Water Quality Data Analysis Summary Report for the Spring Creek, Cypress Creek, Lake Creek, and West Fork San Jacinto River Watersheds

October 2021

This document was prepared by the Houston-Galveston Area Council (H-GAC) for the stakeholders of the Spring Creek Watershed Partnership. It was prepared in cooperation with the Texas Commission on Environmental Quality (TCEQ) and the United States Environmental Protection Agency (EPA).

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SPRING CREEK WATERSHED PARTNERSHIP

Houston-Galveston Area Council

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

EPA United States Environmental Protection Agency

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Abbreviations List

AU	Assessment Unit
CBOD5	5-Day Carbonaceous Biological Oxygen Demand
CFU	Colony Forming Units
CRP	Clean Rivers Program
E. coli	*Escherichia coli*
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
EPA	United States Environmental Protection Agency
IR	Texas Integrated Report of Surface Water Quality
H-GAC	Houston-Galveston Area Council
LDC	Load duration curve
mg/L	Milligrams Per Liter
mL	Milliliters
SAS	Statistical Analysis Software
SSO	Sanitary Sewer Overflow
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TSS	Total Suspended Solids
WPP	Watershed Protection Plan
WWTF	Wastewater Treatment Facility

SECTION 1: INTRODUCTION

The watershed area of Spring Creek includes portions of Grimes, Harris, Montgomery, and Waller Counties. Approximately 440 square miles of land are drained by a network of tributaries into the main stem of Spring Creek before ultimately discharging into the West Fork San Jacinto River and Lake Houston (**Figure 1**). Land cover in the eastern third of the watershed is heavily developed with more development expected to extend westward into land currently covered by pasture, grass, forest, and shrubs. The waterway is a popular recreation area, and a great deal of community focus has been placed on its riparian corridor, including an active greenway.

To continue understanding the status of surface water quality in Spring Creek, the Houston-Galveston Area Council (H-GAC) has analyzed monitoring and report data and summarized the results of these analyses herein. Additionally, analyses of water quality from nearby major waterways including Cypress Creek, Lake Creek, and the West Fork of the San Jacinto River will be included to provide broader, regional context. These assessments will highlight any shot-term changes in water quality observed since the initial 2020 Water Quality Data Analysis Summary Report[1] which served as a baseline for water quality trends and variability in the watershed. This will help to illustrate where improvements can be made in order to meet state water quality standards and support stakeholder-led water quality improvement strategies outlined in the Spring Creek Watershed Protection Plan[2] (WPP).

This document will include:

- A summary of the design and purpose of each analysis,
- A description of the data sources considered for each analysis which include ambient water quality monitoring data, discharge monitoring report (DMR) data from wastewater treatment facilities (WWTFs), and reports of sanitary sewer overflows (SSOs), and
- An overview of the implications of the results of the analyses.

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[1] See the project website for a copy of the 2020 Water Quality Data Analysis Summary Report at: https://springcreekpartnership.weebly.com/

[2] See the project website for a draft copy of the Spring Creek WPP at: https://springcreekpartnership.weebly.com/

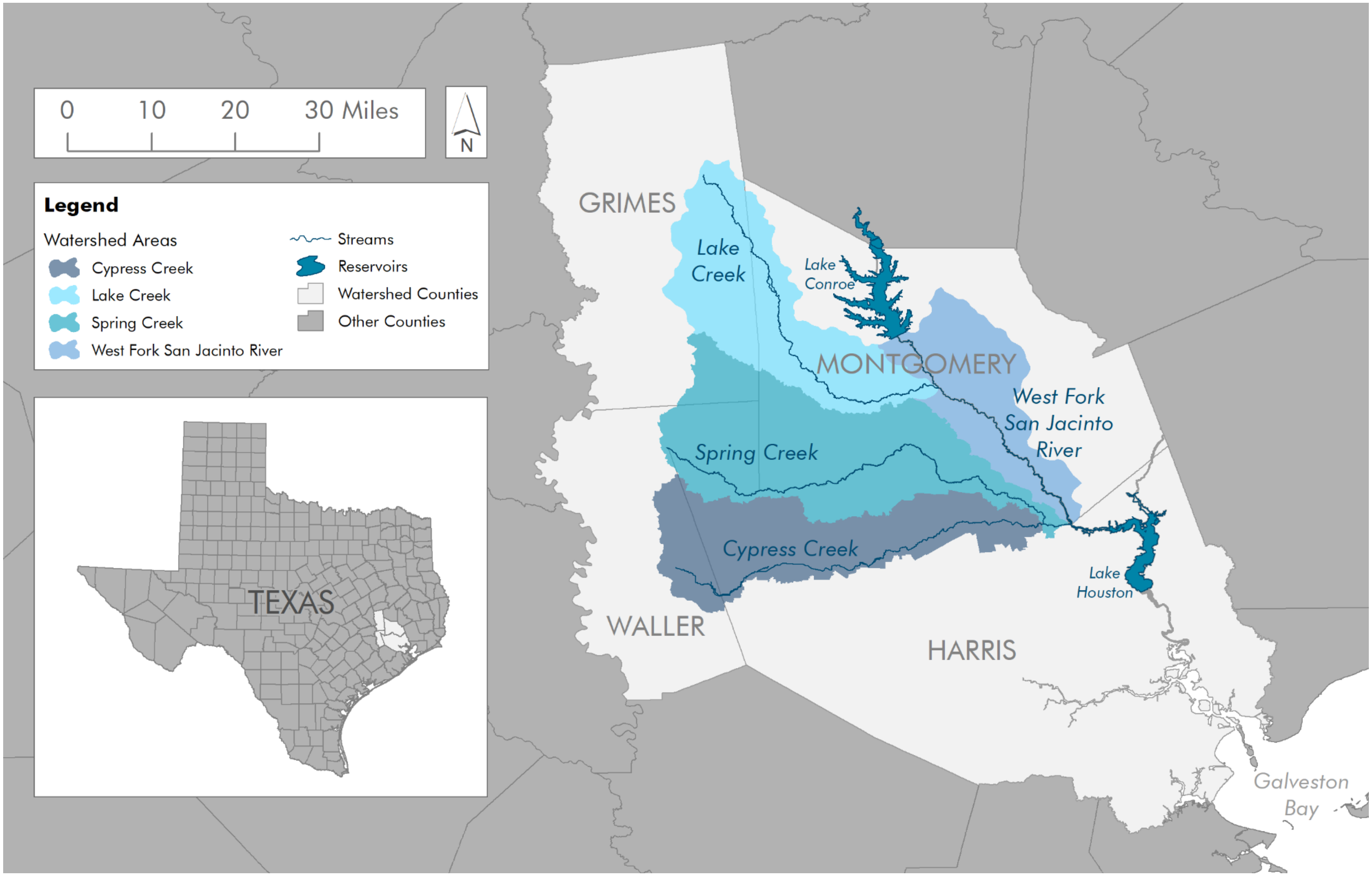

Figure 1. *Regional Context for the Watershed Areas of Spring Creek, Cypress Creek, Lake Creek, and the West Fork of the San Jacinto River*

SECTION 2: ANALYSIS PURPOSE AND DESIGN

2.1 Purpose

Based on findings from the 2020 Texas Integrated Report of Surface Water Quality (IR)[3] produced by the Texas Commission on Environmental Quality (TCEQ), multiple stream segments throughout the Spring Creek watershed and in the neighboring watersheds of Cypress Creek, Lake Creek and the West Fork of the San Jacinto River are listed as impaired for contact recreation. This is due to the frequent exceedance of state water quality standards for fecal indicator bacteria, *Escherichia coli* (*E. coli*). Additionally, low levels of dissolved oxygen (DO) and high levels of nutrients and other constituents were noted in the 2020 IR as concerns for other surface water uses.

2.2 Project Design

To form a more current understanding of the condition of surface water quality in stream segments throughout the Spring Creek Watershed and neighboring watersheds, the following analyses were designed to address the needs outlined below.

- General Understanding
  - Determine whether there is sufficient data to describe water quality in the watershed.
  - Describe the extent of the challenges impacting water quality in the watershed.
  - Visualize whether water quality is spatially variable, and if so, identify focus areas.
- Source Identification
  - Analyze discharge monitoring report data from Texas Pollutant Discharge Elimination System permitted WWTFs to verify whether their discharges are in compliance with permit limits.
  - Quantify the frequency, distribution and causes of SSOs in the watershed.

To answer these requirements data were acquired and evaluated according to the standards below.

- Data Acquisition
  - At least 10 years of data averaging at least 4 sampling events per year from monitoring stations throughout the watershed area will be retrieved from the Surface Water Quality Monitoring Information System (SWQMIS) to characterize ambient conditions.
  - At least five years of data from DMRs and SSO reports from within the watershed will be used to characterize wastewater quality.
- Data Evaluation
  - Ambient (SWQMIS) Data
    - Determine if sufficient data exists for each station.
    - Identify the historical trends for constituents of concern, by segment.
    - Evaluate the relative character of water quality of segments.
  - DMR Data
    - Evaluate the constituents of concern for compliance with WWTF permit limits.

[3] The State of Texas assesses its waterways every two years, based on seven-year sets of SQMIS data. These assessments form the basis by which segments (defined portions of waterways) and their tributaries are classified as having impairments (inability to meet a state water quality standard for which a numerical or other specific limit exists) or concerns (levels of constituents which exceed screening levels or other criteria, but for which numerical or specific limits do not exist). The existence of an impairment is usually the primary driver for developing watershed-based plans for affected segments.

        - Evaluate the general level of compliance for WWTFs.
    - SSO Report Data
        - Evaluate the frequency, volume and causes of SSOs by stream segment.

Table 1. *Data Sources for Constituents of Concern*

Constituent of Concern	SWQMIS Data	DMR Data	SSO Data
Escherichia coli (*E. coli*)	X	X	
Dissolved Oxygen (DO)	X	X	
Temperature	X		
pH	X		
Chlorophyll-a	X		
Nitrate-Nitrite	X		
Nitrate	X		
Ammonia Nitrogen	X	X	
Total Phosphorous	X		
Total Suspended Solids (TSS)	X	X	
Biological Oxygen Demand		X	
SSO Cause			X
SSO Frequency/Volume			X

SECTION 3: EVALUATIONS

3.1 Overview

Using the latest available data from the SWQMIS, DMR, and SSO databases, Statistical Analysis Software (SAS) and the spatial analysis platform ArcGIS v.10.6 were used to generate statistical results and evaluate geographical trends and variations in the data, respectively. The results of all analyses conducted for this report were reviewed by project staff, and outcomes pertinent to the WPP were selected for the focus of discussion in this document. The full data and evaluation worksheets for these efforts are available on request but are not included in this report for sake of brevity.

3.2 Ambient Data

Ambient water quality data are collected at over 400 sites in the 13-county Houston-Galveston region by H-GAC, local partners, and the TCEQ as part of the Clean Rivers Program (CRP). In general, most monitoring stations are sampled by CRP partners on a quarterly frequency for a suite of field, bacteriological, and conventional parameters. Waterways are inherently dynamic systems, and water quality at any given time can vary greatly dependent on conditions at the time. However, a history of samples provides a more representative view of the range of conditions that may be present in that waterway. Ambient data is important for characterizing waterways because it represents a range of conditions and has a historical aspect that allows for the identification of trends over time. The final determination of the regulatory status of each segment is based primarily on these ambient data. The goals and decisions for the WPP were established in part due to the regulatory status, and therefore ambient data is an important source of information for informing stakeholder decisions.

Data collected by CRP partners and incorporated into the SWQMIS include several parameters characterizing conventional, bacteriological, and other field conditions of surface water at each site. For the purposes of this report, a subset of the SWQMIS dataset for stations throughout the watershed areas was selected. The parameters focused on in this analysis include:

- *E. coli* – bacteria common in the intestines of all warm-blooded animals used as an indicator of the presence of fecal wastes. Due to this relationship, it may also be used as a proxy indicator of the safety of waterways for human recreation as fecal waste can be a vector for human pathogens. The state water quality geomean standard for *E. coli* concentrations is 126 colony forming units per 100 milliliters (CFU/100 mL) and the single sample standard is 399 CFU/100 mL.
- DO, grab and 24-hour measurements – an indicator of the ability of the waterway to support aquatic life.
- Temperature – an indicator of a waterway's ability to hold oxygen, and a means for correlating other indicators to conditions in the waterways.
- pH – an indicator of the acidity or basicness of water, which may affect aquatic life and other uses.
- Chlorophyll-a – an indicator of aquatic plant productivity and action, which can indicate areas in which algal blooms or elevated nutrient levels are present, and thus potentially depressed DO.
- Nitrate and Nitrite – a measure of nitrogenous compounds and indicator of nutrient levels (and thus potential DO impacts).
- Ammonia Nitrogen – a measure of specific nitrogenous compound that can impact aquatic life and is an indicator of nutrient levels and potentially of improperly treated sewage effluent.
- Instantaneous Flow – a measure of water volume over time.

- Total Phosphorus – an indicator of nutrient levels, especially in relation to potential for algal blooms and depressed DO in elevated levels.
- TSS – a measure of the number of suspended particles in water that indicates the potential of light infiltration in the water column and the presence of particulate matter on which bacteria may seek shelter.

3.2.1 Monitoring in Spring Creek

The active monitoring stations in the Spring Creek Watershed are shown in **Figure 2** and described in **Table 2**. Between 2005 and 2020, 2,875 sampling events were conducted at the stations listed in **Table 2**. The main segment, Spring Creek (1008), is represented by 6 of 20 active sites throughout the watershed. Sample site density of the remaining sites is highest in and around the township of The Woodlands on the tributaries Panther Branch (1008B and 1008C), Bear Branch (1008E), and the reservoir Lake Woodlands (1008F). Other sites are distributed among the tributaries Mill Creek (1008A), Willow Creek (1008H), Walnut Creek (1008I), and Brushy Creek (1008J). This dataset captures historic trends to reflect water quality before the implementation of the WPP. A full analysis of each constituent for each segment based on sites with sufficient data will be represented as a series of graphs in Error! Reference source not found.[4].

[4] Throughout this ambient water evaluation, statistical significance is defined as a p-value of 0.0545 or less. Any significance not based on this statistical review (e.g., seasonal trends, qualitative comments) will be specifically described as not being related to this significance threshold. The quantitative analysis for the ambient conditions was conducted using SAS. Statistical analyses in the graphs of Appendix A are based on a LOESS curve rather than a straight regression curve to better indicate change in trend over time for disparate stations.

Table 2. *Spring Creek Watershed Monitoring Stations, Locations, Sampling Frequency, and Period of Record*

Station Number	Stream Segment	Assessment Unit	Sampling Events	Earliest Event	Latest Event
11312	Spring Creek	1008_04	140	1/13/2005	11/16/2020
11313	Spring Creek	1008_03	131	1/19/2005	11/18/2020
11314	Spring Creek	1008_02	107	1/19/2005	7/24/2019
11323	Spring Creek	1008_02	147	1/13/2005	11/16/2020
17489	Spring Creek	1008_03	144	1/13/2005	11/16/2020
18868	Spring Creek	1008_02	55	8/16/2006	10/13/2020
20461[5]	Mill Creek	1008A_01	39	10/12/2007	10/4/2016
21957	Mill Creek	1008A_01	16	3/14/2017	10/15/2020
16629	Upper Panther Branch	1008B_02	191	1/25/2005	12/9/2020
16630	Upper Panther Branch	1008B_01	192	1/25/2005	12/9/2020
16422[6]	Lower Panther Branch	1008C_01	74	10/15/2014	12/9/2020
16628	Lower Panther Branch	1008C_01	117	1/25/2005	9/10/2014
16627	Lower Panther Branch	1008C_02	195	1/25/2005	12/9/2020
16631	Bear Branch	1008E_01	193	1/25/2005	12/9/2020
16481	Lake Woodlands	1008F_04	189	1/26/2005	12/9/2020
16482	Lake Woodlands	1008F_03	188	1/26/2005	12/9/2020
16483	Lake Woodlands	1008F_02	190	1/26/2005	12/9/2020
16484	Lake Woodlands	1008F_01	193	1/26/2005	12/9/2020
11185	Willow Creek	1008H_01	137	1/13/2005	11/16/2020
20730	Willow Creek	1008H_01	97	10/8/2009	11/16/2020
20462	Walnut Creek	1008I_01	70	10/12/2007	10/13/2020
20463	Brushy Creek	1008J_01	70	10/12/2007	10/13/2020

[5] Combined data from Stations 20461 and 21957 will be observed in this analysis in order to characterize ambient conditions in Mill Creek. See the **Sufficiency of Data** section on p. 9 for more information.
[6] Combined data from Stations 16422 and 16628 will be observed in this analysis in order to characterize ambient conditions in Lower Panther Branch. See the **Sufficiency of Data** section on p. 9 for more information.

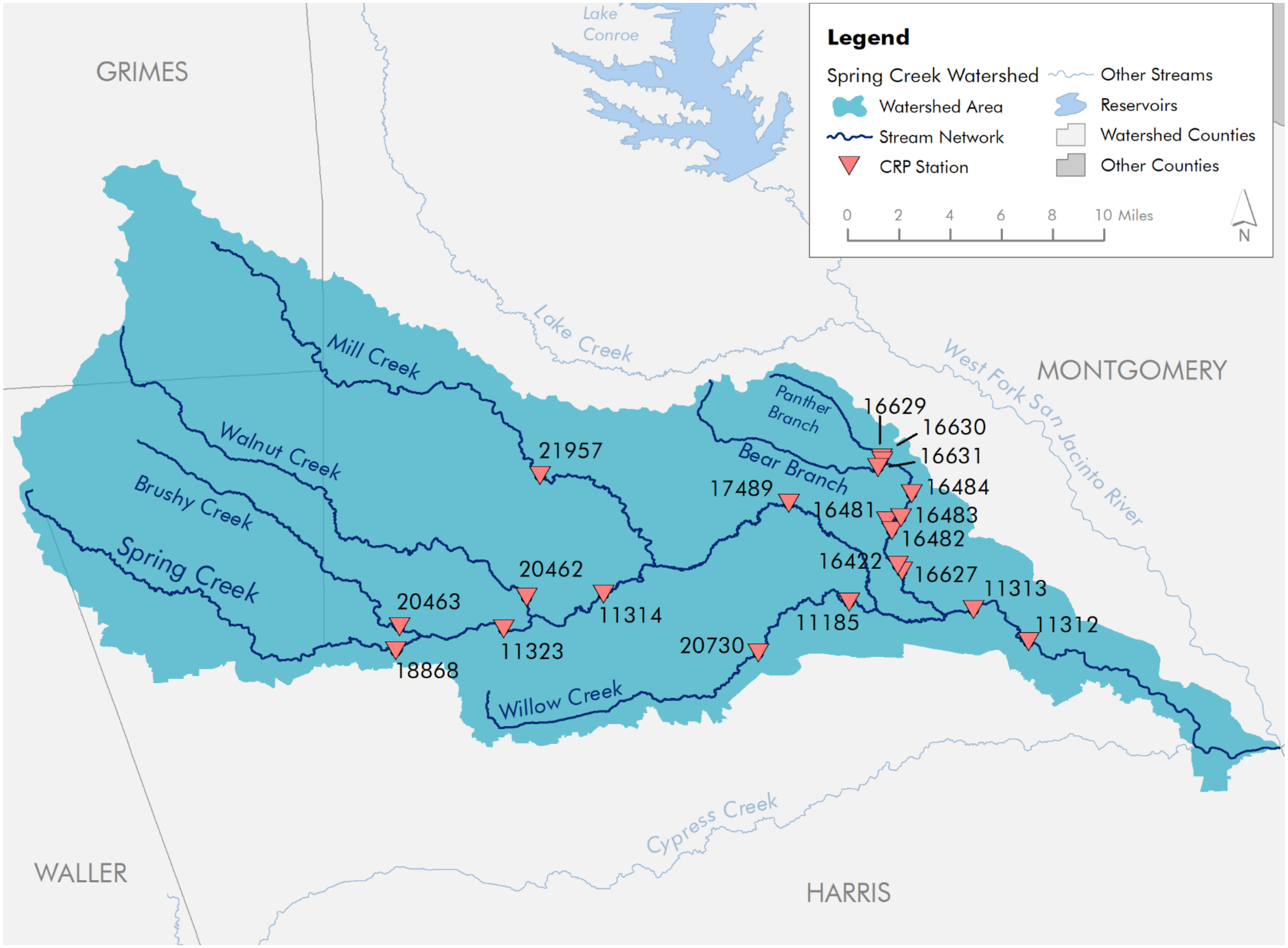

Figure 2. Active Monitoring Sites in the Spring Creek Watershed

Sub-sections of each stream segment classified as assessment units (AUs) are the basic unit of analysis for the IRs produced by TCEQ. The 2020 IR deemed several AUs in the Spring Creek Watershed impaired for recreation use due to high levels of fecal indicator bacteria (*E. coli*). These AUs and others within the watershed were also flagged as concerns for aquatic life and general use due to high nutrient levels and depressed oxygen. A more detailed summary of the results of the 2020 IR for AUs in the Spring Creek watershed are referenced in **Table 3** below.

Table 3. *2020 IR Status of Spring Creek Waterways*

Impairments			
Segment	**AU(s)**	**Parameter**	**Use**
Spring Creek, 1008	02, 03, 04	*E. coli*	Recreation
Lower Panther Branch, 1008C	01, 02	*E. coli*	Recreation
Willow Creek, 1008H	01	*E. coli*	Recreation
Walnut Creek, 1008I	01	*E. coli*	Recreation
Brushy Creek, 1008J	01	*E. coli*	Recreation
Concerns			
Segment	**AU(s)**	**Parameter**	**Use**
Spring Creek, 1008	02	Fish Community	Aquatic Life
Spring Creek, 1008	04	Nitrate	General
Spring Creek, 1008	04	Total Phosphorus	General
Upper Panther Branch, 1008B	01	Cadmium	Aquatic Life
Upper Panther Branch, 1008B	01	Nitrate	General
Upper Panther Branch, 1008B	01	Total Phosphorus	General
Lower Panther Branch, 1008C	01	Nitrate	General
Lower Panther Branch, 1008C	01, 02	Total Phosphorus	General
Lake Woodlands, 1008F	01	Depressed DO	Aquatic Life
Willow Creek, 1008H	01	Nitrate	General
Willow Creek, 1008H	01	Total Phosphorus	General

Sufficiency of Data

Table 2 details the frequency of sampling events for each station in the Spring Creek Watershed as well as establishing the period of record for each site.

Spring Creek (Segment 1008) is well represented by all six of its active monitoring stations with a minimum average of 7.6 sampling events per year of study.

Looking at monitoring data on the tributaries collected since 2005, an important note should be made about Mill Creek (Segment 1008A). Station 20461 was sampled an average of 4.3 times per year, however, it was discontinued as a sampling site in 2016 after determining its proximity to a reservoir was negatively impacting surface water quality (especially DO) measurements. Sampling for Mill Creek has since been conducted upstream at Station 21957 starting in 2017 and has averaged 5.3 sampling events each year. Combined data from Stations 20461 and 21957 will be observed in this analysis in order to characterize ambient conditions in Mill Creek with the caveat that these data may be skewed by the influence of a nearby reservoir.

On Lower Panther Branch (1008C), an abbreviated dataset occurs at station 16422 with its first sampling date recorded in 2014. This site is spatially similar to station 16628 which was discontinued in 2014, and therefore represents a continuation of data to the present for that location.

All other tributary sites have continuous periods of record and sample frequency averages greater than 4.

Monitoring Results

A summary of ambient data represented as the geomean of each parameter for its period of record is shown in **Table 4** below. These results are comparable to that of the 2020 IR, though not identical due to the use of overlapping datasets. Where the 2020 IR examined surface water data collected from 2011-2018, this analysis extends the dataset to cover 2005-2020 where possible. Results shaded in red indicate geomeans that exceed criteria or screening levels, while green shading represents results that are in compliance with criteria or better than the screening level. Lack of shading indicates the data is not being compared to criteria or screening levels.

Table 4. *Spring Creek Watershed Monitoring Results by Segment, 2005-2020 Geomean*

Parameter	Criteria	Unit	1008	1008A	1008B	1008C	1008E	1008F	1008H	1008I	1008J
Ammonia Nitrogen	0.33	mg/L	0.10	0.14	0.16	0.16	0.14	0.14	0.14	0.13	0.14
Chlorophyll-a	14.1	mg/L	2.50								
DO, 24 Hour, Average	Various	mg/L	5.76	5.23						6.15	5.89
DO, 24 Hour, Maximum	Various	mg/L	6.44	5.80						6.96	6.32
DO, 24 Hour, Minimum	Various	mg/L	5.15	4.73						5.23	5.37
DO, grab	Various	mg/L	7.05	5.15	6.53	6.70	6.98	8.42	7.77	6.06	5.51
E. coli	126	CFU/ 100mL	278.95	88.46	127.95	148.91	146.86	48.92	247.54	200.23	230.56
Nitrite	NA	mg/L	0.03								
Nitrate and Nitrite	NA	mg/L	0.24	0.34	1.77	2.37	0.34	1.26		0.22	0.11
Nitrate	1.95	mg/L	0.70		1.73	2.24	0.30	1.14	5.69		
pH	9 (high) 6.5(low)	NA	7.45	7.39	7.30	7.60	7.45	8.33	7.63	7.43	7.12
Total Phosphorus	0.69	mg/L	0.24	0.34	0.74	0.95	0.24	0.80	1.58	0.19	0.14
Temperature	NA	Degrees Celsius	19.74	19.60	21.70	21.40	20.99	22.09	20.93	20.42	20.01
TSS	NA	mg/L	17.04	17.51	8.45	18.35	15.98	17.68	12.20	16.57	9.48

Trends

By examining all parameters collected from surface water samples in the Spring Creek Watershed and how measurements for those parameters have changed over time, trends in the data were determined. Statistically significant ($p < 0.0545$) trends observed in these analyses are summarized in **Table 5** below. Results for parameters with stable trends over time are not represented in **Table 5**, however, graphs depicting the results of those assessments can be found in Error! Reference source not found.. Consequently, parameter measurements that exceeded water quality standards but remained consistently high throughout the study period (such as *E. coli*) may not be captured by the summary.

Table 5. Spring Creek Watershed Water Quality Trends by Segment, 2005-2020

Segment	Parameter	Trend
Spring Creek, 1008	Ammonia Nitrogen	Deteriorating
Spring Creek, 1008	Total Phosphorus	Improving
Spring Creek, 1008	TSS	Deteriorating
Mill Creek, 1008A	DO, grab	Improving
Mill Creek, 1008A	DO, 24-hour	Deteriorating
Mill Creek, 1008A	Nitrate	Improving
Mill Creek, 1008A	TSS	Deteriorating
Upper Panther Branch, 1008B	Ammonia Nitrogen	Deteriorating
Upper Panther Branch, 1008B	DO, grab	Improving
Upper Panther Branch, 1008B	*E. coli*	Improving
Upper Panther Branch, 1008B	pH	Improving
Lower Panther Branch, 1008C	Ammonia Nitrogen	Deteriorating
Lower Panther Branch, 1008C	pH	Improving
Bear Branch, 1008E	Ammonia Nitrogen	Deteriorating
Bear Branch, 1008E	DO, grab	Improving
Bear Branch, 1008E	Total Phosphorus	Deteriorating
Bear Branch, 1008E	pH	Improving
Lake Woodlands, 1008F	Ammonia Nitrogen	Deteriorating
Lake Woodlands, 1008F	DO, grab	Improving
Lake Woodlands, 1008F	*E. coli*	Improving
Lake Woodlands, 1008F	TSS	Improving
Lake Woodlands, 1008F	pH	Improving
Willow Creek, 1008H	pH	Improving
Walnut Creek, 1008I	DO, 24-hour	Improving
Walnut Creek, 1008I	Nitrate	Deteriorating
Brushy Creek, 1008J	Ammonia Nitrogen	Deteriorating
Brushy Creek, 1008J	pH	Deteriorating

Relationship to Flow

Parameter measurements and their relationships to flow conditions were considered in this analysis. Further work on the relationship between flow, bacteria, and DO was completed as part of load duration curve (LDC) model development[7]. According to the results of the LDC models, surface water in the Spring Creek Watershed is likely impacted by nonpoint source pollution. This is indicated by fecal indicator bacteria concentrations that are observed to increase with flow magnitude.

Ambient Analysis Summary

Of the ambient water quality parameters observed, geomean values for fecal indicator bacteria levels measured between 2005 and 2020 exceeded state water quality standards most frequently. Only Mill Creek (1008A) and Lake Woodlands (1008F) showed geomean values for *E. coli* within criteria levels. In fact, *E. coli* levels in Lake Woodlands have followed a significant decreasing

[7] The Spring Creek Bacteria Modeling Report is available at: https://springcreekpartnership.weebly.com/

trend over time. Upper Panther Branch (1008B) also shows improvement thought the geomean value for *E. coli* slightly exceeded that of the standard.

Nutrients also continue to pose a challenge to water quality in the Spring Creek watershed. Total phosphorous geomeans exceeded screening levels on Panther Branch (1008B and 1008C), Lake Woodlands (1008F) and Willow Creek (1008). Nitrate nitrogen geomeans were also found to be above screening levels on the lower portion of Panther Branch (1008C) and Willow Creek (1008H). Spatially, these exceedances occur in the eastern third of the watershed where developed areas are most prevalent.

Targeted assessment and application of best management practices could be expected to reduce or remove impairments and concerns in these watersheds.

3.2.2 Monitoring in Cypress Creek

The active monitoring stations in the Cypress Creek watershed are shown in **Figure 3** and described in **Table 6**. Between 2005 and 2020, 1,334 sampling events were conducted at the stations listed in **Table 6**. The main segment, Cypress Creek (1009), is represented by 7 of 11 active sites throughout the watershed. The remaining sample sites are found on Spring Gully (1009D), Faulkey Gully (1009C) and Little Cypress Creek (1009E). A full analysis of each constituent for each segment based on sites with sufficient data will be represented as a series of graphs in Error! Reference source not found..

Table 6. *Cypress Creek Watershed Monitoring Stations, Locations, Sampling Frequency, and Period of Record*

Station Number	Stream Segment	Assessment Unit	Sampling Events	Earliest Event	Latest Event
11324	Cypress Creek	1009_04	61	3/22/2005	1/15/2020
11328	Cypress Creek	1009_03	152	1/5/2005	11/18/2020
11330	Cypress Creek	1009_03	144	1/5/2005	11/2/2020
11331	Cypress Creek	1009_02	132	1/19/2005	11/2/2020
11332	Cypress Creek	1009_02	178	1/5/2005	11/2/2020
11333	Cypress Creek	1009_01	142	1/5/2005	11/2/2020
20457	Cypress Creek	1009_01	46	10/1/2007	10/14/2020
17496	Faulkey Gully	1009C_01	143	1/5/2005	11/2/2020
17481	Spring Gully	1009D_01	141	1/5/2005	11/2/2020
14159	Little Cypress Creek	1009E_01	142	1/5/2005	11/2/2020
20456	Little Cypress Creek	1009E_01	53	10/1/2007	10/14/2020

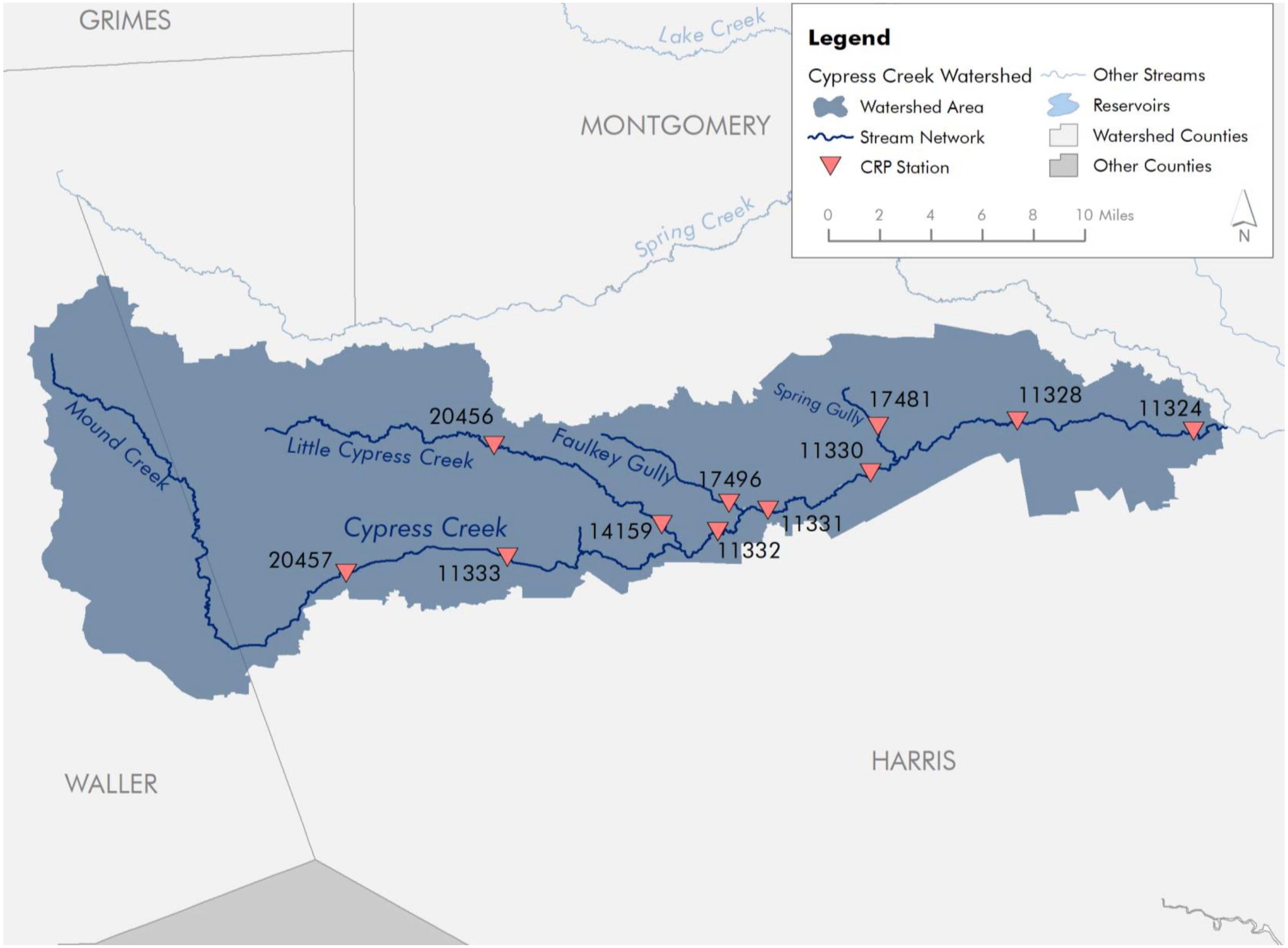

Figure 3. *Active Monitoring Sites in the Cypress Creek Watershed*

The 2020 IR deemed all AUs in the Cypress Creek watershed impaired for recreation use due to high levels of fecal indicator bacteria (*E. coli*). These AUs and others within the watershed were also flagged as concerns for aquatic life and general use due to high nutrient levels and depressed oxygen. A more detailed summary of the results of the 2020 IR for AUs in the Cypress Creek watershed are referenced in **Table 7** below.

Table 7. *2020 IR Status of Cypress Creek Waterways*

Impairments			
Segment	**AU(s)**	**Parameter**	**Use**
Cypress Creek, 1009	01, 02, 03, 04	*E. coli*	Recreation
Faulkey Gully,1009C	01	*E. coli*	Recreation
Spring Gully, 1009D	01	*E. coli*	Recreation
Little Cypress Creek, 1009E	01	*E. coli*	Recreation
Concerns			
Segment	**AU(s)**	**Parameter**	**Use**
Cypress Creek, 1009	01	Depressed DO	Aquatic Life
Cypress Creek, 1009	02	Habitat	Aquatic Life
Cypress Creek, 1009	01, 02, 03, 04	Nitrate	General
Cypress Creek, 1009	01, 02, 03, 04	Total Phosphorus	General
Faulkey Gully,1009C	01	Nitrate	General
Faulkey Gully,1009C	01	Total Phosphorus	General
Spring Gully, 1009D	01	Nitrate	General
Spring Gully, 1009D	01	Total Phosphorus	General
Little Cypress Creek, 1009E	01	Nitrate	General
Little Cypress Creek, 1009E	01	Total Phosphorus	General

Sufficiency of Data

Table 6 details the frequency of sampling events for each station in the Cypress Creek watershed as well as establishing the period of record for each site.

Cypress Creek (Segment 1009) is well represented by six of its seven monitoring stations with well over average sampling events per year of study. Though the newest station (20457) averages only 3.5 events per year, it is still included in this analysis due to having over 10 years of records.

All other tributary sites have continuous periods of record and sample frequency averages greater than 4.

Monitoring Results

A summary of ambient data represented as the geomean of each parameter for its period of record is shown in **Table 8** below. These results are comparable to that of the 2020 IR, though not identical due to the use of overlapping datasets. Where the 2020 IR examined surface water data collected from 2011-2018, this analysis extends the dataset to cover 2005-2020 where possible. Results shaded in red indicate geomeans that exceed criteria or screening levels, while green shading represents results that are in compliance with criteria or better than the screening level. Lack of shading indicates the data is not being compared to criteria or screening levels.

Table 8. Cypress Creek Watershed Monitoring Results by Segment, 2005-2020 Geomean

Parameter	Criteria	Unit	1009	1009C	1009D	1009E
Ammonia Nitrogen	0.33	mg/L	0.13	0.13	0.19	0.13
Chlorophyll-a	14.1	mg/L	8.73			
DO, 24 Hour, Average	Various	mg/L				
DO, 24 Hour, Maximum	Various	mg/L				
DO, 24 Hour, Minimum	Various	mg/L				
DO, grab	Various	mg/L	7.24	8.54	8.09	6.70
E. coli	126	CFU/ 100mL	464.73	382.76	367.64	201.34
Nitrite	NA	mg/L	0.05			
Nitrate and Nitrite	NA	mg/L	1.23			0.30
Nitrate	1.95	mg/L	3.17	5.08	4.94	3.55
pH	9 (high) 6.5(low)	NA	7.72	7.93	8.06	7.66
Total Phosphorus	0.69	mg/L	1.19	1.83	1.78	1.04
Temperature	NA	Degrees Celsius	21.15	22.04	22.89	20.91
TSS	NA	mg/L	28.99	16.18	12.81	17.49

Trends

By examining all parameters collected from surface water samples in the Cypress Creek watershed and how measurements for those parameters have changed over time, trends in the data were determined. Statistically significant ($p < 0.0545$) trends observed in these analyses are summarized in **Table 9** below. Results for parameters with stable trends over time are not represented in **Table 9**, however, graphs depicting the results of those assessments can be found in Error! Reference source not found.. Consequently, parameter measurements that exceeded water quality standards but remained consistently high throughout the study period (such as *E. coli*) may not be captured by the summary.

Table 9. *Cypress Creek Watershed Water Quality Trends by Segment, 2005-2020*

Segment	Parameter	Trend
Cypress Creek, 1009	Ammonia Nitrogen	Deteriorating
Cypress Creek, 1009	Total Phosphorus	Improving
Cypress Creek, 1009	TSS	Deteriorating
Cypress Creek, 1009	pH	Improving
Faulkey Gully, 1009C	Ammonia Nitrogen	Deteriorating
Faulkey Gully, 1009C	DO, grab	Improving
Faulkey Gully, 1009C	Nitrate	Deteriorating
Faulkey Gully, 1009C	Temperature	Deteriorating
Faulkey Gully, 1009C	pH	Deteriorating
Spring Gully, 1009D	Ammonia Nitrogen	Improving
Spring Gully, 1009D	DO, grab	Improving
Spring Gully, 1009D	*E. coli*	Improving
Spring Gully, 1009D	TSS	Improving
Little Cypress Creek, 1009E	Total Phosphorus	Improving
Little Cypress Creek, 1009E	TSS	Deteriorating
Little Cypress Creek, 1009E	pH	Improving

Relationship to Flow

Parameter measurements and their relationships to flow conditions were considered in this analysis. Further work on the relationship between flow, bacteria, and DO was completed as part of LDC model development[8]. According to the results of the LDC models, surface water in the Cypress Creek Watershed is likely impacted by nonpoint source pollution. This is indicated by fecal indicator bacteria concentrations that are observed to increase with flow magnitude.

Ambient Analysis Summary

Of the ambient water quality parameters observed, geomean values for *E. coli*, nitrate and total phosphorous measured between 2005 and 2020 exceeded state water quality standards on every segment.

Of the segments with geomeans that exceeded criteria, Spring Gully (1009D) showed an improving trend. However, as the geomean value for *E. coli* was over 300 CFU/100 mL at this site, action must be taken to continue this trend.

Nitrate and total phosphorous geomeans did not meet the criteria for any of the segments in the watershed. On Cypress Creek (1009) and Little Cypress Creek (1009E), total phosphorous conditions could improve as trends indicate that these concentrations are decreasing over time. However, conditions are deteriorating on Faulkey Gully (1009C) as indicated by increasing trends in nitrate levels.

Targeted assessment and application of best management practices could be expected to reduce or remove impairments and concerns in these watersheds.

[8] The Cypress Creek Bacteria Modeling Report is available at: https://cypresspartnership.weebly.com/

3.2.3 Monitoring in Lake Creek

The active monitoring stations in the Lake Creek watershed are shown in **Figure 4** and described in **Table 10**. Between 2005 and 2020, 210 sampling events were conducted at the stations listed in **Table 10**. The main segment, Lake Creek (1015A), is represented by 2 of 3 active sites throughout the watershed. The remaining site is located on Mound Creek (1015A), Lake Creek's only unclassified segment. A full analysis of each constituent for each segment based on sites with sufficient data will be represented as a series of graphs in Error! Reference source not found..

***Table 10.** Lake Creek Watershed Monitoring Stations, Locations, Sampling Frequency, and Period of Record*

Station Number	Stream Segment	Assessment Unit	Sampling Events	Earliest Event	Latest Event
11367	Lake Creek	1015_01	85	10/11/2007	10/15/2020
18191[9]	Lake Creek	1015_02	66	10/11/2007	8/22/2018
18192	Lake Creek	1015_02	9	10/11/2018	10/8/2020
17937	Mound Creek	1015A_01	50	10/11/2007	10/15/2020

The 2020 IR only noted one impairment in the Lake Creek watershed for recreation use due to high levels of fecal indicator bacteria (*E. coli*). Other concerns including depressed oxygen, poor conditions for the macrobenthic community and high nutrient levels were noted. A more detailed summary of the results of the 2020 IR for AUs in the Spring Creek watershed are referenced in **Table 11** below.

***Table 11.** 2020 IR Status of Lake Creek Waterways*

	Impairments		
Segment	**AU(s)**	**Parameter**	**Use**
Mound Creek, 1015A	01	*E. coli*	Recreation
	Concerns		
Segment	**AU(s)**	**Parameter**	**Use**
Lake Creek, 1015	02	Depressed DO	Aquatic Life
Lake Creek, 1015	01	Macrobenthic Community	Aquatic Life
Lake Creek, 1015	01	Nitrate	General
Lake Creek, 1015	01	Total Phosphorus	General

Sufficiency of Data

Table 10 details the frequency of sampling events for each station in the Lake Creek watershed as well as establishing the period of record for each site.

Lake Creek (Segment 1015) is well represented by both of its active monitoring stations with a minimum average of 4.5 sampling events per year of study. Station 18191 was discontinued after August 2018, but a spatially similar site (18192) was established in October 2018. Data from these two sites will be combined to better represent water quality condition on Lake Creek.

Though the Mound Creek station (17937) averages only 3.8 events per year, it is still included in this analysis due to having over 10 years of records.

[9] Combined data from Stations 18191 and 18192 will be observed in this analysis in order to characterize ambient conditions in Lake Creek. See the **Sufficiency of Data** section for more information.

Figure 4. *Active Monitoring Sites in the Lake Creek Watershed*

Monitoring Results

A summary of ambient data represented as the geomean of each parameter for its period of record is shown in **Table 12** below. These results are comparable to that of the 2020 IR, though not identical due to the use of overlapping datasets. Where the 2020 IR examined surface water data collected from 2011-2018, this analysis extends the dataset to cover 2005-2020 where possible. Results shaded in red indicate geomeans that exceed criteria or screening levels, while green shading represents results that are in compliance with criteria or better than the screening level. Lack of shading indicates the data is not being compared to criteria or screening levels.

Table 12. *Lake Creek Watershed Monitoring Results by Segment, 2005-2020 Geomean*

Parameter	Criteria	Unit	1015	1015A
Ammonia Nitrogen	0.33	mg/L	0.13	0.12
Chlorophyll-a	14.1	mg/L		
DO, 24 Hour, Average	Various	mg/L	7.16	
DO, 24 Hour, Maximum	Various	mg/L	8.31	
DO, 24 Hour, Minimum	Various	mg/L	5.84	
DO, grab	Various	mg/L	5.99	7.34
E. coli	126	CFU/ 100mL	116.93	283.73
Nitrite	NA	mg/L		
Nitrate and Nitrite	NA	mg/L	0.08	0.18
Nitrate	1.95	mg/L		
pH	9 (high) 6.5(low)	NA	7.44	7.38
Total Phosphorus	0.69	mg/L	0.18	0.14
Temperature	NA	Degrees Celsius	22.24	20.54
TSS	NA	mg/L	17.68	19.27

Trends

By examining all parameters collected from surface water samples in the Lake Creek watershed and how measurements for those parameters have changed over time, trends in the data were determined. Statistically significant ($p < 0.0545$) trends observed in these analyses are summarized in **Table 13** below. Results for parameters with stable trends over time are not represented in **Table 13**, however, graphs depicting the results of those assessments can be found in Error! Reference source not found.. Consequently, parameter measurements that exceeded water quality standards but remained consistently high throughout the study period (such as *E. coli*) may not be captured by the summary.

Table 13. *Lake Creek Watershed Water Quality Trends by Segment, 2005-2020*

Segment	Parameter	Trend
Lake Creek, 1015	Ammonia Nitrogen	Deteriorating
Lake Creek, 1015	Nitrate	Deteriorating
Lake Creek, 1015	TSS	Deteriorating
Mound Creek, 1015A	DO, 24-hour	Improving
Mound Creek, 1015A	Nitrate-N	Deteriorating

Relationship to Flow

Parameter measurements and their relationships to flow conditions were considered in this analysis. Further work on the relationship between flow, bacteria, and DO was completed as part of LDC model development[10]. According to the results of the LDC models, surface water in the Lake Creek Watershed is likely impacted by nonpoint source pollution. This is indicated by fecal indicator bacteria concentrations that are observed to increase with flow magnitude.

Ambient Analysis Summary

In keeping with the results of the 2020 IR, only geomean values for *E. coli* on Mound Creek (1015A) exceeded state water quality standards. This might be due to the segment's proximity to the urbanized area of Conroe, TX compared to the relatively rural areas observed throughout the rest of the watershed. Targeted assessment and application of best management practices should be focused on the easternmost areas of the watershed to have the greatest effect in mitigating fecal indicator bacteria impairments.

While nutrient concerns were observed in the 2020 IR for Lake Creek (1015), analyses of ambient data collected between 2005 and 2020 did not capture similar results. This could be due to the longer time period covered by the analysis relative to the 2020 IR (years 2011 to 2018).

3.2.4 Monitoring in the West Fork of the San Jacinto River

The active monitoring stations in the West Fork San Jacinto River watershed are shown in **Figure 5** and described in **Table 14**. Between 2005 and 2020, 532 sampling events were conducted at the stations listed in **Table 14**. The main segment, West Fork San Jacinto River (1004), is represented by 3 of 6 active sites throughout the watershed. The remaining sites are distributed among the tributaries Crystal Creek (1004D), Stewarts Creek (1004E), and White Oak Creek (1004J). A full analysis of each constituent for each segment based on sites with sufficient data will be represented as a series of graphs in Error! Reference source not found..

Table 14. *West Fork San Jacinto River Watershed Monitoring Stations, Locations, Sampling Frequency, and Period of Record*

Station Number	Stream Segment	Assessment Unit	Sampling Events	Earliest Event	Latest Event
11243	West Fork San Jacinto River	1004_01	111	1/19/2005	11/18/2020
11250	West Fork San Jacinto River	1004_02	83	1/18/2005	10/9/2019
11251	West Fork San Jacinto River	1004_02	120	1/19/2005	11/18/2020
16635	Crystal Creek	1004D_01	71	1/19/2005	7/12/2017
16626	Stewarts Creek	1004E_01	109	1/19/2005	11/18/2020
20731	White Oak Creek	1004J_01	38	3/16/2009	10/8/2020

[10] The Bacteria Modeling Report for the West Fork San Jacinto River and Lake Creek Watersheds is available at: https://westfork.weebly.com/

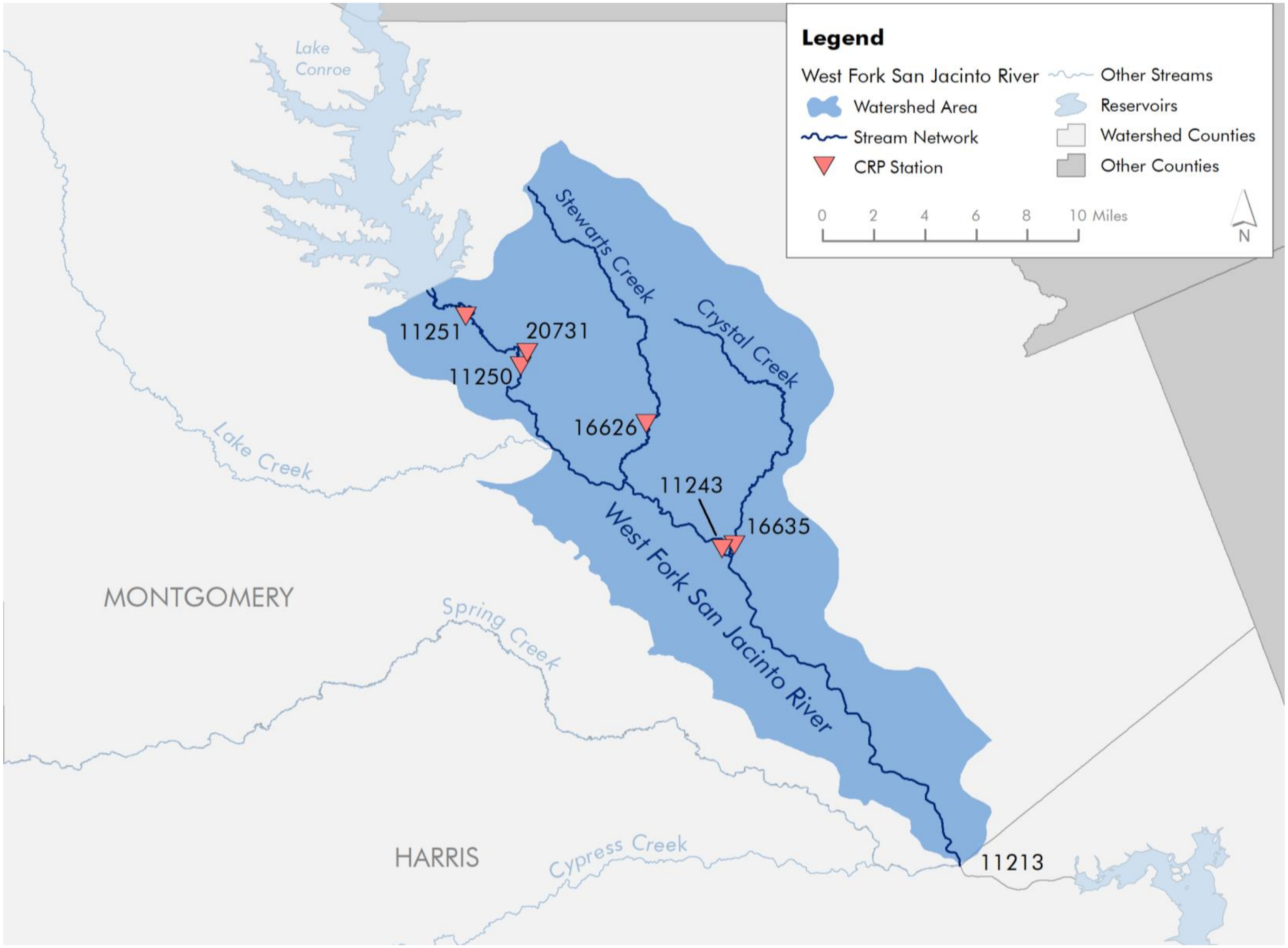

Figure 5. *Active Monitoring Sites in the West Fork San Jacinto River Watershed*

The 2020 IR deemed several AUs in the West Fork San Jacinto River watershed impaired for recreation use due to high levels of fecal indicator bacteria (*E. coli*). These AUs and others within the watershed were also flagged as concerns for aquatic life and general use due to high nutrient levels and depressed oxygen. A more detailed summary of the results of the 2020 IR for AUs in the West Fork San Jacinto River watershed are referenced in **Table 15** below.

Table 15. *2020 IR Status of West Fork San Jacinto River Waterways*

Impairments			
Segment	**AU(s)**	**Parameter**	**Use**
West Fork San Jacinto River, 1004	01, 02	*E. coli*	Recreation
Stewarts Creek, 1004E	01	*E. coli*	Recreation
White Oak Creek, 1004J	01	*E. coli*	Recreation
Concerns			
Segment	**AU(s)**	**Parameter**	**Use**
West Fork San Jacinto River, 1004	02	Macrobenthic Community	Aquatic Life
West Fork San Jacinto River, 1004	01	Nitrate	General

Sufficiency of Data

Table 14 details the frequency of sampling events for each station in the West Fork San Jacinto River watershed as well as establishing the period of record for each site.

West Fork San Jacinto River (Segment 1004) is well represented by all three of its monitoring stations with a minimum average of 5.9 sampling events per year of study. All other tributary sites have continuous periods of record and sample frequency averages greater than 4.

Monitoring Results

A summary of ambient data represented as the geomean of each parameter for its period of record is shown in **Table 16** below. These results are comparable to that of the 2020 IR, though not identical due to the use of overlapping datasets. Where the 2020 IR examined surface water data collected from 2011-2018, this analysis extends the dataset to cover 2005-2020 where possible. Results shaded in red indicate geomeans that exceed criteria or screening levels, while green shading represents results that are in compliance with criteria or better than the screening level. Lack of shading indicates the data is not being compared to criteria or screening levels.

Table 16. West Fork San Jacinto River Watershed Monitoring Results by Segment, 2005-2020 Geomean

Parameter	Criteria	Unit	1004	1004D	1004E	1004J
Ammonia Nitrogen	0.33	mg/L	0.09	0.11	0.10	0.15
Chlorophyll-a	14.1	mg/L	6.22			
DO, 24 Hour, Average	Various	mg/L				
DO, 24 Hour, Maximum	Various	mg/L				
DO, 24 Hour, Minimum	Various	mg/L				
DO, grab	Various	mg/L	8.02	8.51	8.14	8.25
E. coli	126	CFU/100mL	173.60	129.02	244.90	851.87
Nitrite	NA	mg/L	0.02	0.02	0.02	
Nitrate and Nitrite	NA	mg/L	0.53			1.30
Nitrate	1.95	mg/L	0.34	0.14	0.08	
pH	9 (high) 6.5(low)	NA	7.46	7.38	7.49	7.39
Total Phosphorus	0.69	mg/L	0.15	0.11	0.07	0.17
Temperature	NA	Degrees Celsius	19.71	18.38	18.13	21.77
TSS	NA	mg/L	14.81	12.32	12.13	16.69

Trends

By examining all parameters collected from surface water samples in the West Fork San Jacinto River watershed and how measurements for those parameters have changed over time, trends in the data were determined. Statistically significant ($p < 0.0545$) trends observed in these analyses are summarized in **Table 17** below. Results for parameters with stable trends over time are not represented in **Table 17**, however, graphs depicting the results of those assessments can be found in Error! Reference source not found.. Consequently, parameter measurements that exceeded water quality standards but remained consistently high throughout the study period (such as *E. coli*) may not be captured by the summary.

Table 17. West Fork San Jacinto River Water Quality Trends by Segment, 2005-2020

Segment	Parameter	Trend
White Oak Creek, 1004J	pH	Deteriorating

Relationship to Flow

Parameter measurements and their relationships to flow conditions were considered in this analysis. Further work on the relationship between flow, bacteria, and DO was completed as part of LDC model development[11]. According to the results of the LDC models, surface water in the Spring Creek Watershed is likely impacted by nonpoint source pollution. This is indicated by fecal indicator bacteria concentrations that are observed to increase with flow magnitude.

Ambient Analysis Summary

Geomean values for fecal indicator bacteria levels measured between 2005 and 2020 exceeded state water quality standard on each segment. Of the four segments, Crystal Creek (1004D) had the

[11] The Bacteria Modeling Report for the West Fork San Jacinto River and Lake Creek Watersheds is available at https://westfork.weebly.com/.

lowest geomean of 129.02 CFU/100 mL only slightly exceeding the standard. White Oak Creek (1004J) had the highest geomean at 851.87 CFU/100 mL. This segment is part of an ongoing targeted monitoring assessment to investigate sources of bacteria leading to such great exceedances of the standard.

3.3 DMR Data

Discharges from wastewater treatment plants are regulated by water quality permits from TCEQ which require stringent limits for effluent quality. Generally, wastewater treatment plants in the Houston region are able to meet their permits. However, because human waste has an appreciable pathogenic potential, identifying trends in permit exceedances for indicator bacteria by WWTFs is important in understanding overall impacts to waterways. Additionally, effluent (especially if improperly treated) can be a source of nutrient precursors to depressed DO. Discharges from WWTFs are monitored on a regular basis (with a frequency dependent on plant size and other factors). The data from these required sampling events is submitted to (and compiled by) the TCEQ as DMRs. As with any self-reported data, there is an expectation that some degree of uncertainty or variation from conditions may occur, but these DMRs are the most comprehensive data available for evaluating WWTFs in the watershed.

For this project, staff evaluated five parameters common to most WWTF permits, as reported in the last five years (2016-2020) of DMRs available from TCEQ. Some parameters are themselves constituents of concern, while the others are indicators of the presence or potential presence of untreated or improperly treated waste:

- Indicator bacteria (*E. coli*) – bacteria common in the intestines of all warm-blooded animals used as an indicator of the presence of fecal wastes. Due to this relationship, it may also be used as a proxy indicator of the safety of waterways for human recreation as fecal waste can be a vector for human pathogens.
- TSS – this measure of the number of suspended particles in water indicates the efficiency of the WWTF process, and the potential of effluent to impact sedimentation and light transmission in the waterway. Excessive particles in the water quality can foster bacteria survival, among other impacts.
- Ammonia Nitrogen – this nitrogenous compound is specifically harmful to aquatic systems, can impact human health in high concentrations, contributes to algal blooms and low DO, and can indicate the efficiency of wastewater treatment processes.
- DO, grab samples – this indicator directly characterizes the ability of the effluent to support aquatic life, and it indicates the potential presence of nutrients and other oxygen-demanding substances (and thus the efficiency of treatment processes).
- 5-Day Carbonaceous Biological Oxygen Demand (CBOD5) – This indicator, which measures the depletion of oxygen over time by biological processes, indicates the efficiency of treatment.

3.3.1 Spring Creek DMR Analysis

The parameter evaluations were based on the regulatory permit limits specific to each plant, and consider the number of exceedances by each plant, in each year, in each segment, and as a percentage of the total samples.

Indicator Bacteria

As with surface water sampled throughout the watershed to gage ambient conditions, discharge from WWTFs is assessed for compliance with state water quality standards. In the case of *E. coli*, the permitted geomean standard for bacteria concentrations is 126 CFU/100 mL whereas the grab sample standard is 399 CFU/100 mL. For this analysis, compliance with permit limits for bacteria were compared across segments, plant types, years, and seasons. Data from the 61 plants represented by DMRs in the Spring Creek watershed are summarized in the tables below.

In **Table 18**, it is clear that of the plants reporting violations of bacteria criteria, the majority are in exceedance less 2% of the time. The disparity between the number of samples exceeding the geomean standard compared to samples exceeding the grab standard could indicate high variability in the data. Higher rates of exceedance from specific sites may be overshadowed by the broad scope of this analysis.

Table 18. *Spring Creek Watershed DMR* E. coli *Exceedance Statistics, 2016-2020*

Parameter	Number of Plants	Percent of Reports
Plants Reporting Bacteria	61	
Total Records	4,988	
Exceedances of Geomean	16	0.3%
Exceedances of Single Grab	77	1.6%
Total Exceedances	93	1.9%

Below in **Table 19**, no clear trends were observed in either geomean or single grab criteria exceedance or the total number of exceedances observed annually.

Table 19. *Spring Creek Watershed DMR* E. coli *Exceedances by Year*

	2016	2017	2018	2019	2020	Total
By Geomean	4	5	1	4	2	16
By Grab	17	19	8	20	13	77
Total Exceedances	21	24	9	24	15	93

Overall, the results of the analyses of DMR *E. coli* data indicated that the total number of exceedances reported was small relative to the total number of DMR reports submitted for the period of 2016-2020 (93 out of 4,988 records). While WWTFs may be appreciable contributions under certain conditions, in localized areas, the DMR analysis indicates that they are not likely a significant driver of segment bacteria impairments due to the comparatively few exceedances. However, due to the relatively higher risk of pathogens from human waste, and proximity to developed areas, WWTF exceedances are likely still a point of concern for stakeholders.

Dissolved Oxygen

DO levels in WWTF effluent help indicate the efficiency of treatment processes. DO is generally more stable in effluent than it can be in ambient conditions because it is less subject to natural processes and variation in insolation. DO is measured in milligrams per liter (mg/L), and the permit limits can vary based on the receiving water body and other factors. Unlike other contaminants, DO limits are based on a minimum, rather than maximum level, and represent a grab sample as opposed to a 24-hour monitoring event. Generally, permit limits for the data reviewed ranged between 4-6 mg/L. 61 plants reported DO results during this period. The outcomes are summarized in the tables below.

Table 20 summarizes the overall statistics of DO data reported by WWTFs in the Spring Creek Watershed. Very few (14 of 3,679 total reports) samples fell below the minimum standard.

Table 20. *Spring Creek Watershed DMR DO Exceedance Statistics, 2016-2020*

Category	Number	Percent of Records
Plants Reporting DO	61	
Total Records	3,679	
Total Exceedances	14	0.4%

After arranging the data temporally, no annual trends were observed in the reported data (**Table 21**). However, in light of the low occurrence of exceedance relative to the overall dataset, determining trends from these values may not accurately represent DO dynamics in the watershed.

Table 21. *Spring Creek Watershed DMR DO Exceedances by Year*

	2016	2017	2018	2019	2020	Total
Exceedances	2	3	5	3	1	14

Due to the findings of this analysis, it is unlikely that low DO levels in the waterways of the Spring Creek watershed are being driven by WWTF effluent. As with the results of the bacteria analysis, it is important to note that periodic impacts to DO may occur on a localized level but may not be well represented in this broad analysis. While the impacts of WWTFs on DO levels may not be a chronic or widespread issue in the watershed, an analysis of DO values reported in DMRs is still a critical component of this project especially as it pertains to identifying localized impacts.

TSS

To determine the efficiency of wastewater treatment in removing solids, TSS is evaluated. Bacteria use suspended particles as a protected growth medium and can therefore occur in greater concentrations when TSS is high. Additionally, TSS can be useful as an indicator that inefficient treatment may have led to other waste products (nutrients, etc.) being elevated in effluent.

Permit limits for TSS include a concentration based (average) limit in mg/L and a total weight-based limit in weight per day. Both average and maximum monitored results exist for most plants. Evaluations for compliance with concentration and total weight permit limits were made for the overall dataset and for annual data. These results are summarized in the tables below.

The summary of reports made for TSS measurements and the number of exceedances of the concentration and weight standards are presented in **Table 22** below. Compared to the total number of reports submitted between 2016 and 2020, the total frequency of exceedance is very small (less than 2%).

Table 22. *Spring Creek Watershed DMR TSS Exceedance Statistics, 2016-2020*

Category	Number	Percent of Records
Plants Reporting TSS	61	
Total Records	11,440	
Exceedances of Concentration	168	1.5%
Exceedances of Weight	46	0.4%
Total Exceedances	214	1.9%

Viewing the data annually as represented in **Table 23**, there does not seem to be any significant pattern to either concentration, weight or combined total violations.

Table 23. *Spring Creek Watershed DMR TSS Exceedance by Year*

	2016	2017	2018	2019	2020	Total
Concentration	40	54	30	23	21	168
Weight	5	11	16	6	8	46
Total	45	65	46	29	29	214

Though periodic, local impacts may not be captured by these results, water quality throughout the watershed is unlikely to be impacted by TSS from WWTFs at the watershed level. Despite this, observing TSS in WWTF effluent is still worth considering when moving forward with best management practices for water quality. As mentioned previously, TSS is often correlated with nutrient and bacteria levels, and can be tracked as a measure of WWTF improvement.

Ammonia Nitrogen

Ammonia nitrogen is a component that indicates negative impacts to water quality due to nutrient loading. Further, it can be toxic to humans and wildlife. Deficiencies in wastewater treatment that lead to improperly treated sewage entering waterways can be indicated by elevated levels of ammonia nitrogen.

Similar to TSS, concentration and weight measurements are used to assess compliance of ammonia nitrogen levels with permit limits. In **Table 24** below, the results of samples reported to be in exceedance of the standard as reported between 2016 and 2020 are summarized. Ammonia nitrogen violations were infrequent and occurred in 2.6% of the observed records.

Table 24. *Spring Creek Watershed DMR Ammonia Nitrogen Exceedance Statistics, 2016-2020*

Category	Number	Percent of Records
Plants Reporting Ammonia Nitrogen	61	
Total Records	7,294	
Exceedances of Concentration	123	1.7%
Exceedances of Weight	69	0.9%
Total Exceedances	192	2.6%

In **Table 25** below, number of ammonia nitrogen exceedances per year are represented for measurements of both concentration and weight. No trend was observed in the annual data.

Table 25. *Spring Creek Watershed DMR Ammonia Nitrogen Exceedance by Year*

	2016	2017	2018	2019	2020	Total
Concentration	33	32	18	19	21	123
Weight	23	18	14	7	7	69
Total	56	50	32	26	28	192

The results of the analyses of ammonia nitrogen reported by Spring Creek WWTFs between 2016 and 2020 show that exceedances in concentration do not follow a strong annual pattern. Exceedances of weight do seem to decrease over time. Considering the low occurrence of exceedances overall, this indicates that WWTFs are generally operating within permit limits and that ammonia inputs from WWTFs are not likely a chronic issue of importance for Spring Creek waterways. Periodic, localized impacts may not be as apparent when using a broad scope analysis. Ammonia nitrogen may still have use as an indicator of WWTF efficiency much in the same way as TSS and will therefore continue to be considered for best management practices in the watershed.

Biological Oxygen Demand

CBOD5 measures the depletion of oxygen over time by biological processes and indicates the efficiency of treatment. It is not a pollutant itself, but it is informative of the water quality of effluent from WWTFs. In **Table 26** below, the exceedances of concentration and weight standards for CBOD5 in relation to the total number of reported values are summarized. Of all the DMR constituents examined, CBOD5 exceedance is the rarest. Of the 7,362 report values examined, only 30 exceeded either the concentration or weight standard making up only 0.4% of the dataset.

Table 26. *Spring Creek Watershed DMR CBOD5 Exceedance Statistics, 2016-2020*

Category	Number	Percent of Records
Plants Reporting CBOD5	61	
Total Records	7,362	
Exceedances of Concentration	18	0.2%
Exceedances of Weight	12	0.2%
Total Exceedances	30	0.4%

Table 27 examines annual CBOD5 exceedances. No clear trend in CBOD5 exceedance values occurs in the observed data, but it should be noted that determining a trend from exceedance values occurring at such low frequencies might be misrepresentative of the overall dataset.

Table 27. *Spring Creek Watershed DMR CBOD5 Exceedance by Year*

	2016	2017	2018	2019	2020	Total
Concentration	0	6	4	4	4	18
Weight	0	4	5	1	2	12
Total	0	10	9	5	6	30

CBOD5 exceedances were relatively rare in this DMR dataset compared to the other observed parameters. No annual pattern was observed. From this analysis, it can be assumed that WWTFs are not likely a chronic source of poor CBOD5 values in the waterways of the Spring Creek Watershed. As with previous analyses however, it should be noted that determining periodic and localized impacts may require further investigation.

Overview of Results

Exceedances for all constituents compared to their permit standards were uncovered by this analysis. However, plants in the Spring Creek Watershed were largely found to be in compliance with their permit limits for the majority of the period of study. It is unlikely that WWTFs are an appreciable source of contamination in the watershed on a chronic, wide-ranging scale. However, this broad analysis may underrepresent localized impacts of WWTF outfalls.

3.3.2 Cypress Creek DMR Analysis

Cypress Creek had the highest number of WWTFs reporting DMR compared to the other watersheds observed in this analysis. The parameter evaluations were based on the regulatory permit limits specific to each plant, and consider the number of exceedances by each plant, in each year, in each segment, and as a percentage of the total samples.

Indicator Bacteria

In **Table 28**, it is clear that of the plants reporting violations of bacteria criteria, the majority are in exceedance less 2% of the time. The disparity between the number of samples exceeding the geomean standard compared to samples exceeding the grab standard could indicate high variability in the data. Higher rates of exceedance from specific sites may be overshadowed by the broad scope of this analysis.

Table 28. *Cypress Creek Watershed DMR* E. coli *Exceedance Statistics, 2016-2020*

Parameter	Number of Plants	Percent of Reports
Plants Reporting Bacteria	85	
Total Records	8,119	
Exceedances of Geomean	16	0.2%
Exceedances of Single Grab	93	1.1%
Total Exceedances	109	1.3%

Below in **Table 29**, no clear trends were observed in either geomean or single grab criteria exceedance or the total number of exceedances observed annually.

Table 29. *Cypress Creek Watershed DMR* E. coli *Exceedances by Year*

	2016	2017	2018	2019	2020	Total
By Geomean	2	3	2	7	2	16
By Grab	10	20	17	32	14	93
Total Exceedances	12	23	19	39	16	109

Overall, the results of the analyses of DMR *E. coli* data indicated that the total number of exceedances reported was small relative to the total number of DMR reports submitted for the period of 2016-2020 (109 out of 8,119 records). While WWTFs may be appreciable contributions under certain conditions, in localized areas, the DMR analysis indicates that they are not likely a significant driver of segment bacteria impairments due to the comparatively few exceedances. However, due to the relatively higher risk of pathogens from human waste, and proximity to developed areas, WWTF exceedances are likely still a point of concern for stakeholders.

Dissolved Oxygen

Table 30 summarizes the overall statistics of DO data reported by WWTFs in the Lake Creek and West Fork San Jacinto River watershed. Very few (16 of 4,807 total reports) samples fell below the minimum standard.

Table 30. *Cypress Creek Watershed DMR DO Exceedance Statistics, 2016-2020*

Category	Number	Percent of Records
Plants Reporting DO	88	
Total Records	4,807	
Total Exceedances	16	0.3%

After arranging the data temporally, no annual trends were observed in the reported data (**Table 31**). However, in light of the low occurrence of exceedance relative to the overall dataset, determining trends from these values may not accurately represent DO dynamics in the watershed.

Table 31. *Lake Creek and West Fork San Jacinto River Watershed DMR DO Exceedances by Year*

	2016	2017	2018	2019	2020	Total
Exceedances	5	6	3	2	0	16

Due to the findings of this analysis, it is unlikely that low DO levels in the waterways of the Cypress Creek watershed are being driven by WWTF effluent. As with the results of the bacteria analysis, it is important to note that periodic impacts to DO may occur on a localized level but may not be well represented in this broad analysis. While the impacts of WWTFs on DO levels may not be a chronic or widespread issue in the watershed, an analysis of DO values reported in DMRs is still a critical component of this project especially as it pertains to identifying localized impacts.

TSS

The summary of reports made for TSS measurements and the number of exceedances of the concentration and weight standards are presented in **Table 32** below. Compared to the total number of reports submitted between 2016 and 2020, the total frequency of exceedance is very small (less than 1%).

Table 32. *Cypress Creek Watershed DMR TSS Exceedance Statistics, 2016-2020*

Category	Number	Percent of Records
Plants Reporting TSS	88	
Total Records	9,616	
Exceedances of Concentration	56	0.6%
Exceedances of Weight	14	0.1%
Total Exceedances	70	0.7%

Viewing the data annually as represented in **Table 33**, there does not seem to be any significant pattern to either concentration, weight or combined total violations.

Table 33. *Cypress Creek Watershed DMR TSS Exceedance by Year*

	2016	2017	2018	2019	2020	Total
Concentration	13	4	22	12	5	56
Weight	7	0	1	4	2	14
Total	20	4	23	16	7	70

Though periodic, local impacts may not be captured by these results, water quality throughout the watershed is unlikely to be impacted by TSS from WWTFs at the watershed level. Despite this, observing TSS in WWTF effluent is still worth considering when moving forward with best management practices for water quality. As mentioned previously, TSS is often correlated with nutrient and bacteria levels, and can be tracked as a measure of WWTF improvement.

Ammonia Nitrogen

In **Table 34** below, the results of samples reported to be in exceedance of the standard as reported between 2016 and 2020 are summarized. Ammonia nitrogen violations were infrequent and occurred in 1.3% of the observed records.

Table 34. Cypress Creek DMR Ammonia Nitrogen Exceedance Statistics, 2016-2020

Category	Number	Percent of Records
Plants Reporting Ammonia Nitrogen	88	
Total Records	9,616	
Exceedances of Concentration	108	1.1%
Exceedances of Weight	22	0.2%
Total Exceedances	130	1.3%

In **Table 35** below, number of ammonia nitrogen exceedances per year are represented for measurements of both concentration and weight. No trend was observed in the annual data.

Table 35. Cypress Creek Watershed DMR Ammonia Nitrogen Exceedance by Year

	2016	2017	2018	2019	2020	Total
Concentration	21	24	25	20	18	108
Weight	6	3	3	2	8	22
Total	27	27	28	22	26	130

The results of the analyses of ammonia nitrogen reported by Cypress Creek Watershed WWTFs between 2016 and 2020 show that exceedances in concentration do not follow a strong annual pattern. Considering the low occurrence of exceedances overall, this indicates that WWTFs are generally operating within permit limits and that ammonia inputs from WWTFs are not likely a chronic issue of importance for Cypress Creek waterways. Periodic, localized impacts may not be as apparent when using a broad scope analysis. Ammonia nitrogen may still have use as an indicator of WWTF efficiency much in the same way as TSS and will therefore continue to be considered for best management practices in the watershed.

Biological Oxygen Demand

In **Table 36** below, the exceedances of concentration and weight standards for CBOD5 in relation to the total number of reported values are summarized. Of all the DMR constituents examined, CBOD5 exceedance is the rarest. Of the 9,614 report values examined, only 24 exceeded either the concentration or weight standard making up only 0.2% of the dataset.

Table 36. Cypress Creek Watershed DMR CBOD5 Exceedance Statistics, 2016-2020

Category	Number	Percent of Records
Plants Reporting CBOD5	88	
Total Records	9,614	
Exceedances of Concentration	21	0.2%
Exceedances of Weight	3	0.0%
Total Exceedances	24	0.2%

Table 37 examines annual CBOD5 exceedances. No clear trend in CBOD5 exceedance values occurs in the observed data, but it should be noted that determining a trend from exceedance values occurring at such low frequencies might be misrepresentative of the overall dataset.

Table 37. Cypress Creek Watershed DMR CBOD5 Exceedance by Year

	2016	2017	2018	2019	2020	Total
Concentration	2	5	10	3	1	21
Weight	1	1	0	1	0	3
Total	3	6	10	4	1	24

CBOD5 exceedances were relatively rare in this DMR dataset compared to the other observed parameters. No annual pattern was observed. From this analysis, it can be assumed that WWTFs are not likely a chronic source of poor CBOD5 values in the waterways of the Cypress Creek watershed. As with previous analyses however, it should be noted that determining periodic and localized impacts may require further investigation.

Overview of Results

Exceedances for all constituents compared to their permit standards were uncovered by this analysis. However, plants in the Cypress Creek watershed were largely found to be in compliance with their permit limits for the majority of the period of study. It is unlikely that WWTFs are an appreciable source of contamination in the watershed on a chronic, wide-ranging scale. However, this broad analysis may underrepresent localized impacts of WWTF outfalls.

3.3.3 Lake Creek and West Fork San Jacinto River DMR Analysis

Due to the relatively low number of WWTFs in the Lake Creek and West Fork San Jacinto watersheds compared to the watershed areas of Spring Creek and Cypress Creek, DMR data from the Lake Creek and West Fork San Jacinto watersheds were combined for this analysis. The parameter evaluations were based on the regulatory permit limits specific to each plant, and consider the number of exceedances by each plant, in each year, in each segment, and as a percentage of the total samples.

Indicator Bacteria

In **Table 38**, it is clear that of the plants reporting violations of bacteria criteria, the majority are in exceedance less 1% of the time. The disparity between the number of samples exceeding the geomean standard compared to samples exceeding the grab standard could indicate high variability in the data. Higher rates of exceedance from specific sites may be overshadowed by the broad scope of this analysis.

Table 38. Lake Creek and West Fork San Jacinto River Watershed DMR E. coli *Exceedance Statistics, 2016-2020*

Parameter	Number of Plants	Percent of Reports
Plants Reporting Bacteria	35	
Total Records	2,676	
Exceedances of Geomean	9	0.3%
Exceedances of Single Grab	16	0.6%
Total Exceedances	25	0.9%

Below in **Table 39**, no clear trends were observed in either geomean or single grab criteria exceedance or the total number of exceedances observed annually.

Table 39. Lake Creek and West Fork San Jacinto River Watershed DMR E. coli *Exceedances by Year*

	2016	2017	2018	2019	2020	Total
By Geomean	0	2	4	2	1	9
By Grab	2	4	5	4	1	16
Total Exceedances	2	6	9	6	2	25

Overall, the results of the analyses of DMR *E. coli* data indicated that the total number of exceedances reported was small relative to the total number of DMR reports submitted for the period of 2016-2020 (25 out of 2,676 records). While WWTFs may be appreciable contributions under certain conditions, in localized areas, the DMR analysis indicates that they are not likely a significant driver of segment bacteria impairments due to the comparatively few exceedances. However, due to the relatively higher risk of pathogens from human waste, and proximity to developed areas, WWTF exceedances are likely still a point of concern for stakeholders.

Dissolved Oxygen

Table 40 summarizes the overall statistics of DO data reported by WWTFs in the Lake Creek and West Fork San Jacinto River watershed. Very few (8 of 1,671 total reports) samples fell below the minimum standard.

Table 40. Lake Creek and West Fork San Jacinto River Watershed DMR DO Exceedance Statistics, 2016-2020

Category	Number	Percent of Records
Plants Reporting DO	34	
Total Records	1,671	
Total Exceedances	8	0.5%

After arranging the data temporally, no annual trends were observed in the reported data (**Table 41**). However, in light of the low occurrence of exceedance relative to the overall dataset, determining trends from these values may not accurately represent DO dynamics in the watersheds.

Table 41. Lake Creek and West Fork San Jacinto River Watershed DMR DO Exceedances by Year

	2016	2017	2018	2019	2020	Total
Exceedances	2	4	1	0	1	8

Due to the findings of this analysis, it is unlikely that low DO levels in the waterways of the Lake Creek and West Fork San Jacinto watersheds are being driven by WWTF effluent. As with the results of the bacteria analysis, it is important to note that periodic impacts to DO may occur on a localized level but may not be well represented in this broad analysis. While the impacts of WWTFs on DO levels may not be a chronic or widespread issue in the watershed, an analysis of DO values reported in DMRs is still a critical component of this project especially as it pertains to identifying localized impacts.

TSS

The summary of reports made for TSS measurements and the number of exceedances of the concentration and weight standards are presented in **Table 42** below. Compared to the total number of reports submitted between 2016 and 2020, the total frequency of exceedance is very small (less than 1%).

Table 42. *Lake Creek and West Fork San Jacinto River Watershed DMR TSS Exceedance Statistics, 2016-2020*

Category	Number	Percent of Records
Plants Reporting TSS	34	
Total Records	3,342	
Exceedances of Concentration	16	0.5%
Exceedances of Weight	6	0.2%
Total Exceedances	22	0.7%

Viewing the data annually as represented in **Table 43**, there does not seem to be any significant pattern to either concentration, weight or combined total violations.

Table 43. *Lake Creek and West Fork San Jacinto River Watershed DMR TSS Exceedance by Year*

	2016	2017	2018	2019	2020	Total
Concentration	2	8	4	2	0	16
Weight	1	1	3	0	1	6
Total	3	9	7	2	1	22

Though periodic, local impacts may not be captured by these results, water quality throughout the watersheds is unlikely to be impacted by TSS from WWTFs at the watershed level. Despite this, observing TSS in WWTF effluent is still worth considering when moving forward with best management practices for water quality. As mentioned previously, TSS is often correlated with nutrient and bacteria levels, and can be tracked as a measure of WWTF improvement.

Ammonia Nitrogen

In **Table 44** below, the results of samples reported to be in exceedance of the standard as reported between 2016 and 2020 are summarized. Ammonia nitrogen violations were infrequent and occurred in 1.2% of the observed records.

Table 44. Lake Creek and West Fork San Jacinto River Watershed DMR Ammonia Nitrogen Exceedance Statistics, 2016-2020

Category	Number	Percent of Records
Plants Reporting Ammonia Nitrogen	33	
Total Records	3,230	
Exceedances of Concentration	31	0.9%
Exceedances of Weight	9	0.3%
Total Exceedances	40	1.2%

In **Table 45** below, number of ammonia nitrogen exceedances per year are represented for measurements of both concentration and weight. No trend was observed in the annual data.

Table 45. Lake Creek and West Fork San Jacinto River Watershed DMR Ammonia Nitrogen Exceedance by Year

	2016	2017	2018	2019	2020	Total
Concentration	4	10	6	7	4	31
Weight	1	4	1	1	2	9
Total	5	14	7	8	6	40

The results of the analyses of ammonia nitrogen reported by Lake Creek and West Fork San Jacinto watershed WWTFs between 2016 and 2020 show that exceedances in concentration do not follow a strong annual pattern. Exceedances of weight do seem to decrease over time. Considering the low occurrence of exceedances overall, this indicates that WWTFs are generally operating within permit limits and that ammonia inputs from WWTFs are not likely a chronic issue of importance for area waterways. Periodic, localized impacts may not be as apparent when using a broad scope analysis. Ammonia nitrogen may still have use as an indicator of WWTF efficiency much in the same way as TSS and will therefore continue to be considered for best management practices in the watershed.

Biological Oxygen Demand

In **Table 46** below, the exceedances of concentration and weight standards for CBOD5 in relation to the total number of reported values are summarized. Of all the DMR constituents examined, CBOD5 exceedance is the rarest. Of the 3,342 report values examined, only 9 exceeded either the concentration or weight standard making up only 0.3% of the dataset.

Table 46. Lake Creek and West Fork San Jacinto River Watershed DMR CBOD5 Exceedance Statistics, 2016-2020

Category	Number	Percent of Records
Plants Reporting CBOD5	34	
Total Records	3,342	
Exceedances of Concentration	7	0.2%
Exceedances of Weight	2	0.1%
Total Exceedances	9	0.3%

Table 47 examines annual CBOD5 exceedances. No clear trend in CBOD5 exceedance values occurs in the observed data, but it should be noted that determining a trend from exceedance values occurring at such low frequencies might be misrepresentative of the overall dataset.

Table 47. *Lake Creek and West Fork San Jacinto River Watershed DMR CBOD5 Exceedance by Year*

	2016	2017	2018	2019	2020	Total
Concentration	0	1	1	1	4	7
Weight	0	1	1	0	0	2
Total	0	2	2	1	4	9

CBOD5 exceedances were relatively rare in this DMR dataset compared to the other observed parameters. No annual pattern was observed. From this analysis, it can be assumed that WWTFs are not likely a chronic source of poor CBOD5 values in the waterways of the Lake Creek and West Fork San Jacinto watersheds. As with previous analyses however, it should be noted that determining periodic and localized impacts may require further investigation.

Overview of Results

Exceedances for all constituents compared to their permit standards were uncovered by this analysis. However, plants in the Lake Creek and West Fork San Jacinto watersheds were largely found to be in compliance with their permit limits for the majority of the period of study. It is unlikely that WWTFs are an appreciable source of contamination in the watershed on a chronic, wide-ranging scale. However, this broad analysis may underrepresent localized impacts of WWTF outfalls.

3.3.4 Summary of DMR Analyses

WWTFs in the Spring Creek watershed and surrounding watershed areas may not be the largest source of bacteria, but effluent from these facilities has an inherently higher pathogenic potential than other sources due to the treatment of human waste. Additionally, unlike other sources of natural and diffuse fecal waste in the watersheds, WWTF effluent has both regulatory controls and voluntary measures by which improperly treated wastewater may be addressed. Given the nature of WWTF effluent as a human pollutant, and our direct ability to influence its character, WWTF bacteria should be considered as a potential focus for best management practices. While other constituents (e.g., nutrients) are not necessarily any more harmful than other sources in the watershed, the principle of direct control of effluent applies to their consideration as well. This is exacerbated for nutrients given the lack of permit limits for some nutrient parameters, and the likelihood that WWTFs may be appreciable nutrient loading sources in effluent dominated streams.

3.4 SSOs

Though SSOs occur episodically, they represent a high-risk vector for bacteria contamination because they can have concentrations of bacteria several orders of magnitude higher than treated effluent. Untreated sewage can contain large volumes of raw fecal matter, making it a significant health risk where SSOs are sizeable and/or chronic issues. The causes of SSOs vary from human error to infiltration of rainwater into sewer pipes. Data used for these analyses is self-reported and may vary in quality. Even in the best of circumstances, the ability to accurately gauge SSO volumes or even occurrences in the field are limited by several factors. Actual SSO volumes and incidences are generally expected to be greater than reported due to these fundamental challenges. Known causes of SSOs were broken into four broad categories with several subcategories each, to reflect the breakdown in the TCEQ SSO database. It should be noted, however, that this categorization depends on the accuracy of the data reported by the utilities. Additionally, while a single cause is typically listed on the SSO report, many SSOs are caused by a combination of factors.

3.4.1 Spring Creek SSO Analysis

This study considered five years of TCEQ SSO violation data for 2016-2020. There were 128 SSO records from 26 plants considered for the watershed area. Of those 26 plants, 9 plants had >5 SSOs, and of those 9 plants, 3 plants had >10 SSOs. Below, tables and figures reflect the breakdown of SSOs by year and cause, for number and volume, respectively.

As shown in **Table 48** and **Figure 6**, there was not a strong trend in number of SSOs over time. In terms of cause by number, the general category of weather-related issues accounted for 25.0% of the overall total, malfunctions and operational issues accounted for 27.3%, blockages accounted for 28.1%, and 19.5% were listed as unknown causes.

Table 48. *Number of Annual SSO Events in the Spring Creek Watershed*

CAUSE	2016	2017	2018	2019	2020
Weather	**7**	**7**	**9**	**6**	**3**
Rain / Inflow / Infiltration	7	1	9	6	3
Hurricane		6			
Malfunctions	**10**	**2**	**11**	**4**	**8**
WWTF Operation or Equipment Malfunction	4	1	5	1	4
Power Failure	1		1		
Lift Station Failure	3	1	3	3	4
Collection System Structural Failure	1		2		
Human Error	**1**				
Blockages	**5**	**1**	**11**	**10**	**9**
Blockage in Collection System-Other Cause	2	1	7	4	3
Blockage in Collection System Due to Fats/Grease	3		3	4	4
Blockage Due to Roots/Rags/Debris			1	2	2
Unknown Cause	**3**	**4**	**5**	**5**	**8**
Total	**25**	**14**	**36**	**25**	**28**

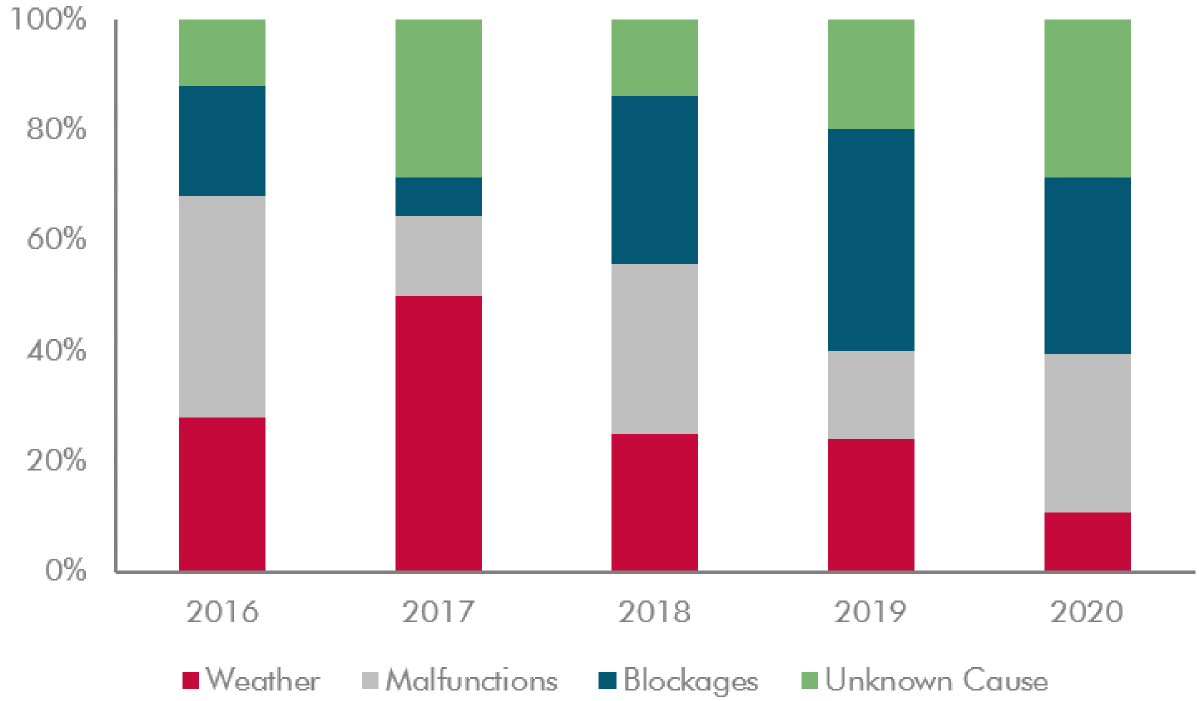

Figure 6. *Percent Total Annual SSO Events in the Spring Creek Watershed*

While numbering SSO events informs how frequently these overflows impact the watershed, volume of overflow is an indicator of the magnitude of impact. The results summarized in **Table 49** and **Figure 7** indicate that as with number of events, there was no real temporal trend in volume of events. Of note, though 2017 had the lowest total overflow volume reported over the five years of study, over 80% of the overflow volume was associated with a hurricane event (Hurricane Harvey). More weather-related issues were observed to contribute over 40% to the total overflow volume in the year 2020.

Of the total volume of overflows reported from 2016-2020, malfunctions were responsible for 43.5%. Blockages comprised 15.5% of the overall volume, weather contributed 18.4% and unknown causes led to the remaining 22.7%. These overall contributions are important to consider in a general sense for estimating impacts to the watershed area.

Table 49. Annual SSO Events by Volume (in Gallons) in the Spring Creek Watershed

CAUSE	2016	2017	2018	2019	2020
Weather	**9,300**	**58,700**	**12,301**	**10,294**	**33,000**
Rain / Inflow / Infiltration	9,300	300	12,301	10,294	33,000
Hurricane		58,400			
Malfunctions	**87,748**	**100.5**	**150,174**	**45,023**	**9,630**
WWTF Operation or Equipment Malfunction	2,050	0.5	724	10,000	8,700
Power Failure	2,500		2,500		
Lift Station Failure	62,300	100	53,850	35,023	930
Collection System Structural Failure	500		93,100		
Human Error	20,398				
Blockages	**4,880**	**2,400**	**81,150**	**10,115**	**5,710**
Blockage in Collection System-Other Cause	3,395	2,400	22,900	7,180	1,800
Blockage in Collection System Due to Fats/Grease	1,485		8,250	1,915	3,285
Blockage Due to Roots/Rags/Debris			50,000	1,020	625
Unknown Cause	**77,060**	**6,740**	**225**	**43000**	**25700**
Total	**178,988**	**6,7940.5**	**243,850**	**108,432**	**74,040**

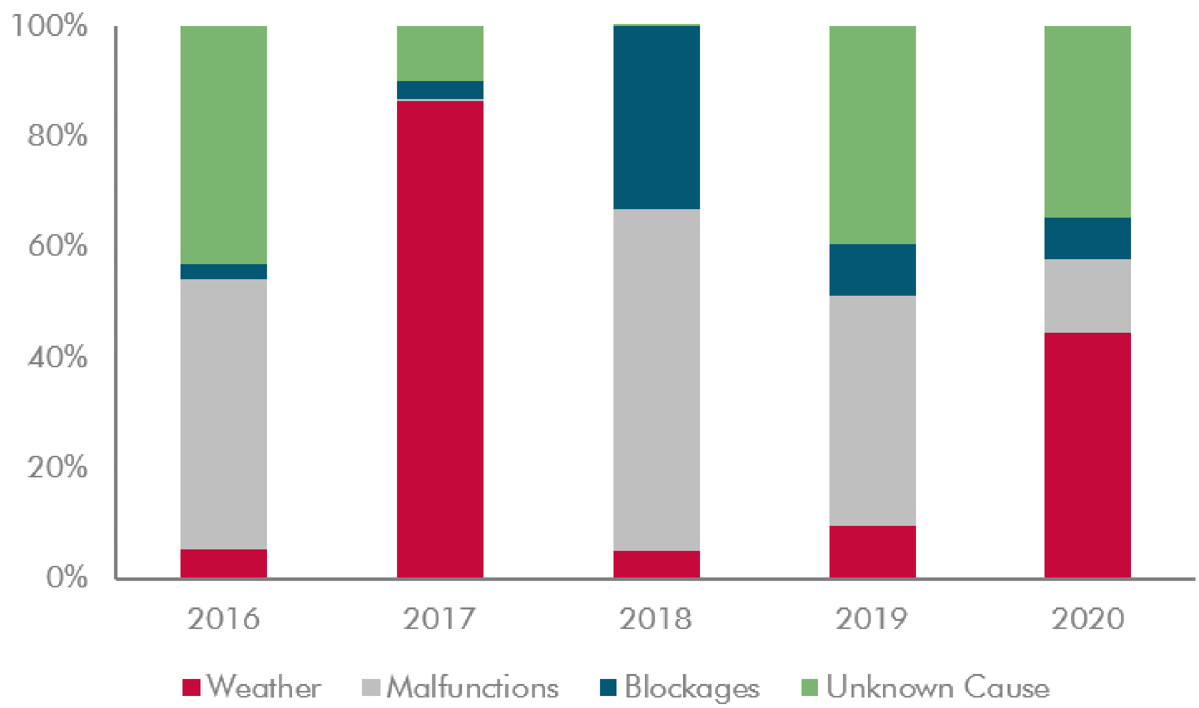

***Figure 7.** Percent Total Annual SSO Volume in the Spring Creek Watershed*

Spring Creek SSO Summary

Of the 26 plants that reported SSOs between 2016 and 2020, 9 had >5 SSOs—9 of those had >10. There was not a strong annual trend in number or volume of SSOs. In terms of general cause, blockages accounted for the highest number of events respective to the other general categories of weather, malfunctions, and unknown causes. In terms of volume, malfunctions contributed nearly half of the total overflow observed between 2016 and 2020.

3.4.2 Cypress Creek SSO Analysis

This study considered five years of TCEQ SSO violation data for 2016-2020. There were 218 SSO records from 50 plants considered for the watershed area. Of those 50 plants, 17 plants had >5 SSOs, and of those 17 plants, 3 plants had >10 SSOs. Below, tables and figures reflect the breakdown of SSOs by year and cause, for number and volume, respectively.

As shown in **Table 50** and **Figure 8**, there was not a strong trend in number of SSOs over time. In terms of cause by number, the general category of weather-related issues accounted for 26.1% of the overall total, malfunctions and operational issues accounted for 30.7%, blockages accounted for 30.3%, and 12.8% were listed as unknown causes.

Table 50. *Number of Annual SSO Events in the Cypress Creek Watershed*

CAUSE	2016	2017	2018	2019	2020
Weather	**10**	**12**	**12**	**11**	**12**
Rain / Inflow / Infiltration	10	3	12	11	12
Hurricane		9			
Malfunctions	**15**	**13**	**11**	**10**	**18**
WWTF Operation or Equipment Malfunction	5	5	5	2	6
Power Failure	3	3			
Lift Station Failure	4	4	6	8	12
Collection System Structural Failure	2	1			
Human Error	1				
Blockages	**4**	**11**	**8**	**20**	**23**
Blockage in Collection System-Other Cause	1	2	1	6	14
Blockage in Collection System Due to Fats/Grease	2	6	4	11	4
Blockage Due to Roots/Rags/Debris	1	3	3	3	5
Unknown Cause	**6**	**8**	**5**	**5**	**4**
Total	**35**	**44**	**36**	**46**	**57**

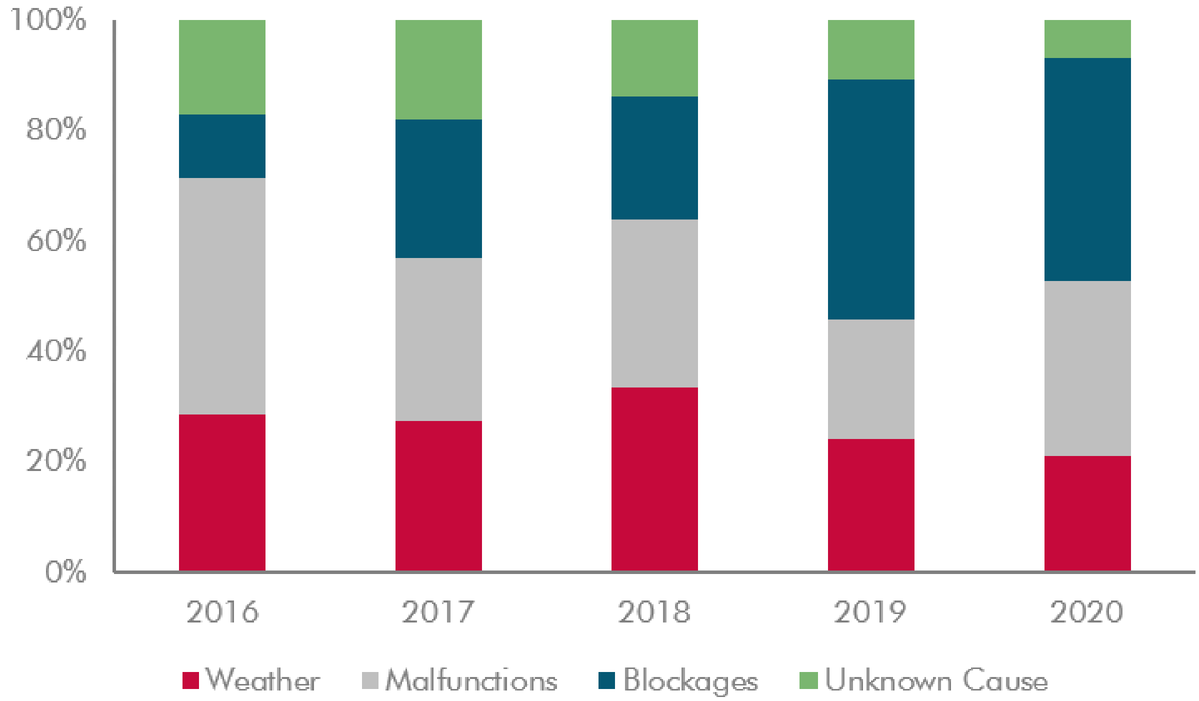

Figure 8. *Percent Total Annual SSO Events in the Cypress Creek Watershed*

The results summarized in **Table 51** and **Figure 9** indicate that as with number of events, there was no real temporal trend in volume of events. Weather and malfunctions contributed to the majority of overflows between 2016 and 2018, but 2019 and 2020 saw a shift to weather and blockages.

Of the total volume of overflows reported from 2016-2020, malfunctions were responsible for 35.2%. Blockages comprised 23.2% of the overall volume, weather contributed 32.6% and unknown causes led to the remaining 9.0%. These overall contributions are important to consider in a general sense for estimating impacts to the watershed area.

Table 51. Annual SSO Events by Volume (in Gallons) in the Cypress Creek Watershed

CAUSE	2016	2017	2018	2019	2020
Weather	**36,512**	**76,260**	**49,545**	**74,690**	**33,515**
Rain / Inflow / Infiltration	36,512	74,800	49,545	74,690	33,515
Hurricane		1,460			
Malfunctions	**150,158**	**77,158**	**16,620**	**27,060**	**21,595**
WWTF Operation or Equipment Malfunction	8,925	12,251	6,050	700	13,300
Power Failure	135,404	3,382			
Lift Station Failure	5,224	1,525	10,570	26,360	8,295
Collection System Structural Failure	105	60,000			
Human Error	500				
Blockages	**1,490**	**23,845**	**8,371**	**123,957**	**34,750**
Blockage in Collection System-Other Cause	705	1,500	1,500	119,020	16,000
Blockage in Collection System Due to Fats/Grease	685	17,120	4,680	4,365	1,620
Blockage Due to Roots/Rags/Debris	100	5,225	2191	572	17,130
Unknown Cause	**26,537**	**6,353**	**501.5**	**19,009**	**22,740**
Total	**214,697**	**183,616**	**75,037.5**	**244,716**	**112,600**

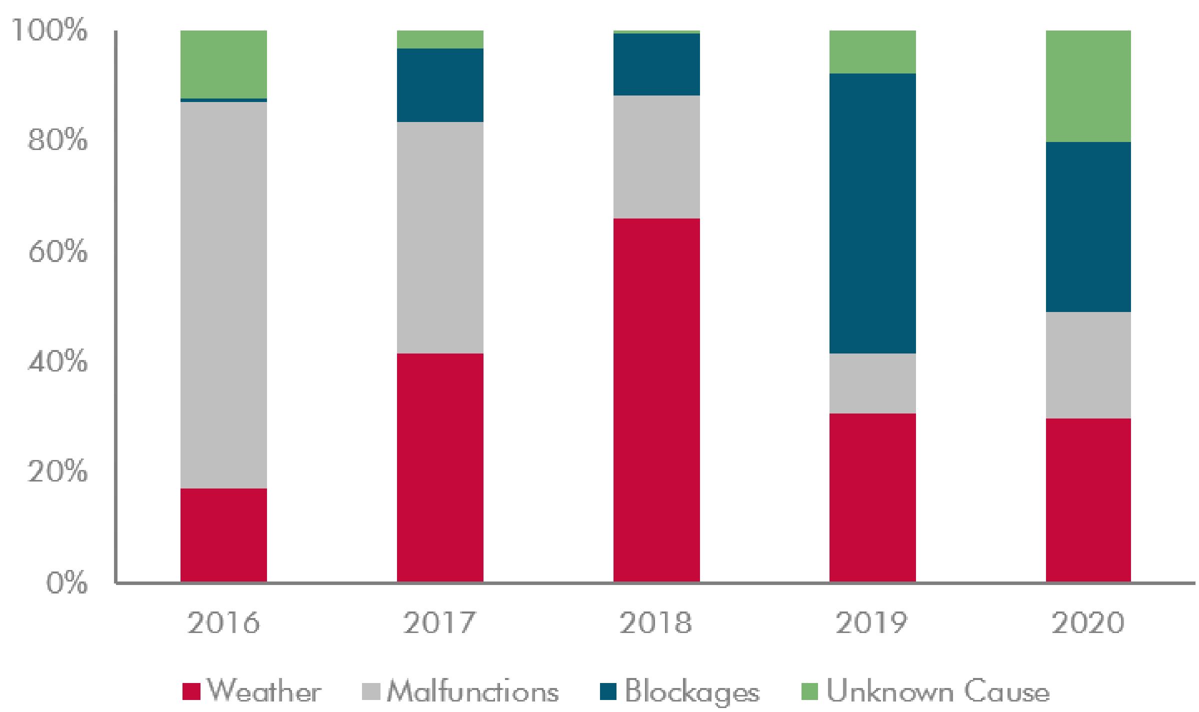

Figure 9. *Percent Total Annual SSO Volume in the Cypress Creek Watershed*

Cypress Creek SSO Summary

Of the 50 plants that reported SSOs between 2016 and 2020, 17 had >5 SSOs—3 of those had >10. There was not a strong annual trend in number or volume of SSOs. In terms of general cause, blockages and malfunctions accounted for the highest number of events respective to the other general categories of weather and unknown causes. In terms of volume, malfunctions contributed more than one third of the total overflow observed between 2016 and 2020.

3.4.3 Lake Creek and West Fork San Jacinto River SSO Analysis

This study considered five years of TCEQ SSO violation data for 2016-2020. There were 68 SSO records from 17 plants considered for the watershed area. Of those 17 plants, 3 plants had >5 SSOs, and of those 3 plants, 2 plants had >10 SSOs. Below, tables and figures reflect the breakdown of SSOs by year and cause, for number and volume, respectively.

As shown in **Table 52** and **Figure 10**, there was not a strong trend in number of SSOs over time. In terms of cause by number, the general category of weather-related issues accounted for 23.5% of the overall total, malfunctions and operational issues accounted for 36.8%, blockages accounted for 26.5%, and 13.2% were listed as unknown causes.

Table 52. *Number of Annual SSO Events in the Lake Creek and West Fork San Jacinto River Watersheds*

CAUSE	2016	2017	2018	2019	2020
Weather	**8**	**3**	**2**	**3**	**0**
Rain / Inflow / Infiltration	8	2	2	3	
Hurricane		1			
Malfunctions	**8**	**6**	**4**	**4**	**3**
WWTF Operation or Equipment Malfunction		1	2		
Power Failure		1		1	
Lift Station Failure	6	4	2	3	2
Collection System Structural Failure	2				1
Human Error					
Blockages	**7**	**5**	**0**	**2**	**4**
Blockage in Collection System-Other Cause	4	1		1	1
Blockage in Collection System Due to Fats/Grease	1	3		1	1
Blockage Due to Roots/Rags/Debris	2	1			2
Unknown Cause	**1**	**0**	**4**	**1**	**3**
Total	**24**	**14**	**10**	**10**	**10**

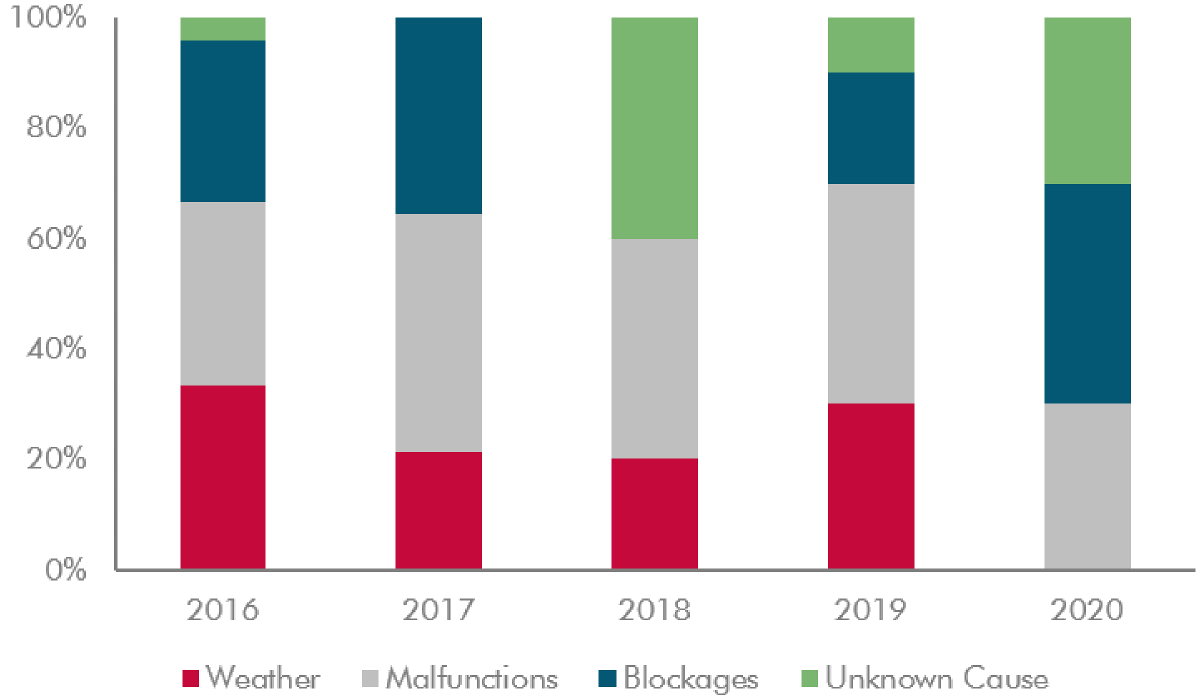

Figure 10. *Percent Total Annual SSO Events in the Lake Creek and West Fork San Jacinto River Watersheds*

The results summarized in **Table 53** and **Figure 11** indicate that as with number of events, there was no real temporal trend in volume of events.

Of the total volume of overflows reported from 2016-2020, malfunctions were responsible for 75.8%. Lift station failures in 2019 attributed to over one million gallons of overflow—one order of magnitude greater than the highest annual overflow volumes observed in any of the other watersheds discussed in this report. The remaining overflow volumes for the period of study are attributed as follows: 12.2% to weather, 11.0% to unknown causes and only 1.0% to blockages.

Table 53. Annual SSO Events by Volume (in Gallons) in the Lake Creek and West Fork San Jacinto River Watersheds

CAUSE	2016	2017	2018	2019	2020
Weather	**170,434**	**5,893**	**3,542**	**4,100**	**0**
Rain / Inflow / Infiltration	170,434	5,493	3,542	4,100	
Hurricane		400			
Malfunctions	**15,979**	**71,870**	**2,750.5**	**1,024,430**	**26,050**
WWTF Operation or Equipment Malfunction		14,000	500.5		
Power Failure		150		500	
Lift Station Failure	14,879	57,720	2,250	1,023,930	2,050
Collection System Structural Failure	1,100				24,000
Human Error					
Blockages	**2,098**	**5,775**	**0**	**600**	**6,770**
Blockage in Collection System-Other Cause	1,368	600		300	850
Blockage in Collection System Due to Fats/Grease	30	4,425		300	4,020
Blockage Due to Roots/Rags/Debris	700	750			1,900
Unknown Cause	**80,000**	**0**	**62,614**	**1,000**	**22,380**
Total	**268,511**	**83,538**	**68,906.5**	**1,030,130**	**55,200**

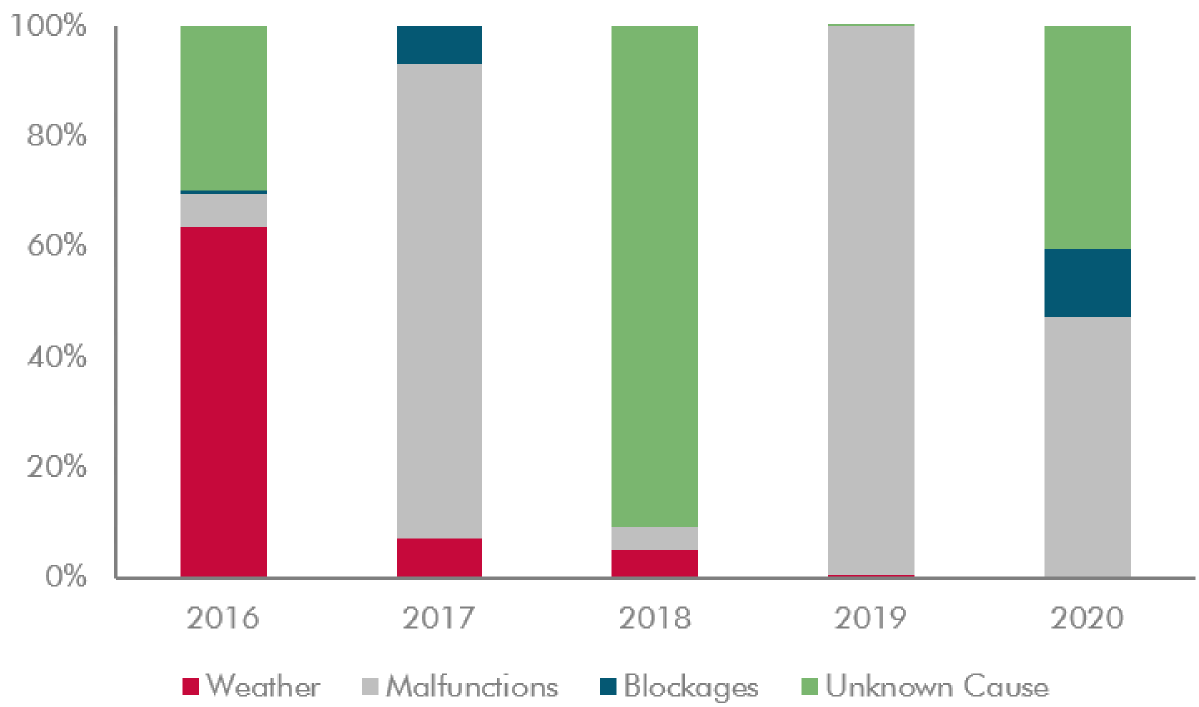

Figure 11. Percent Total Annual SSO Volume in the Lake Creek and West Fork San Jacinto River Watersheds

Lake Creek and West Fork San Jacinto River SSO Summary

Of the 17 plants that reported SSOs between 2016 and 2020, 3 had >5 SSOs—2 of those had >10. There was not a strong annual trend in number or volume of SSOs. In terms of general cause, malfunctions accounted for the highest number of events respective to the other general categories of weather, blockages, and unknown causes. In terms of volume, malfunctions contributed more than three quarters of the total overflow observed between 2016 and 2020.

3.4.4 Summary of SSO Analyses

While this data is useful, it should be noted that it is also self-reported and may vary in quality. Overflow volumes and numbers of events may be greater than the values recorded in the report data. In addition, causes may be overgeneralized due to multiple factors ultimately resulting in SSOs.

In watersheds where bacteria and nutrient loading are of particular concern, the impacts of SSOs are important to understand due to their concentrations of untreated human waste. These events pose a high risk to human health especially due to their proximity to urban populations. Further, despite their episodic occurrences, SSOs can be extreme loading sources in the sense of volume introduced in a short time frame. Though SSOs do not have the same potential to have chronic impacts on waterways as effluent from high volume WWTFs, for the aforementioned reasons, it is still critical to consider SSO management among the best management practices selected to improve water quality in the Spring Creek watershed and other surrounding watersheds.

SECTION 4: OUTCOMES AND IMPLICATIONS

This analysis of ambient, DMR and SSO report data contributes to the continued characterization of water quality concerns in the Spring Creek watershed and surrounding watersheds including those of Cypress Creek, Lake Creek, and the West Fork San Jacinto River. Findings from this report can be used to inform stakeholders as they work to implement best management practices outlined in the Spring Creek WPP.

Data meeting the criteria for sufficiency were used to determine what constituents of water quality are of greatest concern and the extent to which their impacts have been observed throughout the area waterways. As indicated in the 2020 IR results for this watershed, an analysis of the SWQMIS dataset identified high levels of the fecal indicator bacteria *E. coli* as the most pervasive impact to water quality throughout all four watersheds. Further, elevated nutrient (nitrate nitrogen and total phosphorous) levels observed in the highly developed areas of the Cypress Creek watershed and the eastern third of the Spring Creek watershed present challenges to water quality. Depressed DO levels were also highlighted as concerns in segments of Spring Creek, Cypress Creek, and Lake Creek in the 2020 IR, but comparable results were not captured in this analysis. This is most likely due to the incomplete overlap of datasets observed for each report with the analysis described herein including more recent data where increasing trends in DO have been observed.

Permitted wastewater effluent was unlikely to be a widespread or chronic water quality issue but requires further investigation on limited spatial scales and timeframes. However, understanding these discharges is still critical to the development of this project as WWTFs without permit limits for certain nutrients act as source loads—particularly in effluent-dominated streams. Further, as treatment facilities for human waste, improper treatment indicators identified in DMR analyses can have greater implications for risk to human health.

An analysis of SSO reports from the four watersheds indicated that 31.2% of reporting plants experienced greater than five SSO events between 2016 and 2020. Plants reporting 10 events throughout the study period accounted for 8.6% of the data. For both number of SSO events and volume of overflow, malfunctions were among the most common for the general cause categories. However, it is important to note that while only one cause is usually listed on the report, multiple compounding factors can lead to SSOs. Ultimately, causes listed in SSO reports are prone to a degree of subjectivity as opposed to more quantitative measurements. While the episodic overflow volumes reported during these events are relatively small compared to the scale of effluent produced by WWTFs, SSO inputs are of particular concern due to the untreated nature of the sewage associated with them and the subsequent risk to human health.

As future growth projections indicate that increased development in these watershed areas is likely, the balance of pollutant sources and current hydrologic processes could be altered significantly in the coming years. These changes could result in further water quality impacts without intervention. Subsequent efforts should be made to identify causes and sources of the primary constituent of concern (indicator bacteria), and to characterize nutrient sources further to identify areas within the project watersheds most vulnerable to pollutant loadings and/or best suited for the implementation of management strategies.