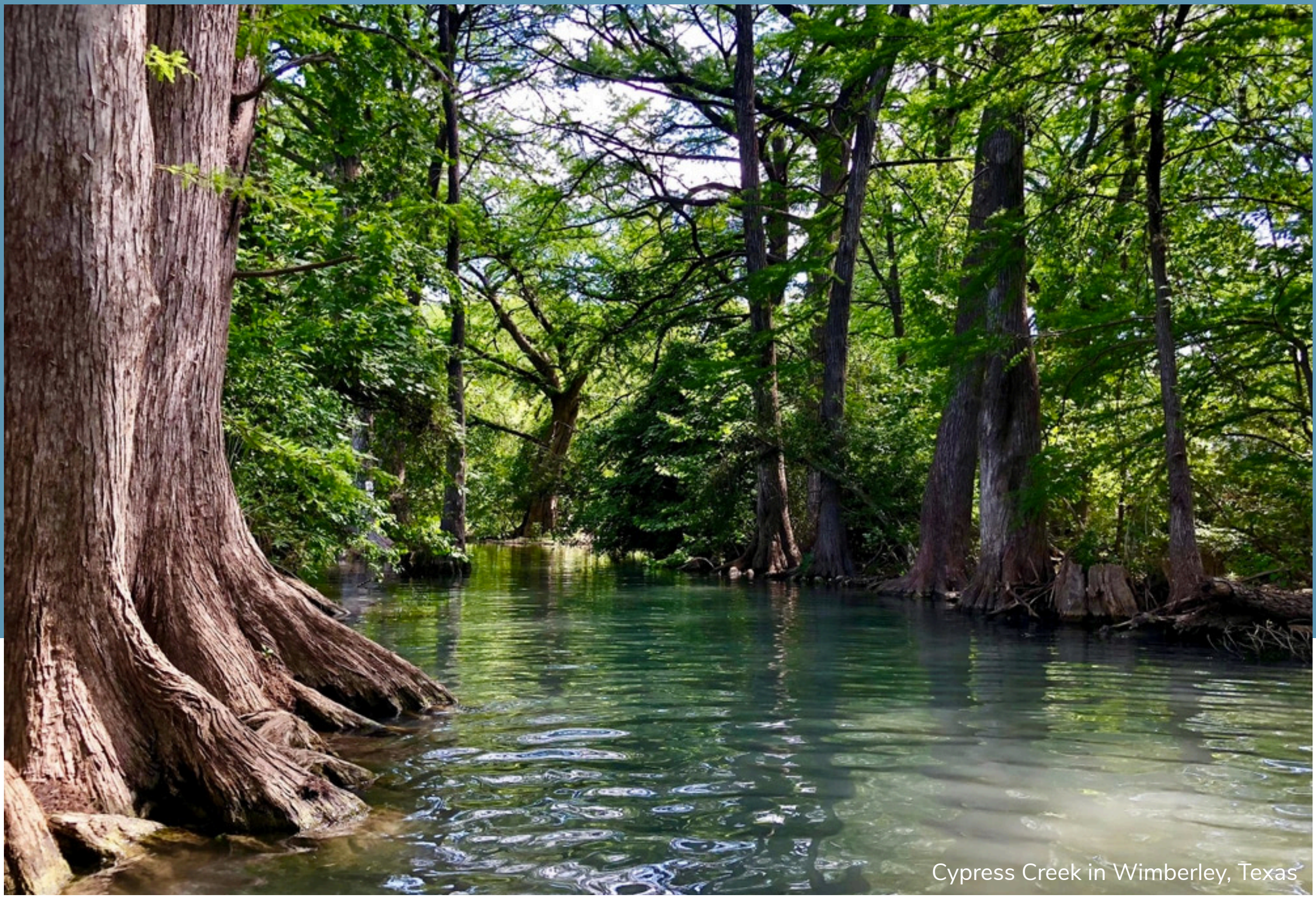
Meadows Report 23-001

Lower Cypress Creek Pilot Project: Assessment of *E. coli* and Optical Brighteners



Cypress Creek in Wimberley, Texas

Prepared by

Sandra S. Arismendez, Ph.D. and Desiree Jackson, B.S.

The Meadows Center for Water and the Environment, Texas State University

May 2023

The Meadows Center for Water and the Environment
Texas State University

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Sandra S. Arismendez, Ph.D., Senior Watershed Scientist

Desiree Jackson, B.S. Graduate Research Assistant

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THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT

TEXAS STATE UNIVERSITY

601 University Drive, San Marcos Texas 78666

512.245.9200 | MeadowsCenter@txstate.edu | www.MeadowsWater.org

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Contents

List of Figures

List of Tables

Executive Summary

E. coli bacteria monitoring has been conducted on Cypress Creek in Wimberley, Texas for over a decade and exceedance of the bacteria water quality standard for the contact recreation use on the lower reach is well documented, however, bacteria source identification techniques are scarce. The goal of this work was to conduct targeted *E. coli* monitoring on lower Cypress Creek with greater resolution in space and time to discern areas of high concentrations of bacteria and identify potential sources. Spatial and temporal analysis of monitoring data from this work identified bacteria likely originate from nonpoint source runoff during rainfall events, seasonal direct deposition of bat guano, and sewage contamination from on-site septic systems.

The Meadows Center for Water and the Environment (The Meadows Center) staff monitored water quality field parameters and observations and *E. coli* bacteria from June 2021 to December 2022. Tampling (tampon + sampling) and fluorometry methods were implemented as a unique, low-cost approach to indirectly assist with bacterial source identification during the project period. Precipitation and streamflow data were also acquired from existing sources to assist with data analysis and interpretation.

Nonpoint source runoff carries pollutants from the surface of the land it drains and is exacerbated as developed land use increases. From 2011 to 2019 developed land use increased by approximately one square mile (2.4%) in the Cypress Creek Watershed. The change in developed land use coupled with a strong ($r^2 = 0.61$) and significant ($p < 0.05$) relationship between precipitation and bacteria concentrations during wet periods suggests nonpoint sources of bacteria from surface runoff are a likely source impacting water quality in Cypress Creek.

A component of the bacteria from nonpoint source can also be attributed to the bat colony residing under the Ranch Road 12 bridge. A 56 percent increase in *E. coli* bacteria concentrations between the sites upstream and downstream of the bridge indicates an impact on water quality from the bats. An increase in bacteria colonies for all sites combined was also detected in the months of September through November when bat densities are presumed to be the highest prior to migration southward to warmer climates. Storm drains under the bridge serve as a conduit for stormwater during rain events that serve as a means of transport for the bat guano from the land surface into Cypress Creek.

Rainfall patterns during the project period significantly differed between 2021 and 2022 and provided opportune circumstances for comparison of bacteria loadings during wet and dry years. Bacteria loadings were calculated using acquired existing data and field measurements collected during this study. Results imply the *E. coli* loads at the most upstream site were minimally affected by runoff during the wet year (2021) and not affected during the dry year (2022) when the bacteria load was below the criterion. The site below the Ranch Road 12 bridge was the only site that exhibited a higher percent difference from the criterion during 2022, the dry year, than during the wet year, implying a point source or direct deposition of bacteria. Because bacteria concentrations exceeded the water quality standard during both wet and dry years, we assume both point and nonpoint sources contributed to the loadings.

The tampling method implemented as an inexpensive preliminary pollution screening tool to discern presence or absence of optical brighteners proved to be a viable approach and determined that tampon deployments from 1 to 3 days were adequate for the detection of optical brighteners.

Fluorometry measurements coupled with *E. coli* bacteria colony counts and the ultraviolet light exposure experiments implemented to discern interference from organic fluorescence also proved to be viable indicators of sewage contamination from on-site septic systems. The lab and field measurement comparisons determined that future water samples could be transported to the lab for analysis with negligible interference of optical brightener photodecay from ultraviolet light exposure while in transit. The ultraviolet light exposure experiment resulted in water samples from all sites exhibiting photodecay rates greater than 35.5 percent after exposures at the 5- and 10-minute intervals indicative of optical brightener presence. The positive and relatively strong ($r^2 = 0.22$) significant ($p < 0.05$) correlation between *E. coli* bacteria and fluorescence in Cypress Creek is symbolic of on-site septic system contamination.

Recommendations for future work include continued water quality monitoring as conducted in this study to assess the effect of connections to the central sewage collection system, along with tracking the connections to the central collection system, monitoring of bat migration patterns, and dye tracer studies to identify malfunctioning septic systems. Remediation efforts to improve water quality should focus on restoring riparian habitat buffers along the creek, especially in bare or denuded areas, and relocation of the bat colony by constructing bat houses throughout the watershed that may aid in dispersing the population to other areas instead of concentrating them under the bridge directly over the creek.

Introduction

Thirty-three percent of the surface water impairments in Texas do not meet the primary contact recreation use water quality standard for *E. coli* bacteria (TCEQ 2022). Although Cypress Creek is not on the list of impaired waters for the contact recreation use, it is showing signs of water-quality degradation with the lower reach below the Ranch Road 12 bridge consistently exceeding the bacteria water-quality standard (Meadows Center 2020). This is cause for concern because of the recreational activities such as swimming, kayaking, and fly fishing that take place on Cypress Creek and the economic importance of ecotourism in the area.

E. coli bacteria originate in the digestive tract of endothermic organisms, are found in feces of warm-blooded animals, and are used by state and federal agencies as freshwater indicators of potential pathogen contamination. Water-quality standards in freshwater streams have been established by the Texas Commission on Environmental Quality using *E. coli* bacteria as an indicator for assessing the health risk associated with primary contact recreation. The State's *E. coli* bacteria water quality standard for the primary contact recreation use for a perennial freshwater stream is 126 most probable number per 100 milliliters of water (MPN/100 ml) and is compared to the geometric mean of a minimum of 20 bacteria samples collected over a seven-year period when flow is greater than or equal to 0.1 cubic feet per second (cfs). The primary contact recreation standard is applied in areas that are presumed to involve a significant risk of ingestion of water while swimming, wading, tubing, diving, and engaging in other activities associated with the water (TCEQ 2022).

E. coli bacteria are ubiquitous and can originate from many different sources. The 2022 Integrated Report identified the potential sources of bacteria impairments for surface waters in Texas as nonpoint source, point source, and unknown (TCEQ 2022). In 2017, a limited short-term bacterial source tracking (BST) study was conducted in Cypress Creek the by Texas A&M AgriLife Research – Soil & Aquatic Microbiology Laboratory and The Meadows Center to better characterize instream *E. coli* bacteria sources (Dornak 2017). They identified wildlife, livestock, and human sewage sources from leaking septic systems to be the most likely sources of *E. coli* bacteria. A bat colony inhabits the bridge at Ranch Road 12 in Wimberley and swaths of guano have been observed along the banks of Cypress Creek under the bridge. Cattle graze on pastures along the banks of Cypress Creek across from Blue Hole Regional Park just upstream of the study area and use Cypress Creek as a drinking water source. Excrement from domestic pets and other wildlife including deer, racoons, and waterfowl can also be sources of bacteria to Cypress Creek.

Saturated drain fields and malfunctioning septic systems are other potential sources of bacterial contamination (Sowah and others 2014). Commercial and residential developments in Wimberley have historically used on-site septic systems for sewage disposal (Venhuizen 2021). Recently, a centralized collection system was installed in Wimberley and connections to the system are beginning to take place.

A combination of targeted bacteria and optical brightener monitoring have been used as an inexpensive and effective pollution screening method to detect human sources of fecal contamination (Petch 1996, Hartel and others 2007, Tavares and others 2008, Makabeh 2016). Optical brighteners are chemical compounds or dyes added to laundry detergents, cleaning agents, textiles, synthetic fibers, and different paper products including toilet paper to make them appear brighter (Hagedorn and others, 2005, Boving and others, 2004). These chemical compounds have been used as proxies of wastewater contamination from illicit discharges in storm drains and failing septic systems because they adsorb to cotton and fluoresce under ultraviolet light, therefore can be easily detected (Petch 1996, Hartel and others 2007, Tavares and others 2008, Makabeh 2016). However, optical brighteners photodecay when exposed to ultraviolet light, biodegrade at a slow rate, and are not the only source of fluorescence in surface water.

Naturally occurring background fluorescence from organic matter and aromatic compounds can interfere with optical brightener fluorometric measurements (Boving and others, 2004, Hagedorn and others, 2005). To differentiate between optical brighteners and other fluorescing organic compounds, Hartel and others (2007) exposed water samples to ultraviolet light to improve fluorometry measurements. When coupled with bacteria counts, they were able to develop a method to identify human fecal contamination quickly and easily.

The Meadows Center, in collaboration with the Watershed Association and the Guadalupe Blanco River Authority, has monitored water-quality parameters at seven sites on Cypress Creek since 2012 on a quarterly basis as part of the Texas Commission on Environmental Quality's Clean Rivers Program. Monitoring occurred throughout the Cypress Creek watershed from the headwaters at Jacob's Well to the confluence with the Blanco River (Meadows Center 2020). Results of the monitoring are used in the state's biennial water quality assessment to determine if water quality is meeting the designated uses. When monitoring data from all Cypress Creek sites are pooled and assessed collectively, the water-quality standard for the contact recreation use is met. The concern arises when sites in the lower reach are assessed individually and exceed the water-quality standard when compared to the sites in the upper reach (Meadows Center 2020). Water quality monitoring on Cypress Creek includes field parameters, nutrients, and bacteria and occurs quarterly on an annual basis but has not historically included optical brightener monitoring.

Analysis of *E. coli* bacteria data from the Clean Rivers Program monitoring conducted on Cypress Creek revealed an increasing spatial trend from the headwaters at Jacob's Well to the confluence with the Blanco River and prompted the current study in the lower one-mile reach of the creek. The purpose of the project was to conduct targeted *E. coli* monitoring on lower Cypress Creek with greater resolution in space and time to discern areas of high concentrations of bacteria and identify potential sources.

Materials and Methods

Site description

Cypress Creek is in Central Hays County in Wimberley, Texas in the Texas Hill Country (Figure 1). The Cypress Creek watershed is comprised of the upper dry or intermittent and the lower wet or perennial streams and collectively encompasses an area of 38 square miles or 98 square kilometers (The River Systems Institute 2010). Cypress Creek flows from northwest to southeast through the cities of Woodcreek and Wimberley primarily through the lower wet watershed with the upper dry watershed flowing during wet weather rain events. The local geology plays a significant role in the hydrology of the area and is characterized by cavernous limestone rock formations that comprise the underlying karst system (Dedden 2008). The climate in this area is characterized as semi-arid and receives an average annual rainfall of 35 inches with peak rainfall occurring in the summer and fall (The River Systems Institute 2010). Land cover change analysis in the watershed was determined from spatial data sets processed in geographic information systems for 2011 and 2019 (Figure 2). Approximately 1 square mile (587 acres) of aggregated developed land cover increased from 2011 to 2019, while the sum of the remaining aggregated land cover types decreased equitably (Table 1).

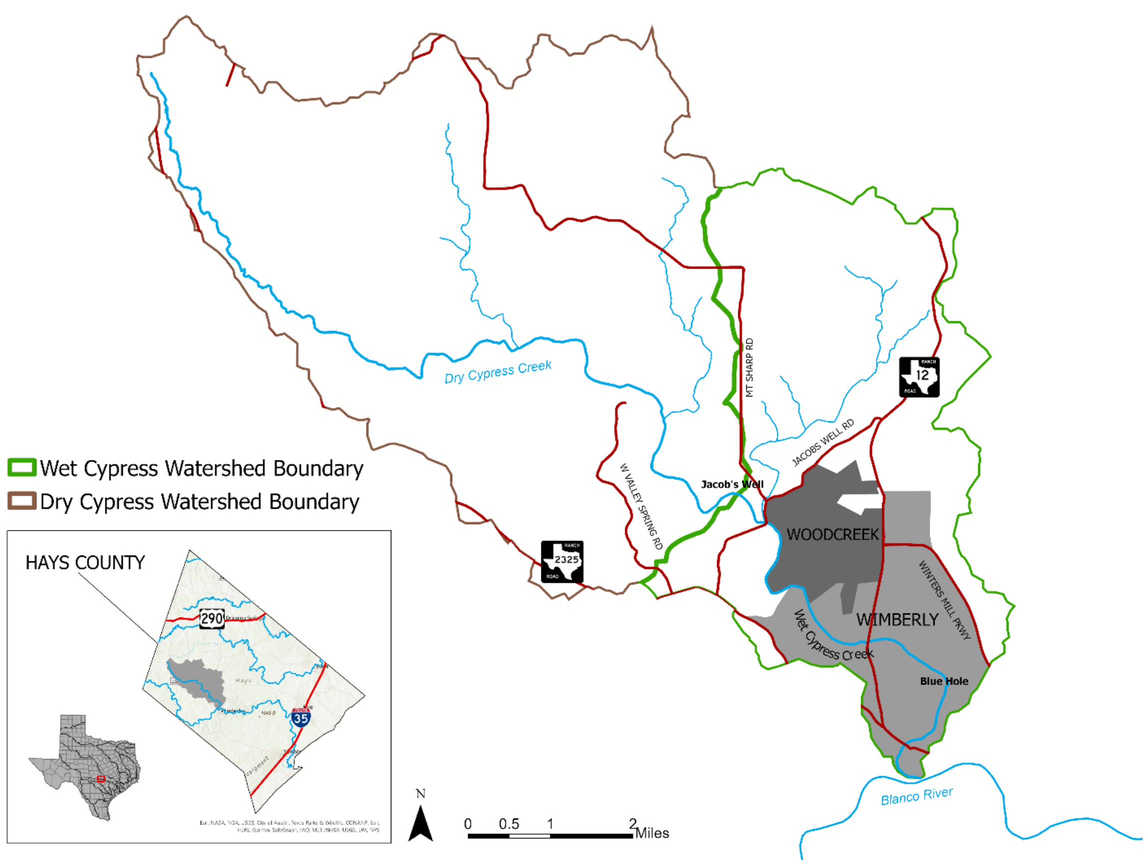

Figure 1. Cypress Creek Watershed, Hays County, Wimberley, Texas.

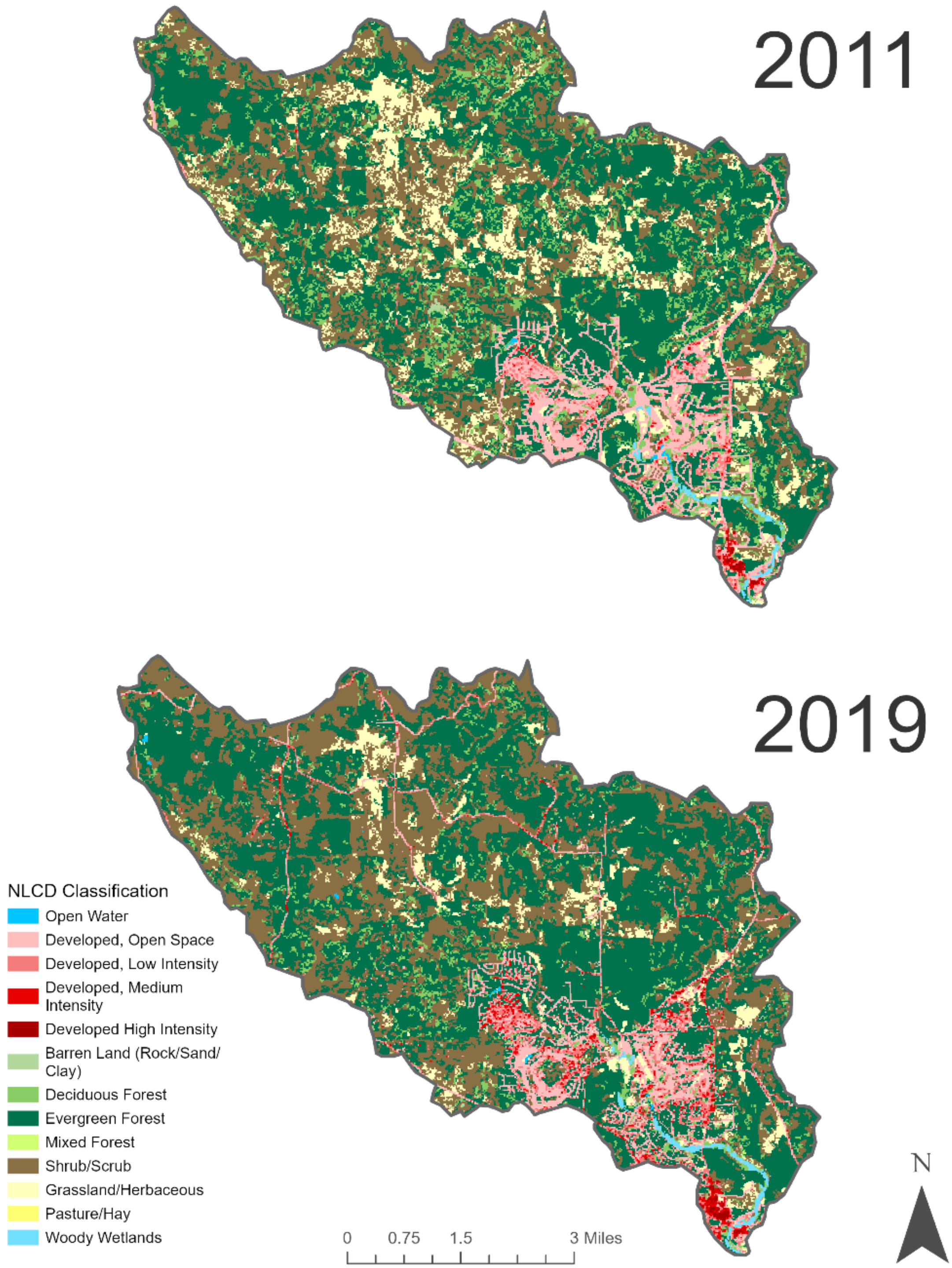

Figure 2. Land cover in the Cypress Creek Watershed, Wimberley, Texas (NOAA National Land Cover Database, 2011 and 2019).

Table 1. Land cover in the Cypress Creek Watershed, Wimberley, Texas (NOAA National Land Cover Database, 2011 and 2019).

LAND COVER CLASSIFICATION	AGGREGATES	2011 – ACRES (%)	2019 – ACRES (%)	DIFFERENCE – ACRES (%)
Barren Land (Rock/Sand/Clay)	Barren	18.6 (0.08)	11.3 (0.05)	-7.3 (-.03)
Deciduous Forest Evergreen Forest Mixed Forest	Forest	12,498.3 (51.4)	12,763.1 (52.5)	264.8 (1.1)
Developed High Intensity Developed Low Intensity Developed Medium Intensity Developed Open Space	Developed	2,188.7 (9.0)	2,776.0 (11.4)	587.3 (2.4)
Grassland/Herbaceous Shrub/Scrub	Grass/ Shrubland	9,509.2 (39.1)	8,635.4 (35.5)	-873.8 (-3.6)
Open Water	Open Water	14.0 (0.06)	18.8 (0.1)	4.9 (0.02)
Pasture/Hay	Agriculture	0 (0)	1.1 (0)	1.1 (0.0)
Woody Wetlands	Wetlands	96.6 (0.04)	119.6 (0.5)	23.0 (0.1)

Table 2. Texas Stream Team monitoring sites in lower Cypress Creek, Wimberley, Texas.

SITE ID	DESCRIPTION	LATITUDE	LONGITUDE
81653	Cypress Creek at Cypress Creek Nature Preserve trail	29.997246	-98.095994
80443	Cypress Creek at Old Kyle Road (upstream of bridge)	29.997119	-98.097039
80926	Cypress Creek at RR12 (downstream of bridge)	29.996657	-98.097873
81663	Wimberley Spring behind Ozona Motor Bank	29.997864	-98.100351
81658	Wimberley Stream about 20 meters upstream of the Cypress Creek confluence	29.996604	-98.098361
81652	Cypress Creek below Wimberley Stream confluence	29.995915	-98.098354
81651	Cypress Creek at 501 River Road	29.994095	-98.099451
81659	Cypress Creek pool downstream of last dam before the Blanco River confluence	29.992039	-98.097231
81627	Cypress Creek at Blanco River confluence	29.991773	-98.095669

Field and laboratory methods

Water quality measurements for this project began in June 2021 and ended in December 2022. Throughout that time, adjustments were made to the sampling frequency, locations sampled, and parameters measured as needed. At the beginning of the study, concurrent measurements of *E. coli* bacteria, field parameters (water temperature (degrees Celsius, °C), dissolved oxygen (milligrams per liter, mg/l), pH (unitless), and specific conductance (microsiemens per centimeter, μS/cm)), field observations (flow severity, algae cover, water color, water clarity, water surface, water conditions, water odor, days since last significant precipitation, and rainfall accumulation) and optical brightener monitoring occurred at eight sites twice weekly for thirteen weeks (Table 2). The monitoring frequency was designed to assess bacteria concentrations during different times of the week (Sunday and Thursday) and to detect optical brighteners (present/absent) associated with potential wastewater contamination using the tampling (tampon + sampling) method with organic cotton tampons (Albus 2021).

In October 2021, some project modifications were implemented. A temporary site was added at Wimberley Spring (Site ID 81663) located behind the Ozona Motor Bank parking lot in Wimberley (Table 2) to detect stormwater runoff as a source of bacteria. The sampling frequency was adjusted to once a week (Thursday) because there was no difference in bacteria concentrations during different times of the week. The tampling for optical brightener detection was suspended because presence was detected at all sites.

In August 2022, we continued to sample at the eight original sites, plus we reinstated the tampling, along with the addition of fluorometric field and lab water sample measurements using a Turner Designs *Aqua*Fluor® Handheld Fluorometer to quantify relative fluorescence. Calibration of the AquaFluor Handheld Fluorometer was conducted before each monitoring event and was performed with a blank (control) sample of deionized water to establish the zero-point relative fluorescent unit (RFU), then with a commercial calibration standard of known concentration (PTSA 400 μg/L) set to 200 RFUs. A calibration test was conducted with known concentrations of the standard solution after the calibration procedure was completed to ensure measurements were within ±0.2 RFUs of the blank and standard. The sampling frequency was adjusted to biweekly from August to December 2022.

Each sampling event began at approximately the same time of day (8:00 am) at the downstream site (81627 – Cypress Creek at the Blanco River confluence) moving systematically in an upstream direction, concluding at the upstream site (81653 – Cypress Creek at Cypress Creek Nature Preserve trail) (Figure 3). Water samples were collected from the mixed surface layer at approximately 0.3 meter depths from the centroid of flow in Nasco Whirl-Pak® Light Sensitive 118 ml bags. A field blank was collected at a different site during each monitoring event using deionized water and was plated and analyzed as a negative control in the lab. *E. coli* bacteria analysis was conducted using Micrology's Coliscan Easygel® media and methods established by the Texas Stream Team (Texas Stream Team 2021a). Field parameters were measured with the Extech DO610 probe kit and field observations were made following Texas Stream Team monitoring protocols (Texas Stream Team 2021b). Optical brightener tampling monitoring was conducted concurrently at the same sites as described by (Albus 2021) with slight modifications including different tampon deployment treatments, using

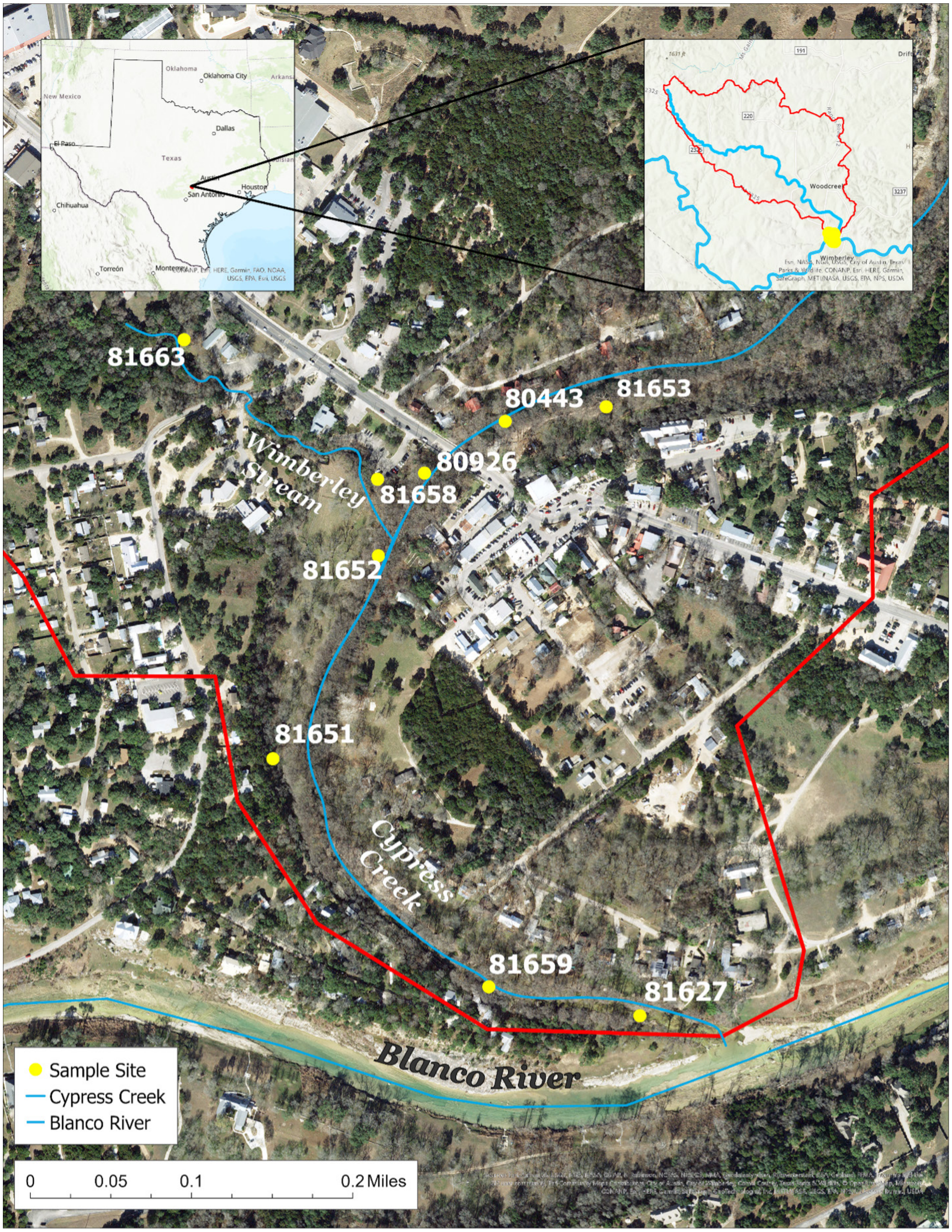

Figure 3. Lower Cypress Creek Watershed project monitoring sites, Wimberley, Texas.

quart-sized food storage bags instead of aluminum foil because the foil fluoresced, and conducting the tampon analysis at The Meadows Center instead of sending them to the University of North Texas.

Optical brightener tampling sample deployment and retrievals occurred from June 2021 to September 2021. Four deployment and retrieval treatments were implemented. Sunday deployments were designed to capture increased human activity resulting from tourism during weekends, while Thursday deployments were designed to capture less human activity from tourism during weekdays. One and two-week deployments were also implemented to help assess deployment durations best suited for the tampling analysis. Upon retrieval of the tampling material from the field, it was critical to maintain the sample in a dark environment during transport because the optical brighteners photodecay, until it was analyzed in the lab then dried and reanalyzed in a dry state. The wet tampon was analyzed immediately upon retrieval in the lab using the Ultraviolet Beast New V3 365 nanometer black light Ultraviolet flashlight. If the sample exhibited blue fluorescence in a dark environment, then the result was “P” for presence. If no blue fluorescence was observed, then the result was “A” for absent. After the wet sample was analyzed, the tampon was placed in a dark environment in the lab for seven days until dry. After seven days of drying time, the tampon was analyzed with the blacklight for the dry analysis the same way it was analyzed for the wet analysis. We suspended the tampling in September 2021 because optical brighteners were detected at all sites and for all treatments with no visible differences between sites and treatments.

In August 2022 we reinstated the tampling deployments alongside field and lab fluorometric measurements of sample water from Cypress Creek to assist with interpretation of the visual presence/absence results. Fluorometric measurements were conducted in the field and in the lab to discern the effect of optical brightener photodecay in the water sample while in transit from the field to the lab. Field and lab fluorometric measurements were conducted in triplicate for each site. In addition to the initial lab measurement, each lab sample was exposed to ultraviolet light for 5- and 10-minute intervals to discern organic fluorescence from optical brightener fluorescence. Fluorometric measurements were taken before and after each exposure treatment.

Data management and analysis

Field and laboratory measurements from this project resulted in four data types: water-quality field measurements and observations, *E. coli* bacteria colony counts, tampling presence/absence results, and field and lab fluorometric measurements. Existing stream flow and precipitation measurements were acquired from the U.S. Geologic Survey (USGS) gage at Jacob’s Well (Site no. 08170990) and the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (Wimberley 1 NW, TX site), respectively.

Water-quality field parameters and observations were entered into a Survey 123 Texas Stream Team form on an iPad in the field. *E. coli* bacteria colony counts were also entered into the Survey 123 form after the petri dishes were plated and incubated for 28 to 31 hours in the laboratory. Tampling study results were entered into an Excel spreadsheet after wet and dry samples were analyzed and photo documentation was archived. Field fluorometric measurements were entered into a Microsoft Excel spreadsheet along with the laboratory ultraviolet light exposure measurements. Data were imported from Survey 123 and merged with an Excel spreadsheet. Data were compiled, analyzed in JMP Pro 15.2.1 (SAS Institute Inc. 2018), summarized, and compared to state water-quality standards, where appropriate. Total dissolved solid (TDS) values were calculated from specific conductance (SC) field measurements (TCEQ, 2020): TDS = SC * 0.65. The *E. coli* bacteria colony counts were transformed using natural logarithms (ln[y]). The fluorometric lab exposure measurements were used to calculate relative percent differences between the initial value and the 5- and 10-minute exposure treatments as described by Cao and others (2009).

For long-term storage and archive, the water quality field measurements, observations, and *E. coli* bacteria counts will be housed in the Texas Stream Team Waterways Dataviewer. The tampling and fluorometric results will be housed at The Meadows Center.

Tests for normality and equal variances were conducted on the log transformed data. Statistical analyses were conducted including summary statistics, t-test, and correlation analysis, and significant trends were determined using an alpha (a) of 0.05 (that is, with 95 percent confidence). Flow and load duration curves were calculated using acquired discharge measurements from the USGS gage at Jacob’s Well (Site no. 08170990) following U.S. Environmental Protection Agency (EPA) (2007). Acquired precipitation data from the NOAA National Weather Service were analyzed over time and space to assess its influence on *E. coli* bacteria.

Results

Water quality field and lab measurements

Sixty-six field sampling events occurred throughout the duration of this project between June 2021 and December 2022 at varying sites and frequencies. We collected, plated, incubated, and counted, alongside field measurements, 484 *E. coli* samples from 9 sites. Forty-four samples, or approximately 8 percent, were lost due to errors in plating or malfunctioning equipment. The optical brightener tampling deployments resulted in 308 tampons for analysis from 8 sites. Laboratory and field fluorometry measurements were collected in triplicate at 10 sampling events from 9 sites and resulted in 657 laboratory and 192 field measurements.

The distribution of natural log-transformed *E. coli* bacteria data was analyzed (Figure 4) and tested for normality and equal variances ($p < 0.0001$). Summary statistics are presented in Table 3.

E. coli bacteria results collected at all sites from June to September 2021 on Sundays and Thursdays were analyzed to test the effect of day of the week. Results show a higher geometric mean for samples collected on Thursday (156 MPN/100 ml) than Sunday (132 MPN/100 ml) (Table 4). A t-test resulted in no significant difference ($p > 0.05$) between *E. coli* means from samples collected on Sunday and Thursday. Therefore, sampling frequency was adjusted to weekly.

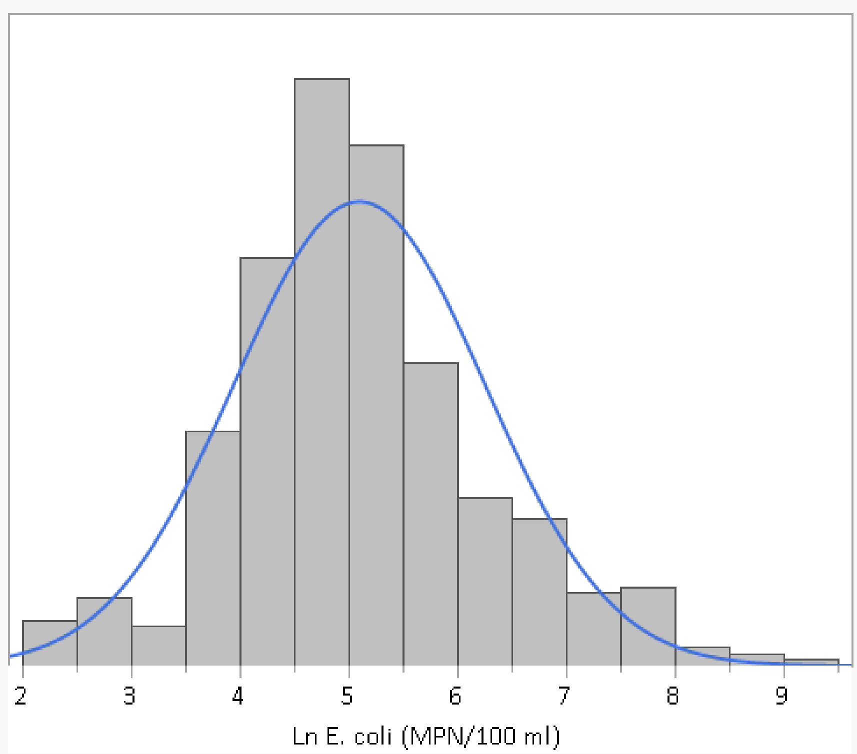

Figure 4. Distribution of natural log-transformed E. coli (MPN/100 ml) data from Cypress Creek, Wimberley, Texas (June 2021 through December 2022).

Table 3. Summary statistics of natural log-transformed *E. coli* (MPN/100 ml) data from Cypress Creek, Wimberley, Texas (June 2021 through December 2022).

STATISTIC	VALUE
Number of Measurements	483
Mean (MPN/100 ml)	5.1
Standard Deviation	1.2
Standard Error of Mean	0.05
Upper 95% of Mean	5.2
Lower 95% of Mean	5.0

Table 4. Summary statistics for *E. coli* (MPN/100 ml) data from Cypress Creek for samples collected Sundays and Thursdays (June through September 2021).

STATISTIC	SUNDAY	THURSDAY
Number of Measurements	94	81
E. coli Geometric Mean (MPN/100 ml)	132	156
Minimum	17	20
Maximum	1,073	4,284

To test the effect of the bats observed under the bridge at Ranch Road 12, *E. coli* monitoring data from the two sites upstream of the bridge (Sites 81653 and 80443) were grouped and compared to the site immediately downstream of the bridge (Sites 80926). *E. coli* monitoring results for the project period of record show a higher geometric mean (181 MPN/100 ml) for the site downstream of the Ranch Road 12 bridge than the two sites upstream of the bridge (116 MPN/100 ml) (Table 5). A t-test resulted in a significant difference ($p < 0.05$) between the means of the sites upstream and downstream of the Ranch Road 12 bridge.

Summary statistics for water-quality parameters measured were calculated by site for the duration of the study (Table 6). The six sites (81653, 80443, 80926, 81652, 81651 and 81627) with the largest number of measurements were the original sites monitored at the inception of the project. We added two sites in August 2021, one at Wimberley Stream (Site 81658) and the other downstream of the last dam before the Blanco River confluence (Site 81659). We also monitored Wimberley Spring (Site 81663) in September 2021, then again in December 2022; however, we discontinued sampling at this site in 2021 because we did not have permission from the landowner at the inception of the project.

Spatial and temporal analysis of E. coli bacteria geometric means generally showed increasing values from upstream to downstream and exceedances of the water quality standard during the fall and winter months. The most upstream site (Site 81653) had the lowest E. coli bacteria geometric mean (107 MPN/100 ml) while Wimberley Spring

(Site 81663) and Wimberley Stream (Site 81658) had the highest geometric means, 327 and 314 MPN/100 ml, respectively (Table 6). The two sites upstream of the Ranch Road 12 bridge (sites 81653 and 80443) had E. coli geometric means at or below the primary contact recreation water quality standard (126 MPN/100 ml), while all remaining sites downstream of the Ranch Road 12 bridge were above the water quality standard for the primary contact recreation use (Figure 5). E. coli geometric means for all sites combined were analyzed temporally by month (Figure 6). Geometric means were below the water quality standard from February through July, but above the standard from August through January.

Table 5. *E. coli* bacteria from Cypress Creek comparing sites upstream and downstream of the RR12 bridge (June 2021 through December 2022).

STATISTIC	CYPRESS CREEK SITES UPSTREAM OF RR12 (81653 AND 80443)	CYPRESS CREEK SITE DOWNSTREAM OF RR12 (80926)
Number of Measurements	128	64
Geometric Mean (MPN/100 ml)	116	181
Minimum	10	20
Maximum	2,706	4,032

Table 6. Water quality parameter summary statistics by site from Cypress Creek, the spring, and Wimberley Stream (June 2021 through December 2022).

PARAMETER/SITE	81653	80443	80926	81652	81651	81659	81627	81663	81658
	Nature Preserve	Kyle Road	RR 12 Bridge	Below Stream Confl.	501 River Road	Downstream Last Dam	Blanco River Confl.	Wimberley Spring	Wimberley Stream
Number of Measurements	64	64	64	63	65	52	65	6	41
**E. coli* (MPN/100 ml)	107	126	181	167	189	155	161	327	314
Water Temperature (°C)	21.4	21.3	20.9	20.8	20.9	19.8	20.5	21.9	18.1
Total Depth (m)	2.0	1.3	0.9	1.1	1.4	0.5	0.3	0.3	0.5
Dissolved Oxygen (mg/l)	6.1	6.1	6.6	6.5	6.1	6.9	6.8	5.4	7.7
pH	7.7	7.7	7.8	7.7	7.6	7.6	7.8	6.2	7.7
Specific Conductance (µS/cm)	599	599	595	601	596	598	583	692	645
**Total dissolved solids (mg/l)	389	389	387	391	387	389	379	450	419

**E. coli* bacteria data are presented as geometric means.

**MPN/100 ml = most probable number of bacteria per 100 milliliters of water; m = meters; mg/l = milligrams per liter; µS/cm = microsiemens per centimenter.

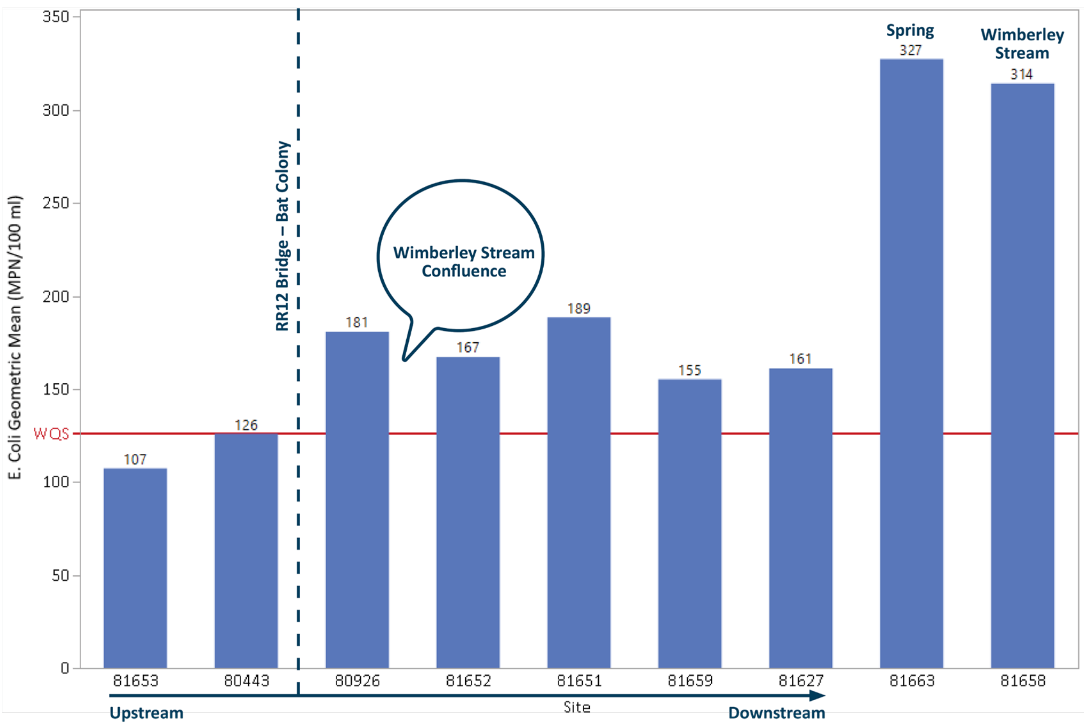

Figure 5. *E. coli* bacteria geometric mean by site from Cypress Creek, the spring, and Wimberley Stream (June 2021 through December 2022). Water quality standard (WQS) = 126 MPN/100 ml; MPN/100 ml = most probable number of bacteria per 100 milliliters of water.

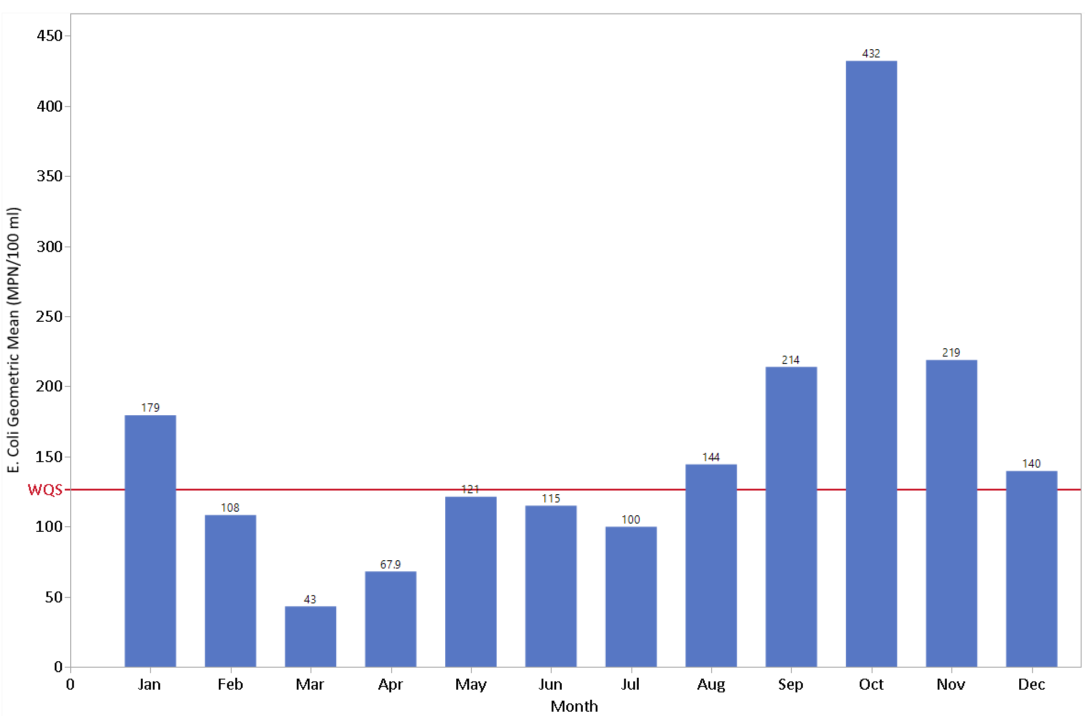

Figure 6. *E. coli* bacteria geometric mean by month from Cypress Creek, the spring, and Wimberley Stream (June 2021 through December 2022). Water quality standard (WQS) = 126 MPN/100 ml; MPN/100 ml = most probable number of bacteria per 100 milliliters of water.

Field measurements assist in characterizing water quality in the study area. The highest average water temperature (21.9 °C) was measured at Wimberley Spring (Site 81663), while the lowest (18.1 °C) was measured at Wimberley Stream (81658). The deepest (2.0 m) site on Cypress Creek proper was the most upstream (81653), while the shallowest (0.3 m) was the most downstream (81627). Average dissolved oxygen was lowest at the spring (5.4 mg/l) and highest at Wimberley Stream (7.7 mg/l). The lowest average pH (6.2) resulted from the spring, although we only collected a limited number of measurements (6), while the average pH at the remaining sites ranged from 7.6 to 7.8. Average total dissolved solids were highest at the spring (450 mg/l) and Wimberley Stream (419 mg/l), while the remaining sites had ranges from 379 to 391 mg/l.

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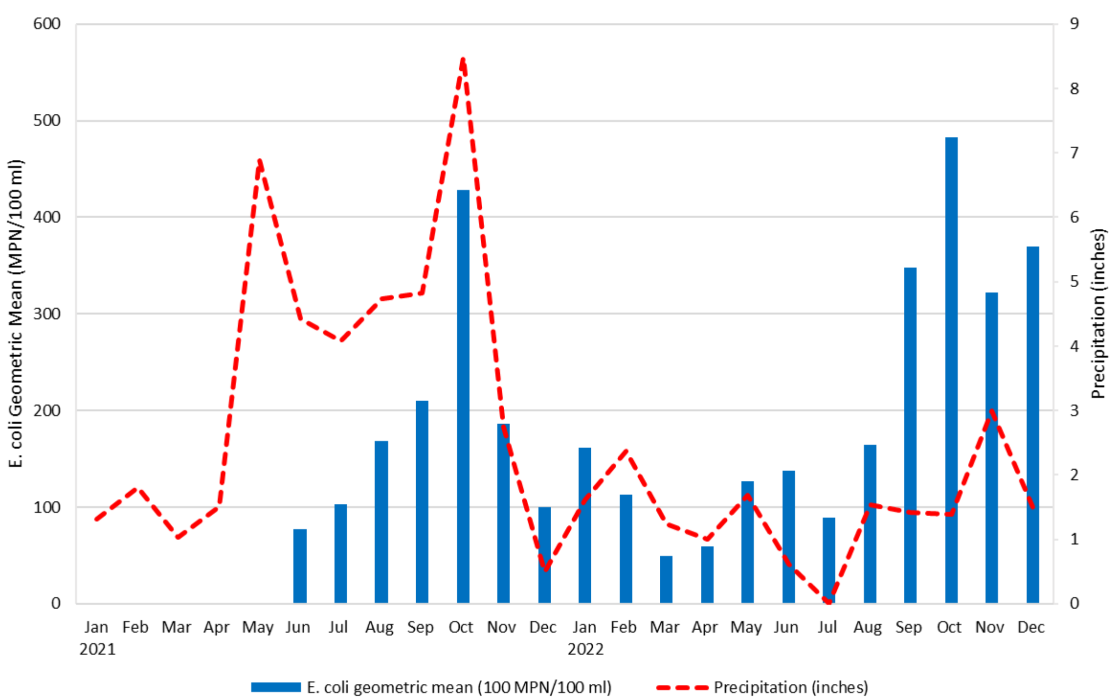

Figure 7. *E. coli* geometric mean (MPN/100 ml) and mean precipitation (inches) by month and year from Cypress Creek (January 2021 through December 2022).

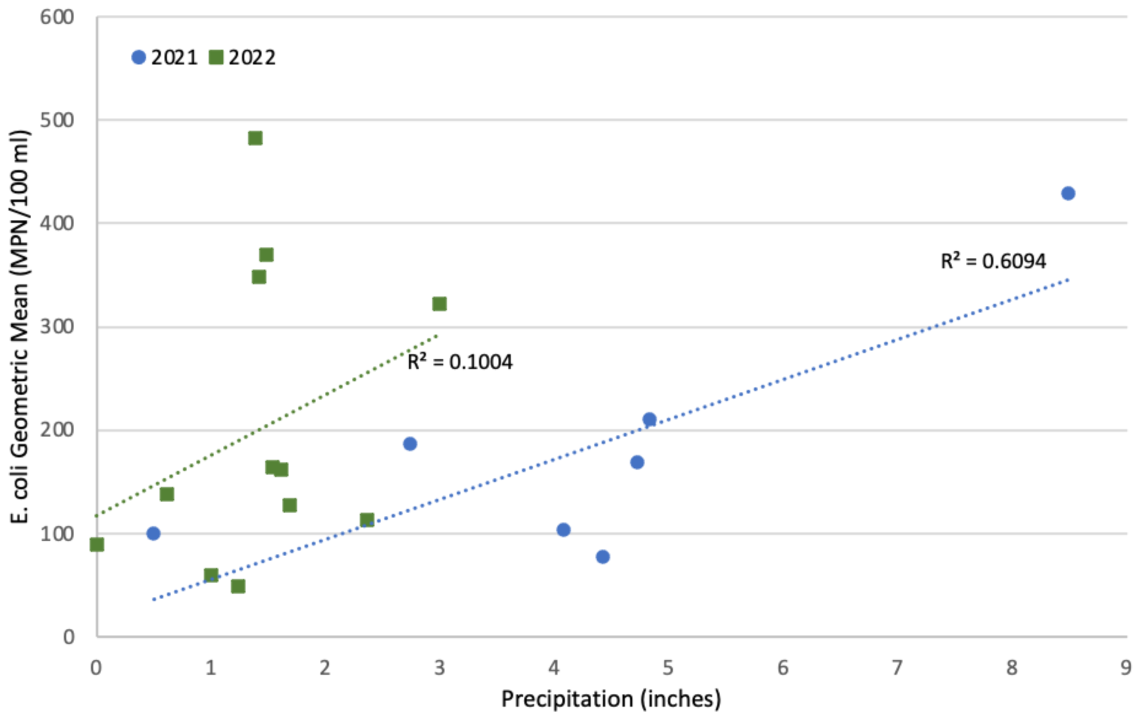

Figure 8. Correlation analysis of monthly *E. coli* geometric mean (MPN/100 ml) and mean precipitation (inches) by year (2021 and 2022) in Cypress Creek, the spring, and Wimberley Stream (June 2021 to December 2022).

Table 7. *E. coli* bacteria summary statistics for all sites from Cypress Creek by year 2021 and 2022 (June 2021, thru December 2022).

STATISTIC	2021	2022
Number of Measurements	275	207
Mean (MPN/100 ml)	295	410
Minimum	17	10
Maximum	4,284	5,649

Precipitation Patterns

NOAA National Weather Service data from Wimberley revealed cumulative precipitation in 2021 was 42.4 inches and 17.4 inches in 2022. The difference in precipitation between the two years prompted the examination of *E. coli* data by year to assess the effect of rainfall.

Mean *E. coli* monitoring results for all sites by year, 2021 and 2022, show a higher average in 2022 (410 MPN/100 ml) than in 2021 (295 MPN/100ml) (Table 7). A t-test resulted in a significant difference ($p < 0.05$) in mean *E. coli* values by year. *E. coli* geometric means were assessed by month and year then compared to precipitation (Figure 7). Different patterns of precipitation over time resulted in different patterns of bacteria concentrations. Correlation analysis between *E. coli* and precipitation resulted in a significant ($p < 0.05$) and strong ($r^2 = 0.61$) correlation in 2021 but not in 2022 ($p > 0.05$, $r^2 = 0.10$) (Figure 8).

Flow and load duration curves

Acquired daily average discharge measurements from the USGS gage at Jacob's Well (Site no. 08170990) for the project period were used to develop a flow duration curve which is designed to correlate flow values to the percent of time those values are met or exceeded (Figure 9). Jacob's Well is located at the headwaters of the watershed and discharge measured continuously by USGS at the well is used as a proxy representative of flow at the downstream sites. The flow duration curve was converted to a load duration curve using streamflow (cfs), the *E. coli* water quality standard (126 MPN/100 mL), and a conversion factor (2.44658×10^{7}). This resulted in the allowable load (MPN/day) at the geometric mean criterion and established a threshold for meeting or exceeding the water quality standard in Cypress Creek under varying streamflow conditions. Ninety percent of the time the discharge from Jacob's Well was greater than 0.1 cfs during the duration of the project, therefore the bacteria water quality standard was not applicable during low flow conditions (Figure 9). Duration curve zones or intervals are used to provide insight to patterns in the hydrologic condition and can be used as a general indicator of wet (high flow) versus dry (low flow) conditions (EPA 2007).

E. coli bacteria monitoring data were converted to loadings (MPN/day) using bacteria concentrations measured at each monitoring event and site, the corresponding streamflow, and a conversion factor (2.44658×10^{7}). Loadings were plotted on the load duration curve developed using the geometric mean criterion. Loading results above the load duration curve exceed the criterion and results below the curve meet the criterion. Because rainfall was significantly different for years 2021 and 2022, we plotted the bacteria loadings by year for each site on Cypress Creek and for Wimberley Stream (Figures 10-17) to determine if sample results from each event at the various sites were influenced by streamflow. Geometric means for each site and year were calculated and plotted along the median streamflow on the x-axis for the corresponding year. The geometric means for all sites exceeded the criterion during both years, 2021 and 2022, except at the most upstream site (81653) which met the criterion in 2022. Percent difference from the criterion shows the effect of streamflow on bacteria loadings for each site and year (Figure 18). In 2021, when there was significantly more rain than in 2022, all sites reflected higher bacteria loadings than in 2022, except the site immediately downstream of the bridge at Ranch Road 12 (80926) where the bats reside. Here, the bacteria loadings were higher in 2022 under dry conditions than 2021 in wet conditions

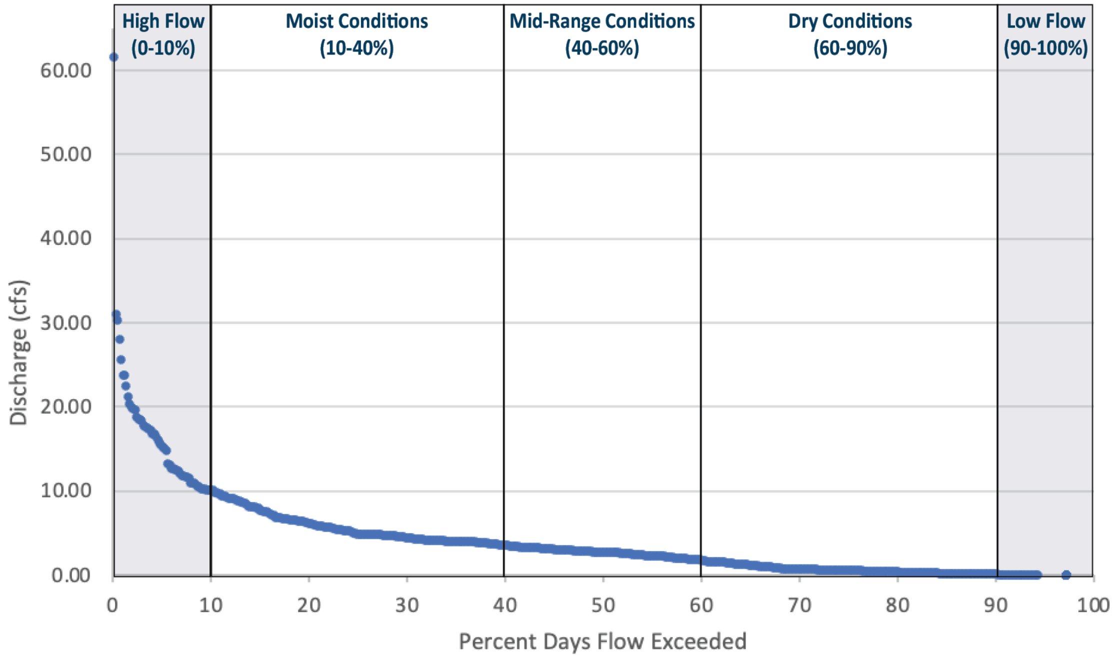

Figure 9. Flow duration curve for discharge from Jacob's Well (June 2021 to December 2022) (USGS gage 08170990). Hydrologic condition classes modeled after Cleland (2003).

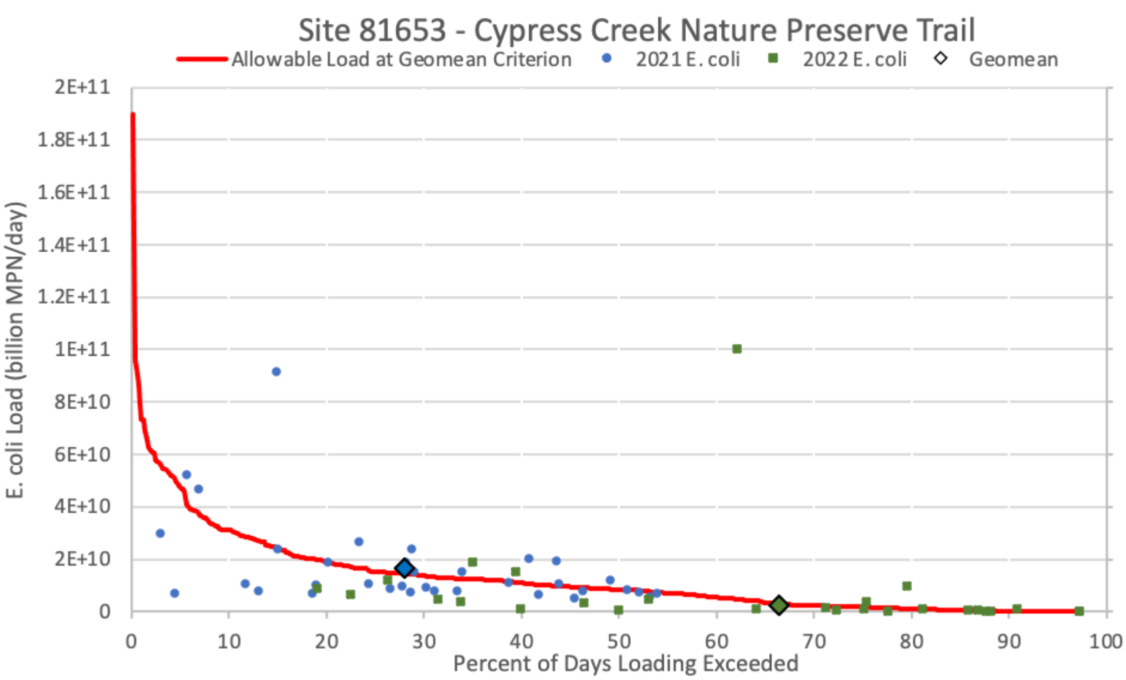

Figure 10. Load duration curve for allowable load at *E. coli* geometric mean criterion (126 MPN/100 ml) by year at Cypress Creek Nature Preserve Trail (site 81653) (June 2021 to December 2022).

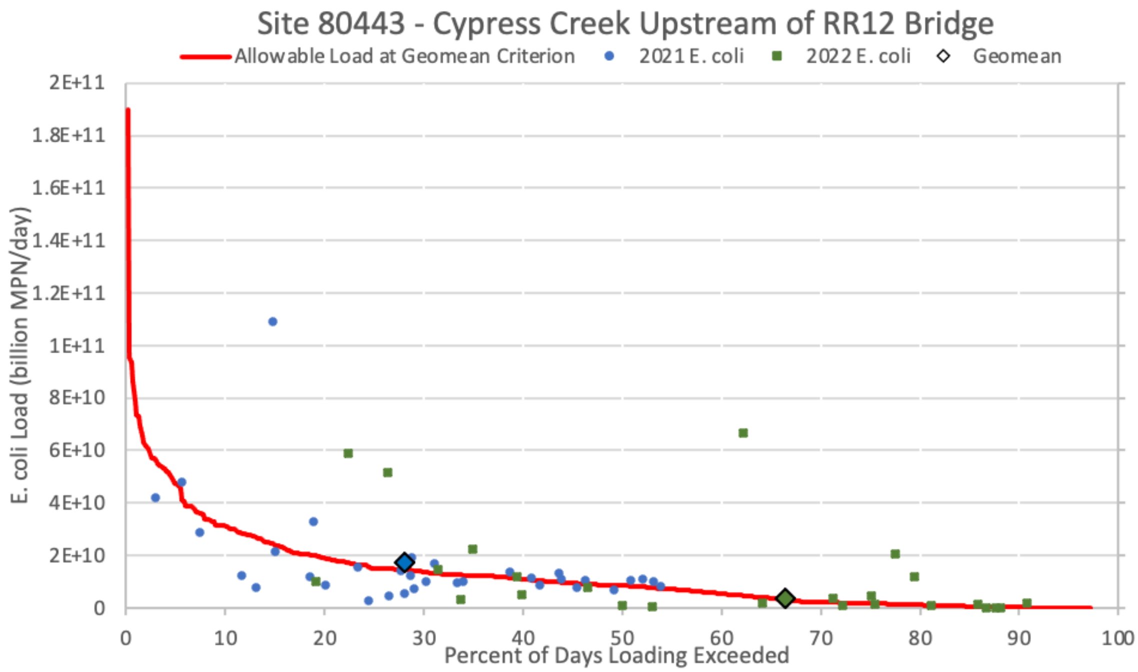

Figure 11. Load duration curve for allowable load at *E. coli* geometric mean criterion (126 MPN/100 ml) by year at Cypress Creek upstream of RR12 bridge (site 80443) (June 2021 to December 2022).

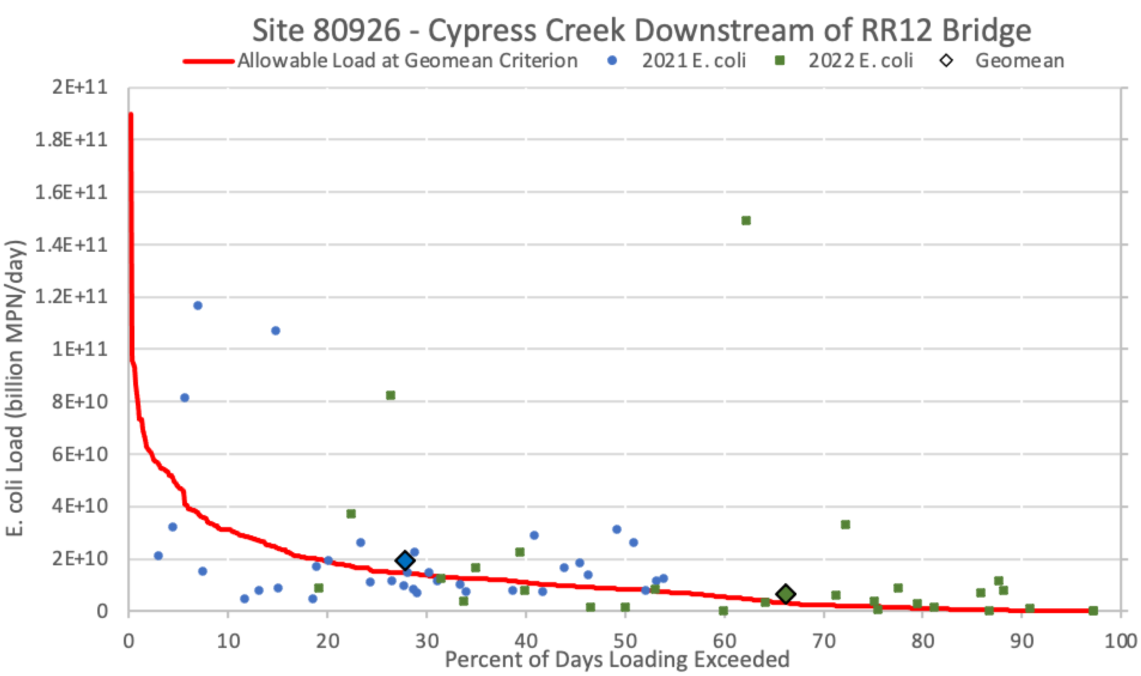

Figure 12. Load duration curve for allowable load at *E. coli* geometric mean criterion (126 MPN/100 ml) by year at Cypress Creek downstream of RR12 bridge (site 80926) (June 2021 to December 2022).

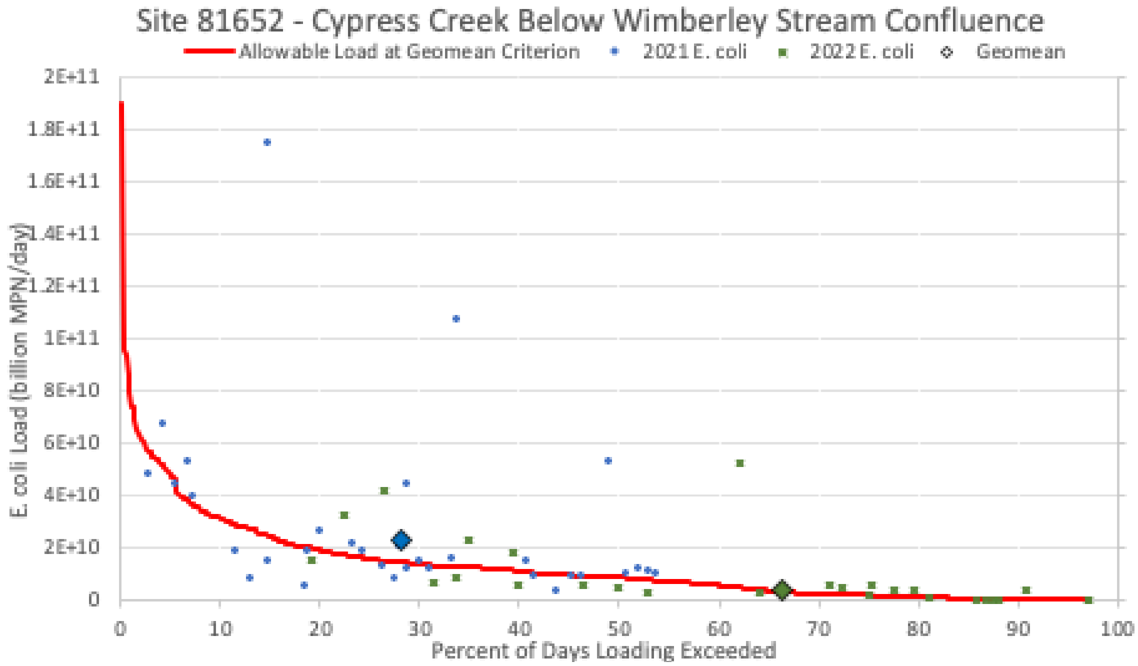

Figure 13. Load duration curve for allowable load at *E. coli* geometric mean criterion (126 MPN/100 ml) by year at Cypress Creek belowWimberley Stream confluence (site 81652) (June 2021 to December 2022).

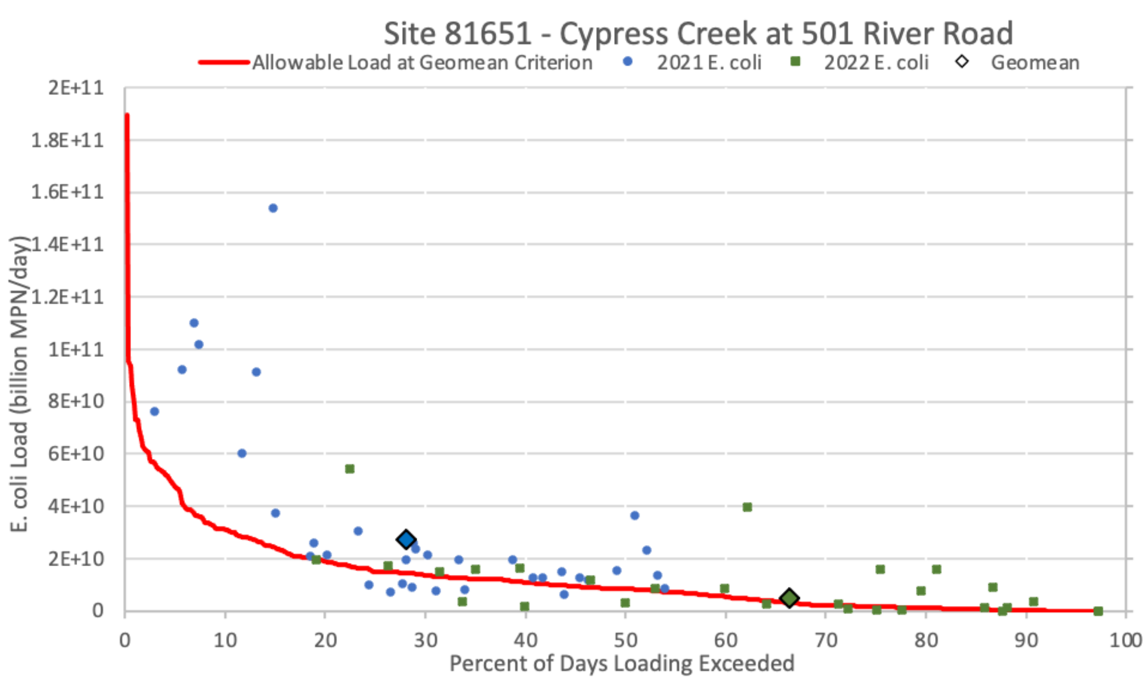

Figure 14. Load duration curve for allowable load at *E. coli* geometric mean criterion (126 MPN/100 ml) by year at Cypress Creek at 501 River Road (site 81651) (June 2021 to December 2022).

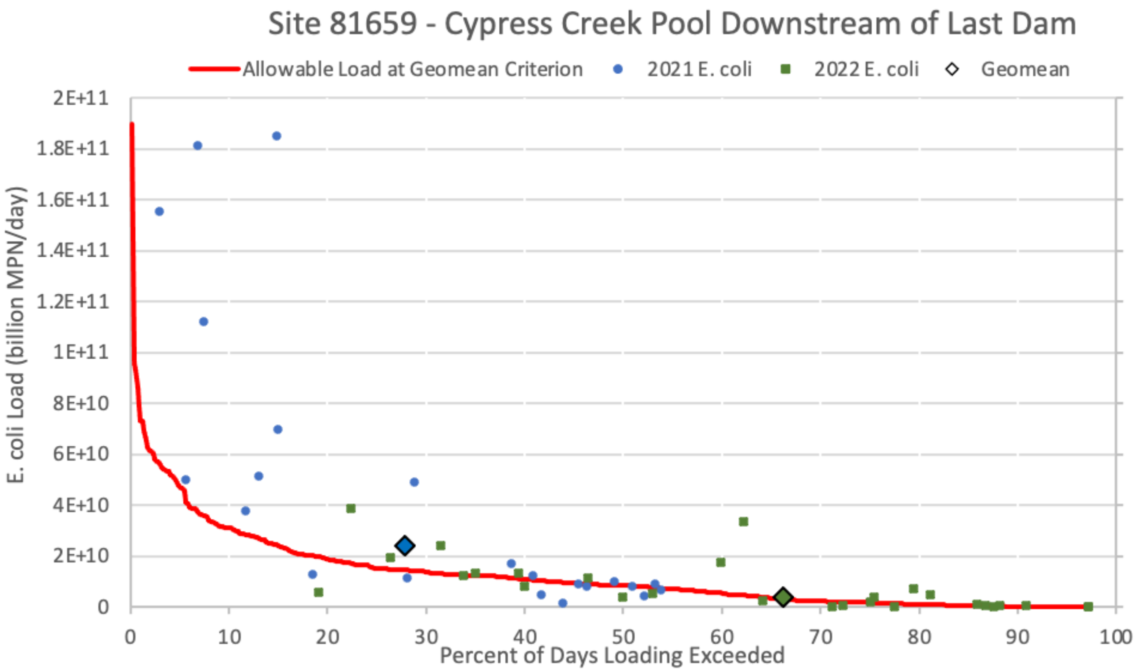

Figure 15. Load duration curve for allowable load at *E. coli* geometric mean criterion (126 MPN/100 ml) by year at Cypress Creek pool downstream of last dam (site 81659) (June 2021 to December 2022).

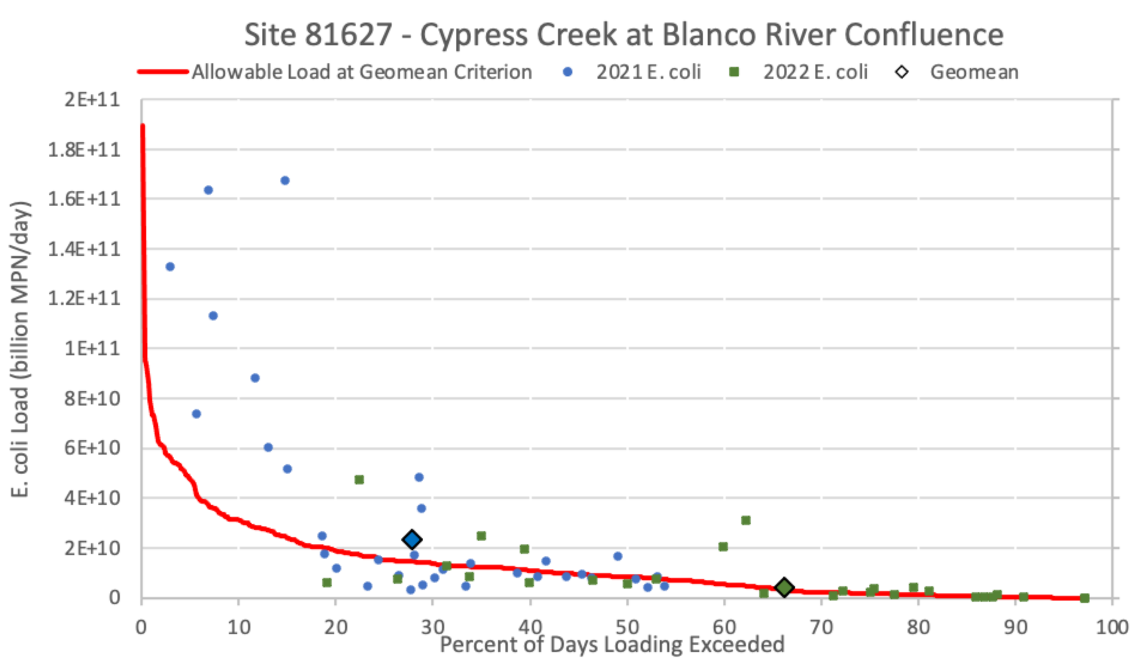

Figure 16. Load duration curve for allowable load at *E. coli* geometric mean criterion (126 MPN/100 ml) by year at Cypress Creek at Blanco River confluence (site 81627) (June 2021 to December 2022).

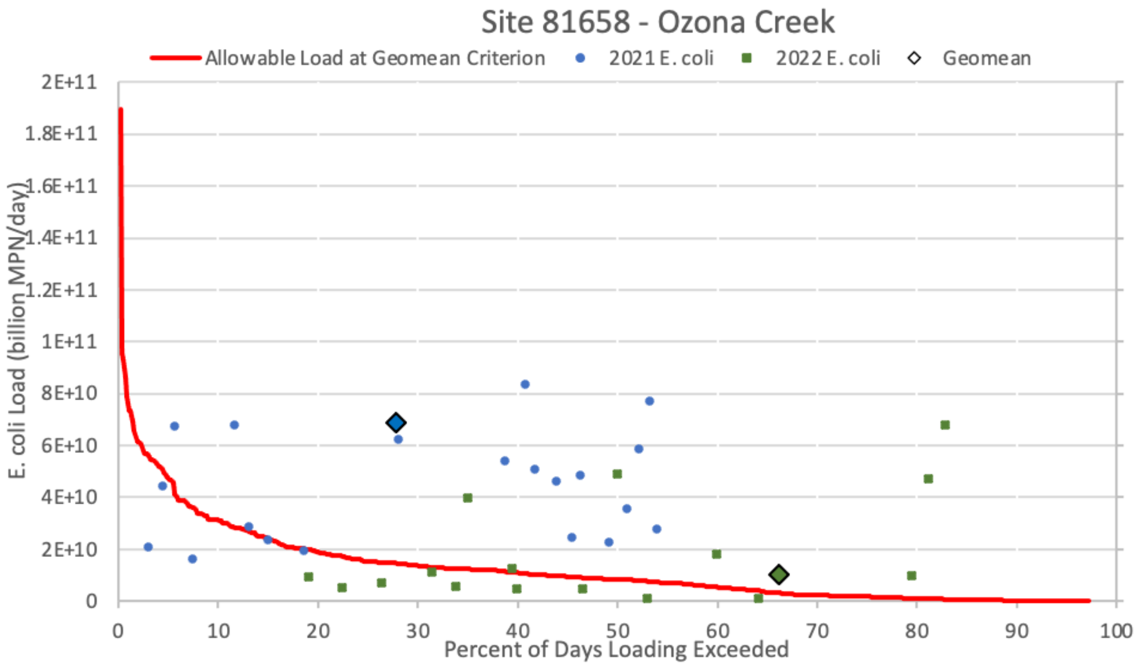

Figure 17. Load duration curve for allowable load at *E. coli* geometric mean criterion (126 MPN/100 ml) by year at Cypress Creek at Wimberley Stream (81658) (June 2021 to December 2022).

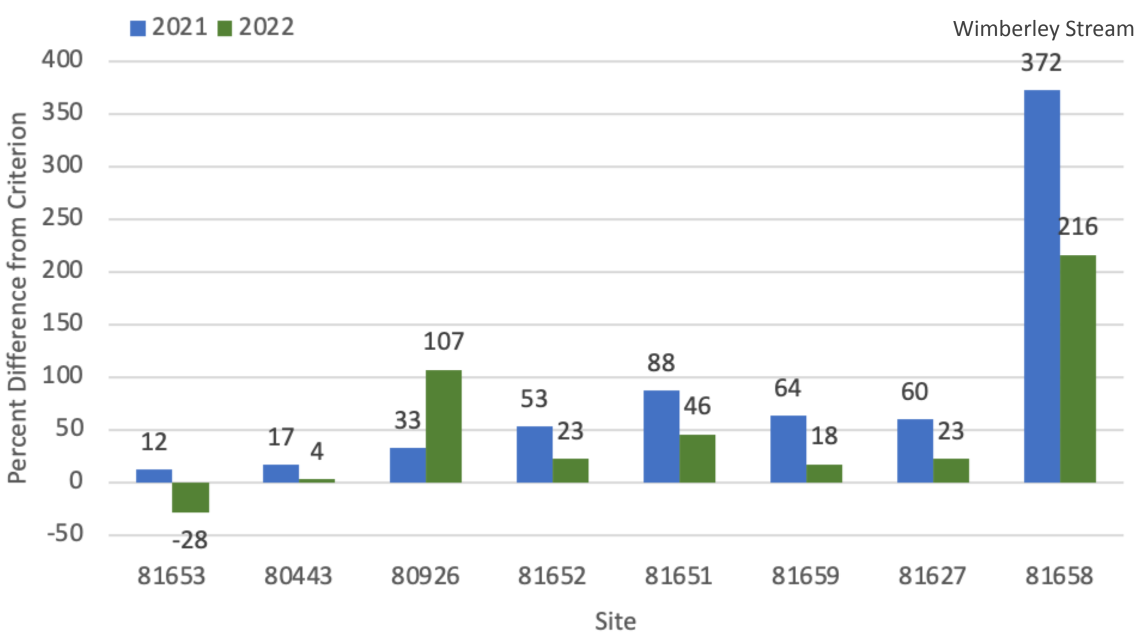

Figure 18. *E. coli* bacteria loading percent difference (above/below total maximum daily load of criterion) by site and year at Cypress Creek (81653, 80443, 80926, 81652, 81651, 81659, and 81627) and Wimberley Stream (81658) sites (June 2021 to December 2022).

Tampling and fluorometry

Tampling results for all treatments and sites resulted in the presence of optical brighteners when viewed under a black light. No discernable qualitative difference in fluorescence intensity was detected in the laboratory observations for the wet or dry multiday treatments of the tampons.

Optical brightener water sample fluorescence was measured with a handheld fluorometer beginning in August 2022 to quantify fluorescence. Field and lab fluorescent measurements were conducted to discern optical brightener photodecay in the water samples during transit from the field to the lab (Figure 19). A t-test resulted in no significant difference ($p > 0.05$) in mean fluorescence between field and lab measurements (Table 8).

Laboratory ultraviolet light exposure experiments were conducted on water samples to discern optical brightener fluorescence from organic matter fluorescence at 5- and 10-minute intervals. Wimberley Stream (Site 81658) exhibited the lowest percent difference for both the 5- and 10-minute exposure times, 35.5 and 44.6 percent, respectively (Figure 20). The site downstream of the Ranch Road 12 bridge (80926) experienced the largest (54.8 percent) difference from the initial measurement for the 5-minute exposure time, while the site below the Wimberley Stream confluence (81652) exhibited the largest (68.3 percent) difference for the 10-minute exposure time (Figure 20). Five-minute exposure times resulted in an average of 49.2 percent difference from initial measurements for all sites combined, while the 10-minute exposure times resulted in an average 61.7 percent difference from initial measurements for all sites combined. A positive and significant ($p < 0.05$) correlation resulted between *E. coli* bacteria and fluorescence for all sites combined (Figure 21).

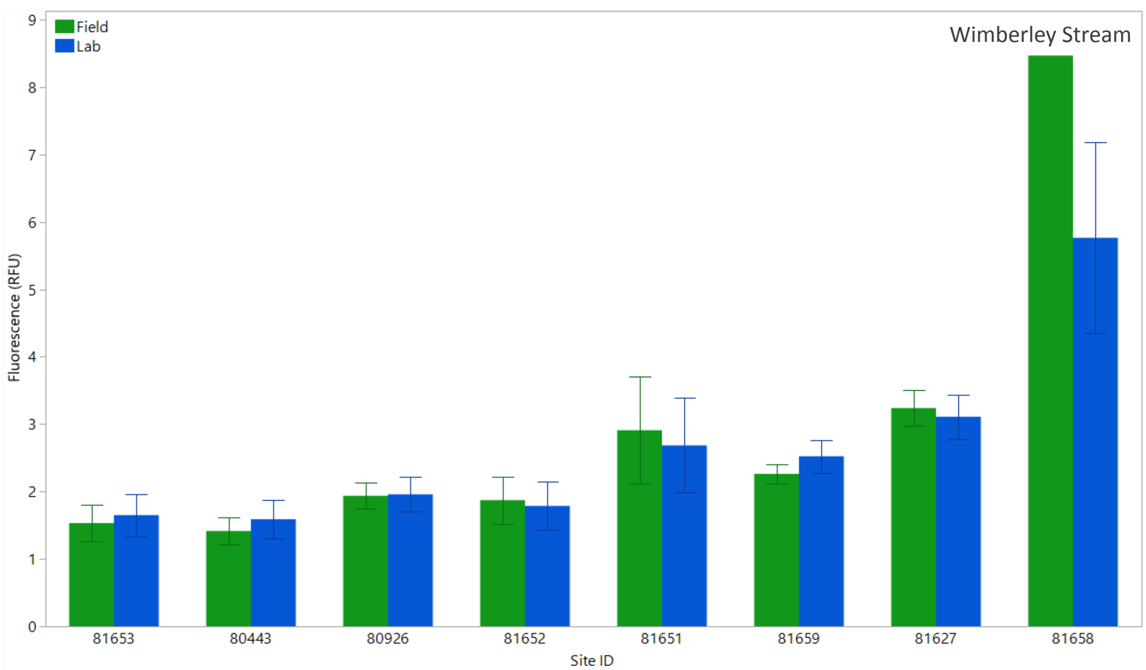

Figure 19. Mean initial field and lab fluorescence measurements at all Cypress Creek (81653, 80443, 80926, 81652, 81651, 81659, and 81627) and Wimberley Stream (81658) sites (August – December 2022). Error bar represents standard error.

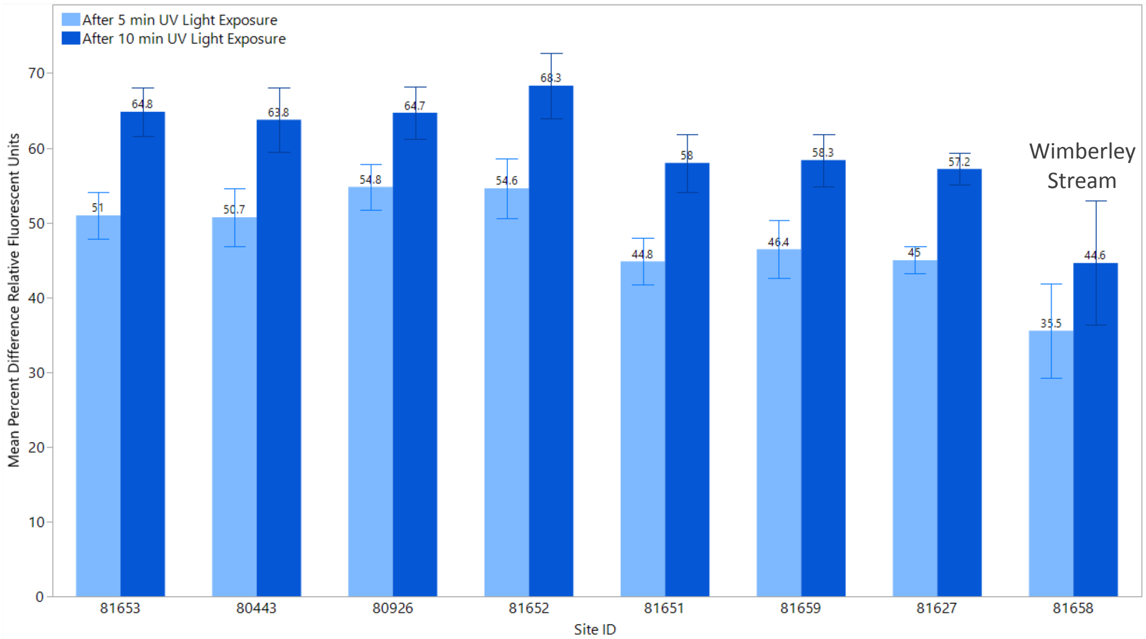

Figure 20. Mean percent difference in relative fluorescent units from initial laboratory measurements for water samples exposed for 5- and 10-minute durations from Cypress Creek (81653, 80443, 80926, 81652, 81651, 81659, and 81627) and Wimberley Stream (81658) sites (August – December 2022). Error bar represents standard error.

Table 8. Summary statistics for initial field and lab fluorescence measurements for all sites on Cypress Creek and Ozona Creek (August to December 2022).

STATISTIC	FIELD	LAB
Number of measurements	65	73
Mean Fluorescence (RFU)	2.27	2.29
Standard error	1.46	1.41
Minimum	0.58	0.29
Maximum	8.5	8.0

RFU = relative fluorescent units.

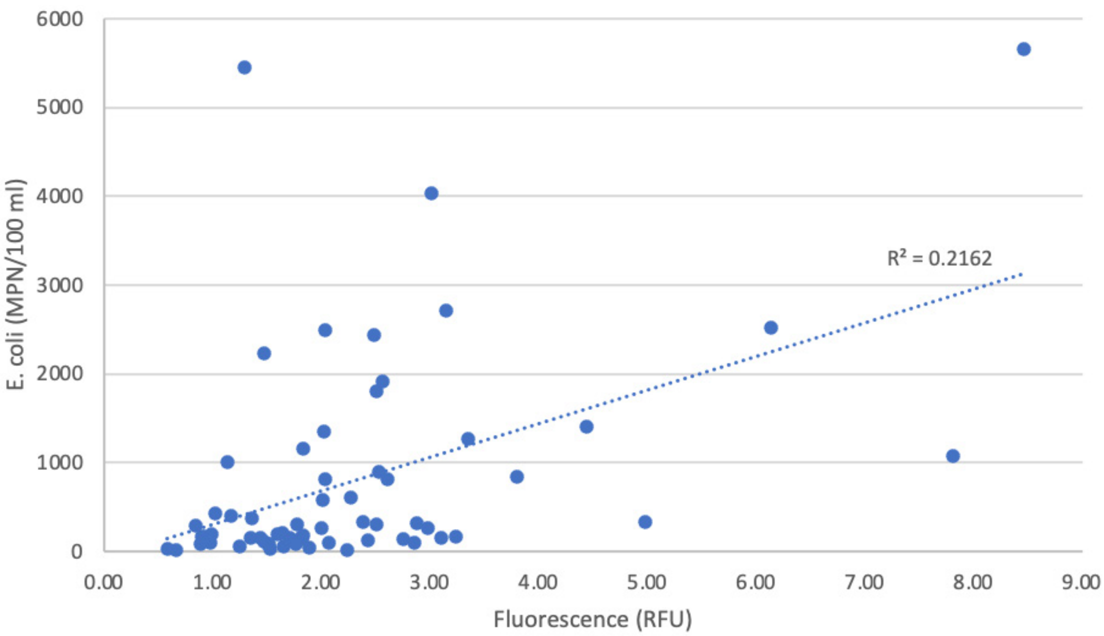

Figure 21. Positive and significant ($p < 0.0001$) correlation analysis between *E. coli* (MPN/100 ml) and field fluorescence (RFU) in Cypress Creek for all sites (Number of measurements = 64) (August - December 2022).

Discussion and Conclusion

E. coli bacteria source identifications from nonpoint sources of pollution are complex, difficult to pinpoint, and require extensive data collection and analyses. The goal of this work was to conduct targeted *E. coli* monitoring on lower Cypress Creek with greater resolution in space and time to discern areas of high concentrations of bacteria and identify potential sources. We monitored water quality field parameters and observations, *E. coli* bacteria, and implemented tampling and fluorometry methods as a unique, low-cost approach to assist with bacterial source identification. We also acquired precipitation and streamflow data from existing sources to assist with data analysis and interpretation. Results of this work identified elevated levels of *E. coli* bacteria concentrations in areas and at a scale previously not monitored and show bacteria likely originate from a combination of sources including nonpoint source runoff during rainfall events, seasonal direct deposition of bat guano associated with migratory patterns, and on-site septic system sewage contamination from Wimberley Stream which drains an area predominantly serviced by on-site septic systems for the treatment of household and commercial waste.

Although Cypress Creek is not on the state's list of impaired waters for not meeting the contact recreation use, the *E. coli* bacteria monitoring results from this study continue to reflect exceedances of the water quality standard at all sites downstream of the Ranch Road 12 bridge (Figure 5). These results likely reflect a combination of the increase in developed land use from 2011 to 2019 in the Cypress Creek Watershed (Figure 2), coupled with the continued use of on-site septic systems for treatment of sewage in the area north and west of Cypress Creek (Figure 22).

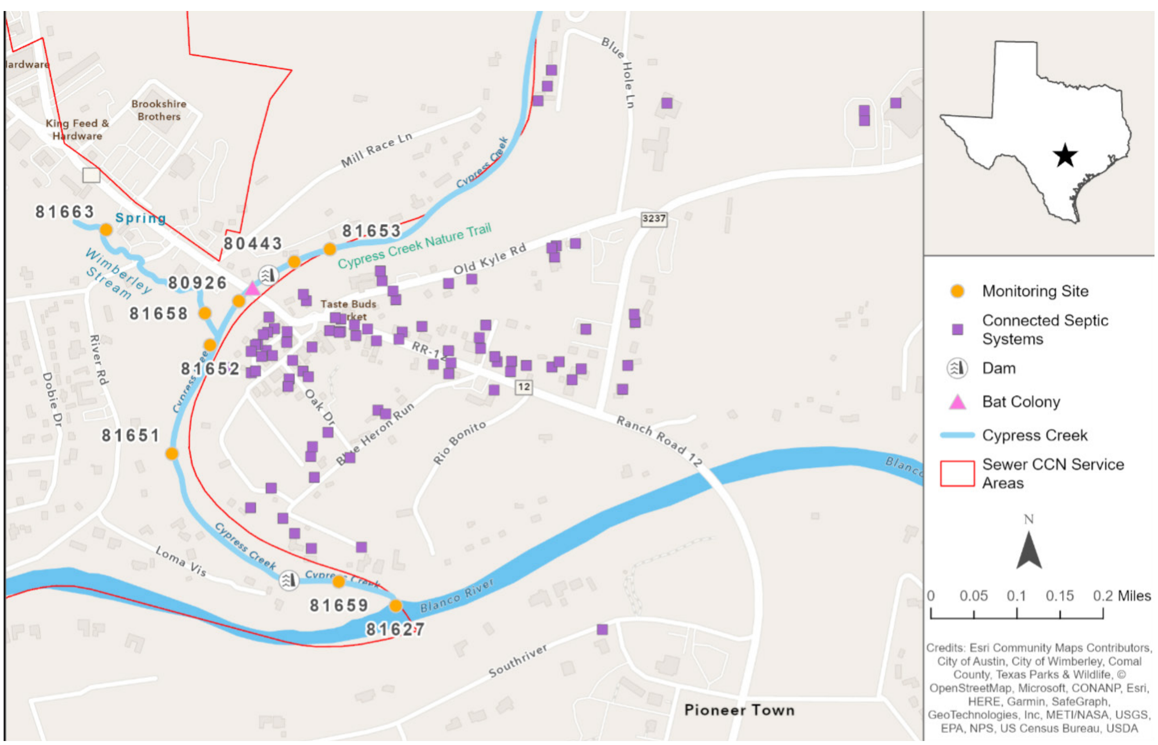

Figure 22. Commercial and residential properties connected to the Wimberley Centralized Sanitary Sewer System as of December 2022.

The targeted water quality measurements from this project provide information about the sources of bacteria affecting Cypress Creek. Temporally, the *E. coli* bacteria results indicate no significant differences in day of the week (Sunday vs. Thursday) (Table 4). Therefore, based on this assessment, it is not likely that increased weekend activities in Wimberley will have an immediate effect on the water quality of Cypress Creek. Other information gleaned from the field measurements include significantly lower bacteria concentrations at the two sites upstream of the Ranch Road 12 bridge (sites 81653 and 80443) than the site immediately downstream of the bridge (site 80926) (Table 5). This analysis shows a 56 percent increase in *E. coli* bacteria geometric means between the sites upstream and downstream of the bridge and suggests an impact on water quality from the bats residing under the bridge.

Other water quality indicators of bat contamination include assessment of the monthly geometric means of *E. coli* bacteria from the site downstream of the Ranch Road 12 bridge (80926) which shows a general pattern of increased values during the months the bats were present (April through November) as opposed to the months the bats migrated away from the area (November through March). Increased bacteria colonies for all sites combined were also detected in the fall months of September through November when bat densities are likely the highest prior to migration southward to warmer climates (Figure 6). Although we did not quantify the bat guano on the creek banks under the bridge, dark swaths of guano were observed, and pungent odors permeated the air during the bats' presence from April through November. Storm drains are located under the bridge and funnel stormwater during rain events that serve as a means of transport for the bat guano from the land surface into Cypress Creek.

Wimberley Stream is a tributary to Cypress Creek that had some of the highest *E. coli* bacteria colony counts in this study. A gradual mixing of water with high bacteria concentrations from Wimberley Stream with Cypress Creek was observed at sites downstream of the point of entry, most prominently at Site 81651 (Table 6). We only sampled Wimberley Spring, located at the headwaters of Wimberley Stream, six times due to limited accessibility, but it had elevated bacteria levels during 5 of the 6 monitoring events. We observed high total dissolved solids and low dissolved oxygen at the spring, which is common in Texas springs in the Edwards Plateau Ecoregion (Heitmuller and Williams 2006).

Characterization of bacteria sources using acquired precipitation and stream flow data from Jacob's Well during the project period identified both point and nonpoint sources of bacteria. A significant difference in precipitation between 2021 and 2022 (Table 7) allowed for comparison of *E. coli* bacteria characteristics between a wet and dry year (Figure 7). A strong and significant correlation between bacteria and precipitation during a wet year (2021) was identified, but not during a dry year (2022) (Figure 8). The *E. coli* geometric mean for all sites combined increased 39 percent from 2021, a wet year, to 2022, a dry year. These results imply nonpoint sources of bacteria resulted from runoff during the wet year (2021) and point sources or direct deposition of bacteria resulted during the dry year (2022), likely from bat guano.

Instantaneous loads derived from measured *E. coli* bacteria concentrations were displayed simultaneously with the bacteria load duration curve established using the water quality criterion (Figures 10-17). Instantaneous loads that plot above the load duration curve indicate the water quality criterion has been exceeded, while the loads that plot below the load duration curve meet the criterion (EPA 2007). Impairments that arise during low flow conditions (less than 0.1 cfs), typically indicate a point source, while those during high flow conditions (greater than 10.0 cfs) generally reflect nonpoint sources (Figure 9). Loading percent differences above and below the bacteria load duration curve reveal all sites exceeded the criterion during 2021 and 2022 except for the most upstream site (81653) which met the criterion in 2022, the dry year (Figure 18). These results imply the *E. coli* loads at the most upstream site were minimally affected by runoff during the wet year (2021) and not affected during the dry year (2022) when the bacteria load was below the criterion. The site below the Ranch Road 12 bridge (80926) was the only site that exhibited a higher percent difference from the criterion during 2022, the dry year, than during the wet year, implying a point source or direct deposition of bacteria, from bat guano.

The tampling method was employed as an inexpensive preliminary pollution screening tool to discern presence or absence of optical brighteners as indicators of human sources of fecal contamination from on-site septic systems. Optical brightener fluorescence was detected at all sites and for all deployment treatments during the project period. No discernable difference in the intensity of fluorescence was detected during visual observations of the tampons in the lab. However, this method proved to be a viable screening approach for detecting the presence of optical brighteners and identified tampon deployment periods from 1 to 3 days were adequate for the detection of optical brighteners.

Fluorometry measurements were collected in the field and lab alongside *E. coli* bacteria measurements. Results of field and lab fluorometry measurements were compared but no significant differences were identified from ultraviolet light exposure during the transport of water samples from the field to the lab (Table 8). These results support future water samples be transported to the lab for analysis with negligible interference of optical brightener photodecay from ultraviolet light exposure during transport.

To discern optical brightener fluorescence from background organic florescence, we employed an ultraviolet light exposure experiment. The results revealed water samples from all sites exhibited photodecay rates >35.5 percent after exposures at the 5- and 10-minute intervals indicative of optical brightener presence (Cao and others 2007) (Figure 20). Although Wimberley Stream exhibited the largest mean initial fluorescent values (Figure 19), which could be interpreted as indicators of high concentrations of optical brighteners, it did not exhibit the largest mean percent difference in the exposure experiment (Figure 20). We believe there is a high organic content in runoff from this area resulting in larger initial fluorescent values. Wimberley Stream drains an area predominantly serviced by septic systems (Figure 22) and exhibits high *E. coli* bacteria concentrations (Figure 5). The positive and relatively strong ($r^2 = 0.22$) significant ($p < 0.05$) correlation between *E. coli* bacteria and fluorescence in Cypress Creek is symbolic of on-site septic system contamination (Figure 21).

Streambed and bank sediments have been documented as sources of bacterial contamination to adjacent waterways (Brinkmeyer and others 2015). The surrounding commercial and residential areas in the Cypress Creek Watershed have predominantly been serviced by on-site septic systems with drainfields for sewage treatment resulting in soils saturated with effluent (Venhuizen 2021). During rainfall events, surface runoff carries effluent-saturated bank sediments, and streambed sediments become suspended with the increased streamflow, likely contributing to elevated bacteria concentrations and detection of optical brighteners.

A central collection system for sewage wastewater is now in place in the City of Wimberley. As of December 2022, the city reported 104 completed sewer connections to the Wimberley Centralized Sanitary Sewer System (Figure 22), however many more residential and commercial properties located in the watershed that drain to the lower reach of Cypress Creek currently use on-site septic systems to treat wastewater and continue to pose a risk for bacterial contamination. Continuation of intensive *E. coli* bacteria and field parameter monitoring including optical brightener fluorometry measurements will provide baseline reference points for comparison to post-completion connections of the central collection system.

Recommendations for future work in Cypress Creek are to continue to monitor water quality including *E. coli*, field parameters, and optical brightener fluorescence at the nine sites sampled in this study. Fluorometry measurements during storm events are highly recommended due to the limited number of measurements collected during wet periods for comparison with dry periods. We also recommend continued observations of the presence/absence of the bat colony located under the Ranch Road 12 bridge to continue to discern future water quality impacts on Cypress Creek from the various sources.

Remediation approaches to improve water quality from nonpoint source runoff may include restoration of riparian habitat buffers along the creek, especially in areas where bare or denuded vegetation currently exist. The impact of bats on increased concentrations of *E. coli* bacteria in waterways due to direct deposition from bridge habitation is well documented (Zara Environmental LLC, 2013). To address the impact from the bat colony inhabiting the underside of the bridge on Ranch Road 12, we recommend relocating the colony by constructing bat houses throughout the watershed that may aid in dispersing the population to other areas instead of concentrating them under the bridge directly over the creek.

Dye studies of on-site septic systems would aid in identification of malfunctioning systems and are currently being planned in the watershed with cooperating businesses. However, extension of the centralized collection system to other areas of the watershed not currently serviced would also help to remediate water quality in the lower reach of Cypress Creek.

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Appendix A

Water quality *E. coli* bacteria and field measurements from Cypress Creek, the spring, and Ozona Creek (June 2021 to December 2022).

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
6/27/2021	80443	20	25.6			7.96		
7/1/2021	80443	160	25		2.44	8.05	616	400
7/4/2021	80443	100	25	1	3.83	7.93	609	396
7/8/2021	80443	117	24.7	1	4.23	7.85	572	372
7/11/2021	80443	57	25	1	6.04	7.95	565	367
7/15/2021	80443	37	24.7	1	6.03	8.17	603	392
7/18/2021	80443	120	25.3	0.66	5.95	7.12	607	395
7/22/2021	80443	107	24.4	1	5.75	5.35	623	405
7/25/2021	80443	64	25.6	0.66	5.56	7.97	607	395
7/29/2021	80443	97	25.8	0.66	5.73	7.97	586	381
8/1/2021	80443	94	25.4	0.66	5.87	7.94	597	388
8/5/2021	80443	207	25.5		6.27	7.89	576	374
8/8/2021	80443	47	25.7	0.66	6.65	7.91	593	385
8/12/2021	80443	150	25.8	1	6.86	7.79	596	387
8/15/2021	80443	134	25.6	1	5.55	7.34	607	395
8/19/2021	80443	170	25.9	1	5.6	7.56	608	395
8/22/2021	80443	104	25.7		6.82	7.48	610	397
8/29/2021	80443	144	25.3	1	5.86	7.58	603	392
9/2/2021	80443	170	25.9		5.48	8.21	544	354
9/5/2021	80443	144	25.3	0.66	4.28	7.55	554	360
9/9/2021	80443	107	24.2			7.19	536	348
9/12/2021	80443	167	22.2		6.97	6.48	550	358
9/16/2021	80443	164	23.3		6.05	6.77	551	358
9/19/2021	80443	140	23.2		6.26	6.3	542	352
9/23/2021	80443	100	22.9		4.97	6.57	543	353
9/30/2021	80443	560	23.9		4.68	7.99	507	330
10/7/2021	80443	160	21.5	1	6.54	7.51	591	384

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
10/14/2021	80443	2172	21.8	1.33	3.56	7.58	284	185
10/21/2021	80443	147	21.3	1	1.85	7.52	585	380
10/28/2021	80443	820	19.6	1	6.92	7.75	627	408
11/4/2021	80443	357	17.3	1	7.74	7.79	616	400
11/11/2021	80443	94	20.9	0.66	6.6	7.71	615	400
11/23/2021	80443	100	15.8		7.8	7.7	574	373
12/2/2021	80443	54	16.4		7.9	8.7	474	308
12/9/2021	80443	37	18.1		7.2	8.1	574	373
12/16/2021	80443	114	19.5		7.3	7.7	649	422
12/21/2021	80443	74	15.5		5.5	7.6	565	367
1/6/2022	80443	430	13.2		8.6	7.9	597	388
1/13/2022	80443	437	12.9		7.4	8.3	623	405
1/21/2022	80443	140	9.8		10.2	8.6	609	396
1/27/2022	80443	134	13.2			8.5	553	359
02/02/2022	80443	227	14.6		7.5	8.3	593	385
02/10/2022	80443	64	11.5		8.3	8.6	622	404
03/03/2022	80443	33	14.0		8.7	7.7	544	354
03/10/2022	80443	57	13.9	2.6	9.9	7.8	602	391
03/24/2022	80443	10	14.2	2.6	8.3	6.4	617	401
04/07/2022	80443	50	18.1	2.6	8.7	7.6	649	422
4/21/2022	80443	10	21.1		7.38	7.34	619	402
5/5/2022	80443	107	22.9		6.67	6.85	588	382
5/26/2022	80443		20.8		6.91	8.21	514	334
6/9/2022	80443	210	25.4	2.2	8.25	8.12	523	340
6/23/2022	80443	1799	25.8		2	7.6	566	368
7/7/2022	80443	44	26	2.6	5.66	7.68	651	423
7/21/2022	80443	54	27.3		5.89	7.73	692	450
8/4/2022	80443	280	27	2	6.8	7.77	648	421
8/18/2022	80443	10	26	2.2	4.34	7.3	674	438
9/1/2022	80443	1806	25.8		2.49	7.66	650	423
9/15/2022	80443	310	22.5	1.9	3.66	7.44	620	403
9/29/2022	80443	83	21	2.1	4.15	7.65	650	423

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
10/13/2022	80443	160	21.3	2	5.14	7.55	652	424
10/27/2022	80443	1,350	16.8	2.1	4.0	7.6	650	423
11/10/2022	80443	100	20.3	0.8	6.3	7.5	917	596
11/22/2022	80443	117	11.0		7.7	7.4	691	449
12/08/2022	80443	34	19.5		4.89	7.83	710	462
12/21/2022	80443	1260	10.8	0.7	8.25	8.63	640	416
6/27/2021	80926	90	25.5			7.94		
7/1/2021	80926	110	25.2		2.34	8.03	616	400
7/4/2021	80926	77	24.9	0.66	4.81	7.96	614	399
7/8/2021	80926	200	24.8	0.33	6.16	7.7	566	368
7/11/2021	80926	130	24.9	0.33	6.49	8.05	566	368
7/15/2021	80926	97	24.7	0.7	6.22	8.26	598	389
7/18/2021	80926	84	25.3	0.66	6.28	7.15	605	393
7/22/2021	80926	74	24.3	0.66	6	5.3	624	406
7/25/2021	80926	64	25.6	0.66	6.14	8.04	605	393
7/29/2021	80926	100	25.7	0.7	6.05	8.02	583	379
8/1/2021	80926	135	25.6	0.66	6.17	8.11	585	380
8/5/2021	80926	107	25.3		6.93	8.01	570	371
8/8/2021	80926	127	25.2	1	6.89	7.92	602	391
8/12/2021	80926	87	26.11		6.97	7.97	607	395
8/15/2021	80926	343	25.9	0.66	6.47	7.36	605	393
8/19/2021	80926	197	25.7	0.66	5.98	7.48	607	395
8/22/2021	80926	90	26.1		7.76	7.49	597	388
8/29/2021	80926	193	25.2	0.66	6.45	7.68	608	395
9/5/2021	80926	217	25.2		4.42	7.42	557	362
9/9/2021	80926	250	24.2			7.05	552	359
9/12/2021	80926	120	22.7		7.21	6.57	556	361
9/16/2021	80926	194	23.1		6.75	6.85	552	359
9/19/2021	80926	213	23.2		8.04	6.08	555	361
9/23/2021	80926	457	22.2		5.72	6.48	558	363
9/30/2021	80926	550	24		5.08	8.04	502	326

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
10/7/2021	80926	393	21.5	0.66	8.65	10.16	568	369
10/14/2021	80926	2136	21.9	1	3.77	7.51	272	177
10/21/2021	80926	250	21.4	0.66	2.04	7.84	593	385
10/28/2021	80926	393	19.5	0.66	7.03	7.7	628	408
11/4/2021	80926	443	17.4	0.66	8.54	7.75	605	393
11/11/2021	80926	47	20.1	0.66	7.77	7.6	621	404
11/18/2021	80926	80	19.1	0.6	7.4	7.5	558	363
11/23/2021	80926	54	15.7		7.9	10.7	582	378
12/2/2021	80926	20	16.6		8.3	8.4	461	300
12/9/2021	80926	37	18.4		7.5	8.2	541	352
12/16/2021	80926	47	19.9		7.7	7.9	628	408
12/21/2021	80926	30	14.4		5.6	7.7	576	374
1/6/2022	80926	273	12.8		8.7	8.1	597	388
1/13/2022	80926	697	12.1		7.9	8.6	643	418
1/21/2022	80926	120	9.5		10.4	8.7	609	396
1/27/2022	80926	253	12.8			8.4	546	355
02/02/2022	80926	167	14.2		7.7	8.5	581	378
02/10/2022	80926	57	11.5		9.3	8.6	595	387
03/03/2022	80926	37	14.0		9.4	7.8	547	356
03/10/2022	80926	90	13.8	2.1	9.9	8.6	594	386
03/24/2022	80926	20	14.6	2.1	9.3	6.8	628	408
04/07/2022	80926	110	17.8	2.1	9.1	8.2	651	423
4/21/2022	80926	140	21.2		8.33	7.28	606	394
5/5/2022	80926	20	23		6.52	7.18	591	384
5/26/2022	80926		20.8		6.64	8.11	518	337
6/9/2022	80926	357	25.5	2.8	8.25	7.87	615	400
6/23/2022	80926	783	25.6		1.9	7.7	565	367
7/7/2022	80926	2062	25.6	1.7	5.15	7.58	639	415
7/21/2022	80926	3098						
8/4/2022	80926	1433	26.6	0.3	4.18	7.71	658	428
8/18/2022	80926	2496	25		1.98	7.74	700	455

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
9/1/2022	80926	4032	25.1		3.16	8.29	665	432
9/15/2022	80926	260	21.3	0.8	5.16	8.2	625	406
9/29/2022	80926	423	18.8	0.55	5.31	7.53	648	421
10/13/2022	80926	583	21	0.4	5.84	8.28	665	432
10/27/2022	80926	817	15.3	1.0	5.4	7.5	642	417
11/10/2022	80926	50	20.8	1.0	6.7	7.5	654	425
11/22/2022	80926	200	10.6		8.3	8.0	683	444
12/08/2022	80926	80	19.4		5.76	8.02	698	454
12/21/2022	80926	317	10.3	0.6	9.46	7.68	675	439
6/27/2021	81627	120	25.2			7.96		
7/1/2021	81627	110	24.4		1.07	8.1	601	391
7/4/2021	81627	137	24.7		6.78	8.05	602	391
7/8/2021	81627	36	24.5	0.33	6.84	8.17	562	365
7/11/2021	81627	80	24.9	0.33		8.1	567	369
7/15/2021	81627	77	24.7	0.33	6.54	8.52	504	328
7/18/2021	81627	27	24.7	0.33	6.7	7.5	586	381
7/22/2021	81627	423	23.9	0.33	6.69	5.85	602	391
7/25/2021	81627	47	24.9	0.33	6.57	8.3	621	404
7/29/2021	81627	44	25	0.7	6.5	8.37	574	373
8/1/2021	81627	74	25.4	0.33	6.31	8.32	573	372
8/5/2021	81627	110	24.6	0.33	7.55	8.23	571	371
8/8/2021	81627	150	25.1	0.33	7.39	8.11	586	381
8/12/2021	81627	107	25.7	0.33	7.4	7.79	598	389
8/15/2021	81627	100	25.3	0.33	6.91	7.71	597	388
8/19/2021	81627	313	25.6	0.33	6.39	7.51	589	383
8/22/2021	81651	157	25.6		7.34	7.9	594	386
8/29/2021	81651	164	24.9	1	6.15	7.18	609	396
9/2/2021	81651	194	25.8		4.94	8.3	547	356
9/5/2021	81651	84	24.7	0.66	4.05	7.51	557	362
9/9/2021	81651	170	23.3			7.38	557	362
9/12/2021	81651	363	22.4		6.61	6.55	554	360

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
9/16/2021	81651	223	23		5.8	5.95	561	365
9/19/2021	81651	144	22.8		6.54	6.48	560	364
9/23/2021	81651	227	21.6		4.9	6.64	547	356
9/30/2021	81651	790	23.2		5.06	8.06	504	328
10/7/2021	81651	550	21.2	1	8.2	7.72	588	382
10/14/2021	81651	2196	21.9	1.66	3.65	7.62	272	177
10/21/2021	81651	283	21.3	1	2.21	7.71	602	391
10/28/2021	81651	370	19.3	1	7.7	7.72	650	423
11/4/2021	81651	393	17.4	1	7.58	7.87	614	399
11/11/2021	81651	170	19.9	1	7.44	7.65	625	406
11/23/2021	81651	357	15.2		8.5	7.7	683	444
12/2/2021	81651	267	16.9		8.1	8.8	452	294
12/9/2021	81651	427	17.6		7.5	8.1	561	365
12/16/2021	81651	197	19.6		7.7	7.6	634	412
12/21/2021	81651	130	13.4		5.2	8	616	400
1/6/2022	81651	397	12.4		9.3	7.9	585	380
1/13/2022	81651	147	11.7		7.5	8.6	625	406
1/21/2022	81651	144	9.6		10.1	8.5	622	404
1/27/2022	81651	184	11.7			8.4	583	379
02/02/2022	81651	160	14.0		7.7	8.0	588	382
02/10/2022	81651	124	10.9		8.7	8.6	606	394
03/03/2022	81651	37	13.7		8.9	8.0	555	361
03/10/2022	81651	20	13.1	3.5	9.6	7.9	603	392
03/24/2022	81651	47	13.5	3.5	7.9	7.2	617	401
04/07/2022	81651	80	16.0	3.5	7.7	7.9	651	423
4/21/2022	81651	140	21.2		7.13	7.36	631	410
5/5/2022	81651	160	23		6.63	6.68	588	382
5/26/2022	81651	190	19.9		5.79	7.83	523	340
6/9/2022	81651	157	25.3	4.9	7.47	7.29	616	400
6/23/2022	81651	44	25.2		1.9	7.3	571	371
7/7/2022	81651	54	25.5		5.26	7.48	639	415

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
7/21/2022	81651	20	27.5		5.11	7.7	690	449
8/4/2022	81651	230	27	0.9	5.35	7.67	520	338
8/18/2022	81651	370	25.8	3	4.2	7.65	700	455
9/1/2022	81651	1073	24.6		4.23	7.57	321	209
9/15/2022	81651	10	21.3		4.22	7.43	642	417
9/29/2022	81651	147	18.8		3.44	7.42	658	428
10/13/2022	81651	154	21.1		4.25	7.65	647	421
10/27/2022	81651	2,516	15.6		3.9	7.4	514	334
11/10/2022	81651	1,150	20.3	0.8	6.3	7.5	917	596
11/22/2022	81651	1,916	11.9		7.0	6.9	653	424
12/08/2022	81651	2236	19.7		5.11	7.75	712	463
12/21/2022	81651	817	10.5		6.68	8.26	692	450
6/27/2021	81652	144	25.7			8.08		
7/1/2021	81652	107	24.8		2.61	7.87	618	402
7/4/2021	81652	1073	24.9	0.66	5.24	7.99	612	398
7/8/2021	81652	160	25.2	0.33	5.77	7.86	572	372
7/11/2021	81652	170	25	0.66	6.76	7.98	565	367
7/15/2021	81652	104	24.7	0.66	6.53	8.28	601	391
7/18/2021	81652	60	25.2	0.66	6.95	7.26	602	391
7/22/2021	81652	180	24.3	0.66	6.77	5.68	620	403
7/25/2021	81652	104	26	0.66	6.32	8.11	593	385
7/29/2021	81652	147	25.6	0.7	6.54	7.89	581	378
8/1/2021	81652	130	26	0.66	6.24	8	577	375
8/5/2021	81652	114	25.3		7.47	8.02	568	369
8/8/2021	81652	173	25.4		7.3	8	594	386
8/15/2021	81652	164	25.5	0.66	6.75	7.66	610	397
8/19/2021	81652	387	25.5		6.73	7.51	611	397
8/22/2021	81652	100	25.8		8.54	7.74	602	391
8/29/2021	81652	114	24.8	0.66	6.37	7.83	606	394
9/5/2021	81652	34	25.2		4.21	7.64	559	363
9/9/2021	81652	114	23.4			7.29	565	367

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
9/12/2021	81652	180	22.6		8.54	6.88	547	356
9/16/2021	81652	170	23.3		8.22	6.65	537	349
9/19/2021	81652	154	23.3		8.51	6.09	550	358
9/23/2021	81652	773	21.8		6.82	7.07	553	359
9/30/2021	81652	896	23.5		5.62	8.17	501	326
10/7/2021	81652	144	21.2	0.66	10.15	7.7	575	374
10/14/2021	81652	1972	21.8	1.33	3.59	7.53	275	179
10/21/2021	81652	134	21.2	0.66	2.27	7.68	603	392
10/28/2021	81652	177	19.3	0.75	7.49	7.82	629	409
11/4/2021	81652	367	17.2	1	7.88	7.77	604	393
11/11/2021	81652	107	19.6	0.66	8.12	7.69	631	410
11/18/2021	81652	164	18.9	0.7	7.5	7.8	570	371
11/23/2021	81652	137	15.2	0.5	8.3	10.7	685	445
12/2/2021	81652	80	16.5		7.5	8.3	465	302
12/9/2021	81652	37	17.7		7.5	8.2	552	359
12/16/2021	81652	74	19.5		7.9	7.6	637	414
12/21/2021	81652	27	13.6		5.4	8	607	395
1/6/2022	81652	233	12.5		9.7	7.9	592	385
1/13/2022	81652	353	11.9		8.0	8.6	633	411
1/21/2022	81652	67	9.8		9.9	8.6	622	404
1/27/2022	81652	204	12.2			8.4	561	365
02/02/2022	81652	227	14.0		8.5	7.9	589	383
02/10/2022	81652	97	10.8		8.8	8.5	602	391
03/03/2022	81652	80	13.7		9.3	7.9	553	359
03/10/2022	81652	67	13.6	2.2	10.0	8.5	598	389
03/24/2022	81652	70	14.2	2.2	9.6	6.9	616	400
04/07/2022	81652	83	17.1	2.2	8.8	8.0	656	426
4/21/2022	81652	50	21		8.09	7.38	613	398
5/5/2022	81652	77	22.7		6.96	7.24	590	384
5/26/2022	81652		20		6.97	8.23	567	369
6/9/2022	81652	357	25	1.9	8.07	6.45	621	404

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
6/23/2022	81652	350	25.5		1.9	7.7	561	365
7/7/2022	81652	313	24.8	1.9	3.73	7.3	649	422
7/21/2022	81652	20	24.8	1.8	3.7	7.27	691	449
8/4/2022	81652	37	26	0.9	5.33	7.31	630	410
8/18/2022	81652	54	25.3	0.7	1.86	7.21	731	475
9/1/2022	81652	1403	24.8		2.82	7.47	578	376
9/15/2022	81652	154	22	1.7	1.3	7.3	650	423
9/29/2022	81652	5448	19.4	2.45	1.88	7.4	690	449
10/13/2022	81652	1000	21.6	1.2	2.29	6.93	685	445
10/27/2022	81652	2,432	18.0	1.5	3.4	7.4	700	455
11/10/2022	81652	400	20.6	0.3	6.2	7.4	658	428
11/22/2022	81652	117	12.6		8.2	7.5	646	420
12/08/2022	81652	77	18.6		5.26	7.96	705	458
12/21/2022	81652	383	11	0.6	8.53	8.17	690	449
6/27/2021	81653	87	25.5			7.85		
7/1/2021	81653	77	25.6		2.31	7.91	614	399
7/4/2021	81653	154	25.1	1	4.45	7.95	602	391
7/8/2021	81653	203	24.7	1	5.87	7.85	574	373
7/11/2021	81653	127	25	1	4.6	7.85	565	367
7/15/2021	81653	74	24.8	1	6.1	8.2	605	393
7/18/2021	81653	84	25.5	1	5.74	7.13	604	393
7/22/2021	81653	64	24.5	1	5.91	5.28	621	404
7/25/2021	81653	134	25.6	1	5.63	7.85	604	393
7/29/2021	81653	77	26	1	5.81	7.98	582	378
8/1/2021	81653	87	25.4	1	5.49	7.98	588	382
8/5/2021	81653	64	25.3		6.13	7.91	579	376
8/8/2021	81653	164	25.8	1	6.92	7.98	592	385
8/12/2021	81653	120	27.8		6.41	7.94	565	367
8/15/2021	81653	237	25.8	1	5.61	7.46	612	398
8/19/2021	81653	210	25.7		6.26	7.58	604	393
8/22/2021	81653	77	25.8		7.05	7.28	606	394

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
8/29/2021	81653	110	25.1	1	6.13	7.51	604	393
9/2/2021	81653	250	26		5.12	8.12	551	358
9/5/2021	81653	140	25.6		4.48	7.79	556	361
9/9/2021	81653	67	25			7.83	534	347
9/12/2021	81653	117	22.8		6.98	6.72	560	364
9/16/2021	81653	90	23.5		6.19	7.57	553	359
9/19/2021	81653	120	23.3		6.26	6.22	549	357
9/23/2021	81653	174	22.7		4.86	6.37	557	362
9/30/2021	81653	470	24		4.88	7.87	516	335
10/7/2021	81653	127	21.9	1.66	6.3	7.56	594	386
10/14/2021	81653	1699	21.7	2	3.42	7.56	288	187
10/21/2021	81653	160	21.5	1.66	2.6	7.75	602	391
10/28/2021	81653	157	20.3	1.75	6.72	7.62	617	401
11/4/2021	81653	810	17.2	1.33	7.65	7.84	610	397
11/11/2021	81653	67	20.6	1.33	7.23	7.65	616	400
11/18/2021	81653	17	18.4	1.6	7.2	8	572	372
12/2/2021	81653	47	16.7		7.8	8.6	459	298
12/9/2021	81653	37	18.5		7.2	8.2	562	365
12/16/2021	81653	127	19.7		7.6	7.4	644	419
12/21/2021	81653	44	15.3		5.6	8.3	554	360
1/6/2022	81653	47	13.1		8.8	8.0	554	360
1/13/2022	81653	100	12.9		6.8	8.4	609	396
1/21/2022	81653	47	9.9		9.8	8.5	626	407
1/27/2022	81653	170	12.6			8.5	559	363
02/02/2022	81653	190	14.7		7.1	8.4	598	389
02/10/2022	81653	57	11.0		8.6	8.6	606	394
03/03/2022	81653	37	14.0		8.7	7.8	559	363
03/10/2022	81653	10	14.7	5.0	9.8	7.7	608	395
03/24/2022	81653	10	14.7	5.0	7.6	7.4	606	394
04/07/2022	81653	30	18.1	5.0	8.0	7.9	655	426
4/21/2022	81653	80	21.4		7	7.26	613	398

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
5/5/2022	81653	47	22.9		6.38	7.2	589	383
5/26/2022	81653		18		6.58	7.8	627	408
6/9/2022	81653	77	25.7	5	7.87		530	345
6/23/2022	81653	17	26.1		2	7.4	564	367
7/7/2022	81653	47	26	4.5	6.11	7.51	644	419
7/21/2022	81653	94	27.4		5.58	7.86	685	445
8/4/2022	81653	154	27	3.5	6.68	7.71	647	421
8/18/2022	81653	27	26.2		4.74	7.78	688	447
9/1/2022	81653	2706	25.4		2.15	7.52	625	406
9/15/2022	81653	90	22.8		3.23	7.65	620	403
9/29/2022	81653	164	20.3		3.7	7.4	648	421
10/13/2022	81653	190	21		5.43	7.82	655	426
10/27/2022	81653	817	17.3		3.3	7.3	651	423
11/10/2022	81653	284	21.4	1.2	6.6	7.5	903	587
11/22/2022	81653	134	11.1		7.9	7.7	698	454
12/08/2022	81653	154	19.8		5.04	7.91	696	452
12/21/2022	81653	1066	10.4		5.76	8.79	666	433
8/8/2021	81658	543	24.4	0.33	7.6	7.96	707	460
8/12/2021	81658	597	25.4		7.25	7.98	693	450
8/15/2021	81658	983	24.6	0.33	7.8	7.62	679	441
8/19/2021	81658	4284	25.8	0.33	6.2	7.57	539	350
8/22/2021	81658	623	24.9		8.59	7.67	649	422
8/29/2021	81658	670	24.9	0.33	6.08	7.09	610	397
9/5/2021	81658	600	24.8	0.33	4.41	7.54	532	346
9/9/2021	81658	330	21.8			7.11	545	354
9/12/2021	81658	917	21.3		7.88	6.52	533	346
9/16/2021	81658	1273	21.1		7.45	5.33	533	346
9/19/2021	81658	477	22.4		7.93	6.03	540	351
9/23/2021	81658	333	18.9		6.01	6.51	486	316
9/30/2021	81658	2662	23.6		5.27	8.09	669	435
10/7/2021	81658	540	19.7	0.33	9.67	7.61	715	465

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
10/14/2021	81658	1479	23.1	0.33	3.57	7.46	417	271
10/21/2021	81658	207	21.3	0.33	1.83	7.6	724	471
10/28/2021	81658	737	18.5	0.33	7.97	7.63	729	474
11/4/2021	81658	1143	18	0.33	8.15	7.73	732	476
11/11/2021	81658	47	20.4	0.33	7.58	7.55	731	475
11/18/2021	81658	110	17.4	0.3	8.1	11.5	667	434
11/23/2021	81658	57	14.2		8.9	7.8	665	432
12/2/2021	81658	303	16.8		8	8.8	518	337
12/9/2021	81658	134	18.9		7.6	8.2	653	424
12/16/2021	81658	124			5.8	7.7	724	471
12/21/2021	81658	120	11.3		5.8	7.9	648	421
1/6/2022	81658	37	10.2		9.6	8.3	669	435
1/13/2022	81658	60	8.3		7.9	8.5	705	458
1/21/2022	81658	107	4.0		13.3	8.9	727	473
1/27/2022	81658	144	9.4			8.6	626	407
02/02/2022	81658	407	14.5		7.7	7.9	697	453
02/10/2022	81658	60	11.4		9.5	8.5	766	498
03/03/2022	81658	57	14.6		10.2	7.7	651	423
03/10/2022	81658	54	11.2	0.9	10.5	7.7	727	473
03/24/2022	81658	723	11.3	0.9	9.1	6.3	737	479
04/07/2022	81658	34	14.5	0.9	10.1	8.0	745	484
4/21/2022	81658	17	21.2		6.79	7.56	708	460
5/5/2022	81658	64	23		5.86	7.17	670	436
5/26/2022	81658	407	18.8		8.65	8.16	509	331
6/9/2022	81658							
6/23/2022	81658							
7/7/2022	81658							
7/21/2022	81658		28.7	1.5	4.58	7.76	691	449
8/4/2022	81658							
8/18/2022	81658							
9/1/2022	81658							

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
9/15/2022	81658							
9/29/2022	81658							
10/13/2022	81658							
10/28/2022	81658	10,697						
11/10/2022	81658							
11/22/2022	81658	5,649	10.3		9.8	8.0	400	260
12/08/2022	81658							
12/21/2022	81658	1066	9.8		10.78	8.05	782	508
8/8/2021	81659	100	25.1		7.45	8.11	601	391
8/12/2021	81659	190	26.5		7.58	7.91	595	387
8/15/2021	81659	147	25.5	0.33	6.85	7.45	610	397
8/19/2021	81659	430	25.9	0.33	6.08	7.57	592	385
8/22/2021	81659	60	25.6		7.85	7.96	608	395
8/29/2021	81659	110	25	0.33	6.13	7.6	610	397
9/5/2021	81659	17	25.1	0.33	4.47	7.09	567	369
9/9/2021	81659	120	23.7			7.22	558	363
9/12/2021	81659	70	22.5		7.83	6.5	556	361
9/16/2021	81659	150	22.9		7.88	6.22	536	348
9/19/2021	81659	117	23.5		8.31	6.1	556	361
9/23/2021	81659	150	21.8		6.22	6.79	554	360
9/30/2021	81659	950	23.2		5.83	2.5	490	319
10/7/2021	81659	120	21.1	0.33	9.11	7.52	581	378
10/14/2021	81659	2319	21.9	1.33	4	7.55	263	171
10/21/2021	81659	154	21.3	0.33	3.17	8.28	597	388
10/28/2021	81659	610	19.3	0.33	7.77	7.72	628	408
11/4/2021	81659	467	17.6	0.45	8.55	7.86	602	391
11/11/2021	81659	347	20.4	0.33	8.38	7.7	609	396
11/23/2021	81659	393	15.2		8.9	7.6	685	445
12/2/2021	81659	167	16.7		8.6	8.2	553	359
12/9/2021	81659	240	17.7	0.3	8.6	8.2	564	367
12/16/2021	81659	367	19.7		7.9	7.7	627	408

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
12/21/2021	81659	80	13.2		5.5	7.5	606	394
1/6/2022	81659	283	12.4		9.2	8.0	571	371
1/13/2022	81659	164	11.1		8.2	8.6	625	406
1/21/2022	81659	230	9.5		11.6	8.7	610	397
1/27/2022	81659	150	11.4			8.5	566	368
02/02/2022	81659	134	14.2		7.9	8.1	580	377
02/10/2022	81659	37	11.0		9.3	8.6	590	384
03/03/2022	81659	124	13.7		9.7	8.1	545	354
03/10/2022	81659	94	12.8	0.7	10.5	8.4	592	385
03/24/2022	81659	57	13.8	0.7	8.8	7.8	615	400
04/07/2022	81659	80	16.0	0.7	9.7	8.0	666	433
4/21/2022	81659	90	21.2		7.14	6.06	630	410
5/5/2022	81659	160	22.8		6.27	7.48	586	381
5/26/2022	81659	393	20		6.67	8.15	495	322
6/9/2022	81659	10	26	0.6	7.16	7.61	621	404
6/23/2022	81659	0	26.6		1.9	7.5	560	364
7/7/2022	81659	30	27	0.5	6.17	7.7	646	420
7/21/2022	81659	10	27.8	0.5	4.34	7.58	676	439
8/4/2022	81659	210	26.8	0.3	4.1	7.5	600	390
8/18/2022	81659	203	25	0.3	3.15	7.72	608	395
9/1/2022	81659	900	24.4		3.52	7.97	623	405
9/15/2022	81659	140	20.8	0.4	4.44	7.74	529	344
9/29/2022	81659	94	18.7	0.4	3.69	7.61	625	406
10/13/2022	81659	37	22	0.3	3.56	7.48	618	402
10/27/2022	81659	317	14.0	0.5	5.7	7.8	638	415
11/10/2022	81659	300	20.9	0.4	7.0	7.7	920	598
11/22/2022	81659	600	11.8		8.6	7.1	648	421
12/08/2022	81659	174	18.9		5.31	7.93	700	455
12/21/2022	81659	767	9.2	0.2	9.36	8	651	423
9/2/2021	81663	643						
9/9/2021	81663	350						

DATE	SITE	*E. COLI* (MPN/100 ML)	WATER TEMPERATURE (°C)	TOTAL DEPTH (M)	DISSOLVED OXYGEN (MG/L)	PH (S.U.)	SPECIFIC CONDUCTANCE (µS/CM)	TDS (MG/L)
9/12/2021	81663	240	22.9		4.12	5.57	677	440
9/16/2021	81663	20	23.8		4.25	5.77	631	410
9/19/2021	81663	767			6.9	6.45	683	444
12/21/2022	81663	1483	19	0.3	6.23	7	778	506

Appendix B

Fluorometric initial lab and field measurements from Cypress Creek and Ozona Creek (August to December 2022).

DATE	SITE ID	LAB/FIELD	INITIAL VALUE (RFU)
8/18/2022	80443	Field	0.66
8/18/2022	80443	Lab	0.89
9/1/2022	80443	Field	2.51
9/1/2022	80443	Lab	2.56
9/15/2022	80443	Field	1.77
9/15/2022	80443	Lab	3.59
9/30/2022	80443	Field	0.89
9/30/2022	80443	Lab	1.02
10/13/2022	80443	Field	0.92
10/13/2022	80443	Lab	0.76
10/27/2022	80443	Field	2.03
10/27/2022	80443	Lab	1.66
11/10/2022	80443	Field	0.98
11/10/2022	80443	Lab	1.22
11/22/2022	80443	Field	1.47
11/22/2022	80443	Lab	1.12
12/8/2022	80443	Field	1.52
12/8/2022	80443	Lab	1.12
8/18/2022	80926	Field	2.03
8/18/2022	80926	Lab	2.42
9/1/2022	81627	Field	3.80
9/1/2022	81627	Lab	3.93
9/15/2022	81627	Field	3.11
9/15/2022	81627	Lab	3.83
9/30/2022	81627	Field	2.86
9/30/2022	81627	Lab	2.41
10/13/2022	81627	Field	3.35
10/13/2022	81627	Lab	2.72
10/27/2022	81627	Field	3.24
10/27/2022	81627	Lab	2.65
11/10/2022	81627	Field	2.98

DATE	SITE ID	LAB/FIELD	INITIAL VALUE (RFU)
11/10/2022	81627	Lab	3.09
11/22/2022	81627	Field	2.39
11/22/2022	81627	Lab	2.21
12/8/2022	81627	Field	2.43
12/8/2022	81627	Lab	2.20
8/18/2022	81651	Field	1.36
8/18/2022	81651	Lab	1.52
9/1/2022	81651	Field	7.81
9/1/2022	81651	Lab	8.04
9/15/2022	81651	Field	2.24
9/15/2022	81651	Lab	2.92
9/30/2022	81651	Field	1.43
9/30/2022	81651	Lab	1.13
10/13/2022	81651	Field	1.35
10/13/2022	81651	Lab	0.98
10/27/2022	81651	Field	6.14
10/27/2022	81651	Lab	5.05
11/10/2022	81651	Field	1.83
11/10/2022	81651	Lab	2.02
11/22/2022	81651	Field	2.56
11/22/2022	81651	Lab	1.76
12/8/2022	81651	Field	1.47
12/8/2022	81651	Lab	1.59
8/18/2022	81652	Field	1.24
8/18/2022	81652	Lab	0.69
9/1/2022	81652	Field	4.44
9/1/2022	81652	Lab	4.43
9/15/2022	81652	Field	1.81
9/15/2022	81652	Lab	2.69
9/30/2022	81652	Field	1.29
9/30/2022	81652	Lab	0.99
10/13/2022	81652	Field	1.14
10/13/2022	81652	Lab	0.98
10/27/2022	81652	Field	2.49
10/27/2022	81652	Lab	2.35

DATE	SITE ID	LAB/FIELD	INITIAL VALUE (RFU)
11/10/2022	81652	Field	1.17
11/10/2022	81652	Lab	1.46
11/22/2022	81652	Field	1.75
11/22/2022	81652	Lab	1.30
12/8/2022	81652	Field	1.51
12/8/2022	81652	Lab	1.35
8/18/2022	81653	Field	0.58
8/18/2022	81653	Lab	0.29
9/1/2022	81653	Field	3.15
9/1/2022	81653	Lab	3.19
9/15/2022	81653	Field	1.77
9/15/2022	81653	Lab	3.44
9/30/2022	81653	Field	0.90
9/30/2022	81653	Lab	1.24
10/13/2022	81653	Field	0.99
10/13/2022	81653	Lab	1.00
10/27/2022	81653	Field	2.03
10/27/2022	81653	Lab	1.92
11/10/2022	81653	Field	0.85
11/10/2022	81653	Lab	1.29
11/22/2022	81653	Field	1.82
11/22/2022	81653	Lab	0.93
12/8/2022	81653	Field	1.70
12/8/2022	81653	Lab	1.46
11/22/2022	81658	Field	8.47
11/22/2022	81658	Lab	7.18
8/18/2022	81659	Field	1.64
8/18/2022	81659	Lab	2.13
9/1/2022	81659	Field	2.52
9/1/2022	81659	Lab	3.03
9/15/2022	81659	Field	2.76
9/15/2022	81659	Lab	3.51
9/30/2022	81659	Field	2.07
9/30/2022	81659	Lab	1.67
10/13/2022	81659	Field	1.89

DATE	SITE ID	LAB/FIELD	INITIAL VALUE (RFU)
10/13/2022	81659	Lab	1.84
10/27/2022	81659	Field	2.88
10/27/2022	81659	Lab	2.86
11/10/2022	81659	Field	2.50
11/10/2022	81659	Lab	3.87
11/22/2022	81659	Field	2.27
11/22/2022	81659	Lab	1.96
12/8/2022	81659	Field	1.83
12/8/2022	81659	Lab	1.82
12/21/2022	80443	Lab	1.95
12/21/2022	80926	Lab	1.52
12/21/2022	81627	Lab	2.54
12/21/2022	81651	Lab	1.83
12/21/2022	81652	Lab	1.64
12/21/2022	81653	Lab	1.72
12/21/2022	81658	Lab	4.35
12/21/2022	81659	Lab	2.54
12/21/2022	81663	Lab	2.78

Appendix C

Fluorometric lab measurements after 5- and 10-minute ultraviolet light exposures from Cypress Creek and Ozona Creek (August to December 2022).

DATE	SITE ID	LAB	INITIAL VALUE (RFU)	5 MIN UV EXPOSURE (RFU)	10 MIN UV EXPOSURE (RFU)
8/18/2022	81627	Lab	5.51	3.42	2.98
8/18/2022	81659	Lab	2.13	1.27	1.03
8/18/2022	81651	Lab	1.52	0.57	0.46
8/18/2022	81652	Lab	0.69	0.16	0.04
8/18/2022	80926	Lab	2.42	1.21	0.96
8/18/2022	80443	Lab	0.89	0.34	0.23
8/18/2022	81653	Lab	0.29	0.18	0.08
9/1/2022	81627	Lab	3.93	2.18	1.83
9/1/2022	81659	Lab	3.03	1.91	1.53
9/1/2022	81651	Lab	8.04	4.86	4.02
9/1/2022	81652	Lab	4.43	2.82	2.09
9/1/2022	80926	Lab	3.30	2.09	1.76
9/1/2022	80443	Lab	2.56	1.58	1.34
9/1/2022	81653	Lab	3.19	1.93	1.58
9/15/2022	81627	Lab	3.83	1.75	1.49
9/15/2022	81659	Lab	3.51	1.76	1.49
9/15/2022	81651	Lab	2.92	1.52	1.30
9/15/2022	81652	Lab	2.69	0.99	0.76
9/15/2022	80926	Lab	3.27	1.38	1.08
9/15/2022	80443	Lab	3.59	1.45	1.26
9/15/2022	81653	Lab	3.44	1.39	1.11
9/30/2022	81627	Lab	2.41	1.39	1.09
9/30/2022	81659	Lab	1.67	0.92	0.62
9/30/2022	81651	Lab	1.13	0.67	0.43
9/30/2022	81652	Lab	0.99	0.56	0.40
9/30/2022	80926	Lab	1.16	0.36	0.20
9/30/2022	80443	Lab	1.02	0.40	0.27
9/30/2022	81653	Lab	1.24	0.63	0.42
10/13/2022	81627	Lab	2.72	1.40	1.16
10/13/2022	81659	Lab	1.84	0.98	0.78

DATE	SITE ID	LAB	INITIAL VALUE (RFU)	5 MIN UV EXPOSURE (RFU)	10 MIN UV EXPOSURE (RFU)
10/13/2022	81651	Lab	0.98	0.38	0.15
10/13/2022	81652	Lab	0.98	0.40	0.25
10/13/2022	80926	Lab	1.67	0.87	0.69
10/13/2022	80443	Lab	0.76	0.24	0.12
10/13/2022	81653	Lab	1.00	0.54	0.49
10/27/2022	81627	Lab	2.65	1.33	0.94
10/27/2022	81659	Lab	2.86	1.86	1.56
10/27/2022	81651	Lab	5.05	3.11	2.40
10/27/2022	81652	Lab	2.35	1.32	1.15
10/27/2022	80926	Lab	2.17	1.16	0.93
10/27/2022	80443	Lab	1.66	1.09	0.85
10/27/2022	81653	Lab	1.92	1.06	0.80
11/10/2022	81627	Lab	3.09	1.86	0.99
11/10/2022	81659	Lab	3.87	0.89	0.65
11/10/2022	81651	Lab	2.02	1.11	0.78
11/10/2022	81652	Lab	1.46	0.68	0.37
11/10/2022	80926	Lab	1.57	0.72	0.43
11/10/2022	80443	Lab	1.22	0.51	0.23
11/10/2022	81653	Lab	1.29	0.52	0.35
11/22/2022	81627	Lab	2.21	1.20	0.95
11/22/2022	81659	Lab	1.96	1.08	0.81
11/22/2022	81651	Lab	1.76	1.17	0.98
11/22/2022	81652	Lab	1.30	0.42	0.24
11/22/2022	80926	Lab	1.22	0.46	0.27
11/22/2022	80443	Lab	1.12	0.68	0.51
11/22/2022	81653	Lab	0.93	0.29	0.18
11/22/2022	81658	Lab	7.18	5.08	4.58
12/8/2022	81627	Lab	2.20	1.10	0.86
12/8/2022	81659	Lab	1.82	0.87	0.60
12/8/2022	81651	Lab	1.59	1.00	0.87
12/8/2022	81652	Lab	1.35	0.62	0.51
12/8/2022	80926	Lab	1.28	0.52	0.42
12/8/2022	80443	Lab	1.12	0.58	0.45
12/8/2022	81653	Lab	1.46	0.63	0.43

DATE	SITE ID	LAB	INITIAL VALUE (RFU)	5 MIN UV EXPOSURE (RFU)	10 MIN UV EXPOSURE (RFU)
12/21/2022	80443	Lab	1.95	0.54	0.98
12/21/2022	80926	Lab	1.52	1.60	0.67
12/21/2022	81627	Lab	2.54	1.07	1.30
12/21/2022	81651	Lab	1.83	0.85	0.84
12/21/2022	81652	Lab	1.64	0.95	0.66
12/21/2022	81653	Lab	1.72	2.53	0.75
12/21/2022	81658	Lab	4.35	1.61	2.05
12/21/2022	81659	Lab	2.54	1.80	1.29
12/21/2022	81663	Lab	2.78		1.46

The Meadows Center
for Water and the Environment
Texas State University

601 University Drive, San Marcos Texas 78666
512.245.9200 | MeadowsCenter@txstate.edu | www.MeadowsWater.org