWilcox 1	24-Aug-2016	Ridoniawilcox1a082416_Limited_Range	2.91	0.98	0.98	8.63	8.09	135.42	22.83
Wastewater	RidoniaWilcox 1 (1:2 dilution)	24-Aug-2016	Ridoniawilcox1a08241612dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RidoniaWilcox 1(1:5 dilution)	24-Aug-2016	Ridoniawilcox1a08241615dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RidoniaWilcox 1 (1:10 dilution)	24-Aug-2016	Ridoniawilcox1a082416110dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Wastewater	RidoniaWilcox 1 (1:20 dilution)	24-Aug-2016	Ridoniawilcox1a082416120dilitionn_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RidoniaWilcox 1	24-Aug-2016	Ridoniawilcox1b082416_Limited_Range	N/A	N/A	N/A	N/A	N/A	97.95	14.18
Wastewater	RidoniaWilcox 1 (1:2 dilution)	24-Aug-2016	Ridoniawilcox1b08241612dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RidoniaWilcox 1(1:5 dilution)	24-Aug-2016	Ridoniawilcox1b08241615dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RidoniaWilcox 1 (1:10 dilution)	24-Aug-2016	Ridoniawilcox1b082416110dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RidoniaWilcox 1 (1:20 dilution)	24-Aug-2016	Ridoniawilcox1b082416120dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RickyJohnson Wilcox2	24-Aug-2016	Rickyjohnsonwilcox2a082416_Limited_Range	2.26	0.13	0.75	6.57	14.64	96.93	17.24
Wastewater	RickyJohnson Wilcox2 (1:2 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a08241612dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RickyJohnson Wilcox2(1:5 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a08241615dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RickyJohnson Wilcox2 (1:10 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a082416110dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RickyJohnson Wilcox2 (1:20 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a082416120dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RickyJohnson Wilcox2	24-Aug-2016	Rickyjohnsonwilcox2b082416_Limited_Range	N/A	N/A	N/A	N/A	N/A	100.19	17.48

Wastewater	RickyJohnson Wilcox2 (1:2 dilution)	24-Aug-2016	Rickyjohnsonwilcox2b08241612dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RickyJohnson Wilcox2(1:5 dilution)	24-Aug-2016	Rickyjohnsonwilcox2b08241615dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RickyJohnson Wilcox2 (1:10 dilution)	24-Aug-2016	Rickyjohnsonwilcox2b082416110dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	RickyJohnson Wilcox2 (1:20 dilution)	24-Aug-2016	Rickyjohnsonwilcox2b082416120dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	Wilcox3	24-Aug-2016	Wilcox3A082416_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	Wilcox3 (1:2 dilution)	24-Aug-2016	Wilcox3A08241612Dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	Wilcox3(1:5 dilution)	24-Aug-2016	Wilcox3A08241615Dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	Wilcox3 (1:10 dilution)	24-Aug-2016	Wilcox3A082416110Dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	Wilcox3 (1:20 dilution)	24-Aug-2016	Wilcox3A082416120Dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wastewater	Wastewater	24-Aug-2016	Wastera030817	12.16	0.17	2.14	3.67	11.82	20.28	21.61
Wastewater	Wastewater	24-Aug-2016	Wasterb030817	12.15	0.17	2.14	3.63	11.73	20.29	21.99

				DOM COMPONENTS										
Sample category	**Sample site**	**Sampling Date**	**Sample Name**	**C1**	**C2**	**C3**	**C1 %**	**C2 %**	**C3 %**	**Sample category**	**Sample Name**	**DOC**	**SUVA□□□ Lmg**	**SR L mg −1**

												mg/l	**−1 m−1**	**m−1**
Wastewater	Ridonia Wilcox1	24-Aug-2016	Ridoniawilcox1a082416_Limited_Range	2.50	68.05	20.73	2.74	74.55	22.71	Wastewater	RidoniaWilcox1A082416_limited_range	30.60	2.20	1.33
Wastewater	Ridonia Wilcox1 (1:2 dilution)	24-Aug-2016	Ridoniawilcox1a08241612dilition_Limited_Range	3.91	31.30	12.96	8.11	64.98	26.91	Wastewater	RidoniaWilcox1A08241612Dilition_limited_range	10.20	2.13	1.30
Wastewater	Ridonia Wilcox1(1:5 dilution)	24-Aug-2016	Ridoniawilcox1a08241615dilition_Limited_Range	2.80	20.43	9.36	8.60	62.69	28.71	Wastewater	RidoniaWilcox1A08241615Dilition_limited_range	5.10	2.12	1.35
Wastewater	Ridonia Wilcox1 (1:10 dilution)	24-Aug-2016	Ridoniawilcox1a082416110dilition_Limited_Range	0.00	110.66	37.73	0.00	74.58	25.42	Wastewater	RidoniaWilcox1A082416120Dilition_limited_range	2.78	3.02	1.31
Wastewater	Ridonia Wilcox1 (1:20 dilution)	24-Aug-2016	Ridoniawilcox1a082416120dilitionn_Limited_Range	1.24	10.14	4.56	7.76	63.61	28.63	Wastewater	RidoniaWilcox1A082416120Dilitionn_limited_range	1.46	2.88	1.36
Wastewater	Ridonia Wilcox1	24-Aug-2016	Ridoniawilcox1b082416_Limited_Range	11.35	55.56	26.60	12.14	59.41	28.44	Wastewater	RidoniaWilcox1B082416_limited_range	30.60	2.16	1.34
Wastewater	Ridonia Wilcox1 (1:2 dilution)	24-Aug-2016	Ridoniawilcox1b08241612dilition_Limited_Range	1.34	20.95	9.73	4.19	65.42	30.39	Wastewater	RidoniaWilcox1B08241612Dilition_limited_range	10.20	2.07	1.60
Wastewater	Ridonia Wilcox1(1:5 dilution)	24-Aug-2016	Ridoniawilcox1b08241615dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	Wastewater	RidoniaWilcox1B08241615Dilition_limited_range	5.10	2.08	1.31

Wastewater	Ridonia Wilcox1 (1:10 dilution)	24-Aug-2016	Ridoniawilcox1b082416110dilition_Limited_Range	2.39	12.39	7.07	10.93	56.71	32.36	Wastewater	RidoniaWilcox1B082416110Dilition_limited_range	2.78	1.91	1.00
Wastewater	Ridonia Wilcox1 (1:20 dilution)	24-Aug-2016	Ridoniawilcox1b082416120dilition_Limited_Range	1.55	7.48	4.63	11.32	54.76	33.92	Wastewater	RidoniaWilcox1B082416120Dilition_limited_range	1.46	1.99	1.31
Wastewater	RickyJohnsonWilcox2	24-Aug-2016	Rickyjohnsonwilcox2a082416_Limited_Range	141.75	0.00	14.89	90.49	0.00	9.51	Wastewater	RickyJohnsonWilcox2a082416_limited_range	101.00	0.66	1.30
Wastewater	RickyJohnsonWilcox2 (1:2 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a08241612dilition_Limited_Range	79.97	15.48	10.21	75.69	14.65	9.66	Wastewater	RickyJohnsonWilcox2A08241612Dilition_limited_range	33.67	0.69	1.57
Wastewater	RickyJohnsonWilcox2(1:5 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a08241615dilition_Limited_Range	59.19	6.17	7.19	81.58	8.50	9.92	Wastewater	RickyJohnsonWilcox2A08241615Dilition_limited_range	16.83	0.77	2.12
Wastewater	RickyJohnsonWilcox2 (1:10 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a082416110dilition_Limited_Range	44.83	3.97	5.15	83.10	7.36	9.54	Wastewater	RickyJohnsonWilcox2A082416110Dilition_limited_range	9.18	1.13	1.58
Wastewater	RickyJohnsonWilcox2 (1:20 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a082416120dilition_Limited_Range	29.33	2.09	3.41	84.21	5.99	9.80	Wastewater	RickyJohnsonWilcox2A082416120Dilition_limited_range	4.81	1.19	2.10
Wastewater	RickyJohnsonWilcox2	24-Aug-2016	Rickyjohnsonwilcox2b082416_Limited_Range	160.22	40.59	17.95	73.24	18.55	8.20	Wastewater	RickyJohnsonWilcox2B082416_limited_range	101.00	1.00	1.61
Wastewater	RickyJohnsonWilc	24-Aug-2016	Rickyjohnsonwilcox2b08241612dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	Wastewater	RickyJohnsonWilcox2B08241612Dilition_limited_range	33.67	0.94	2.14

	ox2 (1:2 dilution)													
Wastewater	RickyJohnsonWilcox2(1:5 dilution)	24-Aug-2016	Rickyjohnsonwilcox2b08241615dilition_Limited_Range	68.03	3.81	7.71	85.52	4.79	9.69	Wastewater	RickyJohnsonWilcox2B08241615Dilition_limited_range	16.83	0.93	1.61
Wastewater	RickyJohnsonWilcox2 (1:10 dilution)	24-Aug-2016	Rickyjohnsonwilcox2b082416110dilition_Limited_Range	131.57	0.00	17.97	87.98	0.00	12.02	Wastewater	RickyJohnsonWilcox2B082416110Dilition_limited_range	9.18	1.05	2.14
Wastewater	RickyJohnsonWilcox2 (1:20 dilution)	24-Aug-2016	Rickyjohnsonwilcox2b082416120dilition_Limited_Range	N/A	N/A	N/A	N/A	N/A	N/A	Wastewater	RickyJohnsonWilcox2B082416120Dilition_limited_range	4.81	0.87	1.77
Wastewater	Wilcox3	24-Aug-2016	Wilcox3A082416_Limited_Range	34.01	1.37	3.79	86.83	3.49	9.68	Wastewater	Wilcox3A082416_limited_range	72.51	3.19	1.05
Wastewater	Wilcox3 (1:2 dilution)	24-Aug-2016	Wilcox3A08241612Dilition_Limited_Range	52.11	7.49	41.90	51.34	7.38	41.28	Wastewater	Wilcox3A08241612Dilition_limited_range	24.17	3.13	1.02
Wastewater	Wilcox3(1:5 dilution)	24-Aug-2016	Wilcox3A08241615Dilition_Limited_Range	30.92	33.04	21.10	36.35	38.84	24.80	Wastewater	Wilcox3A08241615Dilition_limited_range	12.09	2.97	1.02
Wastewater	Wilcox3 (1:10 dilution)	24-Aug-2016	Wilcox3A082416110Dilition_Limited_Range	23.33	22.14	15.44	38.30	36.35	25.35	Wastewater	Wilcox3A082416110Dilition_limited_range	6.59	3.17	1.03
Wastewater	Wilcox3 (1:20 dilution)	24-Aug-2016	Wilcox3A082416120Dilition_Limited_Range	15.21	16.09	10.43	36.44	38.55	25.00	Wastewater	Wilcox3A082416120Dilition_limited_range	3.45	3.19	0.99
Wastewater	Wastewater	24-Aug-2016	Wastera030817	6.02	3.72	5.48	39.54	24.44	36.02	Wastewater	WASTERA030817	12.04	1.44	1.10

Wastewater	Wastewater	24-Aug-2016	Wasterb030817	6.33	3.85	5.21	41.11	25.02	33.87	Wastewater	WASTERB030817	10.60	1.65	1.14

						NUTRIENTS				**BACTERIA**		
Sample category	**Sample site**	**Sampling Date**	**Sample Name**	**E2/E3**	**E4/E6**	**NH4 ug/L**	**Ortho-P ugP/L**	**nitrite ugN/L**	**Nitrate ugN/L**	**E. coli cfu/100 mL**	**Optical Brightner**	**FI**
Waste water	RidoniaWilcox1	24-Aug-2016	Ridoniawilcox1a082416_Limited_Range	3.15	3.08	6250.00	2620.00	19.30	B.D.	N/A	17.50	2.33
Waste water	RidoniaWilcox1 (1:2 dilution)	24-Aug-2016	Ridoniawilcox1a08241612dilition_Limited_Range	3.18	3.15	N/A	N/A	N/A	N/A	N/A	12.63	2.50
Waste water	RidoniaWilcox1(1:5 dilution)	24-Aug-2016	Ridoniawilcox1a08241615dilition_Limited_Range	3.17	3.18	N/A	N/A	N/A	N/A	N/A	9.46	2.56
Waste water	RidoniaWilcox1 (1:10 dilution)	24-Aug-2016	Ridoniawilcox1a082416110dilition_Limited_Range	3.18	3.09	N/A	N/A	N/A	N/A	N/A	7.36	2.64
Waste water	RidoniaWilcox1 (1:20 dilution)	24-Aug-2016	Ridoniawilcox1a082416120dilitionn_Limited_Range	3.24	3.40	N/A	N/A	N/A	N/A	N/A	4.86	2.61

Waste water	RidoniaWilcox1	24-Aug-2016	Ridoniawilcox1b082416_Limited_Range	3.21	3.40	5800.00	2660.00	19.30	B.D.	N/A	19.27	2.20
Waste water	RidoniaWilcox1 (1:2 dilution)	24-Aug-2016	Ridoniawilcox1b08241612dilition_Limited_Range	1.13	1.11	N/A	N/A	N/A	N/A	N/A	9.60	2.61
Waste water	RidoniaWilcox1(1:5 dilution)	24-Aug-2016	Ridoniawilcox1b08241615dilition_Limited_Range	3.18	4.00	N/A	N/A	N/A	N/A	N/A	8.30	2.61
Waste water	RidoniaWilcox1 (1:10 dilution)	24-Aug-2016	Ridoniawilcox1b082416110dilition_Limited_Range	3.38	2.33	N/A	N/A	N/A	N/A	N/A	7.26	2.65
Waste water	RidoniaWilcox1 (1:20 dilution)	24-Aug-2016	Ridoniawilcox1b082416120dilition_Limited_Range	3.33	4.00	N/A	N/A	N/A	N/A	N/A	4.76	2.62
Waste water	RickyJohnsonWilcox2	24-Aug-2016	Rickyjohnsonwilcox2a082416_Limited_Range	3.18	3.15	36950.00	7440.00	4.41	3.45	N/A	11.02	2.11
Waste water	RickyJohnsonWilcox2 (1:2 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a08241612dilition_Limited_Range	4.76	2.24	N/A	N/A	N/A	N/A	N/A	7.55	2.23
Waste water	RickyJohnsonWilcox2(1:5 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a08241615dilition_Limited_Range	4.01	2.19	N/A	N/A	N/A	N/A	N/A	5.43	2.24
Waste water	RickyJohnsonWilcox2 (1:10 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a082416110dilition_Limited_Range	4.97	2.25	N/A	N/A	N/A	N/A	N/A	4.02	2.27
Waste water	RickyJohnsonWilcox2 (1:20 dilution)	24-Aug-2016	Rickyjohnsonwilcox2a082416120dilition_Limited_Range	4.04	2.15	N/A	N/A	N/A	N/A	N/A	2.66	2.30

Waste water	RickyJohnsonWilcox2	24-Aug-2016	Rickyjohnsonwilcox2b082416_Limited_Range	4.97	2.13	39800.00	7350.00	4.21	1.39	N/A	11.74	2.30
Waste water	RickyJohnsonWilcox2 (1:2 dilution)	24-Aug-2016	Rickyjohnsonwilcox2b08241612dilition_Limited_Range	4.14	2.14	N/A	N/A	N/A	N/A	N/A	7.83	1.99
Waste water	RickyJohnsonWilcox2(1:5 dilution)	24-Aug-2016	Rickyjohnsonwilcox2b08241615dilition_Limited_Range	5.19	2.50	N/A	N/A	N/A	N/A	N/A	5.83	2.17
Waste water	RickyJohnsonWilcox2 (1:10 dilution)	24-Aug-2016	Rickyjohnsonwilcox2b082416110dilition_Limited_Range	3.94	2.00	N/A	N/A	N/A	N/A	N/A	4.72	2.16
Waste water	RickyJohnsonWilcox2 (1:20 dilution)	24-Aug-2016	Rickyjohnsonwilcox2b082416120dilition_Limited_Range	5.33	2.00	N/A	N/A	N/A	N/A	N/A	2.71	2.20
Waste water	Wilcox3	24-Aug-2016	Wilcox3A082416_Limited_Range	3.31	3.16	N/A	N/A	N/A	N/A	N/A	51.64	1.95
Waste water	Wilcox3 (1:2 dilution)	24-Aug-2016	Wilcox3A08241612Dilition_Limited_Range	3.30	3.18	N/A	N/A	N/A	N/A	N/A	41.21	1.83
Waste water	Wilcox3(1:5 dilution)	24-Aug-2016	Wilcox3A08241615Dilition_Limited_Range	3.29	3.00	N/A	N/A	N/A	N/A	N/A	22.52	2.19
Waste water	Wilcox3 (1:10 dilution)	24-Aug-2016	Wilcox3A082416110Dilition_Limited_Range	3.34	3.43	N/A	N/A	N/A	N/A	N/A	17.09	2.27
Waste water	Wilcox3 (1:20 dilution)	24-Aug-2016	Wilcox3A082416120Dilition_Limited_Range	3.32	3.00	N/A	N/A	N/A	N/A	N/A	11.91	2.30

Waste water	Wastewater	24-Aug-2016	Wastera030817	5.20	3.67	10320.00	940.00	11.00	52.50	N/A	5.98	2.39
Waste water	Wastewater	24-Aug-2016	Wasterb030817	4.69	3.25	12200.00	1002.00	14.90	66.30	N/A	5.76	2.36