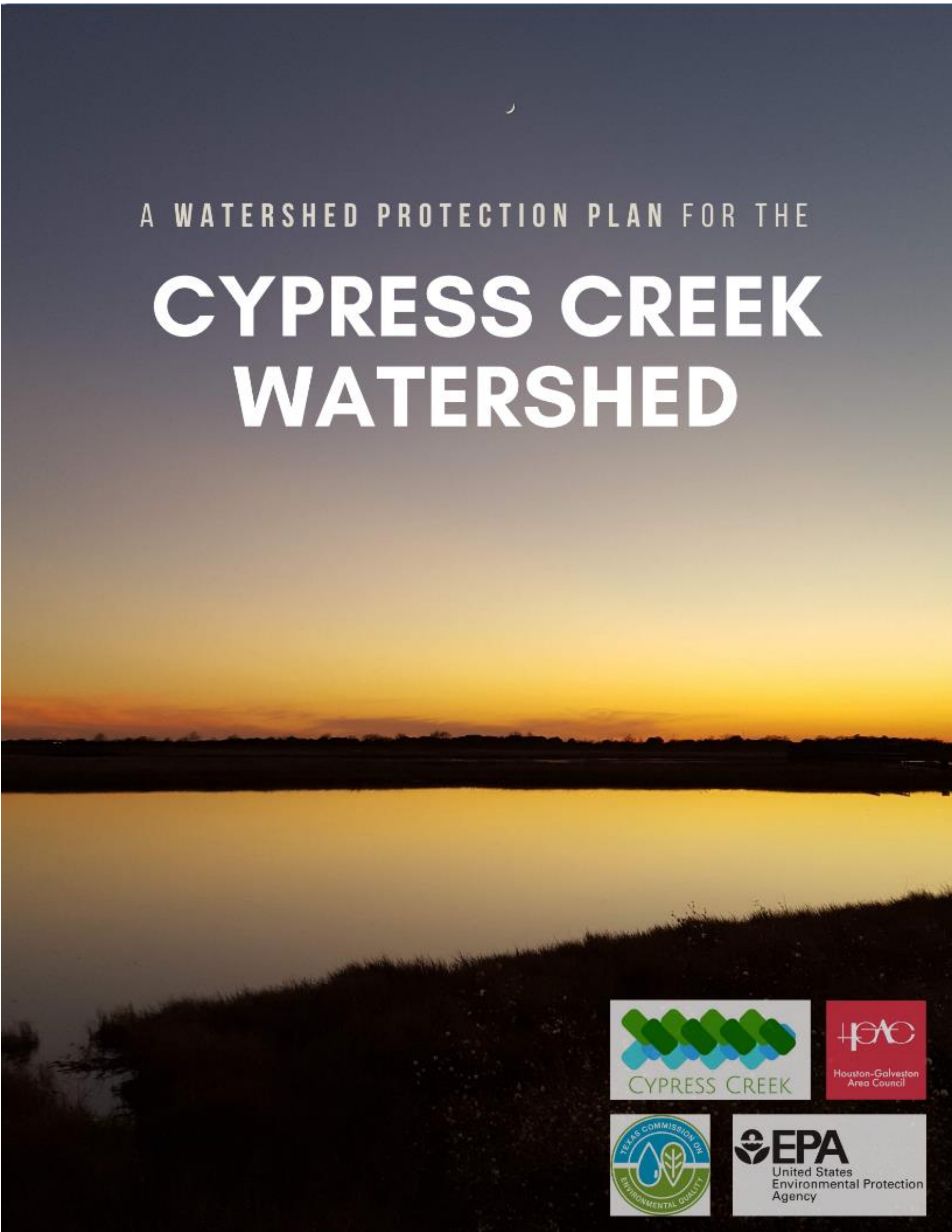
A WATERSHED PROTECTION PLAN FOR THE

CYPRESS CREEK WATERSHED



CYPRESS CREEK

Houston-Galveston Area Council

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

EPA United States Environmental Protection Agency

Cypress Creek

Watershed Protection Plan

Developed for Cypress Creek, Segment 1009 of the West Fork San Jacinto River Basin, by the Houston-Galveston Area Council on behalf of the Cypress Creek Watershed Partnership.

March 2021

Funding for the development of this watershed protection plan was provided by the Environmental Protection Agency through a Clean Water Act Section 319(h) grant to the Houston-Galveston Area Council, administered by the Texas Commission on Environmental Quality.

Acknowledgements

The Cypress Creek Watershed Protection Plan is the result of the knowledge, persistence, and hard work of a dedicated group of local stakeholders. This collaborative locally led effort would not have been possible without their contributions and guidance.

Steering Committee

The Cypress Creek Watershed Partnership (Partnership) wishes to sincerely thank the members of the project's Steering Committee. These individuals and organizations provided leadership and commitment to ensure the continuity and success of the project.

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Glenn Laird and Catherine Elliott, Harris County Flood Control District (Local Government)

Claudette McCamley, Community Member (Residents)

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Mary Anne Piacentini, Katy Prairie Conservancy (Conservation)

Mark Gehringer, Howard Hughes Corporation (Business/Development)

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Jim Robertson, Cypress Creek Flood Control Coalition (Community Organization)

Bill Papp, Ponderosa Joint Powers Association (Districts)

Matthew Berg, Simfero Consultants (Residents)

Technical Advisors

The Partnership also wishes to thank members of regional, state, and national organizations that have provided invaluable technical assistance, guidance, and feedback for this project. These technical advisors helped ensure that our effort was relevant and comparable to broader initiatives and provided resources to inform our stakeholders' decisions.

Galveston Bay Estuary Program

Harris County Flood Control District

Harris County Soil and Water Conservation District

Houston-Galveston Area Council Clean Rivers Program

Navasota Soil and Water Conservation District

Texas A&M University AgriLife Extension, AgriLife Research, Texas Water Resources Institute

USDA U.S. Forest Service

USDA Natural Resources Conservation Service

Texas Commission on Environmental Quality

Texas A&M Forest Service

Texas Master Naturalists

Texas Parks and Wildlife Department

Texas State Soil and Water Conservation Board

Texas Stream Team

The Nature Conservancy

United States Army Corps of Engineers, Galveston

Local Stakeholders

The Cypress Creek Watershed Partnership wishes to especially thank both the local organizations and individuals who have been involved to one extent or another in the development of the watershed protection program. Their local knowledge and participation are crucial elements in protecting the public health, economy, and environment of their waterways and communities.

Daniel Akeroyd, Texas State Rep. Valoree Swanson's Office

Jessica Alanis, Galveston Bay Estuary Program

Jerri Anderson, Community Awareness Services

Shawn Arrajj, Community Impact News

Ryan Bare, Houston Advanced Research Center

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The program exists because of grant funding and staff support from Texas Commission on Environmental Quality (TCEQ), through a Clean Water Act Section 319(h) grant from the United States Environmental Protection Agency (EPA). Meeting space was generously provided by the Harris County Public Library System (Barbara Bush Branch Library), Harris County Precinct 3, and the Cypress Creek Christian Church.

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Several supporting documents providing additional detail about the analyses and processes the Partnership undertook to develop this WPP are hosted on the project website at www.cypresspartnership.com. They include:

- Quality Assurance Project Plan – *the quality assurance document indicating the manner and methods in which project modeling efforts were conducted to ensure results reflect project data quality objectives.*
- Water Quality Data Collection and Trends Report – *a detailed report on the analysis of various water quality data used to characterize the conditions in the project area waterways.*
- Water Quality Modeling Report – *a detailed summary of the development and implementation and results for the bacteria modeling efforts.*
- Public Outreach Report – *a summary of the efforts and activities conducted by H-GAC to engage and inform project stakeholders, key partners, and general watershed audiences.*

Figure 1 – Kickerillo-Mischer Preserve on Cypress Creek

Executive Summary

Cypress Creek flows from its headwaters in the Katy Prairie across a swath of the greater Houston area of the Texas Gulf Coast. It joins Spring Creek, and these waterways combined represent an appreciable part of the flow entering Lake Houston, a regional drinking water source. Along its length, Cypress Creek connects a diverse set of communities with equally different relationships to the Creek and surrounding lands. Cypress Creek is a waterway in transition between its agricultural past and its current, rapid westward expansion of development.

Together, the 530 miles of waterways in the Cypress Creek system drain over 319 square miles of varying land uses in Harris and Waller counties. This complex drainage area is the Cypress Creek Watershed (Figure 2), an essential part of supporting local communities and economies, recreation, fisheries, and a diverse ecology.

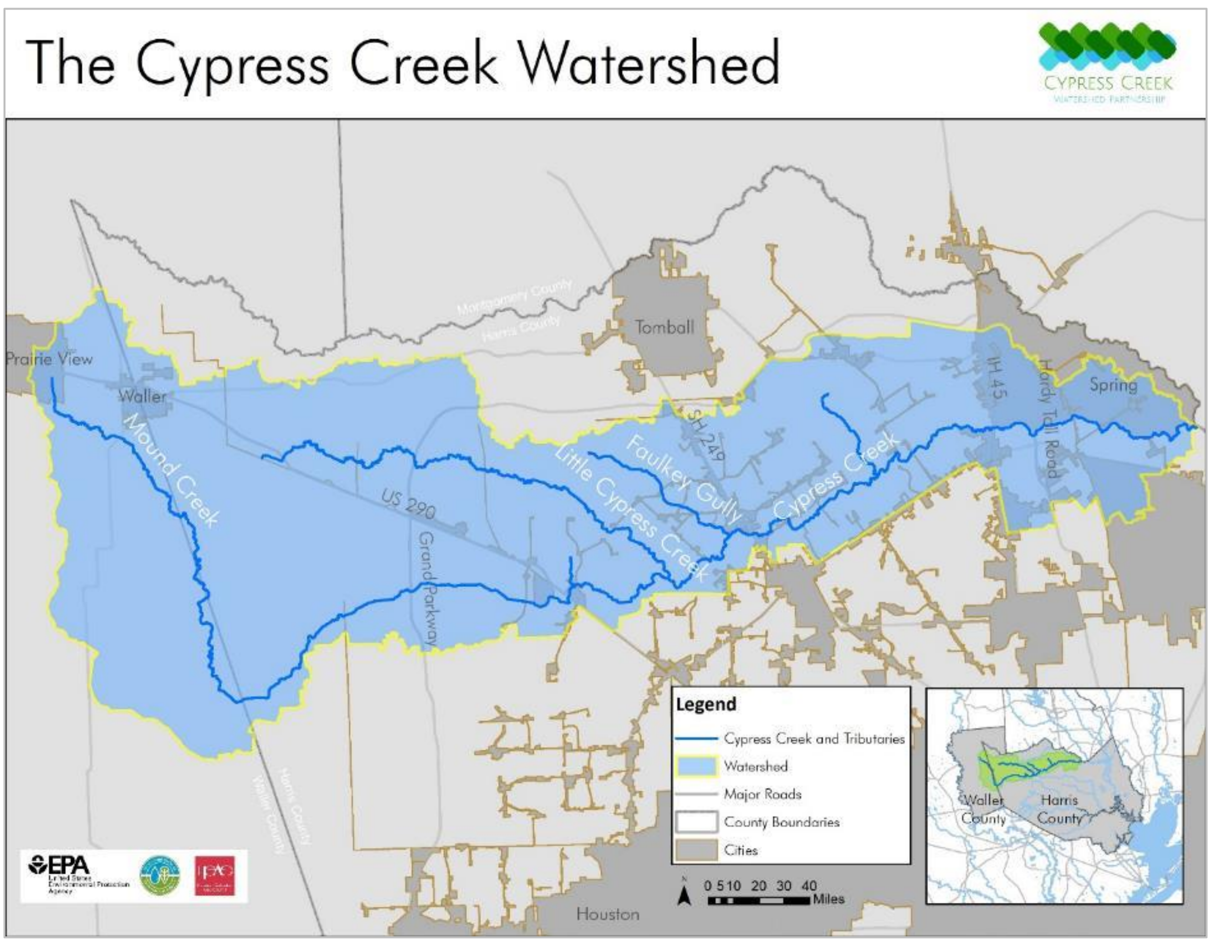


Figure 2 - The Cypress Creek Watershed

Water Quality Challenges

Cypress Creek winds its way from its headwaters in Waller County and the Katy Prairie through increasingly dense residential and commercial areas of Harris County on its way to its confluence with Spring Creek and Lake Houston. Along the way, the creek accumulates water quality issues related to natural and human activity in its watershed. Elevated levels of fecal waste in the water can impact public health, and conditions affecting the amount of dissolved oxygen (DO) in the water can endanger aquatic life. Both issues can have public health, economic, and environmental consequences for the communities of the area. The rapid development of the watershed has created challenges for local stakeholders as they seek to address the impacts of these and other pollutant sources.

In addition to fecal waste levels (as measured by the presence of the bacteria species *Escherichia coli [E. coli])* that exceed the state water quality standard, Cypress Creek and its tributaries face other water quality concerns like excess nutrients (nitrogen and phosphorus compounds that can reduce DO in water), sediment, and trash. Water quality is sampled in Cypress Creek and its tributaries on at least a quarterly basis at eleven monitoring stations, providing the basis for assessing the health of the system. As in past years, the 2020 Texas Integrated Report of Surface Water Quality (a summary of water quality in Texas waterways) indicates that Cypress Creek has a contact recreation impairment due to elevated levels of *E. coli*. Several of Cypress Creek's tributary waterways are also unable to meet the contact recreation standard, including Faulkey Gully (1009C), Spring Gully (1009D), and Little Cypress Creek (1009E). All of these units also have water quality concerns for nitrate and total phosphorus.

Additionally, the most upstream area of Cypress Creek (AU 1009_01) has a water quality concern for depressed dissolved oxygen, and the area between US 290 and SH 249 (AU 1009_02) has a concern for impaired habitat. Mound Creek (1009F), Dry Gully/Pillot Gully (1009B), and Dry Gully (1009G) are not impaired. The sources of fecal waste and other contaminants in this watershed are widespread, diffuse, and diverse in origin, making them more difficult to address through traditional approaches focusing on single entities and regulation. Primary sources of concern are pet waste, human sewage, and livestock. Pollutant sources will continue to increase as area growth drives future development in the watershed, exacerbating the existing situation. Project estimates indicate that necessary reductions of *E. coli* loads range from 64% to 74% currently, and without intervention, would increase to 77% to 86% by 2035. These water quality issues have been impacted by recurring flooding and hydrology issues in the watershed in recent decades.

Local concerns over the future of Cypress Creek, and the strength of existing commitment and efforts to mitigate these issues, were the impetus for the development of this watershed protection plan (WPP) as a voluntary, locally led approach to improving water quality for this area. The Houston-Galveston Area Council (H-GAC) and Texas Commission on Environmental Quality (TCEQ) facilitated the formation and efforts of the Cypress Creek Partnership, a group of local stakeholders representing residents, government, industry, agricultural producers, community groups, and other local partners. The purpose of the WPP is to use sound science and local knowledge to identify sources of pollution and support community-led decision-making about potential solutions.

Finding Solutions

The Partnership used a variety of methods to evaluate the causes and sources of water quality issues. Interpretation of water quality monitoring data and computer modeling efforts were shaped by local knowledge. Local stakeholders reviewed and revised these results and used them to inform decisions about potential solutions. Specific focus was given to reducing fecal waste, which can directly impact human health, and precursors for low dissolved oxygen, which impacts aquatic life and recreational fisheries. Activities to address fecal waste sources and other concerns were identified and discussed by members of the Partnership who worked diligently to balance local interests and ensure that solutions reflected community priorities. Because pollutant sources are diverse, the Partnership's recommendations represent a flexible range of solutions designed to adapt to changing conditions. The result of these efforts is a set of voluntary solutions that will guide efforts to improve water quality through 2035.

Implementing the Plan

Implementation of the WPP will require the continued coordination, cooperation, and commitment of the local partners. The general guidelines for implementation established by the stakeholders are that solutions should be voluntary, solutions should be cost-effective, decisions should continue to be made by local stakeholders, education should be a primary tool, due diligence should be given to avoiding unintended consequences, and that established programs or resources should be used whenever possible in place of new efforts. A crucial aspect of supporting these efforts will be an ongoing education and outreach campaign focused on increasing public awareness and participation. Successful implementation will rely on an active, engaged stakeholder group.

Ensuring Success

As the WPP is implemented, the stakeholders will review efforts periodically to ensure that progress is being made. The stakeholders established a series of milestones and measures of success to aid in determining whether progress is being made. The ultimate test of the WPP's success will be the ability of the waterways to meet state water quality standards based on water quality monitoring data. However, incremental progress will also be measured by achieving programmatic goals. The WPP is based on a policy of adaptive management, in which results of efforts are used as feedback for modifying approaches to meet new challenges and changing conditions. Table ES 1 is a guide to the contents of the WPP. Additional information on specific items can be found in Appendix A.

Table ES 1 - Guide to WPP content

WPP Section	Description	EPA Element	Location
Section 1 – Project Background	An introduction to the watershed planning process for Cypress Creek	NA	pp. 1-8, Appendix A
Section 2 – Watershed Characterization	A summary of the physical (geography, climate, etc.), human (land use, political geography), and water quality characteristics of the watershed	NA	pp. 9-37, Appendix B
Section 3 – Identifying Pollutant Sources	An evaluation of water quality data, stakeholder knowledge and modeling results to identify and characterize causes and sources of pollution	• Element A – Identify the causes and sources of pollution	pp. 38-100, Appendix B
Section 4 – Improving Water Quality	Establishing the amount of pollutant source loads needed to achieve water quality goals	• Element B – Estimate of load reductions	pp. 101-120
Section 5 – Recommended Solutions	A description of the solutions recommended by the Partnership, including information about the selection process, and the cost and technical expertise needed to implement them	• Element C – Description of management measures. • Element D - Estimate of technical and financial resources needed	pp. 121-164, Appendices C, D
Section 6 – Education and Outreach	An outline of the education and outreach efforts that will increase public awareness of the WPP and support its implementation	• Element E – Information and Public Education Component	pp. 165-178
Section 7 – Implementation	The schedules for implementation, and measurable milestones for tracking progress	• Element F – Schedule for implementation • Element G – Interim measurable milestones	pp. 179-200
Section 8 – Evaluating Success	An overview of the criteria and data that will be used to evaluate the success of implementation efforts	• Element H – Criteria for successful implementation. • Element I – Monitoring component to evaluate effectiveness	pp. 201-208

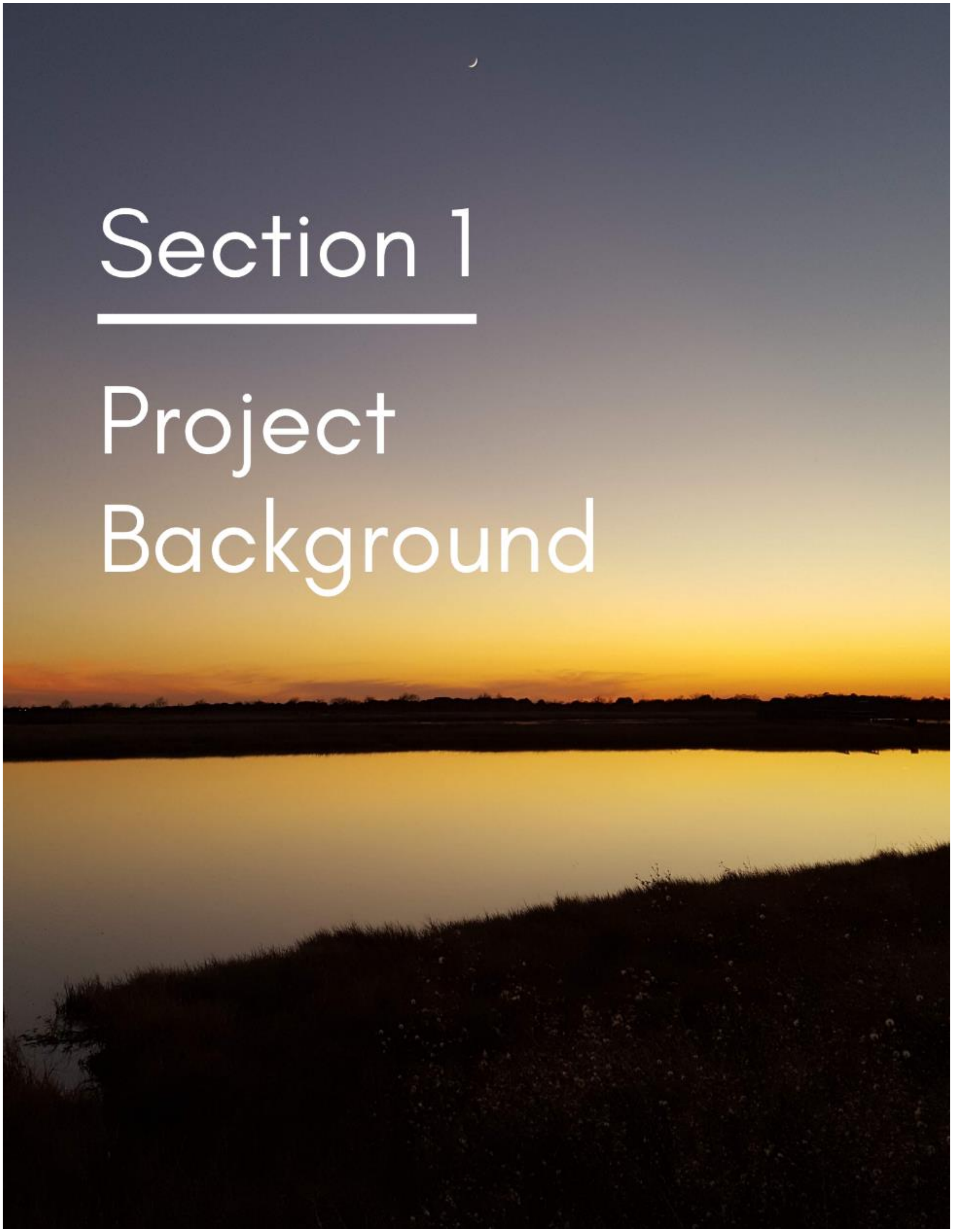
List of Acronyms and Abbreviations

AgriLife Extension	Texas A&M University AgriLife Extension
AgriLife Research	Texas A&M University AgriLife Research
AU	Assessment Unit
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
CBOD5	Carbonaceous biochemical oxygen demand, 5-day
CCFCC	Cypress Creek Flood Control Coalition
CFU	Colony-forming unit(s)
CRP	Clean Rivers Program
CWA	Clean Water Act
CTA	Conservation Technical Assistance (Program)
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FEMA	Federal Emergency Management Agency
FOG	Fats, oils, and grease
GBEP	Galveston Bay Estuary Program
GIS	Geographic Information System
HCFCD	Harris County Flood Control District
H-GAC	Houston-Galveston Area Council
HOA	Homeowners association
HUC	(USGS) Hydrologic Unit Code
I(X)	Interstate
Integrated Report	Texas Integrated Report of Surface Water Quality
LDC	Load Duration Curve
LID	Low Impact Development
MGD	Million gallons a day
MPN	Most probable number
MS4	Municipal separate storm sewer system

MST	Microbial source tracking
MUD	Municipal Utility District
NASS	National Agricultural Statistics Survey
NGO	Non-governmental organization
NPDES	National Pollutant Discharge Elimination System
NRCS	(United States Department of Agriculture) Natural Resources Conservation Service
OSSF	On-Site Sewage Facility
Partnership	The Cypress Creek Watershed Partnership
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental environmental project
SH	State Highway
SSO	Sanitary Sewer Overflow
SSOI	Sanitary Sewer Overflow Initiative
SWCD	Soil and Water Conservation District
SWQS	State Water Quality Standards
TCEQ	Texas Commission on Environmental Quality
TMDL	Total maximum daily load
TMN	Texas Master Naturalists
TPWD	Texas Parks and Wildlife Department
TPDES	Texas Pollutant Discharge Elimination System
TSS	Total suspended solids
TSSWCB	Texas State Soil and Water Conservation Board
TST	Texas Stream Team
TWON	Texas Well Owner Network
TWRI	Texas Water Resources Institute
TWS	Texas Watershed Stewards
USACE	United States Army Corps of Engineers (Galveston)
USDA NRCS	United States Department of Agriculture Natural Resources Conservation Service
USGS	United States Geologic Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility

Section 1

Project Background



1 – Project Background

Background

The Cypress Creek Watershed Partnership (Partnership) developed this watershed protection plan (WPP) to address water quality issues in Cypress Creek and its tributaries. The purpose of this planning effort is to use a watershed approach to identify and reduce sources of contamination in the watershed through effective, voluntary solutions.

A Watershed Approach

A **watershed** is generally defined as all the area of land that drains to a common body of water. Watersheds can range in size from the drainage basins of large rivers, to small catchments that may cover a few square miles of a local neighborhood. Regardless of the scale, they are more than just drainage boundaries. Watersheds are dynamic systems and represent the sum of everything that happens on that land. The way we use the land, the natural processes that take place on it, the way these things change over time; everything that takes place within a watershed influences the quality of the water that flows over it and into its water bodies (Figure 3).

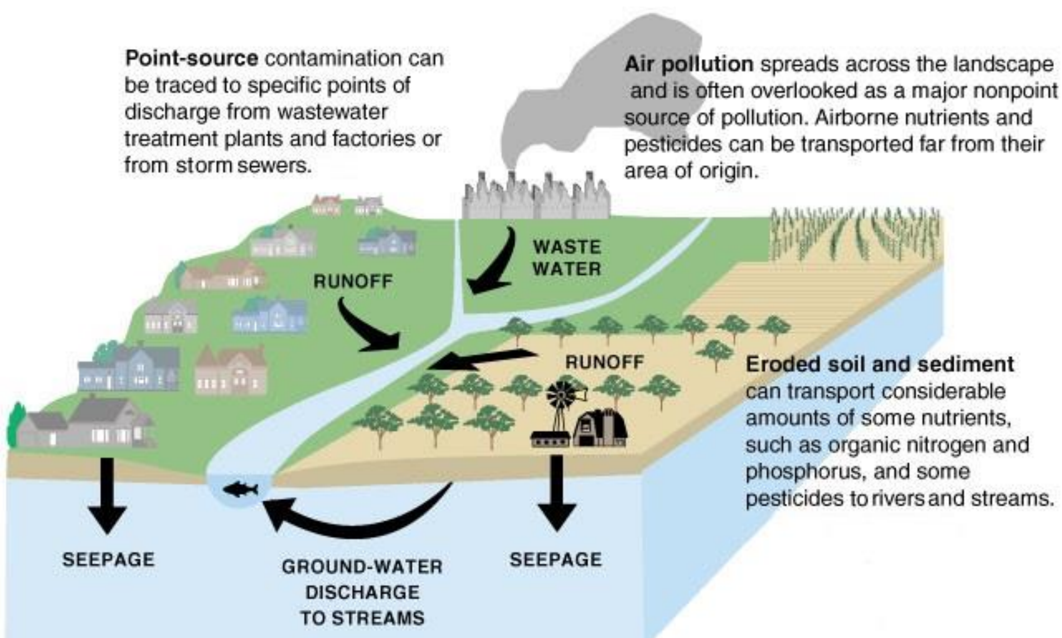


Figure 3 - Pollution sources in a watershed[1]

Because watersheds are determined by the topography of land rather than political boundaries, they often cross multiple political jurisdictions. Water is not bound by political

[1] Image courtesy of United States Geologic Survey (USGS).

geography; contaminants in water can travel freely across borders. Pollution entering the waterway in one part of the watershed can impact areas downstream. This fundamental aspect of watersheds limits the ability of individual political entities to wholly address sources of contamination in their waterways.

A **watershed approach** addresses water quality issues by focusing on both the waterways and their watershed as a linked system in which the drainage area's mix of land uses and potential sources of pollution are considered.

Benefits of a watershed approach are that it:

1) Reflects the connection between land and water,

2) Coordinates efforts by multiple political jurisdictions and focus resources on shared priorities, and

3) Helps stakeholders understand potential future impacts to waterways based on the changing character of their watershed.

In Texas, the watershed approach to address water quality issues is often employed through the development of a WPP.

Watershed Protection Plans

WPPs are planning documents that serve as a road map for local communities to take active stewardship of their surface water resources. In Texas, most WPPs are built on the United States Environmental Protection Agency's (EPA) Nine Element model[2], which outlines several key steps to characterizing a watershed, understanding its water quality challenges, and devising appropriate solutions. Developed through locally led planning projects, WPPs use scientific analysis and stakeholder knowledge to identify and characterize water quality priorities and identify voluntary solutions to meet specific goals. Unlike regulatory actions to restore water quality, the WPP process is a non-regulatory approach based on the use of voluntary management measures employed by local communities who have a stake in their waterways[3]. At the heart of the WPP process is a recognition of the value of natural benefits ("ecosystem services") provided by the watersheds.

Public participation is a core component of the WPP process because the successful implementation of a WPP relies on an engaged and committed stakeholder group.

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[2] More information on EPA's guidance for developing watershed-based plans can be found at https://www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters

[3] While there are no mandatory elements recommended by this WPP, local partners currently engage in regulatory activities that are supplemental to this project as part of their normal operations (e.g. enforcement of municipal pet waste ordinances).

Stakeholders are defined as any person or group in the watershed who has a defined interest in the waterway or who may be impacted by the water quality issues or the WPP recommendations. Stakeholders can include residents, elected officials, local governments, landowners, agricultural producers, recreation enthusiasts, businesses, and community groups. WPPs are best served by a diverse group of stakeholders who can represent the different interests in the watershed. The stakeholder group is often facilitated by state or regional organizations like Texas Commission on Environmental Quality (TCEQ) and Texas State Soil and Water Conservation Board (TSSWCB) who use their expertise in watershed management to guide the stakeholders' efforts. Funding for WPPs is often provided through federal Clean Water Act (CWA) grants, some of which require matching funds or in-kind time from local stakeholders.

Figure 3 - Stakeholders consider pollutant sources in the Cypress Creek Watershed

A Watershed Protection Plan for Cypress Creek

Water quality issues in the Cypress Creek system (Segment 1009) and local concern over the impact of future changes in the watershed were the impetus for undertaking a watershed-based plan. Previous projects in the greater Lake Houston Watershed area, including the Lake Conroe WPP[4], the East and West Forks of the San Jacinto River Total Maximum Daily Load

[4] More information on this project can be found at http://www.sjra.net/wp-content/uploads/2014/12/Lake-Conroe-Watershed-Protection-Plan.pdf

(TMDL)[5], and the West Fork San Jacinto River and Lake Creek Watershed Protection Plan[6], had established there was local interest and commitment to address water quality. The desire to evaluate these areas on a local level for Cypress Creek, and to consider other local concerns, led to the formation of the Partnership in 2019. The WPP model was chosen for its ability to address other local concerns in addition to state water quality standard (SWQS) impairments and for its voluntary nature. Additionally, the intent to coordinate water quality issues with community concerns about hydrologic issues and repetitive flooding were at the forefront of local considerations.

The Cypress Creek Watershed Partnership

The Partnership is a group of local stakeholders from various interests and partner agencies committed to protecting the public health, economy, and environment of their communities. Local facilitation of the Partnership was supported by the Houston-Galveston Area Council (H-GAC) as part of a joint project with TCEQ, funded through a CWA §319(h) grant from EPA. The Partnership is a voluntary association of stakeholders, holding no regulatory power. This WPP is a summary of the multi-year planning effort conducted by the Partnership and serves as guidance for future implementation activities. Using the watershed planning model, this plan is based on local decision-making supported by local knowledge, robust public participation, and technical and scientific analysis.

The Partnership held seven full Partnership meetings and two sets of topical Work Group meetings between July 2019 and August 2020 to discuss and provide feedback on a variety of water quality issues[7] (Table 1). Representation from a diverse range of local stakeholders ensured that recommendations of the group were vetted from multiple viewpoints and interests. All meetings were open to the public, and materials were disseminated on the project website[8] and via email. A core group of stakeholders served as a Steering Committee, and the meetings operated under a set of ground rules spelled out in the project's public participation plan[9]. Topical Work Group meetings were held as needed throughout the project to allow for detailed conversation on specific topics. Work Groups made

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[5] More information on this project can be found at https://www.h-gac.com/watershed-based-plans/east-and-west-forks-of-the-san-jacinto-river-tmdl-and-implementation-plan

[6] More information on this project can be found at https://westfork.weebly.com/.

[7] More information on the individual meetings and process can be found in the project documents at www.cypresspartnership.com and summarized in the project's Stakeholder Outreach Report at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_creek_wpp_stakeholder_outreach_report_final.pdf.

[8] *Ibid.*

[9] Which is available for review at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/public_participation_plan_cypress_creek_wpp_6_19_19.pdf

recommendations to the full Partnership for items that required more detailed knowledge or deeper deliberation.

Table 1 - Meetings of the Cypress Creek Watershed Partnership

Date	Meeting Type	Topic(s)
7/23/19	Partnership (central location)	Introducing the project, water quality data review, invitation to nominate Steering Committee.
7/23/19	Partnership (western location)	Introducing the project, water quality data review, invitation to nominate Steering Committee.
9/26/19	Partnership	Steering Committee formation, water quality and sources review and discussion
11/14/19	*Work Groups (2 - Human Sources; Agricultural and Wildlife)*	*Discussed partner resources and efforts, bacteria sources, recommendations to the Partnership.*
11/21/19	Partnership	Modeling review, discussion of sources and work group recommendations
1/16/20	Partnership	Discussed final modeling results and interim approval, began discussion of solutions.
3/12/20	*Work Groups (3 – Human Sources; Agriculture and Wildlife; Open Group)*	*Discussion of potential solutions, recommendations to Partnership.*
5/28/20	Partnership (virtual)	Discussion of Work group recommendations, solutions for bacteria, and logistics for solutions.
8/5/20	Partnership (virtual)	Interim approval of solution list, discussion of logistics, discussion of WPP development.

In addition, project staff held meetings with local stakeholders and groups to gather more local knowledge and seek additional feedback. Local agencies and other organizations (e.g., local Soil and Water Conservation Districts) served as non-voting technical advisors who helped provide expert knowledge and guidance to support the Partnership and coordinate its efforts with other local projects. In addition to formal Partnership and stakeholder meetings, project staff supported the efforts of the Partnership by engaging the public at local outreach events throughout the project.

Water Quality Goals

As part of developing the WPP, the Partnership developed a set of water quality goals that shaped their approach. Subsequent sections of this WPP expand on the details of how the Partnership established recommendations to meet these aims, and how they will be implemented, but the broad water quality goals for the Partnership are:

- *Plan for 2035* — The stakeholders balanced the need to account for future growth in this developing watershed with the potential uncertainty of future projections past a 15-year window. Based on the level of water quality issues, the likely path of development in the watershed, and the need to phase implementation over time to reduce local burden, 2035 was selected as the end of the planning horizon. The stakeholders and project staff consider this a viable timeframe based on WPPs approved for similar developing areas.

- *Reduce fecal waste* — Potential fecal pathogens, as measured by the bacteria species *E. coli* as an indicator of fecal waste, are the primary focus of the Partnership due to their potential impact on human health, presence as an impairment for many of the segments of the watershed, and relationship to causes and sources within the scope of the voluntary WPP effort. The focus of this WPP is to reduce excess levels of human and animal waste in the water for the sake of public health, recreational economy, and regulatory compliance with the SWQS for contact recreation of a 126 cfu/100 ml *E. coli* geomean. This goal involves identifying and quantifying causes and sources of fecal waste and developing recommended best practices sufficient to meet modeled reduction goals. The priority goal of the WPP is to improve and maintain *E. coli*[10] levels at or below the contact recreation standard (primary contact recreation 1).
- *Improve dissolved oxygen* — Dissolved oxygen (DO) levels are important for maintaining aquatic communities. The goal is to recommend solutions to improve DO levels.
- *Reduce excessive nutrients* — Nutrients (phosphorus and nitrogen compounds) are potential sources of depressed DO due to their role in algal blooms. Nutrients do not have water quality standard numeric criteria associated with them though they may lead to a DO impairment. Because no DO impairment exists for the assessed water bodies of this system, the stakeholders elected to make nutrients a secondary concern. Efforts to reduce nutrients are not modeled or quantified, but instead expected as a secondary benefit from many fecal waste reduction solutions.
- *Address other stakeholder concerns* — The WPP model allows for the consideration of other local water quality issues outside SWQS impairments and concerns. No modeling or specific quantification was conducted for stakeholder concerns, but the goal of the project remains to support or selectively implement related best practices to reduce issues as appropriate. Specific concerns include trash and illegal dumping, sediment, and impacts from hydrologic issues in the watershed.

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[10] Throughout this WPP, "bacteria" or "*E. coli*" should be taken to mean *E.* coli in its role as an indicator of fecal waste and its associated pathogens in water rather than specifically attributing potential health impacts to *E. coli* ..

Guiding Principles

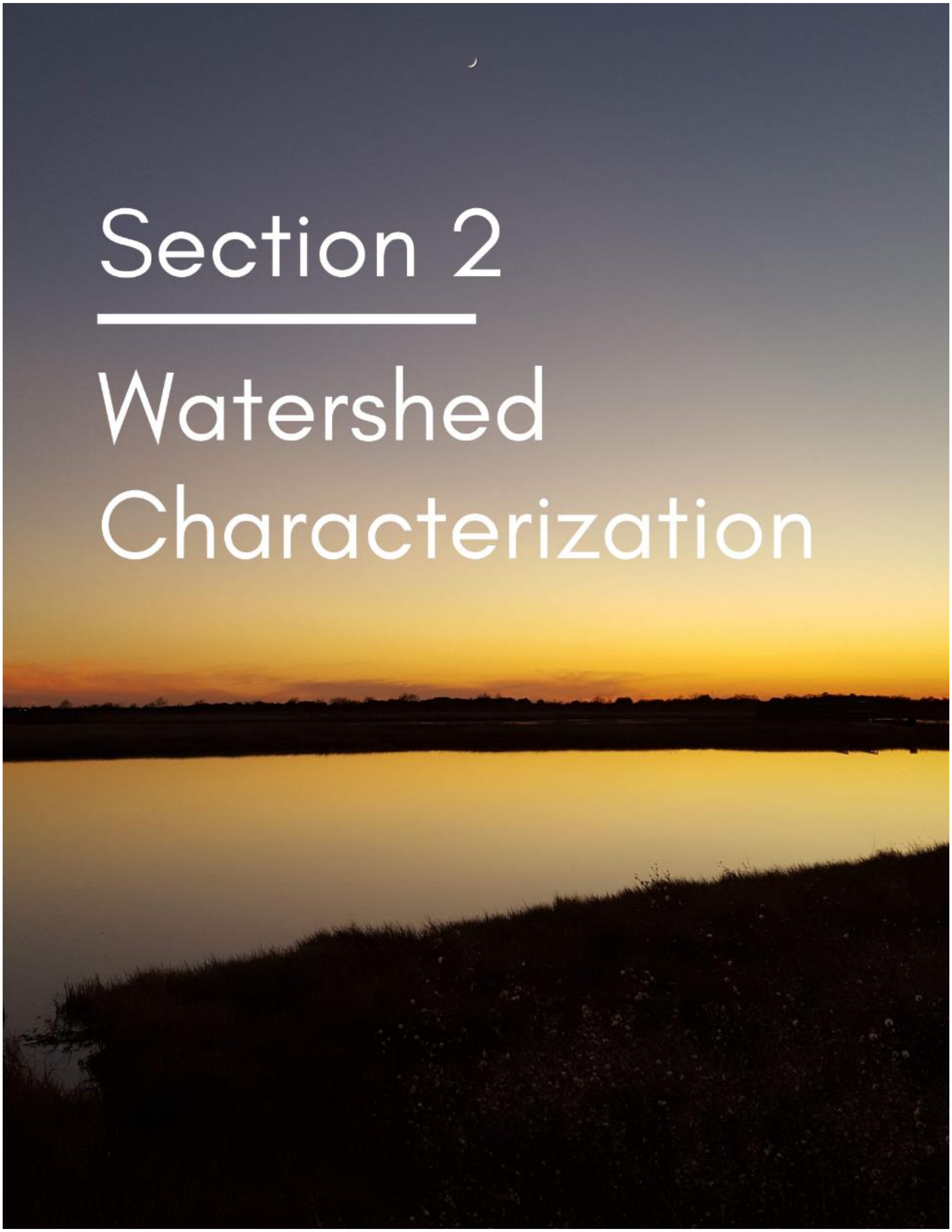
In addition to the water quality goals, the Partnership detailed some guiding principles throughout the development of the WPP. Those principles include an emphasis on:

- **Distinct areas** — While the various elements of the Cypress Creek Watershed are part of a single system, areas within the system are unique in character and challenges. The consideration of the differing needs of these watershed areas is built into this WPP process and recommendations.
- **Locally-led decisions** — While project staff and other parties may provide information and guidance to the stakeholders, the ultimate decisions for the WPP, within the bounds of the WPP model, will be made by local stakeholders.
- **Voluntary solutions** — The WPP will only include recommendations that are voluntary. Neither the Partnership nor H-GAC will exercise any regulatory mandate through this WPP.
- **Use what works** — Where existing programs with proven success are available, they should be used. The Partnership will seek to coordinate efforts with similar projects to ensure a limitation to redundant efforts. The Partnership recognizes and respects the efforts of local agencies, organizations and individuals and seeks to support rather than supplant them.
- **Coordination is key** — an extensive amount of activity is occurring in the watershed, both in terms of development and mitigation activities for hydrologic and environmental factors. Because of the density of actions and actors, this WPP seeks to the highest degree practicable to coordinate its aims and recommendations with related or adjacent efforts.
- **Education and outreach are vital** — Education and outreach are an important part of fostering the implementation of the WPP, and an essential element in its future success. The Partnership will seek to be transparent and build relationships with the community at every feasible opportunity.

Based on these water quality goals, and guided by the principles, the Partnership developed the recommendations and considerations contained in this WPP.

Section 2

Watershed Characterization



2 - Watershed Characterization

The character of a watershed is the sum of the natural features of the land, the human elements that interact with them, and the relationship these factors have with water quality. Understanding the relationship between the waterways and the land that drains to them is the first step in understanding the causes and sources of pollution and identifying effective means to address them. Evaluating all elements and factors that shape the connection between land and water is part of a watershed approach to improving water quality.

Geography

The Cypress Creek Watershed is located in portions of northern Harris County and eastern Waller County of the Upper Gulf Coast of Texas. On the northwest side of the Houston-Galveston region, this drainage area is connected to the Houston metropolitan area by State Highway (SH) 99, United States Highway (US) 290, SH249, and Interstate 45 (I45) transportation corridors.

Regional Context

Cypress Creek and its network of tributaries are part of the broader West Fork San Jacinto River Basin (Segment 1004) between Lake Conroe to the north, and Lake Houston to the south (Figure 5).

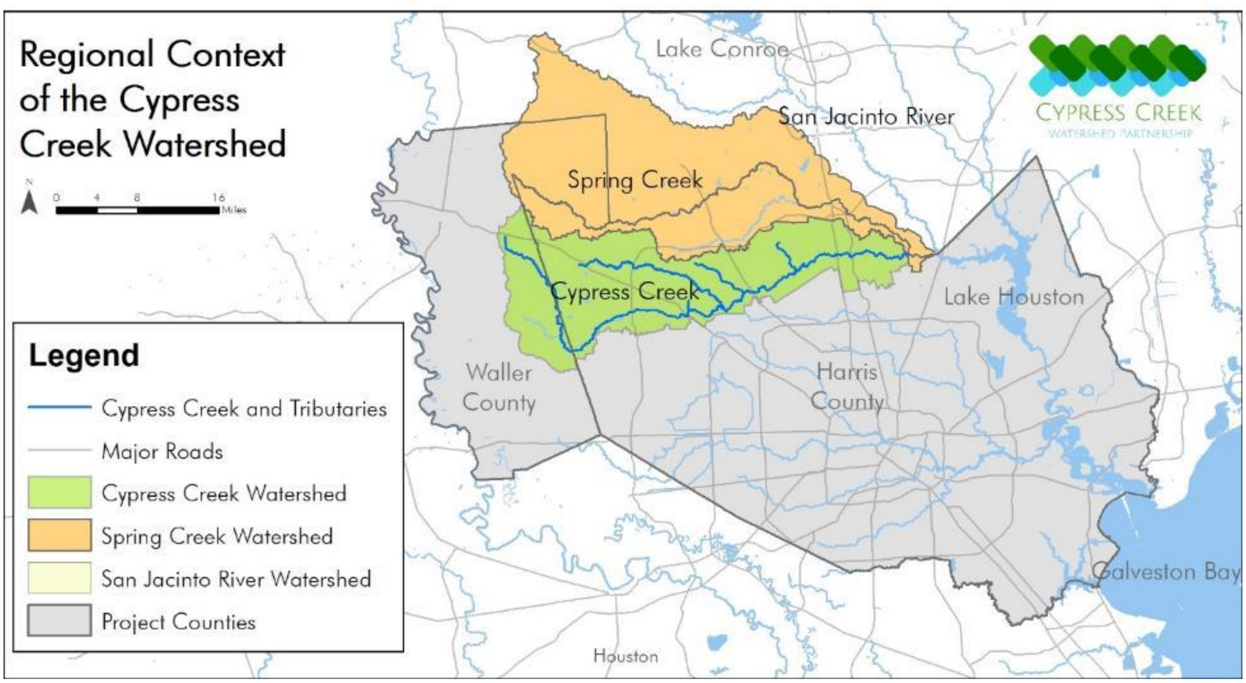


Figure 4 - Regional context of the Cypress Creek Watershed

Cypress Creek flows into Spring Creek directly upstream of that waterway's confluence with the West Fork of the San Jacinto River and Lake Houston. Lake Houston's prominence as a drinking water source, recreational venue, and as an integral part of the complicated hydrology of the San Jacinto River Basin make the contributions from Cypress Creek and other tributaries especially important in a regional context.

Watershed Delineation

The Cypress Creek Watershed was delineated using a combination of existing data, map review, and field observations (Figure 6). The primary watershed and subwatershed delineations were developed from Harris County Flood Control District (HCFCD) watershed layers, with minor adjustments to reflect conditions on the ground, to segregate tributaries, and to normalize subwatershed size. Harris County data was compared with United States Geologic Survey (USGS) Hydrologic Unit Code (HUC) 12 and 10 data, and other local sources. In an evaluation of the different layers against aerials and known hydrologic boundaries, the HCFCD data was closest to expected actual drainage patterns in this highly modified system. Staff members conducted map surveys using HCFCD maps of drainage conveyances, online mapping (Google Maps/Google Streetview), and limited field reconnaissance to confirm assumptions. While HCFCD data considers Little Cypress Creek a separate but related part of the system, the WPP project includes this tributary because it is part of Segment 1009 and there is no reason to exclude it based on water quality considerations.

One complication for this system is the existence of an "overflow" from the Cypress Creek system into the adjacent Addicks Reservoir/Buffalo Bayou system to its south. Because the streamflow from the overflow[11] is out of the system (i.e. not introducing flow or contaminants into the system) and the outflow is only relevant in severe rainfall events, project staff did not consider it to be a concern for the final delineation of the watershed boundary.

[11] For greater information on the overflow and its management by HCFCD, please refer to https://www.hcfcd.org/Find-Your-Watershed/Cypress-Creek/Cypress-Creek-Overflow-Management-Plan .

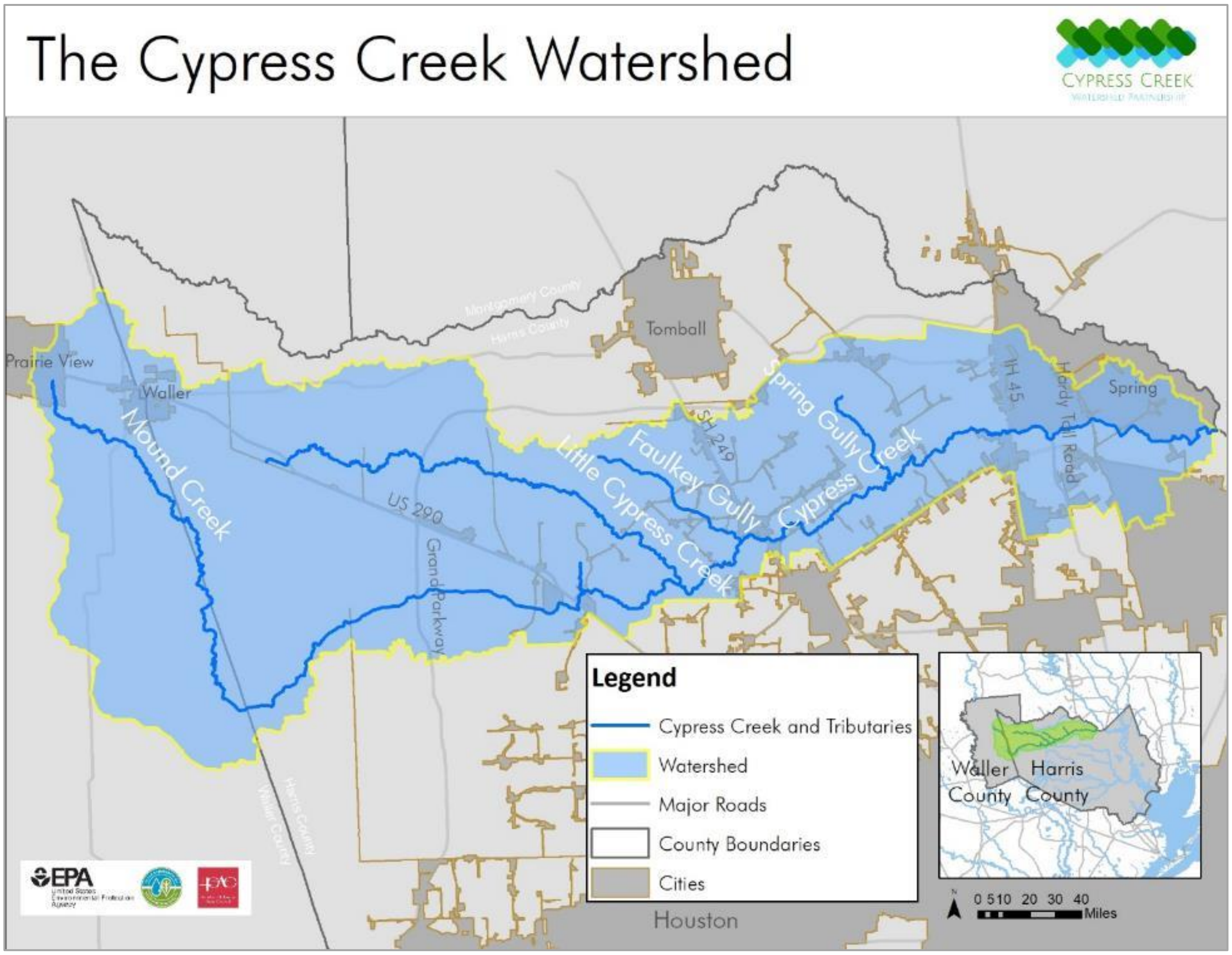


Figure 5 - The Cypress Creek Watershed

Subwatersheds were delineated from a selection of existing and continuing water quality monitoring stations to ensure the ability to evaluate these areas during the implementation of the WPP (Figure 7). Considerations for the selection of the stations were their ability to represent different areas of the watershed, the natural hydrologic elements of the watershed (e.g., major tributaries), and appreciable areas of developmental or land cover type, and general comparability in size. The resulting subwatersheds balance these interests, with the highest priority given to representation by ongoing monitoring stations at their terminal ends.

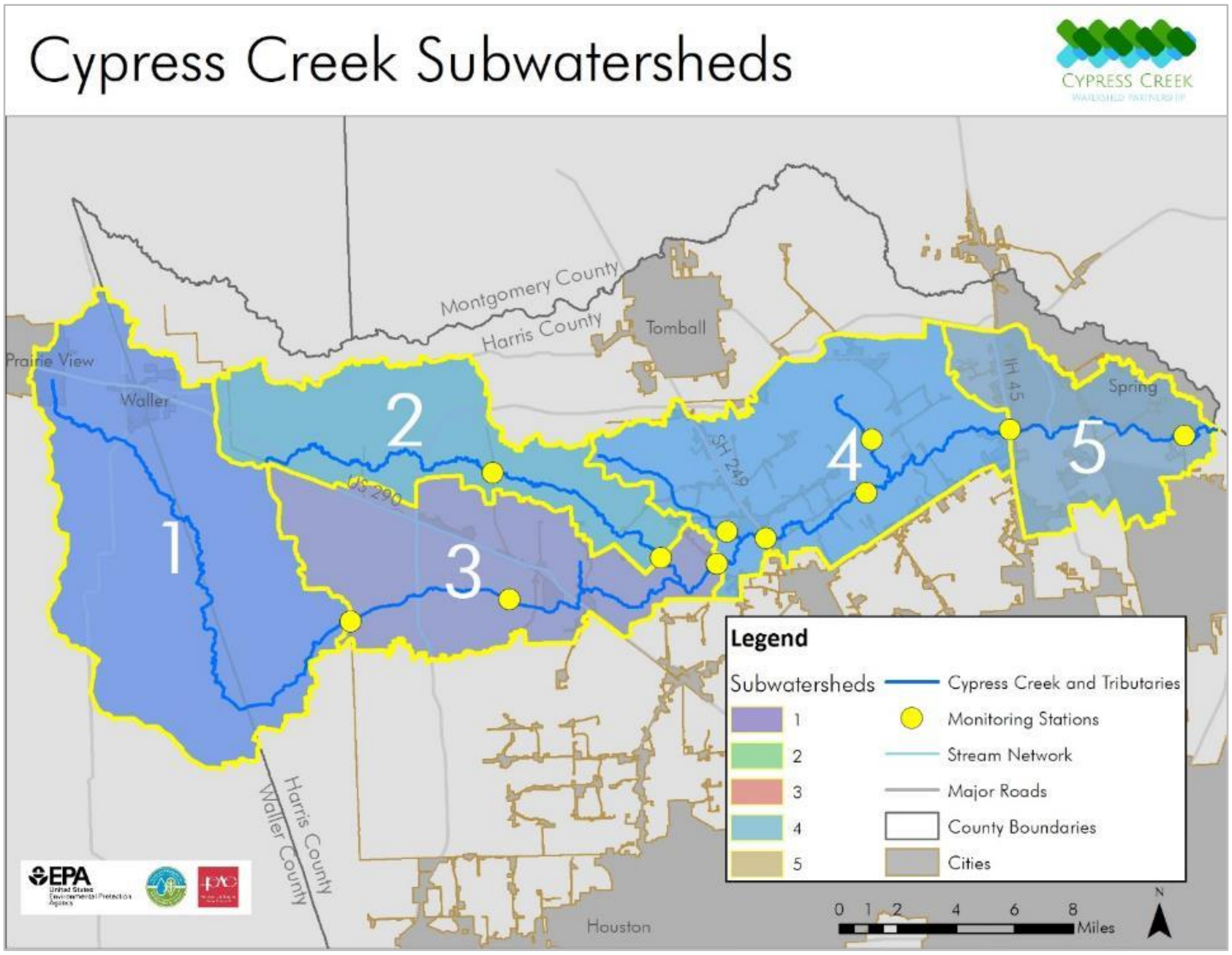


Figure 6 - Cypress Creek subwatersheds

WPP Drainage Area and Stream Network

The full drainage area of the Cypress Creek Watershed is over 319 square miles and the stream network that makes up its drainage system is 554 linear miles of waterways, making it one of the larger watersheds in Harris County (Figure 8). The drainage network includes both natural streams, modified waterways, and manmade drainage (channels and storm sewer systems) of varying size. Each of Cypress Creek's primary tributaries (Mound Creek, Little Cypress Creek, Faulkey Gully, and Spring Gully) are themselves networks of smaller tributaries and drainage conveyances.

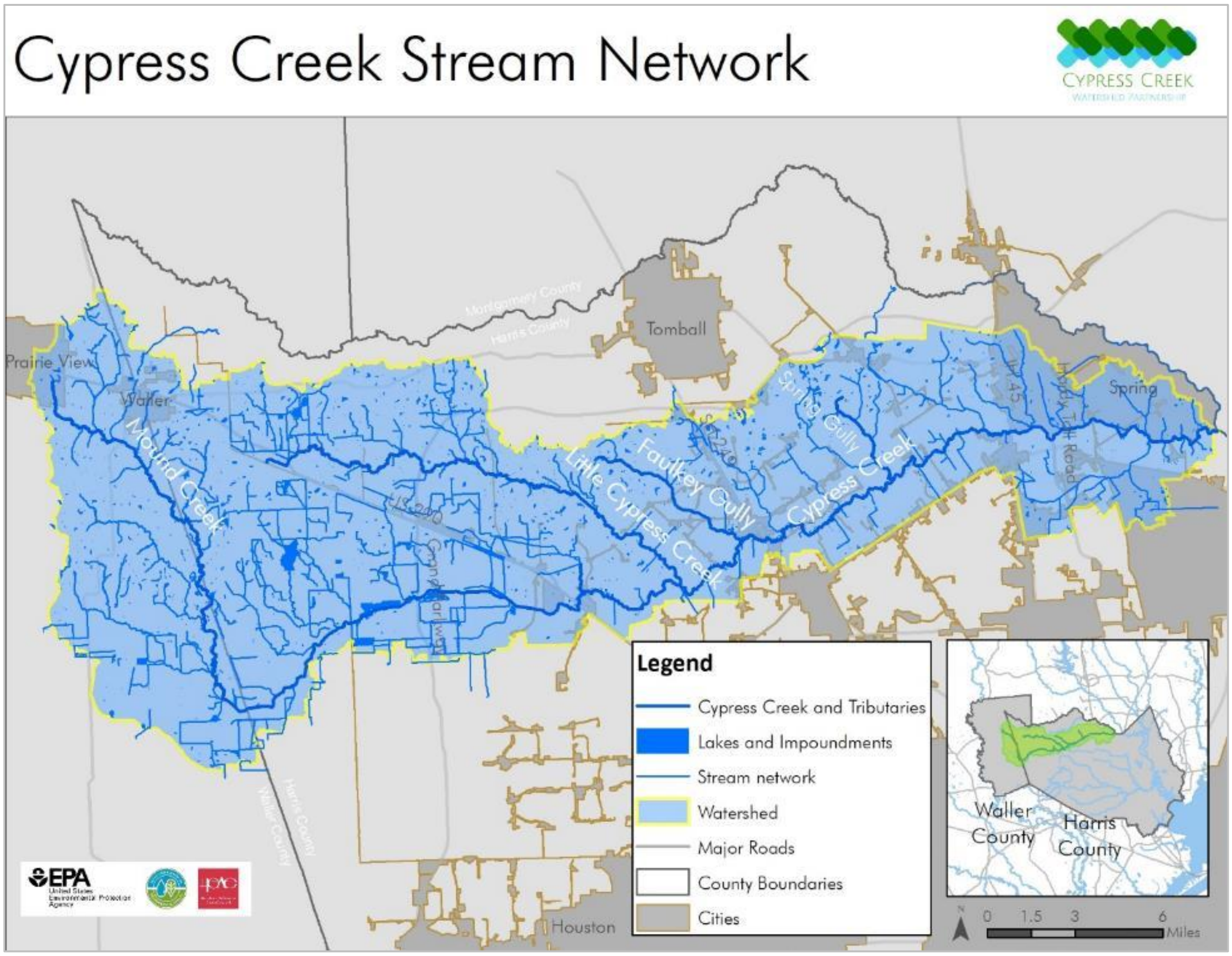


Figure 7 - Cypress Creek Watershed stream network

The main channel of the Cypress Creek starts as a small series of tributaries (including Mound Creek, its primary upstream contributor) in the rural areas of eastern Waller and northwestern Harris County. Drainage in this area contains a mix of small natural tributaries and modified drainage channels from agricultural activity and roadways. The Cypress Creek overflow[12] into the Addicks Reservoir/Buffalo Bayou system begins to occur as the waterway makes its transition from a southerly flow to the east-northeasterly direction it will maintain for the rest of its length. The creek itself has been dredged and modified in many locations.

As it progresses through the Katy Prairie area east of the Brazos River and south of US 290, the waterway grows in size. As the main channel passes into the transitional zone of

[12] For more technical details on the hydrology of this overflow, please refer to the Harris County Flood Control District's *Final Study Report: Cypress Creek Overflow Management Plan*, located online at https://www.hcfcd.org/Portals/62/Watershed/Cy-Creek/cypresscreekoverflowreport_fin2.pdf?ver=2019-10-23-112853-617

development east of SH99 (Grand Parkway), the waterway is a moderately sized creek in normal flow conditions, though its presence and floodplain are much more expansive in high rainfall events. Between SH99 and US290 the waterway begins to receive stormflow from large suburban developments. By the confluence of Little Cypress Creek west of SH249, the creek has broadened, and exhibits sandy banks. Throughout this stretch it is still a sinuous waterway, albeit with some hydrologic modification in areas and riparian buffers of varying size. Throughout the rest of its meandering path it retains this character, although the area it traverses is primarily denser subdivision and commercial development. Immediately upstream of the confluence with Spring Creek there are broader undeveloped areas, but the system still receives appreciable flow from surrounding suburban storm sewer systems[13].

The stream network of the Cypress Creek Watershed contains many primary tributaries[14] (Figure 9). These include, from west to east:

- Mound Creek (1009F) — Mound Creek represents a portion of the headwaters for Cypress Creek, effectively becoming Cypress Creek just west of the Harris County line in the Katy Prairie, at its confluence with Snake Creek. It is primarily characterized rural/agricultural or undeveloped uses, excepting some flow coming from urbanized areas of the City of Prairie View.
- Little Cypress Creek (Segment 1009E) — Little Cypress Creek's headwaters have a mix of land cover in the middle third of the watershed, but quickly transition from rural and agricultural uses to suburban areas.
- Faulkey Gully (Segment 1009C) — Faulkey Gully is a heavily modified waterway primarily serving as a drainage conveyance amidst dense suburban development.
- Spring Gully (Segment 1009D) — Spring Gully is also a heavily modified waterway primarily serving as a drainage conveyance amidst dense suburban development.

[13] Pictures of the waterway at monitoring stations along its length are included in the *Cypress Creek Water Quality Data Collection and Trends Analysis Report* produced for this WPP project, which can be accessed on the project website at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_water_quality_trends_report_final.pdf.

[14] The primary tributaries discussed here are the unclassified segments which are assessed by TCEQ, and are the more prominent tributary systems in the watershed. Additional named tributaries exist in the watershed but are considered part of the general drainage network for the purpose of this WPP, including unclassified tributaries Dry Creek (1009A), Pillot Gully/Dry Gully (1009B), and Dry Gully (1009G) and other waterways such as Senger Gully and Lemm Gully.

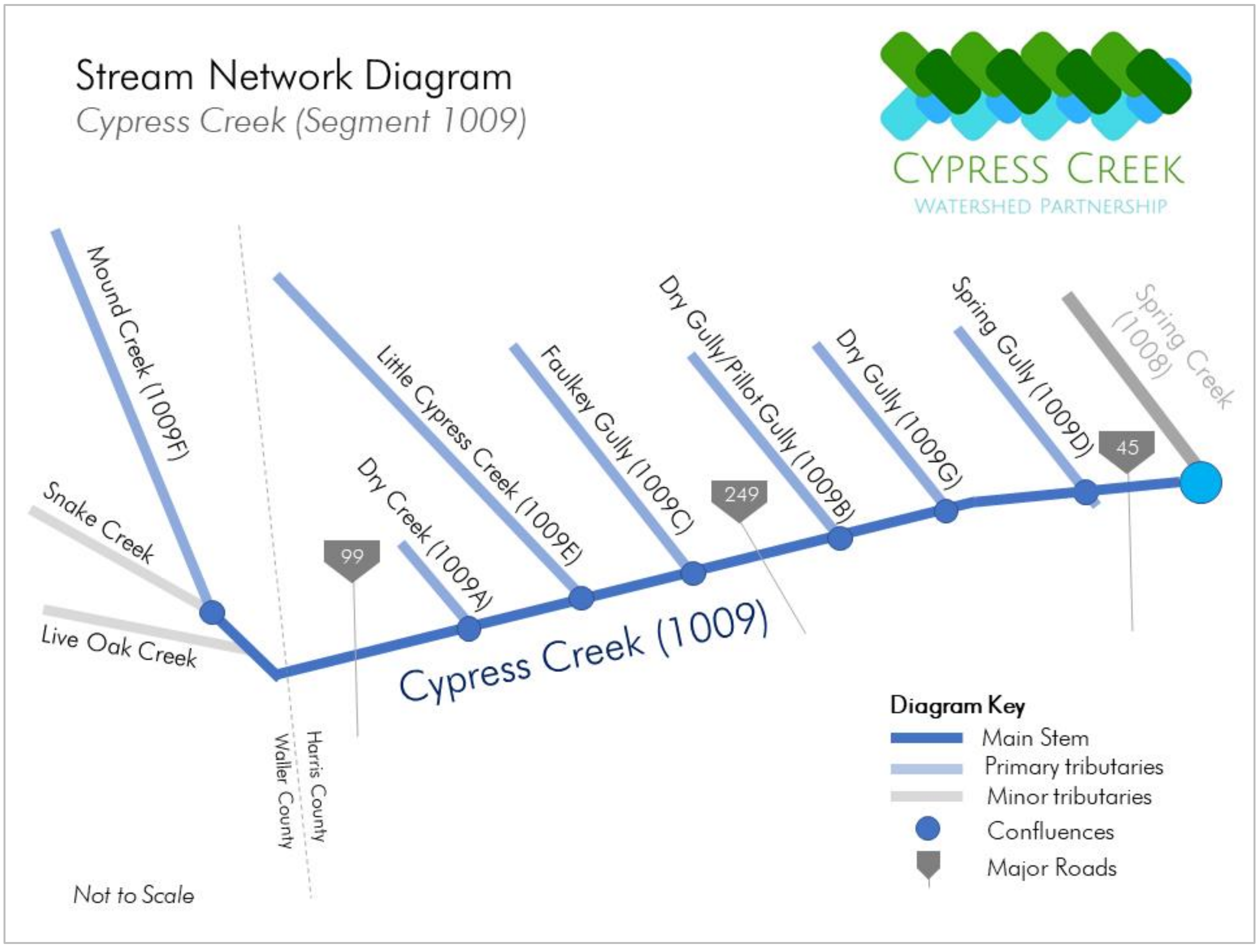


Figure 8 – Stream network representation for Cypress Creek

Recreational paddling and fishing are common on the main stem, and recreational trails are widespread and increasing in its riparian corridors. Some foot trails also exist along the modified drainage conveyance tributaries. The system in general supports a high-quality aquatic ecosystem. Despite the rapid and expansive development along the transportation corridors, much of the waterway maintains a wooded riparian buffer, especially downstream of Highway 99 as it passes out of agricultural areas. However, the riparian buffers on the waterway vary greatly in extent, and for much of the latter half of the waterway receives runoff directly from stormwater outfalls, bypassing riparian areas.

Political Geography

The Cypress Creek Watershed includes a mix of land uses, with a primarily rural western third, a transitional middle third, and a densely suburban/urban lower third. While the watershed overlaps portions of some cities or census-designated place communities (City of Prairie View, City of Waller, City of Houston, City of Tomball, and Spring; Figure 10) the primary urbanized areas are a conglomeration of communities represented by special districts (municipal utility districts, water control and improvement districts, utility districts, etc.) or private utilities within unincorporated Harris County. There are over 190 of these districts or communities that provide water or sewer service within the watershed, ranging from small municipal utility districts (MUDs) representing single neighborhoods, to large master-planned communities (Figure 10; Bridgeland, and others). These areas are the predominant form of residential development in the watershed by area and population, and the watershed in general does not have a strong traditional municipal presence. Much of the higher-level political management of the watershed area is in the jurisdiction of the counties.

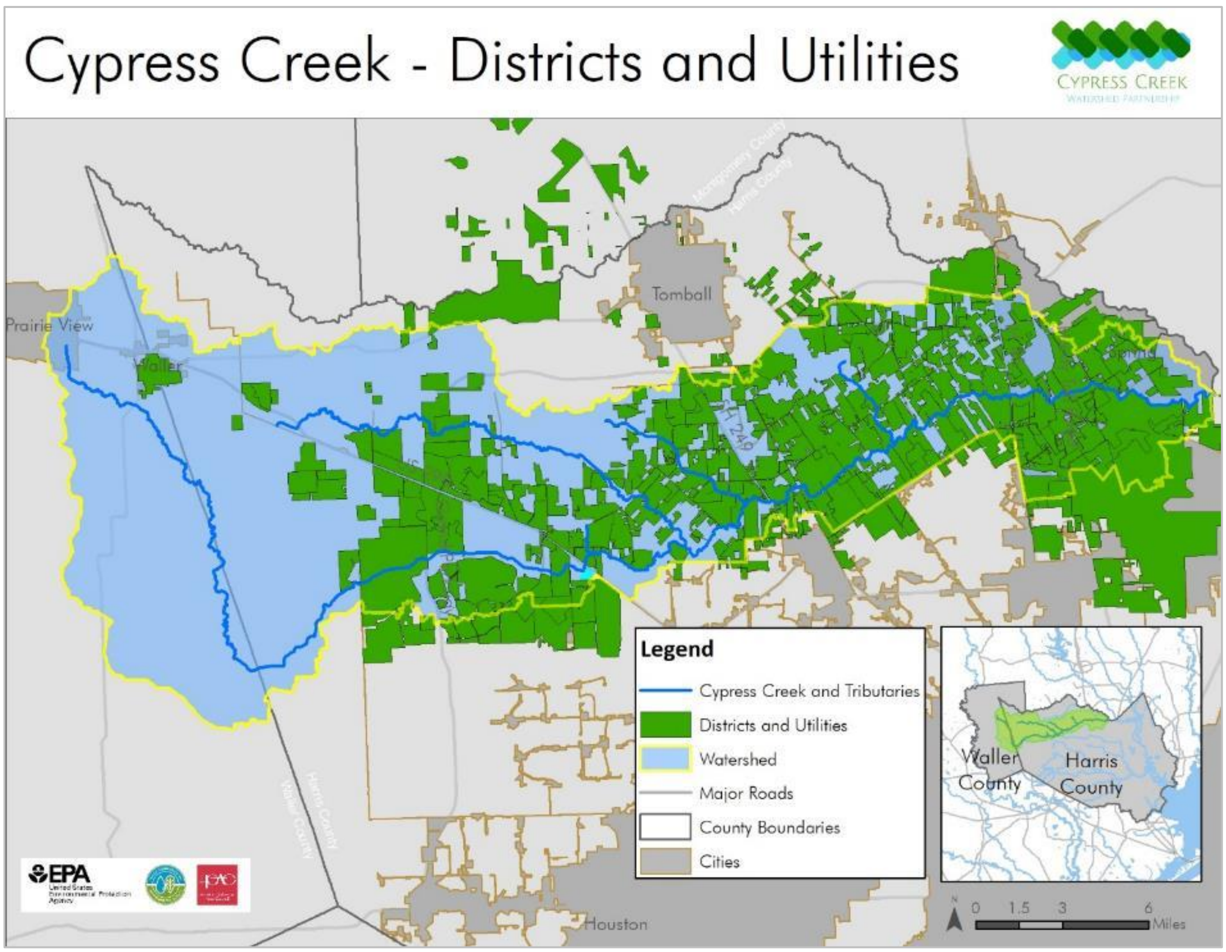


Figure 9 - Districts and utilities

The watershed includes portions of Harris County Commissioner Precincts 1, 3, and 4; the Harris County Flood Control District; and Waller County Precincts 2 and 3. Representation at the national level includes United States House of Representatives Districts 2, 7, 8, 10, and 18 (in addition to the United States Senate general representation). Representation at the state level includes Texas House of Representatives Districts 3, 126, 127, 130, 132, 135, 139, 141, and 150; and Texas State Senate Districts 4, 7, 15, and 18. In addition, the watershed overlaps the service area of a variety of other districts and authorities, including the North Harris County and West Harris County Regional Water Authorities, the San Jacinto River Authority, the Coastal Water Authority, the Harris County Flood Control District and Brookshire-Katy Drainage Districts, the Harris County and Navasota Soil and Water Conservation Districts, several independent school districts, and a number of other special purpose districts.

Much of the population growth in the watershed has followed the major transportation corridors of I45, SH249, US290, and SH99. The completion of a section of the latter between I10 and US290, has accelerated growth westward into the Katy Prairie. The focus of new development is westward, as growth continues to push out of the urban core of Houston. Development in the eastern portion of the watershed, especially east of US290, is primarily densely suburban in character, with some smaller industrial areas. Development and governance between SH249 and SH99 are a mix of traditional rural communities, exurbs, and denser development downstream. While the primary development upstream of SH99 is still light rural residential, agricultural, or undeveloped areas, development is pushing rapidly into this area and its eastern edges are in transition, with development continuing to follow along major east-west corridors like FM529.

Water Rights

Water quality is the focus of this WPP, rather than issues of water supply. However, the Cypress Creek Watershed is a conduit for water augmenting public water supplies in Lake Houston, via Spring Creek and the West Fork San Jacinto River, and relies on water levels to support aquatic life and recreation. Therefore, considerations related to water supply in this watershed can potentially impact water quality.

Texas grants the right to use waters of the state (including waterways like Cypress Creek) through water rights permits. There are nine water rights permits with diversion points in the Cypress Creek Watershed, representing a mix of on-channel reservoirs (impoundments) and diversion points. The impoundments represent a mix of legacy, small agricultural or recreation impoundments as well as those used as part of current development. The maintenance of the 3,931 acre-feet of existing impoundments are not likely to have an impact on average flows in Cypress Creek except potentially in extreme drought conditions, especially as some (approximately 1,360 acre-feet) are used primarily for beneficial purpose of maintaining wetlands and habitat by the Katy Prairie Conservancy and partners. The next largest portions are existing impoundment rights now held by Bridgeland Development, LP and a private family trust. There are approximately 6,113 acre-feet of permitted yearly diversions from the creek, some portion of which are used to maintain the existing impoundments or are taken from them (Table 2). The largest single water diversion right in the watershed is held by Bridgeland Development, LP who is authorized to divert 2,941 acre-feet of water per annum.

Table 2 - Water rights on Cypress Creek

Permit	Permittee	Impoundment (in acre-feet)	Diversion (in acre-feet)	Priority Date
3962	GeoSouthern Intermediate Holdings, LLC	48	NA	1979
3963	David and Pamela Nelson/Katy Prairie Conservancy	220	500	1950
3964	Katy Prairie Conservancy/Warren Family	640	200	1961/1952
3965	Bridgeland Development, LP	1,408	2,941	1951
3966	Bridgeland Development, LP	25		1977
3967	LMJCO, Inc.		100	1963
3968	Harris County	90	96	1956
5514	Katy-Cypress Wetlands Mitigation LLC	500	NA	1995
5644	Alfred P Hegar Childrens Trust/Frank L Hegar Nieces and Nephews trust	1,025	2,250	1999

While these water rights represent appreciable volumes, their primary use is not municipal water supply. Most of the municipal surface water supply in the watershed is provided by the West Harris County and North Harris County Regional Water Authorities, and San Jacinto River Authority from water supplies maintained in the Lake Conroe to Lake Houston system.

Flood Mitigation

Stormwater and flood management in Harris County is a complex web of overlapping jurisdictions, including the county/HCFCD, individual municipalities, and others. Hydrologic complications like its overflow to Addicks/Buffalo Bayou, and robust growth increasing impervious cover in its western extent, complicates management of flood events, and expansive growth has reduced the capacity of the area to absorb rainfall. Approximately 108 square miles, about 34% of the watershed's total area, is within the Special Flood Hazard Areas (100-year floodplain) or 0.2 Percent Annual Chance Flood Hazard areas (500-year floodplains) based on 2015 Federal Emergency Management Agency (FEMA) data[15] (Figure 11). However, recent events like the floods of 2015 and 2016, and Hurricane Harvey have shown that storms and floods of greater magnitude can always occur and therefore the mapped floodplains do not always accurately account for flooding potential in the watershed. Cypress Creek has seen repetitive flooding in recent years, and flood mitigation is a primary

[15] FEMA National Flood Hazard Layer; spatial dataset of flood zones.

source of concern for watershed stakeholders. Areas in which flooding is unexpected may be especially vulnerable to erosion or other flood damage and have pollutant sources not designed for potential flooding situations. Federal, state and local government, non-governmental organizations (NGOs), and individual communities are currently engaged in substantial efforts to mitigate flood risks along Cypress Creek. This WPP is not intended to address hydrologic concerns in the Cypress Creek system, but the extent of local concern and ongoing efforts produces a unique opportunity to coordinate water quality and water quantity decisions for current and future implementation. Efforts to address flooding in the system may alter flow or change the physical conditions of the waterway. While many potential impacts cannot be fully known in advance, coordination with flood mitigation efforts will be important for this WPP to ensure our stakeholder decisions continue to be well informed and effective.

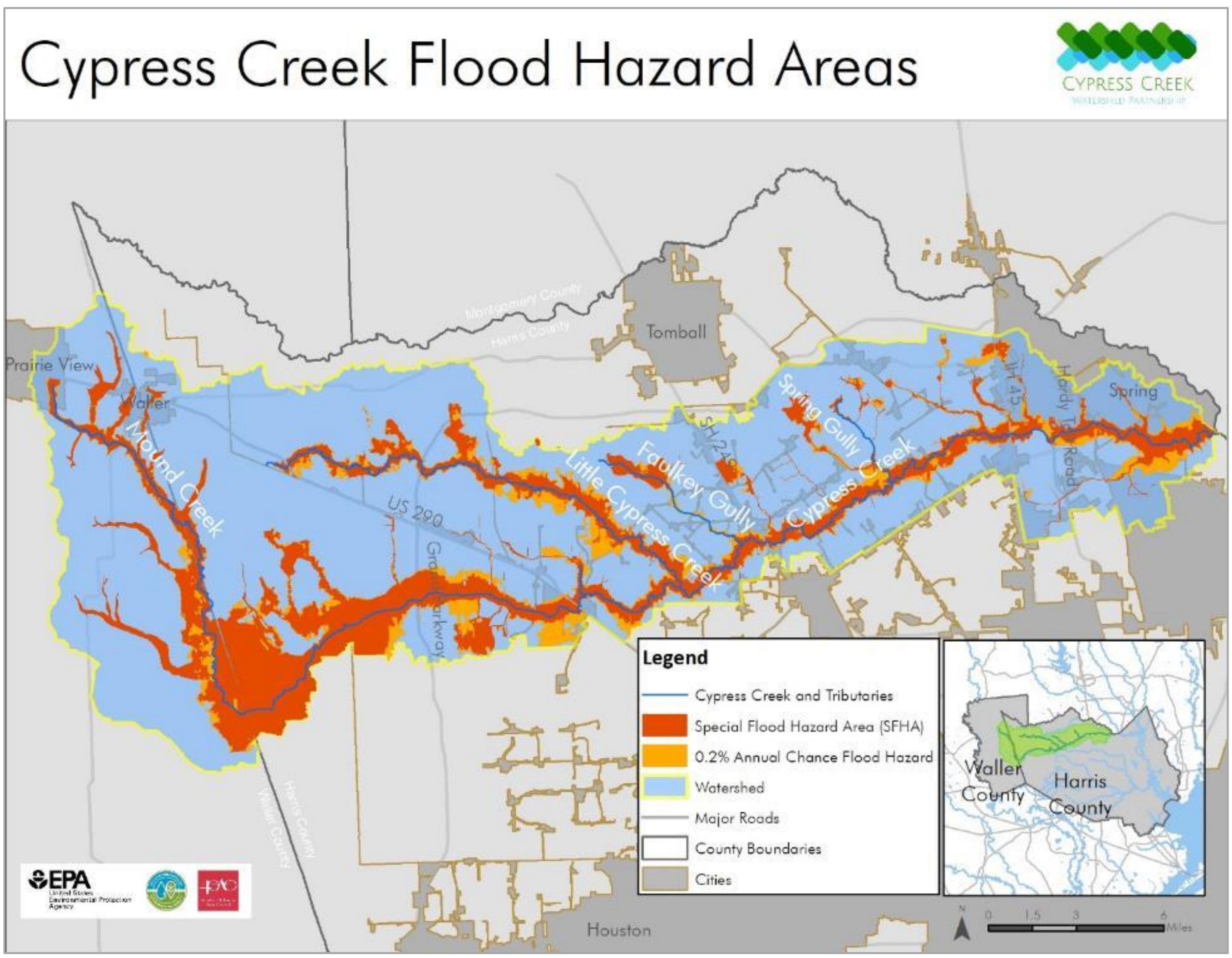


Figure 10 - Cypress Creek Flood Hazard Areas

Physical and Natural Characteristics

The physical aspects of watershed areas can impact how natural processes and effects of human development affect water quality.

Topography

The watershed area is in the Gulf Coast Plains of Texas. As such, it experiences relatively low topographical variation, although it has greater relief than areas closer to the coast in the Houston-Galveston region (Figure 12).

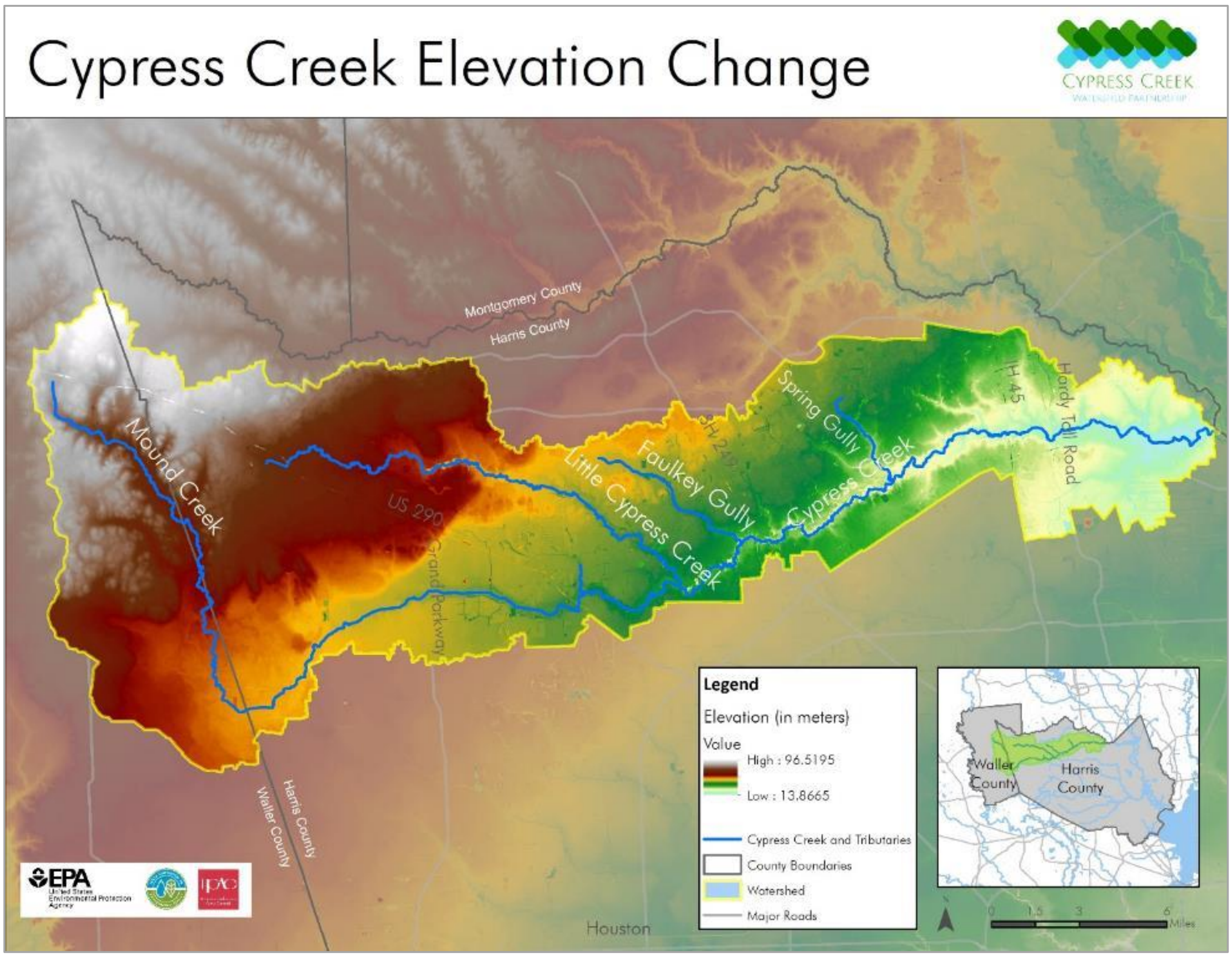


Figure 11 - Elevation change in the Cypress Creek Watershed

Elevation generally decreases from west to east, and from headwaters and uplands toward riparian areas. There is an 83-meter difference between the highest and lowest points[16] of the watershed.

[16] Based on USGS Digital Elevation Model (DEM) 10-meter resolution spatial data

Climate

The climate of the area is categorized as humid subtropical, indicating it has winters cold enough to generate occasional freezing conditions. Average rainfall for the area is between 42-50 inches of rain, with western areas being drier on the average than eastern areas of the watershed. However, drought events can have appreciable effect on the area, as evidenced in the 2011 drought in which western areas were exceptionally dry, and water elevations fell to record levels in downstream areas like Lake Houston into which Cypress Creek is a contributor. In general, excess rainfall is a greater issue for this watershed than drought.

Even though the watershed is not directly influenced by the coast, the area is still well within the range of hurricanes and other large storms coming in from the Gulf of Mexico. The generally warm climate allows for a diverse array of flora and fauna but can exacerbate some water quality issues influenced by temperature (e.g., DO).

Soils

The soil mix[17] of the Cypress Creek Watershed represents the juncture of different landscapes the water bodies traverse. In general, the soils are dominated by mixed alfisols, with smaller areas of mixed entisols and mollisols, primarily in the riparian areas. The transition of soil drainage characteristics of the specific soil complexes reflects the transect between what were traditionally western prairie areas and eastern forested areas in the watershed (Figure 13). The soil areas of greatest drainage potential are found in the remnant prairie areas, especially on either side of the Waller County line. Erosion of soils is prominent in the alluvial sediments along the waterways, an area which is mined in this watershed for sand and/or gravel (along with other areas in less developed portions of the system, including several prominent sites west of SH99). The presence of less well-drained soils in the developed portions of the watershed exacerbates existing issues with drainage and impervious cover and highlights the importance of the western soil complexes with greater degrees of infiltration in general, reducing runoff and flooding.

[17] A key to the soil types represented in the map can be found at the link provided in this note. Data provided by: Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at https://websoilsurvey.nrcs.usda.gov/. Accessed 5/26/2020. Soil survey dates and methods can differ from jurisdiction to jurisdiction and across time periods. Differences between the Waller County and Harris County soil profiles may be in some part due to these survey discrepancies.

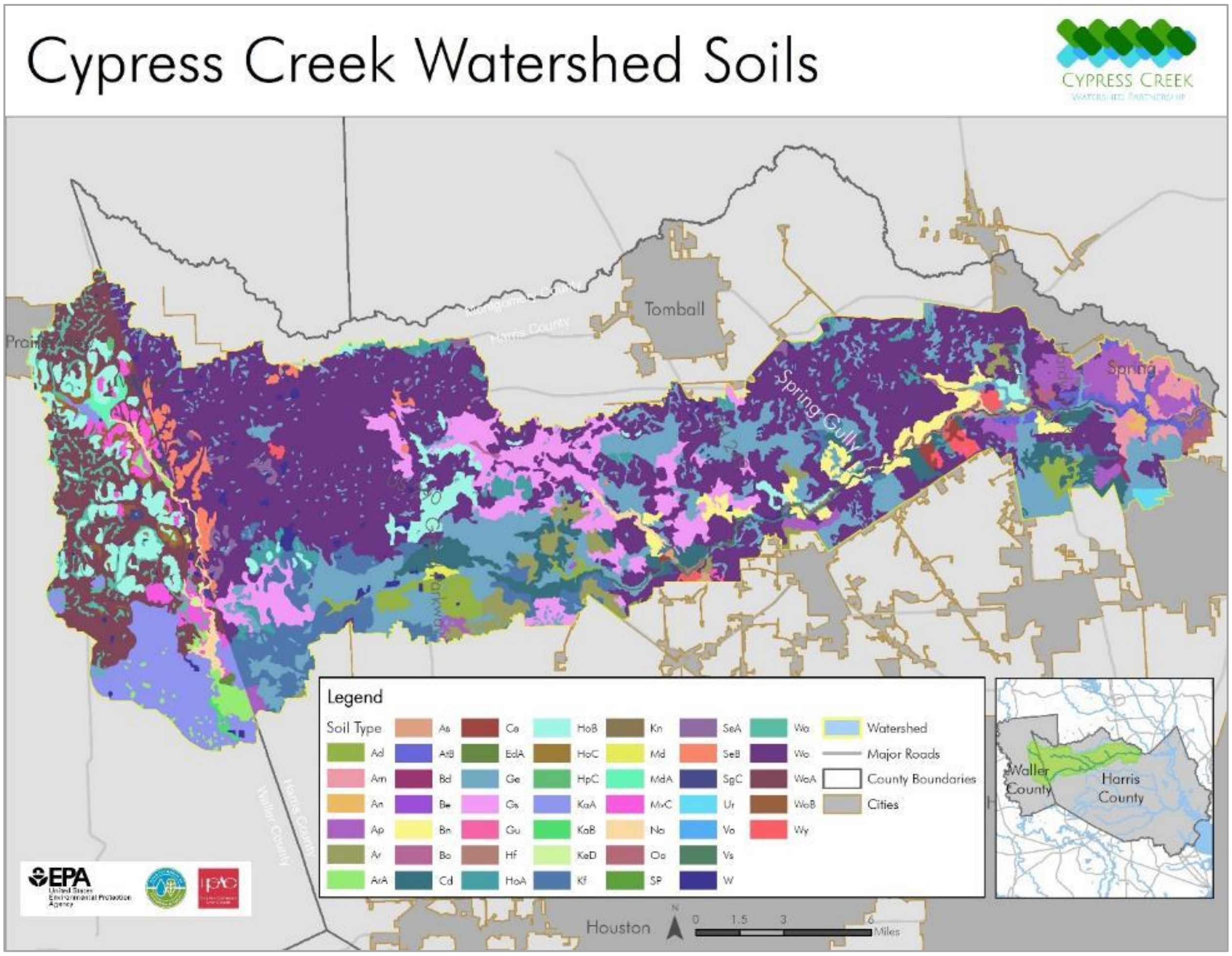


Figure 12 - Soils of the Cypress Creek Watershed

Habitat and Wildlife

The Cypress Creek Watershed is like the Houston region in general, in that it straddles a transitional zone between several different ecosystems, encompassed in two designated ecoregions[18] (areas of similar climate, habitat, and landscape indicated in Figure 14). The majority of the watershed falls within the Northern Humid Gulf Coastal Prairies (EPA Level IV ecoregion 34a) of the Western Gulf Coastal Plain (EPA Level III ecoregion 34), although some of the easternmost areas of the watershed overlap into the Flatwoods (EPA Level IV ecoregion 35f) of the South Central Plains (EPA Level III ecoregion 35). However, within these broader categories, there is a diversity of landscape along the west to east transect of the watershed, from the Katy Prairie, dominated by mixed grasses and other vegetation characteristic of the western portions of the Houston-Galveston region, to the denser riparian forests near the confluence with Spring Creek, with vegetation reflecting a mix of deciduous

[18] Based on EPA Level III (broad) and Level IV (more specific) Ecoregion data accessed on 5/27/20 at https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states.

and coniferous trees and a variety of grass species similar to the northern and eastern extent of the region. Most important, however, to understanding the actual current habitat in the watershed is the extent of modified land cover, both agricultural and urban/suburban that represents much of this watershed. This modified habitat tends toward monocultures (live oaks, crepe myrtles, and similar residential plantings) and less overall habitat value than the remnant areas of western prairie and riparian corridor.

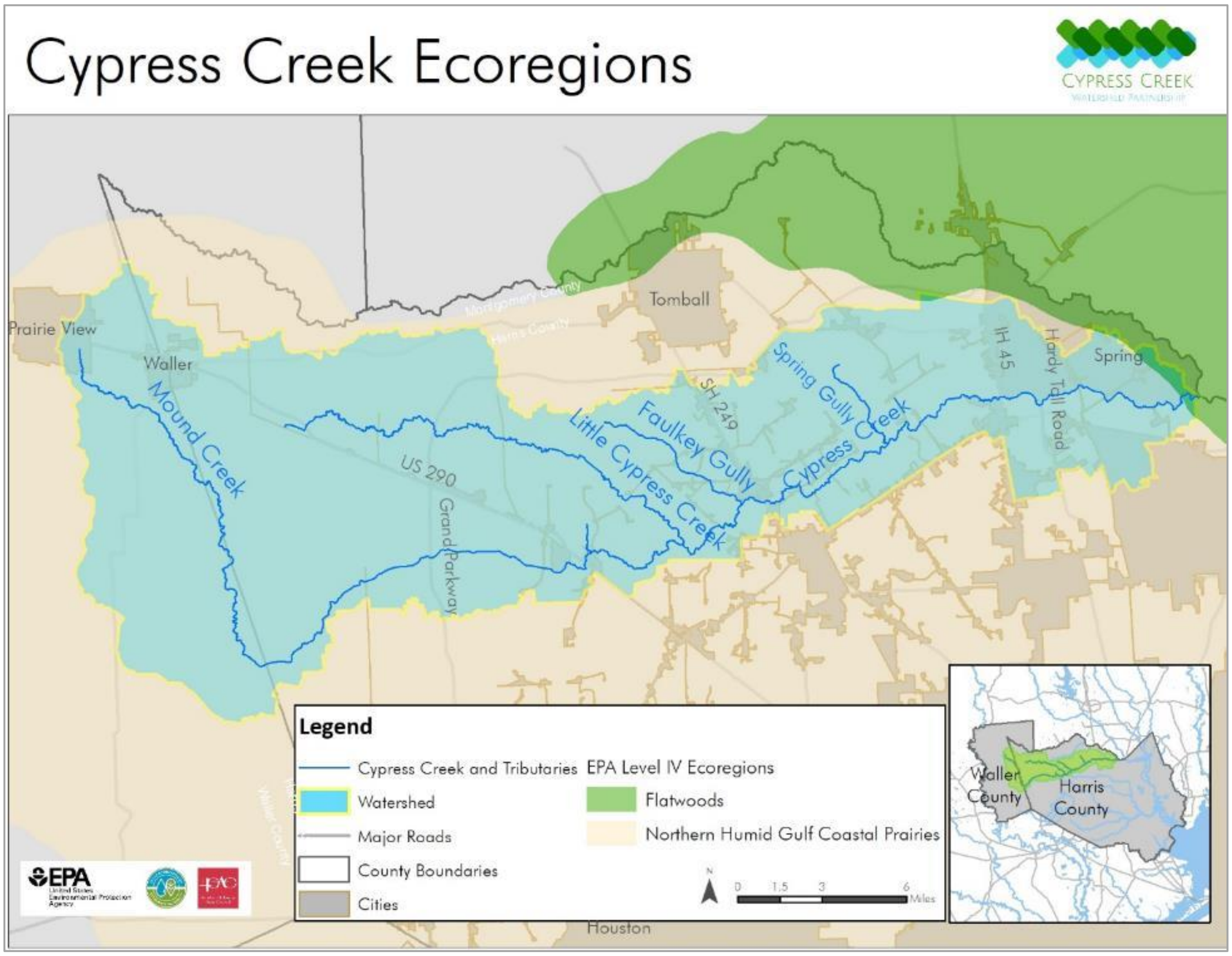


Figure 13 - Level IV Ecoregions of the Cypress Creek Watershed

The broad range of landscapes, including those modified by human activity, means the watershed is host to a diverse array of animal and plant species. Moderate winter temperatures and the location of the watershed in the Central Flyway for migratory birds support a dense and varied community of bird species year-round. Local bird species include wading birds (e.g., Great Blue Heron, White Ibis), a wide variety of passerine species (including a rich abundance of sparrows in prairie areas), and several raptors (e.g. Red-tailed Hawk, Bald Eagle, Barred Owl). Notable local conservation areas include natural or restored lands like the Katy Prairie Conservancy holdings (Indiangrass Preserve, etc.) west of SH99, large mixed-use park areas (e.g., Little Cypress Creek Preserve), and a patchwork of private conservation easements and similar single-landowner conservation parcels. Typical mammal species include White-tailed Deer, Virginia Opossum, Raccoons, Coyotes, Eastern Grey Squirrels, Striped Skunks, Nine-banded Armadillos, and numerous species of rodents and bats. The watershed is also home to many common reptiles and amphibians, including *Nerodia* water snakes, Red-eared Slider turtles, and bullfrogs.

Of particular concern to the watershed are some of the invasive species that are making it home. In addition to exotic plants (e.g., Chinese Tallow, Brazilian Vervain, deep-rooted sedge) and various invasive animals, feral hogs (*Sus scrofa*; Figure 15) are a growing issue for the Houston region, and are present in the Cypress Creek Watershed. Feral hogs threaten native wildlife species through direct competition for food and destruction of habitat. Large feral hog populations can cause damage on agricultural lands like those found in the western third of the watershed but are also a nuisance for suburban and exurban residential areas. Hogs tend to congregate in and around water bodies, causing damage to the riparian corridor and depositing fecal waste directly to the water body.

Figure 14 - Feral hogs in trap

Land Cover and Development

The mixture of natural landscapes in the Cypress Creek Watershed is further diversified by the modifications made to the land by human development. The character and balance of land cover in the watershed greatly influences the density and transmission of pollutant sources, and considerations for implementing solutions.

Land Cover

In general, the watershed transitions from undeveloped and agricultural areas in the western third of the watershed (west of SH99), through a middle transitional zone of small rural communities and growing master-planned suburban development (broadly between SH99 and SH249), to dense suburban/commercial areas for most of the remaining eastern third of the watershed (Figure 16).

Not reflected in the overall range of land cover types are the extensive areas of aggregate mining along the waterway. Aggregate mining is a primary non-agricultural industrial activity in the watershed, though not to the extent found in the adjacent West Fork San Jacinto River Watershed. Commercial activity is focused on the major transportation corridors, the majority of which run roughly north-south (SH99, US290, SH249, and I45), and smaller east-west surface street corridors (e.g., Cypresswood Drive).

Northwestern Harris County has experienced rapid change in recent decades, with growth pushing up and out from the Houston area. The most prominent change in land cover types has been the conversion of agricultural and undeveloped land uses to residential areas. Change in the Waller County portion of the watershed has been less extensive with the primary conversion being from agricultural activities to fallow land, light residential, or small scale industrial/commercial development. A large portion of the growth pushing western into and past the transitional middle third of the watershed into the western headwaters is in the form of large master-planned communities (e.g., Bridgeland). Based on current ownership of parcels adjacent to Cypress Creek west of SH99, this trend is expected to continue for the foreseeable future.

The Cypress Creek Watershed is very much in transition, with rapid change in its western areas. The development of the SH99/Grand Parkway section between I10 and US290 greatly accelerated development in adjacent properties. Additional planned roadways (e.g., the proposed Highway 36A expansion in Waller County) are likely to further accelerate transition in the watershed, absent additional protections.

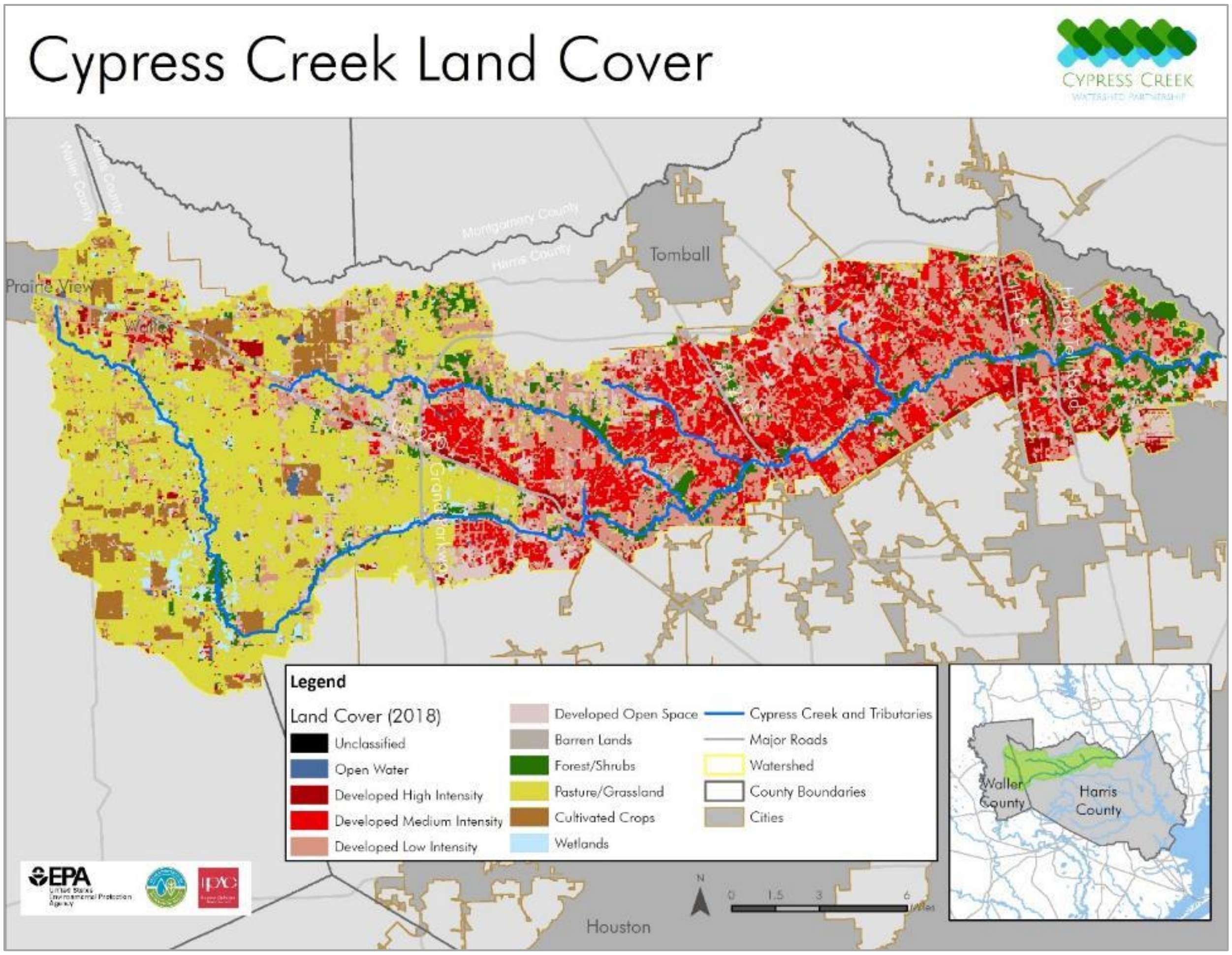


Figure 15 - Land cover in the Cypress Creek Watershed

While developed land uses make up a substantial portion (52%) of the total area of the watershed, agricultural uses (38%) and natural uses (9%) still account for nearly half the remaining area (Table 3[19]). The percentages are more telling when identified at a subwatershed level, with subwatershed 1 being dominated by agricultural and natural land cover types; subwatersheds 2 and 3 being a more transitional mix; and subwatersheds 4 and 5 being mostly developed land cover. The mix of land cover and uses in different areas of the watershed emphasizes the WPP focus on selecting locally-appropriate measures to address local challenges, identifying multiple areas in the watershed at which to monitor progress, and the need to coordinate with a broad array of partners throughout the watershed area.

[19] Data for this analysis represents 10-class data produced by H-GAC in 2018. NLCD and other typical land cover datasets were deemed too outdated for this WPP effort given the area's growth rate.

Table 3 - Land cover as a percentage of watershed area

Land Cover Category	Percentage of Watershed Area
Open Water	0.52%
High Intensity Developed	3.95%
Medium Intensity Developed	14.24%
Low Intensity Developed	23.94%
Developed Open Space	9.83%
Barren Lands	0.37%
Forest/Shrubs	6.38%
Pasture/Grasslands	33.28%
Cultivated Crops	4.81%
Wetlands	2.68%

Agricultural Character

Agriculture is generally in decline in most of the watershed area, with most remaining production taking place in the areas west of SH99 or the northern areas of subwatershed 2 and western areas of subwatershed 3. The transition away from agriculture to other land uses affects estimated future shifts in pollutant sources and land cover. In both counties, economic pressure from encroaching development, declining commodity prices, and the impacts of the 2011 drought are reasons commonly cited by the stakeholders for the decline of agricultural activity in the area[20]. Much agricultural activity still exists in the Katy Prairie areas.

Agriculture in Harris County

Agriculture in the Harris County area of the watershed was an historical mainstay of the local economy. Farming was common in early communities in western Harris County, with rice, cotton, various row crops, and ranching making up the historical agricultural profile of the area. According to the 2017 USDA Census of Agriculture[21], Harris County saw a 14% decrease in the number of farms, and an 8% decrease in the amount of land under production since 2012. Market value of sold products dropped by 22% in the same period. Most farms in the county are under 180 acres (92%) and many are under 50 acres (80%). However, there are several operations of 1,000 acres or larger. Current production value is heavily weighted toward crops (73%) as opposed to livestock (27%), but this is not reflected by total acreage for each type, with pastureland making up 62% of the total farmland, and cropland (24%) and other uses being smaller shares, proportionally. Only 5% of farmland is

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[20] Data reflected in this section is from 2017, the latest data available. Based on anecdotal accounts from stakeholders and partner agencies, the declines in production have continued if not accelerated in the interim.

[21] Derived from the USDA 2017 Census of Agriculture County profile for Harris County, located at: https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Texas/cp48201.pdf. Accessed on 6/3/2020.

irrigated, and while agriculture is in overall decline in the county, over a third of the 3,106 producers are classified as "new and beginning farmers" by USDA. While these numbers are county-wide, discussions with stakeholders, and the concentration of agricultural activity in the western portion of the county, indicate that they are relatively representative of the western watershed area.

Agriculture in Waller County

Agriculture in Waller County was the historical foundation for local communities and continues to be a greater economic force than in adjacent Harris County, relative to the overall economic output of the counties. Overall character of cropland and transition is like Harris County, though less economic pressure from development currently exists in the watershed area of Waller County. According to the 2017 USDA Census of Agriculture[22], Waller County saw only a 2% decrease in the number of farms, but a 20% decrease in the amount of land under production since 2012. Market value of sold products increased in this period by 14%. Like Harris County, most farms in Waller County are under 180 acres (87%), though a smaller number are under 50 acres (64%). Farmed land area is similarly weighted toward pastureland (56%), with cropland being a smaller share (28%). However, the share of sales for each type are disproportionate to their land area, with cropland representing 75% of sales value, and livestock being 25%. Only 3% of farmland is irrigated.

Figure 16 - Cattle in the Cypress Creek Watershed

[22] Derived from the USDA 2017 Census of Agriculture County profile for Waller County, located at: https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Texas/cp48473.pdf Accessed on 6/3/2020.

Recreation

Cypress Creek is a popular destination for a variety of recreational activities. Local partners have invested significant time and effort in developing natural spaces for recreation and flood benefits. Canoeing and kayaking are popular, especially in the downstream area, with many[23] trips originating from Kickerillo-Mischer Preserve and Cypresswood Drive. Small white sand beaches along its length are popular stopovers for paddlers and hikers. Many of the prominent parks and natural areas[24] are adjacent to the creek system and are points of access for recreation (Figure 18). Both recreational and subsistence fishing is popular along the waterway, and in lakes in adjacent parkland[25].

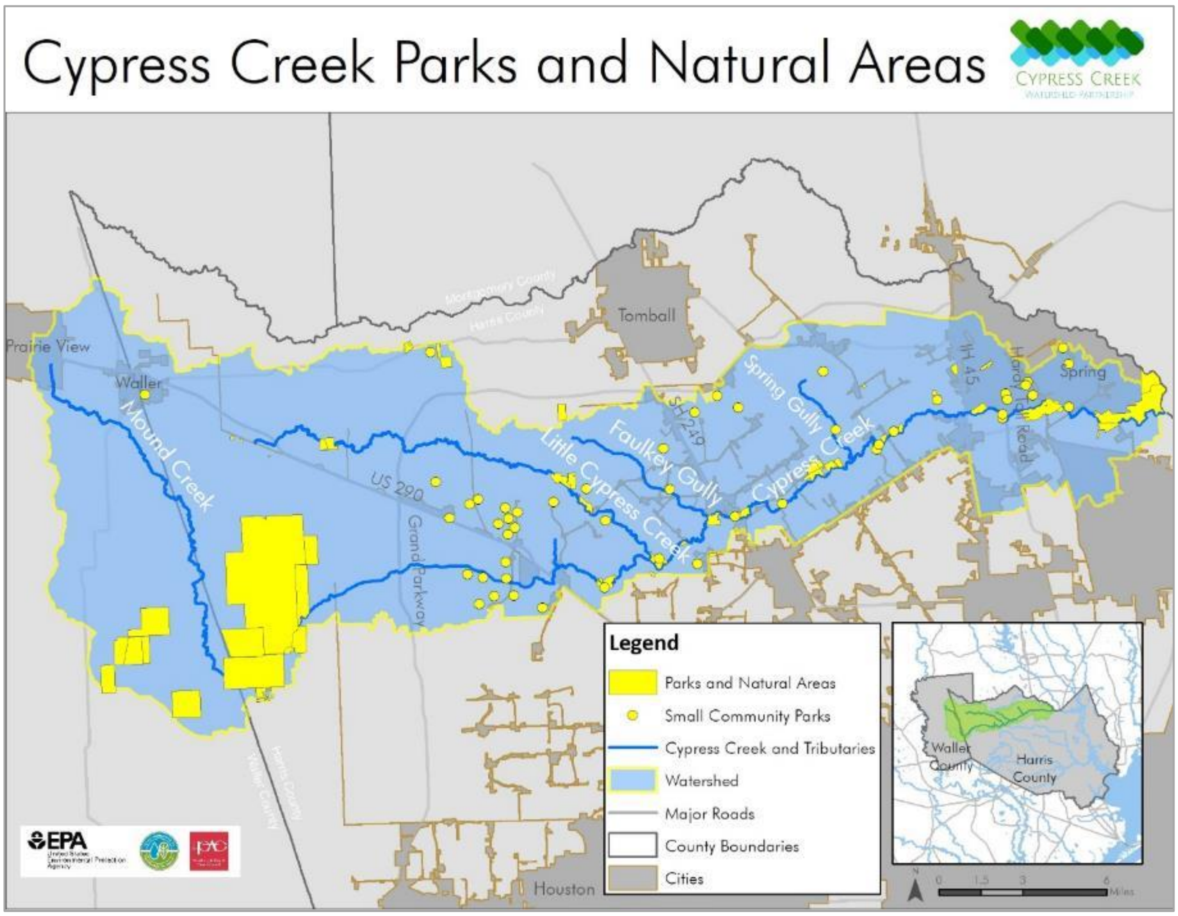

Figure 17 - Parks and natural areas of the Cypress Creek Watershed

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23 As part of its program to encourage the public's appreciation of our area's waterways, the Bayou Preservation Association sponsors the Cypress Creek Paddling Trail https://www.bayoupreservation.org/Bayous/Cypress-Creek/Paddle-Trails. Other organizations that actively promote recreational uses of Cypress Creek include the Houston Canoe Club http://www.houstoncanoeclub.org and Harris County Precinct 4 https://www.hcp4.net/parks/#1545164273963-b9f6802c-8b71.

24 This map is not exhaustive of all parks in the watershed.

25 More information on some of the access points and guidance for fishing can be found on Harris County Precinct 4's website at https://www.hcp4.net/parks/fishing/.

The Cypress Creek Greenway is an ongoing project of Harris County Precincts 3 and 4, the Cypress Creek Flood Control Coalition, and other local partners to develop a signature linear greenbelt trail and park system along Cypress Creek and Little Cypress Creek[26] in the Harris County portion of the watershed, eventually connecting with the existing Spring Creek Greenway. These iconic greenway projects reflect the interest of residents and visitors in natural recreation and take advantage of the proximity of the waterways' greenbelt and developed areas. While still under development, the Cypress Creek Greenway trails are well used.

Recent large master-planned communities like Bridgeland have included riparian areas of the creek's floodplain and connected internal lake systems in the scope of community amenities.

The Katy Prairie dominated the watershed historically, and in the remnants of its area west of SH99, including the extensive riparian corridors and restored prairies of the Katy Prairie Conservancy's holdings and the Little Cypress Creek Preserve maintained by Harris County Precinct 4 and the Bayou Land Conservancy, are still popular for recreation including birdwatching and hiking.

Figure 18 - Recreational paddling (*photo courtesy Tom Douglas)*

[26] For more information in the Cypress Creek Greenway, please refer to Harris County Precinct 4 website at https://www.hcp4.net/parks/ccgw/.

Water Quality

For the State of Texas' routine water quality assessments of its water bodies, water quality parameters are strictly defined and tied to the uses we derive from a waterway. However, water quality for local stakeholders includes other factors specific to the values their community places on their local waterway and they may have concerns not reflected in ambient water quality monitoring that range from other contaminants like trash to more qualitative concepts of sense of place and aesthetic quality. This WPP recognizes that the defined water quality parameters discussed herein should be considered alongside other stakeholder concerns and valuations.

Water Quality Standards

For the lakes, creeks, streams, rivers, bays and bayous of Texas, water quality is evaluated based on Surface Water Quality Standards (SWQSs). Under the delegated authority of the CWA, TCEQ develops the SWQSs and is responsible for ensuring they are met. The intent of the standards is to establish explicit goals and limits to ensure Texas' surface waters continue to support recreation, drinking water supply, aquatic communities, and other established uses (Table 4).

Table 4 - Designated uses for water bodies

The **aquatic life use** designation reflects the ability of the waterways to support aquatic ecosystems and habitat. Compliance with this use is determined by the availability of dissolved oxygen (DO) and an assessment of the diversity and health of existing ecological communities (fish, macrobenthics, and their habitat). High levels of chlorophyll-a, and elevated levels of nutrients, can indicate potential issues related to low DO.
The **contact recreation use** designations indicate the waterway is used for recreational activities, such as swimming, that involve a greater chance of ingesting water. The basis of the SWQS for contact recreation standards is to protect public health. Ubiquitous fecal indicator bacteria organisms (*E. coli* and *Enterococcus*) are used as indicators of the potential contamination level from fecal pathogens. In freshwater systems like the Cypress Creek Watershed, elevated levels of *E. coli* are a sign the waterway does not meet the SWQSs.
The **public water supply use** designation indicates a waterway is used for public water supply. The assessment of compliance for this use is a measure of the suitability of the waterway to serve as a current or future drinking water source. A variety of criteria are used to evaluate this use, including temperature, total dissolved solids, DO, pH range, fecal indicator bacteria, chlorine, and sulfates levels.
The **general use** designation reflects the overall health of the waterway as measured by criteria for temperature, pH, chloride, sulfate, and other parameters.

The vast network of surface water bodies is divided into segments, which are cohesive groupings of waterways and associated tributaries. The Cypress Creek Watershed is designated as Segment 1009. Major tributaries or waterways of interest within this segment are delineated as subordinate unclassified segments. For the Cypress Creek system, that includes 1009A (Dry Creek), 1009B (Dry Gully/Pillot Gully), 1009C (Faulkey Gully), 1009D (Spring Gully), 1009E (Little Cypress Creek),1009F (Mound Creek), and 1009G (Dry Gully), not all of which are actively assessed (Figure 20). Other contributing waterways and drainage networks also contribute to the system (including Snake Creek, Live Oak Creek, Senger Gully and Lemm Gully) but are not designated as unclassified segments by TCEQ and are not actively assessed.

Surface water segments are further divided into assessment units (AUs), the fundamental targets for assessments that determine whether a water body is in compliance with applicable standards. AUs are designated as the segment number followed by the AU number (e.g., 1009_01 for Cypress Creek, AU 1). AUs in the Cypress Creek system include[27]:

- Cypress Creek – 1009_01,_02,_03, and _04.
    - Dry Creek – 1009A_01 and _02
    - *Dry Gully/Pillot Gully – 1009B_01*
    - Faulkey Gully – 1009C_01
    - Spring Gully – 1009D_01
    - Little Cypress Creek – 1009E_01
    - *Mound Creek - 1009F_01*
    - *Dry Gully – 1009G_01, _02*

[27] Italics represent AUs not assessed in the 2020 Integrated Report of Surface Water Quality.

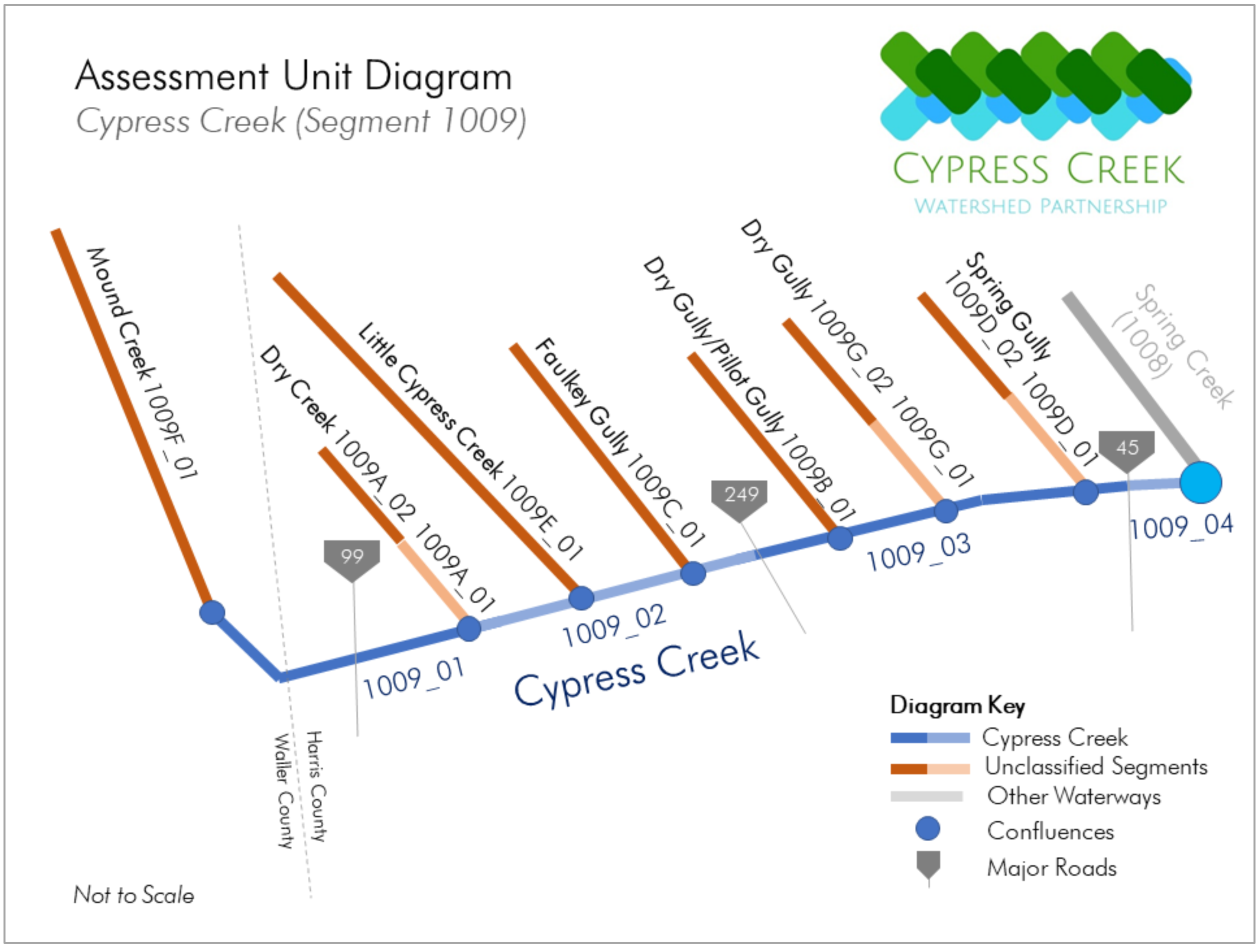

Figure 19 - Network diagram of segments and assessment units

Assessments are made based on data collected under the state's Clean Rivers Program (CRP) and other quality-assured data. TCEQ conducts assessments every two years for the state's water bodies, reviewing the previous seven years of data against the designated uses for the waterways. The results are included as part of Texas' *Integrated Report of Surface Water Quality* (Integrated Report). The results of the assessments of the Cypress Creek AUs only reflect ambient surface water quality, not the quality of tap water provided by utilities in the watershed, which is not the focus of this WPP.

State of the Water

The water quality of the Cypress Creek system is affected by numerous factors, including human activities, natural processes, availability of rainfall, and releases and natural seepage from impoundments to which it is connected. Based on assessment of water quality data[28], many of the assessment units of the system have existing water quality challenges. As development continues over the coming decades, additional sources of contamination may exacerbate these issues if no mitigating action is taken.

Impairments and Concerns

When a water body is unable to meet one or more of the SWQSs, it has an *impairment* for that standard. When an impairment may be imminent, or when substandard water quality conditions exist for a parameter that does not have an established numeric standard, the water body may be listed as having a *concern*. For example, water bodies are protected from excessive nutrient levels using screening levels. When concentrations of certain nutrients are above these screening levels, the water quality is characterized as a concern. Water quality in the Cypress Creek and its tributaries is typical of challenges seen in other freshwater creeks and bayous in the area[29].

Current assessed water quality issues in Cypress Creek and its assessed tributaries include elevated levels of *E. coli*, and concerns related to potential indicators or precursors of low dissolved oxygen (Table 5). The contact recreation impairment exists across all assessment units and is the primary focus of this WPP. Concerns related to elevated levels of nitrogen and phosphorus compounds are also widespread, although concerns over dissolved oxygen are limited to a single assessment unit of Cypress Creek (1009_01).

The 2020 impairments and concerns reflect the current formal assessment status by TCEQ and are the starting point for evaluating water quality in the watershed. Assessment of impairments and concerns to water quality in this WPP begins with the 2016 Report, the most current at the start of this WPP project, but overall water quality data analysis includes data through 2018 and is current with the 2020 Integrated Report.

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[28] For more information on detailed water quality assessments and modeling, refer to Section 3 of this document. For in-depth information on water quality trends in the watersheds, please refer to the *Water Quality Data Collection and Trends Analysis Report* available on the website for this WPP project at*:* https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_water_quality_trends_report_final.pdf

[29] References to assessments and water quality status refer, unless otherwise noted, to the 2020 Integrated Report of Surface Water Quality, the most current report available at the time of publication. Data evaluated as part the *Water Quality Collection and Trends Analysis Report* for this project (see previous footnote) may refer to the 2016 or 2018 Integrated Report year, based on the most current Integrated Report available at the time of any given analyses.

Table 5 - Impairments and concerns for Cypress Creek Watershed assessment units published in the past three Integrated Reports

Integrated Report Year	Assessment Unit(s) Impaired for *E. coli*	Concern Parameter and Affected Assessment Units					
		DO (grab)	Nitrate	Total Phosphorus	Ammonia	Habitat	Chlorophyll-a
2016	1009_01 1009_02 1009_03 1009_04 1009C_01 1009D_01 1009E_01	1009_01 1009E_01	1009_01 1009_02 1009_03 1009_04 1009C_01 1009D_01 1009E_01	1009_01 1009_02 1009_03 1009_04 1009C_01 1009D_01 1009E_01	1009D_01	1009_02	1009_04
2018	1009_01 1009_02 1009_03 1009_04 1009C_01 1009D_01 1009E_01	1009_01 1009E_01	1009_01 1009_02 1009_03 1009_04 1009C_01 1009D_01 1009E_01	1009_01 1009_02 1009_03 1009_04 1009C_01 1009D_01 1009E_01		1009_02	
2020	1009_01 1009_02 1009_03 1009_04 1009C_01 1009D_01 1009E_01	1009_01	1009_01 1009_02 1009_03 1009_04 1009C_01 1009D_01 1009E_01	1009_01 1009_02 1009_03, 1009_04 1009C_01 1009D_01 1009E_01		1009_02	

Other Concerns

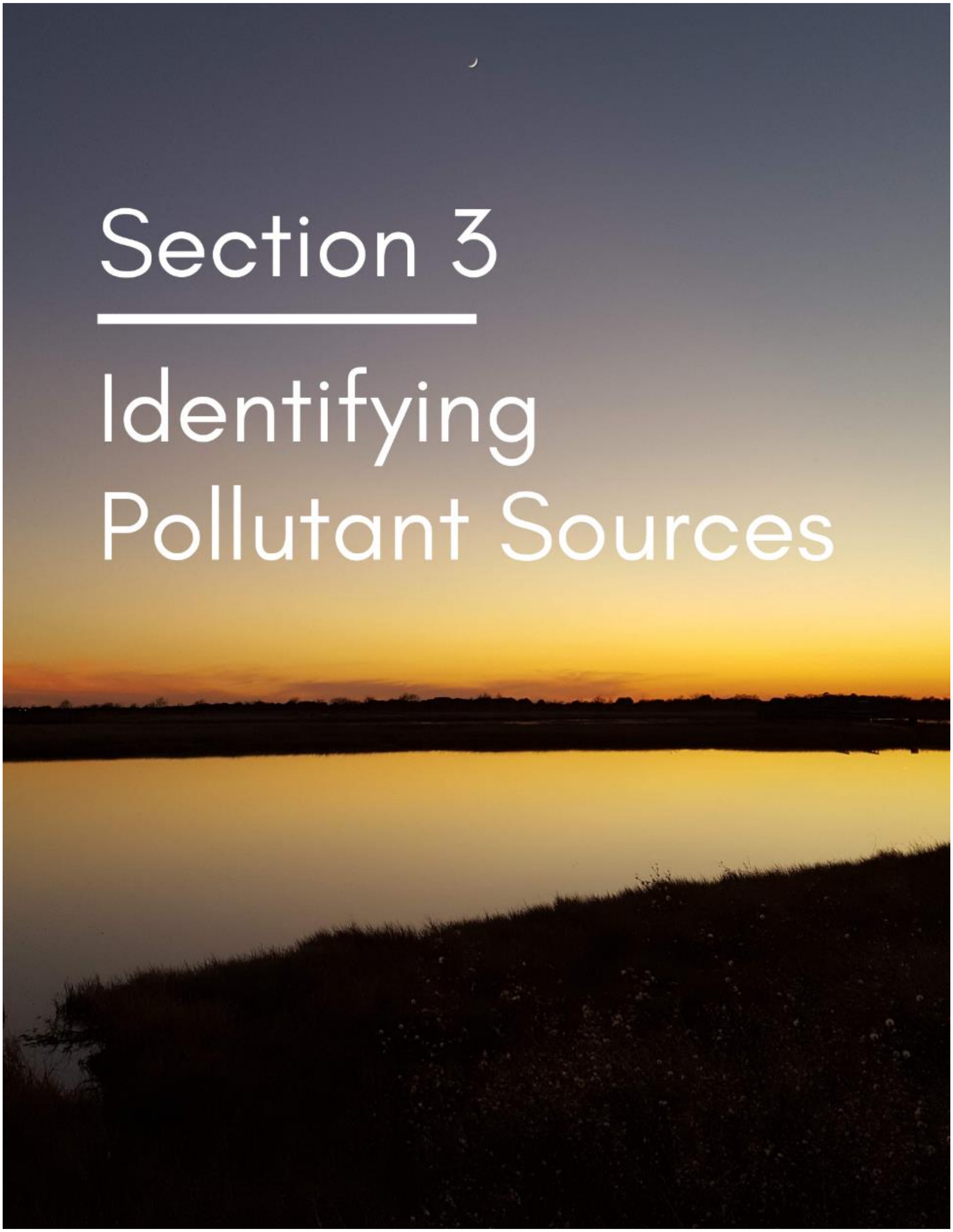
While the primary focus of this WPP is to address water quality impairments and concerns, all water bodies have a range of issues that impact human and wildlife uses. The WPP model is inclusive of other stakeholder concerns as part of a broader effort to improve the waterway. During the development of this WPP, stakeholders identified several other issues as being secondary priorities for implementation activities.

Trash — While illegal dumping is not reported by the stakeholders to be a widespread issue in the watershed, there were hot spots identified in the development of the WPP. Ambient trash from stormwater was raised as a concern as well.

Sediment — The sinuous channels of the waterways of this system have intermittent sand or gravel banks in many places. These alluvial sediments are attractive to aggregate mining operations whose activities have increased in the last decade, primarily in the western half of the watershed. While this issue is not as pronounced as it is in the West Fork San Jacinto River, sediment load from Cypress Creek has been studied in the past as a potential issue for the San Jacinto. Increased development and decreased riparian buffers will likely lead to faster runoff velocities, increased erosion, and decreased filtration. Increased sediment can impact the benthic habitats of aquatic life, shelter bacteria, and increase water treatment costs in addition to exacerbating flooding concerns. Of regional importance is the potential impact of sediment on the water supply capacity of the Lake Houston reservoir.

Flooding and related concerns — Even prior to the flooding and storm events of recent years, local stakeholders expressed concern over drainage, flooding, and potential channel modifications. While flood management is outside the scope of this WPP, changes to flow regimes or increased flooding can alter the impact of pollutant sources. These concerns are being included in this WPP based on their potential water quality impact, and the need to coordinate these efforts with the many flood mitigation projects underway or planned for the system. The primary concern of this WPP is that water quality considerations are included in future decisions that may affect flooding or hydrologic modification of the waterways.

Conservation of Natural Areas/Function — Even prior to the flooding and storm events of recent years, local stakeholders expressed strong concern over continuing loss of natural areas, particularly in the Katy Prairie. Using natural infrastructure to improve water quality, flood mitigation, maintain rural character, and protect natural landscapes and habitat was a standing concern among the stakeholders.



Section 3

Identifying Pollutant Sources

3 – Identifying Pollutant Sources

The process of identifying, characterizing, and quantifying causes and sources of pollution in a watershed provides a rational basis for devising effective solutions to improve water quality. The Partnership used a variety of tools, combined with local knowledge and guidance, to investigate the water quality challenges facing the Cypress Creek Watershed. The purpose of these efforts is to provide local stakeholders the information and context to make informed and effective decisions for their communities.

Figure 20 – Stakeholders discuss pollutant sources

Investigation Methodology

The process of investigating causes and sources of pollution in the watershed used a series of successive steps to bridge the gap between what was known, the existence of impairments and concerns, and the stakeholder's needs: having solid information on potential causes and sources[30] (Figure 22).

[30] More detailed information on the development of this investigation methodology and selection of models can be found in the *Water Quality Modeling Report*, located at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_creek_wpp_water_quality_modeling_report.pdf

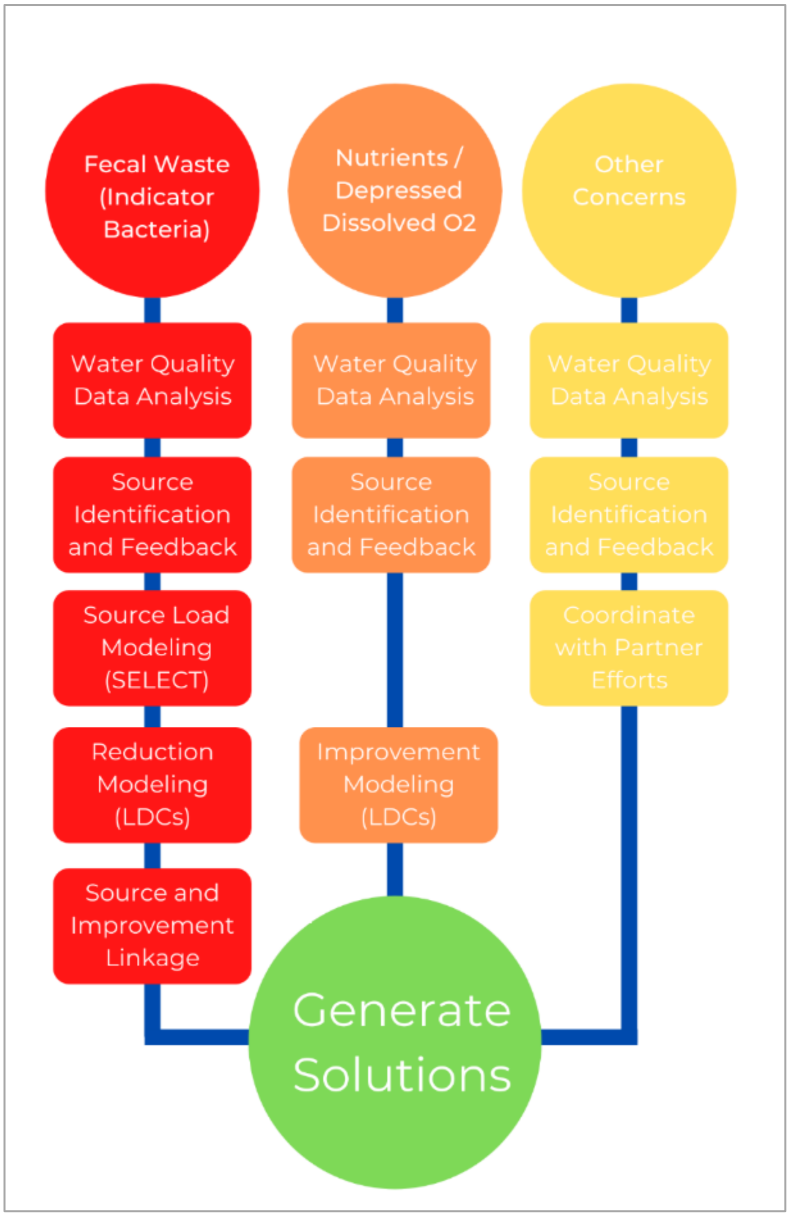


Figure 21 - Pollutant source investigation flow chart

Water Quality Goals

The applicability of each step to different pollutants/conditions of concern is based on the water quality goals[31] established by the stakeholders and is noted in the parentheses for each step.

- Water quality data analysis (all water quality issues) — Project staff identified status and trends in ambient water quality monitoring data and discharge data from

[31] As delineated in Section 1.

wastewater treatment plants. These analyses identify the extent and variability of water quality issues and highlight differences between areas in the watershed.

- **Source identification and feedback (all water quality issues)** — The Partnership used local knowledge, data from other efforts, field reconnaissance, and map analysis to identify potential sources. These steps help to shape subsequent analyses by focusing efforts on sources of priority in the watershed.
- **Source load modeling (fecal waste)** — H-GAC worked with the Partnership to estimate the potential amount of fecal waste/*E. coli* generated in the watershed using computer models guided by local knowledge and feedback. These efforts identified the potential total fecal loads, mix of sources responsible, and variation between different areas of the watershed.
- **Reduction/Improvement modeling (fecal waste, DO)** — H-GAC worked with the Partnership to estimate the amount of improvement needed to meet water quality standards for various areas in the waterway. Results were generated by computer models using then-current water quality monitoring data. These processes generated the percent reduction for *E. coli* and the percent improvement for DO levels (See Section 4).
- **Source and improvement linkage (fecal waste)** — As the primary focus and sole impairment, fecal indicator bacteria estimates were needed to establish numeric reduction goals for *E. coli*. This process applied the percent reduction targets from the improvement modeling to *E. coli* source load estimations to generate the amount of source load that needed to be reduced to achieve the water quality standard (See Section 4).
- **Coordinate with partner efforts (other concerns)** — Most specifically in the case of flood mitigation, the primary focus of developing recommendations for concerns outside the scope of this WPP was coordinating with partners.
- **Emphasize human wastewater as a priority** – While models may downplay the contribution of human wastewater, the stakeholders emphasized the greater risk human waste carries, the greater likelihood it is to be in proximity to our communities, and the potential for acute overflow events that don't reflect average daily loads.

Water Quality Analysis

Assessing water quality data sources is the first step in narrowing the search for the causes and sources of pollution. The Partnership reviewed analyses of 1) ambient water monitoring data; 2) volunteer water quality monitoring data; 3) discharge monitoring reports (DMRs) and sanitary sewer overflow (SSO) data from wastewater treatment facilities; and 4) results from similar projects in the area. While these analyses are summarized here, greater detail on the methods and results can be found in the *Water Quality Data Collection and Trends Analysis*

Report[32] prepared for this WPP. The primary goals of the analyses were to better understand water quality conditions, characterize the quality of wastewater contributions, and identify the availability of sufficient data for the models. The analyses focused on a five-year period of data to represent the most current conditions, but also relevant trends in recent years.

Figure 22 - Water quality monitoring by the Clean Rivers Program

Ambient Water Quality Monitoring Data

Ambient water quality data are collected at over 400 sites in the 13-county Houston-Galveston region by H-GAC, local partners, and TCEQ as part of the Clean Rivers Program[33]. Most monitoring stations are sampled by CRP partners[34]. Waterways are inherently dynamic systems, and water quality at any given time can vary greatly dependent

[32] available on the WPP project website at: https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_creek_wpp_water_quality_modeling_report.pdf.

[33] More information about this state-wide water quality monitoring program can be found at https://www.tceq.texas.gov/waterquality/clean-rivers.

[34] More information about the specific monitoring and programmatic details of the local CRP can be found at https://www.h-gac.com/clean-rivers-program/information/

on conditions at the time[35]. However, a history of ambient water quality samples helps characterize the range of conditions that may be present in a waterway and is important 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 this WPP were established in part due to the regulatory status, and therefore ambient data is an important source of information for informing stakeholder decisions.

The Cypress Creek system is heavily monitored, with 11 monitoring stations; seven on the main body, one on Faulkey Gully (1009C), one on Spring Gully (1009D), and two on Little Cypress Creek (1009E; Figure 24; Table 6). The data for all stations are representative of ten years' worth of sampling and are enough to describe the conditions during the study period.

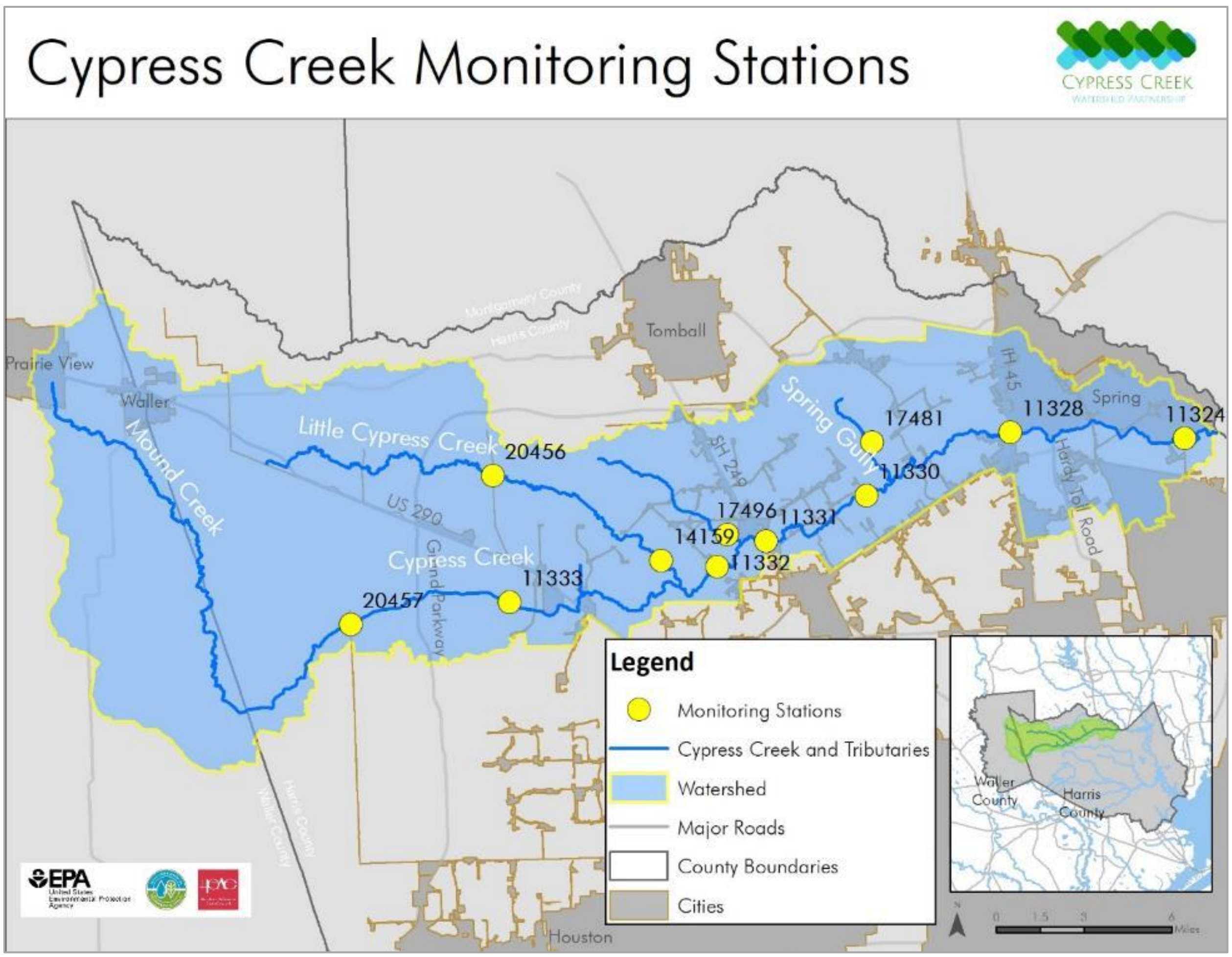


Figure 23 - Cypress Creek monitoring stations

[35] For this report, 24-hour DO data is discussed in this section. In terms of technical terminology under CRP, 24-hour DO sampling is not considered "ambient" data, but rather, "biased sampling" because it is often collected during certain seasonal timeframes. Due to the nature of the 24-hour data for this project, and the basic categorization of this report, it is discussed as ambient data.

Table 6 - Monitoring station locations

Monitoring Station ID	Site Location
11324	Cypress Creek at Cypresswood Drive Bridge
11328	Cypress Creek Bridge on IH 45
11330	Cypress Creek at Stuebner-Airline Road in Houston
11331	Cypress Creek at SH249
11332	Cypress Creek at Grant Road Near Cypress
11333	Cypress Creek at House-Hahl Road Near Cypress
14159	Little Cypress Creek at Kluge Road in Houston
17481	Spring Gully at Spring Creek Oaks Drive in Tomball
17496	Faulkey Gully of Cypress Creek at Lakewood Forest Drive
20456	Little Cypress Creek at Mueschke Road
20457	Cypress Creek at Katy Hockley Road

Constituents of concern

Routine ambient water quality monitoring under the CRP includes sampling for a suite of conventional, bacteriological, and field parameters. For this evaluation, a subset of those parameters most closely related to the goals of the WPP and characterization studies has been selected for in-depth analysis. The parameters reviewed were:

- *Escherichia coli (E. coli)*— a bacterial indicator of the presence of fecal wastes, and an indicator of the safety of waterways for human recreation.
- *DO, grab* — 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 alkalinity 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+Nitrite* — a measure of nitrogenous compounds and indicator of nutrient levels (and thus potential DO impacts).
- *Ammonia (NH3-N)* — 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.
- *Flow (grab)* — a measure of water volume passing a fixed point over time.
- *Total Phosphorus* — an indicator of nutrient levels, especially in relation to potential for algal blooms and depressed DO in elevated levels.

- *Total Suspended Solids (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 *E. coli* may seek shelter.

The analyzed data covers 2009-2018 to show a broad historic view. The primary questions this evaluation sought to answer relate to:

- The sufficiency of the data to characterize conditions;
- The spatial component of variations in water quality conditions;
- The extent of water quality issues; and
- Trends in water quality conditions, including any observable seasonal patterns.

H-GAC completed the assessment on the segment level, with attention to any unclassified tributaries which may be experiencing water quality issues.

Monitoring Analysis

The monitoring results generally reflect the status of the segments in the Integrated Report, although solely assessing nutrients by geomean does not reflect the formal assessment process, which takes into account more than geomean average, and focuses on a smaller range of data (2012-2018 for the 2020 Integrated Report). It should be noted that while the year range of the data available at the time of these analyses includes the data range used for the 2020 Integrated Report, there may be discrepancies linked to the exact number of records submitted, available, or quality assured at the time these analyses were completed including additional years of data used in these analyses. The results for each station represent a geomean of all data from 2008-2019 (Table 7). Results shaded in red indicate a parameter that is not meeting its criterion or screening level, while green shading represent parameters that are in compliance with criteria or are better than the screening level. Lack of shading indicates the data are not being compared to criteria/screening levels.

Table 7 – Results from monitoring analysis of water quality data collected between 2009-2018.

Parameter	Criteria	Units	Results by Segment			
			1009	1009C	1009D	1009E
Temperature	NA	°C	21.09	22.48	23.02	21.07
DO (grab)	Various[36]	mg/L	7.22	8.86	8.13	6.42
pH	9(high)/6.5(low)	NA	7.74	7.99	8.12	7.63
TSS	NA	mg/L	29.42	14.98	13.05	18.21
Ammonia (NH3-N)	0.33	mg/L	0.10	0.09	0.14	0.10
Nitrate+Nitrite	NA	mg/L	0.99	NA	NA	0.25
Total Phosphorus	0.69	mg/L	1.23	2.17	1.91	1.02
E. coli	126.00	CFU/100mL	377.07	272.39	256.50	193.33
Chlorophyll-a	14.10	mg/L	9.53	NA	NA	NA
Nitrate	1.95	mg/L	3.47	7.15	5.81	3.80
Nitrite	NA	mg/L	0.07	NA	NA	0.12

Water Quality Parameter Trends

For some water quality parameters in Cypress Creek and its unclassified tributaries there are statistically significant trends (Table 8). Parameters in red indicate a negative trend (e.g., increasing Total Phosphorus or decreasing DO), and green indicates a positive trend. Parameters in gray indicate neutral perceived impact of the trend. Parameters whose trends were not statistically significant (based on a p-value threshold of 0.0545) are not included in the table. Some trends, especially for the main channel of Cypress Creek, are not consistent across the whole segment, though the issues related to the parameters of primary concern (particularly *E. coli*) are relatively consistent.

While there are numerous water quality issues for Cypress Creek and its tributaries, the main channel and many of the unclassified tributaries show improvement on nutrients and/or DO. *E. coli* samples were often higher than the standard, however they were relatively stable across the data time series, so they do not appear in Table 8. Prior analyses[37] indicated that *E. coli* results period between 2012-2018 were increasing in segment 1009 but were more stable in later years. The parameters were also evaluated for seasonality, although only temperature and DO showed observable seasonal patterns, with DO decreasing inversely but not proportionally to temperature.

[36] The grab screening level and minimums for DO are 5 and 3, respectively, for all segments except 1009C, Faulkey Gully, whose screening level and minimum are 2 and 1.5. Due to variability in DO throughout the day, a geomean in excess of the minimum or screening level should not be taken to mean that DO is consistently good throughout a daily cycle.

[37] Water quality data for Cypress Creek was assessed for 2012-2017 and 2015-2018 as part of the development of a Characterization Report under a previous Clean Water Act 319(h) grant concluded in early 2019.

Table 8 - Water quality trends by segment (2009 – 2018)

Segment	Parameter	Trend	Number of Samples
1009	Flow	Increasing	266
1009	Nitrate-N	Decreasing	405
1009	Total Phosphorus	Decreasing	479
1009	TSS	Increasing	480
1009	pH	Decreasing	500
1009C	Total Phosphorus	Decreasing	89
1009D	Ammonia-N	Decreasing	86
1009D	DO (grab)	Increasing	85
1009D	TSS	Decreasing	87
1009E	Flow	Increasing	36
1009E	Nitrate+Nitrite	Increasing	38
1009E	Nitrate-N	Decreasing	90
1009E	Total Phosphorus	Decreasing	127
1009E	TSS	Increasing	128

Relationship to Flow

As part of the ambient data analyses, staff considered the relationship of parameter levels to flow conditions. Further work on the relationship between flow, *E. coli*, and DO was completed as part of load duration curve (LDC) model development[38]. In general, *E. coli* concentrations in Cypress Creek increased with flow regularly throughout the stations of the waterway.

Ambient Analysis Summary

The Cypress Creek Watershed exhibits water quality challenges and trends that reflect a watershed in developmental transition. Fecal waste remains an issue throughout the watershed, although recent years have seen *E. coli* levels stabilize in some areas.

Despite trends toward generally better water quality, nutrients remain a challenge, suburban and exurban development being likely to increase as prominent sources of legacy agricultural activity diminishes.

[38] Please refer to the Cypress Creek Modeling Report available on the project website at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_creek_wpp_water_quality_modeling_report.pdf.

Elevated TSS levels do not seem directly related to effluent flows (see DMR data analysis results later in this section), though wastewater is likely a component. Additional review may be needed to understand the potential sources of TSS; however, it is likely that disturbance by development and unstable areas of the channels may be sources.

While water quality issues persist in these waterways, they are not extraordinary in extent such that voluntary intervention through watershed-based plans would be fruitless. Targeted assessment and application of best management practices (BMPs) could be expected to reduce or remove impairments and concerns in this watershed.

Stream Team Monitoring

While the WPP relies on quality assured data for trends analyses and model inputs, volunteer data provided by local Texas Stream Team (TST) monitors can be a valuable supplement to routine monitoring sites by providing hints at conditions in areas outside the existing data. One of the most valuable elements of TST data is the observational information from the volunteers. There are seven TST sites in the Cypress Creek Watershed. Project staff reviewed the data at the beginning of the project to help define areas of interest and to guide informal decisions on field reconnaissance. The data will be used in conjunction with formal data sources and analyses to help identify WPP effectiveness going forward.

Figure 24 - Monitoring site on Mound Creek

Wastewater Treatment Facility Discharge Data

Discharges from wastewater treatment facilities (WWTFs) are regulated by water quality permits from TCEQ which require stringent limits for effluent quality. Human waste has a relatively high potential to cause human illness[39], so identifying trends in permit exceedances for *E. coli* by WWTFs is important in understanding overall impacts to human health related to contaminated waterways. Additionally, effluent (especially if improperly treated) can be a source of nutrient or other precursors to depressed DO.

There are 116 permitted WWTFs in the Cypress Creek Watershed, 112 of which are active, and four of which are pending (Figure 26; Appendix B).

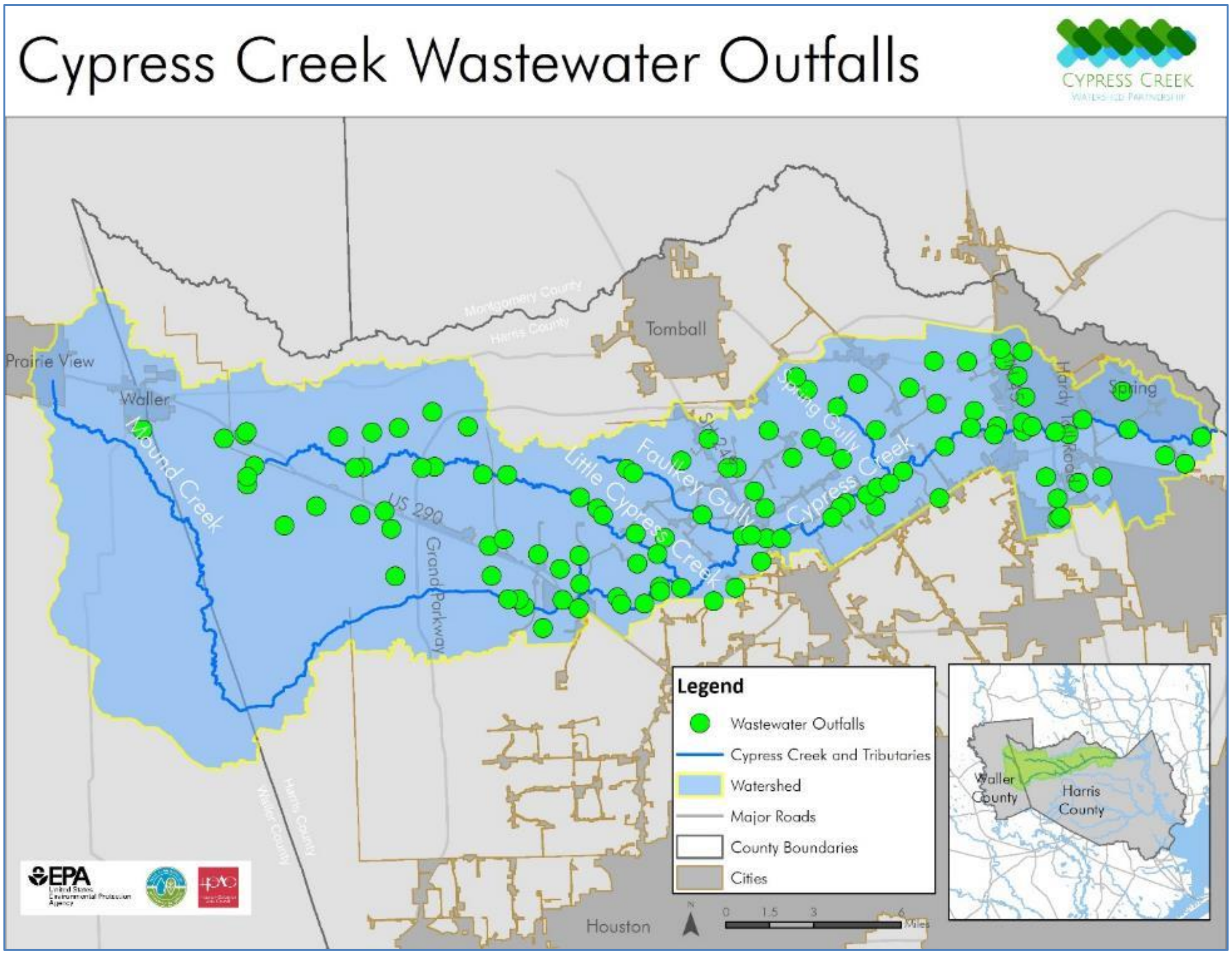


Figure 25 - Wastewater outfalls in the Cypress Creek Watershed

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 are submitted to (and compiled by) TCEQ as discharge monitoring reports (DMRs). As with any self-reported data, there is an expectation that some degree of uncertainty or variation from conditions

[39] While the project considers many sources of fecal bacteria, recent research has indicated that human waste has a significantly higher risk of causing sickness in humans as compared to animal sources. Additional information about one research project illustrating this concept can be reviewed at http://oaktrust.library.tamu.edu/handle/1969.1/158640?show=full.

may occur, but these DMRs are the most comprehensive data available for evaluating WWTFs in the watershed.

Project staff evaluated[40] five parameters common to most WWTF permits, as reported in the last five years (2014-2019[41]) of DMRs available from TCEQ, including *E. coli*, TSS, ammonia nitrogen (NH3-N), DO, and five-day carbonaceous biochemical oxygen demand (CBOD5). While some parameters are themselves constituents of concern, all are indicators of the presence or potential presence of untreated/improperly treated waste[42]. 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.

E. coli

E. coli is an indicator bacterium widely common to the guts of warm-blooded animals. While many strains of *E. coli* are not themselves problematic, they are closely related to the presence of fecal waste, and therefore, to the host of pathogens present in wastes. The water quality standards for ambient conditions are usually incorporated into WWTF permit limits as 126 colony-forming units (cfu) per 100ml of water (for the geomean of samples) and 399 cfu/100ml (for single grab samples), and these standards are generally applied as a permit condition for wastewater as well. Evaluations for compliance with the permit limits were compared between segments, between plants, between years, between category (average or maximum values), and by season. Ninety-one plants reported *E. coli* results for these segments in the timeframe evaluated (Table 9).

[40] More detailed analyses and data are available as part of the Water Quality Data Collection and Trends Analysis Report, available on the project website at: https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_water_quality_trends_report_final.pdf

[41] 2019 data was not complete at the time of the original analysis but was included in an update in year two of the WPP development project along with the previous five years.

[42] In consideration of the nutrient loading capacity of the plants, it should be noted that many nutrient parameters are not standard plant permit limits, and thus may not be tested. Based on review of correlations between nutrient parameters and flow for many stations the analyses did show a likelihood of plants as nutrient loading sources for non-permit limit parameters, particularly in effluent-dominated streams.

Table 9 - *E. coli* permit limit exceedance statistics

Parameter	Number of Plants	Percentage of Plants
Plants in DMR Dataset	95	100%
Plants reporting *E. coli*	91	96%
Less than 1% violations	63	69%[43]
1% to 5% violations	21	23%
5% to 10% violations	6	7%
10% to 25% violations	0	0%
Greater than 25% violations[44]	1	1%
Exceedances of geomean limit	11	12%
Exceedances of single grab limit	34	37%

Most plants have less than one percent of their samples in violation[45]. However, roughly a third of all plants (27) have between one to ten percent of their samples in violation, although most of this range is under 5%. The plants were generally more able to meet the geomean standard than the single grab standard, indicating that conditions may have a high degree of variability, but the small size of the pool of exceedances limits meaningful extrapolation from these data.

In subsequent analysis, there was not a strong relationship between season and exceedance, and exceedances were only slightly variable, across the years of the dataset. Plants were a mix of ages in the watershed, without one age range (before 1980, 1980-2000, 2000-2020) being predominant. As expected, older plants saw a slight increase in exceedances, but it was not a strong trend. Considering plant size in relationship to exceedances, most of the plants in the watershed (76%) are below a permitted flow of one million gallons per day (MGD), characteristic of an area with numerous, small plants as opposed to large centralized treatment. Allowing for uncertainty in reporting in very small, unstaffed plants, there was still not a strong relationship between plant size and exceedances. While not directly proportionate (mid-sized 1-5 MGD plants had a disproportionate number of exceedances, while smaller plants had a disproportionate number of geomean exceedances), the results did not clearly indicate a specific category of plant size was meaningfully related to exceedances.

In general, the results indicated only a small number of exceedances (104 out of 4,769 records), and only three plants had 5-10% of their samples show up as violations. Maximum

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[43] The percentages in this column, starting with this cell, refer to the percentage of plants who report bacteria data who fall into this category, rather than the percentage of all plants.
[44] The single outlier here is a plant with few records during the time period, which may be due to incomplete data.
[45] The data in Table 9 indicates all violations, whether they be for the geomean or single grab sample criteria.

values were more commonly exceeded than average/geomean limits, indicating there is likely some variability in conditions. Seasonality was not generally an issue. Plant size was not a statistically significant indicator of potential to exceed limits[46] but mid-size plants had greater issue with the single sample criteria, and smaller plants the geomean. This may be in part due to relative frequency of monitoring, wherein large plants monitor more frequently and have more data to include in a geomean calculation, or it may be due to operational differences between larger staffed plants and smaller unstaffed plants. 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 *E. coli* 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 mg/L, and the permit limits with which results are compared 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. Evaluations for compliance with the permit limits were for all records, between years, and by season. Ninety-one plants reported DO results for these segments during this period (Table 10).

Table 10 - DO exceedances, 2014-2019

Category	Number	Percentage of samples
Plants in DMR dataset	94	100%
Plants reporting DO	91	97%
Total Records	5410	100%
Total Exceedances	19	0.4%

As with the *E. coli* data, there were very few violations of DO limits (19 total violations for 5,410 records.) There were no statistically significant seasonal components for the evaluated data. Based on these data and analyses, it is unlikely WWTFs are having any appreciable impact from DO levels in effluent, even before the dilution of these small volumes (relative to

[46] As indicated previously, self-reported data obscures underlying uncertainties about variability in conditions. This is exacerbated when comparing staffed, larger facilities who are more likely to sample more frequently, and smaller facilities who sample less frequently and are generally unstaffed. These results should not be taken to have statistical significance.

the larger volumes of the waterways) is considered. However, because these samples are DO grab samples, the potential variability of DO should be considered. Unlike a natural waterway, DO in plant effluent should see less daily cycling and therefore the grabs should be more representative than DO grabs in ambient conditions. The 19 violations represented 14 plants, indicating that there were no appreciable patterns of repetitive violations at single facilities.

Total Suspended Solids

TSS is generally an indication of wastewater treatment efficiency in removing solids. Substantial TSS levels in effluent can contribute to fostering bacterial regrowth as *E. coli* uses suspended particles as a protected growth medium. TSS can also decrease insolation in the water column and lead to deposition of particles on the substrate, etc. However, it can also be useful as an indicator that inefficient treatment may have led to other waste products (nutrients, etc.) being present in effluent.

Permit limits for TSS include a concentration based (average) limit (in mg/L) and a total weight-based limit (in weight/day). Both average and maximum monitored results exist for most plants. Evaluations for compliance with the permit limits were compared for all plants, between the years 2014-2019, for both concentration and total volume, by season, and between categories (average or maximum values). Ninety-four plants reported TSS results for these segments during this period (Table 11).

Table 11 - Monitoring statistics for TSS, 2014-2019

Category	Number	% of samples
Plants in DMR dataset	94	100%
Plants reporting TSS	94	100%
Total Records	16,732	100%
Total Exceedances	163	1.0%
Total Exceedances, Average	112	
Total Exceedances, Maximum	51	
Total Exceedances, Concentration Average (mg/L)	97	
Total Exceedances, Concentration Maximum (mg/L)	51	
Exceedances, Weight Average (kg/d)	15	
Exceedances Weight Maximum (kg/d)	0	

Corresponding to other parameters, TSS violations were rare, making up less than one percent of the total sample records. There were no clear differences by year, although winter and spring months had greater exceedances of both concentration and weight-based limits. TSS results indicate WWTFs are generally operating within their permit limits and that TSS inputs from WWTFs are not likely a chronic issue of importance for the waterways. However, it is likely that they are of concern to stakeholders on a localized basis and may be indicative of opportunities for WWTF improvement. Unlike other parameters, exceedances of TSS occurred at a relatively smaller number of facilities. Thirty WWTFs accounted for the 163 exceedances, with three of the facilities accounting for 70 exceedances. This indicates that there may be localized issues for TSS regardless of the overall result.

Ammonia Nitrogen (NH3-N)

Ammonia is a nitrogenous compound that can be toxic in concentration to people and aquatic wildlife and can also contribute to the deleterious impacts of elevated nutrient loadings. Additionally, excessive ammonia levels in effluent indicate inefficient wastewater treatment and may correlate to the presence of improperly treated sewage.

Like TSS, permit limits for ammonia include a concentration based (average) limit (in mg/L) and a total weight-based limit (in weight/day). Both average and maximum permit limit values exist for most plants. Evaluations for compliance with the permit limits were compared between plants, between the years 2014 and 2019, between seasons, and between categories (average or maximum values). Ninety-one plants reported ammonia results for these segments during the original analysis period (Table 12).

Table 12 – Ammonia exceedances, 2014-2019

Category	Number	% of samples
Plants in DMR dataset	94	100%
Plants reporting TSS	91	97%
Total Records	16,732	100%
Total Exceedances	177	1.0%
Total Exceedances, Average	107	
Total Exceedances, Maximum	70	
Total Exceedances, Concentration Average (mg/L)	93	
Total Exceedances, Concentration Maximum (mg/L)	70	
Exceedances, Weight Average (kg/d)	14	
Exceedances, Weight Maximum (kg/d)	0	

Similar to other parameters, ammonia violations were rare, making up roughly one percent of the total sample records. The yearly rate of exceedance is generally increasing as time passes (with 2019 being an outlier due to incomplete data). There was little if any seasonality to the exceedances. In general, ammonia results indicate WWTFs are operating within their permit limits with little issue and that ammonia inputs from WWTFs are not likely a chronic issue of importance for the waterways. However, it is likely that they are of concern to stakeholders on a localized basis and may be indicative of opportunities for WWTF improvement. Like TSS, the exceedances occurred at a relatively small number of facilities. Forty-two WWTFs accounted for the 177 exceedances, with four of the facilities accounting for 60 of those exceedances. This indicates that there may be localized issues for ammonia regardless of the overall result.

CBOD5

CBOD5 is not a pollutant itself but is a measure of oxygen demand that can potentially indicate the presence of improperly treated effluent in a sample. Like TSS and ammonia, permit limits for CBOD5 include a concentration based (average) limit (in mg/L) and a total weight-based limit (in weight/day). For this evaluation, records for both were considered because of the nature of the test. Both average and maximum permit limit values exist for concentration limits for most plants. Evaluations for compliance with the permit limits were compared between plants, between seasons, between the years 2014 and 2019, and between categories (average or maximum values). Ninety-one plants reported CBOD5 results for these segments during this period (Table 12).

Table 13 - CBOD5 exceedances, 2014-2019

Category	Number	% of samples
Plants in DMR dataset	94	100%
Plants reporting CBOD5	91	97%
Total Records	16,223	100%
Total Exceedances	43	0.3%
Total Exceedances, Average	26	
Total Exceedances, Maximum	17	
Total Exceedances, Concentration Average (mg/L)	93	
Total Exceedances, Concentration Maximum (mg/L)	70	
Exceedances, Weight Average (kg/d)	14	
Exceedances, Weight Maximum (kg/d)	0	

As with the other parameters, CBOD5 violations were rare, making up less than one percent of the total sample records. The yearly rate of exceedance was variable but not clearly trending. Spring and summer months saw more exceedances. However, for both considerations, the number of exceedances is so small as to limit the applicability of any trends. In general, CBOD5 results indicate WWTFs are operating within their permit limits with little issue and that inputs that would be demonstrated by CBOD5 from WWTFs are not likely a chronic issue of importance for the waterways. However, it is likely that they are of concern to stakeholders on a localized basis and may be indicative of opportunities for WWTF improvement. The exceedances occurred at a relatively smaller number of facilities, but few had more than a few exceedances. One plant accounted for almost half (19) of all exceedances. This indicates that there may be localized issues for CBOD5 regardless of the overall result.

Overview of results

While there were exceedances for the evaluated parameters, most WWTFs met their permit limits most of the time without significant issue. Even allowing for variability in effluent conditions not reflected in the DMR results, it is unlikely that WWTFs are an appreciable source of contamination in the watershed on a chronic, wide-ranging scale. Fecal waste source modeling[47] supports this evaluation, indicating that for *E. coli* specifically, WWTFs are projected to account for a minor amount of overall load. However, the potential for localized inputs may be underrepresented by the overall impact of WWTFs for the watershed.

However, in interpreting these results, it should be noted that while WWTFs may not be a large source of fecal waste, they are likely one of the human fecal waste sources, and therefore have an inherently higher pathogenic potential than other sources. Additionally, unlike other sources of natural and diffuse fecal waste in the watershed, 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 effluent should be considered as a potential focus for some BMPs. While other parameters (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.

Sanitary Sewer Overflows

Unlike treated WWTF effluent, SSOs represent a high, if episodic risk, because they can have concentrations of *E. coli* 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 are 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 is limited by several factors. Actual SSO volumes and incidences are generally expected to be greater than reported due to these fundamental challenges. SSO causes were broken into four broad categories with several subcategories

[47] Please refer to the bacteria source modeling information later in this section, or for greater detail, the Cypress Creek Water Quality Modeling Report, available on the project website at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_creek_wpp_water_quality_modeling_report.pdf.

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[48].

This study considered five years of TCEQ SSO violation data for 2014-2018. There were 187 SSO records from 48 plants identified in the watershed area (Table 14). Of those 48 plants, 11 plants had more than five SSOs, and of those 11 plants, two plants had 10 or more SSOs. However, number of SSOs did not correspond well to volume of SSOs. Only three plants had a cumulative SSO volume greater than 50,000 gallons, and only two of those plants had a number of SSOs greater than five (but still less than 10).

Table 14 - SSOs by cause and year (number, 2014-2018)

SSOs by Year and Cause (Number)						
Cause	**2014**	**2015**	**2016**	**2017**	**2018**	**Total**
Weather	**0**	**3**	**10**	**24**	**5**	**42**
Rain / Inflow / Infiltration	*0*	*3*	*10*	*6*	*5*	*24*
Hurricane	*0*	*0*	*0*	*18*	*0*	*18*
Malfunctions	**9**	**15**	**15**	**33**	**7**	**79**
WWTP Operation or Equipment Malfunction	*3*	*1*	*5*	*10*	*2*	21
Power Failure	*1*	*0*	*3*	*2*	*0*	6
Lift Station Failure	*4*	*10*	*4*	*7*	*5*	30
Collection System Structural Failure	*1*	*4*	*2*	*14*	*0*	21
Human Error	*0*	*0*	*1*	*0*	*0*	1
Blockages	**7**	**14**	**4**	**15**	**4**	**44**
Blockage in Collection System-Other Cause	*2*	*6*	*1*	*0*	*1*	10
Blockage in Collection System Due to Fats/Grease	*3*	*8*	*2*	*11*	*2*	26
Blockage Due to Roots/Rags/Debris	*2*	*0*	*1*	*4*	*1*	8
Unknown Cause	***3***	***0***	***6***	***7***	***6***	**22**
Total	**19**	**32**	**35**	**79**	**22**	**187**

While the number of SSOs indicates the frequency with which sewage systems have events, and thus how chronic the load is from those plants, the volume of SSOs indicates the extent of the impact they have (i.e. a small plant with 100 small SSOs may produce a more chronic but smaller discharge than a large plant with a single SSO of a much larger volume). Examination of SSOs by cause and year for volume is somewhat similar, in that 2017 was an

[48] For example, fats, oils, and grease (FOG) causing lift station motor failures can cause overflows in high rain events when excess water is in a system. The event may be listed as lift station failure, but FOG and inflow and infiltration of rainwater were also causative elements.

exceptional year (Table 15). However, outside of 2017, the two breakdowns did not track proportionately, indicating that number and volume of SSO do not necessarily have a direct relationship.

Table 15 - SSOs by year and cause (volume), 2014-2018

SSOs by Year and Cause (Volume)						
Cause	**2014**	**2015**	**2016**	**2017**	**2018**	**Total**
Weather	**0**	**8,750**	**36,512**	**152,918**	**19,345**	**217,525**
Rain / Inflow / Infiltration	0	8,750	36,512	150,000	19,345	**214,607**
Hurricane	0	0	0	2,918	0	**2,918**
Malfunctions	**23,475**	**79,970**	**150,158**	**165,096**	**13,570**	**432,269**
WWTP Operation or Equipment Malfunction	700	2,500	8,925	24,502	3,300	**39,927**
Power Failure	5,000	0	135,404	2,364	0	**142,768**
Lift Station Failure	17,750	15,370	5,224	3,030	10,270	**51,644**
Collection System Structural Failure	25	62,100	105	135,200	0	**197,430**
Human Error	0	0	500	0	0	**500**
Blockages	**3,220**	**19,512**	**1,198**	**42,815**	**3,477**	**70,222**
Blockage in Collection System-Other Cause	1,650	9,180	705	0	1,500	**13,035**
Blockage in Collection System Due to Fats/Grease	970	10,332	393	32,665	477	**44,837**
Blockage Due to Roots/Rags/Debris	600	0	100	10,150	1,500	**12,350**
Unknown Cause	**604**	**0**	**26,537**	**3,303**	**503**	**30,947**
Total	**27,299**	**108,232**	**214,405**	**364,132**	**36,895**	**750,962**

Malfunctions, as a broad category, remain the primary volumetric source of SSOs, accounting for 57.5% of all SSOs. Weather-related events are next at 29.0%, followed by blockages at 9.4%, with an unknown portion making up 4.1% of volume. The breakdown of sources over the entire watershed should not be taken as an accurate cause profile for individual areas in the watershed but reflects the general challenges to the area's wastewater infrastructure.

In terms of seasonality, spring SSOs were predominant, followed by fall. However, the limited number of SSOs over the period and the number of extraordinary high flow events (including Hurricane Harvey in 2017), provide reasons to limit extrapolation of these results to suggest a strong seasonal trend.

The total volume by year varied greatly, representing the often-episodic nature of SSOs. Volume by year for each segment also varied greatly, and not always in relationship to other segments (e.g. in 2012 SSOs in Cypress Creek went down sharply, while those in nearby Spring Creek went up sharply). This suggests that commonly experienced causes (precipitation levels, etc.) may not be a primary driver for SSOs. While preliminary modeling indicates SSOs in general are not likely an appreciable chronic source of fecal waste (and other products from the waste stream) but may be impactful on a local, episodic basis.

SSO Summary

SSOs are always a concern in watersheds with contact recreation impairment and vulnerability to nutrient loading. Their concentrations of untreated human waste pose a disproportionately high risk to human health during recreation, and their episodic nature can make them an acute risk while they are ongoing. In terms of chronic loading, SSOs volumes in the project area are generally too small on an average basis to move conditions in the waterways in general. For comparison, a single plant of small to moderate size may have a discharge of 3 MGD, while the sum of all SSOs in the project area for a year is less than 3 million gallons. The SSOs are far greater in concentration, but their relatively minor volumes negate them to some degree as a primary source in average conditions.

However, given their pathogenic potential, inherently close proximity to urban populations, and the principle of focusing on those sources within our control, SSOs should remain as a consideration for BMPs in the watershed. A specific point of interest for this data in Cypress Creek is the impact and potential future implications for increasing high flow events, which can easily overwhelm even well-functioning sanitary collections systems.

Figure 26 - SSO in progress

Other Water Quality Studies

The Cypress Creek Watershed has been the focus of several water quality efforts in addition to this WPP and ongoing TCEQ and CRP monitoring. While the results from these studies can point to nuance in water quality issues, data from these studies are spread out over differing time periods and derived from different methodologies. For that reason, the data may not be directly comparable to the water quality analyses of this report (or subsequent modeling results). Regardless, the findings of these efforts are informative in directing the investigations of this WPP. The Partnership reviewed results from the following projects:

Lake Houston TMDL

The TCEQ project that culminated in the *Fifteen Total Maximum Daily Loads for Indicator Bacteria in Watersheds Upstream of Lake Houston*[49] and subsequent implementation plan[50] covered a broad area of the Lake Houston watersheds, including Cypress Creek. The findings of the TMDL analyses for Cypress Creek are less current or granular than the WPP analyses but indicate a similar pattern of impairments and concern.

WMOST Modeling

H-GAC is currently working with EPA and the United States Army Corps of Engineers (USACE) on a Watershed Management Optimization Support Tool (WMOST)[51] modeling effort to evaluate water quality and quantity best practices for the Cypress Creek Watershed. The modeling effort may offer insight or additional information for future revisions of this WPP.

Water Quality Analyses Summary

The review of water quality data for the Cypress Creek Watershed provided a better understanding of the character of water quality issues in these systems and will inform subsequent stakeholder decisions. The analyses served to answer questions regarding the sufficiency of the data, the extent and severity of water quality trends, seasonality of water quality issues, and the potential impact of wastewater effluent and SSOs.

In general, the review concluded that data was sufficient for all analyses. As discussed in the individual analyses, the water quality issues facing this watershed are widespread in extent. Trends are mixed, with some positive trends toward stability in *E. coli*, but increasing levels of some other parameters. Compared to modeling results and future growth projections, it is likely that increased development in the watershed will dramatically alter the balance of pollutant sources and change the hydrologic processes and time frames by which pollutants reach the waterways in precipitation events.

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[49] Available for review at https://www.tceq.texas.gov/assets/public/waterquality/tmdl/82lakehouston/82-lakehoustontmdl_adopted.pdf
[50] Available for review at https://www.tceq.texas.gov/assets/public/waterquality/tmdl/00BIG/42-HoustonRegionBacterialPlan-approved.pdf
[51] https://www.epa.gov/ceam/wmost

Permitted wastewater effluent was generally of good quality and unlikely to be a widespread water quality issue except in limited scales and timeframes. The exception to this is the likelihood that nutrients without permit limits are source loads from plants, especially in effluent-dominated streams. SSOs were present in all areas of the watershed, in numbers that were not appreciable but also not negligible. There were few statistically significant relationships between exceedance of water quality standards and WWTF permit limits, or incidences of SSOs, and seasonal change other than expected relationships evident in DO levels in ambient conditions.

Overall, water quality in this watershed faces many challenges but is within the range which may be successfully addressed through BMPs under a watershed-based plan. With continued growth of the Houston region continuing to push west into the watershed, the implication for future water quality is likely negative without intervention. Subsequent efforts should be made to identify causes and sources of the primary parameter of concern (*E. coli*), and to characterize nutrient sources further to identify areas within the project watershed most vulnerable to pollutant loadings and/or best suited for BMP siting.

Figure 27 - Impoundment in the Cypress Creek Headwaters area

Source Identification

Using the information generated through the water quality data analyses, the next step in characterizing pollution in the watershed was to evaluate potential causes and sources. The results of this source identification and prioritization process assisted the Partnership in understanding the range of potential sources and guided the subsequent modeling efforts that estimated the loads from fecal waste and nutrient sources. Fecal waste sources were the primary focus of these efforts, but potential sources of depressed DO, nutrients, and other stakeholder concerns were also considered in relation to potential solutions.

Fecal Waste Source Identification

All warm-blooded animals produce waste bearing *E. coli* and are potential sources of contamination. *E. coli* are not necessarily themselves the source of potential health impacts; however, they signify the presence of fecal waste and the host of other pathogens the waste may contain. There is a wide array of potential fecal waste sources in the watershed. The potential mix of sources in a watershed can vary greatly in both spatial and seasonal contexts. The preliminary process of identifying potential fecal waste sources in a watershed is discussed as being a "source survey"[52]. The results of the survey shaped further analysis under the source modeling efforts of the project.

Source Survey

Characterizing fecal waste pollution in watersheds, and development of analyses to estimate potential loading, requires a consideration of potential sources. In any watershed with a mix of land uses, fecal waste can be produced by a broad mix of sources; this is especially true in a large, diverse watershed like Cypress Creek. The existence and location of some sources are known from existing data (e.g., WWTF outfalls), while many nonpoint sources need to be evaluated from a mix of literature values, land cover analysis, imagery and road reconnaissance, and a robust process of stakeholder review and feedback. As part of developing the source survey, the Partnership completed the following assessments:

- Known Source Characterization[53] — Existing data was used to generate information on discrete (usually permitted) sources. The data sources included[54]:
    - WWTF outfall locations and discharge monitoring reports (TCEQ outfall locations and DMR records)

[52] For greater detail on the source survey and subsequent bacteria modeling outcomes, please refer to the Water Quality Modeling Report, available online at http://weebly-file/9/6/6/3/9663419/cypress_creek_wpp_water_quality_modeling_report.pdf.

[53] As discussed in part as a function of the water quality analyses discussed earlier in this section.

[54] More information on data sources and quality objectives can be found in the project quality assurance project plan (QAPP), available online on the project website at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/90201_cypress_creek_wpp_modeling_qapp-compressed.pdf

    - Permitted on-site sewage facility (OSSF) locations (H-GAC proprietary data provided by local governments)
    - Concentrated animal feeding operations (CAFOs) (TCEQ CAFO locations and violations data from TCEQ Central Registry records)
    - SSOs (TCEQ SSO database)
- Land Cover Analysis — Staff reviewed national land cover datasets and H-GAC proprietary land cover datasets to determine the mix of land cover types within the watershed, and within each subwatershed, in a spatial context. The watershed includes a mix of land cover types, so no sources were eliminated based on lack of land cover (i.e. available habitat/use). Statistics and spatial coverage developed during this analysis were used in the later SELECT implementation as the basis of populating diffuse sources whose assumptions were tied to specific land cover types.
- Imagery Reconnaissance — Staff utilized aerial imagery, online map assets (Google Maps, Google Maps Streetview, Google Earth) and stakeholder feedback to identify any specific locations, specific sources, or issues to raise with stakeholders for further clarification. Examples of items derived from this analysis were:
    - Presence of horse stables
    - Small, unincorporated communities
    - Recreation use
    - Developmental projects in the watershed
- Road Reconnaissance — Staff also conducted ongoing road reconnaissance throughout the watershed specific to this task and as part of all activities in the watershed. Specific items noted or affirmed during road reconnaissance included:
    - Presence of deer in appreciable numbers in lightly developed areas
    - Progress of development (especially in the headwaters attainment area)
    - Sign of feral hog activity in some areas
    - General character of observable agricultural activities
- Stakeholder Feedback — Stakeholder engagement was a primary focus of the source survey. Local knowledge was a key aspect of understanding source composition in the area. Project staff engaged stakeholder consideration of sources through:
    - Direct discussion of sources at Partnership meetings
    - Direct discussion of sources at source-based Work Group meetings
    - Map exercises with small groups following Partnership meetings
    - One-on-one meetings with local stakeholders
    - One-on-one meetings with state and regional experts/agencies (e.g. TPWD, TSSWCB, and others)

Stakeholder feedback specific to the identified sources is discussed later in this section, relative to each source. In general, stakeholder feedback upheld staff expectations of usual sources, and helped refine extent and scale of expected source contributions (e.g. rates of dog ownership, presence of deer in developed areas, hog activity levels, horse stable activity, presence of specific problem sites/dumping) The ultimate selection of sources to include in the model was based on stakeholder decisions and affirmation of H-GAC's proposed modeling methodology, through the revision process.

The estimated extents of the source survey general categories reflect preliminary understandings, rather than the modeled outcomes or final stakeholder feedback (Table 16). Note that these extents reflect current estimated status, and some sources may be expected to increase or decrease in the period assessed by this modeling effort. The results of the fecal waste source survey were used to guide the development of the load estimation modeling (SELECT) described later in this section.

Figure 28 - Wildlife (Nutria) in Cypress Creek

Table 16 - Fecal waste source survey

Category	Source	Origin	Estimated Extent
Human Waste	OSSFs	Failing/improperly sited OSSFs	Moderate
	WWTFs	Improperly treated sewage from permitted outfalls	Minor
	SSOs	Untreated sewage from wastewater collection systems	Minor to moderate (local)
	Direct discharge	Untreated wastes from areas without OSSF or WWTF service	Minor
	Land deposition	Improperly treated or applied sewage sludge	Minor
Agriculture	Cattle	Runoff or direct deposition	Moderate
	Horses	Runoff or direct deposition	Minor to moderate (local)
	Sheep/Goats	Runoff or direct deposition	Minor
	CAFOs	Improper or improperly treated discharge from permitted facilities	Not expected
	Pigs	Runoff	Minor
	Exotic animals	Runoff or direct deposition	Not expected to minor (local)
Wildlife and Non-domestic animals[55]	Feral hogs	Runoff or direct deposition	Moderate
	Deer	Runoff or direct deposition	Minor to moderate (local)
	Birds	Direct deposition	Not expected, no data
	Bats	Direct deposition	Minor, no data
	Other wildlife[56]	Runoff or direct deposition	No data
Other Sources	Dogs (pets)	Runoff	Major
	Dogs (feral)	Runoff	Minor to moderate (local)
	Cats (pets)	Runoff	Not expected
	Cats (feral)	Runoff	None/ minor
	Dumping	Runoff or direct deposition	Minor (local)
	Sediment	Erosion or mining operations	NA[57]

[55] Feral hogs have established wild populations, but are not considered wildlife by TPWD and other state agencies. Consideration of hogs in the same category as other wildlife does not suggest they are viewed as wildlife by this modeling effort or WPP development project. This solely reflects their status as being non-domestic animals.
[56] Other wildlife is used throughout this document as a means of designating all wildlife populations for which sufficient data doesn't exist and which couldn't be assessed (unlike colonial birds and bat colonies). Stakeholder decisions regarding an assumption for this source is discussed in greater detail in its corresponding section.
[57] As with other waterways in the West Fork San Jacinto River system, mining/aggregate operations and erosion is present in many places in the Cypress Creek Watershed. Development and other activities also contribute to erosion, especially in the headwaters and transitional areas. While not a source of bacteria per se, suspended sediment in the water acts to decrease bacteria die-off from insolation, etc.

Estimating *E. coli* Loads

Understanding the distribution and relative prominence of various sources of fecal waste is crucial to empowering stakeholders to make informed decisions about potential solutions. To quantify the potential number of fecal indicator bacteria being generated in the watershed, the Partnership used a combination of stakeholder knowledge and computer modeling. The goal was to identify how much *E. coli* was being generated by each source, and how those sources were distributed in the watershed.

The Spatially Explicit Load Enrichment Calculation Tool (SELECT)

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) is a GIS-based analysis approach developed by the Spatial Sciences Laboratory and the Biological and Agricultural Engineering Department at Texas A&M University[58]. The intent of this tool is to estimate the total potential *E. coli* load in a watershed and to show the relative contributions of individual sources of fecal waste identified in the source survey. Additionally, SELECT adds a spatial component by evaluating the total contribution of subwatersheds, and the relative contribution of sources within each subwatershed. SELECT generates information regarding the total potential *E. coli* load generated in a watershed (or subwatershed) based on land use/land cover, known source locations (WWTF outfall locations, OSSFs, etc.), literature assumptions about nonpoint sources (pet ownership rates, wildlife population statistics, etc.) and feedback from stakeholders. The potential source load[59] estimates are not intended to represent the amount of *E. coli* actually transmitted to the water, as the model does not account for the natural processes that may reduce pollutants on their way to the water, or the relative proximity of sources to the waterway.

Project staff used an adapted SELECT approach to meet the specific data objectives of this project. The implementation of SELECT used for this modeling effort builds on the original tool by adding two modified components.

- **Buffer Approach** — The stock SELECT model assumes all *E. coli* generated within a watershed will have the same impact on instream loads. For example, loads generated 2 miles from a waterway are counted the same as equivalent loads generated within the riparian corridor. Realistically, loads generated adjacent to the waterways are more likely to contribute to instream conditions. However, SELECT

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[58] Additional information about SELECT can be found at http://ssl.tamu.edu/media/11291/select-aarin.pdf. Information about the specific implementation of SELECT utilized by this project can be found in the project modeling QAPP, available at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/90201_cypress_creek_wpp_modeling_qapp-compressed.pdf.

[59] References to loads in this section, unless specifically stated otherwise, should be taken to refer to (potential) source loads, rather than instream loads. As indicated previously, SELECT does not generate instream loading estimates, just the potential source load prior to factors affecting to fate and transport of pollutants.

does not provide a means by which to model fate and transport factors. In a situation in which a particular source is generally located farther from the waterway, it may be overrepresented compared to a source generally located adjacent to the waterway. For example, if OSSFs in a watershed produced 50 units of waste, but were generally located far from the water, while livestock in a waterway produced the same amount of waste, but generally in the riparian corridor, SELECT would treat these potential loads as equal. For stakeholders making decisions on prioritizing BMPs and sources, this is a false equivalency. To strike a balance between project focus on simple but effective modeling and a desire to understand the potential impact of transmission, this implementation of SELECT differentiates between loads generated inside a buffer area surrounding waterways, and loads generated outside this area. The buffer approach assumes 100 percent of the waste generated within 300 feet of the waterway as being transmitted to the watershed without reduction. Outside of that buffer, only 25 percent of the waste is assumed to be transmitted to the waterway[60]. Sources that lack specific spatial locations (unlike permitted outfalls) are assumed to be distributed uniformly in appropriate land uses, inside and outside the buffer. For example, the total number of deer in the buffer is derived from multiplying the assumed density by the numbers of acres of appropriate land use within buffered areas. This approach is designed to provide a very general conception of the effect of distance from the waterway.

- Future Projections — The Cypress Creek Watershed is undergoing rapid developmental change. Current (2018) sources[61] are expected to expand in the future. Therefore, *E. coli* reductions based on current conditions would be inadequate to meet future needs. This implementation of SELECT uses regional demographic projection data to estimate future conditions through 2040 in 5-year intervals[62]. Land use change is the primary driver for estimating changes in source contribution, and spatial distribution of loads[63].

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[60] Buffer percentages were based on previously approved WPPs and reviewed on multiple occasions with project stakeholders.

[61] References to "current" modeled conditions throughout this document refer to 2018 estimations, based on the available data at the time of the modeling effort.

[62] 2040 was chosen as a horizon year to coincide with the extent of the regional demographic model projections at the time and also in consideration of likely planning horizon for partner efforts and developmental projects.

[63] All future projections have some level of uncertainty that cannot be wholly controlled for. The H-GAC Regional Growth Forecast (http://www.h-gac.com/regional-growth-forecast/default.aspx) demographic model projections are widely used in the region and in similar WPPs, and thus considered the best available data for making these projections. Some wildlife sources have additional levels of uncertainty because the model assumes that change between land uses eliminates populations tied to the former land use. However, there is not adequate data or analytical approaches within the scope of this project to determine the potential that wildlife populations will change or consolidate by literature values alone. For example, the model assumes a set density of feral hogs per

Watershed conditions can change greatly from year to year based on rainfall patterns, agricultural activities, increased urbanization, and other landscape-scale factors. To balance this inherent degree of variation and uncertainty, stakeholder feedback on sources, model assumptions, and results were used heavily through the generation of the analysis and its eventual use as a prioritization tool for selecting BMPs. The goal of the SELECT modeling in this WPP effort, other than the general characterization of source loading, is to aid in prioritizing which sources to address by showing their relative contributions and locations. The loads generated by SELECT are combined with LDC reduction percentages to generate source reduction loads. There is an inherent level of uncertainty in any modeling of a dynamic system, but the approach used in this WPP is balanced against the end use of the information to support stakeholder decisions.

The analysis design for this process includes four primary steps: 1) development of a source survey using known locations/sources, suspected sources derived from projects in similar areas, and stakeholder feedback ; 2) stakeholder review of proposed sources and preliminary population/loading assumptions; 3) implementation of the model and internal quality review; and 4) stakeholder review of results and model revision as necessary (Figure 30).

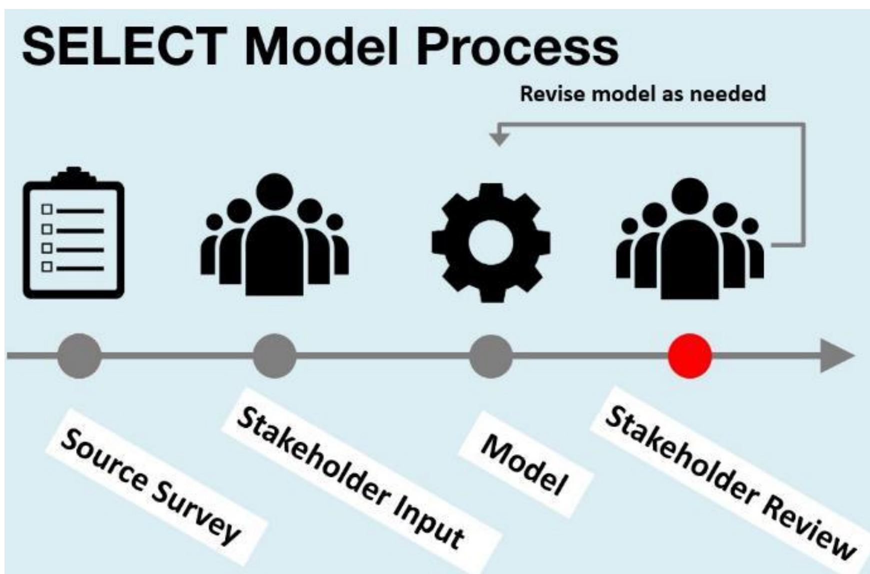

Figure 29 – SELECT modeling process

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unit of area, populated in appropriate land cover types. Feral hog populations are assumed to stay static because there is insufficient data to make assumptions about rate of population growth. Additionally, if an area containing feral hogs converts to developed land cover, the hogs attributed to that area are eliminated from the calculations. In real conditions, this may instead lead hogs to consolidate in greater densities in remaining habitat up to some carrying capacity. This project acknowledges that uncertainty, and the stakeholders discussed potential methods to address it. However, no sufficient data sources or modeling methods within the scope of this project have been identified to account for wildlife population dynamics. Continual assessment of wildlife populations as a source is recommended in the adaptive management recommendations of the WPP to help overcome this uncertainty.

The following subsections detail the sources modeled, including the data used and the feedback received from stakeholders. The maps indicate the relative distribution of source loads and populations, while the charts indicate the relative contribution of different sources. The loadings are given in numbers of *E. coli* per day, using scientific notation[64]. The maps are not comparable to other sources; they show the relative distribution for a given source by color gradation, rather than color being tied to absolute load. The maps also reflect the use of the buffer approach, with darker patches of color adjacent to the waterways, displaying the higher loads from these areas. In viewing the maps, it is important to consider that they display both relative loading by area within a subwatershed (riparian areas versus areas outside the riparian) and between subwatersheds. Lastly the map coloration is based on relative load density (load per acre). Larger subwatersheds will have larger loads, all things being equal. Load density maps help equalize discrepancies in subwatershed size and make fair comparisons.

On-Site Sewage Facilities

Failing or improperly maintained OSSFs (including a mix of septic tanks, aerobic treatment systems, and similar technologies in this watershed) can be significant sources of *E. coli* and are a legacy wastewater solution for less developed or rural areas of the watershed. Some new development uses OSSFs for its primary treatment, but much of the current or proposed development in the transitional and headwaters areas are larger master-planned communities that rely on centralized wastewater treatment. While OSSFs in the area are generally more closely regulated than in some areas of the region, the distributed nature of wastewater treatment by OSSFs makes maintenance for those systems a concern for future water quality as systems continue to age.

Permitted OSSF data was taken from existing spatial data compiled by H-GAC from authorized agents[65]. Assumptions for unpermitted OSSFs are based on a review of household data projections outside of sanitary sewer boundaries for which no permitted OSSF exists. It was assumed that occupied parcels outside service areas without permitted OSSF contained an unpermitted OSSF. Loading rates are based on output from failing/improperly maintained systems. Project staff discussed failure rate with Harris County, the primary authorized agent for the area, as well as the Partnership and Human Waste work group. Based on the stakeholder knowledge of system status in the watershed, their experienced violation rates, and best professional judgement, a 10% failure rate was used for all system types and ages. Stakeholders did not feel further division of failure rates was possible given their knowledge and existing data. Future load projections are based on an increase of systems and system load proportional to increases in households outside the existing service area boundaries for sewer utilities, in five-year increments through 2040.

Some uncertainty exists due to the insufficiency of data concerning both permitted and unpermitted systems. H-GAC's permitted system spatial dataset is not inclusive of all records

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[64] For example, 1.4E+12 is equivalent to 1.4×10^{12}, or 1.4 trillion. E+9 would be billions, E+6 millions, etc.

[65] Data is collected under a CWA §604(b) agreement between H-GAC and TCEQ, and quality assured under the auspices of that contract. Use of this acquired data is detailed in the project modeling QAPP for this project.

obtained from authorized agents in the region, although Harris County's records are well documented. In some cases, issues with the data or inability to geocode a record means that records are excluded even if permitted. Additionally, the deductive analysis that identifies unpermitted system locations is intended to represent potential locations rather than known unpermitted systems. During the project, local authorized agents and knowledgeable partners were asked to review maps of known and suspected OSSF locations. No appreciable changes were recommended. It is also assumed that failure rates will stay constant and that service area boundaries will expand based on projected development. While boundaries may change, there is no feasible way to predict spatially where this will occur. The stakeholders reviewed and confirmed the assumptions and estimates.

Current load estimates for OSSFs in the watershed, relative to each subwatershed' s contribution[66], indicate the highest loads are within subwatersheds 3 and 4 (Figure 31; Table 17).

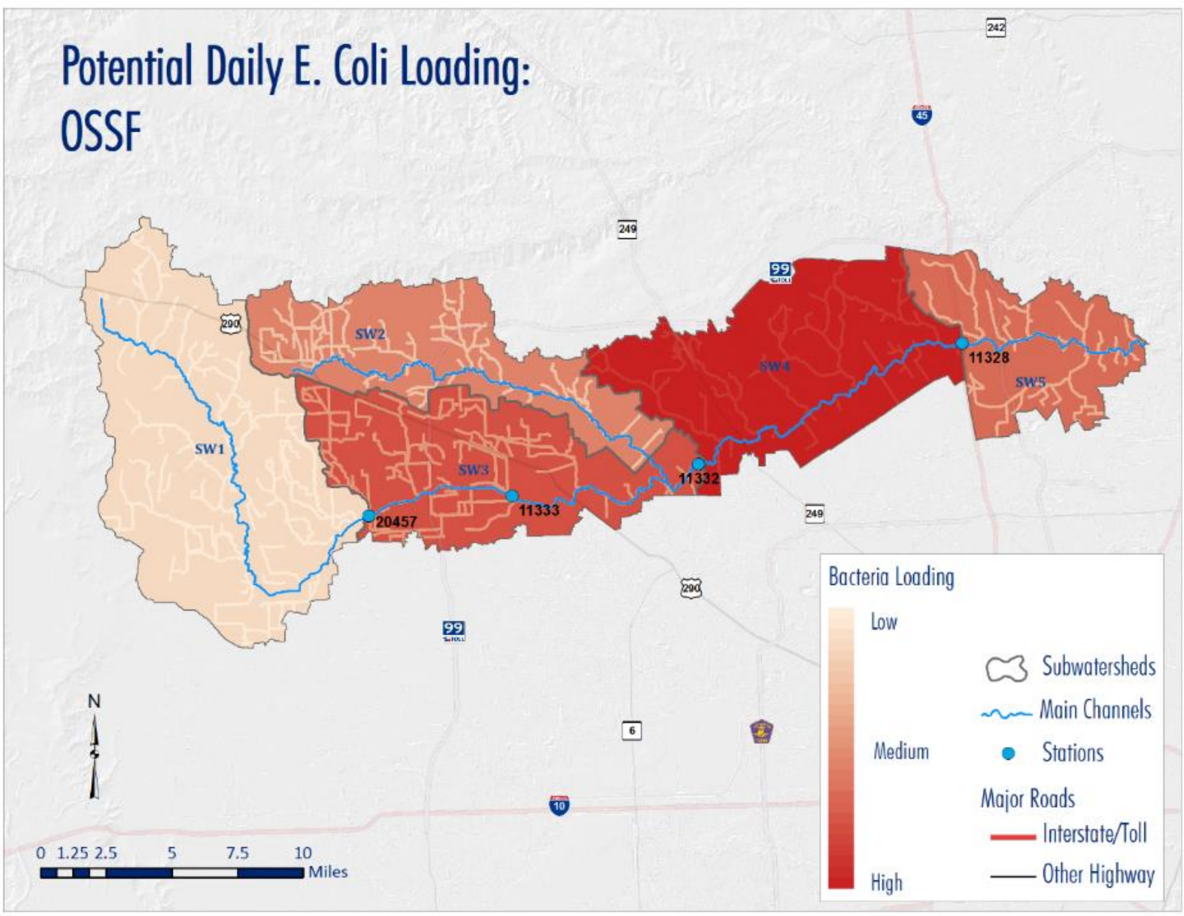

Figure 30 - Potential daily *E. coli* loading from OSSFs

[66] Throughout this section, it should be noted that these loading maps use color to indicate relative loading for each subwatershed. They are not necessarily comparable to degree of color exhibited on maps for other sources. Numerical loading estimates for comparison are given in their respective tables.

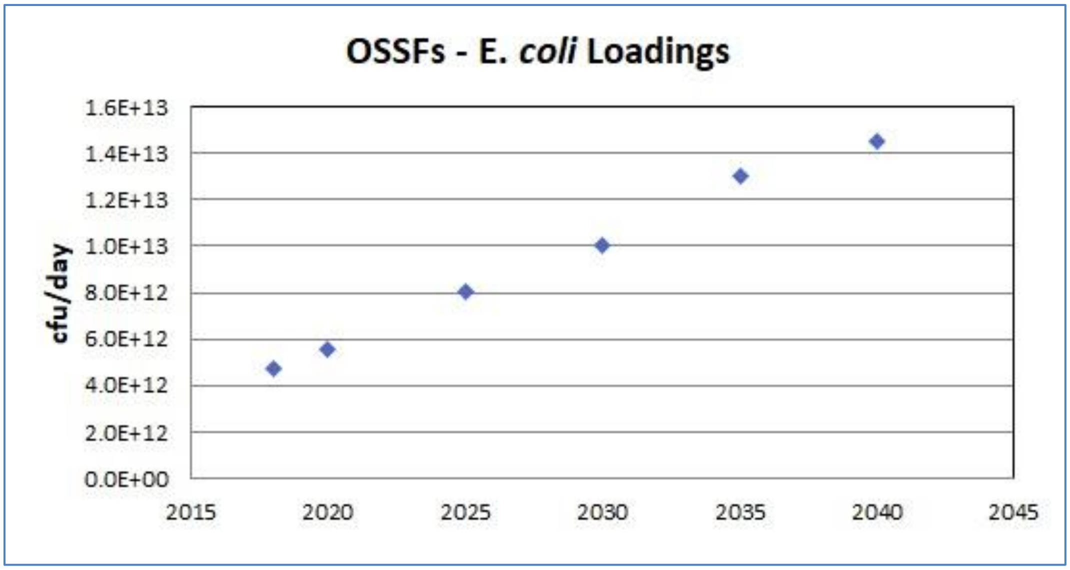

Figure 31 - Future potential load from OSSFs

Table 17 - Current potential *E. coli* loads from OSSFs, by subwatershed

		SW1	SW2	SW3	SW4	SW5	Total
Number of failing OSSFs	Outside Buffer	237	387	682	1584	381	**3,271**
	Within Buffer	26	55	114	210	48	**453**
E. coli Loading	Outside Buffer	2.19E+11	3.59E+11	6.32E+11	1.47E+12	3.53E+11	**3.03E+12**
	Within Buffer	9.53E+10	2.03E+11	4.21E+11	7.79E+11	1.78E+11	**1.68E+12**
Subwatershed % of total load		6.7%	11.9%	22.4%	47.8%	11.3%	**100%**

OSSF loadings are expected to continue to increase through 2040 (Figure 32). The rapidly changing land uses of the watershed, especially in rural areas along the major transportation corridors, is driving the increase in systems. Balancing this increase, Harris County's robust approach to system management and enforcement is expected to continue to keep failure rates relatively low. While OSSFs are not routinely inspected by the county, new systems must be permitted and have regular maintenance, which acts as an informal inspection by the maintenance provider. High property values in many of the new development areas utilizing OSSFs are also expected to keep failure rates for aging systems partially in check. The 10% failure rate is currently being used for all years, based on stakeholder feedback, although the stakeholders recommended that this be checked regularly as some systems continue to age. An increase in failure rate may be necessary if on the ground conditions warrant.

Wastewater Treatment Facilities

Permitted wastewater utilities in a variety of sizes serve populations throughout the watershed. Much of the watershed is outside city limits where MUDs and other special districts are the primary form of centralized waste treatment. There are 112 active WWTF outfalls in the WPP area, representing 112 unique WWTFs[67]. Only four of the plants are industrial, the rest are domestic. The plants range in size from 10 MGD to discharges less than 0.01 MGD. Of these facilities, 100 have DMR data that was included in the modeling. The DMR data indicates exceedances of permit limits for *E. coli* are not common, and do not show a strong relationship to season or plant size.

WWTFs were not expected to be a large source of loading based on previous review of DMR data and stakeholder feedback. WWTFs always have the risk of being acute, localized sources of note, but no evidence or feedback was received that would indicate any specific, chronic problems of a size that might impact loading estimates[68]. To estimate loadings, the total permitted flows for each subwatershed were multiplied by the *E. coli* standard. While most plants discharged well below the standard, this approach was chosen by the stakeholders to ensure a conservative estimate of potential WWTP impact. This is intended to account for times of exceedance and variation of conditions throughout a daily cycle. Loads were applied at the buffer area loading rate to reflect direct outfalls. For future projections, discharges were assumed to be at or below the standard. Future flows were increased proportional to projected household increase within the existing service area boundary.

The actual WWTF source loading estimates by subwatershed indicate loads are greatest in subwatershed 4 (Figure 33; Table 18). WWTF flows and loadings increase through 2040 (Figure 34), but they remain a minor contributor to overall potential loading.

Table 18 - WWTF loading by subwatershed

Subwatershed	Outfalls	Loading
1	1	8.02E+08
2	16	3.35E+09
3	21	9.99E+09
4	41	4.34E+10
5	21	1.40E+10
Total	**112**	**7.15E+10**

[67] More information on the distribution, character, and DMR records for these plants is included in the project's Water Quality Data Collection and Trends Analysis Report on the project website at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_water_quality_trends_report_final.pdf.

[68] Feedback regarding localized issues was taken into consideration for the focus of BMPs in implementing the plan but did not rise to the level of potential impacts to loading numbers, as special cases were episodic and localized.

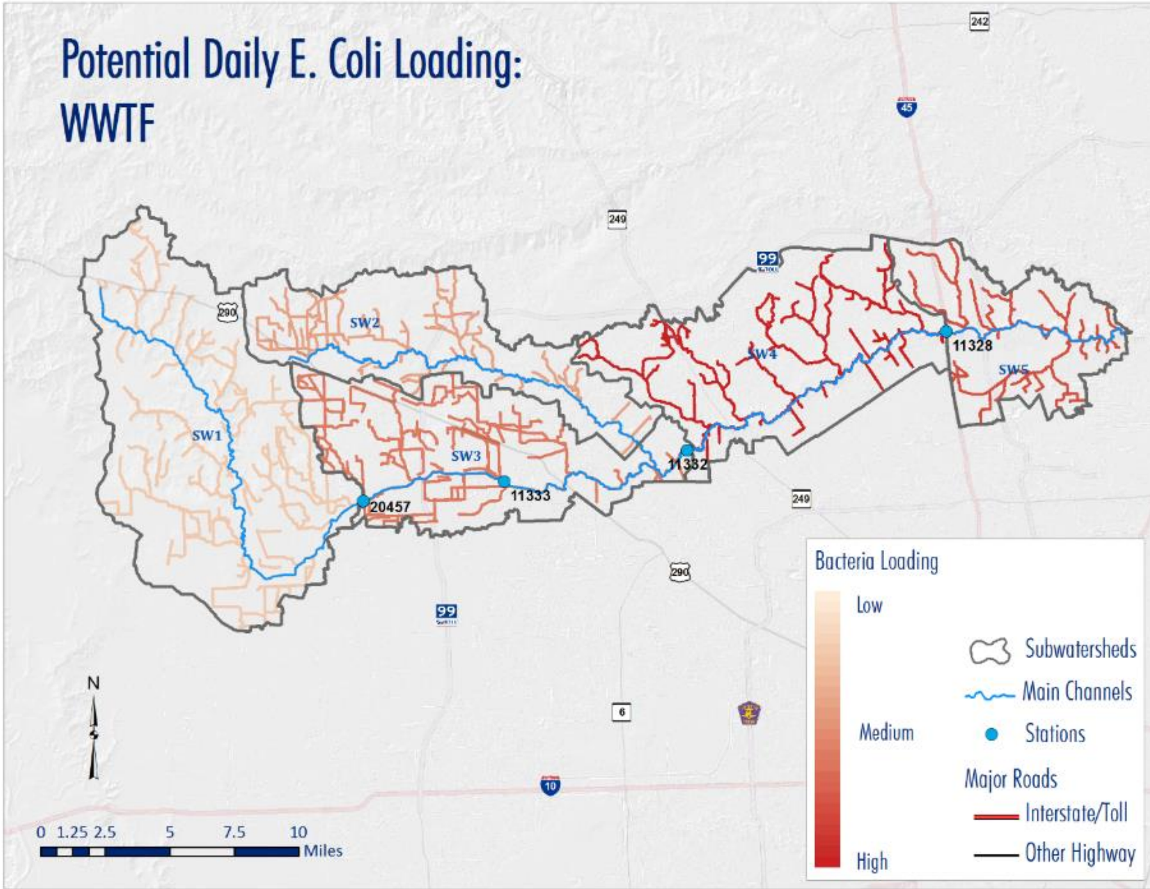

Figure 32 – *E. coli* loadings from WWTFs, by subwatershed

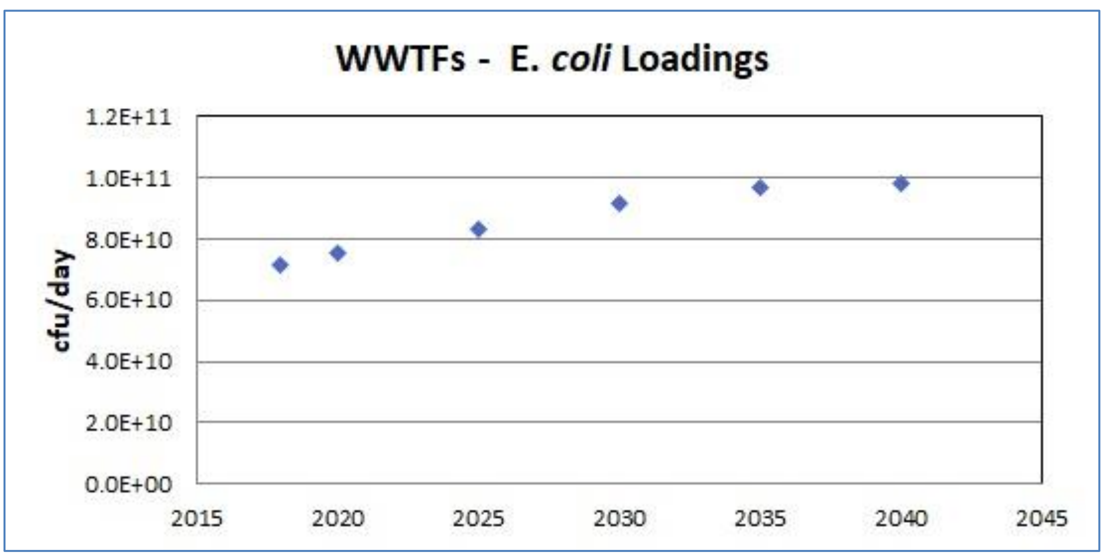

Figure 33 - Future *E. coli* loadings from WWTFs

Sanitary Sewer Overflows

Overflows from sanitary sewer collection systems can introduce large volumes of untreated sewage in short times. At best, they are acute, episodic sources. However, in areas with aging or improperly maintained infrastructure, they can be a chronic source of human fecal waste. Unlike treated wastes discharged by WWTFs, *E. coli* levels in SSOs are often many orders of magnitude greater. SSOs can result from a variety of causes, including human error in system operation, infiltration of rainwater into sewer pipes during storm events, power failures at lift stations, or blockages in pipes[69].

SSOs within the watershed were derived from five years of TCEQ data (figure 35, Table 19). A fundamental level of uncertainty exists because the data relies on reporting and records from permitted utilities as well as TCEQ staff. The number, type, duration, and volume of SSOs in the data may not fully describe the level of SSO activity in the watershed for several logistical reasons[70]. All SSOs related to a WWTF and receiving stream segment in the watershed area[71] were used to characterize this source. Loading values were based on a consideration of the causes identified for SSOs in the watershed, which were primarily dilute (rainwater charger releases) or moderate. Concentrations of *E. coli* can vary greatly based on the composition of sewage at the time of the SSO. EPA literature values[72] were used to identify likely concentrations in SSOs based on the breakout of SSO causes reported. The moderate concentration value was chosen as most representative. Future loads were generated by increasing SSOs proportionately to increases in households within the service areas.

The primary question on how to calculate SSOs stems from their (usually) episodic nature. SSOs in the watershed areas were not generally found to be chronic loads, but rather, acute. Therefore, their live loading is high, but much of the time there is no loading. The stakeholders of the Partnership, local partners, and the work group considered the question of how to estimate SSO flows. The most conservative approach would be to take the highest potential loading and use it as a daily value. However, this would grossly overstate the loading on any given day from SSOs. However, the stakeholders had concerns that using an average of all SSO flow over time (i.e. treating the SSOs as a chronic load averaged over the

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[69] More information on the character and distribution of SSOs is available in the project Water Quality Data Collection and Trends Analysis Report on the project website at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_water_quality_trends_report_final.pdf.

[70] For example, SSOs may not be discovered until they have been discharging for an unknown period of time, estimates of volume may be hard to determine based on field conditions, etc.

[71] While collection systems can straddle boundaries, and WWTFs outside the watershed may have systems partially within it, staff review of spatial distribution of plants in the surrounding area did not lead to an expectation that this was the case in this project area.

[72] As referenced at https://www3.epa.gov/npdes/pubs/csossoRTC2004_AppendixH.pdf

year to produce a daily load value) would underestimate the impact of SSOs. Because of the documented nature of SSOs in the project area, the stakeholders elected to remove SSOs from the load calculation entirely and treat them as a separate item that was given high priority regardless of its relative contribution. The initial estimations by project staff included SSO loads, but they were not appreciable on an average basis, so their removal does not impact the overall loading for the watershed. The intent was to focus on any identified problem areas as localized, acute sources to prioritize for remediation in the WPP. However, because data was available for SSOs, current and future load projections were determined based on the daily average approach, for the sake of spatial prioritization.

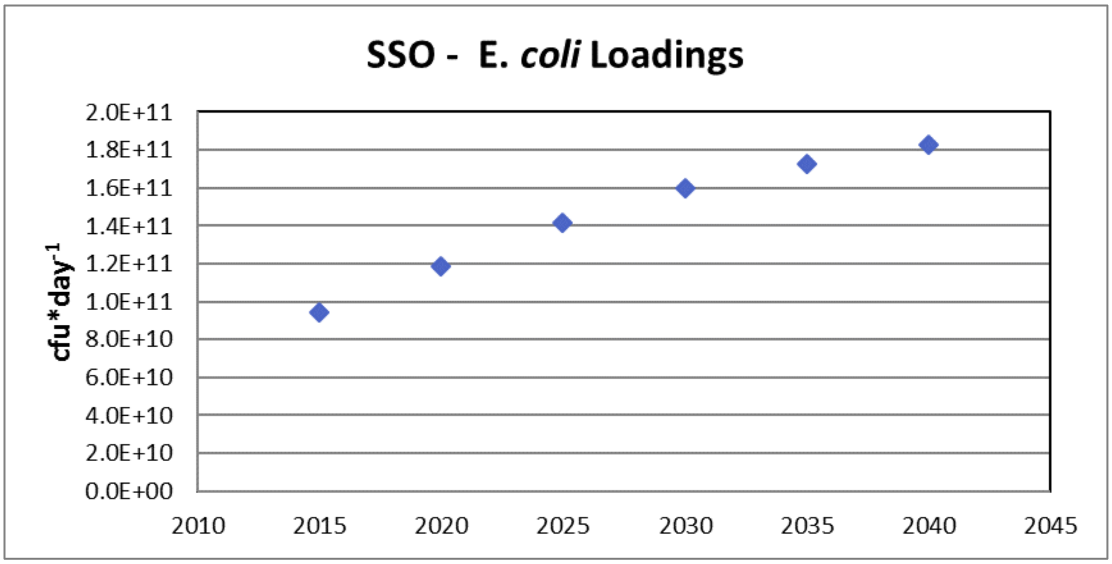

Figure 34 - Future *E. coli* loadings from SSOs

Table 19 – Current potential *E. coli* loadings from SSOs, by subwatershed

Subwatershed	SSOs	Load
SW1	0	0.00E+00
SW2	19	4.31E+09
SW3	34	4.97E+09
SW4	93	5.73E+10
SW5	41	1.13E+10
Total	**187**	**7.79E+10**

The actual SSO source loading estimates by subwatershed, in average daily volume, expressed in MPN/day, and based on the EPA's literature value for a medium dilution concentration (10,000,000 MPN/100ml), indicate the highest loads are within subwatershed

4. While SSOs are currently a minor source of load as an average daily load, they grow with population and development. Additional factors like the potential for increase in the rate of SSOs as systems age could not be extrapolated from known data. Comparison of older and newer systems did not produce any statistically significant differences, primarily due to the small data sets. While SSOs may not be a primary source, the stakeholders felt it was important to include them and highlight them because, 1) they are human waste sources, and thus have higher potential pathogenic impact[73,74]; 2) their peak volumes and concentrations are underrepresented here; and 3) they can be pronounced localized sources in areas where direct human contact is more likely (developed areas). Therefore, SSOs are not included in the loading estimates for this project but are automatically designated as a source of high concern.

Cattle

Cattle production has been historically present throughout the watershed and is currently concentrated primarily in the headwaters area west of SH99, although some production continues in the other attainment areas as well. Developmental pressure, weather events (e.g., the 2011 drought), and other market forces have led to a marked decline in agricultural production in the watershed. Initial estimates of cattle populations for the watershed were based on the latest (2017) livestock census data from the USDA's National Agricultural Statistics Service (NASS). Because the data for cattle are not

Figure 35 - Cattle on the Katy Prairie

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[73] Quantitative microbial risk assessment studies, including work in the Leon River (Gitter, Anna Caitlin *(2016). Application of Quantitative Microbial Risk Assessment and Bacterial Source Tracking to Assess the Associated Human Health Risks from Multiple Fecal Sources During Recreational Exposure in the Leon River Watershed. Master's thesis, Texas A & M University. Available electronically from https://oaktrust.library.tamu.edu/handle/1969.1/158640)* have indicated that sources with equivalent loads may have marked differences in expected microbial risk, with human sources being the most problematic.

[74] Most cases of human gastrointestinal disease associated with recreational waters that are impacted by human sources are actually caused by viruses, as opposed to bacteria. [U.S. EPA Office of Water (2018). *2017 Five-Year Review of 2012 Recreational Water Quality Criteria*. EPA 823-F-18-001, p. 2. Available electronically from https://www.epa.gov/sites/production/files/2018-05/documents/2017-5year-review-rwqc-factsheet.pdf.] Many human intestinal viruses, which are shed in high numbers by infected individuals, are more resistant to inactivation by typical wastewater treatment than are *E. coli* bacteria. These viruses are well adapted to infect humans, and they can persist for prolonged periods of time in the environment. DNA-based analyses or similar tools can provide different insight on the relative extent of fecal indicator bacteria from human sources in waterways.

specific to the watershed area, cattle were assumed to be equally distributed throughout the county, within appropriate land cover types. The ratio of each county's portion of the watershed's acreage in appropriate land cover types to that of the respective county as a whole was generated. This ratio was then applied to county cattle populations, such that a number of cattle proportional to the size of the watershed acreage in that county was established. This approach ensures that the density of cattle in a county's applicable land cover acreage (grassland and pasture/hay) was the same as the density in the watershed's applicable land use acreage. The initial cattle populations were expected to be overly high by project staff. The assumed overestimation was based primarily on the model treating appropriate land cover as being under production for cattle, even if it may be fallow. These data were reviewed with the stakeholders and the SWCDs for each county, and with the topical work group for agriculture. In general, the feedback from these groups was that cattle populations were more accurate than expected based on known herds and activity. However, some reductions were recommended in the subwatersheds of the more urbanized downstream areas.

Based on this feedback, cattle numbers were reduced in each subwatershed based on the information and local knowledge specific to that watershed. In meetings with SWCDs, board members worked with staff on calculations based on known herds in given subwatersheds to determine rough reduction values. Reductions of 30% were applied to subwatersheds 4 and 5. There are no CAFOs in the watershed.

Cattle *E. coli* loads were derived for milestones at every five years starting with current (2018) conditions. Current loading distributions for cattle in the watershed indicate that subwatershed 1 has the highest loadings from this source (Figure 37; Table 20). Cattle production and presence in the watershed is expected to continue to decrease, leading to a corresponding decrease in potential *E. coli* load from this source (Figure 38). Primary forces behind this change in the model are change of land cover to developed areas, but stakeholder feedback also indicated that rising land value and changing conditions ahead of growth were also pressures on cattle production. Additionally, market forces and the result of past weather events unrelated to development are exerting negative pressure on production in the watershed.

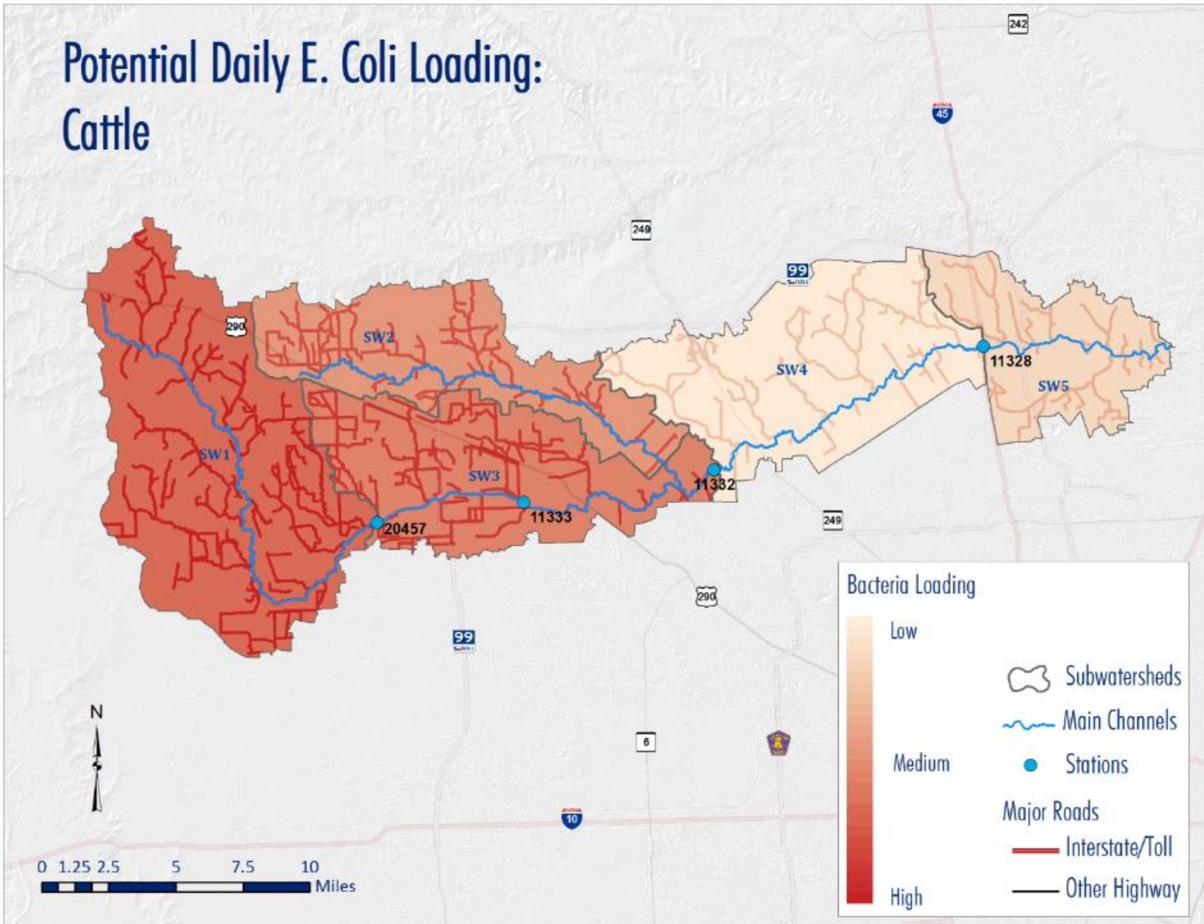

Figure 36 - E. coli loadings from cattle, by subwatershed

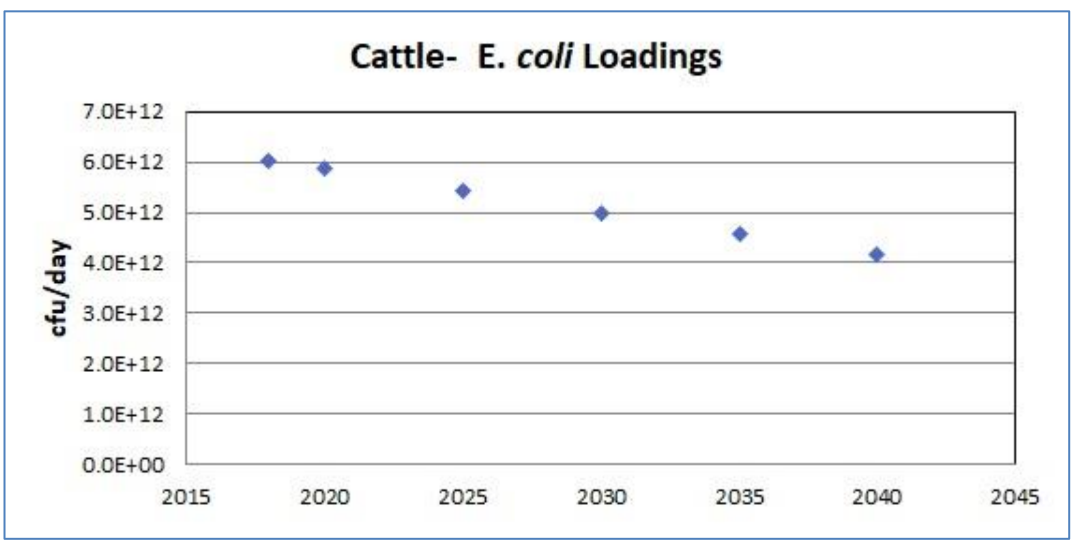

Figure 37 - Future *E. coli* loads from cattle

Table 20 - Current potential *E. coli* loads from cattle, by subwatershed

		SW1	SW2	SW3	SW4	SW5	Total
# of Cattle	Outside Buffer	3057	696	1058	61	42	**4913**
	Within Buffer	574	141	267	12	10	**1004**
E. coli Loading	Outside Buffer	2.06E+ 12	4.70E+ 11	7.14E+ 11	4.09E+ 10	2.86E+ 10	**3.32E+ 12**
	Within Buffer	1.55E+ 12	3.80E+ 11	7.21E+ 11	3.36E+ 10	2.63E+ 10	**2.71E+ 12**
Subwatershed portion of total load		59.9%	14.1%	23.8%	1.2%	0.9%	**100%**

Horses

Unlike cattle populations in the watershed, horses have straddled the divide between rural areas and suburban/exurban development. Dense horse populations are found in both rural areas and in the transitional area, where recreational[75] horse ownership is common and expanding. However, stabling operations are also found in downstream areas. Primary modes of ownership include traditional rural populations accompanying existing agricultural operations, large acreage home sites which may have one or a small number of horses, and boarded horses in stabling operations. Based on stakeholder feedback there were no known problem operations or specific areas of concern, however it was noted that manure piles exist in some areas/operations and may be opportunities for remediation.

Figure 38 - Horse on acreage property

Horse populations were derived using the same methodology as cattle populations, using proportional numbers of county NASS data populations. As with cattle, horse population estimates were first reviewed internally by project staff, then with local experts (SWCDs, etc.), and then with the work group and Partnership. Based on feedback from the SWCDs, and

[75] "Recreational" is used here in comparison to horses who are part of agricultural operations.

affirmed by stakeholders, horse populations were increased by 20% in subwatersheds 1, 2, and 3.

Horse *E. coli* loads were derived for milestones at every five years starting with current conditions. The current loading distributions for horses in the watershed indicate the highest loads within subwatershed 1 and 3 (Figure 40; Table 21). As with cattle and other livestock, horse populations are expected to decline as development pushes further into rural areas (Figure 41). However, the extent of reduction is expected to be somewhat less as exurban acreage developments continue to support small horse populations.

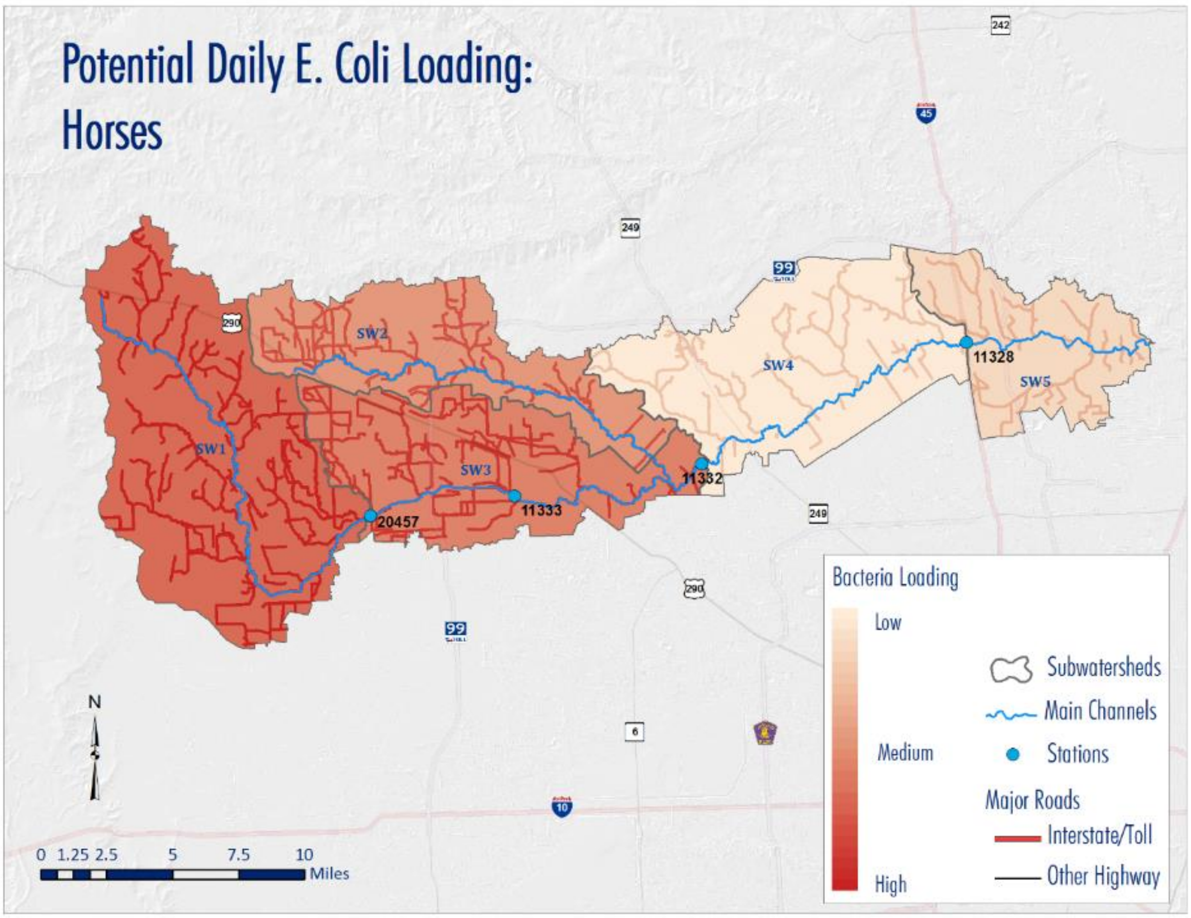

Figure 39 - E. coli loading from horses, by subwatershed

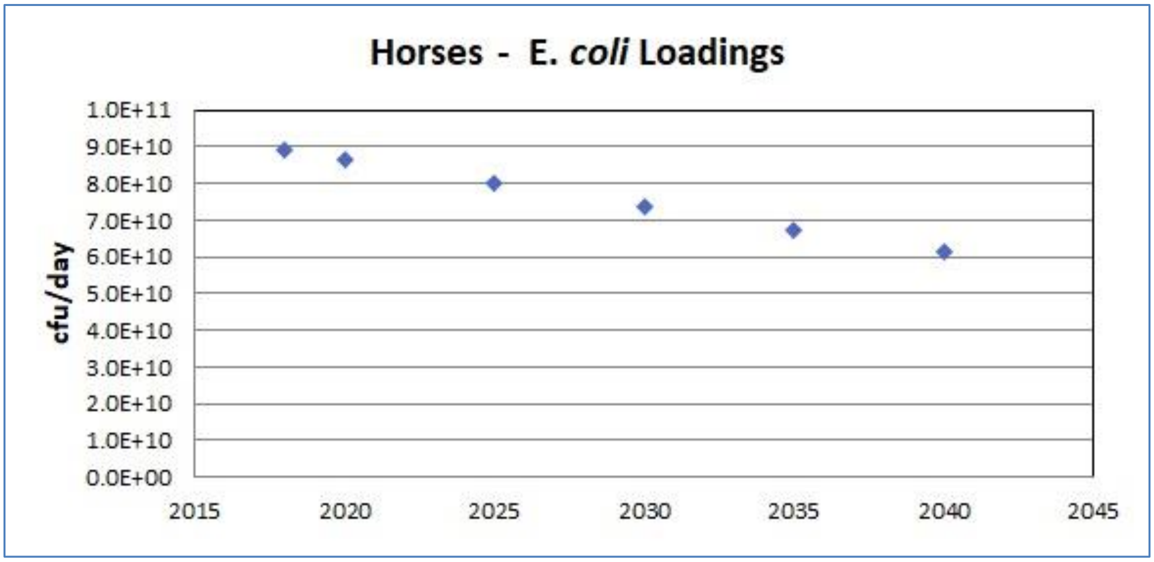

Figure 40 - Future bacteria loadings from horses

Table 21 – Current potential bacteria loadings from horses, by subwatershed

		SW1	SW2	SW3	SW4	SW5	Total
# of Horses	Outside Buffer	577	131	200	14	10	**1,028**
	Within Buffer	108	27	50	3	2	**455**
E. coli Loading	Outside Buffer	3.03E+10	6.90E+09	1.05E+10	7.15E+08	5.00E+08	**4.89E+10**
	Within Buffer	2.27E+10	5.59E+09	1.06E+10	5.87E+08	4.61E+08	**3.99E+10**
Subwatershed % of total load		59.6%	14.1%	23.7%	1.5%	1.1%	100.0%

Sheep and Goats

Sheep and goat populations represent a smaller portion of the livestock in the watershed, but still retain a presence in rural areas. Stakeholders indicated that there were no known large/dense operations or known problem areas in the watershed.

Sheep and goat populations are estimated together because the base NASS data lumps them into a single statistic. Stakeholders indicated they did not expect this conglomeration of populations to pose any significant issue for load estimation in the project area. Populations and loads for current and future conditions were estimated in the same manner as was described for cattle and horses. Assessment and revision of the initial population estimates was conducted concurrently with other livestock, but no specific need for reductions was identified.

Sheep and goat *E. coli* loads were derived for milestones at every five years starting with current conditions. The current loading distributions for sheep and goats in the watershed indicated the highest loads are in subwatershed1 and 3 (Figure 42; Table 22). Future projections indicate that sheep and goat populations will decline with other livestock, but without the same residual presence in exurban areas that horses are likely to experience (Figure 43).

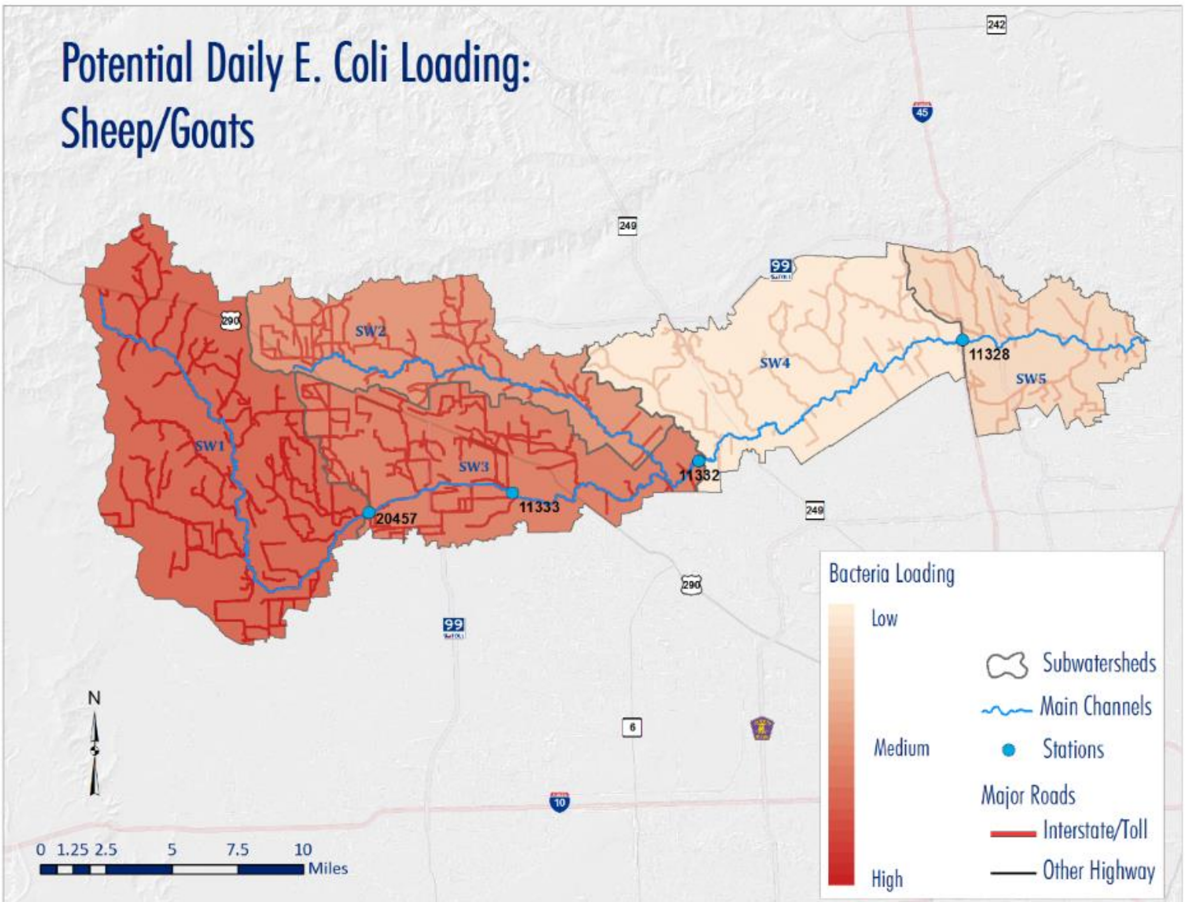

Figure 41 - *E. coli* loadings from sheep and goats, by subwatershed

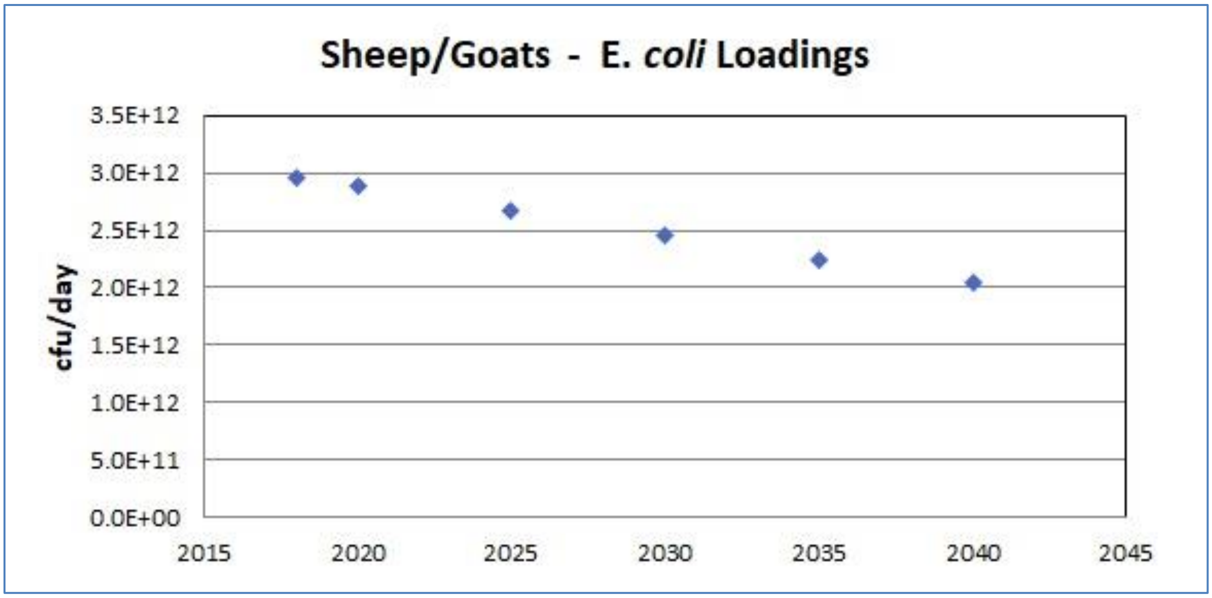

Figure 42 - Future *E. coli* loadings from sheep and goats

Table 22 – Current potential *E. coli* loadings from sheep and goats, by subwatershed

		SW1	SW2	SW3	SW4	SW5	Total
# of Sheep and Goats	Outside Buffer	447	102	155	13	9	**725**
	Within Buffer	84	21	39	3	2	**148**
E. coli Loading	Outside Buffer	1.01E+12	2.29E+11	3.48E+11	2.85E+10	1.99E+10	**1.63E+12**
	Within Buffer	7.54E+11	1.85E+11	3.51E+11	2.34E+10	1.83E+10	**1.33E+12**
Subwatershed % of total load		59.6%	14.0%	23.6%	1.8%	1.3%	**100%**

Feral Hogs

Feral hogs (*Sus scrofa* and related hybrids) are a pressing invasive species issue throughout the Houston-Galveston region in general, and specifically within the project area. Adaptable, fertile, and aggressively omnivorous, their populations are responsible for significant damage to agricultural production, wildlife and habitat, and human landscapes. Hogs can transmit diseases dangerous to humans, pets, and domestic livestock, and can generate large volumes of waste where they concentrate. The riparian corridors adjacent to food resources serve as transportation corridors and shelter for hogs, who then roam adjacent areas to feed. Feedback from stakeholders indicated that feral hogs were a persistent issue in the watershed, but anecdotal reports on extent of hog presence and damage differed significantly, even within the same areas. No specific study of hog populations in the area exists, so literature values from Texas A&M AgriLife were used as initial assumptions. Based on accounts from large landowners like the Katy Prairie Conservancy, hogs were a persistent issue, but no rapid change in populations was noticed in the last 5 years.

Hogs were populated in all land cover types in the watershed except developed and open water areas. Densities were assigned based on Texas A&M AgriLife literature values[76] and experience in previous WPP efforts, as affirmed by project stakeholders. Two hogs per square mile were populated in bare land, cultivated, and pasture/hay cover types, and 2.45 hogs were populated in grasslands, forest, shrublands and wetland areas. While hogs are known to congregate around water bodies to wallow, to use as transport, and as shelter, they also range widely into surrounding areas to feed. Therefore, no specific weighting was given to presence inside the buffer other than the standard buffer weighting used in this implementation of SELECT. Future projections were based on land cover change, with loss of hog population as developed areas increased.

Feral hog *E. coli* loads were derived for milestones at every five years starting with current conditions. The current loading distributions for feral hogs in the watershed indicate the highest load is within subwatershed 1 (Figure 44; Table 23). Future conditions reflect a reduction in hog populations and loading (Figure 45). As noted previously, the model cannot account for concentration of displaced hog populations in surrounding areas, nor can it project populations dynamics without adding an assumption. Project staff and stakeholders did not have literature values or defensible means to suggest a potentially increasing feral hog population based on population increase rather than habitat expansion. Therefore, the modeled projections should be taken to be conservative, as feral hog populations across the state have demonstrated a tendency toward population growth and adaptability to changing developmental conditions.

[76] http://feralhogs.tamu.edu/files/2011/05/FeralHogFactSheet.pdf

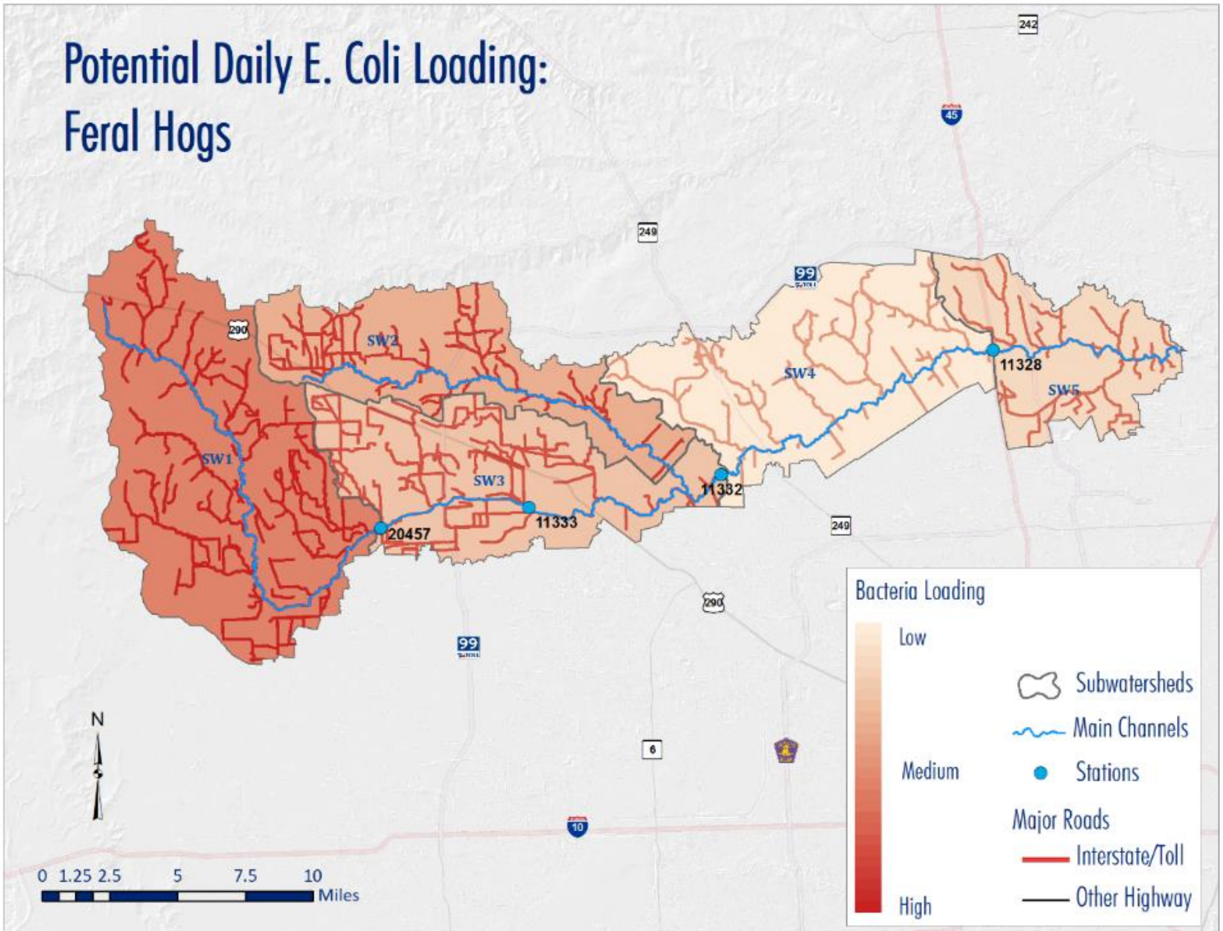

Figure 43 - *E. coli* loadings from feral hogs, by subwatershed

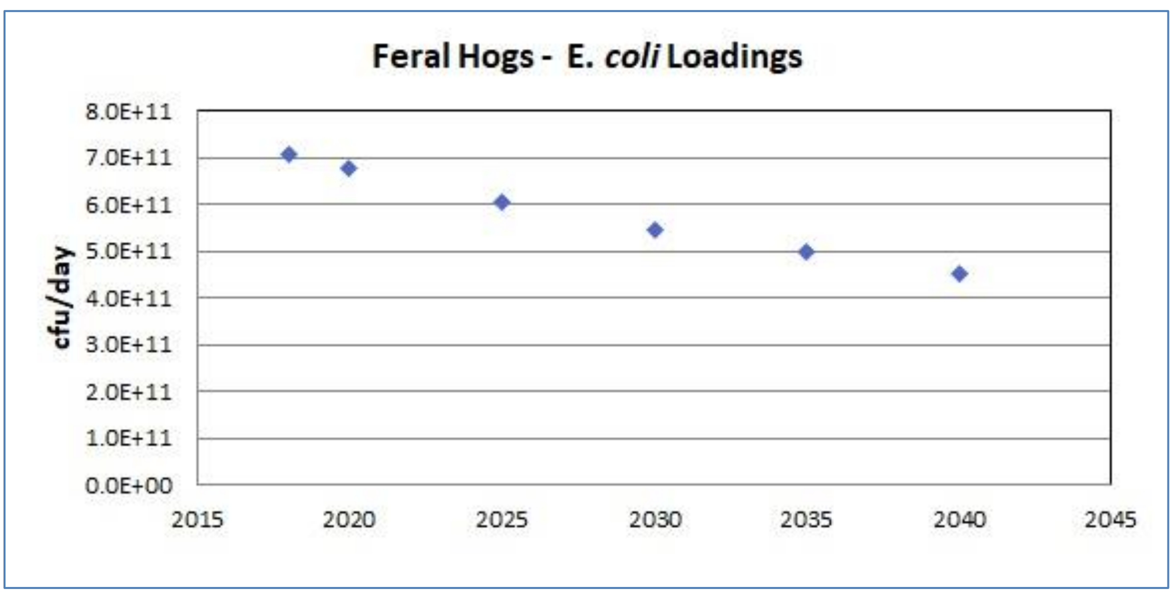

Figure 44 - Future *E. coli* loads from feral hogs

Table 23- Current potential *E. coli* loadings for feral hogs, by subwatershed

		SW1	SW2	SW3	SW4	SW5	Total
# of Feral Hogs	Outside Buffer	170	46	48	11	18	**294**
	Within Buffer	36	12	15	3	4	**71**
E. coli Loading	Outside Buffer	2.08E+11	5.67E+10	5.91E+10	1.34E+10	2.18E+10	**3.59E+11**
	Within Buffer	1.77E+11	6.10E+10	7.24E+10	1.69E+10	2.02E+10	**3.48E+11**
Subwatershed % of total load		54.4%	16.7%	18.6%	4.3%	5.9%	**100.0%**

Dogs

Domestic and feral dog populations are a significant contributor to fecal waste contamination in the greater Houston region, especially in dense developed areas. Unlike cats or other pet species, dog waste is often deposited outside instead of collected in litter boxes or other waste receptacles. Despite local and regional efforts to promote dog waste reduction, feedback from the stakeholders indicated that many owners did not pick up after their dogs.

Pet ownership rates are the key to characterizing load in the SELECT analysis. Other WPP projects have used national averages established by the American Veterinary Medical Association (AVMA)[77] or other industry groups, ranging from 0.6 to 1 dog per household. The current assumption proposed by staff was 0.6 dogs per household based on the AMVA's statistical data for Texas. Stakeholders expressed concern that apartment ownership may not match home ownership rates, and the high number of apartment households might skew the estimation of dog populations. Project staff conducted a study of 21 apartment complexes in urban and suburban areas and determined that there was an average of 0.5+ dogs per household based on property manager estimations. This estimate was close enough to the standard 0.6 dogs per household, assuming there was an undetermined level of tenant underreporting of dog ownership based on property manager feedback, that the stakeholders felt a separate rate for apartment households was not needed. Based on stakeholder feedback, feral dog populations were not widespread, mostly in less dense rural areas where their waste was not a primary issue. No specific data existed, or reasonable literature value was found that was applicable to this area/situation. Since the estimation of apartment density could potentially have some overestimation, and because feral populations were not considered an appreciable source, the stakeholders affirmed the project team's proposal to use 0.6 dogs per household as a uniform assumption. Specific measures to target each

[77] https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx

population will be developed under the WPP, but for the sake of the model, dog waste is tied to the 0.6 assumption.

Dog *E. coli* loads were derived for milestones at every five years starting with current conditions. The current loading distributions for dogs in the watershed indicate the highest load is within subwatershed 4 (Figure 47; Table 24).

Future dog populations were derived from household growth projections, using 0.6 as a static assumption of density for all time periods. As with other sources related to household growth, the relative contribution of *E. coli* from dog waste continues to increase through 2040 (Figure 48). There was no stakeholder expectation that dog ownership rates would be significantly different in the future. One novel consideration for this project was the rate of pet waste bag usage. Based on the apartment survey, stakeholder reports, and a survey of parks in the area, there is an appreciable level of pet waste station infrastructure and usage. Because pet waste bags effectively remove waste from system when used, the stakeholders felt that reduction in load needed to be considered. Reports of usage differed widely, with the most reported use in denser areas. A conservative assumption of a 20% reduction in pet waste was applied to account for waste bags. Stakeholders elected to not increase this percentage in the baseline projections for future years, although they indicated that this would likely occur as bag use increased.

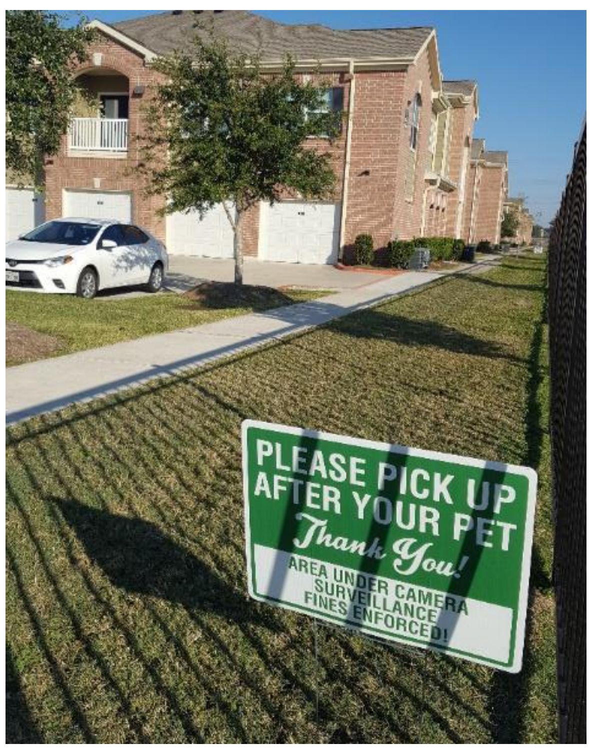

Figure 45 - Enforcement of Pet Waste Disposal at an Apartment Complex

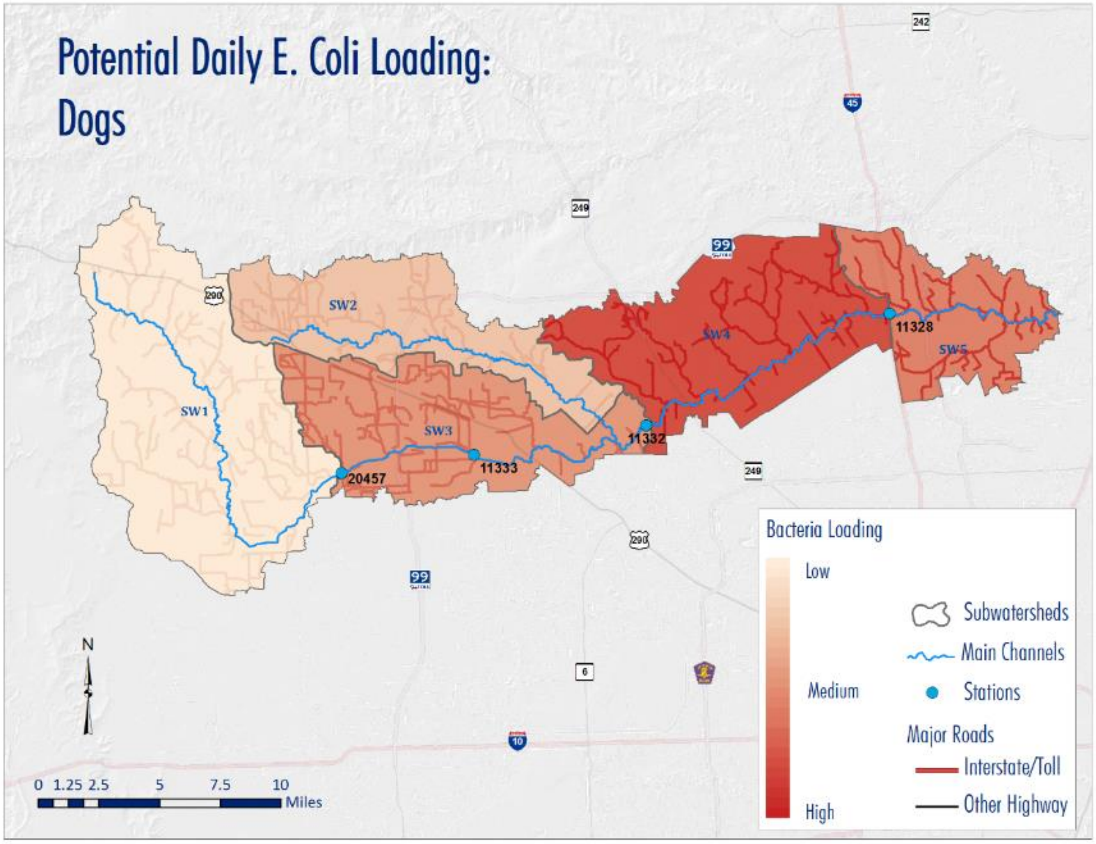

Figure 46 - *E. coli* loadings from dogs, by subwatershed

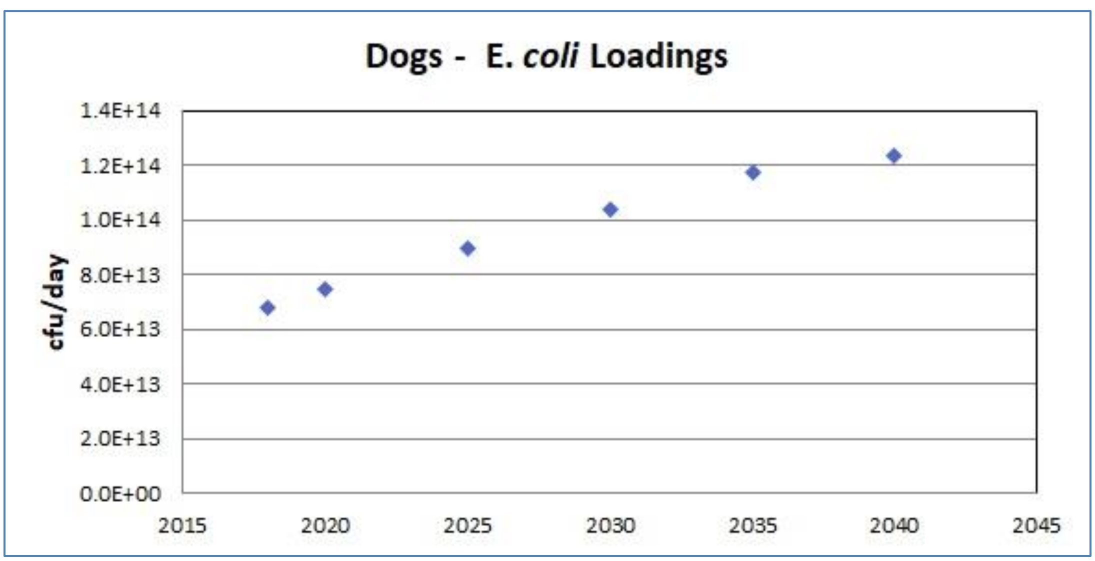

Figure 47 - Future *E. coli* loadings from dogs

Table 24 - Current potential *E. coli* loadings for dogs, by subwatershed [78].

		SW1	SW2	SW3	SW4	SW5	Total
# of Dogs	Outside Buffer	1936	5133	16775	52575	16466	**92,885**
	Within Buffer	246	658	2433	5407	1949	**10,693**
E. coli Loading	Outside Buffer	9.68E+11	2.57E+12	8.39E+12	2.63E+13	8.23E+12	**4.65E+13**
	Within Buffer	4.92E+11	1.32E+12	4.87E+12	1.08E+13	3.90E+12	**2.14E+13**
Subwatershed % of total load		2.2%	5.7%	19.5%	54.7%	17.9%	**100.0%**

Deer

White-tailed deer (deer) are one of the most common large mammals in the watershed areas. Wooded areas and open grasslands in the rural and undeveloped areas of the watershed provide abundant natural habitat. Because deer are among a handful of species that adapt well to the fringe of human development, large lot suburban and exurban development and even open areas in urban neighborhoods can provide alternative habitat. Based on discussions with TPWD staff, local stakeholder feedback, and land cover analysis, deer populations are widespread in the project area to the point of bordering on nuisances in some areas (urban golf courses, etc.). This mirrors findings in nearby watersheds like Lake Creek and the West Fork of the San Jacinto River.

The starting point for estimating deer populations is the use of density projections derived from TPWD's Resource Management Unit data for deer in this ecoregion. Deer were populated in appropriate land cover types in the model, primarily forested areas and open spaces. The RMU density is then applied to these acreages to determine deer populations. Future deer populations are tied to land cover change. As with feral hogs, there is no assumption made of population dynamics other than removal as habitat is removed. Similarly, there is no assumption of concentration to a carrying capacity as habitat is lost. Deer in developed habitat are removed from projections.

Stakeholder review of preliminary assumptions indicated that there were significant deer populations in lightly developed areas, and these acreages were populated in the next run of the model. The stakeholders affirmed the revised numbers based on anecdotal experiences and best professional judgement.

[78] Load estimates reflect the 20% reduction for pet waste bag usage.

Deer *E. coli* loads were derived for milestones at every five years starting with current conditions. The current loading distributions for deer in the watershed indicate the highest load is within subwatershed 5 (Figure 49; Table 25). The adaptation of deer to developed environments led to only minor fluctuations in deer populations as development converts natural habitat (Figure 50).

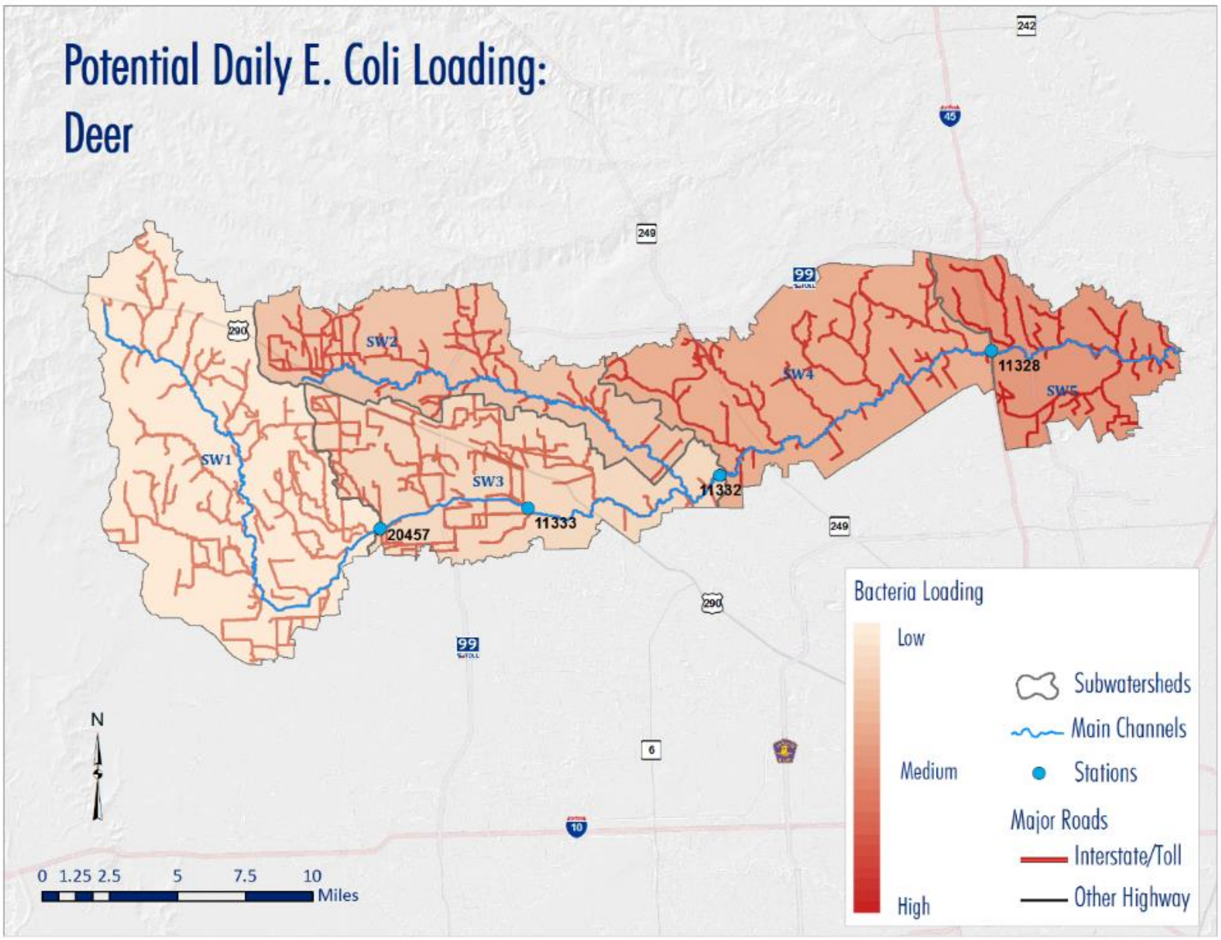

Figure 48 - *E. coli* loadings from deer, by subwatershed

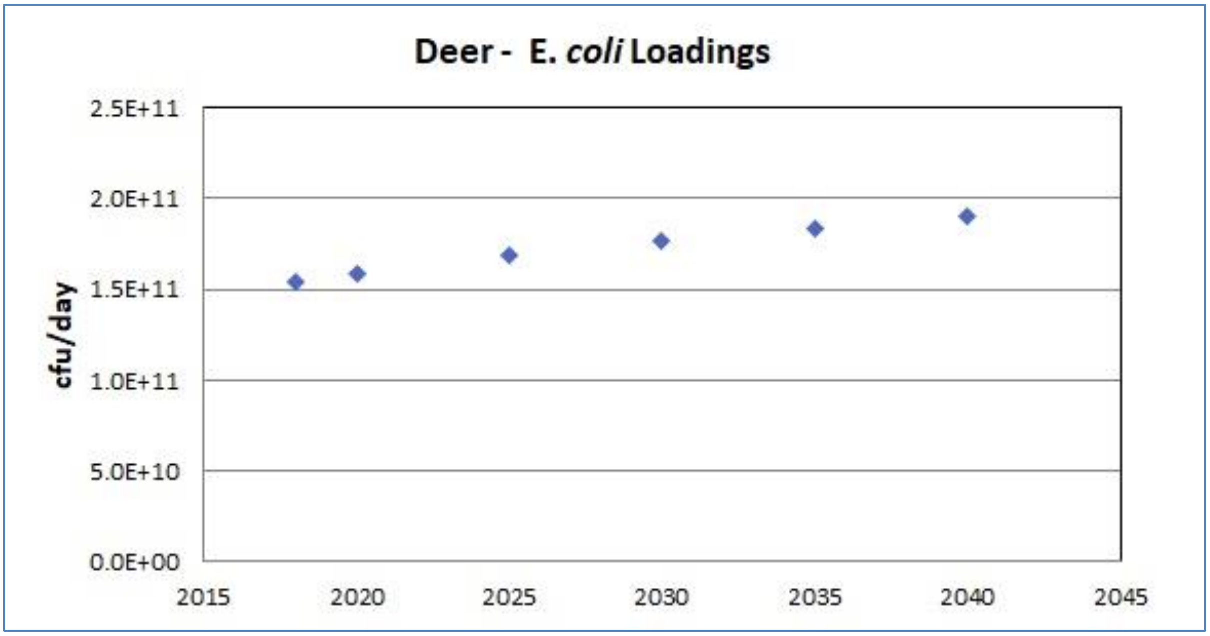

Figure 49 - Future *E. coli* loadings from deer

Table 25 - Current potential *E. coli* loadings for deer, by subwatershed

		SW1	SW2	SW3	SW4	SW5	Total
# of Deer	Outside Buffer	186	321	325	499	321	**1652**
	Within Buffer	51	76	91	104	68	**390**
E. coli Loading	Outside Buffer	8.94E+09	1.55E+10	1.57E+10	2.40E+10	1.54E+10	**7.95E+10**
	Within Buffer	9.81E+09	1.46E+10	1.74E+10	2.00E+10	1.31E+10	**7.49E+10**
Subwatershed % of total load		12.1%	19.5%	21.4%	28.5%	18.4%	**100.0%**

Other Wildlife

The primary missing element discussed by the stakeholders was the impact of wildlife other than deer, including some large animals like coyotes, but inclusive of all other non-modeled warm-blooded wildlife (rodents, wild cats, wild canines, other mammals, birds, etc.) Prior projects in the area have not specifically addressed this source other than to recognize it may be appreciable, but to consider the context of limited potential means to address it. Without studies that identify specific sources of fecal waste (through bacteria source tracking or similar analyses) that might offer greater insights into non-domestic animal contributions, stakeholders provided anecdotal information on various species of interest in both rural and urban areas. There was general concern that not including the load from these animals might produce a less defensible estimation. In review of source tracking information from other, more rural, watersheds[79] in the state it was clear that wildlife contributions were appreciable and not well represented by just deer and feral hogs. Without source tracking data for this area, and allowing for a greater degree of development, the stakeholders considered ways to apply results from other Texas watersheds to Cypress Creek. Because this was a novel approach compared to other area WPPs, and to ensure that the estimate was conservative and reflected the developmental character of the area, other wildlife was assumed to be equivalent to 10% of the total load for the watershed. The value was generated by finding the total for all other sources, assuming that load to be 90% of total load, and then deriving the other wildlife load as the remaining 10% of the revised total load. The stakeholders also felt that the extent of urban wildlife known in the watershed suggested that this load should be applied to all subwatersheds, rather than just the Headwaters and Transitional areas. While the initial load was derived from the current year projections, the load estimate was kept as a constant across future projections, rather than increasing as a set percentage of each milestone year's total. This is intended to reflect a constant or declining wildlife population even as human sources increase. The stakeholders noted that additional research, including potential future source tracking, would be valuable to give this estimation greater precision.

Other Sources of Fecal Waste

The primary other potential sources, and the reasons for not including them in the estimates are elaborated upon here. In general, sources which are not specifically included in the SELECT estimates are still potential targets of mitigation as part of the WPP, especially on a localized scale, depending on the source being discussed. While some of the wildlife populations discussed were not specifically modeled, their contributions are included in this project in the 10% other wildlife load estimate.

Human Waste (Direct Discharges) - Stakeholders discussed the presence of some homeless individuals in some areas, and some small areas which may not have wastewater solutions. Based on feedback from the work group and Partnership, the populations represented by the groups were not found to be large enough to have appreciable impact.

Land Deposition of Sewage Sludge - There were no anecdotal or official reports of sludge application violations or known issues with manure spreading identified by the stakeholders or other partners. Potential impacts would likely be dealt with as part of traditional agricultural BMPs (Water Quality Management Plans – WQMPs – etc.).

[79] For example, bacteria source tracking completed by Texas A&M University for Attoyac Bayou showed *E. coli* from wildlife at greater than 50% of load across flow conditions (https://oaktrust.library.tamu.edu/handle/1969.1/152424); analysis conducted for the Lampasas and Leon Rivers showed similar results (https://oaktrust.library.tamu.edu/handle/1969.1/149197).

Concentrated Animal Feeding Operations - There are no CAFOs in the WPP project area.

Birds - Bird populations in the region can vary greatly by season. Large migratory populations pass through the Houston area as part of the great Central Flyway migration path. However, these populations are transient, staying for days or weeks during two yearly migration seasons. Migratory waterfowl represent longer-term populations, especially in coastal marshes. However, significant migratory waterfowl presence in the watershed has been in long-term decline. The Katy Prairie was traditionally home to large bird populations, and during the height of agricultural production, especially in areas with large amounts of rice and similar cropland, wintering geese were prevalent. However, based on historical data[80] and stakeholder feedback, changes in land cover/land use and regional agricultural shifts have decreased habitat for larger, dense populations. While there are appreciable populations that still visit the Katy Prairie, they are not expected to be an appreciable source of *E. coli*. Previous WPP efforts have evaluated the potential impact of waterfowl in terms of duration, potential *E. coli* load/waste load, and other considerations, and found them to not be significant sources to be modeled. Colonial nesting birds have been identified in other WPP projects as sources of *E. coli* load. Swallows and other similar colonial birds do have nest sites on some bridges throughout the watershed. However, no reasonable data, estimation, or methodology for assessing their populations exists, and no anecdotal account of significant populations exist. Birds of potential concern identified in the stakeholder discussions include domestic exotics (e.g. Muscovy ducks) in parks and other detention facilities. However, no reasonable data exists to characterize this source or to suggest they would be either appreciable in impact or likely to contribute greatly to health risk.

Bats - Bats are present throughout the watershed project area, but there are no known large nesting sites of a size or density likely to represent a source of concern.

Cats - Domestic cat ownership generally revolves around an indoor model in developed areas, in which cat feces are restricted to litter boxes, unlike dog waste which is more likely to be deposited outdoors. Therefore, cat loads were not estimated as part of this project. Feral cats, however, can be a local source when found in sufficiently dense urban populations. Project staff worked with local stakeholders to review potential data sources and anecdotal reports on feral cat populations. However, no literature values or data appropriate under project data quality objectives was located. In a review of other regional WPPs, feral cat populations were generally included as part of diffuse urban stormwater and were not

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[80] No specific literature on populations was identified, but staff reviewed eBird (www.ebird.com, a repository for citizen science on bird populations) records for the last 10 years and consulted with stakeholders and external partners who have been involved in monitoring bird populations through volunteer activities like the Audubon Christmas Bird Count. These sources are not quality-assured data under the project's QAPP and were taken in the context of being informal feedback rather than hard data of known certainty. However, they do provide a linear picture of general decline of bird populations, matching anecdotal accounts from stakeholders.

specifically highlighted as significant sources. As with other sources not specifically modeled, feral cats may still be a focus of implementation efforts dependent on stakeholder decisions. While not wildlife, it is expected that their load is represented to some degree by the 10% other wildlife load.

Dumping - In discussions with stakeholders, illegal dumping was not identified as a widespread issue. Some localized problem areas were identified, but there were no significant accounts of waste dumping that would add appreciably to *E. coli* levels. The primary focus of dumping concerns was trash and other aesthetic and regulatory issues. Some specific sites (a utility easement on Longenbaugh Road, etc.) were identified but not particularly strongly associated with fecal waste.

Sediment - Sand and gravel mining operations are common in the riparian corridors of the greater San Jacinto River watersheds but are less common on much of Cypress Creek. However, there are significant operations in the Headwaters area. Runoff from development and agricultural activity is notable during high runoff events, when Headwaters tributaries and portions of Cypress Creek west of Highway 99 can be appreciably colored by sediment, sometimes differing in color by areas based on the sediment being introduced. Excess sediment is common in the waterways, which can provide shelter for *E. coli* and decrease insolation that may lead to die-off in the water column, can impact dissolved oxygen levels, and have pronounced hydrologic impacts on flow. These effects are already an aspect of the in-stream conditions described under the LDCs, in that recorded *E. coli* levels reflect the end product of these ambient factors as well as other factors that affect them in transport. Mining operations are not a significant source of fecal waste, so no modeled estimation can be completed. Excess sediment introduced into the channel can foster the survival of *E. coli* from other sources, making it an indirect source for *E. coli* that might have otherwise not survived. The considerations regarding sediment will be dealt with in the WPP.

Summary of E. coli Source Modeling Results

The SELECT analyses indicated a mix of sources, but with a few primary contributors for the watershed overall. However, most importantly for stakeholder decision-making, the mix of sources projected for the future, and the spatial distribution of those sources shows marked differences between different areas of the watershed. The novel approaches of reducing pet waste to reflect waste bag usage, and the inclusion of a 10% load for other wildlife were included to reflect best professional judgement, trends in state and regional load estimation under other projects, and stakeholder feedback and decision-making. While neither is modeled under traditional approaches, uncertainty in their estimation should be balanced by the far greater uncertainty inherent in not addressing these issues. The focus on a conservative implementation of these approaches draws a balance between addressing them but remaining as defensible as possible.

Absent a concerted effort to address fecal waste sources, the projections indicate that total *E. coli* loads in the watershed will continue to increase between 2018 and the target date of 2035 and beyond (Figure 51). Between current conditions and those projected for 2040, the mix of sources shifts appreciably away from some of the legacy agricultural activity toward a predominance of sources associated with human development, with dog waste continuing to be a primary and growing contributor (Table 26; Table 27).

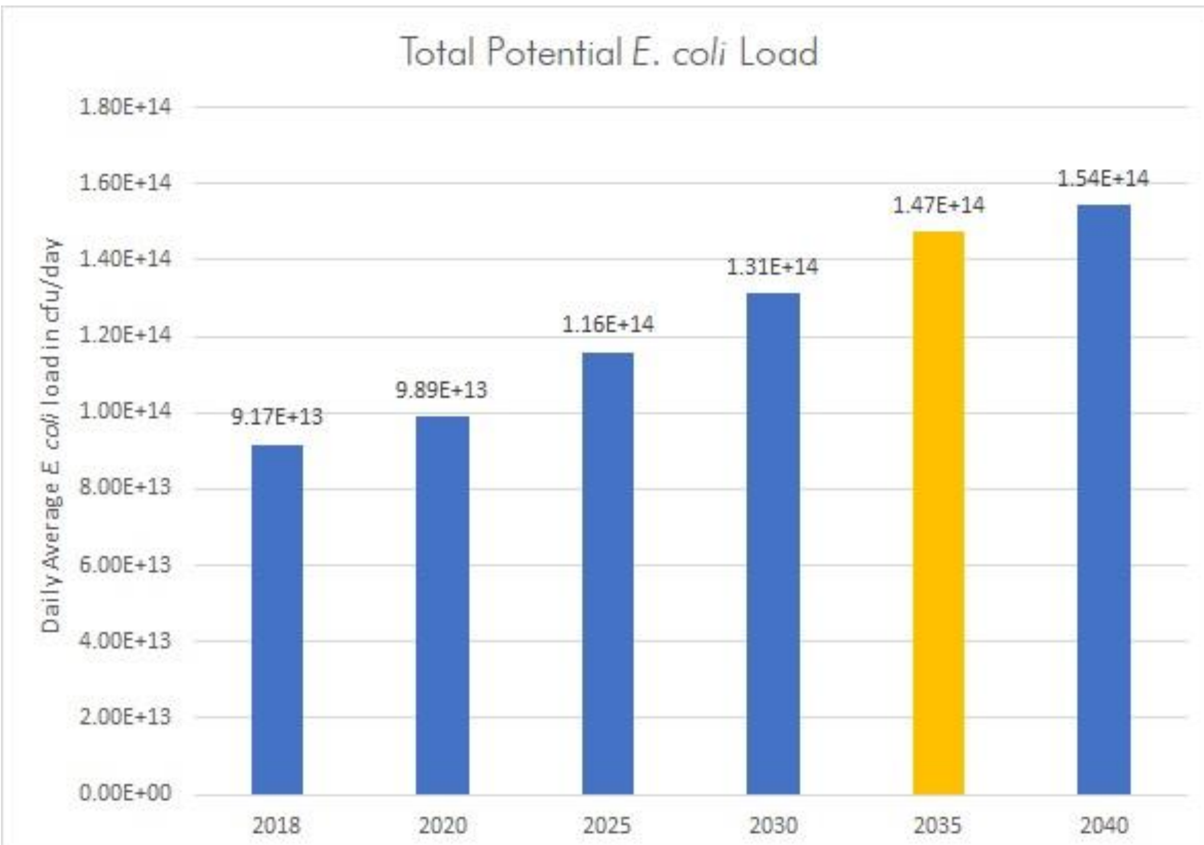


Figure 50 - Total potential *E. coli* load, 2018-2040

Table 26 – Current *E. coli* daily average loadings by source and subwatershed

Subwatershed	OSSFs	WWTF	Dogs	Cattle	Horses	Sheep/ Goats	Deer	Feral Hogs	Other Wildlife	Total Daily Loading
SW1	3.15E+11	8.02E+08	1.46E+12	3.61E+12	5.31E+10	1.76E+12	1.87E+10	3.85E+11	8.45E+11	**8.45E+12**
SW2	5.61E+11	3.35E+09	3.88E+12	8.50E+11	1.25E+10	4.14E+11	3.01E+10	1.18E+11	6.52E+11	**6.52E+12**
SW3	1.05E+12	9.99E+09	1.33E+13	1.44E+12	2.11E+10	6.99E+11	3.31E+10	1.31E+11	1.85E+12	**1.85E+13**
SW4	2.25E+12	4.34E+10	3.71E+13	7.45E+10	1.30E+09	5.18E+10	4.41E+10	3.03E+10	4.40E+12	**4.40E+13**
SW5	5.31E+11	1.40E+10	1.21E+13	5.50E+10	9.61E+08	3.83E+10	2.85E+10	4.19E+10	1.43E+12	**1.42E+13**
TOTAL	**4.71E+12**	**7.15E+10**	**6.78E+13**	**6.03E+12**	**8.89E+10**	**2.96E+12**	**1.55E+11**	**7.07E+11**	**9.17E+12**	**9.17E+13**
% of Total Load	**5.1%**	**0.1%**	**74.0%**	**6.6%**	**0.1%**	**3.2%**	**0.2%**	**0.8%**	**10%**	**100%**

Table 27 – Daily average *E. coli* loadings by source for all milestone years

Category	Source	2018	2020	2025	2030	2035	2040
Human Waste	OSSFs	4.71E+12	5.56E+12	8.04E+12	1.00E+13	1.30E+13	1.45E+13
	WWTFs	5.1%	5.6%	6.9%	7.6%	8.8%	9.4%
Pets	Dogs	7.15E+10	7.58E+10	8.32E+10	9.19E+10	9.69E+10	9.82E+10
Livestock	Cattle	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
	Horses	6.78E+13	7.44E+13	8.94E+13	1.04E+14	1.17E+14	1.24E+14
	Sheep / Goats	74.0%	75.2%	77.3%	79.0%	79.7%	80.1%
Wildlife and Feral Hogs	Deer	6.03E+12	5.87E+12	5.45E+12	5.00E+12	4.56E+12	4.16E+12
	Feral Hogs	6.6%	5.9%	4.7%	3.8%	3.1%	2.7%
	Other Wildlife	8.89E+10	8.66E+10	8.03E+10	7.37E+10	6.73E+10	6.13E+10
Total		**9.17E+13**	**9.89E+13**	**1.16E+14**	**1.31E+14**	**1.47E+14**	**1.54E+14**

Implications of Fecal Waste Source Characterization Findings

The findings of the fecal waste source characterization and modeling efforts for Cypress Creek reinforce the image of a watershed in transition. Driven by the general growth of the Houston area, and pushing outward from transportation corridors, the project area has seen significant growth in recent decades and will continue to do so in coming years. Developmental changes will reduce legacy agricultural sources in many areas, especially the headwaters area west of SH 99. The loss of load from agricultural activities will be outweighed by the increases of sources derived from developed areas.

The increasing loads highlight the need for intervention through the WPP and other means. Current water quality issues will be compounded by future loads, leading to degrading water quality through the planning period absent any effort to the contrary.

Uncertainty is present throughout the assumptions and methodologies of this modeling approach, as noted throughout this document. Project staff used the best available data and stakeholder feedback to minimize uncertainty wherever possible, but the results should be taken in the context of their use in characterizing fecal waste pollution on a broad scale, and for scaling and siting BMPs. For these purposes, the level of uncertainty and precision of the results was deemed to be acceptable by the stakeholders. Further refinement of results may be needed in the future considering changing conditions. While bacteria source tracking or other analyses quantifying host organism DNA instream were not a function of this project, it may be a consideration in the future to further characterize sources, identify location-specific challenges, and refine the linkage between source loads and instream conditions.

Nutrient Source Characterization

Dissolved oxygen (DO) is essential for supporting aquatic communities, but unlike contact recreation impairments, depressed DO issues can result from a variety of causes. The multitude of potential precursors to depressed DO make it difficult to identify the cause of resulting water quality issues in a waterway. However, excessive nutrients from human uses like landscaping and agricultural fertilizers are the source stakeholders have the greatest potential to change. High levels of nutrients entering waterways during rain events can foster blooms of algae. As these algal blooms begin to die off, the decomposition of the algae utilizes oxygen in the water. Even if it is only part of the overall mix of causes for DO issues, reductions or mitigations of nutrient use will reduce the risk of low DO levels. The Partnership evaluated the available means to characterize nutrients, in the context of the water quality goals they established. Because DO is not an impairment in the watershed, and because many of the sources of nutrients overlap with sources of fecal waste[81], the Partnership focused its investigation efforts on identifying potential solutions and specific areas of concern.

Other Concerns

No specific modeling was conducted for other stakeholder concerns such as flooding, trash, and sediment. However, stakeholder feedback was taken on problem areas, and project staff developed recommendations for coordinating with other partner efforts and programs that overlap with these concerns as part of the recommended solutions of this WPP.

Flooding

Repetitive flooding was a primary concern for stakeholders, local governments, and elected officials in the watershed. Based on stakeholder discussions and ongoing conversations with key partners, the project identified several potential areas of overlap with flood mitigation efforts by the Harris County Flood Control District, USACE, local special districts, and Waller County. The potential use of natural infrastructure as supplement to flood mitigation projects, the conservation of open space, and the inclusion of water quality concerns in flood project design were all areas of needed coordination during the implementation of this WPP.

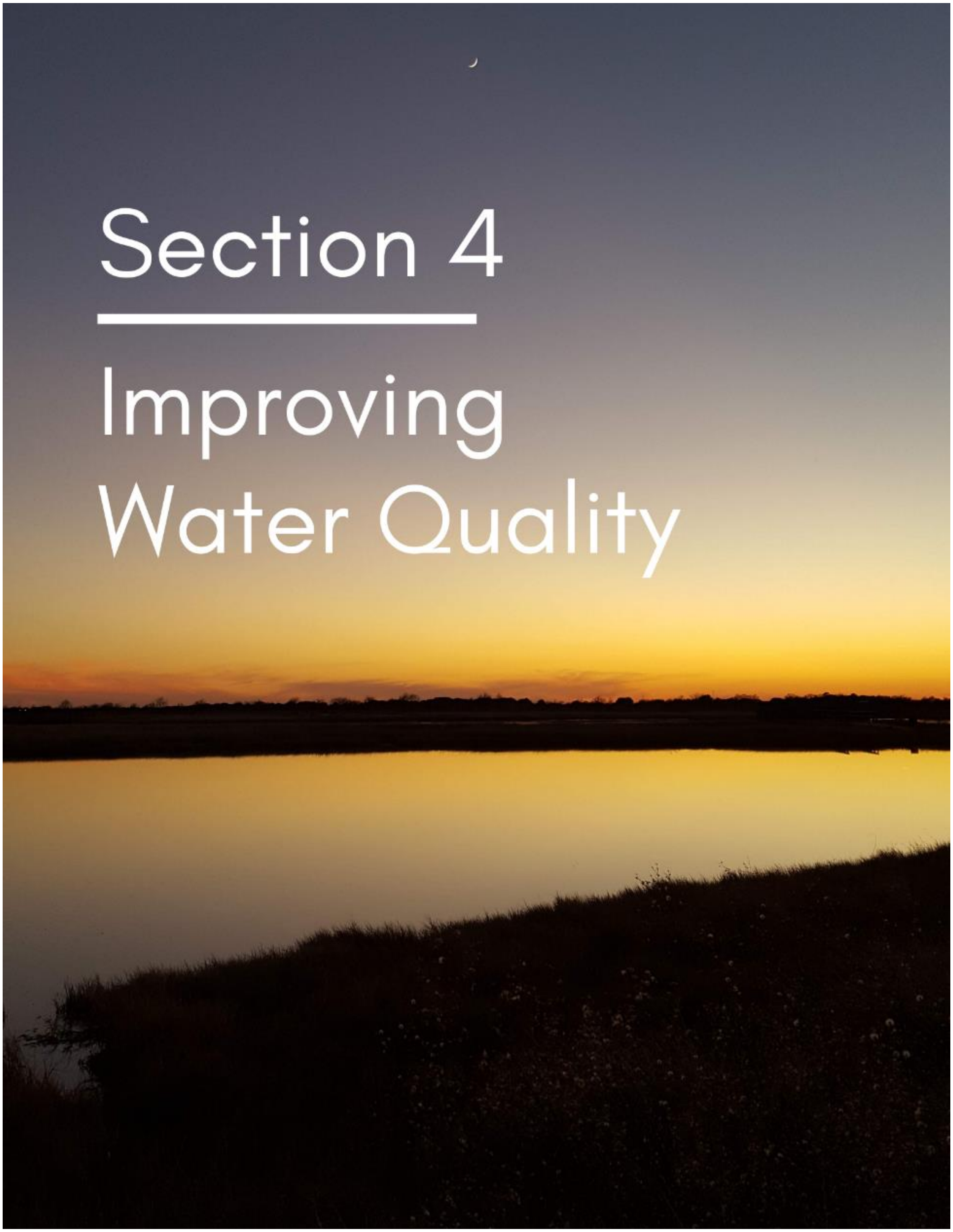
Trash

Other than minor sites in some rural areas (including some small dump sites on easements in areas of the Katy Prairie west of SH99), no specific sites of appreciable concern were designated under this project. No formal survey of trash was conducted under this project. However, trash in the waterway is an ongoing and visible concern for the stakeholders, especially in denser urban areas of the downstream watershed, where trash enters through stormwater and sheet flow. Project staff identified several ongoing efforts in the watershed (including trash reduction efforts like the annual Trash Bash site on Cypress Creek) that would be important points of coordination, with the intent of including trash in water quality conversations, and vice versa.

Sediment

Sediment transfer within and out of the watershed was an issue raised by several stakeholders and is mirrored by similar conversations in adjacent watersheds like the West Fork San Jacinto River. No formal modeling or assessment was completed to identify erosion/deposition patterns in the watershed. However, given the link to flooding, downstream issues with reducing reservoir capacity in Lake Houston, and the potential for sediment-laden waters to enhance fecal bacteria transport, further coordination is needed.

[81] Recommendations for best practices for bacteria sources are expected to be beneficial in reducing nutrient contamination as well (e.g. reducing animal waste high in both fecal pathogens and nitrogenous compounds).


Section 4
Improving
Water Quality

4 – Improving Water Quality

Water Quality Improvement Overview

The success of solutions recommended by this WPP will be due in large part to how well they are scaled and targeted to address the pollutant sources identified in Section 3. The Partnership conducted a water quality modeling effort[82] to determine the amount of improvement needed for each parameter (*E. coli* and DO). The purpose of this effort was to establish how much *E. coli* needed to be reduced in the waterway to meet the SWQS, and how much improvement in DO level is needed to meet the aquatic life use standard. An assessment tool called ***load duration curves*** (LDCs) was used in combination with water quality data to determine these results. Improvement goals were generated for separate areas of the watershed, called attainment areas, based on the points at which future compliance would be measured.

Figure 51 – Flow gauge on Cypress Creek

[82] For greater detail on the modeling efforts for bacteria and DO discussed in this section, please refer to the Water Quality Modeling Report on the project website at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_creek_wpp_water_quality_modeling_report.pdf

Load Duration Curves

The amount of water flowing through a water body can affect the concentration of pollutants, and pollutants can enter the water body from discrete sources or as nonpoint source pollution in different flow conditions. LDCs use observed water quality data (see Section 3) to indicate the difference between the levels of pollutant or condition in a waterway, and the levels at which the applicable water quality standards would be met. The difference then becomes the basis for improvement goals.

The LDC approach uses flow data from a stream gauge or other source to create a flow duration curve. The flow curves indicate what percentage of days the flow of water meets certain flow levels (e.g., a certain waterway may meet its base flow 100% of the time, but its highest peak flows only 5% of the time). Based on the numeric criteria for a water quality standard, a maximum allowable load of pollutant is calculated for all flow conditions. Lastly, monitoring data for the pollutant are multiplied by flows to produce a load duration curve, which shows how the actual load of a pollutant in the water changes in different flow situations (an example LDC is shown in Figure 53). More importantly, the curve indicates under what flow conditions, and by how much, the observed pollutant levels are more than the allowable load. Areas in which the load duration curve line exceeds the maximum allowable load curve line indicate that the standard is not being met in those flow conditions. If the areas of exceedance are primarily in high flow conditions, it is likely that nonpoint sources are most prominent. If areas of exceedance are instead primarily in the low flow conditions, point sources are more likely suspects. In situations where there is a mix of flow conditions related to exceedances, or in which contaminants exceed the allowable limit in all conditions, a mix of point and nonpoint sources is likely. The amount in which the observed loads exceed the allowable loads is the basis for developing improvement goals.

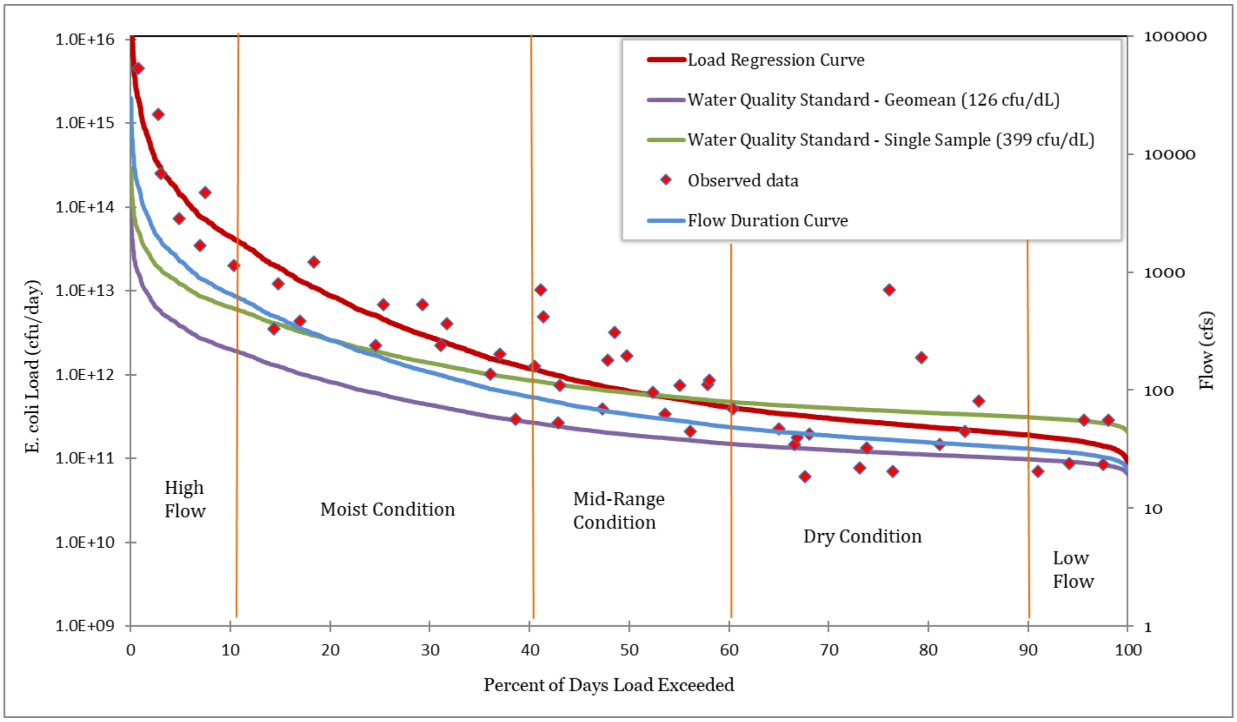


Figure 52 - Example of a load duration curve for *E. coli*

LDCs for *E. coli* and DO

Project staff developed LDCs for *E. coli* and DO at several monitoring stations throughout the Cypress Creek Watershed. The purpose of the LDCs was to evaluate the flow conditions in which exceedances were happening, and to generate improvement goals for *E. coli* reduction and DO improvement.

Site Selection

Site selection for LDCs was based on support for a mix of considerations, including known water quality conditions[83], the need for long-term assessment of progress toward the water quality standard, projected needs for BMP siting decisions, and stakeholder input.

- **Known Water Quality Conditions** — Based on a review of historical ambient water quality trends, wastewater treatment plant discharge monitoring reports, and sanitary sewer overflow information, water quality in the project watershed indicated that conditions in the assessed tributaries and main channel both had a degree of variability and potential for continued exceedance. A single station would not be representative of the variability of conditions based on the water quality review. Therefore, several LDC locations were chosen to represent varying conditions along

[83] For more information, refer to the Water Quality Data Collection and Trends Analysis Report at https://cypresspartnership.weebly.com/project-documents.html.

the waterway. While the stations are all on the main stem, they are positioned to allow consideration of water quality before and after inputs of some large tributaries, particularly Little Cypress Creek. This design allows for a greater degree of scrutiny of geographic variability of loads in the watershed, and an ability to target reductions more precisely. Evaluating several areas independently ensures area-specific problems would not be lost when diluted by a larger waterway, and that end results reflect variability of conditions throughout the waterway.

- Long Term Assessment Considerations — To ensure long-term assessment and continued data, potential LDCs locations were drawn from existing CRP monitoring stations, which will provide ongoing data. All four sites also correspond to USGS stream gauges with flow data. The existing sites were found to be sufficient to characterize conditions in the waterways, as affirmed by the stakeholders. The sites, from mouth to headwaters, are:
    - *Downstream* — The site (station 11328, Cypress Creek at IH 45) represents the most downstream part of the Cypress Creek system is upstream of the final subwatershed and the confluence of Spring Creek. However, the next downstream site does not have gauge data, and is not monitored at the same frequency. A comparison of the land cover and smaller distance between these two locations led to the selection of station 11328 as the more conservative choice, as its water quality was likely to be similar to the downstream station, had better flow data, and had greater sampling frequency. Based on the review of water quality data, the current selected site is expected to be representative of conditions in this general area of the watershed.
    - *Midstream 2* — The site (station 11332 Cypress Creek at Grant Road) represents the middle of the watershed, directly after the confluence of Little Cypress Creek, a primary tributary. This site represents a transitional point where the watershed is moving into more developed areas and is getting additional flows from Little Cypress Creek and other waterways.
    - *Midstream 1* — The site (station 11333, Cypress Creek at House-Hahl Road) represents the transitional area prior to Little Cypress Creek. This site is located at the start of the transitional point where the watershed is moving into more developed areas but before it gets significant additional flows from Little Cypress Creek and other waterways.
    - *Headwaters* — The site (station 20457, Cypress Creek at Katy-Hockley road) is close to the end of the headwaters area of the watershed, which drains primarily light rural residential and agricultural areas to the west. This area includes the areas of the Katy Prairie.
- BMP Siting Requirements — As discussed previously, LDCs were chosen in part to reflect geographic variability. A greater number of LDC locations is beneficial to compare with

modeling results to scale and site solutions (i.e., solution requirements can be refined to the subwatershed level based on the specific reduction needs of the LDC assessment area in which the subwatershed falls).

- Stakeholder Input — Project staff built the aforementioned considerations into a set of LDC locations, which were reviewed with stakeholders in the preliminary meetings of the Cypress Creek Watershed Partnership.

Based on these considerations, project staff conducted four LDC site analyses, three of which would be used to generate *E. coli* load reduction targets[84] and all of which would be used to identify necessary DO improvement (Figure 54; Table 28).

Table 28 - LDC locations

LDC Site	CRP Station	USGS Gauge	Assessed Area
Cypress Creek at IH 45	11328	08069000	Subwatersheds 4 (and 5 by proxy)
Cypress Creek at Grant Road	11332	08068800	Subwatershed 2 and 3
Cypress Creek at House-Hahl Road	11333	08068740	Subwatershed 2
Cypress Creek at Katy-Hockley Road	20457	08068720	Subwatershed 1

[84] Station 11333 is intermediate between 20457 and 11332 and does not reflect the input from the relatively large Little Cypress Creek system. It is useful for many of the considerations noted in the preceding discussion of site selection, but its watershed is not useful to break out from station 11332 as the areas are not different enough to form unique subdivisions of the watershed. Therefore, the watershed is split between headwaters, transitional area, and downstream/developed.

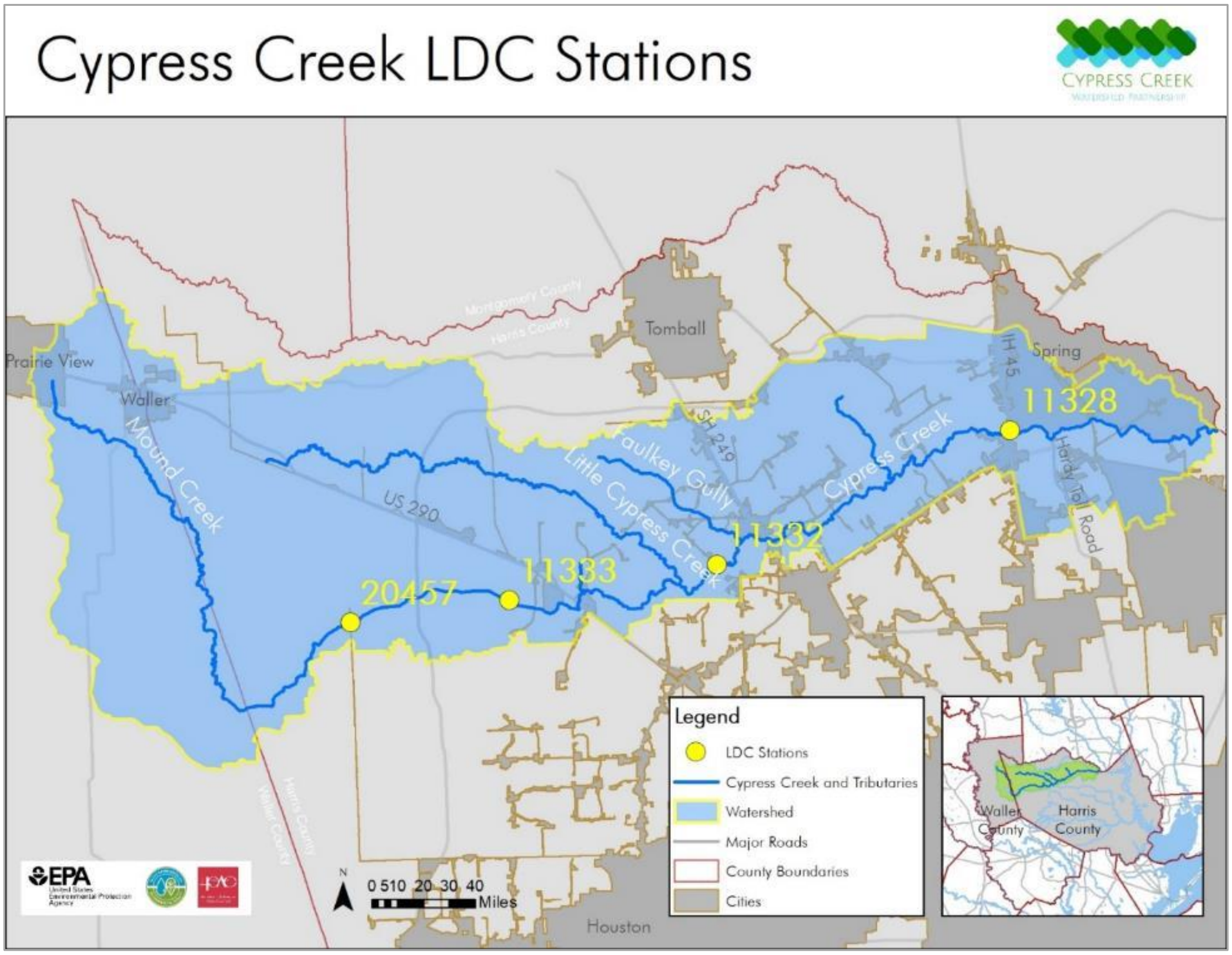


Figure 53 - Cypress Creek LDC stations

Data Development

Flow Data — LDCs require a sufficient amount of ambient water quality data, as well as flow data (with continuous flow data being preferable). All four of the Cypress Creek LDC sites have corresponding USGS gauges. Data from these gauges were used to develop the flow duration curves.

Ambient Water Quality Data — Quality-assured ambient water quality results from CRP monitoring was available for all four stations[85]. All stations had at least 10 years of data available (34-104 data points for *E. coli*, and 33-103 data points for DO), which is sufficient

[85] More information on the ambient water quality data for these and other stations, and other relevant quality data, can be found in the Water Quality Data Collection and Trends Report produced for this project, available on the project website at https://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_water_quality_trends_report_final.pdf.

to develop the LDCs based on the data quality objectives of the project (Table 29). For *E. coli*, both single sample and geomean values were evaluated against their respective criteria, but only geomean values were used in the process of assessing reductions for this modeling effort.

Table 29 – Number of *E. coli* samples by station

LDC Location	Station	Number of *E. coli* Samples	Number of DO samples
Downstream	11328	53	58
Midstream 2	11332	104	103
Midstream 1	11333	88	86
Headwaters	20457	34	33

Both the requisite flow and constituent sample data was sufficient to develop LDCs for all locations and will likely continue to support future revisions and the adaptive management process of evaluating WPP success.

LDC Implementation

Flow curves and LDCs were generated for each of the target stations and reviewed internally and with project stakeholders. No issues with the data development and implementation were identified based on quality assurance review and feedback. Full profiles for each LDC site are included in the Water Quality Modeling Report[86].

LDC Summary

The Partnership reviewed the data and had no concerns about the representativeness of the chosen sites. As development continues, especially in subwatersheds 1 and 2, future revisions of this WPP may wish to consider whether additional coverage for Little Cypress Creek is warranted. The current LDCs, and the attainment areas for which they provide data, were deemed to be sufficient for the WPP, because content was developed for upstream and downstream of the Little Cypress Creek confluence. The general hypothesis carried over into the discussion of sources and the linkage was that stream flow volume was a primary factor in assimilative capacity in this project area.

Overall, the results indicated that while DO may have some assimilative capacity, *E. coli* loads are greatly in excess of the standard in almost all locations and flow conditions, regardless of flow volume and developmental character (Table 30). The most pronounced need is in the lowest portion of the watershed, likely as a combination of upstream inputs and

[86] Please refer to the *Water Quality Modeling Report* on the project website at http://cypresspartnership.weebly.com/uploads/9/6/6/3/9663419/cypress_creek_wpp_water_quality_modeling_report.pdf

the decrease in natural filtration of land cover in the more densely developed downstream areas. In consideration of the purpose of the contact recreation standard to safeguard human health, it is worth noting that most recreation noted by stakeholders in the watershed takes place in the lower third of the watershed. This corresponds both to access and the significantly higher populations in these areas.

Table 30 – LDCs summary for *E. coli*

LDC Location	Area Represented	Findings
Downstream (11328)	Segment 1009; developed areas between Little Cypress Creek and I-45	Results at this station suggest significant *E. coli* reductions are necessary across all flow conditions, although some assimilative capacity may still exist for DO.
Midstream 2 (11332)	Segment 1009; after the confluence of Little Cypress Creek	Results at this station suggest a shift away from the better conditions at station 11333. While there is some very limited assimilative capacity in the lowest flows, more appreciable reductions are needed across the rest of the flow conditions. DO capacity is likewise more limited.
Midstream 1 (11333)	Segment 1009; transitional areas between the headwaters and Little Cypress Creek	Results at this station suggest a range of conditions, with *E. coli* reduction needed primarily in higher flow conditions, with some assimilative capacity in low flows. DO capacity also increases appreciably from the upstream station. The existence of large undeveloped tract, wetland areas, and other natural buffers upstream of this station may be responsible for a portion of the improvement at this location.
Headwaters (20457)	Segment 1009; headwaters west of SH99	Results at this station suggest that *E. coli* reductions are necessary during all flow conditions, while DO results suggest there is some assimilative capacity in all flow conditions.

The primary point of discussion and review was the improved conditions at station 11333. Project staff reviewed the data and ensured they were accurate. Changes in flows and inputs, and the potential impact of land cover in the area may result in the improvement. The expansion of development, even with the buffer of extensive conservation properties (especially Katy Prairie Conservancy holdings), is likely to increase the need for improvement at this location. To generate final source load reductions, the percent reduction targets from the LDCs were applied to the source loads from each source, for each attainment area.

Improvement Goals for *E. coli* and DO

The LDCs provided the basis for setting improvement goals for *E. coli* and DO, in the form of percentage reductions of instream loading (for *E. coli*) and percent improvement in DO levels. For DO, no further linkage to sources was calculated due to the lack of an impairment or widespread water quality concerns, the uncertainty of multiple potential precursors to low DO conditions, and the water quality goals set by the stakeholders. Based on the LDC results, where negative values indicate no improvement is needed and additional assimilative capacity may be present, DO conditions at all four LDC sites had additional assimilative capacity. However, the data represents ambient sampling, and not 24-hour DO, so variation in conditions is likely to happen throughout the daily cycle. Additionally, these data represent the four main stem LDC sites, and conditions on tributaries with less flow may vary more widely. However, as indicated in the 2020 Integrated Report, DO is only currently listed as a concern for AU 1009_01.

Attainment Areas

In developing improvement goals, the Partnership considered whether a single, watershed-wide goal for *E. coli*, and one for DO, was appropriate. Based on the varied character of the watershed, the number of unclassified segments and AUs of Segment 1009, and to provide for better monitoring of project progress, the Partnership elected to set separate goals for distinct areas in the watershed.

The LDC sites were intended as the focus of long-term attainment; therefore, project staff proposed three attainment areas, each with specific reduction goals (Figure 55). Based on a comparison of the results between stations 11333 and 11332, the Partnership decided to choose the downstream station (11332) as the terminus for a combined attainment area. The final selection of attainment areas is designed to reflect the three primary developmental zones of the watershed: the headwaters (subwatershed 1), the transitional zone (subwatersheds 2 and 3), and the downstream/developed area (subwatersheds 4 and 5). The stakeholders affirmed this approach, with the understanding that through adaptive management, additional targets may be added if needed (e.g. breaking out subwatershed 2/Little Cypress Creek from the second attainment area). The monitoring stations and their associated LDCs and improvement goals for these three areas will be the primary focus of measuring water quality achievements under the WPP.

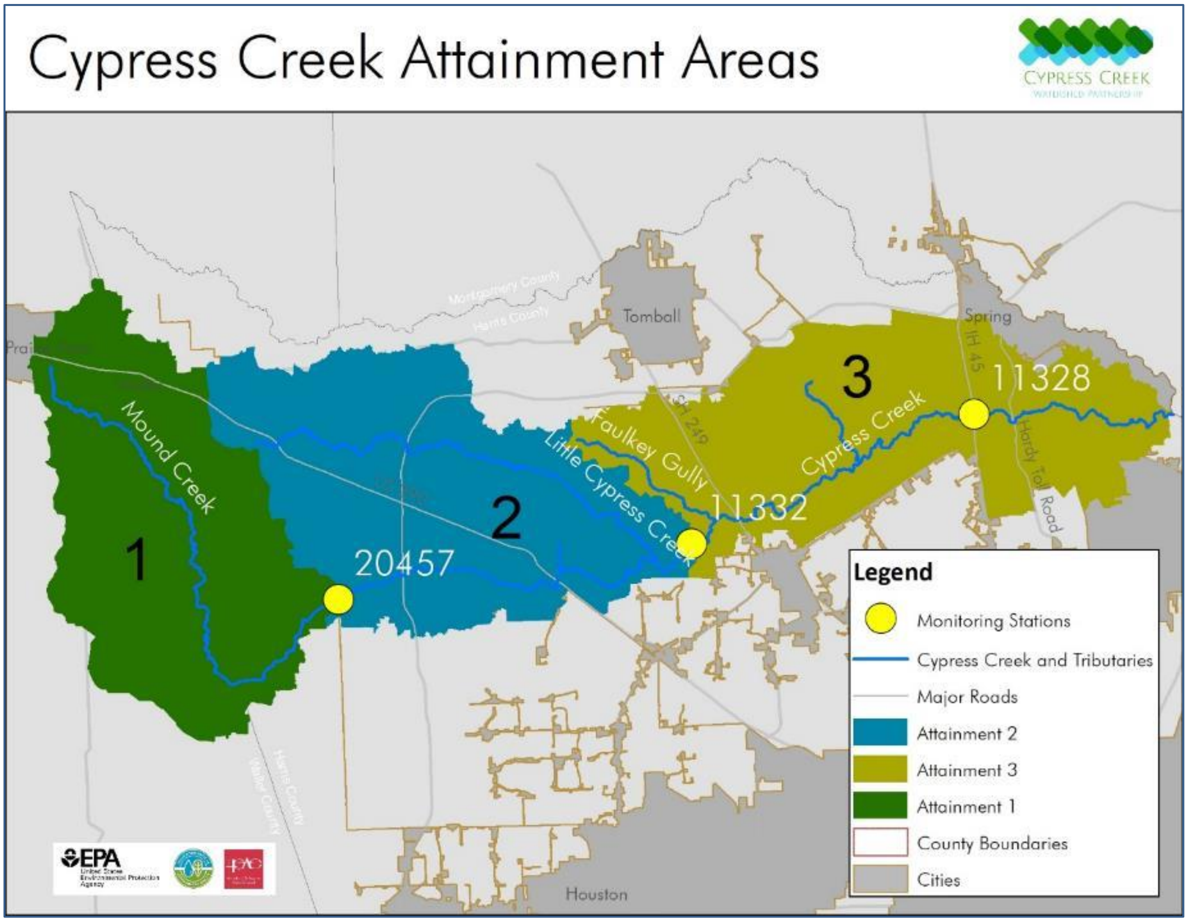


Figure 54 - Cypress Creek attainment areas

E. coli Source Load Reduction Goals

With the establishment of the three primary attainment areas, the Partnership developed specific *E. coli* reduction targets for current and target year (2035) conditions. The first step was to identify a single improvement goal based on the LDCs for each attainment area.

The design for generating single target reductions for each attainment area[87] was based on a compromise between the worst-case scenario (i.e., equating the reduction need to the highest possible reduction need in any flow category) and the least conservative approach (i.e., equating the reduction to the average reduction needed based on all flow conditions). H-GAC proposed, and the stakeholders affirmed, a moderate approach in which reduction targets would be established based on a weighted average of the flow conditions in which reductions were needed, for each attainment area. For example, Station 11333 indicated a need for reductions in the four highest flow categories, but not in the lowest flows. The most conservative approach would be to apply the greatest overall reduction to the watershed in general. The least conservative approach would be to average all flow conditions, thus

[87] As opposed to the modeled reduction values for each flow category.

diluting the reductions needed in the highest categories. The approach taken finds the flow weighted average of the categories needing reduction (i.e. the conditions driving the impairment) and uses that as a load reduction target (Table 31). These area-specific reduction targets are designed to represent the variability of conditions in the watershed and allow for long-term evaluation of progress.

Table 31 - *E. coli* load reduction goals, by instream percentage of load

Attainment Area	LDC Station	Subwatersheds	Weighted Average *E. coli* Reduction Target (%)
Headwaters	20457	1	74.6
Transitional Area	11332	2,3	63.9
Downstream	11328	4,5[88]	70.9

To generate numeric *E. coli* reductions for current conditions, the percent reduction targets for each attainment area were applied to the source loads from SELECT to generate numeric source load reductions (Figure 56). Future source load reduction targets assumed that any estimated additional source loads would be added to current condition reduction target loads (i.e. no new assimilative capacity was assumed for the waterway, so 100% of additional load added would need to be reduced). The resulting current and future reduction loads of this LDC/SELECT model linkage were generated for each of the attainment areas, with the intent of targeting BMPs sufficient to meet these reduction targets specific to each area. Source load reduction improvement goals were developed for each of the 5-year future projection milestones, with a focus on 2035 as the target year for compliance.

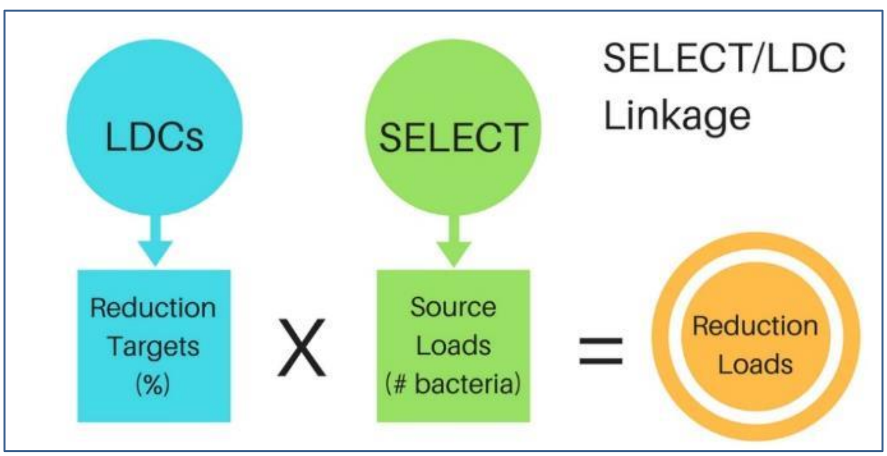


Figure 55 - SELECT/LDC linkage

[88] As indicated previously, while station 11328 is upstream of the final subwatershed, it is being used as the indicator for goal development for both subwatersheds 4 and 5, due to a lack of appropriate data downstream and potential issues with mixing at or near the confluence with Spring Creek.

Model Linkage

SELECT was used to generate potential source loads and characterize the source profile. The percent reduction improvement goals developed under the LDCs were applied directly to the source loads to generate the source load reduction targets. This process was developed with H-GAC and TCEQ project staff and reviewed and accepted by the stakeholders. No granular fate and transport modeling was completed for this project. Instead, the linkage relies on the assumption of a linear relationship between source loads and instream conditions. The percent reduction from the LDCs, rather than an absolute number of *E. coli* to reduce, is used for the linkage.

E. coli Reduction Considerations

With the model linkage established, calculating *E. coli* reduction targets required that the stakeholders consider two other primary questions: 1) what milestone year would reduction targets be based on; and 2) how would source load reductions be spread out among the fecal waste sources?

- **Milestone Year** — WPPs typically are written for a 5-15-year basis. The existing projections developed during the SELECT analyses allowed the stakeholders to target any of the five-year milestone dates between 2018 and 2040. However, the further out the projections went, the greater the uncertainty. In deciding on a target milestone year, the stakeholders balanced the need to set near term, achievable goals within a period of relative certainty, and the need to account for the amount of future growth projected for the watershed. A 5-year plan would not adequately address the appreciable increase in loads through 2040, whereas a more long-term plan would have to rely on less certain predictions[89]. Project staff proposed 2035 as a compromise, allowing a long-term focus to account for watershed change, while focusing on meaningful interim action. For a WPP approved in 2021, this would represent a 15-year plan life.
- **Allocating Reductions** — The mix of sources present in the watershed, and the shift of relative contribution through 2040, posed a challenge for allocating how reduction targets would be met. Stakeholders considered several options, including: 1) targeting all sources proportional to their contribution (e.g. if in 2035 source X made up 30% of the total load, then 30% of the reduction value would be met by addressing that source.); 2) allocating reduction subjectively based on potential solutions; and 3) allocating reduction based on current relative contribution (rather than 2035). Project staff proposed the first option, with the understanding that the WPP would stress opportunistic implementation and that short-term efforts may focus on sources that are

[89] This should not be taken to indicate a failure of the modeling methodology, but a reflection of the potential for unaccountable change the further out a model is used to predict conditions.

currently pressing (e.g., livestock) even if they are not as significant in the 2035 projections. The proportional allocation was modeled for the whole watershed, subwatersheds, and attainment area groupings, with the proposed allocations to focus on the attainment areas. Stakeholders affirmed the proposal.

Based on these decisions, project staff generated reduction targets for each attainment area, subwatershed, and source. Overall reduction targets for each of the attainment areas and the linkage of the reduction target percentages to the source loadings were used to generate the target source load reductions for current and 2035 milestones years (Table 32).

The load reductions needed by source for each of the three attainment areas, were also determined for current conditions and conditions in 2035 (Tables 33 and 34).

Table 32 - Current and 2030 source load reduction targets

Attainment Area	Subwatersheds	LDC Reduction (current)	Current Source Load[90]	Current Source Load Reduction Target	Incremental load 2018-2035[91]	2035 Source Load Reduction Target[92]
Headwaters	1	73.7%	8.45E+12	6.23E+12	4.02E+12	1.02E+13
Transitional Area	2,3	63.9%	2.50E+13	1.60E+13	3.76E+13	5.36E+13
Downstream	4,5	70.9%	5.83E+13	4.13E+13	1.39E+13	5.53E+13

[90] Current source load is generated by summing the source loads for the subwatersheds within the attainment area.

[91] The incremental load represents the difference between the 2035 load and the 2018 load. See the next footnote for explanation of its use in generating 2035 source reduction load target.

[92] The 2035 reduction target is generated by using the equation: 2035 source load reduction target = $C_r+(F_l-C_l)$; where C_r= current source reduction load, F_l = future total source load, and C_l = current total source load. In essence, the incremental load generated between 2018 and 2035 is added to whatever existing reduction load exists in 2018. This approach is used because LDCs cannot estimate future reduction percentages, and because it is assumed the waterway will not have additional assimilative capacity in 2035.

Table 33 - Current source reduction loads distributed by source and attainment area

		OSSFs	WWTFs	Dogs	Cattle	Horses	Sheep/ Goats	Deer	Feral Hogs	Other Wildlife	Total
Headwaters	Source Load	3.15E+11	8.02E+08	1.46E+12	3.61E+12	5.31E+10	1.76E+12	1.87E+10	3.85E+11	8.45E+11	8.45E+12
	% Total Load	3.73%	0.01%	17.28%	42.75%	0.63%	20.83%	0.22%	4.56%	10.00%	100.00%
	Reduction Load	2.32E+11	5.91E+08	1.08E+12	2.66E+12	3.91E+10	1.30E+12	1.38E+10	2.84E+11	6.23E+11	6.23E+12
Transitional Area	Source Load	1.61E+12	1.33E+10	1.71E+13	2.29E+12	3.36E+10	1.11E+12	6.32E+10	2.49E+11	2.50E+12	2.50E+13
	% Total Load	6.46%	0.05%	68.52%	9.14%	0.13%	4.45%	0.25%	1.00%	10.00%	100.00%
	Reduction Load	1.03E+12	8.52E+09	1.09E+13	1.46E+12	2.15E+10	7.11E+11	4.04E+10	1.59E+11	1.60E+12	1.60E+13
Downstream	Source Load	2.78E+12	5.74E+10	4.92E+13	1.29E+11	2.26E+09	9.01E+10	7.26E+10	7.22E+10	5.83E+12	5.83E+13
	% Total Load	4.77%	0.10%	84.50%	0.22%	0.00%	0.15%	0.12%	0.12%	10.00%	100.00%
	Reduction Load	1.97E+12	4.07E+10	3.49E+13	9.18E+10	1.60E+09	6.39E+10	5.15E+10	5.12E+10	4.13E+12	4.13E+13

Table 34 - 2035 source reduction loads distributed by source and attainment area

		OSSFs	WWTFs	Dogs	Cattle	Horses	Sheep/ Goats	Deer	Feral Hogs	Other Wildlife	Total
Headwaters	Source Load	1.34E+12	8.54E+08	4.81E+12	3.40E+12	4.99E+10	1.66E+12	2.60E+10	3.43E+11	8.45E+11	1.25E+13
	% Total Load	10.75%	0.01%	38.56%	27.26%	0.40%	13.28%	0.21%	2.75%	6.78%	100.00%
	Reduction Load	1.10E+12	7.02E+08	3.95E+12	2.79E+12	4.10E+10	1.36E+12	2.13E+10	2.82E+11	6.94E+11	1.02E+13
Transitional Area	Source Load	7.31E+12	2.87E+10	5.10E+13	1.07E+12	1.57E+10	5.22E+11	8.54E+10	9.26E+10	2.50E+12	6.26E+13
	% Total Load	11.68%	0.05%	81.42%	1.71%	0.03%	0.83%	0.14%	0.15%	4.00%	100.00%
	Reduction Load	6.26E+12	2.46E+10	4.36E+13	9.17E+11	1.35E+10	4.47E+11	7.31E+10	7.92E+10	2.14E+12	5.36E+13
Downstream	Source Load	4.35E+12	6.73E+10	6.17E+13	9.32E+10	1.63E+09	6.49E+10	7.25E+10	6.07E+10	5.83E+12	7.22E+13
	% Total Load	6.02%	0.09%	85.41%	0.13%	0.00%	0.09%	0.10%	0.08%	8.07%	100.00%
	Reduction Load	3.33E+12	5.15E+10	4.72E+13	7.13E+10	1.25E+09	4.96E+10	5.55E+10	4.64E+10	4.46E+12	5.53E+13

Representative Units and Scaling Implementation

To determine what the source load reduction targets meant in terms of the scaling of solutions, representative units were used. Representative units are an average, quantifiable component of each fecal waste source. For example, solutions targeting waste reduction for pet dogs would be scaled based on a representative unit of a single dog (i.e. if one had to reduce 10 hypothetical units of fecal waste, and each dog represented one hypothetical unit, then one would need to address 10 dogs). The total number of units that would need to be addressed in each attainment area in 2035 was calculated by dividing the target load reductions by the per unit *E. coli* source load of the representative unit (Table 35). The representative unit load is the full SELECT loading rate (i.e. not reduced for being outside the buffer area). In the case a specific solution is sited in an area outside the riparian buffer, the number of representative units will be less than the actual number of units to address. Likewise, for any solution with a reduction efficiency of less than 100%, the number of actual units to address will be more than the representative units. All units are rounded up to the nearest whole unit.

Because Other Wildlife as a category does not have a representative unit, it is not included in this table. Deer and Other Wildlife reduction targets were converted into equivalent OSSFs, which will be over-converted to account for stakeholder preference in not selecting specific solutions to target deer and wildlife.

Figure 56 - Feral hog being addressed

Table 35 - Representative units to address by 2035, by attainment area

E. coli Source	Representative Unit	Representative Unit Daily Load	Units to Address (2035), by Attainment Area		
			Headwaters	Transitional	Downstream
OSSFs	1 Failing OSSF[93]	3.70E+9	492 (298)	2,290 (1,691)	2,120 (900)
WWTFs	1 million gallons of effluent[94]	4.77E+9	1	6	11
Dogs	1 dog	2.50E+9	1,581	17,448	18,877
Cattle	1 cow	2.70E+9	1,035	340	27
Horses	1 horse	2.10E+8	196	65	6
Sheep/Goats	1 sheep or goat	9.00E+9	152	50	6
Deer[95]	1 deer	1.75E+8	NA (122)	NA (418)	NA (18)
Feral Hogs	1 feral hog	4.45E+9	64	18	11

The solutions for livestock are based on the implementation of WQMPs and similar conservation plans through TSSWCB and USDA NRCS. Section 5 provides details on these solutions. To translate the number of livestock units to address into number of plans, project staff worked with TSSWCB and the local SWCDs in this and previous projects to develop an assumed average number of livestock units (50) to be served by each plan. The number of plans is then derived by dividing the number of livestock units by the average units per plan and rounding up to the nearest whole representative plan (Table 36). The actual load reduction value for each plan will differ depending on the mix of livestock involved (given their different representative unit loading values).

[93] The OSSF numbers are increased to cover the deer and other wildlife reduction loads, per stakeholder preference. Deer loadings are shown, but no units will be addressed. Because there is no representative unit for other wildlife, that reduction value is not shown, but an equivalent reduction value in OSSFs is added to the OSSF total. The number in parentheses represents the number of OSSFs that would have had to have been addressed if deer and other wildlife loads were not converted into equivalent OSSFs.

[94] This representative unit assumes effluent discharged at a typical permit concentration standard of 126 MPN/100mL of *E. coli*.

[95] Deer units to address are shown as NA as the Partnership elected to over convert reductions on OSSFs given a lack of viable solutions for deer. The numbers in parentheses represent the number of units that would have had to have been addressed if the Partnership had not chosen this course.

Table 36 - Agricultural plans to address livestock loads (2035)

Attainment Area	Total Livestock Units to Address	Total Plans (rounded up to the nearest plan)
Headwaters	1,383	28
Transitional	455	10
Downstream	39	1

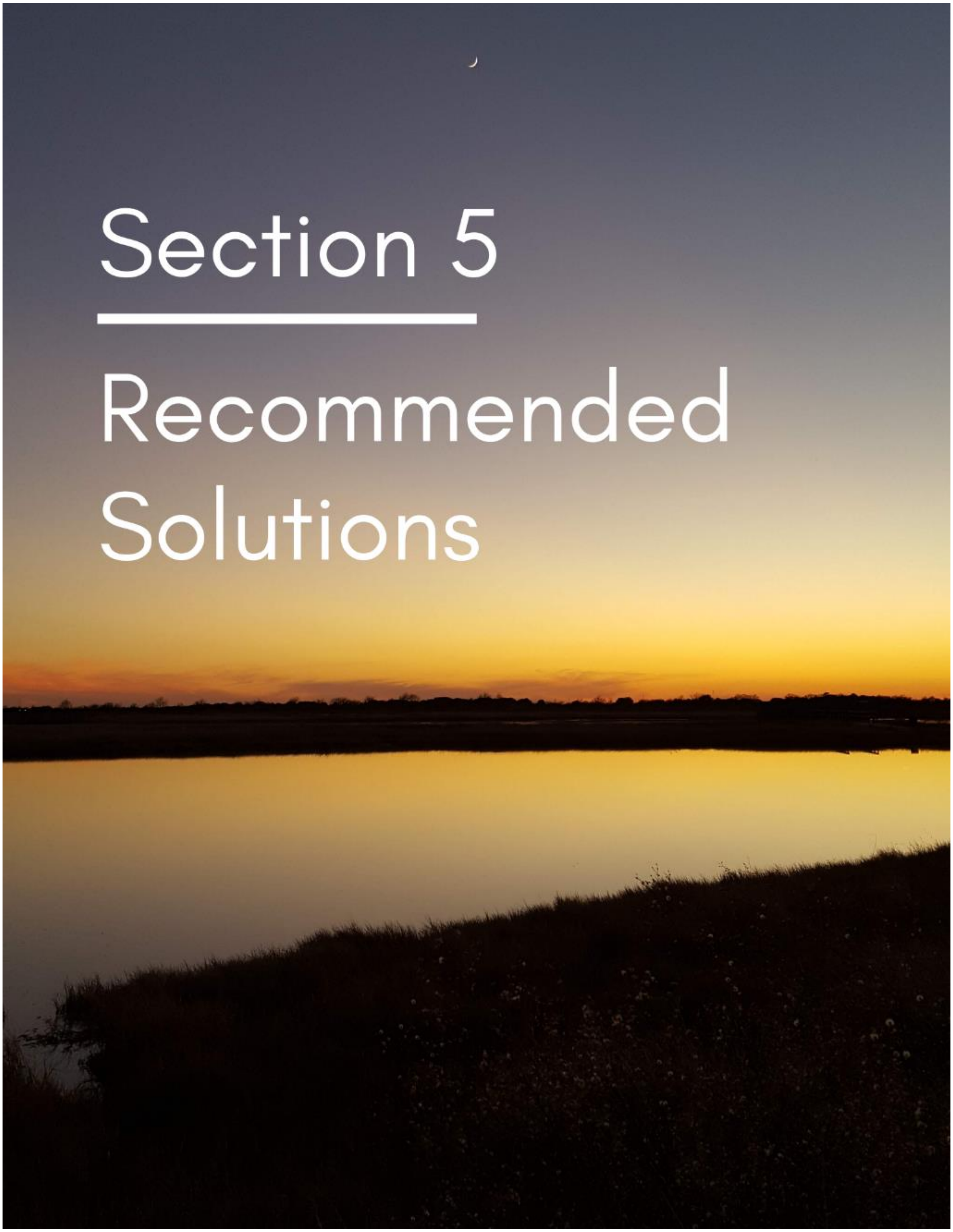
The cumulative impact of the recommended solutions identified in Sections 5 and 6 will be to address the number of representative units identified in Table 35. The solutions, or alternatives identified in future WPP revisions, will meet the load reductions required to meet the SWQS. Where a solution indicates a pollutant removal efficiency of less than 100%, the number of representative units it addresses will reflect the actual removal efficiency (e.g., if a pet waste station removes 50% of the load from 2 actual dogs, it will represent removal of one representative unit for dog waste, or one representative dog).

Source Load Reduction Summary

The findings of the *E. coli* modeling efforts for Cypress Creek reinforce the image of a watershed in transition. Driven by the general growth of the Houston area, and pushing outward from transportation corridors, the project area has seen significant growth in recent decades and will continue to do so in coming years. Developmental changes will reduce legacy agricultural sources in many areas, especially the Headwaters attainment area. The loss of load from agricultural activities will be outweighed by the increases of sources derived from developed areas.

The increasing loads highlight the need for intervention through the WPP and other means. Current water quality issues will be compounded by future loads, leading to degrading water quality through the planning period absent any effort to the contrary.

Uncertainty is present throughout the assumptions and methodologies of this modeling approach, as noted throughout this document. Project staff used the best available data and stakeholder feedback to minimize uncertainty wherever possible, but the results should be taken in the context of their use in characterizing fecal waste pollution on a broad scale, and for scaling and siting BMPs. For these purposes, the level of uncertainty and precision of the results was deemed to be acceptable by the stakeholders. Further refinement of results may be needed in the future in light of changing conditions. While *E. coli* source tracking or other DNA source tracking analyses were not a function of this project, it may be a consideration in the future to further characterize sources, identify location-specific challenges, and refine the linkage between source loads and instream conditions.


Section 5
Recommended
Solutions

5 – Recommended Solutions for Water Quality Issues

Concern into Action

Sources of pollution in the Cypress Creek Watershed are widespread, diverse, and expected to increase in the future. Without intervention, water quality will likely continue to degrade. Identifying a path forward that details a comprehensive approach for addressing these water quality issues is a necessary step in linking stakeholder concerns to achievable results. While the situation is challenging, potential solutions[96] exist that can be implemented on a voluntary basis and in a cost-efficient manner.

This WPP is designed to establish a clear link between the causes and sources of contamination, and the solutions identified and scaled to address them. Section 3 quantified the sources that contribute to water quality impairments and Section 4 identified the *E. coli* reductions and DO improvements needed to meet the Partnership's water quality goals. This Section details the voluntary solutions identified and prioritized by the stakeholders and discusses the financial and technical resources needed to implement them. Section 6 links these activities to corresponding education and outreach elements, Section 7 details the timeline and milestones associated with implementation, and Section 8 provides a path forward to evaluate their success.

Figure 57 – Volunteers collecting trash along Cypress Creek

[96] In WPPs, TMDL I-Plans, and other watershed restoration work, solutions are often referred to as best management practices (BMPs), implementation activities (IAs), or management measures. In this WPP these efforts are referred to generally as "solutions". The stakeholders preferred to put an emphasis on outreach that avoided jargon and technical terms.

Identifying Solutions

Guiding Principles

As detailed in Section 1, the stakeholders established six guiding principles for the recommendations of the WPP. The stakeholders emphasized: 1) recognizing the uniqueness of the areas in the system; 2) making decisions locally; 3) using voluntary solutions; 4) utilizing proven strategies; 5) coordinating with flood mitigation, conservation, and other adjacent activities occurring in the watershed; and 6) incorporating a strong education and outreach campaign. This focus provided a framework for identifying a set of feasible solutions in line with community priorities. These considerations shaped the discussion of potential solutions and the ultimate selection processes.

Identifying Potential Solutions

Stakeholders reviewed a wide range of potential solutions, starting with those identified in existing projects[97] and ongoing local efforts[98]. The diversity of pollutant sources in the watershed required that stakeholders consider an equally wide range of potential solutions sufficient to address each source[99] in proportion to the prominence of the source. This palette of potential solutions served as a starting point for local customization and development of area-specific actions. Recommendations were discussed at multiple meetings of the Partnership. In the interim, the topic-specific Work Groups refined ideas and added expertise in the form of recommendations to the Partnership for further discussion. The primary focus of the discussions was solutions to reduce fecal waste loads, with the assumption that most of the fecal waste solutions proposed would also benefit DO and other water quality goals. However, the Partnership discussed some solutions specific to other concerns. After several rounds of discussion and one-on-one meetings with specific partners, the Partnership formed the set of recommended solutions described herein. Both ongoing projects and new efforts are reflected.

This list of solutions is built around the understanding that the WPP operates on a process of adaptive management that will add or remove solutions based on efficacy, funding levels, changing conditions, or opportunities.

Solution Prioritization

The prioritization of solutions was a primary discussion point for the stakeholders. Funding limitations were a key concern for some structural solutions. In general, the stakeholders favored the

[97] Including previous WPPs and TMDL I-Plans conducted in other watersheds, as well as the I-Plan for the Bacteria Implementation Group, under whose auspices the Cypress Creek/Lake Houston TMDL project now rests.

[98] Including planned or potential activities of local government partners like the Harris County Precincts and Harris County Flood Control District; NGOs like the Katy Prairie Conservancy, Cypress Creek Flood Control Coalition, and Bayou Land Conservancy; regional efforts like USACE studies; private developers, and others.

[99] Deer, migratory birds, and other wildlife for which no feasible solutions existed were not considered under this process, based on stakeholder feedback or regulatory restriction.

enhancement or supplementing of existing efforts before the addition of new elements. High priority was placed on solutions that:

- Had potential funding sources;
- Served multiple benefits (e.g., vegetative riparian buffers that reduce the transmission of *E. coli* and nutrients while also slowing storm flows and reducing hydrologic impacts of runoff);
- Were already proven programs with sustaining support from agencies or other organizations;
- Involved or emphasized voluntary conservation, especially in the Headwaters attainment area;
- Were related to or supplemental to flood mitigation efforts;
- Had a strong outreach and education component or tie-in; and
- Were focused on areas most adjacent to the water.

These priorities are reflected in both the set of recommended solutions, as well as the priorities for their implementation, as discussed later in this section.

Figure 58 – Presenting potential solutions to community groups

Recommended Solutions

In developing solutions, the stakeholders considered the purpose of the solution, the scope of its implementation, the responsible parties[100], the period in which it would be implemented[101], the contaminants addressed, its status as either an existing or new effort, the technical and financial resources needed for implementation, and its potential for reducing *E. coli*. The solutions will be implemented together, or in phases, such that they cumulatively address the *E. coli* reduction goals for each source. Estimated costs reflect the period through 2035. The solutions identified in this section are for direct structural or programmatic elements. Solutions related to education and outreach for each source category are highlighted in Section 6. While solutions are intended to be implemented in all appropriate subwatersheds, proportional to the load from the subwatersheds, specific focus areas are indicated for each source category. Focus areas identify the subwatersheds for which a set of solutions is most applicable. For all solutions the Partnership, as an ongoing point of coordination facilitated by H-GAC or a successor agency, is assumed to be a supporting party, though the level of support will differ based on the solution. Additional information on potential funding mechanisms is included as Appendix D.

On-site Sewage Facilities (OSSFs)

Failing OSSFs are a priority source due to the high potential of human waste to endanger health, and their increasing share of total load by 2035. The general intent of the stakeholders was to prioritize failing systems that are unlikely to be addressed otherwise, and to attempt to prevent future failures through education and outreach to the community and licensed professionals and direct intervention with a focus on economically disadvantaged households. These solutions are in addition to the existing requirements of Harris and Waller counties, which include mandatory maintenance contracts for systems, and other authorized agents, and the enforcement thereof. It should be recognized, however, that those county and authorized agent efforts are a primary foundation for all other efforts.

The solutions identified by the stakeholders include:

- OSSF 1 — Convert OSSFs to sanitary sewer;
- OSSF 2 — Improve and update spatial data to identify priority areas.; and
- OSSF 3 — Remediate failing OSSFs (repair, replace, pump, decommission).

The focus areas for this solution are all subwatersheds with existing sanitary sewer systems, with a focus on the Headwaters and Transitional attainment areas. Educational elements (e.g. homeowner workshops) are included in the discussion of education and outreach activities in Section 6.

[100] Throughout this section, references to categories (Counties, Districts) are made unless a specific party is named.

[101] The period represented for each solution is the timeframe within the initial 14-year implementation window between an assumed approval in 2021 and the target year of 2035. Many solutions will likely continue to be implemented as ongoing efforts or as needed to maintain water quality after that point.

(Image courtesy Texas A&M AgriLife Extension)

OSSF 1 – Convert to Sanitary Sewer

Purpose: Convert old and/or failing OSSFs to sanitary sewer service where available and appropriate.

Description: Local partners, in coordinating with funding sources like H-GAC's Supplemental Environmental Project (SEP) for OSSF remediation[102], will focus on identifying and pursuing opportunities to convert OSSFs within service area boundaries to sanitary sewer service. Cities will consider promoting or requiring conversion of areas within existing or annexed boundaries[103]. Priority should be given to failing systems, and this recommendation only applies where sanitary service is available/feasible.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; Harris County; Waller County; Special districts and utilities; homeowners	Ongoing-2035	Bacteria, Nutrients	Enhance an existing, ongoing effort.

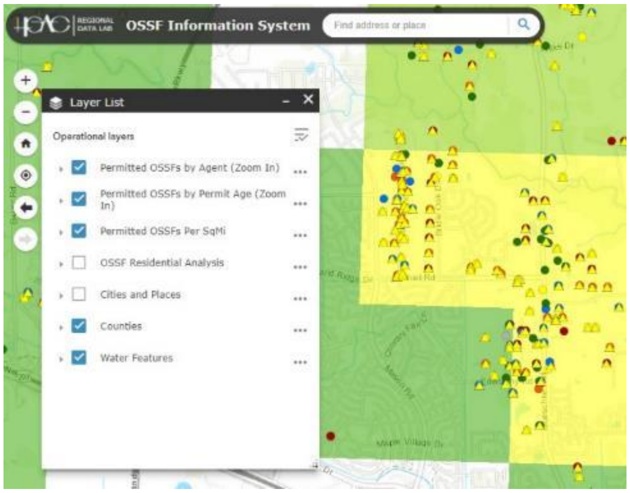
Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources include available staff at local governments, H-GAC, Harris and Waller counties to promote and/or process conversion projects. Homeowners or funders will need to have, or contract for, personnel skilled in this specific type of construction. Financial resources include the cost to permit the service connection, construct the service line, and pump/decommission the OSSF. It's expected that a good number of conversions may result in abandoned OSSFs as development of master-planned communities displaces existing residences.	Estimated costs of converting a residence to sewer service are \$3,000-\$5,000. No specific number of OSSFs is slated for this specific action (see OSSF 2). Funding sources include expected routine costs from homeowner, as supplemented by H-GAC SEP or CWA §319(h) grant funding.

Bacteria Reduction Capability

This solution is expected to provide 100% removal rate by actively converting systems to alternate service.

[102] H-GAC's SEP is used to remediate, repair, pump, or decommission OSSFs for homeowners making less than 80% of the Area Median Income.

[103] The City of Conroe does not currently allow new septic systems in areas that are served by the city.



OSSF 2 – Improve Spatial Data

Purpose: Inform decisions about prioritizing OSSF remediation.

Description: H-GAC will work with Harris and Waller Counties and other local partners to continue to collect spatial data on OSSF locations as part of H-GAC's existing OSSF spatial database[104]. The partners will update and improve designations for priority remediation areas based on the data and other factors (e.g., growth, developmental trends).

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; Harris and Waller counties; special districts and utilities	Ongoing-2035	Bacteria, Nutrients	Expansion of existing efforts (e.g. H-GAC OSSF database)

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources include existing staff capacity at H-GAC and partner agencies. H-GAC currently maintains the database as part of a CWA Section 604(b) grant project with TCEQ. No additional technical resources are needed for this aspect of the task. Financial resources needed include staff time from local partners to continue to submit and review OSSF data, and to coordinate with H-GAC on maintaining and updating priority areas for H-GAC SEP and other funding in the watershed. Specific focus will be given to economically disadvantaged households and OSSFs in riparian or flood-prone areas.	Estimated costs include existing funding of staff time which is variable depending on workload for this element. Funding sources are the ongoing H-GAC CWA §604(b) grant and local partner staff time.

Bacteria Reduction Capability

This solution does not directly reduce fecal waste pollution but is designed to better inform other solutions (OSSF 1 and OSSF 3; OSSF homeowner workshops) to enhance their effectiveness.

[104] Available for review online at http://datalab.h-gac.com/ossf/.

	# OSSF 3 – Remediate Failing OSSFs **Purpose:** Reduce bacteria and nutrient contributions from failing OSSFs through physical remediation. **Description:** H-GAC will work with Harris and Waller Counties and OSSF owners to inspect and remediate failing systems through pumping, repair, replacement, or abandonment/conversion to sanitary sewer. H-GAC will use Supplemental Environmental Program (SEP), CWA §319(h), or other grant funding to address priority systems. Authorized agents will work with homeowners to enforce existing requirements concerning OSSF function and inspection. In remediation efforts, priority will be given to failing systems near the waterways.		
Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; homeowners; Harris and Waller Counties (enforcement); utilities (for conversion projects)	Ongoing-2035	Bacteria, Nutrients	Expansion of existing efforts (e.g. H-GAC OSSF SEP, residential maintenance)
Technical and Financial Resources Needed			Estimated Costs and Funding
Technical resource needs include data on OSSF locations from H-GAC's regional OSSF database, the counties, local utilities/special districts, who may also provide violation information as appropriate. Actual remediation conducted by H-GAC, the homeowner, or another party; enforcement and referrals will be provided by the other responsible parties. Inspection will be conducted as needed by authorized entities based on existing ordinance or other authority. Financial resources required include H-GAC staff time to manage remediation contracts, other parties' staff time in enforcement, and funding for the remediation. Staff time is variable and is not included in cost estimates. Homeowners are expected to provide most of the funding, with other sources supplementing routine maintenance and replacement costs.			Estimated costs are an average[105] of $5,500 per unit, with a total cost of $26,961,000 for 4,902 systems. Funding Sources include routine homeowner maintenance costs, as supplemented by H-GAC SEP and other grant programs (CWA §319(h), etc.).
Bacteria Reduction Capability			
Remediating failing OSSFs is assumed to remove 100% of their daily load. Full implementation of this solution will meet the bacteria reduction goal for OSSFs by 2035.			

[105] Average cost numbers were based on a review of OSSF work completed under other projects and approved WPPs in the area, including pump outs, repairs, replacements, and related costs. The range of potential costs for all services mentioned runs from several hundred dollars for a pump out to over $10,000 for replacement of a new system in some areas.

Actual implementation will be opportunistic and will seek to emphasize priorities noted in each OSSF solution. Proposed siting of OSSF implementation projects within the watershed (Table 37[106]) include additional units to convert in order to cover reduction loads from deer and other wildlife, as noted previously.

Table 37 - Proposed siting for OSSF solutions by subwatershed

Attainment Area	Total OSSFs to Address	Subwatershed	OSSFs to Address per Subwatershed in 2035
Headwaters	492	1	492
Transitional	2,290	2	1,328
		3	962
Downstream	2,120	4	1,548
		5	572

Figure 59 - OSSF being installed

[106] The number of OSSFs designated to be addressed by subwatershed is based on each subwatershed' s proportional contribution to the total OSSF load for its segment area. This proportion is applied to the reduction load for the segment area and divided by the load per BMP unit to produce the number of BMP units per subwatershed. As with other sources, the focus of implementation will continue to be on siting BMPs opportunistically to generate the greatest bacteria reduction for each segment area. Therefore, actual implementation in each subwatershed may differ from these targets based on opportunities and changing conditions in the watershed.

Wastewater Treatment Facilities (WWTFs) and Sanitary Sewer Overflows (SSOs)

WWTFs in the watershed are generally able to meet their bacteria limits, with few exceedances, but enhancements to structural and operational elements and a focus on addressing SSOs can reduce these sources of human fecal pathogens. Based on established jurisdictions for WWTF operation and SSOs, the responsibilities for these recommendations will largely fall to the local utilities and special districts, who provide the overwhelming amount of sanitary sewer service in the watershed. Many of these MUDs, UDs, WCIDs, private utilities and other entities are actively engaged in these efforts and have had noteworthy success. Priority is placed on aging systems, smaller systems with less oversight, systems with chronic issues, economically disadvantaged areas, or facilities located in floodplains vulnerable to storm events.

Despite the relatively low daily load from WWTFs and SSOs, these sources are being considered a high priority because of their proximity to developed areas, and the relatively high risk of human waste. The primary focus of WWTF and SSO solutions are continuation and enhancement of utility operations. Supplemental support from the Partnership, or additional activities beyond normal operations emphasize information sharing, funding identification, and prioritization.

These recommendations are in supplement to the existing day-to-day operations of the WWTFs in the area. The focus areas are the Transitional and Downstream attainment areas. The recommendations for WWTFs and SSOs:

- WWTF 1 — Address problem plants and consider regionalization;
- WWTF 2 — Recommend increased testing;
- SSO 1 — Remediate Infrastructure; and
- SSO 2 — Consider additional preventative measures

Educational elements related to WWTFs and SSOs are expanded on in Section 6. Due to the variety of operations in the watershed, cost estimates for these solutions vary widely or are future costs that cannot be predicted. However, the primary focus of funding in this section is existing utility funding resources as augmented with support from the Partnership in identifying and pursuing additional funds. More information about funding sources is available in Appendix D.

WWTF 1 – Address Problem Plants; Consider Regionalization

Purpose: To increase oversight of facilities with discharge violations and potentially consolidate operations where appropriate to increase economies of scale and phase out outdated treatment infrastructure.

Description: The Partnership will work with local authorized agents and interested utilities to promote remediation of plants or processes in which exceedances are occurring or likely to occur. This may happen through: routine or augmented investment by the utilities; support from the coordinating entity of the Partnership in identifying or pursuing additional funding resources; or action or recommendation from the counties regarding regionalizing problem, undersized, or aging plants and infrastructure. Because of the relatively large number and smaller average size of plants in areas (Downstream, specifically) where transmission distances may not be a primary limiting factor, regionalization of some areas may be appropriate within the timeframe of this WPP implementation. No specific problem facilities were identified in the watershed characterization, but as systems age, problem areas may arise.

Responsible Parties	Period	Contaminant Addressed	Status
Utilities; Counties	Ongoing-2035	Bacteria, Nutrients	Extends existing management; potential enhancement to existing operations

Technical and Financial Resources Needed	Estimated Costs and Funding
The technical resources needed to fulfill these recommendations are sufficient utility staff to address system elements, and Partnership support for funding identification. Financial resources needed for this recommendation are highly variable, but include utility staff time costs, and infrastructure costs as warranted.	Costs involved with WWTP rehabilitation or regionalization are highly variable and not estimated individually here. Funding sources potentially include tax or utility revenue, TWDB loans or grants or other applicable grant programs (USDA Rural Utilities Service, etc.).

Bacteria Reduction Capability

This activity directly reduces bacteria, nutrients, and additional concerns stemming from poorly treated effluent. Because there is not a significant pattern of exceedance existing already among watershed WWTFs, future reductions cannot be quantified as they will be dependent on the future state of infrastructure. The primary reduction potential for this task is as a preventative measure.

WWTF 2 – Recommend Increased Testing

Purpose: To increase oversight of plants with infrequent testing and enhance nutrients data through voluntary testing.

Description: The Partnership will recommend additional bacteria testing to local utilities that do not have daily testing requirements. The intent of the increased testing is to expand the ability to identify operations that would benefit from additional resources. Infrequent testing may mask issues, especially in smaller facilities with less consistent loading. The Partnership also recommends that utilities consider testing, as appropriate, for a wider suite of nutrients, to include total phosphorus and nitrogenous compounds. This data would help establish the potential impacts of effluent on nutrient loading to the waterway and potentially help prepare facilities for future permit changes, including future statewide additions of other nutrient criteria by TCEQ.

Responsible Parties	Period	Contaminant Addressed	Status
Utilities	2021-2030	Bacteria, Nutrients	Expands existing functions.

Technical and Financial Resources Needed	Estimated Costs and Funding
The technical resources needed to fulfill these recommendations are sufficient utility staff to handle increased testing. Financial resources needed for this recommendation are the incremental costs of sampling, dependent on the frequencies and constituents involved.	Testing costs are highly variable by the frequency of testing and costs specific to the individual entity involved. Funding sources are expected to be tax or utility revenues of the utility.

Bacteria Reduction Capability

This activity does not directly reduce bacteria; it provides information for decision-makers to address current or future operations to directly reduce pollutants.

SSO 1 – Remediate Infrastructure

Purpose: To physically remediate collection system SSOs through rehabilitation and preventative maintenance.

Description: Utilities will continue to identify and address areas in collection systems prone to SSOs and consider structural and operation changes that will reduce SSOs, including:

- prioritizing rehabilitation of problem elements/areas
- considering additional funding for rehabilitation where appropriate
- pursuing additional grant or loan funding to expand resources for rehabilitation

Responsible Parties	Period	Contaminant Addressed	Status
Utilities	Ongoing-2035	Bacteria, Nutrients	Enhance existing efforts.

Technical and Financial Resources Needed

Technical resources for remediating SSOs include sufficient staff capacity for investigating problem areas and implementing capital projects or operational adjustments. For grant projects, staff grant administration capacity would be needed.

Financial resources for remediating SSOs are typically borne by utilities directly, through rate revenue or ad valorem tax revenue. Potential supplemental funding sources include Texas Water Development Board (TWDB) Clean Water State Revolving Fund loans or grants, funding from resiliency-based funding sources from federal agencies[107], and traditional commercial loan or bond opportunities.

Costs are highly variable depending on the size, age, and type of infrastructure and the nature of the causative factor for SSO problem areas. Resources needed include maintaining adequate staff capacity, equipment to conduct inspections and supplement operations, and cost of rehabilitation and contractor services. Residents are responsible for maintenance and repair of their private line connections.

Estimated Costs and Funding

Estimated costs for addressing SSOs are highly variable depending on the extent of the issues, size of the system, and nature of the fix. Example costs from other regional WPPs include mid-sized cities who spend $1,000,000-$5,000,000/year on addressing aging collection system infrastructure. The distributed nature of service in the watershed means costs per utility are likely lower than this estimate, but in conglomerate amount to appreciable investment.

Funding sources include tax or utility revenue and loans/grants from TWDB or other programs.

Bacteria Reduction Capability

This activity is expected to reduce SSO activity at chronic locations. Efficiency is variable depending on extent of the local problem and nature of implementation. The primary benefit is expected to be localized, but significant in those localities based on the relatively high risk of untreated sewage. While the total volume of SSO flow that will be reduced cannot be projected, the reduction efficiency is 100% for each gallon of effluent not released.

[107] See Funding Resources List in Appendix D

<table>
<tr><td rowspan="3"></td><td colspan="3"><h1>SSO 2 – Consider Additional Preventative Measures</h1></td></tr>
<tr><td colspan="3">Purpose: To enhance operations and infrastructure capacity to help prevent SSOs.</td></tr>
<tr><td colspan="3">Description: Utilities will consider enhancing their operations and preparations for mitigating SSOs by implementing one or more of the following best practices (if not already in place):
• Evaluate and enhance lift station[108] backup capacity, including backup power or capacity for bypass pumping or other remediations in the event of power outages.
• Consider implementing grease trap inspections where not already required.
• Consider implementing or upgrading a proactive asset management program to evaluate and prioritize rehabilitation needs.
• Revise response procedures/standard operating procedures for identifying and mitigating SSOs in high rain events.
• Consider participation in TCEQ's Sanitary Sewer Overflow Initiative (SSOI) for problem systems.</td></tr>
<tr><td>Responsible Parties</td><td>Period</td><td>Contaminant Addressed</td><td>Status</td></tr>
<tr><td>Utilities</td><td>2021-2030</td><td>Bacteria, Nutrients</td><td>Enhancement of existing effort</td></tr>
<tr><td colspan="3">Technical and Financial Resources Needed</td><td>Estimated Costs and Funding</td></tr>
<tr><td colspan="3">Technical resources for additional preventative measures include sufficient staff capacity to evaluate lift station capacity, implement capital projects, conduct grease trap inspections, oversee asset management efforts, review standard operating procedures for SSOs, and/or make recommendations on operational changes. Staff costs are variable dependent on the size and scope of the project and staff involvement.

Financial resources for enhancing lift station capacity are borne by the utility. Additional financial resources include loan and grant programs.</td><td>Estimated costs are variable, depending on the type and scale of measures selected and implemented.

Funding sources include government tax or utility revenue and loans/grants from TWDB or other grantors.</td></tr>
<tr><td colspan="4">Bacteria Reduction Capability</td></tr>
<tr><td colspan="4">This activity is expected to reduce SSO activity by ensuring lift station functionality in all conditions and enhancing preventative measures. While the total volume of SSO flow that will be reduced cannot be projected, the reduction efficiency is 100% for each gallon of effluent not released.</td></tr>
</table>

[108] Lift stations are an essential part of collection systems in relatively flat regions, transferring waste between pipes at different elevations to maintain flow. However, during power outages or similar events, lift stations can cease to function and be prone to overflow without backup capacity. Utilities will evaluate and consider enhancing their backup capacity (generators, bypass pumps, etc.) for their lift stations to ensure continuity of operations during power outages or other events.

Dog Waste

Waste from both pet and feral dogs is a substantial source of bacteria and nutrients in the Cypress Creek Watershed, especially in the more densely developed areas. The general focus of the recommended solutions is to enhance existing pet waste reduction efforts, install new structural elements, and promote spay/neuter programs to reduce unwanted populations. The implementation of these tasks is designed to focus on making pet waste reduction easy and visible to dog owners, especially in public places.

Figure 60 – Pet dog in recreational area

The solutions recommended by the stakeholders include:

- Pet Waste 1 — Install pet waste stations in local areas;
- Pet Waste 2 — Add dog parks or dog areas in public places;
- Pet Waste 3 — Hold spay/neuter clinics to reduce feral populations; and
- Pet Waste 4 — Increase enforcement of pet waste rules and ordinances.

The focus of implementation for these solutions will be on public areas with high traffic from pet owners, including parks, trails, and large multi-family complexes. The priority areas are the urban centers and regional park areas, especially the developed portions of the Transitional and Downstream attainment areas adjacent to waterways. The recommendations are in supplement to existing pet ordinance enforcement by local governments and existing structural elements (pet waste stations, etc.). Grouping multiple stations at single locations increases ease of use and visibility.

Pet Waste 1 – Install Pet Waste Stations

Purpose: To reduce pet waste in runoff by encouraging pet owners to pick up after pets in public areas.

Description: Pet waste stations are a widely used, proven technology for reducing pet waste in public areas where dog owners bring their pets. The stations are cost-effective, with low maintenance aside from refilling bags as needed. This solution would install 40 or more pet waste stations in the watershed, which would be installed and continually maintained by the entity receiving them. The pet waste stations would be targeted for high traffic public areas in the watershed, such as the Cypress Creek Greenway, large area parks like Meyer Park and Mercer Arboretum, other neighborhood and county parks, other recreational areas, and new development. Temporary stations at large events are another potential supplement to this effort.

Responsible Parties	Period	Contaminant Addressed	Status
Counties; HOAs; Special districts; Developers; NGOs	2021-2030, (installation). 2030-2035 (ongoing use)	Bacteria, Nutrients	Expand on existing efforts.

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources required are limited to adequate staffing commitment to install and maintain the sites, functions within the scope of the partners' existing capabilities. Financial resources are needed for the purchase of the stations and initial materials (identified sources include existing funding from local partners, CWA §319(h) grants - wholly or in cost-share with partners, and private sector donations through H-GAC); installation and ongoing maintenance (staff time, provided by the receiving partner); and bag refills (provided by the receiving partner, or as appropriate under future grants). Alternative funding sources for initial materials include partnerships with local industry/commercial entities or park volunteer groups. The Partnership will explore with H-GAC the potential to do an H-GACBuy[109] cooperative purchasing arrangement.	Estimated costs for 40 pet stations include installation costs of $200 per station, $50 in bags, $200 in labor and materials (total $18,000). Maintenance is estimated at $300/year per station ($168,000 for 14-year period). The total cost is $186,000. Costs for mobile stations at events are variable. Funding sources include local government tax or utility revenues, or grants from CWA §319(h) or other sources.

Bacteria Reduction Capability

The number of dogs impacted by this solution will vary based on the location. An average of 50 dogs a day per station served was chosen based on stakeholder description of high-traffic area parks. Assuming half of the dog's daily waste is served, full implementation of this solution would yield 2,000 dogs, or 1,000 representative units, addressed. This would represent a daily bacteria reduction of 2.5E+12 in riparian areas (300-foot buffer), and 6.25E+11 in areas outside the buffer based on SELECT assumptions.

[109] More detail about H-GAC's cooperative purchasing program can be found online at https://www.hgacbuy.org/.

Pet Waste 2 – Expand Dog Parks

Purpose: To provide additional areas for dog owners to bring dogs, to sequester waste and increase the likelihood of owners picking up waste.

Description: This solution would entail partners developing dog park/areas at their properties or developing new specific dog parks. Dog park areas already exist in the watershed (e.g., Bridgeland Dog Park, Meyer Park). Heavily used recreation areas and other parks adjacent to waterways are prime locations for dog parks or off-leash areas with waste stations. Newly developing private communities (e.g., Bridgeland) with strong amenity focuses are also potential opportunities for expanded parks. Priority areas are based on highest potential use/traffic and population served.

Responsible Parties	Period	Contaminant Addressed	Status
Local government; Counties; HOAs; Developers; Special districts	2021-2025 (1 new park area), 2025-2035 (another)	Bacteria, Nutrients	New/expanded effort

Technical and Financial Resources Needed

Technical resources needed are sufficient staff capacity for park owners to evaluate potential expansion of dog areas, manage capital projects, and/or seek funding.

Financial resource needs reflect the stages for which technical resources are needed. Identified sources of funding include internal revenue of the partners, grants from governmental sources and private endowments, and partnerships with private industry/organizations.

Dog park costs are highly variable based on location and composition, and whether new land is acquired, or dog facilities are developed in existing parkland.

Estimated Costs and Funding

Cost estimates for new park acquisition in area plans range from \$500,000 to \$1,000,000+, whereas development of new facilities in existing parks range from \$50,000 to \$300,000.

Funding sources include municipal revenues, CWA §319(h) grant funding, TPWD park grant funding, or foundation grants.

Bacteria Reduction Capability

This solution indirectly reduces waste, by sequestering it where it can be more easily addressed by owners and park staff. The number of dogs served is based on the number and scale of parks/park areas added. An assumption of 50% reduction of daily load per dog visiting the park is used based on stakeholder input.

Pet Waste 3 – Promote Spay/Neuter Events

Purpose: To reduce feral dog populations through reproductive controls.

Description: Spay and neuter programs are an effective means of curbing feral and unwanted pet populations[110]. The Partnership will work with a spay and neuter provider to hold local spay and neuter events or promote local services to pet owners through local governments, special districts, NGOs and HOAs. Potential models include existing spay and neuter programs at Harris County and NGOs like Friends For Life[111].

Responsible Parties	Period	Contaminant Addressed	Status
Service provider (such as SPCA or similar); Local partners	2021-2035, every 5 years (3)	Bacteria, Nutrients	New effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical expertise would be provided by the existing spay/neuter program staff. Similarly, outreach materials already exist for these programs. H-GAC and partners will adapt materials as needed. Various providers have had mobile programs in the area. Financial resources needed include funding for the events, which has been proposed for a combination of local government funds, other grant funding, or funding from private endowments, in addition to any contributions received from other interested partners. Funding for the spay/neuter of residential pets would be provided by the residents, or to some degree by the spay/neuter program itself based on its internal funding sources.	Costs estimates for Spay/Neuter education events are \$5,000 per event, (\$15,000 total) and spay/neuter costs for owners are \$40-\$150 per animal[112]. Funding sources include pet owners, local partner or non-profit funding, and grants.

Bacteria Reduction Capability

This solution's efficiency will vary based on the number of dogs addressed. A single female dog can have up to three litters a year or an average litter size of seven puppies, yielding up to thousands of dogs in five years or less[113]. Even with a low feral survival rate, this is an appreciable, if not directly quantifiable, reduction. The reduction of each average litter represents a 1.75E+10 daily source load reduction[114].

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[110] Harris County has an existing Trap, Neuter, Release program for community (feral) cats. More details are available at https://www.countypets.com/Pet-Resources/Community-Cat-Program.

[111] More information on a model program by this NGO to curb pet populations in underserved communities can be found at https://friends4life.org/programs-and-events/fix-houston/.

[112] Based on cost estimates provided by the Houston Humane Society, available online at https://www.houstonhumane.org/clinic/spay-neuter.

[113] https://dogpages.net/health/how-many-puppies-do-dogs-have/

[114] The reduction represents a total potential source load reduction and does not consider spatial location.

Pet Waste 4 – Consider Increased Enforcement

Purpose: To reduce pet waste through enforcement of existing or new ordinances or other restriction.

Description: Requirements to pick up pet waste vary throughout the watershed in both public and private areas. The focus of this solution is to provide model ordinances and outreach materials, as well as direct engagement, for entities considering increasing their enforcement. Specific attention will be given to apartment complexes and high traffic public areas, especially those adjacent to waterways.

Responsible Parties	Period	Contaminant Addressed	Status
Local governments; Special districts; HOAs; Counties; Apartment complexes	2021-2030	Bacteria, Nutrients	New effort

Technical and Financial Resources Needed

Limited technical resources are required for this solution. Model materials already exist and can be adapted as needed.

Financial resources needed for the solution are primarily an issue for increased enforcement costs if active enforcement is conducted. Otherwise, costs are limited to staff time in developing and seeking approval for additional restrictions.

A primary focus for this watershed is large apartment complexes. Existing models for multifamily property enforcement exist in the watershed.

Estimated Costs and Funding

Cost estimates for developing new ordinances or outreach materials will vary by scope and type. However, H-GAC maintains model materials on its website[115]; as do partners like Harris County. Costs for increased enforcement will vary based on the entity involved and scope of enforcement.

Funding sources for developing new enforcement or materials is expected to come primarily from the enforcing entity's existing revenue streams. Model materials already developed do not require additional funding.

Bacteria Reduction Capability

This solution is not a direct intervention, but a reinforcement or expansion of restrictions that serve to prevent wastes.

[115] http://www.h-gac.com/pet-waste-pollutes/default.aspx

Dogs are a substantial portion of the modeled source load for Cypress Creek. While they are concentrated most densely in the transitional and downstream areas, they are present in good numbers throughout the watershed, and will be addressed by the preceding recommendations wherever opportunities lie. The Partnership's goal is to address dog waste proportional to the number of dogs in any subwatershed, but special attention will be given to riparian areas and high-use public facilities. Discussions during this WPP indicated there are a good number of public and private parks adjacent to the creek and its tributaries that would be good candidates for pet waste stations (including enhancement of existing stations), enforcement, or spay and neuter events (Table 38). However, the Partnership recommends the expansion of these elements to any appropriate areas where opportunities exist, including smaller HOA and private parks.

Table 38 - Proposed siting for dog waste solutions, by subwatershed (2035)

Attainment Area	Total Dogs to Address	Subwatershed	Dogs to Address by Subwatershed	Potential Waste Station Sites
Headwaters	1,920	1	1,920	(Future parks in new development)
Transitional	20,400	2	6,800	Little Cypress Creek Preserve, Zube Park, Hockley Park
		3	13,600	HOA parks, Bridgeland trails, Telge Park, Budd Hattfield Park, Cypress Park, Grantwoods Park
Downstream	24,800	4	17,200	Kickerillo-Mischer Nature Preserve, Cypress Creek Greenway, Meyer Park, 100 Acre Wood Preserve
		5	7,600	Cypress Creek Greenway, Mercer Arboretum

Urban Stormwater

Stormwater runoff from populated areas with large amounts of impervious cover can contribute pollutants from a variety of sources that often reach waterways through storm sewers without filtration. While urban stormwater is not an original source, but a conveyance for sources, several solutions exist to mitigate its impacts.

The primary means for addressing these sources in most of the urban areas of the watershed are the Municipal Separate Storm Sewer System (MS4) permits through TCEQ's General Permit (TXR040000). The permits require stormwater utilities to address sources of pollutants they may discharge to impaired waterways[116]. The recommendations of this WPP are not designed to supplant

[116] More information on the permits can be found at https://www.tceq.texas.gov/permitting/stormwater.

the existing efforts of the MS4s in the watershed. It is intended to supplement those activities, which form the basis of stormwater quality management in the area[117]. The MS4s' activities are likely to have the most impact on bacteria and nutrient levels in the Downstream area. In addition to MS4 permit activities, the stakeholders recommended several additional solutions, including:

- Urban Stormwater 1 — Investigate drainage channels for illicit discharges;
- Urban Stormwater 2 — Promote and implement riparian buffers;
- Urban Stormwater 3 — Install stormwater inlet markers;
- Urban Stormwater 4 — Promote low impact development

A heavy focus of this category are education and outreach activities, as reflected in Section 6. The focus areas for implementation are the urbanized portions of the Downstream and Transitional attainment areas. These recommendations are in addition to the general recommendation by the stakeholders that infrastructure should be properly maintained. For both Urban Stormwater 1 and Urban Stormwater 2, the Partnership recommends that the investigation program and inlet installation program both include reporting of damaged infrastructure as a standard operating procedure. This will help ensure utilities or other property owners are aware of infrastructure problems and can work effectively to address them, which produces both water quality and flood mitigation benefits to the community. It should be noted that targeted monitoring that is complementary to Urban Stormwater 1 is a recommendation for the broader Bacteria Implementation Group[118] (BIG) area, and active projects are currently underway which may serve as valuable models for this watershed. All efforts under this category will be coordinated to the greatest extent possible with efforts occurring as part of the BIG.

Development of new features in existing rights of way has to be balanced against other uses for our urban corridors, including flood mitigation. Siting of riparian buffers should take this into account. Limitations on vegetation or other measures in drainage easements, or access requirements for maintenance may limit buffers in some areas, or require they be further from the channel.

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[117] No funding other than that from the MS4 permittees themselves is expected to be applied to activities specific to their permit activities. Any mention of funding sources in the solutions identified for this subsection is intended in reference to activities above and beyond permit requirements.

[118] The BIG is an ongoing TMDL effort addressing fecal indicator bacteria for a number of segments in the H-GAC region, including Cypress Creek. The WPP provides a more specific focus on Cypress Creek, and considers additional pollutants and stakeholder concerns, and makes watershed-specific recommendation, but is working in conjunction with the broader BIG effort to reduce fecal contamination in local waterways. More information can be found at https://www.h-gac.com/bacteria-implementation-group.

Urban Stormwater 1 – Investigate Drainage Channels

Purpose: To identify and reduce illicit discharges in drainage areas with high bacterial loads.

Description: This solution involves targeted reconnaissance of waterway and drainage channels by H-GAC or partner agency staff on foot to identify broken infrastructure, illicit discharges, or other pollutant sources. Illicit discharge detection is a minimum control measure for MS4 permits, but targeted reconnaissance based on "hotspots" and coordination of follow-up to anything found would be efforts above and beyond permit requirements. The models for this recommendation are similar TCEQ/Galveston Bay Estuary Program (GBEP) projects[119] identifying high bacteria load streams in the Houston urban area. This effort can be paired with monitoring activities. The more heavily modified tributaries and the main channel in denser areas would be opportune sites. Lower Little Cypress Creek prior to the confluence, Faulkey Gully, Dry Gully, Pillot Gully, and Spring Gully all receive appreciable flow from urban stormwater inputs.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; MS4s; Harris County; TCEQ	2021-2035, with a focus on 2021-2025	Bacteria, Nutrients, Sediment, Trash	New or expanded effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources include staff capacity in investigation of water and drainage channels. Enforcement data and knowledge from the county and other jurisdictions would aid in choosing sites and channels. Financial resources include costs of staff time and travel expenses. Staff time would likely be only an incremental addition above a base cost for watershed facilitation in implementation by H-GAC or another lead agency (see Section 6).	Estimated costs include an hourly cost of $40-50 for staff time and overhead. The total cost is dependent on scale of effort. A $20,000 project could fund 200-300 hours of field investigation and follow-up. Funding sources include grants (CWA §319(h), GBEP, etc.), collaborations with MS4s, or existing partner resources.

Bacteria Reduction Capability

This activity is expected to have an indirect impact on bacteria, nutrients, and sediment by identifying potential sources, which would then be referred to responsible enforcement jurisdictions.

[119] The Top 5/Least 5 project and a current targeted monitoring project are GBEP and H-GAC partnership projects to detect potential sources of contamination in highly contaminated waterways, and those close to meeting the standard. The project was successful in identifying sources for several waterways in excess of MS4 permit requirements in the area, through targeted monitoring and reconnaissance.

Urban Stormwater 2 – Promote and Implement Urban Riparian Buffers

Purpose: To reduce pollution from sheet flow by maintaining or restoring riparian buffers where appropriate.

Description: While much of the flow from urban areas enters waterways through MS4s, sheet flow from areas adjacent to the waterways can bring pollutants into the waterway over impervious surfaces. Maintaining a vegetated buffer (forest, native plantings, etc.) along waterways can slow storm flows, decrease erosion, filter pollutants, lower temperatures and increase DO, and provide other ecosystem services. When maintained in areas appropriate to drainage needs, riparian buffers are a natural, lower cost infrastructure solution. Implementation can take place on public or private land and use a mix of vegetative approaches. Urban forests and tree canopy within the watershed area can also help mitigate impacts of development. This solution is to maintain or restore areas of vegetative buffer in riparian areas and expand tree canopy in urban areas, with a focus on subwatersheds 3,4 and 5.

Responsible Parties	Period	Contaminants Addressed	Status
MS4s; Local governments; Special districts; Texas A&M Forest Service (forestry technical support); NGOs; Private landowners/businesses	2021-2035	Bacteria, Nutrients, Sediment, Trash	Expansion of ongoing efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources include staff capacity or partner support in design and installation of vegetative barriers (for restoration) or legal support for conservation easements or similar maintenance projects[120]. NGOs like Trees for Houston, American Forests, and Bayou Land Conservancy may be able to offer technical advice on riparian easement management. Financial resources vary depending on the size and type of project, but should consider ownership/acquisition costs, maintenance costs, and restoration costs. Funding sources are dependent in part on the applicant and property type. A focus of this solution is public land in the Downstream area.	Estimated costs vary greatly depending on the size and type of project. Funding sources include CWA §319(h) grants, NGO/endowment funding, TPWD grants, private land investment, or local government/MS4 funding.

Bacteria Reduction Capability

This activity is expected to have an indirect impact on bacteria, nutrients, sediment, and trash by providing filtration to sheet flow in stormwater runoff events. Filtration capacity is dependent on site-specific factors.

[120] Restoration or expansion of forested areas in and adjacent to riparian zones in urban areas should consider specific practices and resources available from the Texas Forest Service, available at https://tfsweb.tamu.edu/LandownerAssistance/

(Image courtesy Harris County)

Urban Stormwater 3 – Install Stormwater Inlet Markers

Purpose: To increase public visibility of stormwater drains as vectors for pollution.

Description: This solution involves installation of stormwater inlet markers, where appropriate for local governments, special districts, and neighborhoods. Local organizations (e.g., Harris County's Stormwater Inlet Marking program[121].) have existing programs for this purpose. This solution reflects partners intent to continue or expand programs. Inlet markers will be installed based on the requirements of the specific jurisdictions. The intent is to utilize this as a project to engage local volunteers in coordination with outreach efforts.

Responsible Parties	Period	Contaminant Addressed	Status
Harris County; Local governments; Special districts; HOAs; local volunteers	2021-2035, with a focus on 2021-2030	Bacteria, Nutrients, Sediment, Trash	New or expanded effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources include staff capacity to train volunteers and manage installation programs. This capacity already exists in the watershed. Financial resources include costs of staff time in installation or managing volunteers, and the costs of the inlet markers. Potential sources include existing programs (Harris County), local government/organization funding, CWA §319(h) grant funding, neighborhood HOA funding, or private foundation funding.	Estimated costs include the markers themselves (average of $5 or less when bought in bulk), and time in installation (which will vary dependent on whether staff or volunteers are involved). Total costs depend on the extent of the implementation. Funding sources include existing programs (Harris County provides marking kits upon request), utility revenues, or NGO partner funds.

Bacteria Reduction Capability

This activity is expected to have an indirect impact on bacteria, nutrients, and sediment by providing structural outreach to residents. No specific reduction efficiency is assumed.

[121] Harris County maintains a Stormwater Inlet Marking program. More details can be found at https://www.cleanwaterways.org/swim/.

<table>
<tr><td rowspan="3"></td><td colspan="3"><h1>Urban Stormwater 4 – Low Impact Development</h1></td></tr>
<tr><td colspan="3">Purpose: To reduce pollutants in stormwater flows through infrastructure that mimics or improves on natural hydrology.</td></tr>
<tr><td colspan="3">Description: This solution involves promoting and implementing low impact development (LID) design and green infrastructure to filter, slow, and increase infiltration of stormwater runoff. H-GAC and local partners will promote LID through model materials on our website, through coordination with local and regional LID projects, and including LID as part of broader discussions of MS4 permits and new development. Local partners may elect to use LID practices in new institutional development (government buildings, parks, etc.) Focus areas for this solution are the denser portions of the Transitional area and the Downstream area.</td></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant Addressed</th><th>Status</th></tr>
<tr><td>H-GAC; MS4s; Harris County; Local governments; Special districts</td><td>2021-2035</td><td>Bacteria, Nutrients, Sediment, Trash</td><td>New or expanded effort</td></tr>
<tr><th colspan="3">Technical and Financial Resources Needed</th><th>Estimated Costs and Funding</th></tr>
<tr><td colspan="3">Technical resources include staff capacity to facilitate discussions for promotion and staff capacity among local partners to implement LID projects.

Financial resources of promotion include costs of staff time in developing and disseminating LID materials and coordinating discussion. Financial costs of implementing include the engineering, staff, and structural costs of each project which will vary widely by type and scale.</td><td>Cost estimates for promotion are included in the general duties of a watershed coordinator, and do not represent appreciable additional costs. Costs for implementation are dependent on the projects undertaken by local partners.

Funding sources include local government revenues with potential grant supplement (CWA §319(h), etc.)</td></tr>
<tr><th colspan="4">Bacteria Reduction Capability</th></tr>
<tr><td colspan="4">This activity is expected to have a direct impact on bacteria, nutrients, sediment, and trash by providing structural barriers. However, reduction capacity is dependent on the practices used. No reduction is assumed specifically for this activity in the WPP.</td></tr>
</table>

Agricultural Operations

Agriculture is still a presence in the watershed, despite declines in recent years. Legacy agricultural areas in the Headwaters and Transitional attainment areas maintain healthy populations of livestock in addition to row crops. While modern agricultural practices are often efficient in reducing bacteria and nutrient transmission to waterways, loads from cattle, horses, sheep, and goats are still present in the watershed. Fertilizers are also a potential source of nutrient pollution, and pesticides and herbicides can impact macrobenthic communities and aquatic vegetation. The solutions identified by the Partnership focus on addressing wastes from livestock by expanding and supporting existing, successful programs by TSSWCB, USDA NRCS, and AgriLife Research and Extension in coordination with local producers and conservation efforts on agricultural lands by the Katy Prairie Conservancy and other NGOs. The intent of these solutions is to provide financial assistance or technical resources for local producers to make voluntary improvements to their property and operations. These improvements are designed to be beneficial to the producer and to water quality. These recommendations recognize the benefit well-run agricultural lands provide.

Figure 61 – Historic agriculture presence in the watershed

The solutions selected by the stakeholders include promoting and implementing voluntary, site-specific management plans for individual farms. The efforts will focus on implementing multiple BMPs where appropriate. The focus areas for these solutions are subwatersheds 1-3. Recommended solutions include:

- Agricultural Operations 1 — Develop land management plans including TSSWCB Water Quality Management Plans (WQMPs) and NRCS Conservation Plans;
- Agricultural Operations 2 — Implement other land management techniques through financial assistance and technical programs; and
- Agricultural Operations 3 — Implement Horse manure composting program.

Agricultural Operations 1 – WQMPs and Conservation Plans

Purpose: Provide technical and financial assistance to agricultural producers to plan and implement land management practices that benefit water quality.

Description: Both the NRCS and TSSWCB offer agricultural producers technical and financial assistance for "on-the-ground" implementation. To receive financial assistance from TSSWCB, the landowner must develop a Water Quality Management Plan (WQMP) with the local Soil and Water Conservation District (SWCD) that is customized to fit the needs of their operation. The NRCS offers options for development and implementation of both individual practices and whole farm conservation plans. Priority for WQMPs and other projects will be given to management practices which most effectively control bacteria contributions to the waterways, with a focus on areas adjacent to riparian corridors. Based on site-specific characteristics, plans will include one or more of the TSSWCB's approved practices[122]. Examples of these practices include but are not limited to filter strips, riparian buffers, prescribed grazing, and providing alternative shade and water. Additional information on the practices is included in Appendix C. Similarly, the USDA NRCS offers conservation planning services through its Conservation Technical Assistance (CTA) program[123] and financial assistance through its Environmental Quality Incentive Program (EQIP) and related programs. These services assist landowners to conserve resources and protect water quality by providing NRCS expertise and financial assistance. In addition to WQMPs and Conservation Plans, NRCS offers a broad range of other land and habitat management programs[124].

Continued on next page

[122] More information on the WQMP program can be found at http://www.tsswcb.texas.gov/en/wqmp.
[123] More information on the CTA and other NRCS programs can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/cp/.
[124] More information on NRCS programs can be found here: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/.

<table>
<tr><th colspan="4">Agricultural Operations 1 – WQMPs and Conservation Plans (continued)</th></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant Addressed</th><th>Status</th></tr>
<tr><td>TSSWCB; SWCDs; USDA NRCS; agricultural producers/landowners</td><td>2021-2035</td><td>Bacteria, Nutrients, Sediment, Pesticides</td><td>Ongoing and expanded effort</td></tr>
<tr><th colspan="3">Technical and Financial Resources Needed</th><th>Estimated Costs and Funding</th></tr>
<tr><td colspan="3">Technical resources required by this solution are the expertise of TSSWCB and USDA NRCS staff involved with their respective programs, and the local knowledge of the agricultural producers. Additional WQMP technician(s) may be needed to assist in plan development depending on demand. H-GAC and other partners will assist in promoting WQMPs to landowners.

Financial resources required for this solution vary based on the type and scope of plan implemented. Costs for implementing WQMPs is borne in part by the landowner, and in part by TSSWCB, with up to $15,000 in financial assistance available for qualified WQMPs. Sources of funding for these costs include agricultural producer contributions and TSSWCB allocated funds. Resources for NRCS conservation plans and financial assistance programs include NRCS staff time and related costs, funding from EQIP and other programs, and contribution from the landowner. The funding for these costs is expected to come directly from the respective parties. WQMPs or other plans addressing an average of 50 livestock units will need to be implemented (Table 36).</td><td>Estimated costs for WQMPs include up to $15,000 per WQMP in financial incentives[125], with the landowner share of costs being variable. NRCS Conservation Plan costs are estimated at $2,000-$3,000 in NRCS staff time , with landowner costs being variable.

Funding sources include existing programs (TSSWCB, USDA NRCS) and landowner funding.</td></tr>
<tr><th colspan="4">Bacteria Reduction Capability</th></tr>
<tr><td colspan="4">This solution’s bacteria reduction capacity assumes a direct reduction of bacteria loading from lands covered by a WQMP/etc. The specific mix of efforts under a given project may affect the overall efficiency, in conjunction with the nature and location of the property.</td></tr>
</table>

[125] This cost estimate assumes: 1) the maximum cost per WQMP for all WQMPs; 2) that all agricultural operation solutions are handled solely by WQMPs; and 3) that the average size of the existing WQMPs remains standard for future WQMPs.

Due to the nature of nonpoint source pollution and differing needs of individual properties, a combination of agricultural best practices is commonly required to address bacteria loading from agricultural operations. Selection of practices for WQMPs or similar efforts is site specific and tailored to address the physical and operational characteristics of the property. Therefore, it is not feasible to attempt to quantify individual practices implemented across all plans prior to WQMP development.

To optimize the water quality benefits of plan development and implementation, management practices which most effectively control bacteria and nutrients from livestock, and which are near waterways, will be promoted and given top priority. It must also be stressed that WQMP development and subsequent implementation can only be realized with cooperation and discretion of the individual landowner. Subject to the needs of the site, plans may include one or more of the management practices detailed in Appendix C.

Agricultural areas in the watershed provide a flood mitigation benefit in addition to providing open space and maintaining rural character. To the greatest extent possible, this WPP will focus on coordinating efforts between agricultural agencies and flood management efforts to maximize these benefits when appropriate.

Additional elements regarding conservation of rural properties are discussed later in this section under Conservation and Land Management.

Figure 62 - Managing access to waterways

Agricultural Operations 2 – Maintain or Restore Riparian Buffers

Purpose: To reduce transmission of pollutants by slowing and filtering runoff from agricultural areas.

Description: Vegetative buffers (including filter strips and riparian forests) in areas adjacent to waterways are an effective means of reducing the transmission in runoff of wastes, organic materials, and nutrients from agricultural operations. This solution would seek to promote and implement voluntary landowner and public entity land management to increase the existing healthy riparian buffers of the watershed.

In addition to WQMPs and conservation plans, potential methods of implementation include utilizing conservation easements held by land trusts; voluntary individual landowner implementation; or as part of an NRCS Farm Bill program (e.g., EQIP or similar). Priorities for this solution are maintaining and expanding buffers in subwatersheds 1, 2, and 3 (Headwaters and Transitional areas).

Responsible Parties	Period	Contaminant Addressed	Status
Landowners/producers (on a voluntary basis); NGOs; Agricultural agencies	2021-2035	Bacteria, Nutrients, organic wastes, pesticides	Expanded existing efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resource needs include staff capacity at support agencies to provide technical services and knowledge to landowners. Funding resources for this solution are projected to be a mix of landowner costs (including opportunity costs of acreage removed from production and actual costs of installation and/or maintenance); funding under applicable financial incentive programs (WQMP; NRCS Farm Bill programs); and existing staff capacity among support agencies in staff time and travel costs. If used in conjunction with conservation easements, legal and staff costs include establishing and maintaining the easement, potentially through conservation NGOs.	Cost estimates are variable with type and extent of buffer. Costs may be limited to simply not mowing an area (opportunity cost of productive acreage) to restoration/plantings. Funding sources include established programs and property owner contributions

Bacteria Reduction Capability

Efficiency will vary based on the extent and size of the barrier and its composition. Reduction estimates for fecal bacteria range from 50%[126] to 95%[127].

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[126] Rifai, H. 2006. Study on the Effectiveness of BMPs to Control Bacteria Loads. Prepared by University of Houston for TCEQ as Final Quarterly Report No. 1.

[127] Larsen, R.E., R.J. Miner, J.C. Buckhouse and J.A. Moore. 1994. Water Quality Benefits of Having Cattle Manure Deposited Away from Streams. Biosource Technology Vol. 48 pp 113-118.

Agricultural Operations 3 – Implement Horse Manure Composting Program

Purpose: To reduce transmission of wastes from non-agricultural horses through collection and composting of wastes.

Description: Recreational horse (i.e. horses not attached to an agricultural operation) ownership is prevalent and increasing in the watershed, with several large stabling operations in the watershed. Horse manure is well suited for composting[128] under correct conditions. The Partnership will work with local government, stabling operations, and commercial partners to implement a horse manure composting program to reduce manure piles at existing operations and potentially produce a viable commodity[129] or resource to defray program costs. This will involve a mix of centralized, collected compost and composting sites at individual operations. This solution is focused on large stabling operations throughout the watershed.

Responsible Parties	Period	Contaminant Addressed	Status
Horse owners; Stabling operations; Counties; Local governments; NGOs (potentially)	2021-2035	Bacteria, Nutrients	New effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical expertise required includes staff capacity of local partners to develop and maintain a composting program and logistics and assist sites with developing composting infrastructure and operations. Potential technical support could be obtained from Texas A&M AgriLife Extension or other partner programs. Financial resources needed will depend on the nature of the final program elements. Estimates for built facilities for a single site vary widely from hundreds of dollars for simple pile systems[130] to tens of thousands for more complicated building structures. Funding for individual site systems may be available from agricultural agencies. A commercial venture with a private or NGO partner may not require additional funding if it utilizes existing capacity.	Costs estimates assume existing staff capacity (at $40-$50 total hourly cost per employee) and resources (vehicles). Funding sources include local government revenue and manure compost sales.

Bacteria Reduction Capability
Efficiency will vary based on the extent of operations. Removal of unmanaged manure is assumed at 100% reduction. Effectiveness may benefit from voluntary audits of facilities to identify priority operations.

[128] Additional information about methods and uses can be found at https://agrilifeextension.tamu.edu/library/ranching/composting-horse-manure/.

[129] A variety of estimates on the marketability of composted manure exist. An example is the discussion of value and logistics found in industry publication *Stable Management* at https://stablemanagement.com/articles/making-money-on-manure#:~:text=Automated%20Composting&text=This%20greatly%20reduces%20the%20labor,time%20with%20Moon%20as%20needed.

[130] An example of a low cost aerobic pile system for a single site can be found here: https://ag.umass.edu/sites/ag.umass.edu/files/fact-sheets/pdf/low_cost_equine_manure_composting_16_01.pdf

Feral Hogs, Deer and Other Wildlife

Feral hogs are a potential source of bacteria in watersheds, especially those with large rural areas. Within this general category of wildlife and non-domestic animals, feral hogs are the primary focus of this WPP because of their relatively high bacteria concentration, the other damages they create, and the availability of feasible solutions to address them[131]. Other animals included in this WPP's estimates of loading for Deer and Other Wildlife sources are not intended to be addressed specifically by this WPP, primarily for lack of effective solutions and stakeholder preference in addressing other sources.

There are ongoing discussions at the state and national level about alternative means (chemical controls, etc.) to address feral hogs. The recommendations of this WPP focus on solutions within the scope of local implementation, and already known to be best practices. The focus of implementation for the feral hog solution will be in agricultural and open space areas in which feral hog damage is a potent incentive for landowner participation. Reduction from feral hogs is expected to derive directly from landowner efforts, as supported by partner agencies through information and technical services, although the Partnership recommends that local and state governments consider active involvement in feral hog reduction efforts.

While the WPP does not specifically seek to address deer and other wildlife, the stakeholders considered the benefit of providing alternative habitat away from riparian areas to reduce population densities and time spent near waterways. The wildlife solution presented here represents that indirect focus.

The focus areas for these solutions in general are subwatersheds 1-3 in the Headwaters and Transitional areas, and wherever localized hog problems or conservation opportunities may exist in the watershed. To one degree or another, hog, deer, and other wildlife populations are found throughout the project area.

The solutions selected for feral hogs, deer, and other wildlife include:

- Feral Hogs 1 — Remove Feral Hogs
- Wildlife 1 — Restore Upland Habitat

The Partnership's approach to the feral hog, deer and other wildlife source category includes a strong corresponding focus on education and outreach recommendations, as detailed in Section 6.

[131] Contributions from deer were also modeled, but the Partnership does not recommend direct solutions for deer due to a lack of feasible solutions or means to achieve them.

Feral Hogs 1 – Remove Feral Hogs

Purpose: To encourage landowners and local governments to directly reduce feral hog populations through trapping and hunting.

Description: This solution seeks to reduce feral hog populations in the watershed through active hunting and trapping. The primary focus of this effort is voluntary efforts from individual landowners, but the Partnership recommends abatement activities on behalf of local governments, as appropriate.

Responsible Parties	Period	Contaminant Addressed	Status
Landowners; Local governments; Special districts; Agricultural agencies (technical support)	2021-2035	Bacteria, Nutrients, Sediment	Expansion of existing efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources needed for this solution are advice and support for landowners engaged in feral hog abatement, and technical knowledge on behalf of the landowners themselves. The primary agency providing technical support on feral hog issues is Texas A&M AgriLife Extension. Financial resources of this project include the staff time and related costs of the partner agencies, and the cost of implementing solutions borne primarily by the landowners on a voluntary basis. No grant funds have been identified to supplement these contributions. Potential other resources include leasing property to hog hunting at a potential net gain of costs.	Costs estimates for an estimated 93 to reduce, assumption each trap would serve to reduce five hogs, 19 traps would be needed as a starting point. With an average cost of $1,000 for a medium sized trap, this would represent an annual cost of $19,000[132], not inclusive of staff/landowner time. Funding sources include local government and property owners. No specific grant resources were identified for this solution.

Bacteria Reduction Capability

This solution nominally reduces feral hog waste by a maximum daily *E. coil* load of 4.45E+9 for each hog reduced, representing a 100% efficiency. However, this may not account for the volatility of hog population dynamics in which lost members may be replaced through reproduction in excess of population maintenance and does not consider SELECT spatial discounting of source load contributions.

[132] The solution covers a range of practices from hunting to trapping. Assumptions of trap usefulness and costs are based on stakeholder feedback on success rates, and review of varying trap options and pricing. Single animal small box traps from $400 to automated drop corral traps at $4000-$5000. Costs do not include time, feed, and other elements. The estimate given should be considered conservative due to the capability of feral hog populations to breed rapidly up to (or beyond) the carrying capacity of the areas they inhabit. Rates of removal below 75% are not likely to have a net reduction of feral hog populations.

Wildlife 1 – Conserve or Restore Upland Habitat

Purpose: To encourage landowners, NGOs, and local governments to conserve and restore upland habitat to relieve wildlife pressures on riparian areas.

Description: This solution seeks to encourage voluntary conservation and restoration of upland habitat away from riparian areas. This solution is intended to coordinate directly with the Conservation and Land Management solutions found later in this section, and will be based on the same approaches, partners, and technical/financial needs.

Responsible Parties	Period	Contaminant Addressed	Status
Landowners; NGOs; Local governments; Agricultural agencies (technical support); Developers	2021-2035	Bacteria, Nutrients, Sediment, Flooding	Expansion of existing efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
The primary technical resources needed for this solution are staff capacity for pursuing and implementing voluntary conservation projects or ecosystem restoration. Potential technical resources include existing NGOs in the watershed (e.g., Katy Prairie Conservancy, Bayou Land Conservancy), agricultural agencies, and local governmental staff (e.g., County precincts already involved in habitat conservation in parks and public areas like Harris County Precinct 4's Kickerillo-Mischer Preserve). Financial resources needed are dependent on the scale. Costs may be limited to opportunity costs of unrealized development potential (conservation) or costs associated with physical remediation of property (restoration). Existing efforts in the watershed (e.g., Katy Prairie Conservancy properties) provide a basis for estimating costs of restoration activities specific to the western watershed land cover types. New development is an opportunity to increase set asides.	Cost estimates vary based on scale and type of conservation or restoration and area Funding sources include agricultural agencies (e.g., USDA NRCS Farm Bill programs), other grants, and local governmental or NGO funding (including private donation and in-kind donation of land value from property owners).

Bacteria Reduction Capability

This solution is not intended to directly impact sources, but is expected to generally reduce feral hog, deer, and other wildlife time in riparian areas by providing alternative range. Due to the wide variety of species this may impact, and the potential variety of lands involved, no specific reduction potential can be generated. However, this solution is modeled after existing agricultural best practices designed to reduce cattle time adjacent to streams by providing alternative water/shade. It will contribute to the general reduction of these sources.

Other Concerns

In addition to the practices recommended for specific sources in the preceding pages, the Partnership recommends several solutions to other local concerns. The recommendations fall into three primary categories:

- Conservation and Land Management
  - Conservation and Land Management 1 — Riparian buffers
  - Conservation and Land Management 2 — Voluntary conservation
  - Conservation and Land Management 3 — Increase Tree Canopy
- Trash/Illegal Dumping
  - Illegal Dumping 1 — Report Chronic Dump Sites and Consider Increased Enforcement
- Flooding
  - Flooding 1 — Coordinate with Ongoing Flood Mitigation Efforts

Conservation and land management activities relate to conserving or developing natural barriers to pollutants entering the water body. These solutions are approached on a voluntary basis. Prioritization is placed on areas adjacent to riparian corridors in the Headwaters and Transitional areas of the watershed but may include open space areas in the watershed in general and may be appropriate for restoration activities in more developed areas (e.g., increasing tree canopy or restoring riparian vegetation). Conservation practices recommended by this WPP are wholly limited to voluntary landowner decisions supported by resources from local government, landowners, and conservation NGOs (e.g., Katy Prairie Conservancy and Bayou Land Conservancy), and the Partnership. This WPP makes no recommendations concerning recreational trails or development; its sole focus in this category is improving water quality by maintaining or restoring ecosystem services from conserved land. The stakeholders placed a strong emphasis on the multiple values of prairie areas and trees. A variety of successful, model conservation activities exist in the watershed.

Trash and illegal dumping are a visible impact on local waterways and were a secondary focus of the Partnership. The WPP's role in trash reduction is primarily in support of the efforts of other agencies or efforts (e.g. local MS4s as part of TPDES permit activities). Illegal dumping is the primary focus for the Partnership under this category.

Flooding is an ever-present concern for Cypress Creek communities and is the focus of several large-scale study and remediation efforts. The focus of this WPP will be to coordinate with and support the advancement of flood mitigation activities, with an eye toward advocating for inclusion of water quality features.

These recommendations are supplementary to ongoing efforts by the area's local governments, organizations, and MS4s relating to these issues.

Conservation and Land Management 1 – Riparian Buffers

Purpose: To reduce transmission of bacteria, nutrients, trash, and sediment to waterways by maintaining or implementing vegetated buffers in riparian corridors.

Description: This solution is supplementary to Agricultural Operations 2 – Maintain and Restore Riparian Buffers and Urban Stormwater 2 – Promote and Implement Urban Riparian Buffers, with a focus on non-agricultural areas.

This solution would engage local landowners and local governments to install and/or maintain vegetative buffers along waterways and drainage channels (as appropriate based on drainage needs). Implementation will differ widely in type and scale. Support for these efforts will be provided for residents by the same agencies and partners indicated in the urban and agricultural versions of this solution. This solution focuses specifically on current and new developments in the Transitional and Headwaters areas.

Responsible Parties	Period	Contaminant Addressed	Status
Dependent on location but may include Counties; Local Government; Special districts; Agricultural agencies; NGOs; Developers; Private landowners; commercial properties	Ongoing, with focus on 2021-2025 to prevent degradation	Bacteria, Nutrients, Sediment, Flooding	Expanded efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources needed for this solution include the existing programmatic resources and staff expertise of the partners identified above, which are considered sufficient to meet this need. Financial resources needed for this solution include the staff resources and landowner contributions previously detailed for the other versions of this solution. Other costs include opportunity costs related to lost property value.	Cost estimates are variable depending on type, size, and location of buffer. Savings in maintenance (mowing, etc.) may counter some potential costs. H-GAC offers a riparian buffer planning tool for landowners to estimate potential costs[133]. Funding sources include local government revenues (public buffers), landowner funding, or NGO/local partner funding.

Bacteria Reduction Capability

This solution's efficiency will vary greatly based on the type, and extent of riparian buffer and local area. Nutrient/sediment removal may be a greater benefit than bacteria removal based on existing literature. However, some literature values indicate fecal bacteria removal rates more than 80-90%[134].

[133] Available at http://www.h-gac.com/riparian-buffer-tool/default.aspx

[134] See references under Agricultural Operations 2

<table>
<tr><td rowspan="3"></td><td colspan="3">

Conservation and Land Management 2 – Voluntary Conservation

</td></tr>
<tr><td colspan="3">Purpose: To reduce transmission of bacteria, nutrients, trash, and sediment to waterways through voluntary land conservation.</td></tr>
<tr><td colspan="3">Description: This solution is intended to represent the range of efforts and need for increased voluntary conservation projects as a mitigating factor for changing land use. This solution has three primary facets:
• Individual conservation — voluntary efforts by local landowners (including commercial properties) to manage property to maintain natural value, alone or with other entities;
• Organizational projects — projects by the local governments, special districts, and NGOs in the watershed to implement voluntary conservation projects;
• Developer-driven projects — projects or supplemental elements in new development that maintain or restore natural function or mitigate impacts.

The primary focus of this solution is the Headwaters and Transitional areas, especially in riparian corridors and projects like the Cypress Creek Greenway.</td></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant Addressed</th><th>Status</th></tr>
<tr><td>Dependent on location but may include Counties; Local Government; Special districts; Agricultural agencies; NGO; Developers; Private landowners; Commercial properties</td><td>2021-2035, with a focus on 2021-2030</td><td>Bacteria, Nutrients, Sediment, Flooding</td><td>Expanded efforts</td></tr>
<tr><td colspan="4">Continued on next page</td></tr>
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Conservation and Land Management 2 – Voluntary Conservation, Continued	
Technical and Financial Resources Needed	**Estimated Costs and Funding**
Technical resources needed for this solution include the existing programmatic resources and staff expertise of the partners identified above, which are considered sufficient to meet this need. Financial resources needed for this solution include the staff resources or individual landowner resources to develop and maintain conservation easements or conservation lands, including staff time, easement or land acquisition costs, and ongoing maintenance funding.	Cost estimates are variable depending on type, size, and location of properties. Tax savings may offset potential lost land value in easements. Funding sources include existing project funding[135], new grant sources; developer funding or in-kind value for land set-asides or remediation; and additional investment by public and private partners.
Bacteria Reduction Capability	
This solution's efficiency will vary greatly based on the type, and extent of conserved lands. No specific reduction efficiency is assumed. Reduction is based on the difference between transmission rates of developed land uses and natural land uses. The value of the land conserved and the potential alternative use for the land (suburban development, etc.) determine the difference in potential transmission.	

The watershed has extensive existing conservation activity, with the Katy Prairie Conservancy maintaining large preserves in the Headwaters area, local governments like Harris County who have done extensive work on public lands adjacent to the riparian, and a network of other NGOs and local partners. Ongoing efforts by these and other partners form the backbone of conservation efforts in the watershed and are an important aspect of water quality and flood mitigation efforts.

Developers in the watershed stand to play a large role in the future use of natural systems for water quality and flood mitigation. Specific focuses of these voluntary conservation measures include developing wetland areas in wet or dry detention facilities or including wetland plantings in floodplain mitigation ponds along the corridor. Wetland areas in detention or mitigation facilities can add water quality improvement using existing infrastructure. In large master-planned communities, the ability or desire to use floodplain mitigation ponds as wetland structures would add appreciable water quality benefit without requiring additional land. The Partnership recommends continued exploration with public and private partners into opportunities to expand required elements with voluntary, incremental improvements that benefit water quality. These recommendations are also relevant for the Urban Stormwater 4 – Promote Low impact Development recommendation to the extent existing facilities in developed areas can add natural elements.

135 Projects of note in the watershed include the Harris County Precincts 3 and 4 Cypress Creek Greenway project; existing conservation efforts by prominent NGOs (Katy Prairie Conservancy and Bayou Land Conservancy), and current partnership opportunities being sought with USDA NRCS and other federal funding sources, including a Katy Prairie Conservancy proposal for a Regional Conservation Partnership Program (RCPP) funding allocation for a Coastal Prairie Initiative that could include portions of the watershed area in both counties.

Conservation and Land Management 3 – Increase Tree Canopy

Purpose: To reduce transmission of bacteria, nutrients, trash, and sediment to waterways by increasing trees in the watershed.

Description: Trees and tree canopy provide a highly beneficial set of ecosystem services, including increased flood retention and interception by canopy, improvements to air and water quality, decreased heat impacts to waterways, decreased erosion, etc. There are a variety of efforts underway in the region to increase the use of trees as natural infrastructure for water quantity and quality.

Stakeholders coordinated with Texas A&M Forest Service and other forestry programs to identify adjacent efforts and practices that would address fecal waste and other concerns. Based on preliminary i-Tree Hydro modeling by Texas A&M Forest Service[136], increasing the number of trees and canopy in the watershed would have appreciable impact on stormwater and associated pollutants, especially in developed portions of the Downstream and Transitional areas of the watershed.

This solution will include Partnership support for existing forestry efforts by City of Houston, Harris County and Harris Country Flood Control District, Waller County, the Katy Prairie Conservancy and the Bayou Land Conservancy, and agricultural/silvicultural agencies; and seek to supplement them with additional support in identifying funding, promoting urban forestry to local partners, and partnering on tree planting events where appropriate. A key focus will be coordinating with new development to promote increased tree canopy where appropriate.

Responsible Parties	Period	Contaminant Addressed	Status
Counties; Local Government; Special districts; Agricultural agencies; NGOs; Developers; Private landowners; commercial properties	Ongoing, with focus on 2021-2025 to prevent degradation	Bacteria, Nutrients, Sediment, Flooding	Expanded efforts

Continued on next page

[136] Texas A&M Forest Service project liaison Mac Martin worked with H-GAC project staff to provide modeling information on the impact of increased tree canopy and numbers in various areas of the watershed. The purpose of this modeling effort was to provide their technical support in identifying priorities and potential impacts of tree plantings as a land management best practice. The modeling was done with i-Tree, wholly by Texas A&M staff and therefore was not covered under this project's QAPP. The data from this model is not being used to develop reduction goals or removal assumptions as it was not quality assured by this project. However, i-Tree is an established forestry modeling package, and the results are valuable information for potential implementation of this solution.

Conservation and Land Management 3 – Increase Tree Canopy, Continued	
Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources needed for this solution include the existing programmatic resources and staff expertise of the partners identified above. Additional i-Tree modeling may be used to further refine benefits of tree canopy increases at varying locations or percentage increases in canopy. The Partnership will rely on Texas A&M Forest Service, local NGOs, USDA NRCS, and other subject experts for identifying opportunities and potential funding sources. The Partnership will seek to coordinate with existing large-scale planting programs and flood mitigation efforts, including those of the Harris County Flood Control District to take advantage of existing organizational capacity. Financial resources needed for this solution include the staff resources to manage tree plantings or restoration projects, and the physical costs of the materials for these efforts.	Cost estimates are variable depending on the type and size of forestry practice implemented. Tree costs vary greatly by size, with stock material and labor for a single planting of a 5-gallon tree potentially costing $100 for a small-scale effort, with a large economy of scale for greater efforts that involve cost saving measures like volunteers and corporate donations. Funding resources include a wide variety of grant resources including existing operating resources of flood control entities, forestry agencies, and other technical experts. Potential funding sources should consider the related flood mitigation impacts and associated funding sources that may be available.
Bacteria Reduction Capability	
This solution's efficiency will vary greatly based on the type, and extent of tree planting or restoration practice, its proximity to the riparian areas of the watershed, and the nature of the surrounding land use. Nutrient/sediment removal may be a greater benefit than bacteria removal based on existing literature regarding riparian buffers and tree benefits in general. However, as nonpoint sources are a leading cause of *E. coli* loads in the watershed, and tree benefits include stormwater flow reductions, additional trees should provide a benefit.	

Urban and other forestry practices discussed in this solution and emphasized by the stakeholders produce water quality improvements as a primary benefit. The connection between hydrological and community benefits and water quality benefits highlights the need to coordinate between water quality and adjacent efforts in this watershed. Significant resources and technical expertise exist in forestry and flood management spheres within the watershed, including Texas A&M Forest Service staff and regional forestry efforts. The WPP development process relied heavily on members of these practice areas to guide assumptions about future coordination and best practices and will continue to do so through implementation. The chance to coordinate with larger regional efforts will be key to this recommendation for Cypress Creek. In addition to existing work by Harris County and other partners, the City of Houston's Resilient Houston plan goal of 4.6 million new area trees will likely include large-scale plantings along Cypress Creek by public, NGO, and private partners.

Illegal Dumping 1 – Report Chronic Dump Sites and Consider Increased Enforcement

Purpose: To reduce trash in waterways at chronic dump sites by encouraging reporting and increased enforcement.

Description: This solution is intended to augment existing County and local efforts to reduce illegal dumping by:

- Encouraging reporting (see Section 6 for outreach elements)
- Coordinating between the Partnership and local enforcement to ensure reporting for sites; and
- Consider using cameras to identify dumpers[137].

The solution targets the Transitional and Headwaters area, where problem areas were identified by the stakeholders (including the site on Longenbaugh Road shown to the left). The primary focus of this solution is chronic dump sites, with emphasis on those adjacent to or near waterways.

Responsible Parties	Period	Contaminant Addressed	Status
H-GAC; Counties; Local governments; Residents	2021-2035	Trash	New and expanded efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources needed for this solution are local enforcement capacity, especially through the counties, to respond to reports and enforce violations. Enforcement capacity already exists in the watershed. Technical resources for potential camera-based enforcement would require staff capacity to install, operate and maintain the cameras. The camera systems are relatively simple to install and operate and are assumed to be within existing staffing capacity. Financial resources needed for this solution include staff time for local enforcement (variable) and costs of camera technology, which may be eligible for existing solid waste grant programs through H-GAC and other sources.	Cost estimates include the incremental costs to local enforcement, which will be dependent on extent of use; Prior camera programs have spent approximately \$500- \$1,000 a unit for high end equipment and maintenance. Funding sources include local government revenues and solid waste grant programs.

Bacteria Reduction Capability

This solution is not expected to directly address bacteria, although it may be an ancillary benefit.

[137] While not currently funded, H-GAC and other local partners have successfully utilized camera systems for illegal dumping curtailment in the past. The relatively low cost of camera systems provides an efficient way to monitor problem areas.

Flooding 1 – Coordinate with Ongoing Flood Mitigation Efforts

Purpose: To promote water quality elements in flood mitigation projects and share resources among adjacent efforts.

Description: Flooding is a persistent and high-profile issue in the Cypress Creek Watershed. In addition to area-wide studies by the USACE and Harris County Flood Control District[138] and local organizations like the Cypress Creek Flood Control Coalition (CCFCC), there are several large-scale flood mitigation projects underway, including projects from the Harris County Flood Control District's 2018 Bond Program[139] and the Little Cypress Frontier program[140].

This solution focuses on areas where flood planning and projects are active and seeks to coordinate WPP efforts with flood mitigation efforts, including the promotion of water quality elements or considerations in these projects. The recent acquisition of the former Raveneaux golf course property[141] to develop as a mixed-use detention site in the watershed is a specific current opportunity for consideration of water quality elements.

The Partnership will seek to coordinate with new development on water quality features for drainage and detention, as appropriate.

Responsible Parties	Period	Contaminant Addressed	Status
Harris County Flood Control District; Special districts; Local governments; Counties; NGOs	2021-2035, Ongoing	Bacteria, Nutrients, Sediment, Flooding	Current and expanded efforts

Continued on next Page

[138] Including the Buffalo Bayou and Tributaries Resiliency Study, which examines the overflow of floodwaters from upper Cypress Creek into the Buffalo Bayou/Addicks Reservoir System and the San Jacinto Regional Watershed Master Drainage Plan. More information on these efforts can be found at https://www.swg.usace.army.mil/Portals/26/BBTnT_Interim_Report_202001001_Final_1.pdf and https://sanjacstudy.org/, respectively.

[139] The updated status of projects under the 2018 Bond Program can be found at https://www.harriscountyfemt.org/cb.

[140] More information on the Frontier program to coordinate detention from new development in the Little Cypress portion of the watershed can be found at https://www.hcfcd.org/Find-Your-Watershed/Little-Cypress-Creek/F-26-Little-Cypress-Creek-Frontier-Program.

[141] More information about this site and potential plans that may impact water quality can be found at https://www.hcfcd.org/Find-Your-Watershed/Cypress-Creek/Champions-Stormwater-Detention-Basin-K500-24-00.

Flooding 1 – Coordinate with Ongoing Flood Mitigation Efforts - Continued	
Technical and Financial Resources Needed	**Estimated Costs and Funding**
Technical resources needed for this solution are primarily found on the flood mitigation entities' side, with the primary WPP role being to coordinate water quality efforts with their work. Continued facilitation of the Partnership would help provide those technical skills, but local technical partners like the CCFCC are already actively engaged in these projects. Other potential points of coordination include the Regional Flood Mitigation Committee[142], and the newly formed San Jacinto River Regional Flood Planning Group. Financial resources needed for the Partnership's role are primarily staff time for coordination.	Costs estimates are limited to staff time, scaled as necessary to coordinate effectively with the intended efforts. This is conservatively estimated at approximately 10-20 staff hours per year. Funding sources include new grants for WPP implementation (CWA §319(h), etc.) or local partner contributions.
Bacteria Reduction Capability	
This solution is expected to directly and indirectly address fecal waste and other water quality concerns, although it may be a wholly ancillary benefit. Rates of reduction from detention facilities and other flood mitigation projects will vary widely based on the project type. However, several studies[143] have shown appreciable impacts of wet bottom detention and other mitigation practices that incorporate natural infrastructure of natural elements on nutrients and, to a lesser degree, *E. coli*.	

H-GAC and other local partners have an active role in both water quality and flood mitigation programs and will continue to seek opportunities to represent water quality concerns in efforts to curb flooding. The Partnership will specifically seek to identify funding opportunities under several of the large disaster mitigation resources available currently and for the short term, including:

- Community Development Block Grant – Mitigation funding opportunities related to 2015, 2016, and Hurricane Harvey competitions;
- Texas Water Development Board Flood Infrastructure Fund;
- Various FEMA disaster mitigation programs.

[142] http://www.h-gac.com/board-of-directors/advisory-committees/regional-flood-management-committee/default.aspx

[143] Including studies from North Carolina (http://lshs.tamu.edu/docs/lshs/end-notes/indicator%20bacteria%20removal%20in%20stormwater%20bmps%20in%20charlotte,%20nc-3678140698/indicator%20bacteria%20removal%20in%20stormwater%20bmps%20in%20charlotte,%20nc.pdf), and Virginia (Clary, J., R. Pitt, and B. Steets, eds. 2014. Pathogens in Urban Stormwater Systems. Reston, VA: ASCE. 289 pp.), among others.

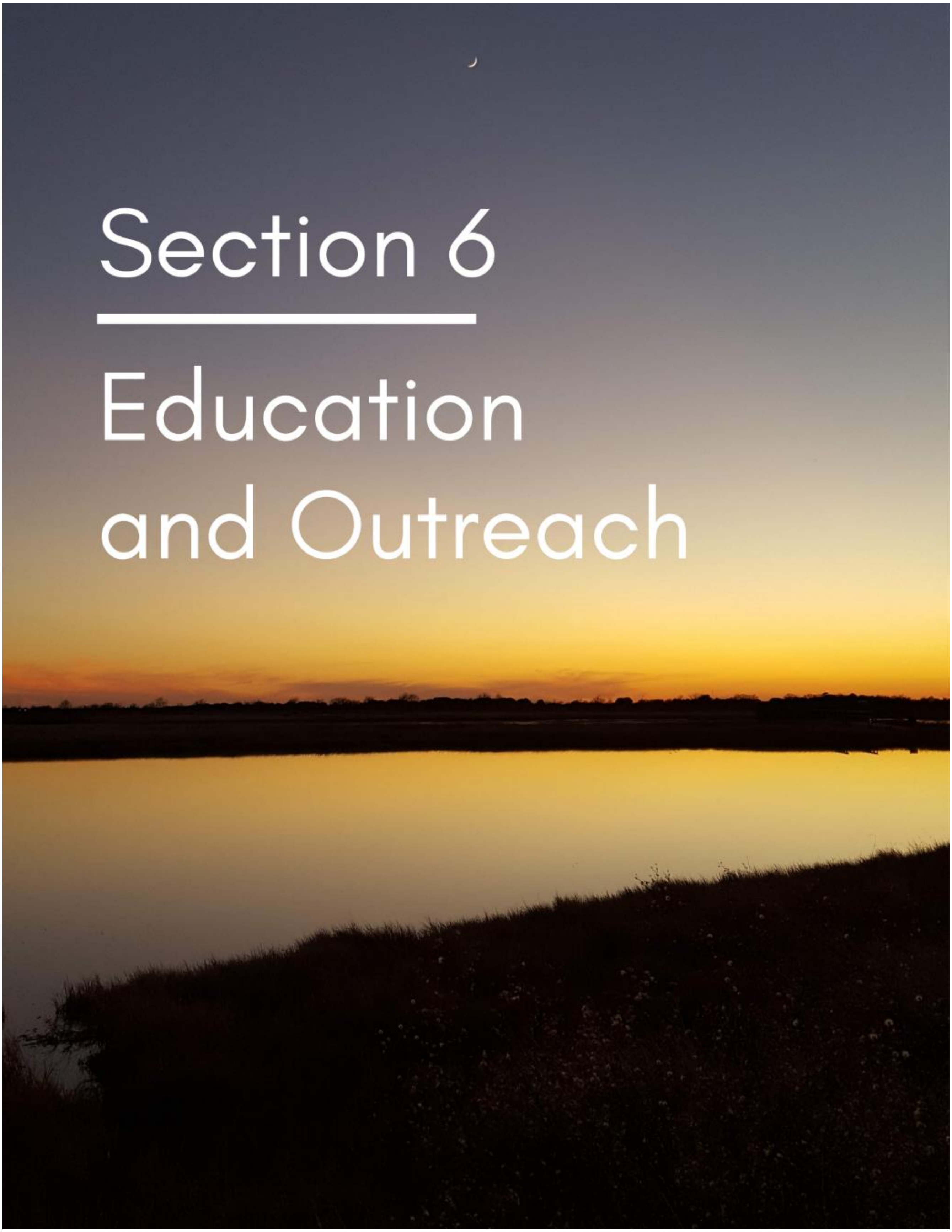
Solutions Summary

The recommended solutions presented in this section are intended to meet the *E. coli* reduction goals defined in Section 5 and to also reduce nutrient sources, or to address other local water quality concerns not specifically related to the primary pollutants. The solutions represent a variety of options for each primary source, that will be scaled to address the number of representative units identified for each source, in each attainment area.

These recommendations were developed and vetted by a diverse stakeholder group as part of a locally led decision-making process. However, the WPP recognizes that additional efforts are ongoing in the watershed that will be complementary to the recommended solutions. These recommendations are not intended to be exclusive of other potential stakeholder projects and efforts that serve the same goals. They represent areas of overlapping concern and agreement among the various interests of the Partnership. It is expected that the toolbox of solutions will change over time as part of local priorities and the adaptive management process.

Further efforts to engage and educate the public are reflected in Section 6, and specifics about the timelines and logistics of implementation are discussed in Section 7.

Figure 63 – Conserved lands in the Little Cypress Creek Preserve


Section 6
Education
and Outreach

6 – Education and Outreach

Engaging both the general public, key project partners, and specific targeted audiences is a crucial component of ensuring the success of the WPP. This section outlines the various educational programs, outreach efforts, and related strategies the Partnership will use to support the implementation of this WPP. The purpose of these efforts is to ensure ongoing stakeholder involvement in the effort as well as to increase public awareness of the water quality issues faced by their community. The recommended engagement elements are presented by the solution category they support.

Engagement Strategies

In keeping with the water quality goals and guiding principles of this WPP, the strategies for engaging with the public are designed to reflect the specific character and needs of the local communities. These strategies provide general guidance for the implementation of the activities discussed in this section.

- Strategy 1: Facilitation — To ensure the continuity of the effort and a consistent point of coordination, a designated facilitator(s) will oversee the early implementation of the WPP (see General Outreach below).
- Strategy 2: Existing Resources — To maximize the use of resources and effectively reach existing stakeholder bases, the Partnership will endeavor to use existing communication networks and work within existing outreach opportunities and partners as one of the tools to further project goals.
- Strategy 3: Audience-specific messaging — While some outreach is aimed at a broad base of potential stakeholders, the Partnership will focus on making sure its message for individual groups, communities, etc. is tailored to the specific needs and concerns of that group. The underlying assumption in this strategy is that messages are best received when they have an overlapping nexus of value with the audience. A key focus in the watershed is emphasizing the WPP's respect for private property and voluntary solutions.
- Strategy 4: Adjacent Efforts — The density of other efforts planned or ongoing in the watershed provides a wealth of opportunities to build connections and benefit from shared resources with adjacent efforts from practice areas like forestry, flood mitigation, and conservation. As with the implementation of solutions, public engagement efforts will seek to build on work of adjacent programs wherever appropriate and seek to cross-promote water quality messages with communication networks of other practice areas.

Figure 64 - Outreach at local events

General Outreach

The Partnership is one of many organizations working toward similar goals in the watershed but is the primary focal point for the specific aims of the WPP. A fundamental aspect of ensuring implementation success and community support is to promote public awareness and interest in the watershed and the WPP. To accomplish this goal, the Partnership must maintain itself as an active organization, continue to build its "brand" among the public, represent the watershed among regional and state organizations, and seek to coordinate with related efforts to the greatest degree possible. The Partnership will not seek to supplant existing efforts, but to support them however possible and seek to find opportunities to expand or enhance links to water quality and the goals of the WPP.

Maintaining the Partnership

The Partnership will seek to maintain its varied composition and strong local commitments through continued facilitation of an active group by H-GAC and TCEQ. The importance of this effort is to continue the use of the Partnership as a platform for coordination of watershed efforts. Meeting this goal will require:

- Periodic meetings of the Partnership (at least twice a year)
- Dissemination of information regarding WPP activities among stakeholders through e-mail and/or newsletters or other appropriate medium (e.g., social media).
- Individual meetings with strategic partners to maintain commitments and coordinate efforts

Building the Brand

The Partnership must maintain a visible representation of its specific goals in the eyes of the public. To accomplish this goal, the Partnership will:

- Maintain a presence at local events and meetings that includes information on the Partnership, the WPP, and their goals.
- Maintain and expand the Texas Stream Team monitoring sites and trainings.
- Continue to maintain the project website and social media.
- Actively support local partners.
- Seek to build relationships with adjacent practice areas of forestry, conservation, and flood mitigation.

Coordination

The Partnership is one of many watershed-based groups in the area, state, and nation. Finite resources and overlapping areas of interest make coordination of partner efforts a vital part of the WPP's role. To accomplish this goal, the Partnership will:

- Maintain a regional presence with participation in collaboration groups like the Texas Watershed Coordinator's Roundtable, Regional Watershed Coordinators Steering Committee, Galveston Bay Estuary Program, Clean Rivers Program, and others.
- Seek to support other area efforts like the Spring Creek WPP, the West Fork San Jacinto River and Lake Creek WPP, and the various TMDL projects represented by the Houston Area Bacteria Implementation Group.
- Identify and/or pursue funding opportunities that would assist local partners in opportunities of shared interest.
- Pursue additional data necessary to inform stakeholder decisions or evaluate progress[144].

Figure 65 - Brand as a focal point for coordination

[144] Specific examples identified in the project include wildlife loading estimates, quantifying the relationship between sediment and bacteria concentrations, erosion rates, and spatial data for features like pipelines and new development.

Existing Outreach in the Watershed

Many local stakeholder organizations and regional, state, and national organizations have ongoing education efforts in the watershed. The Partnership recognizes the value of these ongoing programs to positively impact water quality and public awareness in the WPP area. Specific programs of note are described in the discussion of source-based elements. The Partnership will seek to coordinate and support efforts with partners that include[145] the entities listed in Table 39.

Table 39 - Outreach partners

Outreach Partner	Focus Areas
Bayou Land Conservancy	Conservation, general outreach
Bayou Preservation Association	Conservation, water quality, general outreach, citizen science, recreation, invasive species management, flood mitigation, trash reduction.
City of Houston	Source water protection
Cypress Creek Flood Control Coalition	Flood mitigation, general public outreach
Galveston Bay Estuary Program	Galveston Bay, source water protection
Harris County, Harris County Flood Control Districts, and Harris County Precincts 3 and 4	Riparian corridors, stormwater, general environmental outreach, recreation, OSSFs, illegal dumping, animal control, environmental enforcement, flood mitigation
Houston Advanced Research Center	Research, urban forestry, water quality
Houston Audubon	Conservation, wildlife, recreation
Houston-Galveston Area Council	Watershed management, water quality, forestry, public outreach, OSSFs, trash reduction
Houston Canoe Club	Recreation, conservation, general outreach
Hughes Development Corporation – Bridgeland	Resident outreach, development industry outreach
Katy Prairie Conservancy	Public education, conservation, land management, restoration
Klein ISD, Cy-Fair ISD, Waller ISD, and Spring ISD	Environmental education, student outreach
League of Women Voters Cy Fair	Constituent outreach, environmental policy outreach
Local HOAs (multiple)	Resident outreach, pet waste, inlet marking
Local MUDs/Special Districts (multiple, including Ponderosa Joint Powers Association)	Utilities, stormwater, general outreach
Local Soil and Water Conservation Districts (Harris, Navasota)	Agriculture, land management programs

[145] This list is not intended to be exhaustive, but a representative sample of area efforts currently in progress that overlap with WPP goals. The Partnership will actively seek to engage with partners through existing outreach efforts wherever appropriate, including those not specifically listed here. This is undertaken with the caveat that the Partnership will seek to supplement, enhance, or offer general support to activities completed by partners as part of permit or other regulatory requirements, but will not fund or supplant efforts by those partners.

Outreach Partner	Focus Areas
Harris-Galveston Subsidence District / Bluebonnet Groundwater Conservation District	Water conservation
Waller County	Riparian corridors, stormwater, general environmental outreach, recreation, OSSFs, illegal dumping, animal control, environmental enforcement
Other Cities and Communities (Prairie View, Cypress, Spring)	Utilities, stormwater, general outreach, resident outreach
Texas Commission on Environmental Quality	Water quality, wastewater, nonpoint source pollution
Texas A&M University AgriLife Extension/AgriLife Research/Texas Water Resources Institute	Agriculture, OSSFs, water quality, land management, feral hogs, riparian buffers
Texas A&M Forest Service / USDA US Forest System	Forestry
Texas Master Naturalists	Environmental education and outreach, habitat
Texas Parks and Wildlife	Wildlife, habitat, water quality
Texas Stream Team	Water quality, volunteering
TSSWCB	Agriculture/silviculture
USDA Natural Resources Conservation Service	Agriculture, land management, habitat, conservation
USDA US Forest Service	Forestry
The Nature Conservancy	Urban forestry, conservation, habitat, water resources
United States Army Corps of Engineers, Galveston	Flood mitigation, water quality modeling
State and Federal Elected Officials	Constituent outreach, environmental events

Figure 66 – Wildlife survey at the Audubon Cypress Creek Christmas Bird Count

Source-based Outreach and Education elements

In keeping with the guiding principle of engaging stakeholders with targeted messages, the Partnership will engage, enhance, or support a series of outreach and education efforts aimed at specific pollutant or solution categories. Unless otherwise specified, costs for coordination and outreach tasks by the Partnership are assumed to be part of the cost of maintaining a facilitator for the watershed. Specific costs are called out where applicable.

OSSFs

There are several existing programs targeting homeowner and practitioner knowledge for OSSFs. The Partnership recommends the following as specific actions under the WPP:

OSSF E1 — Hold residential OSSF Workshops

Both H-GAC and AgriLife Extension have existing OSSF programs aimed at educating the general public and specific audiences on general maintenance and visual inspection of OSSFs. The recommended frequency is at least one workshop every other year throughout the project period. Costs for these efforts range from $450+ per workshop and are paid for by a mix of existing projects (CWA §319(h) grants for both agencies, H-GAC CWA §604(b), and internal organization funding).

OSSF E2 — Participate in County-wide OSSF Workshops for Practitioners

Harris County holds an annual OSSF workshop for local OSSF practitioners. The Partnership will support the county with publicity and participation as appropriate and seek to support Waller County efforts as well. This activity will happen throughout the implementation period.

OSSF E3 — Provide Model Educational Materials[146] online

In addition to existing educational materials from the county, AgriLife, and local governments, the Partnership will host or promote materials on its website. Materials will be developed in the first two years of implementation and maintained/updated indefinitely.

OSSF E4 — Texas Well Owner Network (TWON)

The Partnership will work with TWON to hold informational meetings or testing events in the watershed and seek to include an OSSF message related to water well siting. The expected frequency is every seven years, with a focus on the Headwaters area.

OSSF E5 — Enhance OSSF Data

H-GAC and Harris and Waller counties will continue to cooperate on development or refinement of spatial (GIS) data for permitted OSSFs in the county and make the data available online for local partners (ongoing effort). H-GAC will work with the counties and local communities to develop better OSSF data for unpermitted systems by reviewing analyses

[146] For this and subsequent source category recommendations, materials may include, but not be limited to model flyers, fact sheets, educational program guides, pamphlets, ordinances, technical resources, etc.

with local communities for refinement. This latter effort will happen during the first three years of implementation, in conjunction with an ongoing effort funded by a CWA §604(b) grant to H-GAC.

OSSF E6 — Signage at Remediation Sites

H-GAC works with the Harris County Attorney's Office and TCEQ to provide funding to remediate failing OSSFs as part of a Supplemental Environmental Project to benefit economically disadvantaged households. H-GAC will post signage at completed project sites as an outreach tool for generating additional interest. This practice has been successful in other areas.

Wastewater and SSOs

The focus of outreach and education for permitted wastewater and SSOs is on the local governments and utilities of the watershed. However, the Partnership can help promote messages to their communities to serve water quality goals. The Partnership recommends the following activities as specific, supplementary actions under this WPP:

WWTF E1 — Promote Fats, Oils, and Grease (FOG) Awareness

FOG issues are a source of SSOs and operational challenges for local wastewater utilities. Programs like the San Jacinto River Authority's No Wipes in the Pipes (Patty Potty)[147] and the regional Galveston Bay Cease the Grease[148] campaign already exist. The Partnership seeks to promote these programs and maintain model materials on its website, social media, and at outreach events. Local partners will seek to promote the message through their online presence, utility bills, or through established programs[149]. The promotion will take place throughout the implementation period, and model materials will be added in the first year of implementation.

WWTF E2 — Promote Floodwater Contact Awareness

Flooding is a repetitive issue in some areas of the watershed, and floodwaters may contain untreated sewage if collection systems or WWTFs are compromised. Residents who enter the water during these events should be aware of exposure risks. The Partnership will include materials on its website (first year of implementation) and seek to coordinate with other local flood safety outreach efforts to ensure this message is represented (throughout the implementation period).

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[147] http://www.pattypotty.com/

[148] http://ceasethegrease.net/

[149] These efforts are in addition to existing management of utility functions.

WWTF E3 — Work with Partners to Increase Public SSO Reporting

The Partnership will coordinate with the numerous special districts and utilities in the area to utilize their existing communication networks (bill inserts, websites, etc.) as appropriate to promote messages regarding reporting SSOs.

Pet Waste

Pet waste is an area in which direct engagement with the public is a necessary component of an effective outreach strategy. Unlike centralized sources like WWTFs, pet waste reduction relies on the individual efforts of thousands of residents. The Partnership recommends the following activities as specific actions under this WPP:

Pet Waste E1 — Pet Waste Dispensers at Local Events

Figure 67 - Pet waste bag dispensers at a local event

H-GAC currently focuses on pet waste reduction as specific action individual residents can take. To support the message, H-GAC uses refillable dog waste bag dispensers with branding or messaging on the dispenser. These units are a low-cost way to engage community members and facilitate reductions. The dispensers take the place of event giveaways to raise awareness, and cost approximately $1.50 each. A standard giveaway would be 50 dispensers per outreach event, on average. For a 14-year implementation period, assuming 6 outreach events per year, this would equate to a cost of $6,300.

Pet Waste E2 — Elementary School Visits

Elementary-age children are a good candidate for educational programs and can influence activities of their parents. H-GAC or other local partners will visit local schools (at least one a year) to put on educational programming appropriate for the age range and subject topic of the classes involved. Past education efforts have included general water quality education with a pet waste message included. Costs for this activity are limited to staff time.

Pet Waste E3 — Provide Model Educational Materials online

In addition to existing educational materials from local partners, the Partnership will host or promote materials on its website. Materials will be developed in the first two years of implementation and maintained/updated indefinitely.

Urban Stormwater

Education and outreach elements[150] for urban stormwater will include efforts aimed both at MS4s and at diffuse flow off the land directly into waterways in urban areas. Much of the education and outreach for the former is conducted by the MS4s under the TPDES stormwater permits. For these areas, the Partnership will seek to coordinate and support, but will not add additional elements[151]. The need for maintaining stormwater infrastructure and LID features requires well informed community members. The Partnership recommends the following activities as specific actions under this WPP:

Urban Stormwater E1 – Expand Texas Stream Team Participation

TST[152] volunteers provide valuable information on local conditions in areas where there is not existing CRP monitoring. The role volunteers play as ambassadors to their community about local water quality is an equally important aspect of TST volunteering. H-GAC and local partners foster local volunteers in these efforts. The goal of this element is to increase TST monitoring by 10 volunteers by 2035.

Urban Stormwater E2 – Promote Urban Forestry as a Stormwater Solution[153]

Many of the stakeholders and regional partners in the WPP (e.g., Texas A&M Forest Service) promote urban forestry projects for the ecosystem services[154] they produce. The urbanized areas of Harris County were part of the *Houston Area Urban Forests*[155] project which identified priorities for promoting urban forestry, including as part of stormwater management efforts. Similar projects addressing the link between water quality and forestry are also active through Texas A&M Forest Service and USDA United States Forest Service, including the i-Tree modeling completed for this WPP to quantify tree benefits and inform stakeholder choices. The Partnership will seek to coordinate with ongoing urban forestry projects and programs, including those of the Harris County Flood Control District and the Houston Area Urban Forestry Council[156], and highlight water quality benefits. As appropriate, the Partnership will seek funding and technical support for local partners who are doing restoration or new plantings that have a water quality link[157]. Model materials will be hosted

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[150] While inlet stream marking is included in the structural solutions noted in Section 5, this program has a significant education and outreach component and has been successfully used by Harris County and other partners in the watershed to engage organizations and neighborhoods. Implementation of that solution should emphasize its outreach aspects.

[151] Except for promoting LID, as indicated in Section 5.

[152] https://h-gac.com/texas-stream-team/

[153] These recommendations are supplemental to existing ordinances that address urban trees. Existing ordinances may be used as model materials.

[154] Including but not limited to flood mitigation, water and air quality improvement, heat reduction, erosion control, atmospheric carbon storage, health benefits, and aesthetic benefits.

[155] www.houstonforests.com

[156] https://www.haufc.org/

[157] Specific urban forestry practices and technical resources are available from the Texas Forest Service at http://texasforestservice.tamu.edu/abouturbanandcommunityforestry/

on the Partnership website in the first year of implementation, and the Partnership will promote local urban forestry projects. The Partnership will also coordinate efforts regarding urban forestry with broader regional conservation efforts, including the Gulf-Houston Regional Conservation Plan[158], the BIG, and City of Houston source water protection efforts. Lastly, the Partnership will seek to work with new development to promote maintenance, restoration, or development of new forested areas in new development, as appropriate to the surrounding land cover.

Figure 68 - Trees as stormwater features

Agricultural Operations

A wealth of information and programs exists to promote water-friendly practices for agricultural operations. The focus of the Partnership for this category is largely to support the existing efforts of the Soil and Water Conservation Districts, TSSWCB, Texas A&M AgriLife, USDA NRCS, and other agricultural partners in promoting their programs in the watershed. The Partnership recommends the following activities as specific actions under this WPP:

Agricultural Operations E1 – Develop and Implement Education Measures and Materials for Livestock Operations (Non-CAFO)

There are several horse stable operations and livestock operations present in the watershed. The stakeholders identified the need for best practices and educational materials for these facilities. The Partnership will work with the agricultural agencies to identify existing source material and develop educational materials specific to the stabling operations, etc. in the watershed within the first two years of implementation.

[158] https://www.gulfhoustonrcp.org/

Agricultural Operations E2 – Hold Agricultural Resources Workshops

The Partnership will hold workshops for local landowners and producers at least once every three years. The workshops will have representation from agricultural and other land management agencies (TSSWCB, AgriLife, USDA NRCS, and others) as a "one-stop shop" for residents to hear about available programs and meet one on one with several agencies.

Agricultural Operations E3 – Support Local Agricultural Conservation

The Partnership will support efforts to develop partnerships or funding sources to implement local conservation initiatives, including the Katy Prairie's proposed Coastal Prairie Initiative in partnership with the USDA NRCS and future elements of regional conservation plans in agricultural areas, including the H-GAC Regional Conservation Framework program.

Agricultural Operations E4 – Targeted Outreach for Recreational Horses

The Partnership will work with existing agricultural outreach efforts (Lone Star Healthy Streams[159], etc.) to develop or promote materials for recreational horse owners, either stabled or on acreage lots. This specific focus is to bridge the gap between general outreach and programs aimed primarily at agricultural operations. The intent of the outreach is to modify behaviors regarding horse manure handling and concentrated grazing at stables, with a focus on riparian areas.

Land Management

Beyond programs focused on agricultural/silvicultural properties, there are many programs and opportunities to promote or support land management practices that are beneficial to water quality, including Farm Bill programs through NRCS, conservation easements and similar conservation mechanisms. The Partnership recognizes the ample effort already put forth by local partners in developing land management projects for habitat (e.g., Katy Prairie Conservancy preserves), recreation (e.g. Harris County's Cypress Creek Greenway) and flood retention. The key focus for water quality is lands adjacent to the waterways. The Partnership will generally support and promote voluntary projects and programs however appropriate, and recommends the following outreach activities as a specific action under this WPP:

Land Management E1 – Promote Riparian Buffers (Tools and Workshops)

In addition to the specific action of developing conservation areas, easements, etc. in riparian corridors, the Partnership will maintain resources on its website relating to riparian buffers, including a link to the H-GAC riparian buffer planning tool[160] for landowners. Resources will be developed/obtained and hosted during the first year of implementation. The Partnership will seek to promote the Texas Water Research Institute (TWRI) *Texas Riparian and Stream Ecosystem Education Program* and *Urban Riparian and Stream Restoration Program*[161] and

[159] http://lshs.tamu.edu/

[160] http://www.h-gac.com/community/water/riparian-buffer-planning-tool.aspx

[161] More information is available at http://texasriparian.org/riparian-education-program/

similar workshops from Texas A&M AgriLife. Expected frequency is once every five years for these programs. Funding is currently provided by CWA §319(h) grants, and attendee fees. This will focus on both fecal waste and DO benefits in this watershed.

Land Management E2 – Texas Watershed Stewards

Texas A&M AgriLife Extension's Texas Watershed Stewards (TWS) program is an effective way of developing knowledge among the local communities of watershed issues and actions they can take. A TWS training was held in the watershed during the development of this WPP. The Partnership will work with AgriLife to bring the program back on an expected frequency of every five years.

Land Management E3 – Conservation Coordination

In addition to long-standing efforts by NGOs and local governments in the watershed, several regional conservation and open space planning projects are currently active in the watershed. The Partnership has, and will continue to, participate meaningfully in the Gulf-Houston Regional Conservation Plan, the Regional Conservation Framework, the Waller County Parks, Trails, and Open Space Master Plan, Bayou Preservation Association Stream Corridor Restoration Committee, and other local efforts that may have implications or opportunities for riparian-oriented conservation in the watershed.

Feral Hogs

Feral Hog abatement is a strong concern for properties throughout the watershed, but especially in developing areas of the Transitional and Headwaters attainment areas, and along riparian corridors. Existing outreach programs through Texas A&M AgriLife Extension and other sources are well developed. The Partnership seeks to promote these elements through the website, social media, partner networks, and with event publicity as appropriate. The following programs are of specific interest for the watershed:

Feral Hogs E1 – Lone Star Healthy Streams –Workshops and Feral Hog Resource Manual

The Partnership will promote the AgriLife Lone Star Healthy Streams[162] program by promoting the Feral Hog Resource manual and hosting a workshop in the watershed at least twice during implementation, subject to AgriLife availability.

Feral Hogs E2 – Feral Hog Management Workshop

The Partnership will work with Harris and/or Waller County AgriLife Extension to host a local feral hog management workshop. The expected frequency for this element is at least once every six years, based on AgriLife availability.

[162] http://lshs.tamu.edu/workshops/

Deer and Other Wildlife

Although the Partnership elected not to recommend any direct solutions for reducing deer populations or addressing other wildlife, stakeholders expressed interest in having better data regarding wildlife contributions (see recommendations regarding additional research in Section 7). The Partnership will, however, seek to use existing wildlife events as potential platforms for general outreach. Specifically, the Partnership recommends:

Deer and Other Wildlife E1 – Cypress Creek Christmas Bird Count

Project staff have taken part in this annual event in which stakeholders from the western portion of the Cypress Creek Watershed conduct an Audubon Christmas Bird Count[163] on January 1 of each year alongside birdwatchers from the local area and environmental agencies. The event provides valuable data for assessing avian wildlife populations in the area, but also serves as an informal outreach opportunity and a chance to assess via field reconnaissance parts of the watershed normally not accessible to the general public.

Trash and Illegal Dumping

In addition to enhanced enforcement, the stakeholders recommended that trash reduction is a local priority and serves as a visible form of outreach. Harris and Waller Counties, and other local jurisdictions, will continue to enforce dumping issues. In addition, the Partnership recommends:

Trash and Illegal Dumping E1 – Trash Bash Site

The Texas Rivers, Lakes, Bays N' Bayous Trash Bash[164] is a one-day trash reduction and community outreach event that takes place throughout the region. Upwards of hundreds of volunteers attend each site, where outreach materials and education about water quality accompany the trash reduction elements. The cleanups focus on areas adjacent to local waterways. There is an existing Trash Bash site for Cypress Creek at Collins Park, with several satellite locations in the watershed. The Partnership will participate in this annual effort as a direct way of engaging the public on visible examples of water pollution, and in providing an accompanying water quality message.

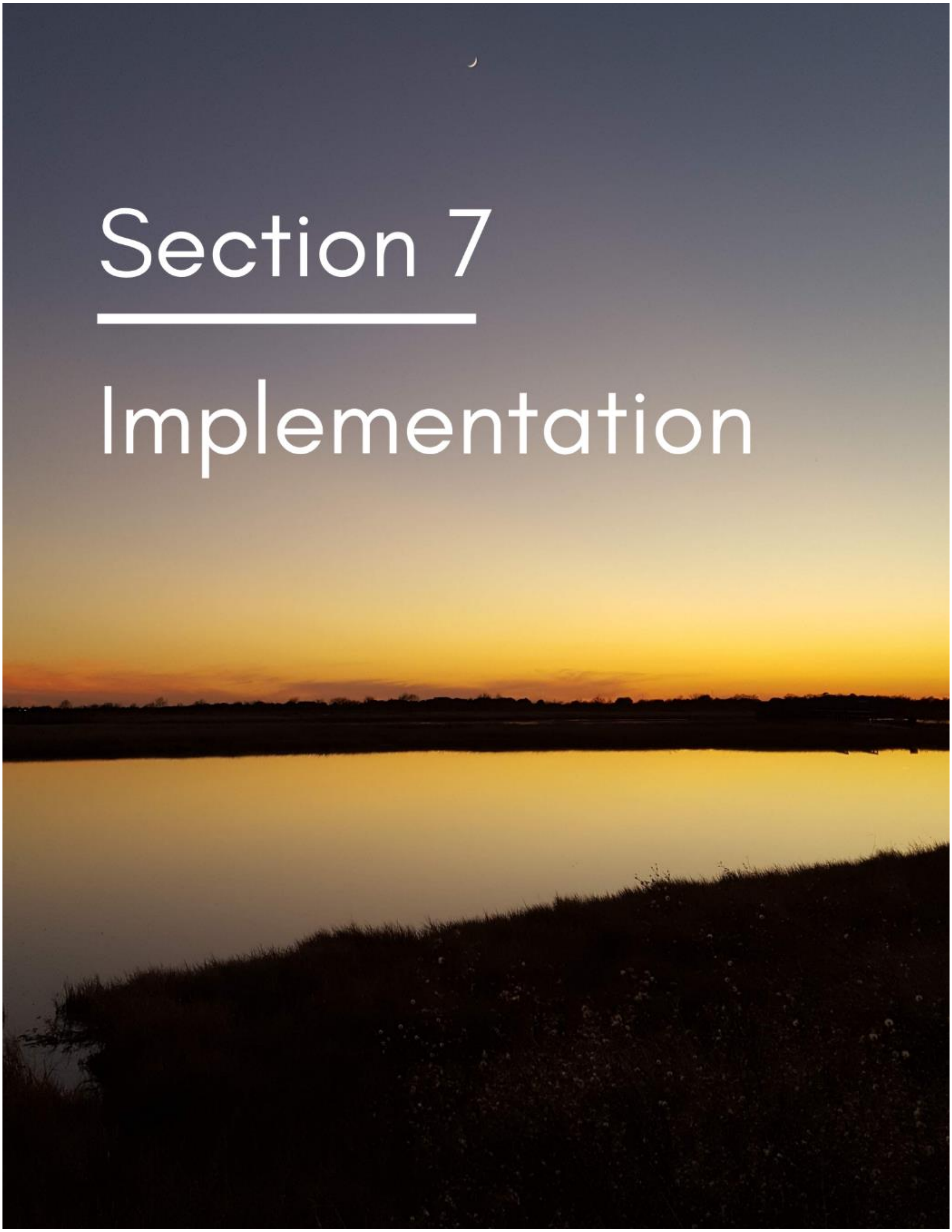
Figure 69 - Partnership staff engage the public at area events

[163] https://www.audubon.org/conservation/science/christmas-bird-count

[164] http://www.trashbash.org/

Section 7

Implementation



7 - Implementation

Implementation is the process of transforming the concerns, ideas, and commitment that went into developing this WPP into tangible action and results. This section details the principles that will guide implementing the solutions identified in sections 5 and 6, the estimated schedule of implementation, and interim milestones along the way that can be used to gauge progress.

Figure 70 – Flood mitigation and habitat creation at a mixed-use park

Implementation Strategy

The Partnership balanced the development of potential solutions with the considerations of the logistics of implementation. Some solutions were discarded because they were unfeasible to implement, some were focused to specific areas of the watershed, etc. The starting point for developing the WPP's implementation strategy is the water quality goals and guiding principles (described in Section 1). From there, the local stakeholders of the Partnership discussed the best ways to translate project ideas into achievable timelines of activity that would be acceptable to the community. The implementation of this WPP will be based on:

- Coordination provided by a watershed coordinator serving as a focal point for WPP efforts;
- Decisions made locally, implemented on a voluntary basis;

- Siting of solutions that considers local needs and conditions, but overall favors areas closest to waterways;
- An opportunistic approach that is flexible enough to maximize resources and opportunities;
- Timelines that consider the changing mix of sources through the implementation period;
- An integrated approach that uses education and outreach to support related solutions;
- A recognition that human waste sources represent a relatively greater pathogenic risk to human health;
- An ongoing focus on adapting plans to meet changing conditions; and
- A special focus on coordinating implementation activities with flood mitigation, source water protection, conservation, and forestry projects in the watershed and region.

Locally Based Watershed Coordinator

Implementing, maintaining, evaluating, and adapting the ongoing and proposed solutions is essential to the success of this project and the future of water quality in the Cypress Creek Watershed. A local watershed coordinator will be necessary to guide implementation, education, and outreach solutions as the focal point for coordinating these efforts for the WPP. The coordinator will work with local partners to seek opportunities to implement solutions and to find common priorities. The coordinator will maintain a high awareness of and involvement in water quality issues in the area through engagement with related efforts, educational programs, outreach through social media, and communication with the local media. The position will routinely interact with local city councils, county commissioner courts, SWCDs, and other stakeholder groups to keep them informed and involved in implementation activities being carried out in the watershed. Coordinating efforts among key partners will be crucial for success and should be one of the primary roles of the position. The watershed coordinator will also work to secure external funding to facilitate implementation activities and coordinate with partner efforts, specially the existing and planned studies and efforts involving flood mitigation in the system. H-GAC will provide facilitation for the phase of the WPP directly after the submission of the WPP. An estimated $70,000 per year including travel expenses will be necessary for this position, which assumes only a portion of the time of a full-time senior level position, or a greater portion of an entry level position. Initial funding for the watershed coordinator will be incorporated into a CWA §319(h) grant proposal. The Partnership will consider after that point how best to house ongoing facilitation of the Partnership through a watershed coordinator, including consideration of integrating coordination of other local watershed efforts and other local partners.

Comprehensive Strategy for Pet Waste

While human waste sources can produce the greatest risk of illness[165], pet wastes are a prominent source of fecal bacteria and nutrients. As the watershed continues to develop, pet wastes will continue to grow in prominence as a fecal waste source. Pet waste represents both a unique challenge and an opportunity because it is a significant contributor, generally concentrated in more densely populated areas with higher impervious cover, and a source that's generally under our control as pet owners (as opposed to wildlife sources).

This WPP recommends solutions and education/outreach activities (Sections 5 and 6, respectively) designed to engage the public and promote proper management of pet wastes. Integration of these elements will be necessary to ensure successful implementation. The strategy for pet waste under this WPP will be conducted based on the following principles:

- Message Support — As possible, structural solutions will be supported by targeted outreach and education to enhance public awareness and utilization. For example, installation of pet waste stations will be accompanied by promotional messages for the specific area (in the form of partner messaging, relevant online venues, or other appropriate means).
- Local Integration — As possible, education and outreach efforts will be coordinated with existing events or programs. This ensures a broader reach than more narrowly targeted events and reduces costs and logistics for project resources. For example, H-GAC and other local partners will include pet waste messaging and outreach as part of broader messages at general events or seek a presence at community/regional events where local pet owners may be present (e.g., the Houston Dog Show).
- Targeted Implementation — The specific needs of subwatersheds or other areas will be considered in the selection of solutions and outreach messaging that is directed towards their communities. For example, implementation in more densely urban areas may focus more on individual behaviors (picking up after pets) and addressing feral populations, while less dense suburban area messaging may focus on pet waste stations in public spaces and promoting dog park development. In general, the focus of efforts will be heaviest on the Downstream area and new development in the Transitional area.

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[165] Research has indicated that human waste has a significantly higher risk of causing illness in humans as compared to animal sources. Additional information about an example of this research in Texas can be reviewed at http://oaktrust.library.tamu.edu/handle/1969.1/158640?show=full.

Coordination with Adjacent Efforts

Coordination with the adjacent practice areas of flood mitigation, conservation, and forestry will be key to successful implementation of this WPP.

- Flood Mitigation — An overwhelming amount of general public concern in the watershed is focused on repetitive flooding. Similarly, many of the primary grant funding sources (as referenced in Appendix D) currently available to local partners focus on resiliency and flood mitigation. To maintain visibility as an effort, and have the opportunity to tie water quality messages and considerations to flood mitigation efforts, the Partnership will maintain a strong focus on coordinating with local partners (Harris County Flood Control District, and others) and actively participating, as appropriate, in public processes linked to the flood mitigation efforts.
- Conservation — The strong tradition of conservation in the watershed and existing organizational capacity among local governments and NGOs provides an opportunity to enhance water quality through the ecosystem services provided by conserved land. The Partnership will seek to actively engage with and support conservation initiatives in the watershed and help represent the unique character and needs of the watershed in regional initiatives. Current efforts include the Gulf-Houston Regional Conservation Plan (Houston Wilderness), the Regional Conservation Framework (H-GAC), the USDA NRCS RCPP, and others.
- Forestry — Based on preliminary modeling, inclusion of forestry practices will have a dramatic impact on stormwater runoff in the watershed. Urban forestry is a growing focus in the Houston region, as evidenced by its inclusion in the City of Houston's recent climate change and resilience planning efforts, with a 4.6 million new tree goal for the city alone, and innovative riparian restoration and linear forest programs. Other regional efforts include large scale planting programs by the Harris County Flood Control District, Centerpoint Energy, Texas Department of Transportation, and others; significant research and restoration work by Texas A&M Forest Service and conservation NGOs; local collaborations like the Tree Strategy Implementation Group, Stream Corridor Restoration Committee, and Houston Area Urban Forestry Council; and broad regional partnerships like the Texas Forests and Drinking Water Partnership[166]. Project staff have been engaged with local partners in all these pursuits, the Partnership will continue to participate and actively promote water quality considerations and appropriate areas of the watershed within these efforts.

166 https://tfsweb.tamu.edu/partnership/#:~:text=The%20Texas%20Forests%20and%20Drinking,important%20and%20interdependent%20natural%20resources.

Timelines for Implementation

Implementation of this WPP is intended to take place over a 14-year initial implementation timeframe (2021-2035), broken into three distinct phases: early (2021-2025), middle (2025-2030) and late (2030-2035). Some of the recommended solutions and outreach elements are intended for the whole implementation period, while some are intended for specific timeframes within that period. Some activities recommended by the Partnership are already underway or are likely to initiate prior to the approval of the WPP. The schedules were developed with the stakeholders to ensure that implementation took place at a feasible rate and meshed with other planned activities and priorities. The timelines are intended to reflect the period in which each solution will be implemented, along with the responsible entities and costs they will incur (Table 40). Solutions in the 2019-2020 range represent partner activities that began or were ongoing during the development of this WPP are not included as future activities but set a solid foundation for implementation. Additional information about each solution, its intended implementation, and estimated costs can be found in Sections 5 and 6[167]. This table will be updated as part of future WPP updates, after each implementation phase, or as needs warrant.

Figure 71 - Implementing LID practices in new development

[167] While not specifically noted in Sections 5 and 6, the Supporting Research tasks identified in Section 8, following, are also included in the planning for implementation.

Table 40 - Implementation schedule

Solution Category	Recommended Solution or *Outreach Element*[168]	Responsible Parties	Implementation Period[169]
General	Watershed Coordinator	Partnership[170]	Ongoing
OSSFs	OSSF 1 - Convert to Sanitary Sewer	H-GAC; Harris County; Waller County; Special districts and utilities; homeowners	Ongoing
	OSSF 2 – Improve Spatial Data	H-GAC; Harris and Waller counties; special districts and utilities.	Ongoing
	OSSF 3 - Remediate Failing OSSFs	H-GAC; homeowners; Harris and Waller Counties (enforcement); utilities (for conversion projects)	Ongoing
	OSSF E1 – Hold Residential OSSF Workshop	*H-GAC; Partnership; AgriLife Extension*	*Ongoing - Periodic*
	OSSF E2 – Participate in County Wide OSSF Workshop for Practitioners	*Partnership; Harris County*	*Ongoing - Periodic*
	OSSF E3 – Provide Model Educational Materials Online	*Partnership*	*Early*
	OSSF E4 – Texas Well Owner Network Events	*Partnership; TWRI; AgriLife Extension; TSSWCB*	*Ongoing-Periodic*
	OSSF E5 – Signage at Remediation Sites	*H-GAC; Harris County; TCEQ*	*Ongoing*
WWTFs and SSOs	WWTF 1 - Address Problem Plants and Consider Regionalization	Utilities; Counties	Early (recommendations); Ongoing (actions)
	WWTF 2 – Recommend Increased Testing	Utilities	Early; Middle
	SSO 1 – Remediate Infrastructure	Utilities	Ongoing

168 Outreach and Education elements are designated with italics.
169 Potential periods include Early (2021-2025), Middle (2025-2030), and Late (2030-2035). Projects spanning these are denoted as Ongoing. Items listed with a "-periodic" suffix indicate an outreach element with a periodic frequency.
170 Where Partnership appears on this table, it indicates H-GAC, a successor agency, or a watershed coordinator for the WPP acting on behalf of the stakeholders and WPP. While H-GAC is currently acting as the watershed coordinator for the Partnership, this table refers to elements conducted by H-GAC under other projects (CRP, etc.) as "H-GAC".

Solution Category	Recommended Solution or *Outreach Element*[168]	Responsible Parties	Implementation Period[169]
	SSO 2 – Consider Additional Preventative Measures	Utilities	Early (consider measures); Ongoing (implement measures)
	WWTF E1 – Promote Fats, Oils, and Grease Awareness	*Partnership; Utilities*	*Ongoing*
	WWTF E2 – Promote Floodwater Contact Awareness	*Partnership; Counties; Special districts*	*Ongoing*
	WWTF E3 – Work with Partners to Increase Public SSO Reporting	*Partnership; Counties; Utilities*	*Ongoing, with a focus on Early*
Pet Waste	Pet Waste 1 - Install Pet Waste Stations	Counties; HOAs; Special districts; Developers; NGOs	Early (installation); Ongoing (maintenance)
	Pet Waste 2 - Expand Dog Parks	Local government; Counties; HOAs; Developers; Special districts	Early (1 new park area); Middle – Late (1 new park area)
	Pet Waste 3 - Promote Spay and Neuter Events	SPCA (or similar provider); H-GAC; local government/HOA (venue/promotion)	Ongoing (1 every 5 years)
	Pet Waste 4 – Consider Increased Enforcement	Local governments; Special districts; HOAs; Counties; Apartment complexes	Early; Middle
	Pet Waste E1 – Pet Waste Dispensers at Local Events	*Partnership; H-GAC*	*Ongoing*
	Pet Waste E2 – Elementary School Visits	*Partnership*	*Ongoing - Periodic*
	Pet Waste E3 – Promote Model Educational Materials Online	*Partnership*	*Ongoing - Periodic*
Urban Stormwater	Urban Stormwater 1 - Investigate Drainage Channels	H-GAC; MS4s; Harris County; TCEQ	Early; Middle
	Urban Stormwater 2 - Promote and Implement Urban Riparian Buffers	MS4s; Local governments; Special districts; Texas A&M Forest Service (forestry technical support); NGOs; Private landowners/businesses	Ongoing
	Urban Stormwater 3 - Install Stormwater Inlet Markers	Harris County; Local governments; Special districts; HOAs; local volunteers	Early; Middle (ongoing as needed)
	Urban Stormwater 4 - Low Impact Development	H-GAC; MS4s; local governments	Ongoing

Solution Category	Recommended Solution or *Outreach Element*[168]	Responsible Parties	Implementation Period[169]
	Urban Stormwater E1 – Expand Texas Stream Team Participation	*H-GAC; Partnership; TST Partners*	*Ongoing*
	Urban Stormwater E2 – Promote Urban Forestry as a Stormwater Solution	*Partnership; Texas A&M Forest Service; H-GAC*	*Ongoing*
Agricultural Operations	Agricultural Operations 1 - WQMPs and Conservation Plans	TSSWCB; SWCDs; USDA NRCS; agricultural producers/landowners	Ongoing
	Agricultural Operations 2 - Maintain or Restore Riparian Buffers	Landowners/producers (on a voluntary basis); NGOs; Agricultural agencies	Ongoing
	Agricultural Operations 3 – Implement Horse Manure Composting Program	Horse owners; Stabling operations; Counties; Local governments; NGOs (potentially)	Early (development); Ongoing (implementation)
	Agricultural Operations E1 – Develop and Implement Education Measures and Materials for Livestock Operations (non-CAFO)	*Partnership; TSSWCB; AgriLife Extension*	*Early*
	Agricultural Operations E2 – Hold Agricultural Resources Workshops	*Partnership; TSSWCB; AgriLife Extension; USDA NRCS*	*Ongoing - Periodic*
	Agricultural Operations E3 – Support Local Agricultural Conservation	*Partnership; USDA NRCS; Katy Prairie Conservancy; Other local conservation partners*	*Ongoing, with a focus on Early*
	Agricultural Operations E4 – Targeted Outreach for Recreational Horses	*Partnership; Texas A&M AgriLife; TSSWCB; local SWCDs*	*Early*
Feral Hogs	Feral Hogs 1 - Remove Feral Hogs	Landowners; Local governments; Special districts; Agricultural agencies (technical support)	Ongoing
	Feral Hogs E1 – Lone Star Healthy Streams – Workshops and Feral Hog Resource Manual	*Texas A&M AgriLife Extension; TSSWCB; Partnership*	*Ongoing - Periodic*
	Feral Hogs E2 – Feral Hog Management Workshop	*Texas A&M AgriLife Extension; TSSWCB; Partnership*	*Ongoing - Periodic*

Solution Category	Recommended Solution or *Outreach Element*[168]	Responsible Parties	Implementation Period[169]
Deer and Other Wildlife	Wildlife 1 – Conserve or Restore Upland Habitat	Landowners; NGOs; Local governments; Agricultural agencies (technical support); Developers	Ongoing
	Deer and Other Wildlife E1 – Cypress Creek Christmas Bird Count	*Partnership; Audubon; Local volunteers*	*Ongoing*
Conservation and Land Management	Conservation and Land Management 1 - Riparian Buffers	Dependent on location but may include Counties; Local governments; Special districts; Agricultural agencies; NGOs; Developers; Private landowners; commercial properties	Ongoing; focus on Early
	Conservation and Land Management 2 - Voluntary Conservation	Dependent on location but may include Counties; Local governments; Special districts; Agricultural agencies; NGOs; Developers; Private landowners; Commercial properties	Ongoing; with a focus on Early and Middle
	Conservation and Land Management 3 – Increase Tree Canopy	Counties; Local Government; Special districts; Agricultural agencies; NGO; Developers; Private landowners; commercial properties	Ongoing; with a focus on Early and Middle
	Conservation and Land Management E1 – Promote Riparian Buffers (Tools and Workshops)	*Partnership; TWRI; TSSWCB/TCEQ (granting)*	*Ongoing - Periodic*
	Conservation and Land Management E2 – Texas Watershed Stewards	*TWRI; Partnership*	*Ongoing - Periodic*
	Conservation and Land Management E3 – Conservation Coordination	*Partnership; NGOs; USDA NRCS; Other local conservation partners*	*Ongoing, with a focus on Early*
Illegal Dumping and Trash	Illegal Dumping 1 – Report Chronic Dump Sites and Consider Increased Enforcement	H-GAC; Counties; Local Governments; Residents	Ongoing
	Trash and Illegal Dumping E1 – Trash Bash Site	*H-GAC; Partnership; San Jacinto River Authority*	*Ongoing*

Solution Category	Recommended Solution or *Outreach Element*[168]	Responsible Parties	Implementation Period[169]
Flooding	Flooding 1 – Coordinate with Ongoing Mitigation Efforts	Harris County Flood Control District; Special districts; Local governments; Counties; NGOs	Ongoing; with a focus on Early

Interim Milestones for Measuring Progress

Interim milestones are identified as goalposts to measure the progress of implementation. Whereas water quality and other criteria will be used to measure the effectiveness of implementation (Section 8), interim milestones measure whether implementation is occurring on schedule (Table 41).

Table 41 - Interim milestones for solutions and outreach activities

Solutions[171]	Overall Implementation Goal[172]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
General – Watershed Coordinator	Retain a Watershed Coordinator to manage the day to day coordination, pursue resources and guide implementation	2020 – The Partnership reassesses facilitation during early implementation	2021 – Funding application is made for a 2022 start date	2022 – Watershed Coordinator position retained	2025 – Partnership reassess facilitation need after early implementation
OSSF 1 – Convert to Sanitary Sewer	In conjunction with OSSF 3 – Remediate Failing OSSFs, address failing OSSFs	2025 – First third of OSSFs addressed, or failures prevented	2030 – Second third of OSSFs addressed, or failures prevented	2035 – Final third of OSSFs addressed, or failures prevented	
OSSF 2 – Improve Spatial Data	Improve OSSF location spatial data to guide remediation efforts	2023 – Partners have reviewed and commented on existing spatial data, which is revised accordingly	2025 – Authorized Agents have continued to provide new data regularly	2030 – Authorized Agents have continued to provide new data regularly	2035 – Authorized Agents have continued to provide new data regularly
OSSF 3 – Remediate Failing OSSFs	In conjunction with OSSF 1 – Convert to Sanitary Sewer, address failing OSSFs	2025 – First third of OSSFs addressed, or failures prevented	2030 – Second third of OSSFs addressed, or failures prevented	2035 – Final third of OSSFs addressed, or failures prevented	

[171] Availability and timing of all solutions, especially those not directly facilitated by the Partnership, are subject to changes in partner schedules in the future. Timing of some events (workshops, etc.) may be adjusted based on partner availability as needed.
[172] Target goals are based on the data summarized in Table 27, and may vary based on opportunity, resources, and regulatory changes in the future. All numeric targets (i.e. x number of dogs) refer to representative units. Actual units addressed may change based on pollutant removal efficiency, location, etc.

Solutions[171]	Overall Implementation Goal[172]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
OSSF E1 – Hold Residential OSSF Workshop	*Empower homeowners and real estate inspectors to identify the signs of failing/failed OSSFs and promote proper OSSF management to avoid failures*	*2025 – 2 workshops held*	*2030 – 2 additional workshops held*	*2035 – 2 additional workshops held*	
OSSF E2 – Participate in County-wide OSSF Workshop for Practitioners	*Harris County's annual OSSF workshop provides a point of coordination with practitioners*	*2035 – Annual meetings [173] have been held; Partnership participated*			
OSSF E3 – Provide Model Educational Materials Online	*Provide model educational materials online to facilitate education by other organizations*	*2021 – Review existing materials and select suite of model materials*	*2022 – Host materials online; create any materials not already covered*		
OSSF E4 – Texas Well Owner Network Events	*Educate well owners about potential risks from OSSFs and potential contamination of drinking water wells*	*2025 – First TWON event held*	*2032 – Second TWON event held*		
OSSF E5 – Signage at Remediation Sites	*Use OSSF remediation sites as outreach to neighbors via signage*	*2035 – Signage placed at OSSF remediation locations*			

[173] This education and outreach measure is an activity of Harris County. The county may change the nature or frequency of this meeting in the future.

Solutions[171]	Overall Implementation Goal[172]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
WWTF 1 – Address Problem Plants and Consider Regionalization	Improve treatment of sewage	2022 – At least 1 WWTF makes operational/ structural changes resulting in effluent improvement	2030 – At least 1 additional WWTF makes operational/ structural changes resulting in effluent improvement	2035 – At least 1 additional WWTF makes operational/ structural changes resulting in effluent improvement	
WWTF 2 – Recommend Increased Testing	Enhance monitoring to better characterize effluent	2025 – Partnership worked with at least 10 plants to identify capacity for increased testing	2030 – Partnership worked with at least 10 additional plants to identify capacity for increased testing		
SSO 1 – Remediate Infrastructure	Reduce contamination from human fecal waste by reducing overflows from WWTF collection systems	2025 – 5 fewer SSOs occurred than average since 2020	2030 – 7 fewer SSOs occurred than average since 2020	2035 – 10 fewer SSOs occur than average, over implementation period	
SSO 2 – Consider Additional Preventative Measures	Improve infrastructure capacity, operations, and preventive measures to reduce SSOs	2025 – At least 3 utilities have reviewed and/or upgraded backup capacity or other measures	2030 – At least 3 additional utilities have reviewed and upgraded backup capacity or other measures		

Solutions[171]	Overall Implementation Goal[172]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
WWTF E1 – Promote FOG Awareness	*Reduce SSOs by affecting utility customer behavior regarding FOG*	*2021 – Model materials identified and added to website*	*2030 – Consistent promotion with partners throughout implementation period*		
WWTF E2 – Promote Floodwater Contact Awareness	*Reduce exposure to bacteria by educating residents about floodwater contact*	*2021 – Model materials identified and added to website.*	*2030 – Consistent promotion with partners throughout implementation period*		
WWTF E3 – Work with Partners to Increase Pubic SSO Reporting	*Enhance reporting by increasing public visibility and community knowledge*	*2025 – Partnership has worked with local utilities to develop and disseminate materials to customers/ community members*			
Pet Waste 1 – Install Pet Waste Stations	Reduce wastes by facilitating use of bags in public areas	2025 – At least 20 pet waste stations installed	2030 – At least 20 additional stations installed; all stations maintained throughout the implementation period	2035 – All stations maintained throughout the implementation period	

Solutions[171]	Overall Implementation Goal[172]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Pet Waste 2 – Expand Dog Parks	Increase availability of controlled dog recreation areas to sequester wastes in public areas	2030 – 1 new dog park area developed	2035 – Second new dog park area developed		
Pet Waste 3 – Promote Spay and Neuter Events	Reduce pollutants from feral populations through voluntary population control	2025 – 1 spay/neuter event held	2030 – Second spay /neuter event held	2035 – Third spay/neuter event held	
Pet Waste 4 – Consider Additional Enforcement	Reduce dog waste by promoting enforcement	2025 – The Partnership will have worked with at least 5 local partners to promote enforcement	2030 – The Partnership will have worked with at least 5 more local partners to promote enforcement	2035 – The Partnership will have worked with at least 5 more local partners to promote enforcement	
Pet Waste E1 – Pet Waste Dispensers at Local Events	*Educate residents about impacts of dog waste and reduce waste in stormwater*	*2025 – Distribution of 1,200 dispensers at 24 local events*	*2030 – Distribution of 1,500 additional dispensers at 30 local events*	*2035 – Distribution of 1,500 additional dispensers at 30 local events*	
Pet Waste E2 – Elementary School Visits	*Educate children on pet waste and other water quality issues*	*2025 – 4 visits held*	*2030 – 5 additional visits held*	*2035 – 5 additional visits held*	

Solutions[171]	Overall Implementation Goal[172]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Pet Waste E3 – Promote Model Educational Materials Online	*Provide model materials to facilitate other organizations' education efforts*	*2021 – Identify needs beyond existing materials*	*2022 – Develop and host model materials*		
Urban Stormwater 1 – Investigate Drainage Channels	Locate potential sources of pollutants in urban channels[174]	2021 – Potential priority areas and grant resources identified	2025 – Pilot project completed; at least 1 waterway completed field reconnaissance project	2030 – At least 1 additional waterway completed field reconnaissance project	2035 – At least 1additional waterway completed field reconnaissance project
Urban Stormwater 2 – Promote and Implement Urban Riparian Buffers	Reduce pollutants in urban sheet flow and erosion through vegetative barriers	2025 – At least 1 urban riparian project completed	2030 – At least 1 additional urban riparian project completed	2035 – Partnership has been consistently active in promoting riparian buffers.	
Urban Stormwater 3 – Install Stormwater Inlet Markers	Raise awareness and shift behavior of residents served by stormwater systems to reduce pollutants entering drains/waterways	2025 – At least 2 neighborhoods have markers added	2030 – At least 2 additional neighborhoods have markers added	2035 – At least 2 additional neighborhoods have markers added	
Urban Stormwater 4 – Low Impact Development	To reduce pollutants in stormwater flows through promoting and implementing infrastructure that mimics or improves on natural hydrology	2022 – LID materials developed and hosted on website	2030 – At least 1 LID demonstration project installed	2035 – At least 1 additional LID demonstration project installed	

[174] This solution is intended as a supplement to MS4 activities to detect illicit discharges, etc. It is expected additional investigations will take place as part of TPDES MS4 permits. This activity will not replace requirements under permits.

Solutions[171]	Overall Implementation Goal[172]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Urban Stormwater E1 – Expand Texas Stream Team Participation	*Supplement existing monitoring data with volunteer sites and empower volunteers to acts as water quality ambassadors*	*2025 – 3 volunteers added*	*2030 – 6 total volunteers added*	*2035 – 10 total volunteers added*	
Urban Stormwater E2 – Promote Urban Forestry as a Stormwater Solution	*Coordinate and promote urban forestry programs and projects for water quality benefits*	*2021 – Model materials identified and hosted online*	*2025 – Revised modeling completed to support forestry measures' effectiveness*	*2035 – Coordination and promotion consistent throughout implementation period*	
Agricultural Operations 1 – WQMPs and Conservation Plans	Address waste from 1,433 cows, 488 horses, and 41 sheep and goats through 40 WQMPs/Conservation Plans	2025 – First third of plans (or plans representing a third of the reduction load) addressed by the solution	2030 – Second third of plans (or plans representing a third of the reduction load) addressed by the solution	2035 – Final third of plans (or plans representing a third of the reduction load) addressed by the solution	
Agricultural Operations 2 – Maintain or Restore Riparian Buffers	In conjunction with, or in supplement to, Agricultural Operations - WQMPs and Conservation Plans and Land Management - Riparian Buffers, install or maintain riparian buffers in agricultural areas to reduce transmission of pollutants	2025 – At least 2 rural properties have riparian projects, at least 1 is agricultural	2030 – At least 2 additional rural properties have riparian projects, at least 1 is agricultural	2035 – At least 2 additional rural properties have riparian projects	
Agricultural Operations 3 – Implement Horse Manure Composting Program	Reduce horse manure entering waterways by turning it to beneficial use	2022 – Program developed with local partners	2025 – At least 3 participants in the program	2030 – At least 3 additional participants in the program	2035 – At least 3 additional participants in the program

Solutions[171]	Overall Implementation Goal[172]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Agricultural Operations E1 – Develop and Implement Education Measures and Materials for Livestock Operations (non-CAFO)	*Develop specific recommendations for stabling and other livestock operations to reduce contributions from these sources*	*2021 – Needs, potential local partners identified*	*2022 – Materials developed and reviewed locally; hosted and disseminated*		
Agricultural Operations E2 – Hold Agricultural Resources Workshops	*Promote agricultural programs by facilitating one on one meetings with landowners*	*2024 – First workshop held*	*2027 – Second workshop held*	*2030 – Third workshop held*	*2033 – Fourth workshop held*
Agricultural Operations E3 – Support Local Agricultural Conservation	*Increase conservation efforts by lending support and coordination to local partners pursuing opportunities*	*2021 – Collaborate with at least 1 local partner on a project proposal*	*2025 – collaborate with at least 1 additional partner on a project proposal*	*2030 – Collaborate with at least 1 additional partner on a project proposal*	*2035 – Collaborate with at least 1 additional partner on a project proposal*
Agricultural Operations E4 – Targeted Outreach for Recreation Horses	*Reduce pollution from horse manure in stables and individual households*	*2022 – Develop targeted outreach campaign*	*2025 – Work with partners to disseminate materials*		
Feral Hogs 1 – Remove Feral Hogs	Implement trapping or other removal programs to remove feral hogs from the watershed to reduce pollutants and ancillary damages	2025 – Develop or augment trapping program with local partners	2030 – Expand program to additional properties	2035 — Expand program to additional properties	

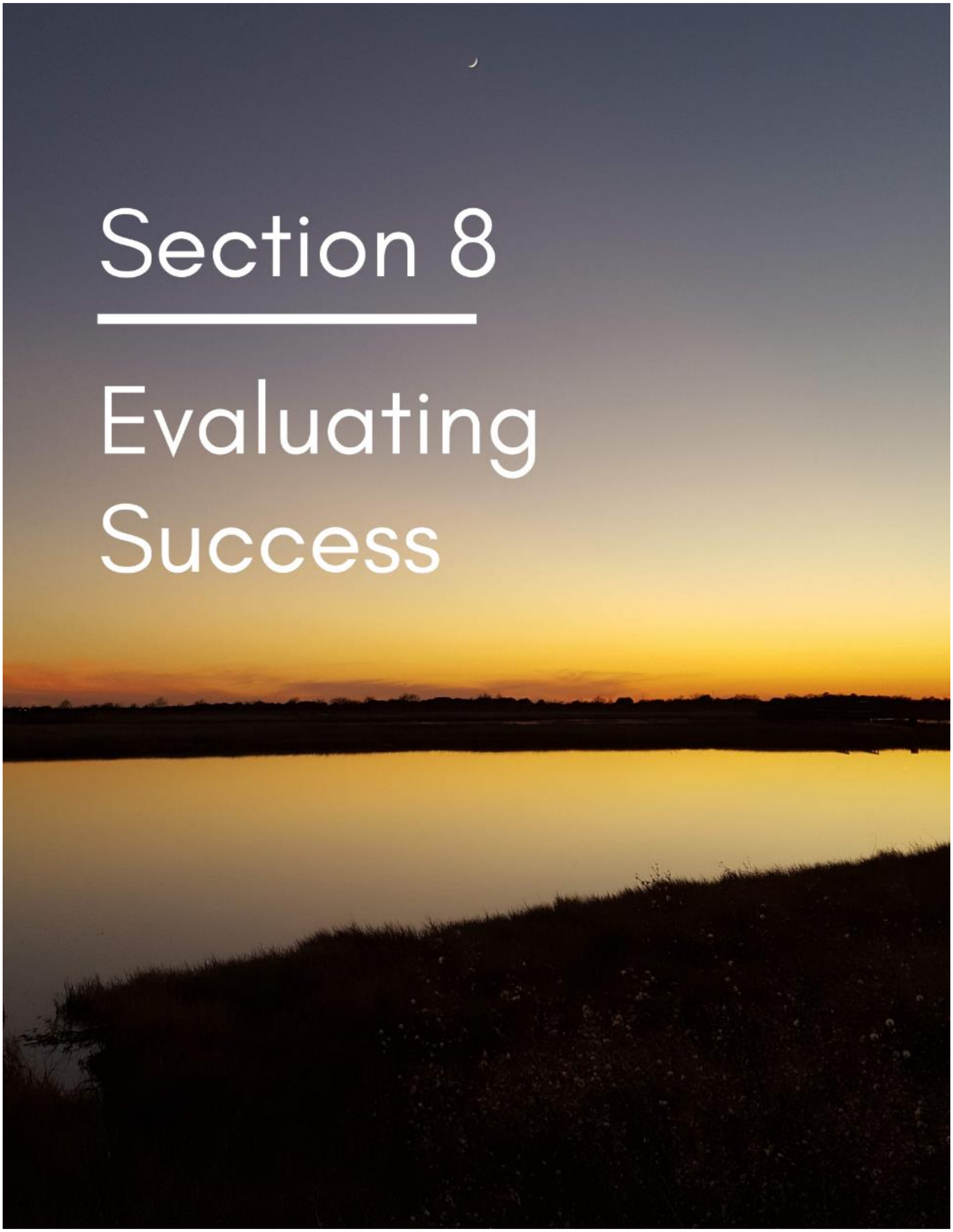
Solutions[171]	Overall Implementation Goal[172]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Feral Hogs E1 – Lone Star Healthy Streams – Workshops and Feral Hog Resource Manual	*Educate local stakeholders to promote feral hog reduction*	*2025 – First workshop has been held*	*2030 – Second workshop has been held*		
Feral Hogs E2 – Feral Hog Management Workshop	*Educate local stakeholders to promote feral hog reduction*	*2022 – First workshop has been held*	*2026 – Second workshop has been held*	*2030 – Third workshop has been held*	
Wildlife 1 – Restore Upland Habitat	Restore upland habitat to provide wildlife alternative areas and reduce concentration in riparian zones	2030 – Develop at least 1 acre or greater restoration project	2035 – Develop an additional 1+ acre restoration project		
Deer and Other Wildlife E1 – Cypress Creek Christmas Bird Count	*Participate in a citizen science effort to generate data and coordinate with other agencies, landowners, and NGOs in the watershed*	*Annual Event, ongoing through 2035*			
Conservation and Land Management 1 – Riparian Buffers	Promote riparian buffers in all land uses to reduce transmission of pollutants (in conjunction with Land Management – Voluntary Conservation)	2028 – At least 2 properties have riparian projects	2035 – At least 2 additional properties have riparian projects		
Conservation and Land Management 2 –– Voluntary Conservation	Promote voluntary conservation to reduce pollutants from developed areas	2025 – At least one 1+ acre property has a conservation project	2030 – At least 2 additional properties have conservation projects	2035 – At least 2 additional properties have conservation projects	

Solutions[171]	Overall Implementation Goal[172]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Conservation and Land Management 3 – Increase Tree Canopy	Reduce storm flow runoff and generate additional ecosystem services by expanding tree canopy in appropriate areas	2021 – Develop additional i-Tree modeling and 5-year planting priorities	2025 – Plant trees sufficient to meet the developed 5-year priority	2030 – Plant trees sufficient to meet the developed 5-year priority	2035 – Plant trees sufficient to meet the developed 5-year priority
Conservation and Land Management E1 – Promote Riparian Buffers (Tools and Workshops)	*Reduce pollutant loads by promoting riparian buffer areas*	*2025 – Hold one workshop*	*2030 – Another workshop held*	*2035 – Another workshop held*	
Conservation and Land Management E2 – Texas Watershed Stewards[175]	*Educate stakeholders on water quality/watershed issues*	*2025 – Workshop held*	*2030 – Additional workshop held*	*2035 – Additional workshop held*	
Conservation and Land Management E3 – Conservation Coordination	*Promote and help coordinate conservation efforts in the watershed*	*2021 – 2035, Partnership has been active in all appropriate conservation initiatives in the watershed*			
Illegal Dumping 1 – Report Chronic Dump Sites and Consider Increased Efficiency	Promote enforcement efforts to reduce chronic dumping sites	2022 – Identify additional dumping sites and enforcement priorities with local partners	2025 – Address at least 1 chronic site	2030 – Address at least 1 additional chronic site	2025 – Address at least 1 additional chronic site

[175] A TWS workshop was held in the watershed during the WPP development process.

Solutions[171]	Overall Implementation Goal[172]	Milestone 1	Milestone 2	Milestone 3	Milestone 4
Trash and Illegal Dumping E1 – Trash Bash Site	Reduce trash and educate participants on water quality issues	Annual Event			
Flooding 1 – Coordinate with Ongoing Flood Mitigation Efforts	Promote water quality features as supplementary elements in flood mitigation studies and projects	2021 – Identify flood mitigation priority projects for water quality enhancements	2022 through 2035 – Partnership or successor maintains a standing presence in flood mitigation projects through public processes, comments, etc.		

It should be noted that developing and ensuring funding to cover the cost of implementation activities without current funding sources is a primary challenge and focus for the successful implementation of a WPP. While the WPP recognizes the need for support from a local coordinator and local partners to identify funding resources, and emphasizes an opportunistic approach to utilizing funding sources, funding will be a primary determining factor in the pace and extent of implementation.



Section 8

Evaluating Success

8 – Evaluating Success

Evaluating Success

The WPP is designed as a roadmap for implementation, charting the course to the Partnership's water quality goals. Progress toward those end goals is measured by the observable changes in water quality in the watershed and by achieving programmatic milestones (Section 7). Water quality monitoring data and other monitoring or reported data related to water quality permits will be the primary means for measuring observable change. Records of programmatic achievements compared to established milestones will serve as a measure of the level of effort by the Partnership. These sources of data are compared to established criteria to gauge success. A key to successful implementation of this WPP is continual focus on adaptive management, in which evaluations of success are used to revise decisions for better effectiveness.

Monitoring Program

CRP partners (H-GAC, TCEQ, and others) will conduct long-term ambient surface water quality monitoring in Cypress Creek. TST volunteers are an additional source of supplemental data[176]. The Partnership will also evaluate compliance by permitted wastewater dischargers using DMR and SSO data reported to TCEQ. Special studies, including microbial source tracking or other DNA-based categorization of *E. coli* or host species, may be used to supplement these ongoing data collection efforts if the Partnership deems them necessary in the future. The combination of ambient surface water quality data, permitted discharge data, and other sources (as appropriate) will be used by the Partnership to understand the end result of WPP actions on the project waterways. Assessments will be conducted in conjunction with CRP annual reporting (Basin Highlights Report/Basin Summary Report) efforts. Formal full water quality evaluations will be conducted by the Partnership at the end of every phase of implementation (2025, 2030, and 2035) or as necessary in interim periods.

CRP Data

Ongoing monitoring in Cypress Creek and its tributaries includes eleven long-term sites (seven on Cypress Creek, and four on tributaries). All sites are monitored at least quarterly. The current sites[177] are:

Segment 1009 – Cypress Creek

- 11324, Cypress Creek near Cypresswood Drive/Old Tettar Road

[176] Stream team data will be used for qualitative assessment, and not as part of formal quantitative assessments of water quality.

[177] More information on the sites can be found at https://cms.lcra.org/seg_map.aspx?Sid=1009. The site locations are also indicated in Figure 24 of Section 3 of this document.

- **11328, Cypress Creek at I45 (Downstream Station)**
- 11330, Cypress Creek at Stuebner-Airline Road
- 11331, Cypress Creek at SH249
- **11332, Cypress Creek near Grant Road (Transitional station)**
- **20457, Cypress Creek at Katy-Hockley Road (Headwaters station)**

Segment 1009C – Faulkey Gully

- 17496, Faulkey Gully near Lakewood Forest drive

Segment 1009D – Spring Gully

- 17481, Spring Gully at Spring Creek Oaks Drive

Segment 1009E – Little Cypress Creek

- 14159, Little Cypress Creek near Kluge Road
- 20456, Little Cypress Creek at Mueschke Road

The quality-assured data from these sampling efforts are the primary means for evaluating compliance with water quality standards and will serve as the primary indicator of success under this WPP. The ambient parameters sampled are the same as to those sampled during the WPP development project.

While data from all the stations will be reviewed, the most downstream station (shown in bold above) of each of the attainment areas for this WPP[178] is the ultimate focus of evaluation. However, special attention will also be given to tributary stations to evaluate whether additional attention or modeling is needed to isolate the tributaries. Monitoring will be conducted under an approved quality assurance project plan (QAPP).

Additional Data

In addition to the CRP/TCEQ monitoring, other state, regional, and local sources will be used to evaluate specific aspects of water quality in the waterways. These sources include:

- DMR (TCEQ) – The Partnership will review outfall discharge monitoring data from WWTFs in the watershed.
- SSOs (TCEQ) – SSOs reported to TCEQ will be assessed periodically to evaluate progress in reducing this source.
- TST volunteers – TST volunteer data will be used to supplement CRP data as an indicator of change over time and site-specific areas of concern. Observations made by volunteers can provide important information on localized conditions.

[178] Indicated in Figure 55, Section 4.

The combination of these data will provide the Partnership with a robust picture of the changing health of the waterways. The ambient stations at the end of each attainment area and the WWTF permit data will be the primary point of comparison to indicators of success for the WPP.

Supporting Research

In addition to the solutions identified in Sections 5 and 6, and the implementation strategies outlined in Section 7, the Partnership identified several areas of data in which additional research was warranted to ensure informed future decisions by the Partnership. These proposed research activities may or may not be pursued by the Partnership but are identified areas of inquiry, under a future QAPP, that would benefit future WPP updates.

Wildlife Source Estimation

The current *E. coli* load totals assume a conservative additional load for Other Wildlife as a category, representing the sum of other warm-blooded animals in the watershed for which there was insufficient data. This source has been an appreciable contributor to instream loads in some other watersheds (especially in more rural areas), exceeding 40-50% in some microbial source tracking studies[179]. Absent any microbial source tracking data for the Cypress Creek Watershed, and in consideration of its more developed character, a conservative estimate of 10% of total source load in current conditions was assigned to Other Wildlife. However, additional data, in either the form of microbial source tracking information or wildlife population data estimates or established statewide wildlife loading assumptions based on land cover, could refine those estimates. This need is especially relevant given the propensity for wildlife to use stream corridors to traverse developing areas like this watershed. The Partnership will work with AgriLife, Texas A&M University and other academic institutions, and TPWD to determine the feasibility of establishing general or species-based estimates for wildlife populations not usually addressed in WPPs. The intent is to establish loading estimates for the background concentrations of fecal bacteria to ensure WPP projections are as accurate to watershed conditions as possible.

Microbial Source Tracking

Microbial source tracking (MST) (also referred to as bacterial source tracking or fecal typing in this context) is a general name for a range of methods[180] that use genetic information to

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[179] For example, the *Watershed Protection Plan for the Leon river Below Proctor Lake and Above Belton Lake* indicated that its bacterial source tracking conducted at three stations showed "…between 41 and 55 percent of bacteria sources originate from wildlife or invasive species (e.g., avian species, wild animals, and feral hogs)…". http://leonriver.tamu.edu/media/1110/final-leon-wpp.pdf. Accessed 10/12/19.

[180] For the purpose of this discussion, the term is being used to include a broad range of other assays and identification methods using genetic or species-specific markers.

identify the origins of biological pollutants present in a water body. Identification for *E. coli* is based on the presence of bacteria strains specific to different animal types. MST can help characterize uncertainties in modeling efforts (e.g., the "other wildlife" component) and give more information on what sources are represented instream, as opposed to source loads. However, MST or similar methods can have an appreciable amount of uncertainty and reflects the period of time in which samples were collected, so it should be considered in addition to other data sources. More narrowly focused approaches of testing for host-specific DNA (instead of host-specific bacterial DNA) are also used and may help overcome some uncertainties related to representativeness of *E. coli* strains across the watershed area or across time. The stakeholders recommended that source tracking or analysis of the most applicable type be employed in the Cypress Creek Watershed, with an intended focus on small areas on short time frames for purposes such as illicit discharge detection, understanding localized spikes, etc. The Partnership recognizes its potential use as a tool for guiding decisions when opportunity and resources to utilize it exist.

Hydrologic Impacts on Water Quality

Several large studies and efforts are currently evaluating various aspects of the hydrology/hydraulics of the Cypress Creek system. Additionally, there is significant investment underway and planned for flood mitigation activities that may change flow patterns in the waterway. The potential for these factors to influence water quality conditions is unknown. While flood mitigation measures are expected to have a relatively positive impact (e.g., settling of pollutants in wet bottom detention basins), water quality impacts have not been a primary focus of the ongoing efforts. The Partnership does not have a specific recommendation, other than ongoing coordination with these efforts, but expressed an interest in subsequent research that might help predict water quality impacts. H-GAC, EPA and USACE are currently involved in a WMOST modeling effort that may provide additional detail prior to, or immediately subsequent to, the approval process for this WPP. This information will help guide future decisions and WPP updates, but it is likely additional research will be needed given the scale of potential flood mitigation efforts in the watershed.

Indicators of Success

The Partnership identified key criteria for success for use in evaluating the progress of the WPP. The success indicators are used to measure the effectiveness of the implementation effort and the pace of progress (Table 42). Ultimate success in the waterways of the Cypress Creek Watershed is found in achieving the water quality goals of the stakeholders. However, the changing nature of the watershed may mask some achievements in early years, as pollutant sources continue to increase rapidly even as implementation begins. However, the future focus of the WPP takes these considerations into account. To ensure that progress can be evaluated against this background, programmatic metrics will also be used as indicators of successful progress.

Compliance with Water Quality Standards

The primary goal of the WPP is to achieve and maintain compliance with SWQSs at the attainment area stations. A secondary goal is to ensure source reduction by meeting TPDES water quality permit limits. Therefore, the primary indicators of success are:

- The status of the waterways on the most current Integrated Report, with specific focus on the SWQSs for contact recreation standard (bacteria criteria for primary contact recreation 1) and aquatic life use (DO, etc.). Success is measured by fully supporting all uses, and progress in abating concerns;
- A positive or stable trend in WWTF compliance, as indicated in the DMRs/SSOs.

While the goal of the WPP is to move water quality toward compliance, the changing nature of the watershed may mean that in interim years a reduction of projected degradation will also be considered as interim progress. Based on known development and current trends, which includes a strong impact from large, master-planned communities, growth in the Transitional and Headwaters areas is likely to continue to be strong but not necessarily linear. Large blocks of developed area can come online in shorter time frames, meaning sudden influxes of sources rather than steady growth or decline. The rapid development of the Headwaters area, especially, is likely to result in short term increases in source load that may overshadow beneficial actions in the same time frame. This dynamic environment differs from a watershed in which a similar effort each year can be expected to attain and maintain compliance. While the end goal for 2035 remains the focus of the WPP, some interim periods will be better measured by programmatic milestones or water quality change in localized areas related to implementation efforts than a broad survey instream quality.

Programmatic Achievement

The ability to maintain the Partnership, fund implementation, and put solutions in place are indicators of the success of the implementation efforts. Additional program elements include the progress partners make toward related requirements (MS4 permits, etc.). These programmatic indicators are:

- implementing solutions at a pace that is sufficient to meet interim milestones;
- a Partnership group that continues to be active and engaged in implementation; and
- acquisition of funding levels and technical resources sufficient to realize implementation goals.

Table 42 - Indicators of success

Goal	Indicator of Success	Source of Indication
Compliance with Water Quality Standards	Fully support all designated uses	CRP data; Integrated Report status
	Comply with TPDES permit limits	WWTF DRM/SSO
Implement WPP	Solutions implemented (based on implementation milestones)	Partnership records; MS4 Annual Reports; partner information
	Implementation funded sufficiently	Funding sources identified and acquired.
	Maintain Partnership	At least annual meetings held

Adaptive Management

As conditions change within the watershed, the practices and approach we use to address water quality issues must adapt. This WPP is a living document used to guide implementation of the solutions developed by local stakeholders. It is designed to be flexible to changing conditions. The WPP will engage in a process of continual review and revision called ***adaptive management*** to ensure it remains relevant to its purpose and the stakeholders' decisions. Adaptive management is a structured process by which changes in conditions and evaluation of progress and programmatic achievements are used to identify potential revisions to the WPP. Feedback on progress shapes future planning. The Partnership understands that a continual process of review and revision will be needed in the future to ensure the WPP 's success. The content and efforts of this WPP will be reviewed at several points during implementation, with the fundamental questions being as to whether the solutions are having their desired effects, and whether progress is being made on water quality standards compliance (Table 43).

Table 43 - Adaptive management process

Adaptive Management Process	
Component	Description
Ad hoc review	Each partner responsible for implementing any activity will do due diligence in evaluating the continuing effectiveness of the activity. This review happens on an informal or project-specific basis. Partners are encouraged to share any insights on what is working well or what is working poorly with the Partnership at large. Facilitation staff will talk regularly with partners to assess progress.
Annual Review	Every year the Partnership will review progress made during that year during a public meeting. The results of the annual reviews will be summarized for dissemination to the stakeholders and the WPP may be amended as needed.
Formal WPP Reviews	At least every four years [181] the Partnership will conduct a formal review and revision (as appropriate) of the WPP. This process will include at least a 30-day review period and open public meeting. The result of the review will be an amended WPP. Criteria for review will include but not be limited to: • Stakeholder feedback on implemented solutions and resources (stakeholders) • Water quality data summary of segment conditions (H-GAC or successor watershed coordinator) • Review of progress in meeting programmatic milestones • Progress in complementary efforts (MS4 permits, etc.)
Continuity Review	Two years prior to 2035, the Partnership will discuss during its Annual Review, how it will plan for the next period of implementation (if needed). At this time, the Partnership will identify any modeling, data analysis and collection, or other information needed to make further projections for future implementation periods.

[181] Corresponding to the implementation phases of early (2021-2025), middle (2025-2030) and late (2030-2035) implementation. Some partners use different planning cycles. The 4-year milestone is a minimum.


Appendices

Appendix A – WPP Information Checklist

Table A.1 - Guide to WPP information

Name of Water Body	Cypress Creek (Segment 1009)
Assessment Units	1009_01, 1009_02, 1009_03, 1009_04, 1009A_01. 1009A_02, 1009B_01, 1009C_01, 1009D_01, 1009D_02, 1009E_01, 1009F_01, 1009G_01, 1009G_02
Impairments addressed	Contact recreation / *E. coli*
Concerns addressed	Nitrate, Total Phosphorus, Habitat, Dissolved Oxygen (grab), Ammonia, Chlorophyll-a

Element[182]	Report Section(s) and Page Number(s)
Element A: Identification of Causes and Sources	
1. Sources Identified, described, and mapped	Section 3 • pp. 38-61; water quality analysis and point source contribution descriptions; • pp. 62-99; formal source descriptions, modeled loadings, and maps of spatial distribution.
2. Subwatershed sources	Section 3 • pp. 62-99; sources are described in terms of their general spatial distribution and loads by subwatersheds. • Tables 26 and 27 summarize all loadings by subwatersheds.

[182] These elements correspond to the 9 minimum elements required by EPA for developing watershed-based plans using Clean Water Act 319(h) grant resources. For more information on these guidelines, please refer to EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* at https://www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters

Element	Report Section(s) and Page Number(s)
3. Data sources are accurate and verifiable	Section 2 • In general, data used for characterization and mapping is discussed throughout with footnote links to specific sources. • P. 35; description of water quality data and links to the project water quality report. Section 3 • Pp. 42-61; discussion of water quality monitoring analyses, point source data analyses, and data sources. • Pp. 62-99; description of sources and loadings with references to data used. Section 4 • Pp. 102-109; description of LDCs and data sources. • Pp. 109-120; application of data sources to load reduction goals discussed. Section 8, Pp. 202-208; discussion of data sources to be used for evaluating success.
4. Data gaps identified	Section 3, Discussion of uncertainty in various modeling and data approaches (pp. 49,51 for WWTF data; pp.68-69, 94, 98 and footnote 63 for SELECT modeling; pp. 74 for SSO data; pg. 109-110 for DO precursors.) Section 8, Pp. 203-208, Specific discussion of additional data sources that may be helpful (other wildlife estimations, BST/MST, etc.)
Element B: Expected Load Reductions	
1. Load reductions achieve environmental goal	Section 4 • Pp. 109-120; description of linkage of environmental goal (via LDC reductions) to source loads (via SELECT estimations); • Summarized specifically in Tables 32-35.

Element	Report Section(s) and Page Number(s)
2. Load reductions linked to sources	Section 4 • Pp. 109-120; description of linkage of environmental goal (via LDC reductions) to source loads (via SELECT estimations); • Summarized specifically in Tables 32-35.
3. Model complexity is appropriate	Section 3 • Pp. 62-69; description of modeling approach (p. 66-69 specific to SELECT); link to project modeling report; p. 68 contains specific description of rationale for modeling approach. • Results of modeling indicated above in B1/B2. Section 4 • Pp. 102-108; description of LDC modeling approach. • Pp. 111-113; description of LDC and SELECT linkage.
4. Basis of effectiveness estimates explained	Section 4, Pp. 117-119; description of use of representative units Section 5, Pp. 125-163; BMP effectiveness/reduction efficiency discussed in the bottom of each recommended solution page.
5. Methods and data cited and verifiable	Section 3, Throughout (pp. 38-99); data and methods for water quality analyses, point source analyses, and source estimations discussed with references in footnotes as appropriate and links to project modeling and water quality analysis reports. Section 4, Throughout (pp. 101-119); data for load reduction goals discussed, links to project modeling report included.

Element	Report Section(s) and Page Number(s)
Element C: Management Measures Identified	
1. Specific management measures are identified	Section 5, pp. 120-163; specific measures described, including technical and financial support needed, roles and responsibilities, etc. Section 6, pp. 165-177; specific educational measures described, including responsible parties.
2. Priority areas	Section 5, As described in B1, priority areas for each category of recommendations specific focus areas (e.g., p. 124) Section 6, Pp. 165-177; general description of intended audiences/areas for educational activities.
3. Measure selection rationale documented	Section 5 • Pp. 122-124; specific description of guiding principles for selection and selection process. • Pg. 163; summary of selection process and intention. Section 6, Pp. 165-170; description of Partnership's goals for selected educational measures.

Element	Report Section(s) and Page Number(s)
4. Technically sound	Section 5, pp. 120-163; specific measures described, including technical detail. Section 6, pp. 165-177; specific educational measures described. Section 7, pp. 179-182; specific implementation strategies for measures in general, and pet waste as a focus.
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	Section 5, pp. 124-162; technical assistance needs detailed for each measure in their one-page summary.
2. Estimate of financial assistance	Section 5 • pp. 124-162; financial assistance needs detailed for each measure in their one-page summary. • Appendix D – list of potential funding sources related to measures in this WPP.
Element E: Education/Outreach	
1. Public education/information	Section 6, pp. 165-177; description of public outreach activities.
2. All relevant stakeholders are identified in outreach process	Section 1, pp. 4-8; description of initial outreach, forming the Partnership, links to Public Participation Plan for the project. Section 6 , pp. 165-177; description of public outreach activities including existing partners/roles and focus areas.
3. Stakeholder outreach	Section 1, pp. 4-8; description of initial outreach, forming the Partnership, links to Public Participation Plan and Stakeholder Outreach Report for the project.

Element	Report Section(s) and Page Number(s)
4. Public participation in plan development	Section 1 • pp. 4-8; description of initial outreach, forming the Partnership, links to Public Participation Plan and Stakeholder Outreach Report for the project. Section 3 • pp. 41-43; description of Partnership process in identifying sources and assumptions (specific to each source, pp. 62-100) Section 4 • pp. 109-119; description of stakeholder choices in reduction linkage, load allocation, etc. Section 5 • pp. 122-124; description of stakeholder participation in measures selection. Section 6 • pp. 165-167; description of stakeholder decisions on outreach strategies. Section 7 • pp. 179-183; description of stakeholder input on implementation strategies. Section 8 • pp. 201-205; description of the Partnership's role in determining how the project evaluates success.

Element	Report Section(s) and Page Number(s)
5. Emphasis on achieving water quality standards	Section 1 • pp. 6-7; description of specific water quality goals for project/Partnership. • All Other Sections – water quality standards are the focus of water quality analyses (Section 3); the focus of all load reduction calculations (Section 4); the focus of recommended solutions (Section 5 and 6); the focus of implementation strategies (Section 7); and the primary measure of success (Section 8, pp. 201-206)
6. Operation and maintenance of BMPs	Section 5, pp. 120-163; discussion of specifics of recommended solutions are included with each solution and/or solution category description.
Element F: Implementation Schedule	
1. Includes completion dates	Section 7, pp. 183-188; implementation schedule.
2. Schedule is appropriate	Section 7, pp. 183-188; implementation schedule.
Element G: Milestones	
1. Milestones are measurable and attainable	Section 7, pp. 188-199; Milestones described for all measures.
2. Milestones include completion dates	Section 7, pp. 188-199; Milestones described for all measures.
3. Progress evaluation and course correction	Section 8, pp. 201-207; describes all methods uses to evaluate success for the project (pp. 206-208 specifically describes adaptive management processes.)
4. Milestones linked to schedule	Section 7, pp. 188-199; Milestones described for all measures with timeframes indicated.
Element H: Load Reduction Criteria	
1. Criteria are measurable and quantifiable	Several sections detail the process of developing load reductions, including (as noted in Element B) Section 3 (source loads), Section 4 (load reductions), and Section 8 (evaluation criteria).
2. Criteria measure progress toward load reduction goal	Section 8, pp. 201-207; describes evaluation criteria and data sources used to evaluate both water quality and programmatic milestones.

Element	Report Section(s) and Page Number(s)
3. Data and models identified	Section 8, pp. 201-207; describes evaluation criteria and data sources used to evaluate both water quality and programmatic milestones.
4. Target achievement dates for reduction	Throughout the document, the plan states that 2035 is the intended goal year (as noted previously). Section 4 bases load reductions on this timeline. Section 5/6 recommendations are based on time period within this planning horizon. Section 7 schedule and milestones are based on this period (pp. 184-199). Section 8 evaluation criteria also assumes this date (pp. 201-207)
5. Review of progress toward goals	Section 8 details the methods that will be used to evaluate progress, including water quality (pp. 201-205) and programmatic means (pp. 206-208)
6. Criteria for revision	Section 8 describes the indicators of success and adaptive management process (pp. 204-207)
7. Adaptive management	Section 8 describes the adaptive management process (pp. 206-207)
Element I: Monitoring	
1. Description of how monitoring used to evaluate implementation	Section 8, pp. 201-204 describes the monitoring plan and other potential data sources.
2. Monitoring measures evaluation criteria	Section 8, pp. 204-206 describes the indicators of success, including water quality/monitoring outcomes.
3. Routine reporting of progress and methods	Section 8, pp. 201-207, describes both the monitoring process and its reporting/evaluation, as well as the project evaluation and formal reviews process with the Partnership (Table 43, etc.)
4. Parameters are appropriate	Section 8, pp. 201-203 describes the monitoring program.
5. Number of sites is adequate	Section 8, pp. 201-203 describes the monitoring program.
6. Frequency of sampling is adequate	Section 8, pp. 201-203 describes the monitoring program.
7. Monitoring tied to QAPP	Section 8, pp. 201-203 describes the monitoring program, under CRP QAPP. Pp. 202-204 describes the potential use of other data sources.
8. Can link implementation to improved water quality	Section 8, pp. 201-203 discusses the monitoring program; pp. 204-206 discussed water quality indicators of success.

Appendix B – Wastewater Treatment Facilities

These Cypress Creek Watershed WWTFs have current permits with TCEQ. Permits and permittees in italics are pending permits that are expected to be active in the near future.

Table B.1 - WWTF permittees

Permittee	Permit Number
Vls Recovery Services LLC	WQ0003627000
Dxc Technology Services LLC	WQ0004879000
Goodman Manufacturing Company LP	WQ0005185000
Northwest Airport Management LP	WQ0005256000
City of Waller	WQ0010310001
Harris County FWSD 52	WQ0010528001
Inverness Forest Improvement District	WQ0010783001
Harris County WCID 116	WQ0010955001
Harris County WCID 113	WQ0010962001
Harris County WCID 119	WQ0011024001
Memorial Hills UD	WQ0011044001
Ponderosa Joint Powers Agency	WQ0011081001
Lake Forest Plant Advisory Council	WQ0011084001
Prestonwood Forest Utility District	WQ0011089001
Bammel UD	WQ0011105001
Treschwig Joint Powers Board	WQ0011141001
Timber Lane Utility District	WQ0011142002
Meadowhill Regional MUD	WQ0011215001
CNP Utility District	WQ0011239001
Timberlake Improvement District	WQ0011267001
Aqua Texas Inc	WQ0011314001
Cypress-Klein UD	WQ0011366001
Kleinwood Joint Powers Board	WQ0011409001
Charterwood MUD	WQ0011410002
Harris County WCID 99	WQ0011444001
Hunters Glen MUD	WQ0011618003
Boys and Girls Country of Houston Inc	WQ0011814001
Northwest Harris Co MUD 5	WQ0011824002
Northwest Harris Co MUD 5	WQ0011824003
Faulkey Gully MUD	WQ0011832001
Bridgestone MUD	WQ0011835001
North Park PUD	WQ0011855001
Clp Splashtown LLC	WQ0011886001
Tilles, Tina Lee	WQ0011900001
Northwest Harris County MUD 10	WQ0011912002

Permittee	Permit Number
Northwest Freeway MUD	WQ0011913001
Harris County MUD No 104	WQ0011925001
Woodcreek MUD	WQ0011933001
Northwest Harris County MUD No 15	WQ0011939001
Harris County MUD 58	WQ0011941001
Harris County WCID 110	WQ0011964001
Tower Oak Bend WSC	WQ0011986001
Harris County MUD 24	WQ0011988001
Harris County MUD 24	WQ0011988002
Harris County MUD 24	WQ0011988003
Bilma PUD	WQ0012025002
Klein ISD	WQ0012224001
Harris County MUD 36	WQ0012239001
UQ Holdings 1994-5 LP	WQ0012248001
Cypress Hill MUD 1	WQ0012327001
Richey Road MUD	WQ0012378002
Harris County MUD No 221	WQ0012470001
Spring West MUD	WQ0012579001
Elite Computer Consultants LP	WQ0012600001
Harris County Utility Dist. No 16	WQ0012614001
Champs Water Co	WQ0012730001
Harris County MUD 230	WQ0012877001
Harris County MUD 286	WQ0013020001
Kwik-Kopy Corp	WQ0013059001
Northwest Harris County MUD 32	WQ0013152001
Harris County MUD 358	WQ0013296002
Millenium Rail Inc	WQ0013472001
Golden State Holdings Inc	WQ0013569001
Northwest Harris County MUD No 36	WQ0013573001
Northwest Harris County MUD No 20	WQ0013625001
Spring Cypress Water Supply Corporation	*WQ0013711002*
Harris County MUD 360	WQ0013753001
Harris County MUD 249	WQ0013765001
Quadvest LP	WQ0013819001
Harris County MUD 383	WQ0013875002
Harris County MUD No 365	WQ0013881001
Dia-Den Ltd	WQ0013893001
Harris County MUD 371	WQ0014028001
Northwest Harris County MUD 9	WQ0014030001
Aqua Texas Inc	WQ0014032001

Permittee	Permit Number
Aqua Texas Inc	WQ0014106001
Utilities Investment Co Inc	WQ0014172001
Foley Kennard Tom	WQ0014193001
Harris County MUD No 391	WQ0014327001
Harris County MUD 374	WQ0014354001
Quadvest LP	WQ0014434001
Harris County MUD No 389	WQ0014441001
Harris County MUD No 405	WQ0014448001
Harris County MUD No 418	WQ0014476001
Harris County MUD No 434	WQ0014576001
Northwest Harris Co MUD No 10	WQ0014643001
Quadvest LP	WQ0014675001
290 Wr Holdings LP	WQ0014799001
Barker Utilities GP LLC	WQ0014828001
Cw-Mhp Ltd	WQ0014886001
Huffsmith-Kohrville Inc.	WQ0014923001
South Central Water Co	WQ0014924001
Harris Co MUD Dist. No 500	WQ0014936001
M&D Development LLC	WQ0015090001
Grant Road PUD	WQ0015098001
Harris County MUD 530	WQ0015139001
Harris County MUD No 531	WQ0015218001
Cypress 600 Dev Partners LP	WQ0015231001
Bethesda Lutheran Communities Inc	WQ0015244001
Quadvest LP	WQ0015336001
Goodman Manufacturing Company LP	WQ0015344001
Nantucket Housing LLC	WQ0015381001
Texas Providence Investments LLC	WQ0015460001
290 Kickapoo Development Inc	WQ0015483001
Dunham Pointe Development LLC	WQ0015490001
Grand Northwest MUD	WQ0015537001
SSPS Properties LLC	WQ0015578001
Harris County MUD No 418	WQ0015596001
Mcalister Opportunity Fund 2012 LP	WQ0015644001
Friendswood Development Co LLC	WQ0015683001
Golden Shamrock Realty Inc	WQ0015745001
Humble Joint Venture 1 LLC	WQ0015746001
Mcnabb Utilities LLC	*WQ0015765001*
93 Schiel Road Ltd	WQ0015779001
Harris County MUD 43	*WQ0015783001*

Appendix C – Typical Agricultural Best Management Practices

This appendix details the typical practices implemented in WQMPs and similar agricultural land management projects. Emphasis for this WPP is put on practices that reduce animal wastes or impede transmission of wastes to water.

Practice	Description
Residue Management	Management of the residual material left on the soil surface of cropland, to reduce nutrient and sediment loss through wind and water erosion.
Critical Area Planting	Establishes permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical, or biological conditions that prevent the establishment of vegetation with normal practices.
Filter Strips	Establishes a strip or area of herbaceous vegetation between agricultural lands and environmentally sensitive areas to reduce pollutant loading in runoff.
Nutrient Management	Manages the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments to minimize agricultural nonpoint source pollution of surface and groundwater resources.
Riparian Forest Buffers	Establishes an area dominated by trees and shrubs located adjacent to and up-gradient from watercourses to reduce excess amounts of sediment, organic material, nutrients, and pesticides in surface runoff and excess nutrients and other chemicals in shallow groundwater flow.
Terraces	Used to reduce sheet and rill erosion, prevent gully development, reduce sediment pollution/loss, and retain runoff for moisture conservation.
Grassed Waterways	Natural or constructed channel-shaped or graded and established with suitable vegetation to protect and improve water quality.
Prescribed Grazing	Manages the controlled harvest of vegetation with grazing animals to improve or maintain the desired species composition and vigor of plant communities through adaptive multi-paddock grazing and other techniques.

Practice	Description
Riparian Herbaceous Buffers	Establishes an area of grasses, grass-like plants, and forbs along watercourses to improve and protect water quality by reducing sediment and other pollutants in runoff, as well as nutrients and chemicals in shallow groundwater.
Watering Facilities	Places a device (tank, trough, or other water-tight container) that provides animal access to water and protects streams, ponds, and water supplies from contamination through alternative access to water.
Field Borders	Establishes a strip of permanent vegetation at the edge or around the perimeter of a field.
Conservation Cover	Establishes permanent vegetative cover to protect soil and water.
Stream Crossings	Creates a stabilized area or structure constructed across a stream to provide a travel way for people, livestock, equipment, or vehicles, improving water quality by reducing sediment, nutrient, organic, and inorganic loading of the stream.
Alternative Shade	Creation of shade reduces time spent loafing in streams and riparian areas, thus reducing pollutant loading and erosion of riparian areas.

Technicians work with local landowners/producers to design WQMPs on a site-specific basis. More information about WQMPs, standard practices, and related TSSWCB programs can be found at https://www.tsswcb.texas.gov/programs/water-quality-management-plan.

Appendix D – Potential Funding Resources

This appendix contains examples of funding resources, by category, that may be utilized to implement aspects of this WPP's recommendations. These resources represent potential external sources of funding other than existing or local contributions (ad valorem tax revenue, landowner contributions, etc.). The Partnership will continue to track, evaluate, and match grant sources for potential implementation activities as part of the ongoing facilitation of this WPP.

Grant Program	Grantor	Uses
Clean Water Act 319(h) Nonpoint Source grants	TCEQ, TSSWCB	Multiple implementation and outreach activities
Clean Water Act 604(b) water quality management planning grants	TCEQ	Data development, forestry outreach
Flood Infrastructure Fund / Flood Mitigation Assistance Program	TWDB	Flood mitigation, resilience
Clean Water State Revolving Fund	TWDB	Utility infrastructure, related planning
Community Development Block Grant (MIT/DR)	GLO/HUD	Flood mitigation, resilience
Private Foundation Grants	Private Foundations (e.g., Houston Endowment, Hershey Foundation, Powell Foundation, and others)	Multiple, specific to foundations
Various grant programs	TPWD	Wildlife, parks and recreation, farm and ranchland preservation, trails
Building Resilient Infrastructure and Communities (BRIC)	FEMA/Texas Division of Emergency Management	Disaster resilience
WQMP	TSSWCB	Agricultural best practices
Regional Conservation Partnership Program (RCPP)	USDA NRCS	Conservation
H-GAC OSSF SEP	TCEQ/WWTFs; Harris County	OSSF remediation for low income households
Restoring America's Wildlife Act	TPWD	Federal support for ecosystem restoration and related projects.
Farm Bill Programs (EQIP, and others)	USDA NRCS, local SWCDs	Landowner support for property improvements with environmental benefits, including conservation easements, forest reserves, watershed protection, wetland mitigation, water quality, etc.

Corporate donations	Corporate partners	Varies by entity
Land and Water Conservation Fund	US Forest Service	Conservation
Various grant programs	US Fish and Wildlife Service	Conservation, habitat restoration, wetlands restoration, endangered species
Various grant programs	National Park Service	Outdoor recreation, conservation
Various other grant programs	EPA	Coastal watersheds/estuaries, brownfields, clean water
Wetland and Stream Mitigation Banks	USACE	Wetland and stream mitigation banking
Deepwater Horizon/RESTORE Act Settlement funds	Gulf Coast Ecosystem Restoration Trust Fund, State of Texas (representative)	Conservation, restoration, resilience