Coordinating Implementation of the Watershed Protection Plan for Mid and Lower Cibolo Creek

Final Report 2021

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Prepared for Texas State Soil and Water Conservation Board
Project # 19-52

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College Station, Texas 77843-2118
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CONTENTS

ACRONYMS

BMPs	Best Management Practices
CEA	County Extension Agent
cfs	Cubic feet per second
DO	Dissolved Oxygen
DQO	Data Quality Objectives
EPA	U.S. Environmental Protection Agency
HLHW	Healthy Lawns & Healthy Waters
in	Inch
L	Liter
m	Meter
mg	Milligram
mi	Mile
mL	Milliliter
MPN	Most Probable Number
NELAC	National Environmental Laboratory Accreditation Conference
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service, part of USDA
QA/QC	Quality Assurance/Control
QAPP	Quality Assurance Protection Plan
QPR	Quarterly Progress Report
SARA	San Antonio River Authority
SWCD	Soil and Water Conservation District
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWRI	Texas Water Resources Institute
USDA	U.S. Department of Agriculture
WPP	Watershed Protection Plan

EXECUTIVE SUMMARY

The 2020 303(d) List identifies the Lower Cibolo Creek (Segment 1902) as exceeding the contact recreation criterion for *E. coli* bacteria. It has been listed as impaired since 2004. To address the high bacteria levels, as well as low levels of depressed dissolved oxygen present in the watershed, WPP development began in 2017 and was completed in August 2020. This plan included the impaired segments and surrounding tributaries that have several water quality concerns. This project, *Coordinating Implementation for the Mid and Lower Cibolo Creek Watershed Protection Plan* project #19-52, continued work that began in *Development of a Watershed Protection Plan for Mid and Lower Cibolo Creek* project #17-50. Specifically, water quality monitoring continued and work was done to receive Watershed Protection Plan (WPP) acceptance from the US Environmental Protection Agency (EPA). Effort was also spent to support and engage stakeholders through meetings and educational programs.

The San Antonio River Authority (SARA) led monitoring efforts for the project which focused on stormwater and intensive monitoring along Mid and Lower Cibolo Creek. Stormwater monitoring efforts focused on collecting discrete samples over the hydrograph of a storm event to characterize the stormwater quality within the watershed. In water quality modeling conducted prior to this project, a significant portion of increased bacteria and nutrient levels were observed in elevated flows associated with rainfall events. Stormwater monitoring conducted during this project helps assess the pollutant loads during a storm event.

Intensive monitoring efforts focused on developing a spatial understanding of *E. coli* concentrations in the tributaries of the Mid Cibolo Creek watershed during a single point in time. Martinez and Salitrillo Creek were identified as areas with water quality concerns from the stakeholders. Intensive monitoring results illustrated variations in *E. coli* concentrations throughout these Mid Cibolo Creek tributaries and highlight areas where further water quality monitoring is needed to define pollutant sources.

Results from both stormwater and intensive monitoring events show variability in bacteria and nutrient concentrations throughout the watershed. However, initial results help show where some implementation efforts should be focused to help reduce nonpoint source (NPS) pollutants in the watershed.

Results of project goals:

- EPA-acceptance of Mid and Lower Cibolo Creek WPP in August 2020.
- Delivered three educational programs (one in-person and two virtual) in the watershed.
- Hosted virtual stakeholder meeting in November 2020.
- One stormwater and one intensive sampling event occurred in this project period (5/1/19 – 4/30/21) in the watershed. Monitoring results were combined with the two storm events and one intensive sampling events conducted previously in project #17-50 to help prioritize implementation and identify potential priority areas.

INTRODUCTION

Mid Cibolo Creek is defined as from a point 100 meters (m) downstream of IH-10 in Bexar/Guadalupe County to the Missouri-Pacific Railroad Bridge west of Bracken in Comal County. The Lower Cibolo Creek is defined as from the confluence with the San Antonio River in Karnes County to a point 100 m downstream of IH-10 in Bexas/Guadalupe County. The Mid and Lower sections of Cibolo Creek flow south approximately 90 miles (mi) through parts of Comal, Guadalupe, Bexar, Wilson and Karnes counties before its confluence with the Lower San Antonio River. Martinez Creek, Salitrillo Creek and Clifton Branch are tributaries within the watershed.

The 2020 303(d) List identifies the Lower Cibolo Creek (Segment 1902) as exceeding the contact recreation criterion for *E. coli* bacteria. It has been listed as impaired since 2004. To address the high bacteria levels, as well as low levels of depressed dissolved oxygen present in the watershed, a WPP began being developed in 2017 and accepted in August 2020. This plan included the impaired segments as well as surrounding tributaries that have several water quality concerns. The ultimate water quality goal for this segment is to reduce bacterial concentrations to within acceptable risk levels for the stream to meet the Primary Contact Recreation Standard 1. (https://www.sara-tx.org/public_resources/library/documents/water_quality_monitoring/2013BSR-web.pdf).

The Mid Cibolo and Lower Cibolo Creek have seen increased development in the residential sector as well as increased activity because of hydraulic fracturing activity in the Eagle Ford Shale formation. With this increased development, it is important that the plan being developed to protect the watershed's creeks and streams continue to be supported and implemented to protect the biological and riparian resources in the Mid and Lower Cibolo Creek watershed.

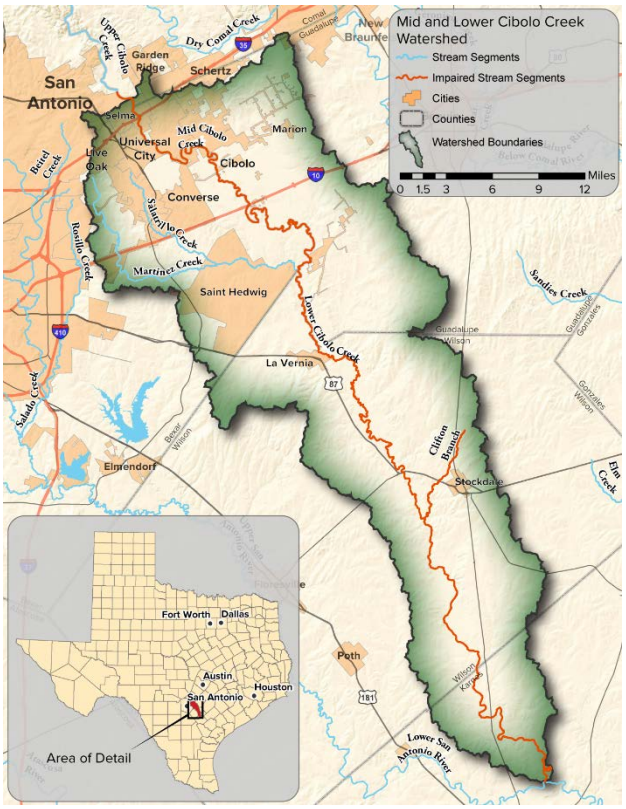
To ensure the overall success of the WPP from development to implementation, education and outreach programs need to be continued throughout the watershed. Education and outreach programs allow stakeholders to gain knowledge on water quality issues in the area and what can be done to mitigate water quality impacts. Coordinating the delivery of these programs and tracking the successful implementation of the WPP requires a concerted effort. Continued support for the development and implementation of the Mid and Lower Cibolo Creek WPP is important because strong connections have been started with locals who live and work in the watershed. We have an engaged stakeholder group, and we would like to maintain these connections with the community to keep them interested and active in the plan. This will provide greater fluidity from planning to implementation, increasing the likelihood for adoption of best management practices (BMPs) discussed in the WPP.

Previous monitoring efforts conducted by the SARA include intensive monitoring efforts in the Mid Cibolo Creek watershed and stormwater monitoring at three stations in the Mid and Lower Cibolo Creek. Continuing these monitoring efforts will assist in identifying areas that may be contributing to elevated pollutant loads in the watershed and help track implementation progress of the WPP.

PROJECT DESCRIPTION

The Texas Water Resources Institute (TWRI) and SARA continued working with key stakeholders and partner agencies to facilitate implementation outlined in the WPP. TWRI served as the primary conduit for interaction with landowners, citizens, and entities to facilitate completion of the WPP and implementation. TWRI coordinated with the stakeholder group to update them on progress of WPP acceptance, seek their input and recommendations on needed activities and educational programs in the watershed, and continue to support implementation efforts of the plan. TWRI and SARA continued to assist stakeholders to implement management measures to improve water quality and acquire resources to enable implementation as well as work with state and federal agencies, as appropriate, to bring technical and financial assistance to the watershed.

Outreach and education coordination efforts by TWRI supported public participation by private individuals and local officials during implementation. TWRI developed publications, factsheets, website content, and other



materials to promote and communicate watershed pollution prevention efforts. Additionally, TWRI coordinated water resources education and outreach efforts across the watershed, organizing educational programs such as the Riparian and Stream Ecosystem Training, Lone Star Healthy Streams, Texas Watershed Stewards and Texas Well Owner Network and various other programs identified in subtask 3.6.

The project included automated stormwater monitoring at three locations on the Mid and Lower Cibolo Creek. Samplers collected discrete samples along the hydrograph of various storm events. Data supported WPP development/implementation and other projects underway at SARA, including the Cibolo Creek Holistic Watershed Master Plan.

Project Goals

1. Achieve EPA acceptance on Mid and Lower Cibolo Creek WPP.
2. Facilitate watershed stakeholders and foster coordinated assistance activities between cities, counties, TSSWCB, local Soil and Water Conservation Districts (SWCDs), and Natural Resource Conservation Service (NRCS) by providing a presence in the watershed.
3. Conduct public meetings to provide updates on progress, seek stakeholder input and recommendations on needed activities, and encourage citizen participation.
4. Support and facilitate stakeholders in implementing management measures identified in the WPP to improve water quality, developing proposals to acquire funding for implementation, and facilitating education programs in order to encourage adoption of BMPs.
5. Work with state and federal agencies, as appropriate, to bring technical and financial assistance to the watersheds.
6. Coordinate and conduct water resources education and outreach across the watershed by developing publications and website content to promote and communicate watershed efforts, and by organizing training programs.
7. Continue to conduct stormwater quality monitoring throughout the watershed.

TASK 1: PROJECT ADMINISTRATION

Objective: To effectively administer, coordinate and monitor all work performed under this project including technical and financial supervision and preparation of status reports.

TWRI with assistance from SARA prepared electronic quarterly progress reports (QPRs) for TSSWCB throughout the project period: May 1, 2019 to April 30, 2021. QPRs documented all activities preformed within a specific quarter and any issues that may have arisen during the quarter.

TWRI corresponded through email and phone calls with SARA and TSSWCB to edit the WPP prior to acceptance and discussed project activities and educational programs, water quality monitoring, and other deliverables. All meetings were held virtually during the project due to COVID-19 meeting and travel restrictions.

Results from the water quality monitoring, a description of educational and outreach events, and other project deliverables are outlined in this Final Report. A greater description of project goals and outcomes are described in Task 3 and 4 of this report.

TASK 2: QUALITY ASSURANCE

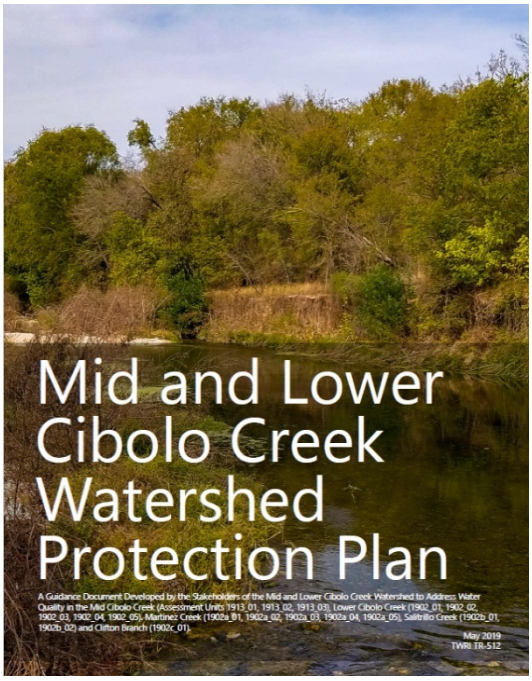
Objective: To develop data quality objectives (DQOs) and quality assurance/control (QA/QC) activities to ensure data of known and acceptable quality are generated through this project.

SARA developed a QAPP for activities in Task #4 consistent with the most recent versions of *EPA Requirements for Quality Assurance Project Plans (QA/R-5)* and the *TSSWCB Environmental Data Quality Management Plan*. All monitoring procedures and methods prescribed in the QAPP were consistent with the guidelines detailed in the *TCEQ Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue (RG-415)* and *Volume 2: Methods for Collecting and Analyzing Biological Assemblage and Habitat Data (RG-416)*. The QAPP was accepted onMarch 6, 2020.

SARA implemented the approved QAPP. SARA submitted revisions and necessary amendments to the QAPP as needed.

TASK 3: ENGAGEMENT, SUPPORT, AND FACILITATION OF WPP IMPLEMENTATION

Objective: To facilitate continued stakeholder engagement in the watershed planning process and to ensure successful implementation of the WPP and the track implementation.



The first half of the project period involved finalizing the WPP that was initiated in the *Development of a Watershed Protection Plan for Mid and Lower Cibolo Creek* project #17-5. This included initial rounds of edits with TSSWCB and TCEQ to finalize the draft WPP before sending to EPA for final revisions and acceptance. EPA accepted the WPP on August 2020. An online version of the WPP is available on our project website (http://cibolo.tamu.edu/) and the WPP is being printed and will be distributed at future events. After acceptance, TWRI focused on starting implementation in the watershed through meeting with stakeholders and organizing educational programs.

Throughout the project period, TWRI maintained and updated the stakeholder list generated from the project #17-50. The list was updated after each outreach event. Funding opportunities, educational events, and meeting information was distributed though the stakeholder list. TWRI also secured funding for additional implementation to continue through TSSWCB beginning in FY22.

A key way to continue stakeholder engagement and increase awareness on the WPP and water quality concerns was through educational programs. These outreach programs are important to support the implementation of the WPP and increase participation in the process. Several programs were scheduled to occur throughout the project period; unfortunately, a few were canceled or postponed due to meeting and travel restrictions from COVID-19. Educational programs that were able to be switched to a virtual delivery format were scheduled and advertised to stakeholders.

Over the course of the Mid and Lower Cibolo Creek WPP Continuation Project, three educational and outreach programs were held within the watershed (Table 14). These included Introduction to Septic Systems for Homeowners, the Texas Riparian and Stream Ecosystems Training, and Healthy Lawns Healthy Waters (HLHW). All three programs are managed by Texas A&M AgriLife and are offered statewide for stakeholder education. All events were advertised and meeting materials were uploaded onto the project website: http://cibolo.tamu.edu/. The final, accepted version of the WPP is also linked on the project website. Events and meetings were advertised through social media and emails to our stakeholder list.

Introduction to Septic Systems for Homeowners provides a basic understanding of the operation and maintenance activities of a conventional septic system, and explains how actions within the home affects septic systems. Presentations covered the treatment process, health and safety considerations, how to inspect, and maintain the system. The program was held at the Guadalupe County AgriLife Extension Office in Seguin, TX on January 30, 2020. Sixteen people attended the training.

The Texas Riparian & Stream Ecosystems Training focuses on the nature and function of riparian zones, the benefits and direct economic impacts from ecological services of healthy riparian zones, best management practices for enhancing and protecting riparian zones, and technical and financial resources available to landowners for implementing riparian BMPs and riparian protection measures. The program was held virtually on December 8, 2021 and was attended by 65 people.

The Healthy Lawns and Healthy Waters program is an educational training program that aims to improve and protect surface water quality by enhancing Texas residents' awareness and knowledge of best management practices for residential landscapes. The program was held virtually on March 26, 2021 and was attended by 31 people.

In all, education and outreach activities were well received by those in attendance, and have helped to foster relationships between TWRI, Texas A&M AgriLife Extension, SARA, and local stakeholders even during a time where face-to-face meetings were not possible. Connections made through these and potential future education events will be of great value to any future watershed planning activities. Updates on the Mid and Lower Cibolo Creek WPP and future implementation goals were presented at each educational program along with an opportunity to join our stakeholder list for future meetings and programs.

A virtual stakeholder meeting was held on November 10, 2020 to announce the acceptance of the WPP and start planning first steps in implementation. A "hot topic" presentation was also given on Discouraging Wildlife Feeding to encourage more participation in an online meeting. The presentation also discussed how a neighboring watershed implemented sections of their WPP by adding educational signage on wildlife feeding. This presentation helped serve as an example of successful implementation projects. Ten people attended the virtual stakeholder meeting. The meeting was also recorded and made available to be viewed later for stakeholders who could not attend the meeting. The recorded meeting has been viewed twelve times as of April 15, 2021, increasing our reach to community members. **Recording of Virtual Stakeholder Meeting held on November 10, 2020: https://www.youtube.com/watch?v=UJvRHeXNdoc**

Texas Water Resources Institute
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TEXAS STATE Soil & Water CONSERVATION BOARD

SAN ANTONIO RIVER AUTHORITY
Leaders in Watershed Solutions

Agenda

Mid and Lower Cibolo Creek Watershed Planning

Tuesday, November 10, 2020
Online Zoom Meeting
10:00 AM – 11:30 AM

10:00 – 10:15 Welcome and Sign-In
Clare Escamilla, Texas Water Resources Institute

10:15 – 10:45 Discouraging Wildlife Feeding
Mark Enders, City of New Braunfels
Jessica Alderson, Texas Parks & Wildlife

10:45 - 11:15 Update of Watershed Protection Plan and Upcoming Events
Clare Escamilla, Texas Water Resources Institute

11:15 – 11:30 Open Discussion and Questions

Presentations included:

- *Update on Mid and Lower Cibolo Creek Watershed Protection Plan* at Introduction to Septic System Workshop on January 30, 2020
- *Update on Mid and Lower Cibolo Creek Watershed Protection Plan, Upcoming Events, and Next Steps* at the virtual Mid and Lower Cibolo Creek Watershed Stakeholder Meeting on November 10, 2020.
- *Update on Mid and Lower Cibolo Creek Watershed Protection Plan* at the virtual Texas Riparian & Stream Ecosystem Training for San Antonio Area Watersheds on December 8, 2021.
- *Update on Mid and Lower Cibolo Creek Watershed Protection Plan* at the virtual Healthy Lawns and Healthy Waters training on March 26, 2021.

TASK 4: WATER QUALITY MONITORING

Objective: To complete water quality monitoring for storm events of varying size and intensity to support the development and calibration of a Hydrological Simulation Program-Fortran (HSPF) water quality model for the Cibolo Creek watershed.

The monitoring efforts for the project focused on stormwater monitoring and intensive monitoring along Mid and Lower Cibolo Creek. The stormwater monitoring efforts focused on the collection of discrete samples over the hydrograph of a storm event to characterize the water quality of stormwater within the watershed. In previous water quality modeling, a significant portion of the increased bacteria and nutrient levels have been observed in elevated flows in conjunction with rainfall events. The stormwater monitoring conducted during this project helps assess the pollutant loads during a storm event.

Intensive monitoring efforts focused on developing a spatial understanding of *E. coli* concentrations in the tributaries of the Mid Cibolo Creek watershed during a single point in time. Martinez and Salitrillo Creek were

identified as areas with water quality concerns from the stakeholders. The intensive monitoring was used to help understand *e. coli* levels through the Mid Cibolo Creek tributaries.

Stormwater Sampling Events

Three locations equipped with automated samplers were monitored by SARA and SWCA Environmental Consultants for stormwater sampling in the Mid and Lower Cibolo Creek watershed (Table 1; Figure 1). The monitoring sites are included in the San Antonio River Authority Instream Stormwater Monitoring Project. This project includes using automatic samplers to collect hydrograph stormwater samples from various types of storm events within the basin. The sample locations are identified on the map below (Figure 1).

These samples were collected over the hydrograph for one qualifying storm event over the project period and two storm events during project #17-50. A minimum of five samples were collected over the hydrograph at each site to characterize the pollutant load for the duration of the storm event. Each sampler began collecting samples once a minimum rise in water level was detected. Qualifying storm event produced a minimum of 0.5 inches of rainfall at the sample site occurred. Once sampling began, sampling continued every hour until flow decreased to baseline conditions or all sample containers were full. Sampling intervals were occasionally adjusted to ensure that the full stormwater event could be collected at each site: baseline, increasing flow, peak, and decreasing flow. The staff collected the samples from the units based upon the amount of time that has elapsed since the unit was triggered. Once adequate time had passed, the samples were collected and transported to the laboratory for analysis.

The sample design was focused on stormwater monitoring of *E. coli* levels but several other parameters were also collected during the qualifying storm events. For this project, *E. coli*, Ammonia as N, Nitrate and N, and Total Phosphorus are described in this report as those are the water quality concerns and impairments present in the watershed.

Table 1. Stormwater Monitoring Locations in the Mid and Lower Cibolo Creek Watershed.

Stormwater Monitoring Locations				
Site	**Description**	**Location**	**Latitude**	**Longitude**
12919	Cibolo Creek at IH/US 90	Mid Cibolo Creek	29.500555	-98.18639
12806	Cibolo Creek at CR337	Lower Cibolo Creek	29.351424	-98.074412
20777	Cibolo Creek at FM 2724	Lower Cibolo Creek	28.990219	-97.883742

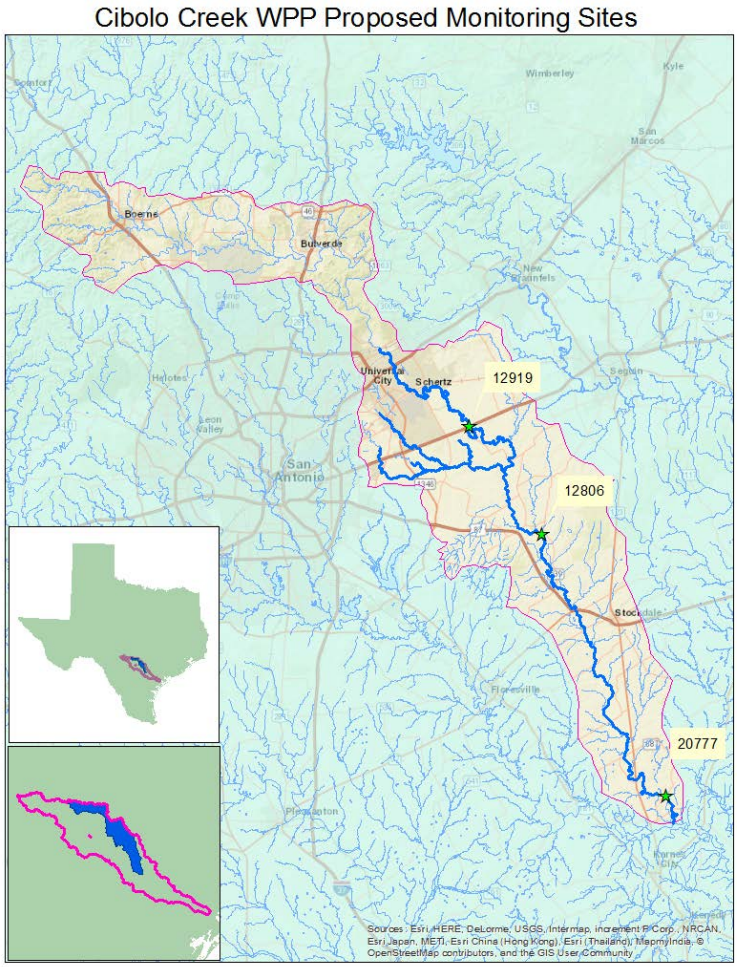


Figure 1. Map of the three stormwater monitoring locations in the Mid and Lower Cibolo Creek watershed.

Results of SARA water quality monitoring from the two 2019 storm events are shown in Table 2. Table 3 shows the results of the 2020 storm event (all *E. coli* data from the three events are shown in Appendix A). From all three storm events SARA collected between 5 and 14 samples at each station (Table 2 and 3). Storm events were all above the minimum 0.5 inches of rain needed for a qualifying storm event.

E. coli concentrations ranged from 169.2 MPN/100mL to 5,271 MPN/100mL between each storm event showing the high variability of *E. coli* levels during storm events. Based on Surface Water Quality Monitoring Information System (SWQMIS) data from the last decade (2010 – 2020), the geometric means for *E. coli* are 35.2 MPN/100mL in Mid Cibolo Creek and 172.8 MPN/100mL in Lower Cibolo Creek. For all three storm events, recorded *E. coli* levels were higher than the geometric means from routine data sampling (Table 1; Table 2, Table 3) as expected. In general, there was also a sharp spike in *E. coli* concentrations at the beginning of the storm event (Figure 2; Figure 3; Figure 4). The "first-flush" of stormwater is usually the poorest quality water received during the storm event as it commonly contains an initially high load of particulate matter and pollutants from the watershed. Initial instream sediment disturbances due to higher flow velocities during storms are also known to produce elevated *E. coli* concentrations. However, variations in *E. coli* concentrations within a storm event can and do commonly occur illustrating the dynamic and challenging nature of managing bacteria loading during storm events. These results highlight the fact that implementing best management practices for stormwater to help

capture a portion of runoff during an event can be an important step to reducing the amount of pollutants entering the creek during storm events. Implementing stormwater BMPs also supports management measure 5 of the Mid and Lower Cibolo Creek WPP.

Table 2: Sampling stations and data collected from the two 2019 Storm events

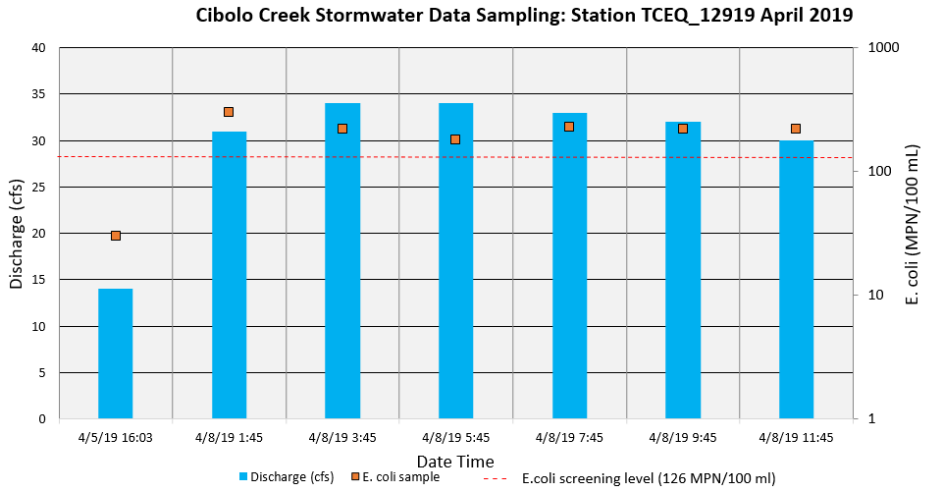
Station	Name	Date of Storm Event	Samples	Average Rainfall for Duration of Storm Event (in)	Geomean (MPN/100mL)
12919	Cibolo Creek at IH/US 90	4/5/19 – 4/8/19	7	0.83	169.2
12806	Cibolo Creek at CR337	4/5/19 – 4/11/19	7	2.4	200.5
		4/23/19 – 4/25/19	5	1.6	1,915.8
20777	Cibolo Creek at FM 2724	4/23/19 – 4/26/19	11	0.96	5,271

Table 3: Sampling stations and data collected from 2020 Storm event

Station	Name	Date of Storm Event	Samples	Rainfall for Duration of Storm Event (in)	Geomean (MPN/100mL)
12806	Cibolo Creek at CR337	NA*	NA*	NA*	NA*
12919	Cibolo Creek at IH/US 90	9/5/20 – 9/8/20	14	0.5	976.1
20777	Cibolo Creek at FM 2724	9/4/20 – 9/5/20	12	1.57	496.9

** Dense canopy cover blocked the solar panel at 12806 and the ISCO did not collect any samples over the storm event.*

a.



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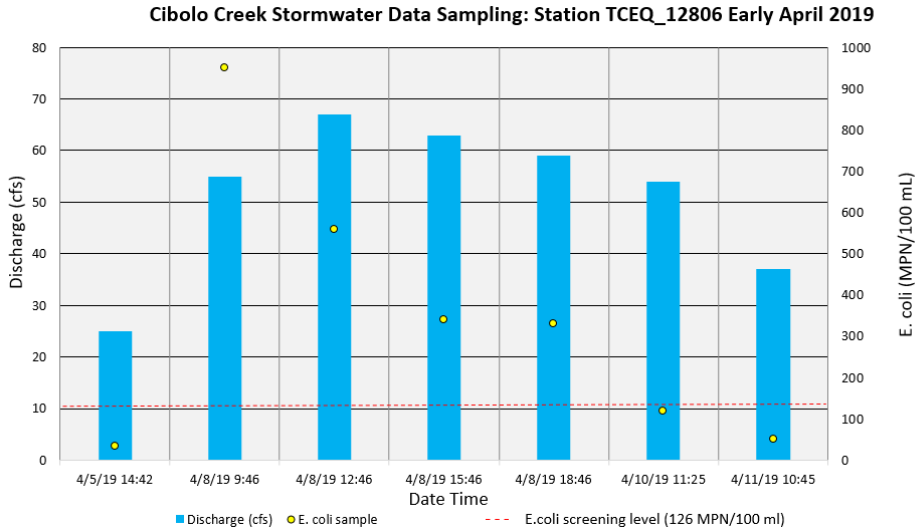
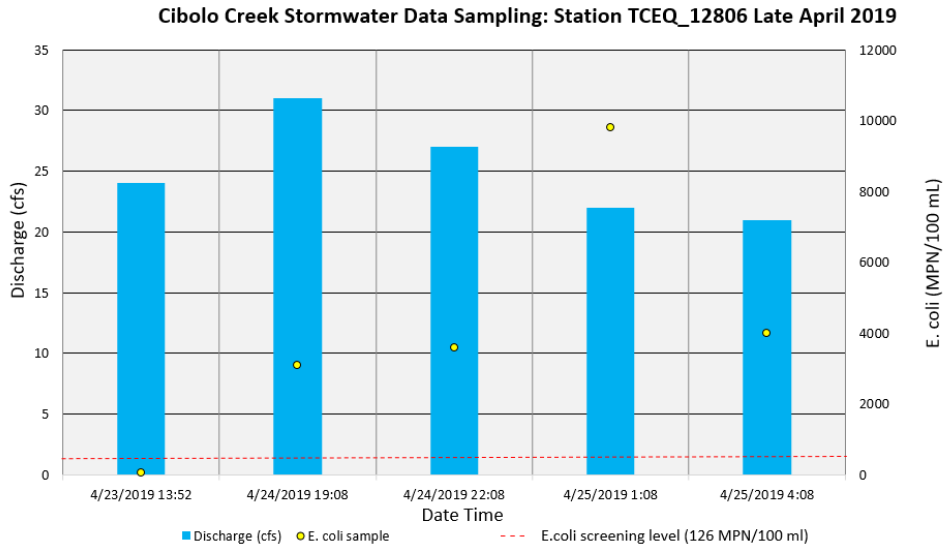


Figure 2. Discharge and *E. coli* concentrations at two sites (a. 12919 and b. 12806) during the early April storm event (4/5/19 to 4/11/19).

a.



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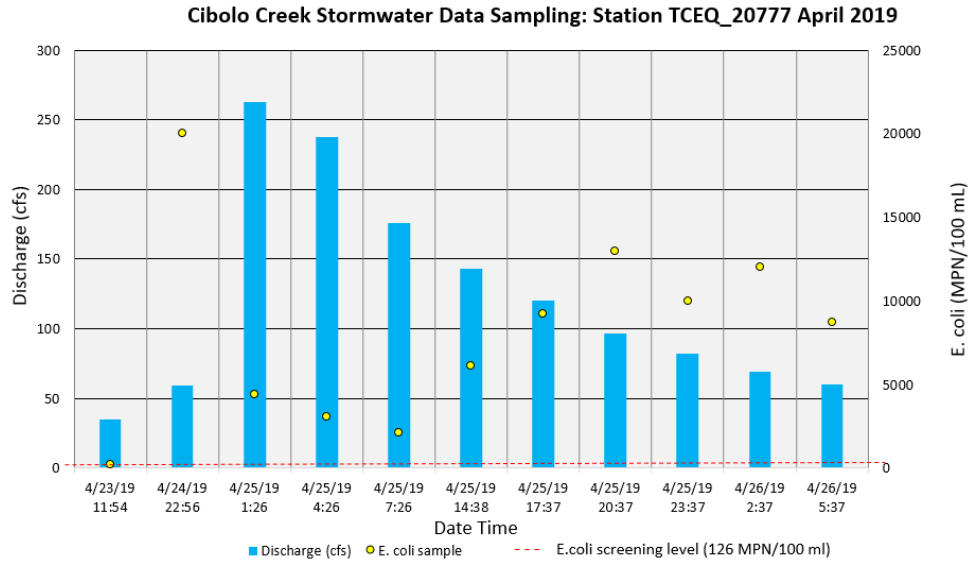
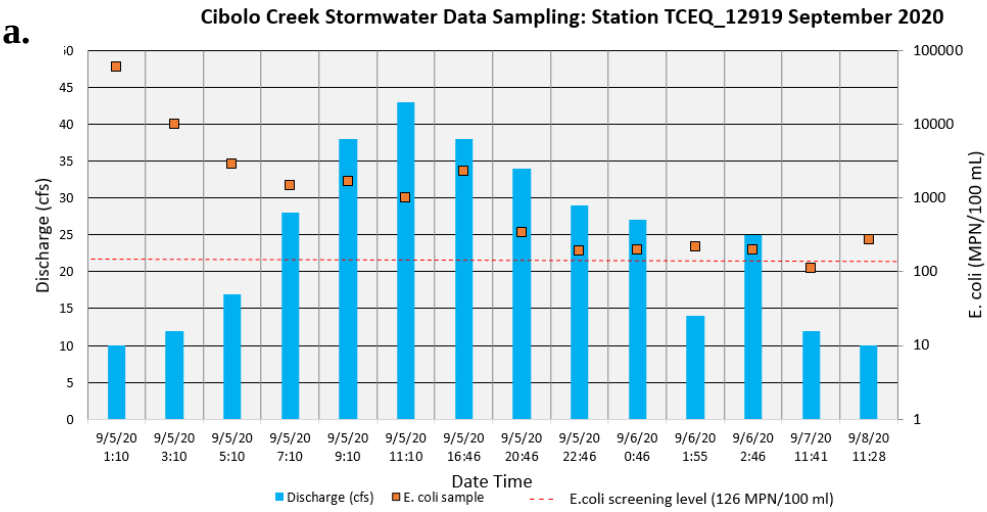


Figure 3. Discharge and *E. coli* concentrations at two sites (a. 12806 and b. 20777) during the late April storm event (4/23/19 to 4/26/19).



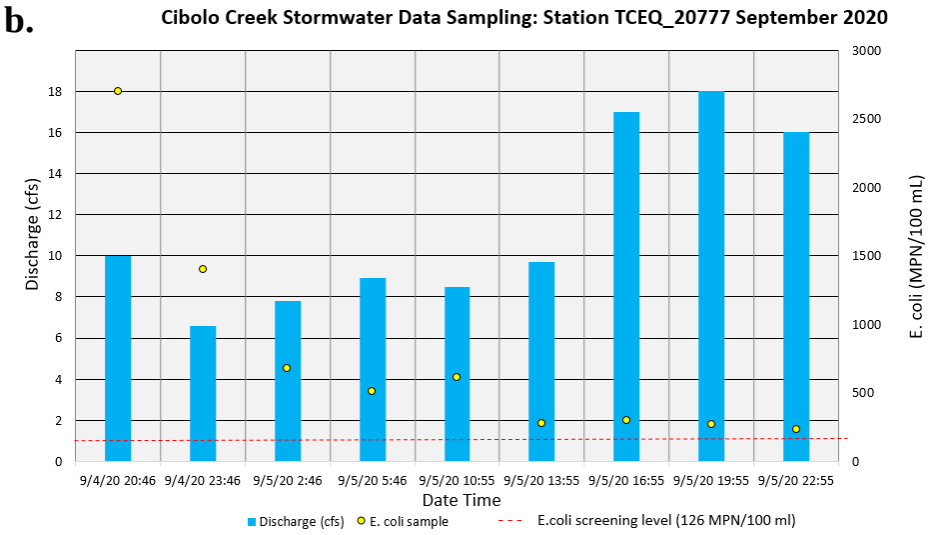


Figure 4. Discharge and *E. coli* concentrations at two sites (a. 12919 and b. 20777) during the September storm event (9/4/20 to 9/8/20).

Nitrate nitrogen (Figure 5 and Figure 8), ammonia nitrogen (Figure 6 and Figure 9) and total phosphorus concentrations (Figure 7 and Figure 10) recorded during the two 2019 storm events and one 2020 storm event are graphed along with the screening level for each nutrient. Ammonia concentrations were well below the screening level of 0.33 mg/L at all three stations over all three storm events. Ammonia is currently not listed as a water quality concern for the main branches of Mid and Cibolo Creek, however water quality data over the last decade (2010 – 2020) shows that Mid Cibolo Creek has an average ammonia concentration of 1.1 mg/L which is over the screening criteria. This could be due, in part, to ammonia water quality concerns in Martinez Creek – a tributary of Mid Cibolo Creek. The low levels of ammonia recorded during storm events suggest that stormwater runoff is not a big contributor to ammonia concentrations in the creek.

Mid and Lower Cibolo Creek have water quality concerns for elevated total phosphorus and nitrate nitrogen concentrations. Water quality data collected over the last decade (2010 – 2020) and available on SWQMIS show that average nitrate and phosphorus concentrations were 3.5 mg/L and 0.96 mg/L respectively for Mid Cibolo Creek and were 1.4 mg/L and 0.37 mg/L respectively for Lower Cibolo Creek. Stormwater data from the three events show that nutrient concentrations were generally higher in the Mid Cibolo station 12919 (Figure 5, Figure

7, Figure 8, and Figure 10). With the variability of nitrate and phosphorus concentrations between each storm event and each station and the small number of collection events, it is hard to determine if nonpoint source pollutants transported in stormwater runoff is a major contributor to nutrient concerns in the watershed. One possible explanation to the differences in nutrient concentrations during the storm events are antecedent weather conditions. There had not been any rain the two week period before the prior to the April 4 – 8, 2019 event. Nutrients from fertilizers in the watershed may have been transported during the first event. In between the two April events there were small storm events that may have impacted the amount of nutrients running off the landscape during the April 23 – 26, 2019 event. Additional monitoring is needed to understand nutrient contributors in the watershed and if it is from nonpoint (NPS) or point source pollutants. Implementation of various management measures from the Mid and Lower Cibolo Creek WPP will help in reducing NPS pollutant sources and may help reduce some of the higher spikes of nutrients shown during storm events.

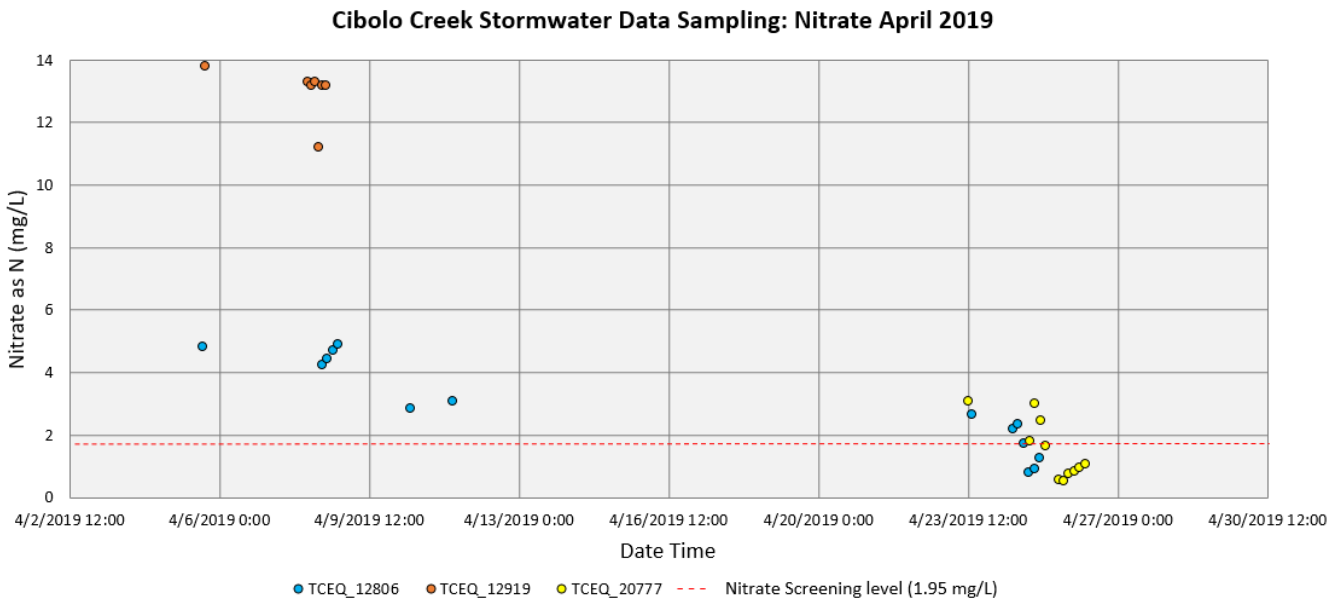


Figure 5. Nitrate Nitrogen (mg/L) data from the two April 2019 storm events. Red dotted line is the screening level of 1.95 mg/L.

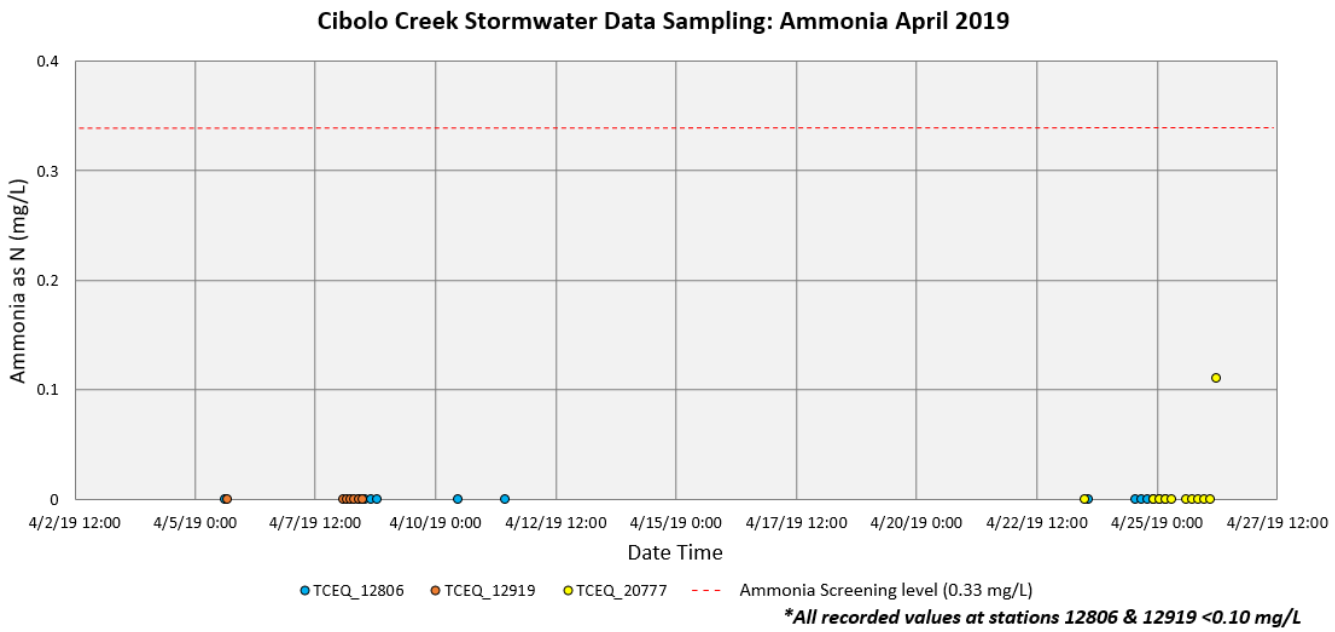


Figure 6. Ammonia Nitrogen (mg/L) data from the two April 2019 storm events. Values less than the detection limit of 0.01mg/L are plotted as 0.01 mg/L. Red dotted line is the screening level of 0.33 mg/L.

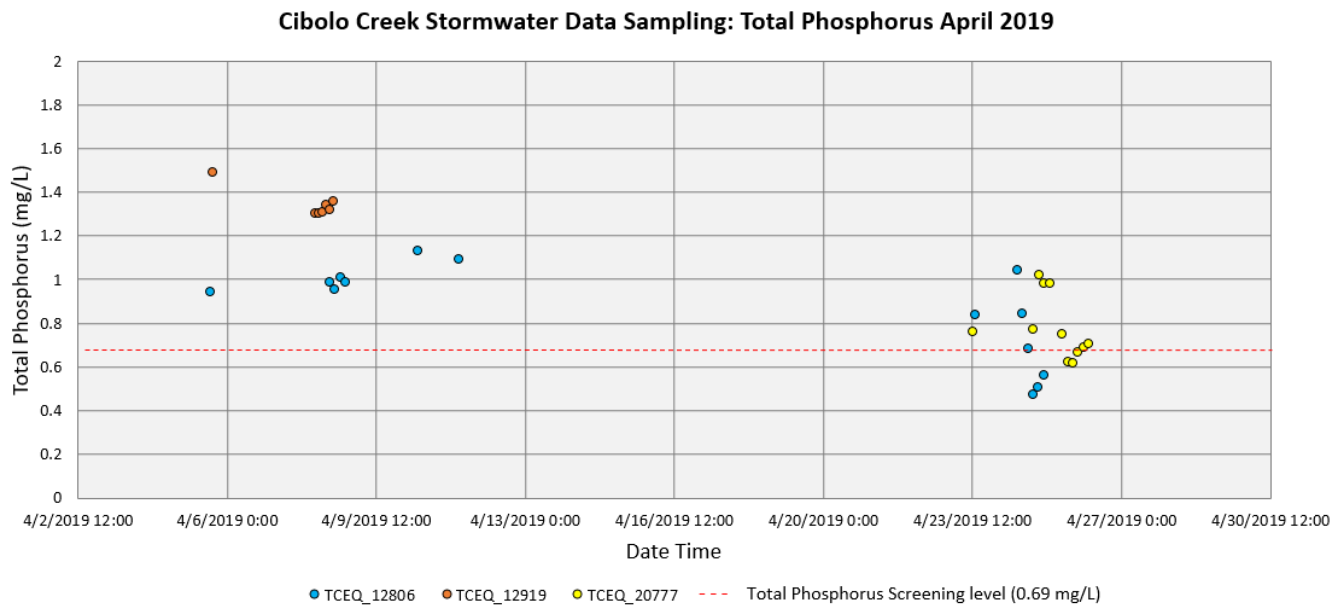


Figure 7. Total Phosphorus (mg/L) data from the two April 2019 storm events. Red dotted line is the screening level of 0.69 mg/L.

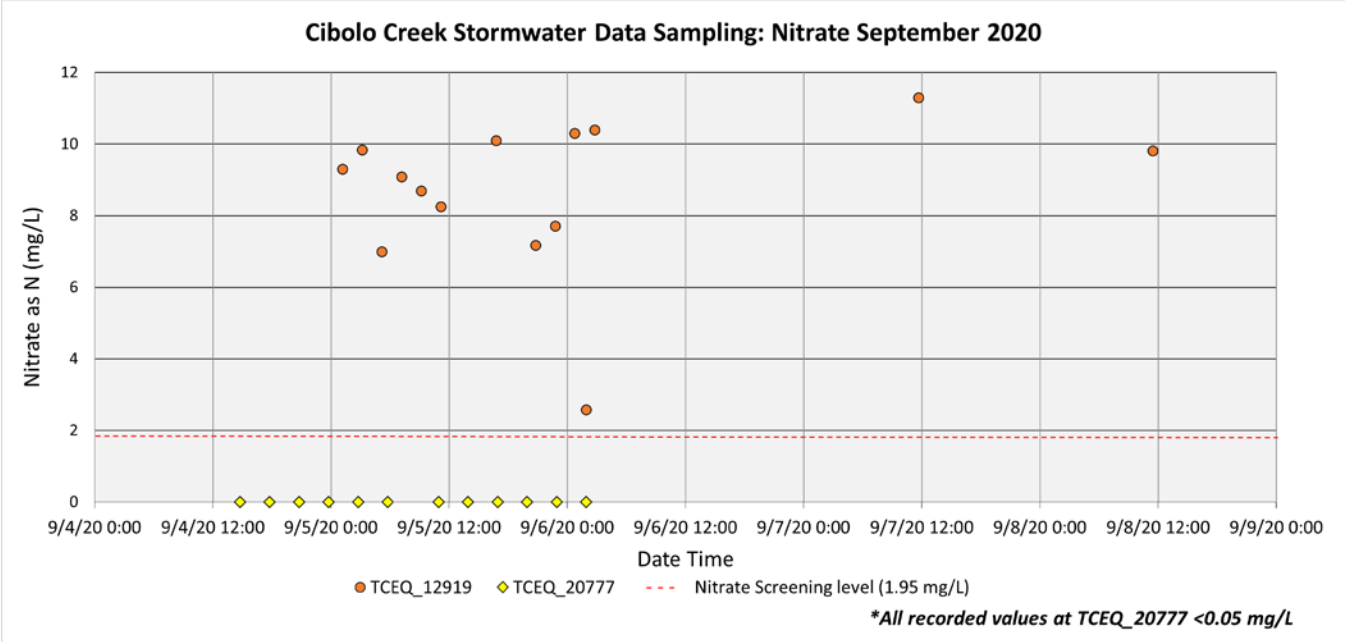


Figure 8. Nitrate Nitrogen (mg/L) data from the September 2020 storm event. Values less than the detection limit of 0.05mg/ml are plotted as 0.05 mg/ml. Red dotted line is the screening level of 1.95 mg/L. Red dotted line is the screening level of 1.95 mg/L.

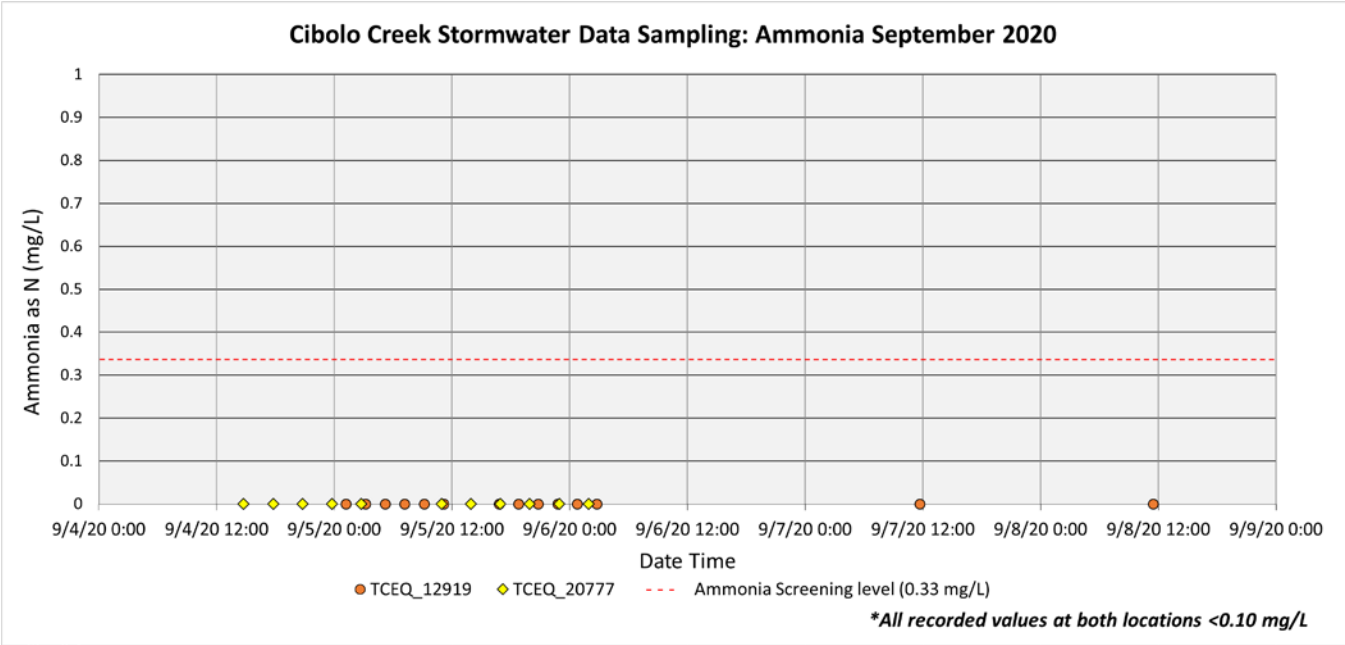


Figure 9. Ammonia Nitrogen (mg/L) data from the two April 2019 storm events. Values less than the detection limit of 0.01mg/L are plotted as 0.01 mg/L. Red dotted line is the screening level of 0.33 mg/L.

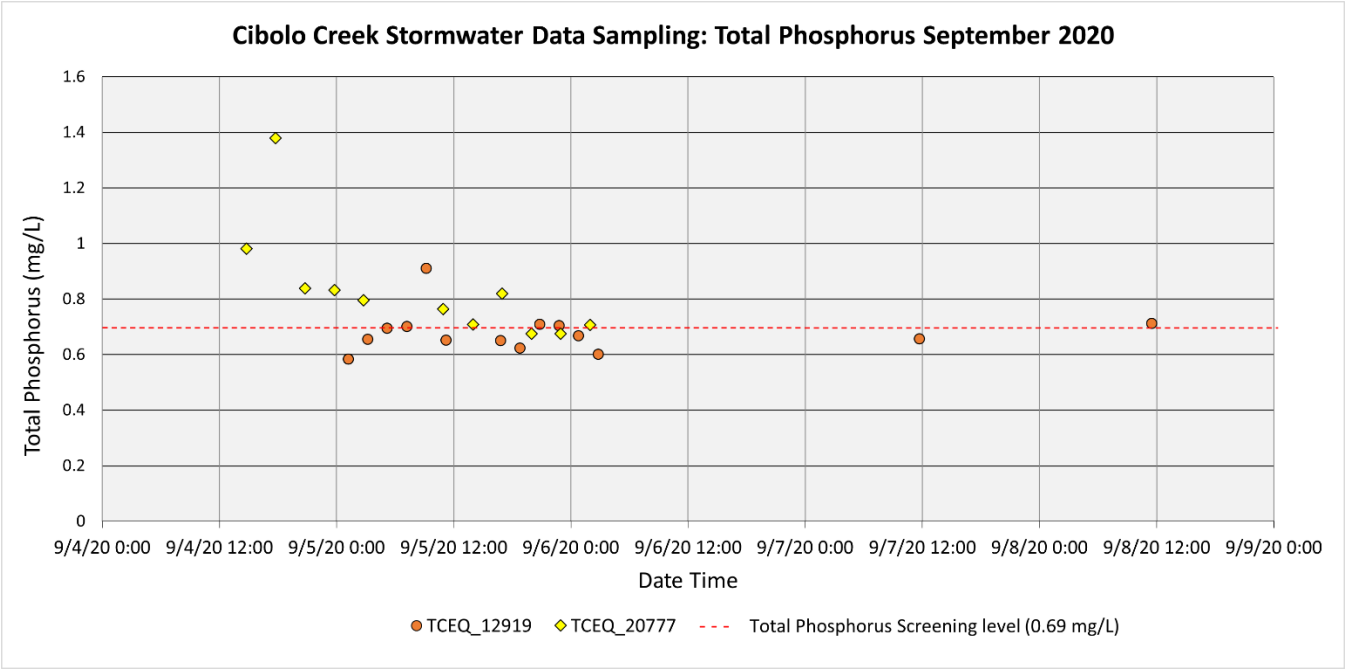


Figure 10. Total Phosphorus (mg/L) data from the two April 2019 storm events. Red dotted line is the screening level of 0.69 mg/L.

Intensive Sampling Events

Targeted monitoring on Salitrillo and Martinez Creeks, two tributaries for Mid Cibolo Creek, was planned as a way to narrow down areas of the creeks with higher *E. coli* concentrations relative to the remainder of the creek. The first intensive sampling event occurred on May 29, 2019 as part of *Development of a Watershed Protection Plan for Mid and Lower Cibolo Creek* project #17-50. Twenty-one sites were chosen to provide a spatial understanding of *E. coli* concentrations at a single point in time (Table 4 and Figure 11). The second intensive sampling event took place over two days March 2, 2021 and March 4, 2021. Thirty-four samples were taken on Martinez, Salitrillo, Woman Hollering, and Santa Clara Creeks (Table 5, Table 6, and Figure 12). Waterbodies were sampled by SARA staff for both the 2019 and 2021 collection events. Sampling on each waterbody was conducted independently of each other; however, all samples collected within a particular stream were collected on the same day in a downstream to upstream order. The number of sampling sites was maximized for each waterbody but the ability to sample depended on ambient flow conditions on the sampling day.

Following data collection, *E. coli* results were reviewed to identify where sizable changes in *E. coli* concentrations occur and where potential *E. coli* 'hot spots' exist in those creeks. *E. coli* concentrations were plotted across the watershed (Figure 13 and 14). While variations exist between the two collection events, there are a few areas that stand out as potential 'hot spot' areas that may warrant additional monitoring. In both *E. coli* concentration maps (Figure 13 and 14) the stretch of Martinez Creek below IH-10 to when it joins Salitrillo Creek had high *E. coli* concentrations during both sampling events. Martinez Creek at Gable and Miller Roads (TCEQ_12741 and TCEQ_12742) also had higher *E. coli* concentrations during both sampling events (Figure 13 and 14) relative to most of the upstream sampling locations. During the development of the Mid and Lower Cibolo Creek WPP, Martinez Creek was identified as an area of concern for many stakeholders and the 2020 303(d) List identifies a bacterial impairment along Martinez Creek. Additional monitoring may be needed to

understand potential causes for the bacterial impairment along Martinez Creek and implementation efforts should be prioritized in this area, when applicable. *E. coli* concentrations varied on Salitrillo Creek between sampling events so it is difficult to notice any emerging trends (Figure 13 and 14).

Table 4: Site descriptions for Investigative Sampling – May 2019

Station ID	Description of Location	Latitude	Longitude	*E. coli* (MPN/100 mL)
TCEQ_12741	Martinez Creek on Gable Rd	29.444155	-98.168897	440
TCEQ_12742	Martinez Creek at Miller Road	29.449455	-98.19295	270
TCEQ_12743	Martinez Creek at FM 1518	29.444667	-98.222507	140
TCEQ_14203	Martinez Creek at Abbott Road East of San Antonio	29.441499	-98.239051	110
TCEQ_12744	Martinez Creek at Loop 1604	29.433989	-98.272323	240
TCEQ_12745	Martinez Creek at Shuwirth Road	29.432766	-98.300388	150
TCEQ_15306	Martinez Creek below Martinez II	29.435915	-98.318443	550
TCEQ_15305	Martinez Creek below Martinez II	29.436638	-98.319191	81
TCEQ_12746	Martinez Creek at FM 1516	29.43857	-98.326649	140
TCEQ_12747	Martinez Creek at US 90 East of San Antonio	29.455305	-98.328538	68
TCEQ_12749	Martinez Creek at Bing-Engleman	29.46769	-98.328264	120
TCEQ_12756	Salitrillo Creek at FM 1518	29.444663	-98.22251	93
TCEQ_14201	Salitrillo Creek at Abbott Rd	29.451548	-98.233495	120
SARA_S0084	Salitrillo Creek at Freudenburg Rd	29.45622	-98.2498	110
SARA_S0085	Salitrillo Creek at N Graytown Rd	29.46362	-98.2629	75
TCEQ_12757	Salitrillo Creek at US90 East of San Antonio	29.472458	-98.269829	91
SARA_S0086	Salitrillo Creek at Scenic Lake Dr.	29.47344	-98.2816	47
TCEQ_12759	Salitrillo Creek at FM 1604 near Converse Permit 0010749-001	29.48544	-98.293277	50
TCEQ_14202	Salitrillo Creek at Autumn Run	29.495978	-98.298015	110
TCEQ_15303	Salitrillo Creek below WWTP	29.50692	-98.299084	330
SARA_S0010	Salitrillo Creek at Judson High School	29.510926	-98.300959	920
SARA_S0087	Salitrillo Creek at John E Peterson Blvd/FM 78	29.51992	-98.3083	77

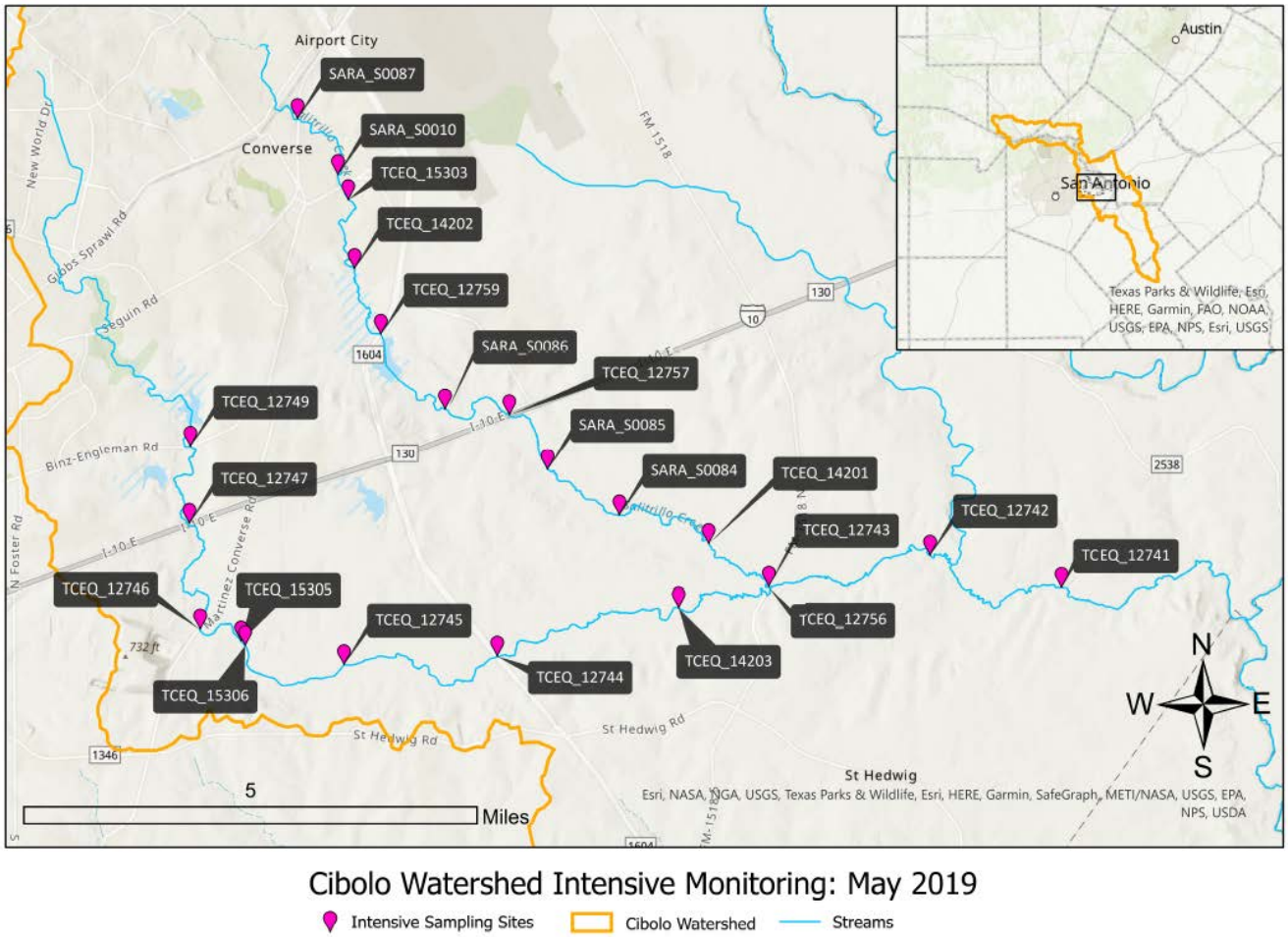


Figure 11. Site descriptions from May 29, 2019 Intensive Sampling event.

Table 5: Site descriptions for Investigative Sampling – March 2, 2021

Station ID	Description of Location	Latitude	Longitude	*E. coli* (MPN/100 mL)
TCEQ_12784	Santa Clara Creek on CR 315 Santa Clara Rd Northwest	29.48807	-98.119581	NA*
TCEQ_12757	Salitrillo Creek at US90 East of San Antonio	29.472458	-98.269829	520
SARA_S0081	Santa Clara Creek at CR404	29.51328	-98.1124	51
SARA_S0086	Salitrillo Creek at Scenic Lake Dr.	29.47344	-98.2816	370
SARA_S0082	Santa Clara Creek at IH-10/US-90	29.52743	-98.1179	30
TCEQ_12759	Salitrillo Creek at FM 1604 near Converse Permit 0010749-001	29.48544	-98.293277	220
SARA_S0083	Santa Clara Creek at Stagecoach Rd	29.54651	-98.1318	6
TCEQ_14202	Salitrillo Creek at Autumn Run	29.495978	-98.298015	150
TCEQ_12756	Salitrillo Creek at FM 1518	29.444663	-98.22251	48
TCEQ_15303	Salitrillo Creek below WWTP	29.50692	-98.299084	74
TCEQ_14201	Salitrillo Creek at Abbott Rd	29.451548	-98.233495	83

SARA_S0084	Salitrillo Creek at Freudenburg Rd	29.45622	-98.2498	33
TCEQ_15304	Salitrillo Creek 100M Upstream of Salitrillo WWTP Permit 001	29.508222	-98.299773	NA*
SARA_S0085	Salitrillo Creek at N Graytown Rd	29.46362	-98.2629	190
SARA_S0087	Salitrillo Creek at John E Peters Blvd/FM 78	29.51992	-98.3083	390

Table 6: Site descriptions for Investigative Sampling – March 4, 2021

Station ID	Description of Location	Latitude	Longitude	*E. coli* (MPN/100 mL)
TCEQ_12741	Martinez Creek on Gable Rd	29.444155	-98.168897	330
TCEQ_12742	Martinez Creek at Miller Road	29.449455	-98.19295	220
TCEQ_14208	Womans Hollow Creek at New Berlin Road Bexar County Texas	29.452513	-98.19295	15
TCEQ_14192	Womans Hollow Creek at Miller Road Bexar County Texas	29.460532	-98.184785	210
TCEQ_12743	Martinez Creek at FM 1518	29.444667	-98.222507	140
TCEQ_12752	Womans Hollow Creek at Abbott Road	29.481934	-98.198957	88
TCEQ_14203	Martinez Creek at Abbott Road East of San Antonio	29.441499	-98.239051	240
TCEQ_12753	Womans Hollow Creek Immediately Downstream of IH10	29.493055	-98.2075	120
TCEQ_12744	Martinez Creek at Loop 1604	29.433989	-98.272323	4400
SARA_S0088	Woman Hollering Creek at Trainer Hale Rd	29.50222	-98.2253	28
TCEQ_12745	Martinez Creek at Shuwirth Road	29.432766	-98.300388	770
TCEQ_12754	Womans Hollow Creek at FM 1518	29.508862	-98.237388	980
TCEQ_12755	Womans Hollow Creek at Lower Seguin Rd	29.5014961	-98.26655	3
TCEQ_15305	Martinez Creek below Martinez II	29.436638	-98.319191	200
SARA_S0089	Woman Hollering Creek at Golf Rd	29.51682	-98.2755	NA*
TCEQ_15306	Martinez Creek below Martinez II	29.435915	-98.318443	1000
TCEQ_12746	Martinez Creek at FM 1516	29.43857	-98.326649	41
TCEQ_12747	Martinez Creek at US 90 East of San Antonio	29.455305	-98.328538	20
TCEQ_12749	Martinez Creek at Bing-Engleman	29.46769	-98.328264	100

**Sites were dry and no water quality samples were taken.*

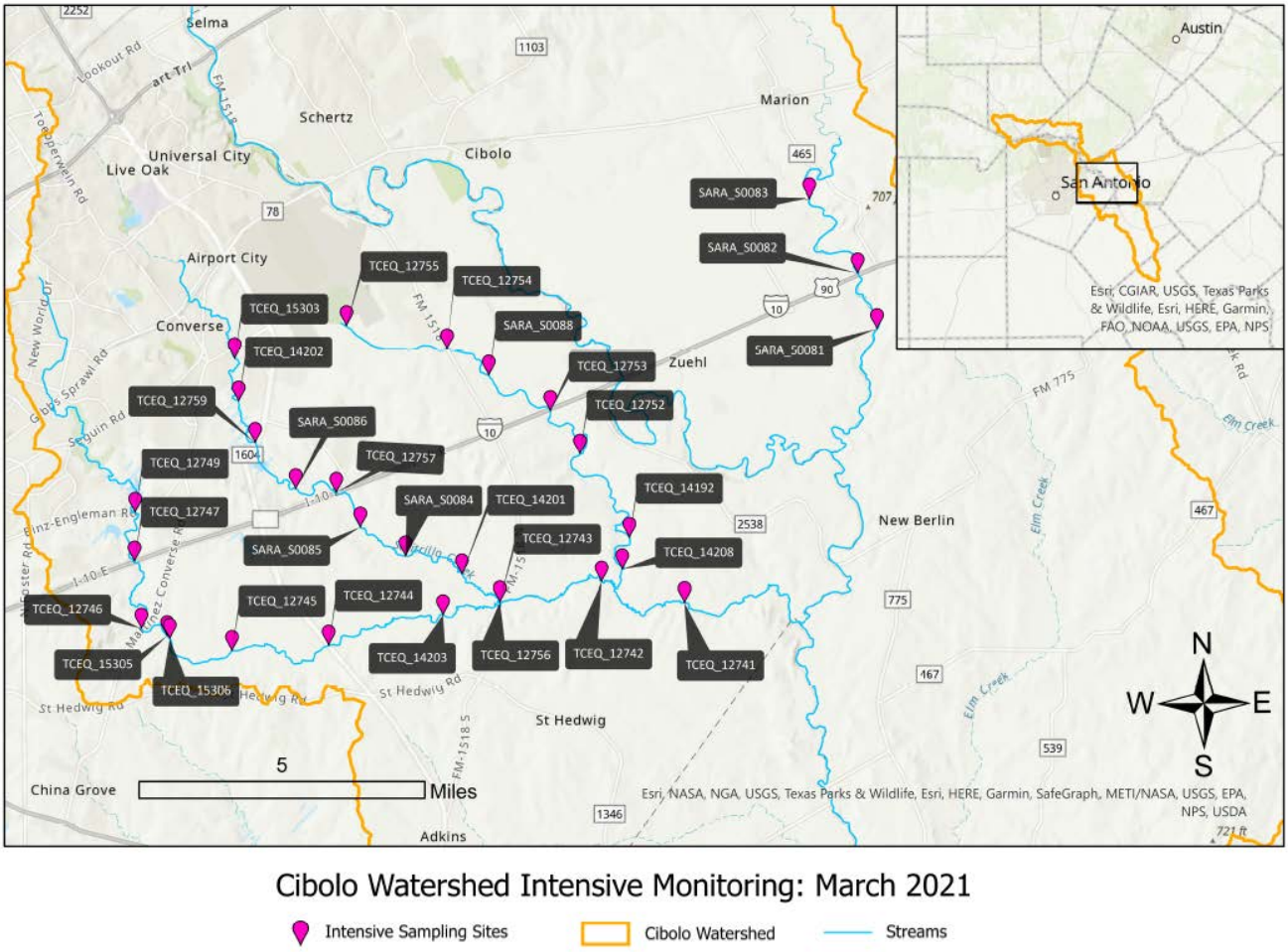


Figure 12. Site descriptions from March 2 and 4, 2021 Intensive Sampling event.

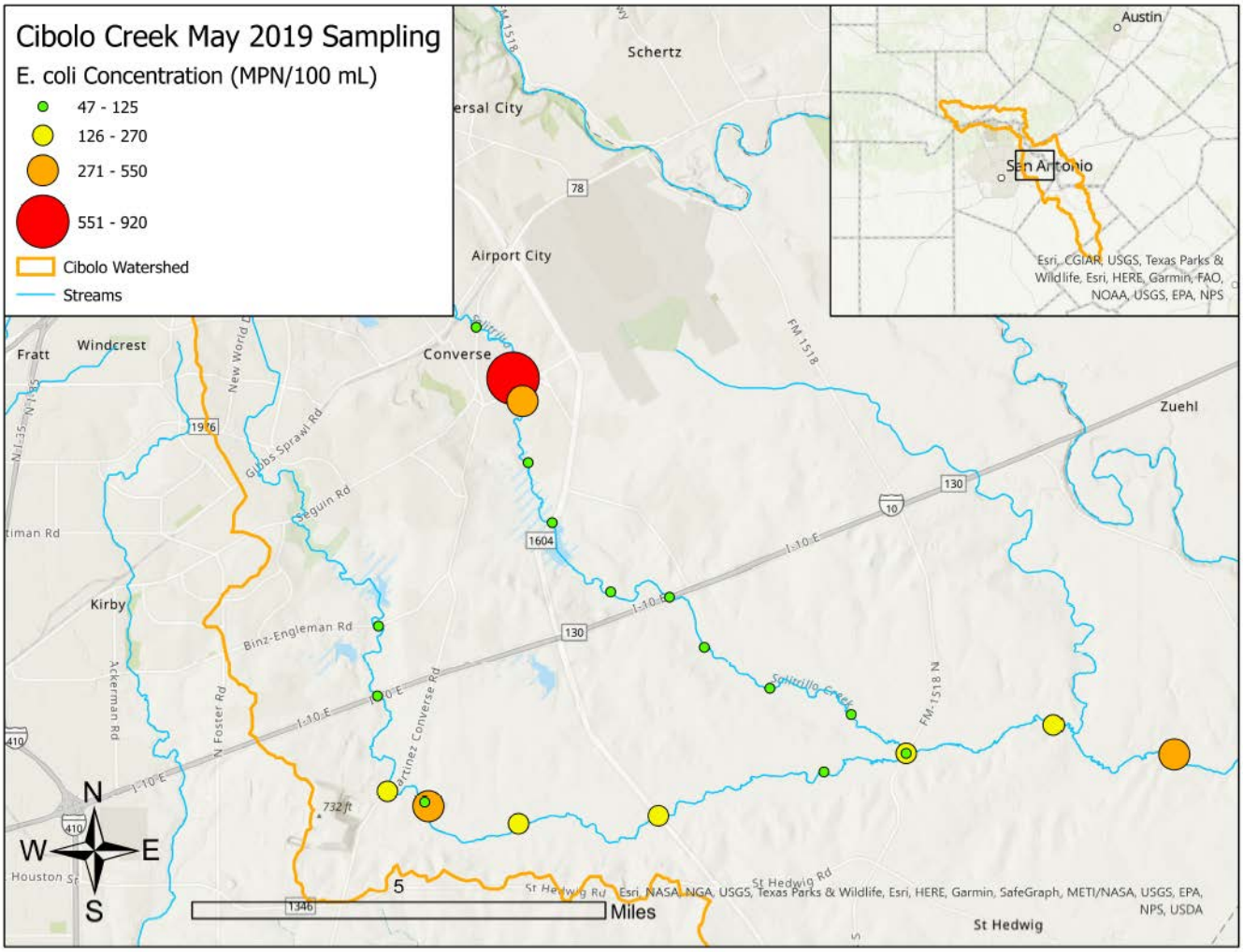


Figure 13. Results from Mid Cibolo Creek tributaries May 29, 2019 Intensive Sampling event.

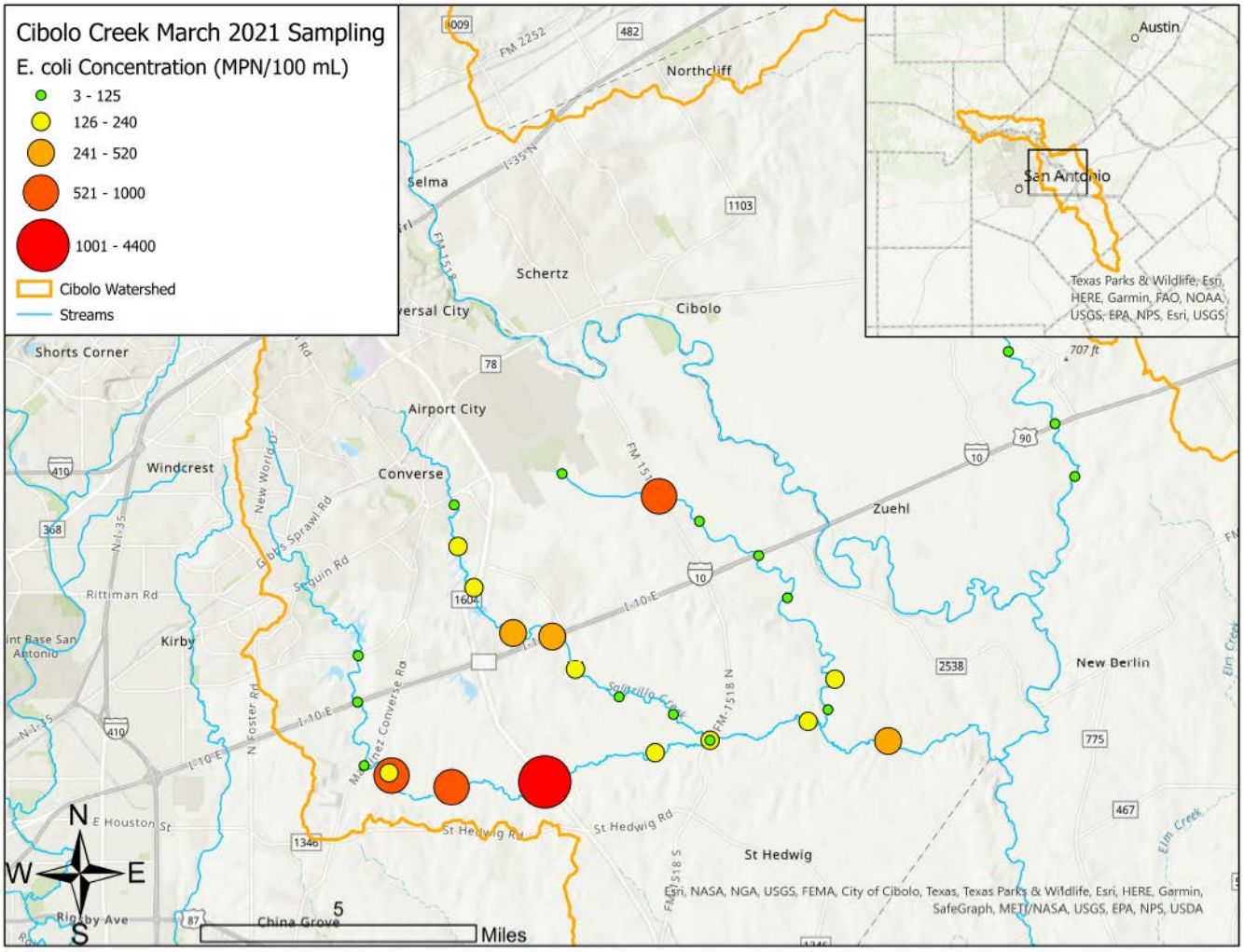


Figure 14. Results from Mid Cibolo Creek tributaries March 2 and 4, 2020 Intensive Sampling event.

Conclusion

Results from the three stormwater monitoring events and two intensive sampling events show the high variability in *E. coli* levels throughout the watershed during storm events and normal flow conditions. Martinez Creek was identified as an area of concern by stakeholders due to increased development, permitted dischargers, and a landfill and the intensive sampling results support the idea that Martinez Creek should be concerned a priority area for WPP implementation. Additional work on Martinez Creek is needed to identify the primary causes of high bacteria concentrations and allow management implementation to be better targeted.

Additional intensive monitoring events and an expanded routine sampling regime in waterbodies with identified *E. coli* concentration increases will help improve understanding of the spatial and temporal water quality trends in the watershed. Expanded monitoring efforts will help provide additional information to refine target areas for implementation and possible bacteria "hot spots." Practices that can help reduce and capture stormwater runoff would help reduce the peak bacteria concentrations and flow volumes during storm events.

Appendix A. Stormwater Quality Data

Table A.1: *E. coli*, Nitrate Nitrogen, Ammonia Nitrogen, Total Phosphorus, and Discharge from the two 2019 storm events.

Station ID	Date Time	*E. coli* (MPN/100 mL)	Nitrate Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Total Phosphorus (mg/L)	Discharge (cfs)
TCEQ_12919	4/5/19 16:03	30	13.8	<0.10	1.49	14
TCEQ_12919	4/8/19 1:45	300	13.3	<0.10	1.3	31
TCEQ_12919	4/8/19 3:45	220	13.2	<0.10	1.3	34
TCEQ_12919	4/8/19 5:45	180	13.3	<0.10	1.31	34
TCEQ_12919	4/8/19 7:45	230	11.2	<0.10	1.34	33
TCEQ_12919	4/8/19 9:45	220	13.2	<0.10	1.32	32
TCEQ_12919	4/8/19 11:45	220	13.2	<0.10	1.36	30
TCEQ_12806	4/5/19 14:42	35	4.82	<0.10	0.945	25
TCEQ_12806	4/8/19 9:46	950	4.25	<0.10	0.99	55
TCEQ_12806	4/8/19 12:46	560	4.45	<0.10	0.954	67
TCEQ_12806	4/8/19 15:46	340	4.7	<0.10	1.01	63
TCEQ_12806	4/8/19 18:46	330	4.89	<0.10	0.988	59
TCEQ_12806	4/10/19 11:25	120	2.86	<0.10	1.13	54
TCEQ_12806	4/11/19 10:45	52	3.09	<0.10	1.09	37
TCEQ_12806	4/23/2019 13:52	59	2.65	<0.10	0.84	24
TCEQ_12806	4/24/2019 19:08	3100	2.19	<0.10	1.04	64
TCEQ_12806	4/24/2019 22:08	3600	2.33	<0.10	0.842	50
TCEQ_12806	4/25/2019 1:08	9800	1.73	<0.10	0.684	31
TCEQ_12806	4/25/2019 4:08	4000	0.803	<0.10	0.474	27
TCEQ_20777	4/23/19 11:54	200	3.08	<0.10	0.759	35
TCEQ_20777	4/24/19 22:56	20000	1.8	<0.10	0.773	59
TCEQ_20777	4/25/19 1:26	4400	3	<0.10	1.02	263
TCEQ_20777	4/25/19 4:26	3100	2.46	<0.10	0.984	238
TCEQ_20777	4/25/19 7:26	2100	1.66	<0.10	0.98	176
TCEQ_20777	4/25/19 14:38	6100	0.573	<0.10	0.75	143
TCEQ_20777	4/25/19 17:37	9200	0.542	<0.10	0.621	120
TCEQ_20777	4/25/19 20:37	13000	0.763	<0.10	0.618	97
TCEQ_20777	4/25/19 23:37	10000	0.84	<0.10	0.666	82
TCEQ_20777	4/26/19 2:37	12000	0.938	<0.10	0.691	69
TCEQ_20777	4/26/19 5:37	8700	1.05	0.111	0.704	60

Table A.2: *E. coli*, Nitrate Nitrogen, Ammonia Nitrogen, Total Phosphorus, and Discharge from the 2020 storm events.

Station ID	Date Time	*E. coli* (MPN/100 mL)	Nitrate Nitrogen (mg/L)	Ammonia Nitrogen (mg/L)	Total Phosphorus (mg/L)	Discharge (cfs)
TCEQ_12919	9/5/20 1:10	60000	2.59	<0.10	0.714	10
TCEQ_12919	9/5/20 3:10	10000	7.00	<0.10	0.658	12
TCEQ_12919	9/5/20 5:10	2900	7.71	<0.10	0.602	17
TCEQ_12919	9/5/20 7:10	1500	8.26	<0.10	0.669	28

TCEQ_12919	9/5/20 9:10	1700	8.70	<0.10	0.705	38
TCEQ_12919	9/5/20 11:10	1000	9.09	<0.10	0.71	43
TCEQ_12919	9/5/20 16:46	2300	7.18	<0.10	0.625	38
TCEQ_12919	9/5/20 20:46	340	9.84	<0.10	0.653	34
TCEQ_12919	9/5/20 22:46	190	10.1	<0.10	0.911	29
TCEQ_12919	9/6/20 0:46	200	10.3	<0.10	0.702	27
TCEQ_12919	9/6/20 1:55	220	NA	<0.10	NA	14
TCEQ_12919	9/6/20 2:46	200	10.4	<0.10	0.696	25
TCEQ_12919	9/7/20 11:41	110	11.3	<0.10	0.657	12
TCEQ_12919	9/8/20 11:28	270	9.82	<0.10	0.585	10
TCEQ_20777	9/4/20 20:46	2700	<0.05	<0.10	0.838	10
TCEQ_20777	9/4/20 23:46	1400	<0.05	<0.10	0.833	6.6
TCEQ_20777	9/5/20 2:46	680	<0.05	<0.10	0.796	7.8
TCEQ_20777	9/5/20 5:46	510	<0.05	<0.10	1.38	8.9
TCEQ_20777	9/5/20 10:55	610	<0.05	<0.10	0.764	8.5
TCEQ_20777	9/5/20 13:55	280	<0.05	<0.10	0.708	9.7
TCEQ_20777	9/5/20 16:55	300	<0.05	<0.10	0.819	17
TCEQ_20777	9/5/20 19:55	270	<0.05	<0.10	0.675	18
TCEQ_20777	9/5/20 22:55	230	<0.05	<0.10	0.675	16