A Watershed Protection Plan for the Clear Creek Watershed

Galveston Bay Estuary Program
A PROGRAM OF TCEQ

Clear Creek
Watershed Partnership

Houston-Galveston Area Council

Texas Commission on Environmental Quality

EPA
United States Environmental Protection Agency

Clear Creek Watershed Protection Plan

Developed for Clear Creek, Segments 1101 (Clear Creek Tidal) and 1102 (Clear Creek Above Tidal) of the San Jacinto-Brazos Coastal Basin, by the Houston-Galveston Area Council on behalf of the Clear Creek Watershed Partnership.

April 2024

Water Body	Segment	Assessment Units
Clear Creek Tidal	1101	01, 02, 03, 04
Magnolia Creek	1101A	01
Chigger Creek	1101B	01, 02
Cow Bayou	1101C	01
Robinson Bayou	1101D	01, 02
Unnamed Tributary	1101E	01
Unnamed Tributary	1101F	01
Clear Bayou Above Tidal	1102	01, 02, 03, 04, 05
Cowart Creek	1102A	01, 02
Mary's Creek	1102B	01
Hickory Slough	1102C	01
Turkey Creek	1102D	01
Mud Gully	1102E	01
Mary's Creek Bypass	1102F	01
Unnamed Tributary of Mary's Creek	1102G	01

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Steering Committee

The Clear 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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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

Texas Commission on Environmental Quality

Texas Master Naturalists

Technical Advisors, continued.

Harris County Soil and Water Conservation District

Houston-Galveston Area Council Clean Rivers Program

NASA Clear Lake

Navasota Soil and Water Conservation District

Texas A&M Forest Service

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

Texas Parks and Wildlife Department

Texas State Soil and Water Conservation Board

Texas Stream Team

U.S. Army Corps of Engineers

USDA Natural Resources Conservation Service

USDA U.S. Forest Service

Local Stakeholders

The Partnership wishes to especially thank both the local organizations and other 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.

Sunset at El Franco Lee Park

Contents

Acronyms that appear in the Tables of Contents, Tables, and Figures are defined in the Abbreviations List on pages xii-xiv.

Figures

Tables

Abbreviations List

AgriLife Extension	Texas A&M University AgriLife Extension
AU	Assessment Unit
BIG	Bacteria Implementation Group
BMP	Best Management Practice
BST	Bacteria Source Tracking (*see also, MST*)
CAFO	Concentrated Animal Feeding Operation
$CBOD_5$	Carbonaceous Biochemical Oxygen Demand, 5-day
CFU	Colony Forming Unit(s)
CN	Concern for near nonattainment
CRP	Clean Rivers Program
CS	Concern for screening level
CTA	Conservation Technical Assistance
CWA	Clean Water Act
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EQIP	Environmental Quality Incentive Program
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FOG	Fats, Oils, and Grease
GBEP	Galveston Bay Estuary Program
GIS	Geographic Information System
GLO	Texas General Land Office
HCFCD	Harris County Flood Control District
H-GAC	Houston-Galveston Area Council
HHW	Household Hazardous Waste
HOA	Homeowners Association
HUD	United States Department of Housing and Urban Development
I-Plan	(TMDL) Implementation Plan

Texas Integrated Report	*Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)*
LDC	Load Duration Curve
LID	Low Impact Development
LLC	Limited Liability Corporation
MGD	Million Gallons per Day
mL	Milliliters
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
MUD	Municipal Utility District
NASS	National Agricultural Statistics Service
NGO	Non-governmental Organization
NH3-N	Nitrate Nitrogen
NHD+	National Hydrography Dataset Plus
NRCS	(USDA) Natural Resources Conservation Service
OSSF	On-Site Sewage Facility
Partnership	Clear Creek Watershed Partnership
PCB	Polychlorinated Biphenyls
POA	Property Owners Association
QAPP	Quality Assurance Project Plan
RMU	Resource Management Unit
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental Environmental Project
SH	State Highway
SPCA	Society for the Prevention of Cruelty to Animals
SSO	Sanitary Sewer Overflow
SWCD	Soil and Water Conservation District
SWQS	Surface Water Quality Standards
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
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
TWDB	Texas Water Development Board
TWON	Texas Well Owner Network
TWRI	Texas Water Resources Institute
USACE	United States Army Corps of Engineers (Galveston)
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WCID	Water Control and Improvement District
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility

Supporting Documents

Several supporting documents providing additional detail about the analyses and processes the Partnership undertook to develop this watershed protection plan are hosted on the project website[1]. 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.
- **Public Participation Plan** – the planned methods and avenues for engaging stakeholders to raise awareness and seek input on the planning effort.
- **Water Quality Data Collection and Trends Analysis Summary Report** – a detailed report on analyses 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, implementation, and results of the bacteria modeling efforts.

[1] Visit http://www.clearcreekpartnership.weebly.com to lean more.

Executive Summary

The Clear Creek Watershed

Clear Creek drains portions of Fort Bend, Brazoria, Galveston, and Harris Counties as it flows east toward its eventual confluence with Clear Lake. The creek connects many local communities across a diverse landscape of remnant undeveloped areas and the developed land uses that constitute most of its watershed. Approximately 172 square miles of land area drain into 412 linear miles of stream network within the Clear Creek watershed (Figure 1), including two primary segments, 1101 (Clear Creek Tidal) and 1102 (Clear Creek Above Tidal). This area and its waterways represent an essential part of supporting local communities and economies, recreation, fisheries, and a diverse ecology. Additionally, the waterway is a primary focus for flood mitigation efforts for over 450,000 residents that call its watershed home.

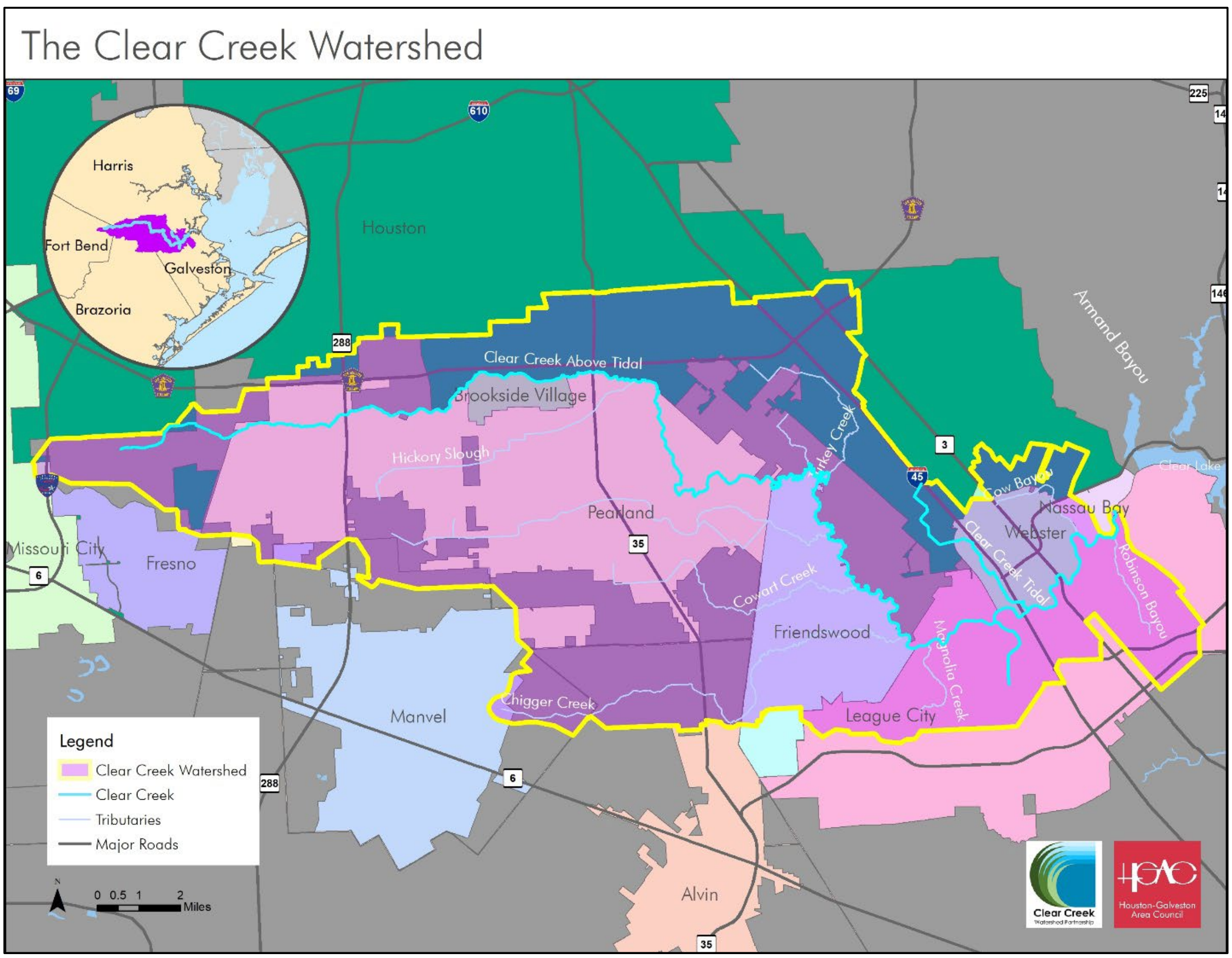

Figure 1 - The Clear Creek Watershed

Water Quality Challenges

Water quality issues, primarily high levels of fecal waste indicated by the presence of the indicator bacteria *Escherichia coli* (*E. coli*) in the Above Tidal Segment (1102) and Enterococcus in the Tidal Segment (1101), are prevalent throughout the Clear Creek watershed. Elevated levels of fecal waste in area waterways can be a result of both human activities, such as overflow from sanitary sewers, on-site sewage facilities, pet waste, and fertilizer runoff; as well as natural influences like waste from native wildlife and invasive species. Harmful pathogens associated with fecal waste can impact public health. The threat to human health is of particular concern in this densely developed watershed and popular recreation area. In addition to water quality issues related to fecal waste, Clear Creek and its tributaries face other water quality concerns like low levels of dissolved oxygen, which can endanger aquatic life, and excess nutrients (nitrogen and phosphorus compounds) which can exacerbate low dissolved oxygen levels. Other challenges noted by area stakeholders include increased sedimentation and trash, and flooding.

Water quality is sampled in both segments of Clear Creek and their tributaries at least quarterly at 17 active monitoring stations, providing the basis for assessing the health of the system. As in past years, the *2022 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)* (2022 Texas Integrated Report; a summary of water quality in Texas waterways) indicates that Clear Creek has a primary contact recreation impairment due to levels of *E. coli* that exceed the state water quality standard. Many tributaries to both of Clear Creek's segments are also unable to meet the contact recreation standard. The 2022 Texas Integrated Report also indicated concerns for low levels of dissolved oxygen in Clear Creek Above Tidal, and various tributaries of both segments. Concerns for high nutrient concentrations were observed in many waterways throughout the system. Other water quality issues of note in the 2022 Texas Integrated Report include impairments for PCBs and Dioxins in edible fish tissue[2] in the tidal segment, and a concern for impaired habitat in one area of the above tidal segment.

The sources of water quality concerns and impairments in this watershed are widespread, diffuse, and diverse in origin, making them more difficult to address through traditional approaches focusing on single permitted entities with single discrete sources and regulation. While the watershed is relatively developed, pollutant sources related to human activity will continue to increase as area growth drives future development in the watershed, exacerbating the existing situation. Watershed Protection Plan (WPP) project estimates indicate that necessary reductions of fecal bacteria loads currently range from 24.5% to

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[2] PCB and Dioxin impairments are included due to the connection of the Tidal Segment to Clear Lake/Galveston Bay. These legacy pollutants are not the focus of this planning effort.

84.8% in different areas of the watershed. With continued development and no intervention, these reductions would increase through 2035, the target year for this planning effort.

Local concerns over the current status and future of Clear Creek led to the development of this WPP as a voluntary, locally led approach to improving water quality for this area. The Houston-Galveston Area Council (H-GAC) and the Texas Commission on Environmental Quality (TCEQ) facilitated the formation and efforts of the Clear Creek Watershed 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 make informed 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 fishing. 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 will utilize adaptive management to modify approaches to meet new challenges and changing conditions. The table on the following page is a guide to the contents of the WPP. Additional information can be found in Appendix A.

This WPP will help frame the conversation about Clear Creek's future.

Watershed Protection Plan Content Guide

WPP Section	Description	EPA Element	Location
Section 1 – Project Background	An introduction to the watershed planning process for Clear Creek	NA	pp. 1-7
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. 8-35
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. 36-96, Appendix B, Appendix C
Section 4 – Improving Water Quality	Establishing the amount of reduction in pollutant source loads needed to achieve water quality goals	• Element B – Estimate of load reductions	pp. 97-115
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. 116-156, Appendix D, Appendix E
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. 157-169
Section 7 – Implementation	The schedules for implementation, and measurable milestones for tracking progress	• Element F – Schedule for implementation • Element G – Interim measurable milestones	pp. 170-188
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.189-196

Section 1:

Project Background

Section 1. Project Background

Background

The Clear Creek Watershed Partnership (Partnership) developed this watershed protection plan (WPP) to address water quality issues in Clear 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 2[3]).

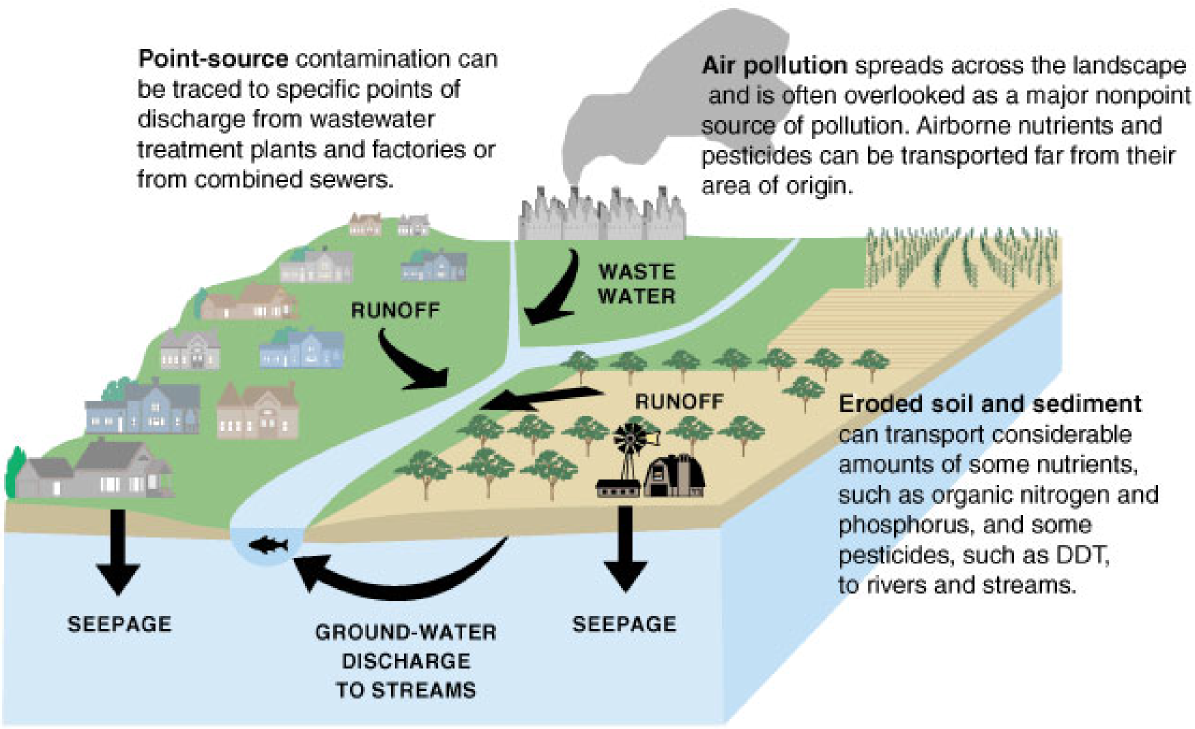

Figure 2 - Pollution sources in a watershed

[3] Image courtesy of United States Geological Survey (USGS)

Because watersheds are determined by the topography of the land rather than political boundaries, they often cross multiple political jurisdictions. Water is not bound by political geography; contaminants in the water can travel freely across borders. Pollution entering the waterway in one part of the watershed can impact other areas downstream. This fundamental aspect of watersheds limits the ability of individual political entities to fully address sources of contamination in the 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 include:

- Reflecting the connection between land and water,
- Coordinating multi-jurisdictional efforts to focus on shared priorities, and
- Helping 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, approved WPPs follow the United States Environmental Protection Agency's (EPA) nine element model[4], 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[5]. 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. **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

[4] 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

[5] 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).

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 the 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.

A Watershed Protection Plan for Clear Creek

Water quality issues in the Clear Creek system (composed of Segments 1101-Tidal, 1102-Above Tidal, and their respective tributaries) and local concern over their impact on communities in the watershed were the impetus for undertaking a watershed-based plan. Portions of this watershed were previously evaluated as part of a Total Maximum Daily Load (TMDL) study[6] specifically for fecal bacteria included in the broader Bacteria Implementation Group (BIG) effort. However, these evaluations only considered fecal bacteria, and the implementation plan is not specific to Clear Creek. The desire to evaluate these areas on a local level for Clear Creek, and to consider other local concerns, led to the formation of the Partnership in 2022. The WPP model was chosen for its ability to address other local concerns in addition to surface water quality standard (SWQS) impairments and for its voluntary nature. Additionally, the intent to coordinate water quality issues with community concerns about hydrologic issues were at the forefront of local considerations.

The Clear 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, and with additional funding from the Galveston Bay Estuary Program of the TCEQ. 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 H-GAC, TCEQ and 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

[6] More information about the TMDL study for Clear Creek can be found at https://www.h-gac.com/bacteria-implementation-group/studies/clear-creek, and more information about current efforts to address water quality issues over a broader area that included Clear Creek can be found at https://www.h-gac.com/bacteria-implementation-group.

analysis. The Partnership held seven full Partnership meetings and two sets of topical Work Group meetings between March 2022 and January 2023 to discuss and provide feedback on a variety of water quality issues (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 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[7]. Topical Work Group meetings were held as needed throughout the project to allow for detailed conversation on specific topics. Work Groups made recommendations to the full Partnership for items that required more detailed knowledge or deeper deliberation.

Table 1 - Meetings of the Clear Creek Watershed Partnership

Date	Meeting Type	Topics
March 3, 2022 (afternoon)	Partnership	Project introduction, water quality data review, and invitation to nominate Steering Committee
March 3, 2022 (evening)	Partnership	Project introduction, water quality data review, and invitation to nominate Steering Committee
April 27, 2022	Partnership	Steering Committee formation, water quality analysis discussion
July 15, 2022	Partnership	Discussion of modeling, project update
September 21 , 2022	Work Groups • Human Sources & Pet Waste • Agriculture, Wildlife & Invasives	Review of water quality modeling and preliminary discussions of solutions.
September 28, 2022	Partnership	Discussion of Work Group recommendations, further discussion of bacteria modeling
December 15, 2022	Partnership	Preliminary approval of modeling results, beginning of solutions discussion.
January 18, 2023	Work Groups • Human Sources & Pet Waste • Agriculture, Wildlife & Invasives	Continued discussion on solutions.
January 25, 2023	Partnership	Approval of preliminary set of solutions, discussion of next steps and logistics.

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 served as non-voting technical advisors who helped provide expert knowledge and

[7] The Public Participation Plan is available online at: https://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/clear_creek_watershed_ppp_final.pdf

guidance to support the Partnership and coordinate its efforts with other local projects. Project staff further supported the efforts of the Partnership by engaging the public at local outreach events throughout the project, and holding several project-oriented training sessions, including a Texas Stream Team volunteer monitoring training (on 6/18/22) and a Texas Watershed Stewards training (on 4/5/22).

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 goals, 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 10–12-year window (although projections through 2050 were completed). 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 are indicators of fecal wastes and are measured by the bacteria indicator species *Escherichia coli* (*E. coli*)[8] in Segment 1102 and Enterococcus in Segment 1101. Fecal waste pathogens 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 priority goal of the WPP is to reduce both *E. coli* and Enterococcus geomeans to at or below the contact recreation standard (primary contact recreation 1).** This goal involves identifying and quantifying causes and sources of fecal waste and developing recommended best practices sufficient to meet modeled reduction goals.
- *Improve dissolved oxygen* — Adequate dissolved oxygen (DO) levels are important for maintaining aquatic communities. The goal is to recommend solutions to improve DO levels, to the greatest extent practicable to coincide with solutions to address fecal waste.

[8] 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*.

- *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 riverine numeric water quality standards associated with them though they may lead to a DO impairment. Efforts to reduce nutrients are not modeled or quantified, but instead expected as a corresponding benefit from many fecal waste reduction or general source solutions.
- *Address other stakeholder concerns* — The WPP approach 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 impacts from hydrologic issues in the watershed and a need to coordinate with large scale flood mitigation efforts.

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 Clear 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, especially surrounding flood mitigation, which was one of the greatest concerns of many stakeholders. 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.

Figure 3 - Canoe and kayak launch area in 1776 Park, Friendswood.

Section 2: Watershed Characterization

Section 2. Watershed Characterization

Watershed characterization considers the natural features of the land, the human elements that interact with them, and the relationship these factors have with water quality. This represents the first step in understanding the causes and sources of pollution in the watershed to identify 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 Clear Creek Watershed is an urbanized watershed lying between the cities of Houston and Galveston adjacent to Galveston Bay on the Texas Gulf Coast (Figure 4). Clear Creek and its network of tributaries are part of the broader San Jacinto-Brazos Coastal Basin that drains to the west side of Galveston Bay and incorporates much of the core of the Houston-Galveston region. Clear Creek drains into Clear Lake, a prominent and popular recreational area adjacent to Galveston Bay. The potential impacts to contact recreation, importance of local fisheries, dense populations in the watershed area, and prominent recreation economies make the contributions from Clear Creek and other tributaries especially important in a regional context.

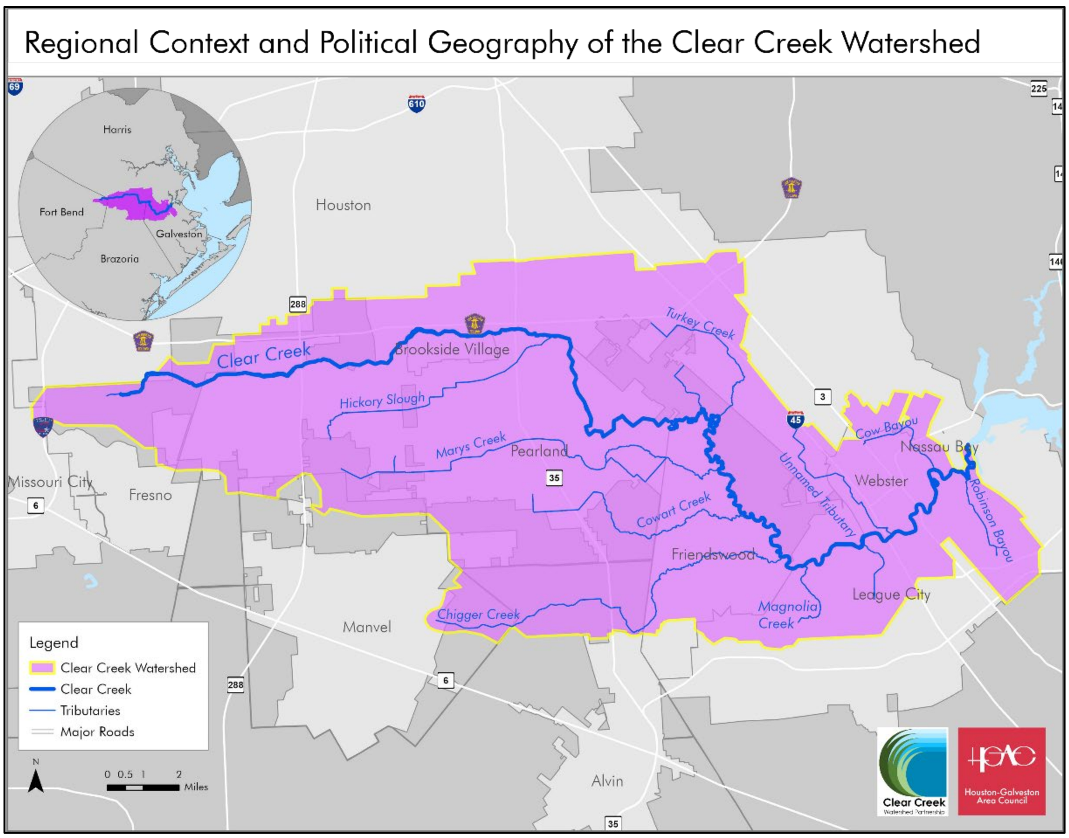

Figure 4 - Clear Creek Watershed in regional context

Watershed Delineation

The Clear Creek watershed was delineated using a combination of existing data, map review, and field observations, starting with a review of the underlying hydrology of the system (Figure 5). The primary watershed and subwatershed delineations were developed from a comparison of the National Hydrography Dataset Plus (NHD+), United States Geological Survey (USGS) Hydrologic Unit Code data, and proprietary Harris County Flood Control District (HCFCD) watershed/subwatershed datasets. The boundaries were compared to aerials, known hydrologic boundaries, feedback from local partners and Clean Rivers Program (CRP) staff, and field observations. After this assessment, the HCFCD data was closest to expected actual drainage patterns in this system. Like many coastal systems in highly urbanized areas, the watershed is the best approximation of drainage in most conditions. During high enough flow events it remains possible that drainage patterns can shift, and the complexity of modified urban drainage systems adds uncertainty.

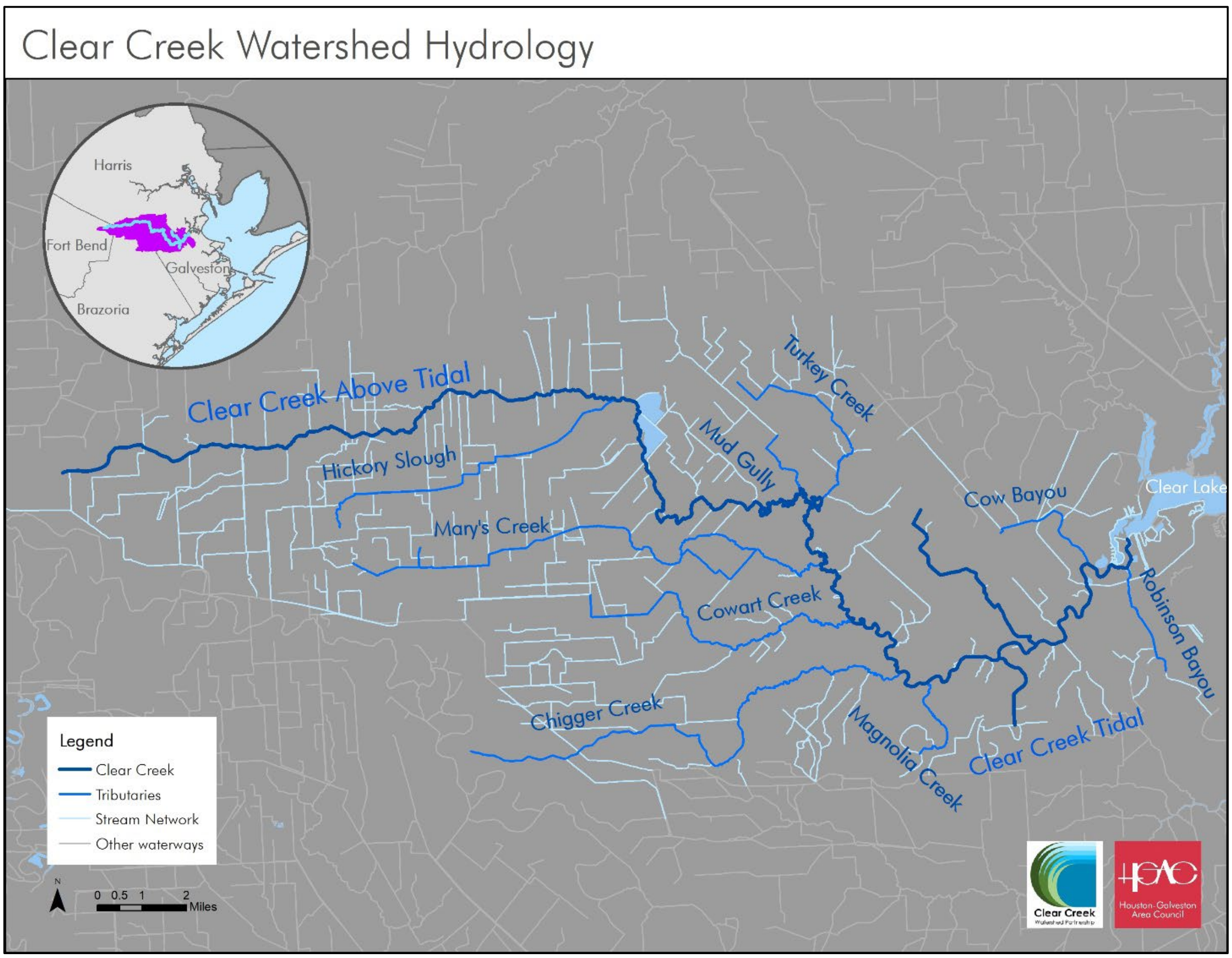

Figure 5 - Clear Creek Watershed hydrology

Minor adjustments were made to the final watershed to account for known drainage/hydrologic boundaries. Subwatersheds were further delineated from a comparison of the HCFCD subwatershed data, boundaries for TCEQ assessment units (AUs) in the system, and CRP monitoring sites. Final subwatershed delineation was strongly influenced by the monitoring station locations which will be used to evaluate these areas during the implementation of the WPP (Figure 6). Considerations for the selection of the representative monitoring stations for each subwatershed were their ability to represent different areas of the watershed, the natural hydrologic elements of the watershed (*e.g.*, major tributaries), 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.

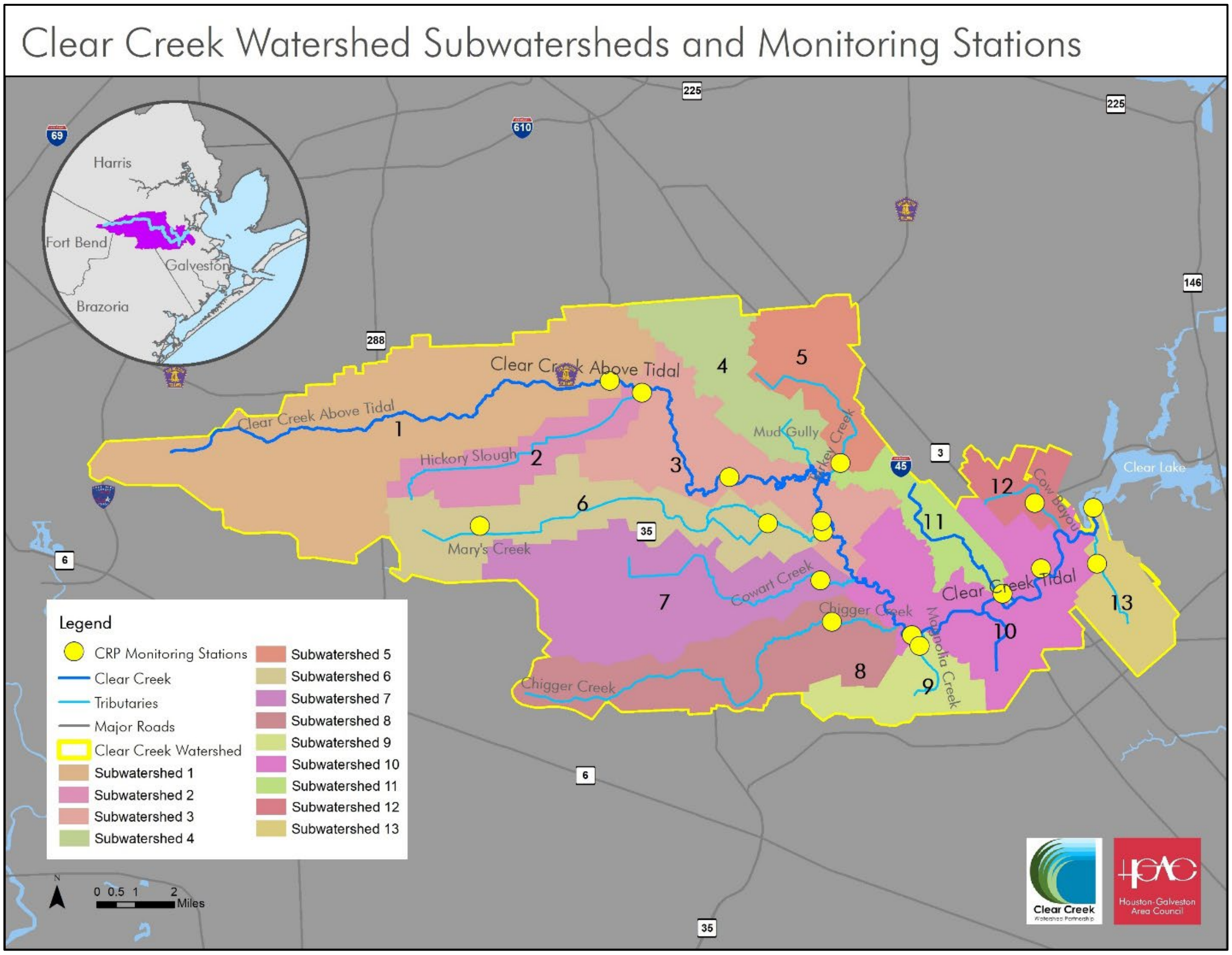

Figure 6 - Clear Creek subwatersheds and monitoring station locations

Drainage Area and Stream Network

The full drainage area of the Clear Creek watershed covers over 172 square miles, and its stream network includes 412 linear miles of waterways. This drainage network includes both natural streams, modified waterways, and manmade drainage (channels and storm sewer systems) of varying size. It is an important drainage conveyance for this low-lying area, reflected in its modified and maintained character. Each of Clear Creek's primary tributaries (Hickory slough, Mud Creek, Turkey Creek, Mary Creek, and Cowart Creek in the Above Tidal Segment 1102; and Chigger Creek, Magnolia Creek, Robinson Bayou, Cow Bayou, and two unnamed tributaries in the Tidal Segment 1101) are themselves networks of smaller tributaries and drainage conveyances. The densely developed nature of the watershed, its lack of appreciable elevation change, and the widespread modification of its drainage channels represent a complicated hydrology where flow patterns can shift in high flow events.

The main channel of Clear Creek Above Tidal starts from its headwaters of small surface drainage in the developing areas of eastern Fort Bend County, southern Harris County, and northern Brazoria County. As it progresses east, paralleling the State Highway (SH) 8 corridor, the waterway grows in size but is primarily a bermed drainage channel with drainage dominated by stormwater inflows from development, including large, collected inputs from areas like Shadow Creek Ranch and other master planned communities. Some minor amounts of flow are diverted to off-channel reservoirs in adjacent area like El Franco Lee Park, throughout the first third of the watershed, the creek's tributaries are also primarily maintained drainage channels with little riparian buffer (Figure 7). Starting at the confluence of Mud Creek and Turkey Creek, Clear Creek enters into a southerly flowing stretch of older development with greater riparian corridor vegetation (Figure 8). Many of the Clear Creek tributaries show signs of appreciable erosion along the banks, which are reinforced with concrete in some sections. As it approaches the confluence of Cowart Creek and the boundary of the tidal segment, Clear Creek has broadened into a larger waterway (Figure 9). Even in areas with greater riparian buffer, signs of erosion on the banks persist, indicating the greater surges of water that accompany high flow events.

Figure 7 - Erosion along Mary's Creek

Figure 8 - Riparian vegetation on Clear Creek

Once the main channel passes the tidal boundary at FM528 (near monitoring site 16576), it continues to broaden, and the riparian corridor is characterized by a large number of adjacent pools and wetlands. However, its tributaries retain a similar mix of modified drainage channels and more natural flow, also exhibiting signs of eroded banks and mixed levels of riparian vegetation. As the creek nears its confluence with Clear Lake, it broadens appreciably with significant pools near the confluence with tributaries. Docks and other signs of water recreation are commonplace. Well before the official designation of the terminus for Segment 1101, two miles downstream of El Camino Real Road, the waterway has effectively become an arm of Clear Lake.

Figure 9 - Clear Creek at I-45 (top) and SH3 (bottom)

The stream network of the Clear Creek watershed contains many unclassified tributaries[9] that provide a majority of the flow to the waterway (Figure 10). These include (in order from northwest to southeast):

Clear Creek Above Tidal (1102)

- **Hickory Slough (1102C)** is a moderately sized, maintained drainage channel for primarily suburban and light commercial areas.
- **Mud Gully (1102E)** is a small waterway with a mix of more natural and modified stretches, draining suburban and light commercial areas, including portions of the SH8 corridor and the Brio Superfund Site[10].
- **Turkey Creek (1102D)** is a medium sized waterway, also with a mix of more natural and modified stretches, draining suburban and light commercial areas, including portions of the SH8 corridor.
- **Mary's Creek (1102B)** is a longer system of several unclassified tributaries, all of which are primarily maintained drainage channels, serving suburban, exurban, and light commercial areas. Besides 1102B, it includes:
  - **Mary's Creek Bypass (1102F)**
  - **Unclassified Tributary of Mary's Creek (1102G)**
- **Cowart Creek (1102A)** is similar to many of the other tributaries in the system, draining residential areas for much of its length. However, the development is more mixed, with large lot residential areas and greater riparian vegetation near its confluence, and large undeveloped and commercial areas in its headwaters.

Clear Creek Tidal (1101)

- **Chigger Creek (1101B)** drains an area similar to Cowart Creek, with larger residential area, broader and more vegetated riparian corridor, and with even larger sections of undeveloped areas in its western half.
- **Magnolia Creek (1101A)** drains a large area of newer master-planned subdivisions as a linear maintained drainage channel, except for a short stretch near its confluence with Clear Creek, which is more sinuous and has more thickly vegetated riparian corridor.
- **Unnamed Tributary (1101E)** is a highly modified waterway, much of which is channelized and concreted lined that drains dense suburban development. It has

[9] 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. None represent significant waterways on their own warranting specific focus.
[10] More information on this site can be found at: https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Cleanup&id=0602601#bkground

connections or direct proximity to other drainage networks at League City Parkway which can impact it in some circumstances.

- **Unnamed Tributary (1101F)** is unique in the watershed as it drains an area along the I-45 corridor that is almost entirely large commercial and industrial areas, reflected by its heavily modified character.
- **Cow Bayou (1101C)** drains a mix of residential, commercial, and industrial uses along the SH3 corridor, and is heavily modified without many remaining natural elements. It potentially connects to other drainage networks, including Horsepen Bayou to the north in certain circumstances.
- **Robinson Bayou (1101D)** also drains a mix of land uses, but for most of its length is a smaller, linear drainage channel, before it broadens out at the confluence with Clear Creek.

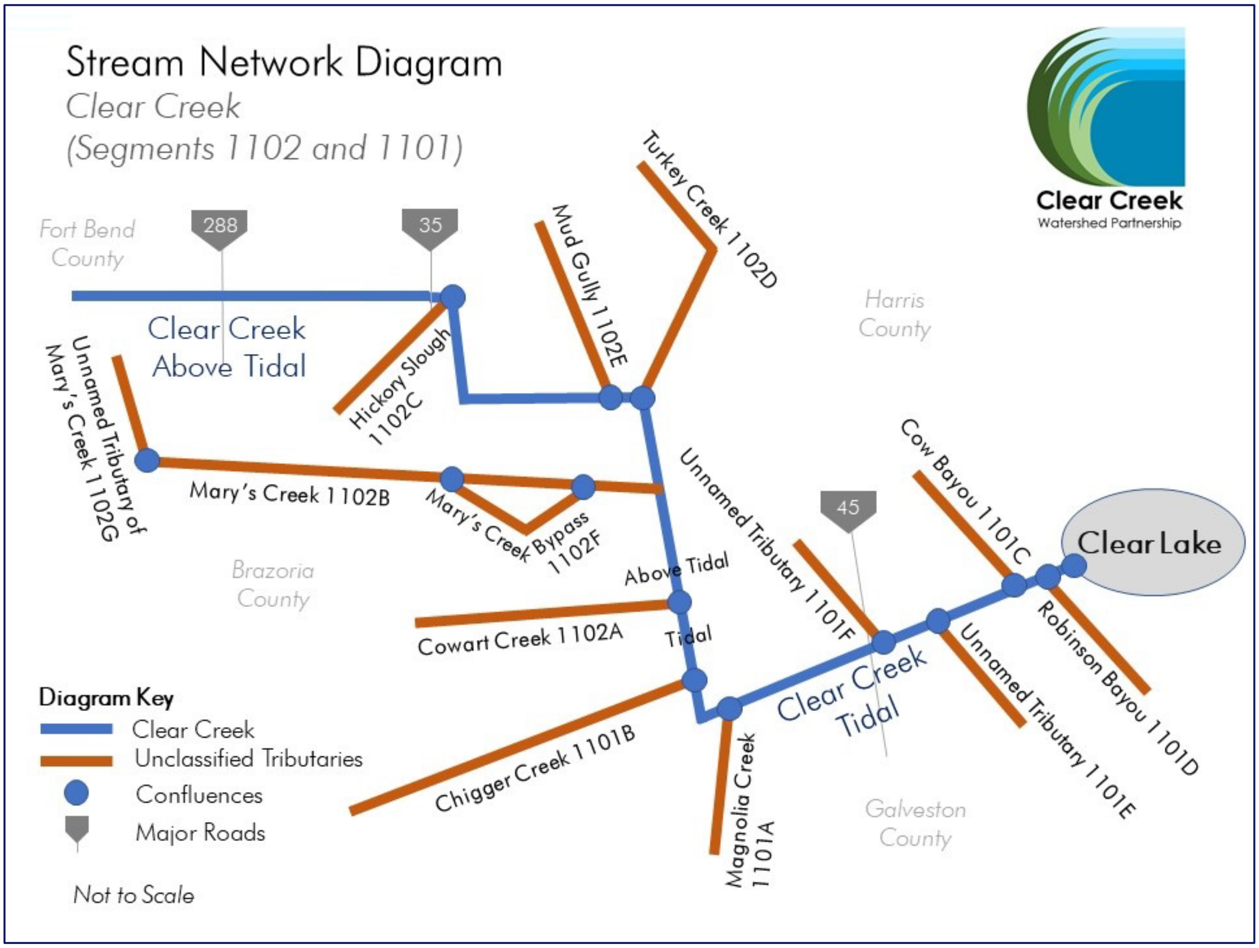

Figure 10 - Stream network diagram

Recreational paddling and fishing are common on the main stem, especially on Clear Creek Tidal and recreational trails are widespread and increasing in its riparian corridors.

The system in general supports a high-quality aquatic ecosystem. Flooding events have been pronounced in this waterway in recent decades, impacting the stream network.

Political Geography

The watershed area of Clear Creek includes portions of Harris, Galveston, Brazoria, and Galveston counties. On the southeast side of the Houston-Galveston region, this drainage area is connected to the Houston metropolitan area by the SH 288, SH 35, SH 8, and Interstate 45 (I-45) transportation corridors. The watershed includes parts of the cities of Missouri City, Fresno, Houston, Manvel, Pearland, Friendswood, League City, Nassau Bay, Webster, Alvin, and Brookside Village (Figure 11). Other than a small headwaters area in the west, and some developing areas in the south central, most of the watershed is within a city boundary. However, some areas are in unincorporated county areas, and are served by 40 community level special districts (municipal utility districts, water control and improvement districts, *etc.*) or private utilities. The local districts are shown in Figure 12.

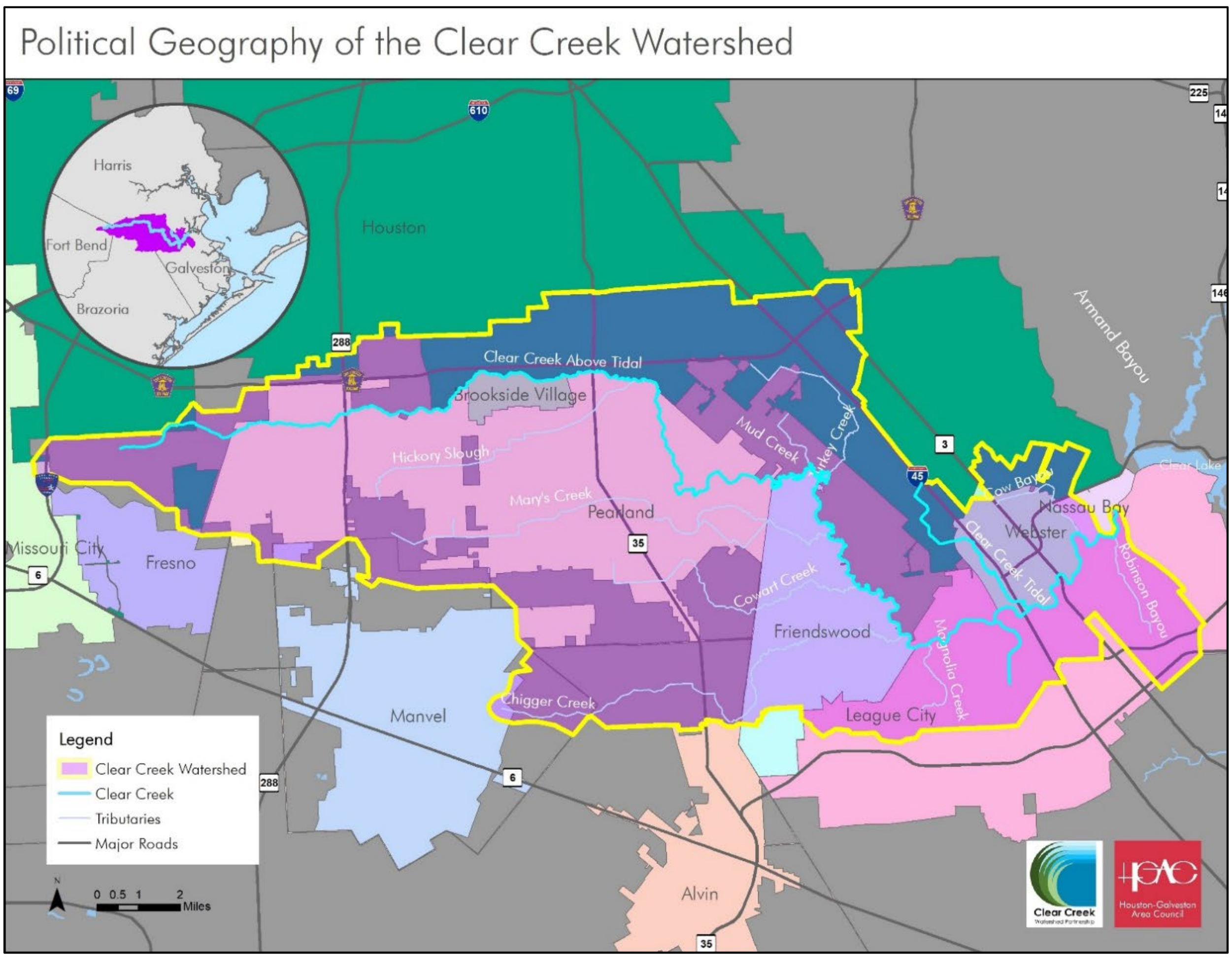

Figure 11 - Political geography of the Clear Creek Watershed

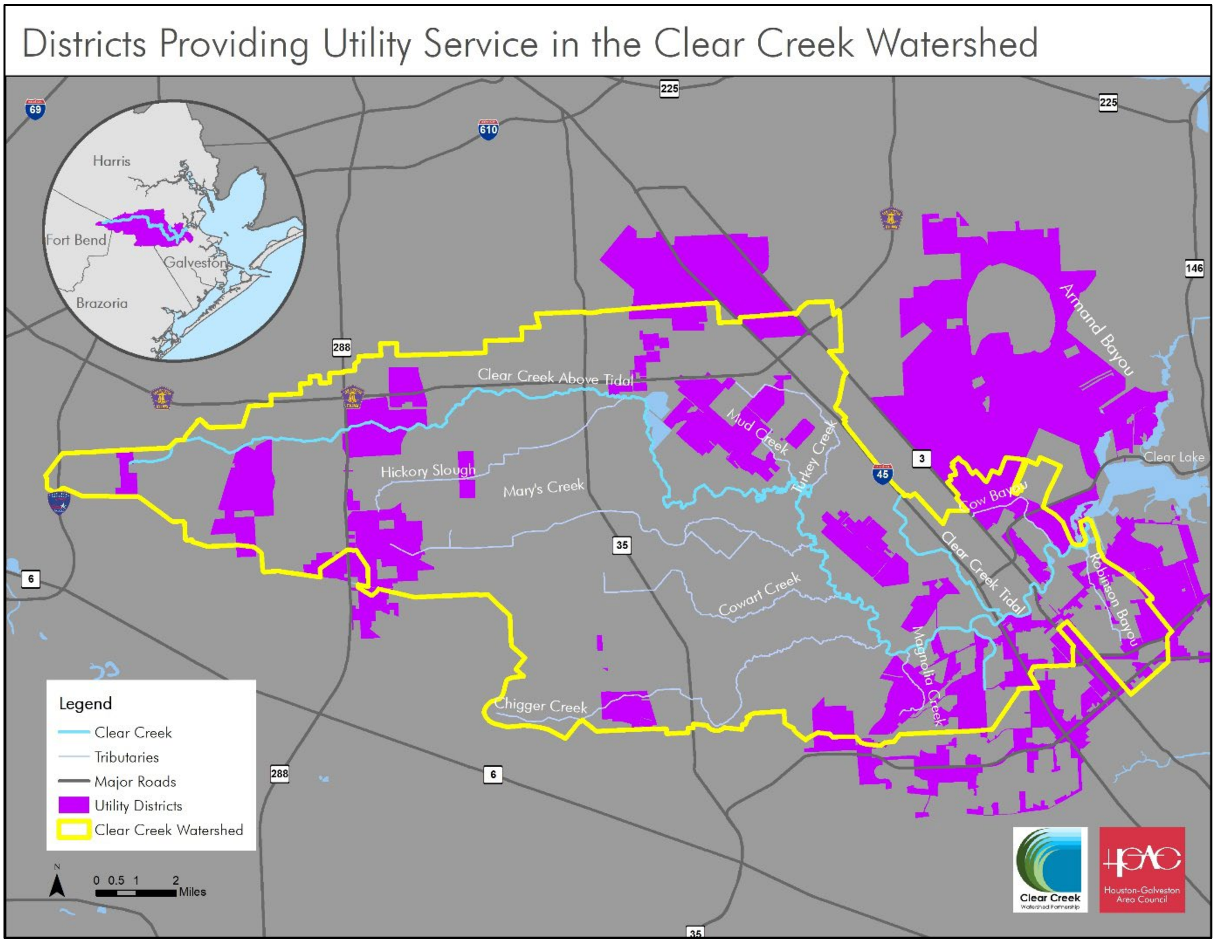

Figure 12 - Districts Providing Utilities in the Clear Creek watershed

In addition, the watershed overlaps the service area of a variety of other regional authorities, including the Gulf Coast Authority, the Gulf Coast Water Authority, the HCFCD, the Harris Galveston Subsidence District, the Fort Bend Subsidence District, and Port of Houston Authority. Soil and Water Conservation Districts include those for Fort Bend County (Coastal Plains), Harris County, Brazoria County/Galveston County (Waters Davis). Additionally, several independent school districts and other management districts overlap with the watershed area.

Much of the historical development in the watershed spread south from the Houston area along the major transportation corridors of I-45, SH 288, and SH 35, or arose from coastal communities adjacent to the Clear Lake area. The focus of new development is westward and southward, as growth continues to push out from the SH 8 corridor and existing cities, though there are few large areas left to develop in the watershed. Other than the dense commercial activity along I-45 and other corridors, most of the communities have a suburban or small city character, ranging in ages from older communities of Houston to new master-planned development spreading out from the Pearland and Friendswood areas.

Flood Mitigation

Much of the area in the watershed is in flood prone areas (including the 100- or 500-year floodplains indicated by the Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Maps (FIRM)), shown in Figure 13. However, recent events like the floods of 2015 and 2016, and Hurricane Harvey in 2017 have shown that the floodplain maps do not always accurately account for flooding potential in the watershed. Areas in which flooding is unexpected may be especially vulnerable to erosion, flood damage, and pollution from sources not designed for flooding situations. Flooding is a primary concern for many of the stakeholders and local partners and has been widespread in the watershed during the aforementioned flooding events. Many large-scale efforts are underway in the watershed, including the multijurisdictional Lower Clear Creek and Dickinson Bayou Watershed Study[11]/Lower Clear Creek Flood Mitigation Plan. While the focus of this WPP is on water quality, flooding has an appreciable impact on pollutant concentrations and channel erosion, and mitigation activities can often involve water quality enhancing features.

[11] More information on this study can be accessed at https://www.leaguecity.com/LCCDB.

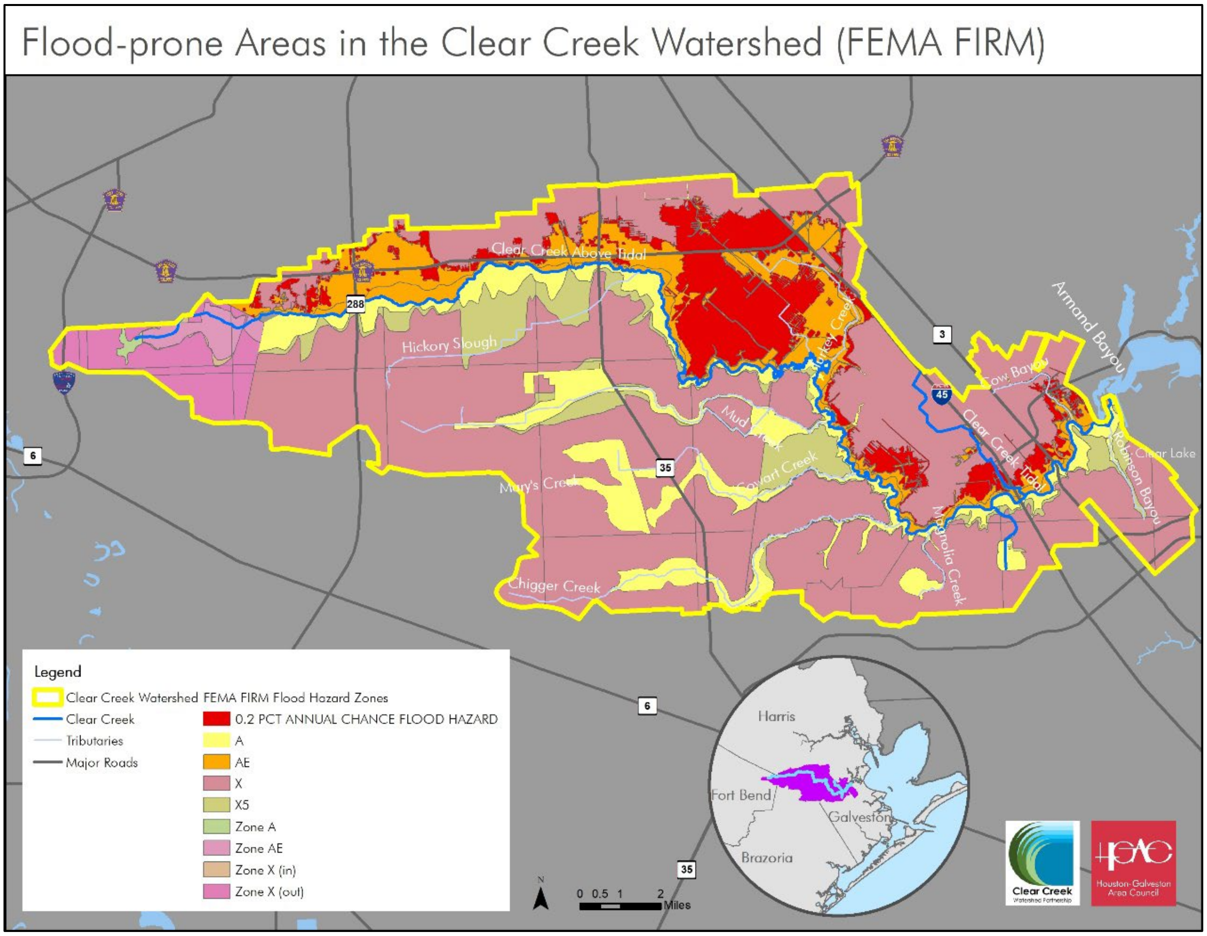

Figure 13 - Flood-prone Areas in the Clear Creek watershed

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 relatively flat and slow draining Gulf Coastal Plain. As such, it experiences less topographical variation than areas further from the coast in the Houston-Galveston region (Figure 14). The slow-moving nature of the system is a challenge for both water quality and flood mitigation.

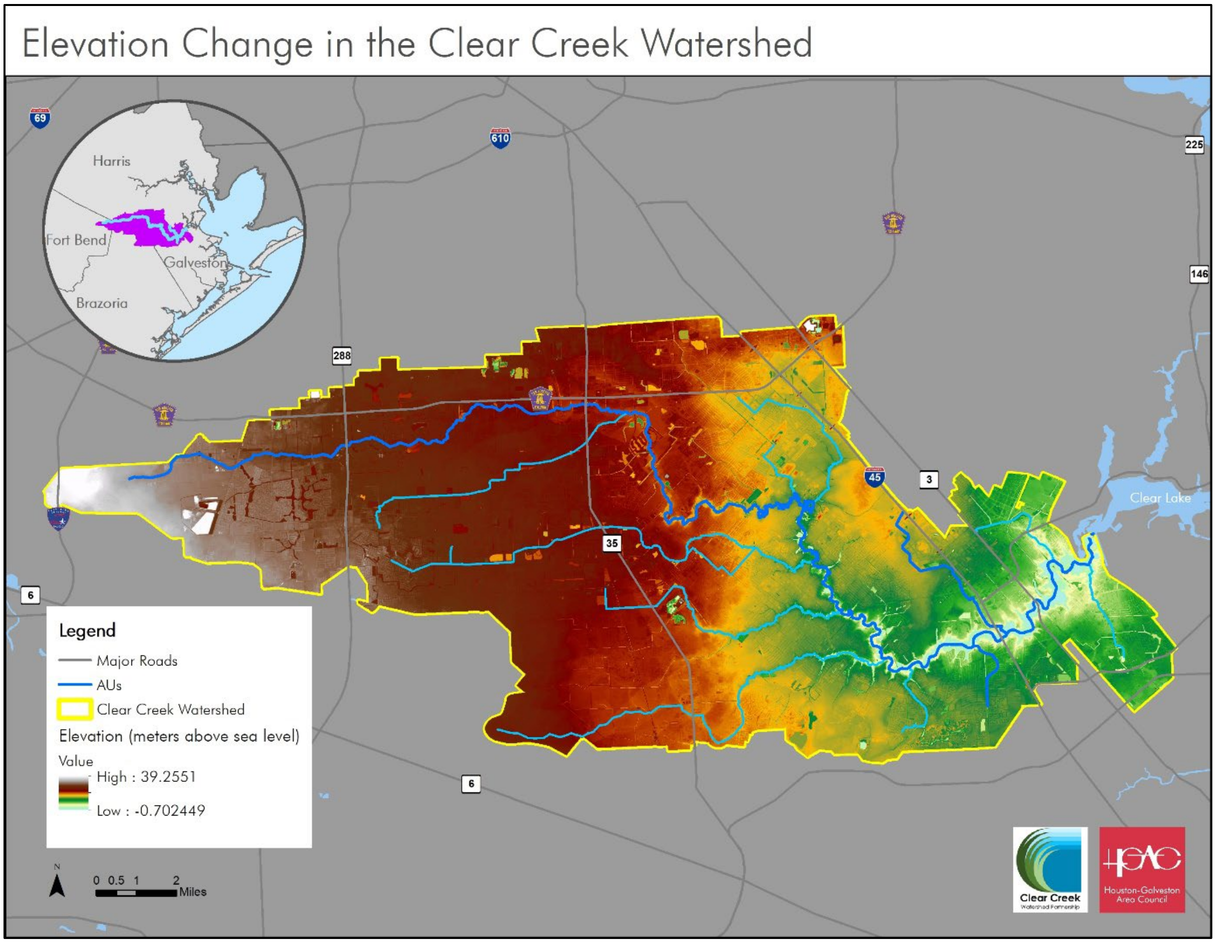

Figure 14 - Elevation in the Clear Creek watershed

Elevation generally decreases from northwest to southeast, and from headwaters toward the drainage pathways. There is approximately a 40-meter difference between the highest and lowest points[12] of the watershed.

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. However, drought events can have appreciable effects on the area, as evidenced in the 2011 drought. Throughout this period, the region was exceptionally dry, and some channels may be ephemeral in drier conditions. The watershed is directly adjacent to the coast, 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, algal growth).

[12] Based on USGS Digital Elevation Model 10-meter resolution spatial data.

Soils

The soil mix[13] of the Clear Creek watershed is characteristic of the coastal plains in which it falls. In general, soils in the Clear Creek watershed are dominated by hydrologic soil group D, which are soils having slow infiltration rates when saturated (Figure 15). Erosion of soils is prominent in the alluvial sediments along the waterways, especially in riparian corridors that experience large changes in volumes during high flow events and/or which are maintained without trees or vegetation other than maintained grasses.

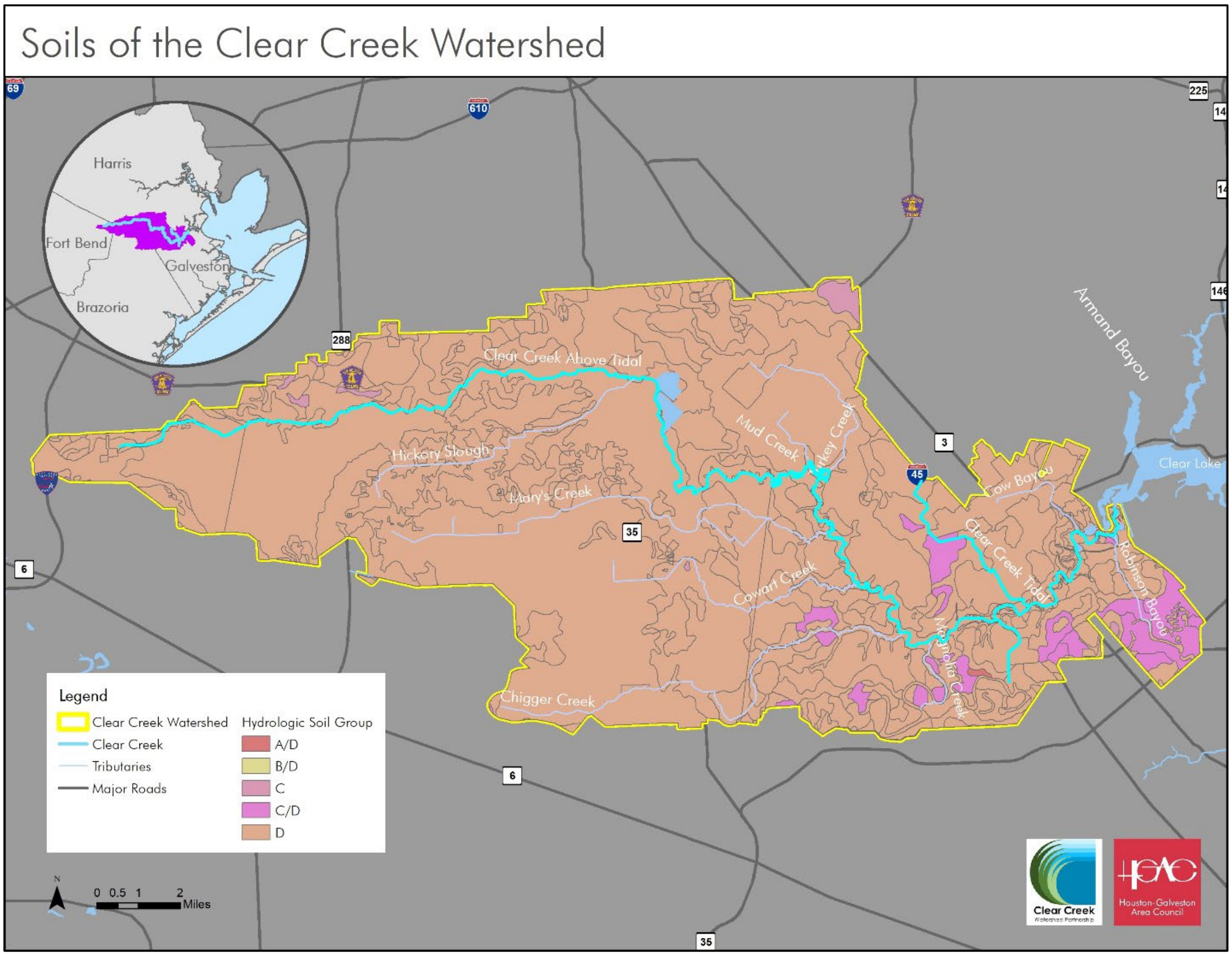

Figure 15 - Soils in the Clear Creek watershed

Habitat and Wildlife

While the Clear Creek Watershed covers a variety of different microhabitats in its differing land uses, its overall designation is uniform for the entire drainage area. Based on Level IV Ecoregion data (areas of similar climate, habitat, and landscape), the Clear Creek

[13] 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. Accessed on 11/24/2021 at: https://websoilsurvey.nrcs.usda.gov/. Soil survey dates and methods can differ from jurisdiction to jurisdiction and across time periods.

Watershed falls wholly within the Northern Humid Gulf Coastal Prairies, Level IV ecoregion 34a.

Mixed grasses and other vegetation characteristic of the coastal prairie portions of the Houston-Galveston region are (or were) common in the watershed. Traditionally, the areas would have been dominated by coastal prairie grasses with isolated oak mottes or pine stands, with greater number of trees and bottomland vegetation along the riparian corridors. However, only a small part of the watershed remains in undeveloped condition, and much of the unoccupied land has previously been altered by agriculture. These modified habitats tend toward monocultures (live oaks, crepe myrtles, and similar residential plantings in suburban areas; reduction of plant and animal biodiversity in fallow agricultural areas) and less overall habitat value than less developed watersheds in the region.

Even though the watershed is highly modified by human activity, it still hosts a diverse array of animal species, reflecting the rich biodiversity of the Houston area. 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 in the area, with some specific areas within the watershed like parts of El Franco Lee Park set aside for habitat. Local bird species include wading birds (*e.g.*, great blue heron, white ibis), a wide variety of passerine species, and several raptors (*e.g.*, red-tailed hawk, bald eagle, barred owl). Birding is a popular recreational pastime in the watershed, with over 30 "hotspots" identified in the citizen-scientist data on eBird[14]. Notable local conservation or mixed-use areas with habitat value include natural or restored lands like El Franco Lee Park, Tom Bass Regional Park, Shadow Creek Ranch Nature Park, the Clear Creek Bayou Greenway, the Nassau Bayou Wildlife Peninsula Park and the Dr. Ned and Fay Dudney Clear Creek Nature Center, and the Delores Fenwick Nature Center, along with a host of municipal, county, and private parks and holdings. Typical mammal species throughout the watershed 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* genus water snakes, American alligators, red-eared slider turtles, and bullfrogs.

Of particular concern in the watershed are invasive species. In addition to exotic plants[15] (*e.g.*, Chinese tallow) and various invasive animals, feral hogs (*Sus scrofa*) are a growing

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[14] eBird Hotspots indicate areas of specific interest or profundity for identifying bird populations. Based on data referenced on 3/5/23 at https://ebird.org/hotspots.
[15] The Challenger Seven Memorial Park habitat Restoration Project by the Bayou Preservation Association is an example of local concern and efforts to deal with invasive plants. More information can be found at: https://www.bayoupreservation.org/_files/ugd/98befb_cf19ecdc8adf4ce89e16587b0178b51f.pdf

issue for the Houston region and are present in the Clear Creek watershed, especially in the fringes of development in the west and south-central areas, and along riparian corridors. 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 and residential areas. Hogs tend to congregate in and around water bodies, causing damage to the riparian corridor and depositing fecal waste directly into the water body.

Land Cover and Development

The Clear Creek watershed has a mix of land cover types, even though it is primarily characterized by developed areas. 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 less developed areas in the western and south-central reaches of the watershed to increasingly dense development as it approaches the I-45 corridor. Remaining natural or undeveloped land cover types outside of the undeveloped patches in the west and south-central areas are predominantly found in protected and conserved lands and parks or remaining riparian corridor and floodplain (Figure 16). Urban development is primarily suburban and commercial, but densities vary with age and type of communities in the watershed. Land cover is summarized in Table 3.

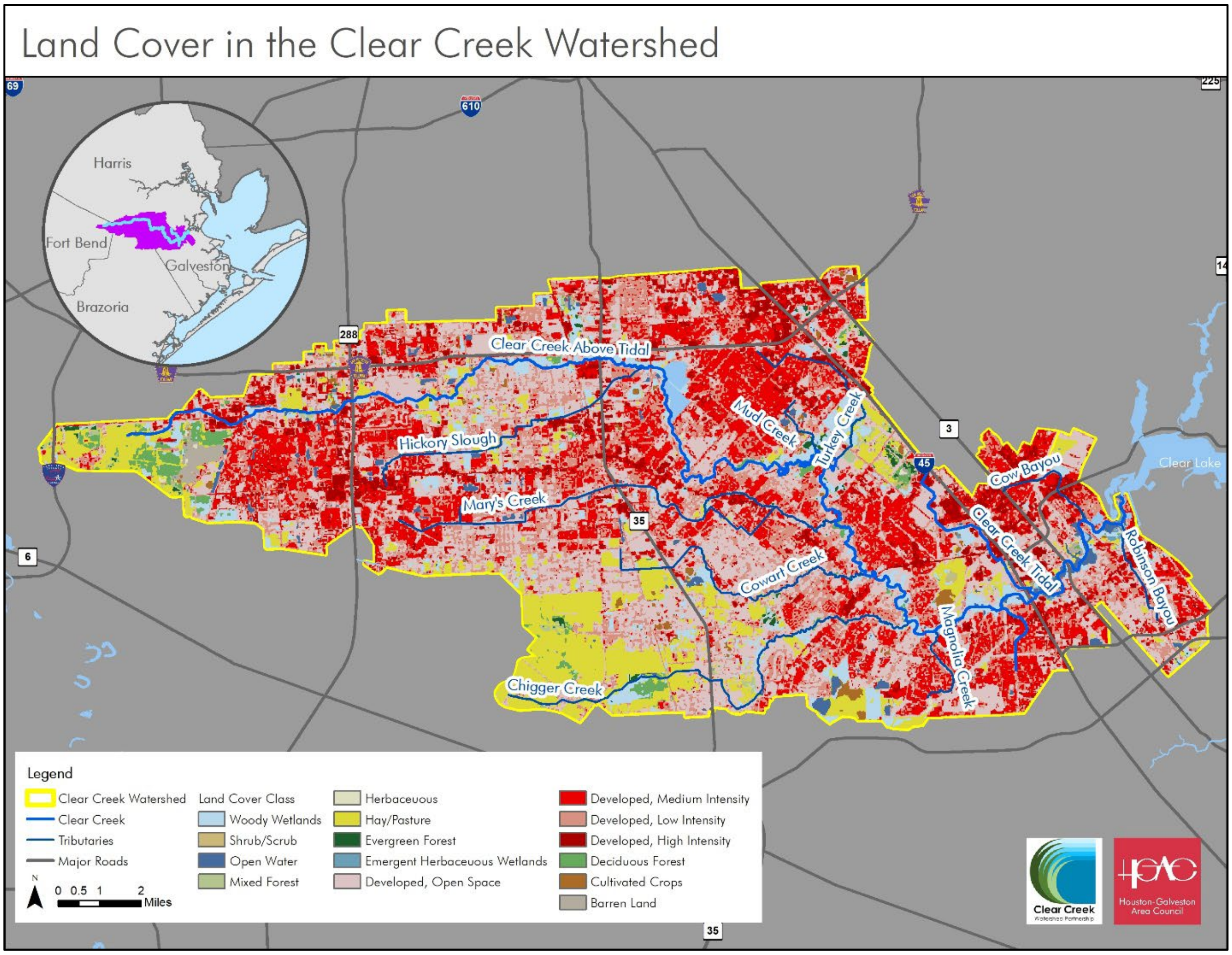

Figure 16 - Land cover in the Clear Creek watershed

Developed land uses dominate the watershed at approximately 80% of the total area of the watershed. Agriculture still makes up about 10% of the watershed area, but this includes many fields that are likely fallow or waiting on development as almost all of the agricultural land cover is in hay/pasture. Natural or undeveloped land cover types account for the remaining 10%, in total, though a majority of this is open water and wetlands in floodplain or otherwise protected areas not suitable for development[16]. The full breakdown of the 15 land cover categories present in the watershed is summarized in Table 2[17]. However, it should be noted that these watershed totals are not proportional across all subwatersheds (shown in Figure 6 on pg. 11). For example, subwatersheds 1, 7, and 8 in the western and southern headwaters have much higher percentages of undeveloped area, while

[16] Land cover projections for regulated wetland are dependent on the state of regulation, and bear some uncertainty.

[17] Data for this analysis represents 15-class data produced by H-GAC in 2020. National Land Cover Database and other typical land cover datasets did not have data current enough for this WPP effort given the area's growth rate. H-GAC's proprietary data has consistently been used for many local WPPs, making the results more comparable across efforts.

subwatersheds 10 and 11, are proportionally higher in developed uses, given their location on the I-45 corridor. 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. With the current trajectory toward development, future implementation is likely to focus most strongly on sources related to the developed land cover type.

Table 2 - Land cover as a percentage of watershed area

Land Cover Category	Percentage of Watershed Area
Open Water	1.7%
Developed-High Intensity	6.6%
Developed-Medium Intensity	23.1%
Developed-Low Intensity	21.2%
Developed-Open Space	29.0%
Barren Land	0.5%
Deciduous Forest	1.3%
Evergreen Forest	0.4%
Mixed Forest	0.4%
Shrub/Scrublands	0.1%
Herbaceous/Grasslands	0.1%
Hay/Pasture	9.6%
Cultivated Crops	0.7%
Woody Wetlands	5.2%
Emergent Herbaceous Wetlands	0.1%

Agriculture

Agriculture has been generally in decline in most of the watershed area, with most remaining production taking place in small portions of the west and south-central areas of the subwatershed. 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. Traditionally, agriculture in the watershed consisted of shifting regimes of hay, livestock, rice farming, and various row crop production.

Recreation

Clear Creek is a popular destination for a variety of recreational activities as an adjacent waterway to Clear Lake and the Galveston Bay system. Local partners have invested significant time and effort in developing natural spaces for recreation benefits. Many of the prominent parks and natural areas[18] are adjacent to the creek system and are points of access for recreation (Figure 17). Both recreational and subsistence fishing is popular along the waterway, and in lakes in adjacent parkland. In the tidal segment, docks for recreational boats are common, in addition to other signs of water recreation[19]. Local parks of various sizes have dedicated boat or paddling access points, including Walter Hall Park, Challenger 7 Park, League City Boat Ramp and Park, Heritage Park, Lynn Gripon Park, Countryside Park, and 1776 Park[20]. Recreation in and around the water is the focus of many local efforts including the City of League City's Clear Creek Master Plan[21] and their prior "Parks, Trails, and Open Space Master Plan" of 2017.

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[18] This map is not exhaustive of all parks in the watershed.
[19] Examples of local paddling activity can be read at https://thcc.clubexpress.com/content.aspx?page_id=22&club_id=496051&module_id=164295
[20] Paddling trails are a marketing point for many local communities, including the City of League City, as evidenced by this promotional piece on the League City Convention and Visitors Bureau website: https://www.leaguecitycvb.com/clear-creek-paddle-trail.
[21] This effort was ongoing during the writing of this WPP. The 2017 plan can be viewed at: https://www.leaguecitytx.gov/DocumentCenter/View/15744/Parks-Trails-and-Open-Space-Master-Plan---November-2017?bidId=

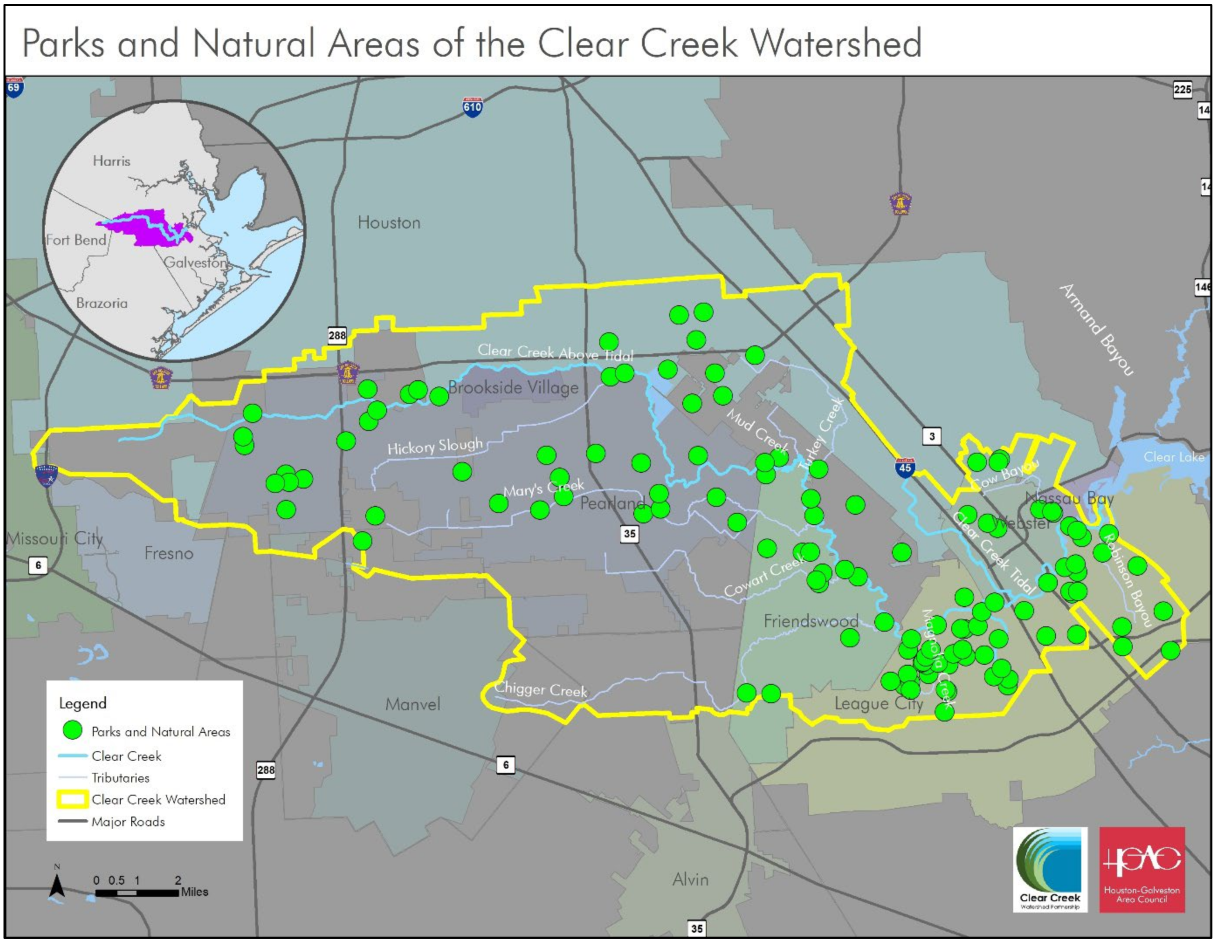


Figure 17 - Parks and natural areas in the Clear Creek watershed

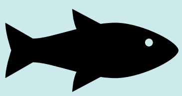
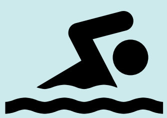
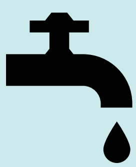
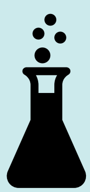
Water Quality

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 (Table 3). 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 such as 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 SWQSs[22]. 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 3 - 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 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 Clear 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 primary classified segments in the Clear Creek watershed are Segment 1101 (Clear Creek Tidal) and Segment 1102 (Clear Creek Above Tidal). Major tributaries or waterways of interest within these classified segments are delineated as unclassified tributaries. Unclassified tributaries in this watershed are summarized in Table 5. Other contributing waterways and drainage

[22] *More information on these and other SWQSs can be found online at* [*https://www.tceq.texas.gov/waterquality/standards*](https://www.tceq.texas.gov/waterquality/standards)

networks also contribute to the system but are either not designated as unclassified tributaries by TCEQ or 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.*, 1101_01 for Clear Creek Tidal, AU 1). AUs in the Clear Creek system are summarized in Table 5 and Figure 18.

Table 4 - Clear Creek segments and assessment units

Segment/Unclassified Tributary	Assessment Units
1101 – Clear Creek Tidal	01, 02, 03, 04
1101A – Magnolia Creek	01
1101B – Chigger Creek	01, 02
1101C – Cow Bayou	01
1101D – Robinson Bayou	01 ,02
1101E – Unnamed Tributary to Clear Creek Tidal	01
1101F - Unnamed Tributary to Clear Creek Tidal	01
1102 – Clear Creek Above Tidal	01, 02, 03, 04, 05
1102A – Cowart Creek	01, 02
1102B – Mary's Creek	01
1102C – Hickory Slough	01
1102D – Turkey Creek	01
1102E – Mud Gully	01
1102F – Mary's Creek Bypass	01
1102G – Unnamed Tributary to Mary's Creek	01

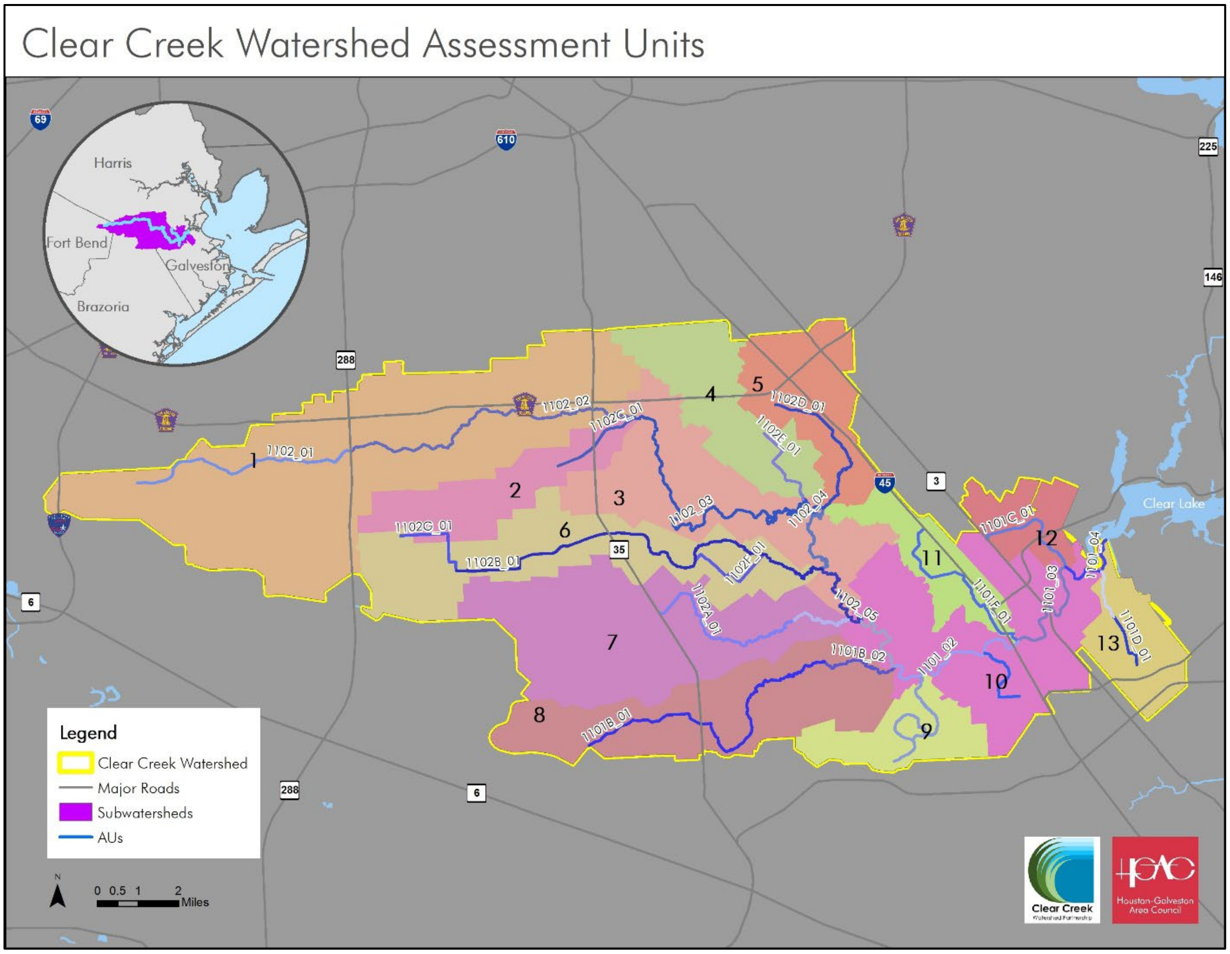


Figure 18 - Segments and AUs in the Clear Creek watershed

Assessments are made based on data collected under the state's 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 and criteria for the waterways. The data discussed in this WPP and evaluated as part of this project's *Water Quality Data Collection and Trends Analysis Report*[23] are included as part of TCEQ's 2020 Texas Integrated Report of Surface Water Quality (2020 Texas Integrated Report)[24]. The results of the assessments of the Clear Creek AUs only reflect ambient surface water quality,

[23] 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://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/clear_creek_water_quality_trends_report_phase_1_final.pdf

[24] The 2022 Integrated Report came out subsequent to the end of this project, but references within this document refer to the 2020 report.

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 Clear 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, many of the AUs in the watershed 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 Clear Creek and its tributaries is typical of challenges seen in other creeks and bayous in the area[25], but is compounded to some degree by the complexity of its hydrology and its connection to Clear Lake and the Galveston Bay system.

According to recent iterations of the Texas Integrated Report, current assessed water quality issues in Clear Creek and its assessed tributaries include elevated levels of *E. coli*, and concerns related to potential indicators or precursors of low dissolved oxygen (Table 6). The contact recreation impairment exists across many of the watershed's AUs and is the primary focus of this WPP. Concerns related to elevated levels of nitrogen and phosphorus compounds are also widespread, and though less common, concerns and impairments related to dissolved oxygen have also been observed. Lastly, due to its connection to the Clear Creek/Galveston Bay system, there is a system wide impairment for PCBs and Dioxins in edible fish tissue.

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. Overall water

[25] References to assessments and water quality status refer, unless otherwise noted, to the 2020 Texas Integrated Report of Surface Water Quality, the most current report available at the time of publication.

quality data analysis includes data through 2018 and is current with the 2020 Texas Integrated Report[26].

Figure 19 - Monitoring Water Quality

[26] The 2020 Integrated Report was the most current set of data and assessment available during the development of the water quality analyses for this project. During the latter stages of the project, the 2022 Integrated Report was released and additional monitoring data was collected. The report on water quality trends will be updated to identify changes during that period. However, as indicated in Table 6, no substantial changes to concerns or impairments arose between the 2020 and 2022 Integrated Reports.

Table 5 - Impairments and concerns in the Clear Creek watershed, 2018-2022

Texas Integrated Report Year	Assessment Units Impaired for *E. coli or Enterococcus*	Assessment Units Impaired for 24hr. Dissolved Oxygen	Assessment Units Impaired for PCBs or Dioxin in edible fish tissue.	Concern Parameter and Affected Assessment Unit(s)					
				Depressed Dissolved Oxygen	Nitrate	Total Phosphorous	Chlorophyll-a	Ammonia	Impaired Habitat
2018	Enterococcus 1101_01, 1101_02, 1101_03, 1101A_01, 1101B_01 (CN), 1101C_01, 1101D_01, 1101D_02, 1101E_01 *E. coli* 1102_04, 1102A_01, 1102A_02, 1102B_01, 1102D_01, 1102F_01, 1102G_01	1101E_01 (minimum and average)	PCBs 1101_01, 1101_02, 1101_03, 1101_04, 1102_01, 1102_02, 1102_03, 1102_04, 1102_05 Dioxins 1101_01, 1101_02, 1101_03, 1101_04,	1101_03, 1101C_01, 1101D_01, 1101D_02, 1101F_01, 1102_02 (CN min.; CS screen), 1102_03, 1102_04, 1102_05, 1102C_01, 1102D_01, 1102E_01, 1102F_01	1101_02, 1101_03, 1101_04, 1101A_01, 1102_03, 1102_04, 1102_05, 1102B_01, 1102D_01, 1102E_01	1101_02, 1101_03, 1101_04, 1101A_01, 1102_02 , 1102_03, 1102_04, 1102B_01, 1102D_01, 1102F_01	1101_04	1102_02, 1102_03, 1102D_01	1102_02

Texas Integrated Report Year	Assessment Units Impaired for *E. coli or Enterococcus*	Assessment Units Impaired for 24hr. Dissolved Oxygen	Assessment Units Impaired for PCBs or Dioxin in edible fish tissue.	Concern Parameter and Affected Assessment Unit(s)					
				Depressed Dissolved Oxygen	Nitrate	Total Phosphorous	Chlorophyll-a	Ammonia	Impaired Habitat
2020	Enterococcus 1101_01, 1101_02, 1101_03, 1101A_01, 1101B_01, 1101C_01, 1101D_01, 1101D_02 *E. coli* 1102_02, 1102_03, 1102_04, 1102A_01, 1102A_02, 1102B_01, 1102D_01, 1102F_01, 1102G_01	1101E_01 (minimum and average)	PCBs 1101_01, 1101_02, 1101_03, 1101_04, 1102_01, 1102_02, 1102_03, 1102_04, 1102_05 Dioxin 1101_01, 1101_02, 1101_03, 1101_04, 1102_01, 1102_02, 1102_03, 1102_04, 1102_05	1101_03, 1101C_01, 1101D_01, 1101D_02, 1101F_01, 1102_05, 1102C_01, 1102D_01, 1102F_01	1101_02, 1101_03, 1101_04, 1101A_01, 1102_02, 1102_03, 1102_04, 1102_05, 1102B_01, 1102D_01, 1102E_01	1101_02, 1101_03, 1101A_01, 1102_02, 1102_03, 1102_04, 1102B_01, 1102D_01, 1102F_01	1101_04, 1102D_01	1102_02, 1102_03, 1102A_02	1102_02
2022	Enterococcus 1101_01, 1101_02, 1101_03, 1101A_01, 1101B_01, 1101C_01, 1101D_01, 1101D_02, 1101E_01 *E. coli* 1102_02, 1102_03, 1102_04, 1102A_01, 1102A_02, 1102B_01, 1102D_01, 1102F_01, 1102G_01	1101D_01 (grab minimum), 1101E_01 (minimum and average)	PCBs 1101_01, 1101_02, 1101_03, 1101_04, 1102_01, 1102_02, 1102_03, 1102_04, 1102_05 Dioxin 1101_01, 1101_02, 1101_03, 1101_04	1101_02, 1101_03, 1101C_01, 1101D_01, 1101D_02, 1102_02, 1102_05, 1102C_01, 1102E_01	1101_02, 1101_03, 1101A_01, 1102_02, 1102_03, 1102_04, 1102_05, 1102B_01, 1102D_01, 1102E_01	1101_02, 1101_03, 1101_04, 1101A_01, 1102_02, 1102_03, 1102_04, 1102B_01, 1102D_01, 1102F_01		1102_03, 1102A_02, 1102D_01	1102_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

Increased sediment from erosion can impact the benthic habitats of aquatic life, shelter bacteria, increase water treatment costs, impact downstream recreation, and exacerbate flooding concerns. The impact of flood events has caused concerns regarding sediment transport in the Clear Creek system.

Flooding

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. Entities representing flood mitigation efforts on municipal, regional, and community levels have been involved in the development of this WPP.

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. 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

Section 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 Clear 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.

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 the known existence of impairments and concerns, and the calculation of defensible estimations of causes and sources of pollution to meet the needs of the stakeholders[27].

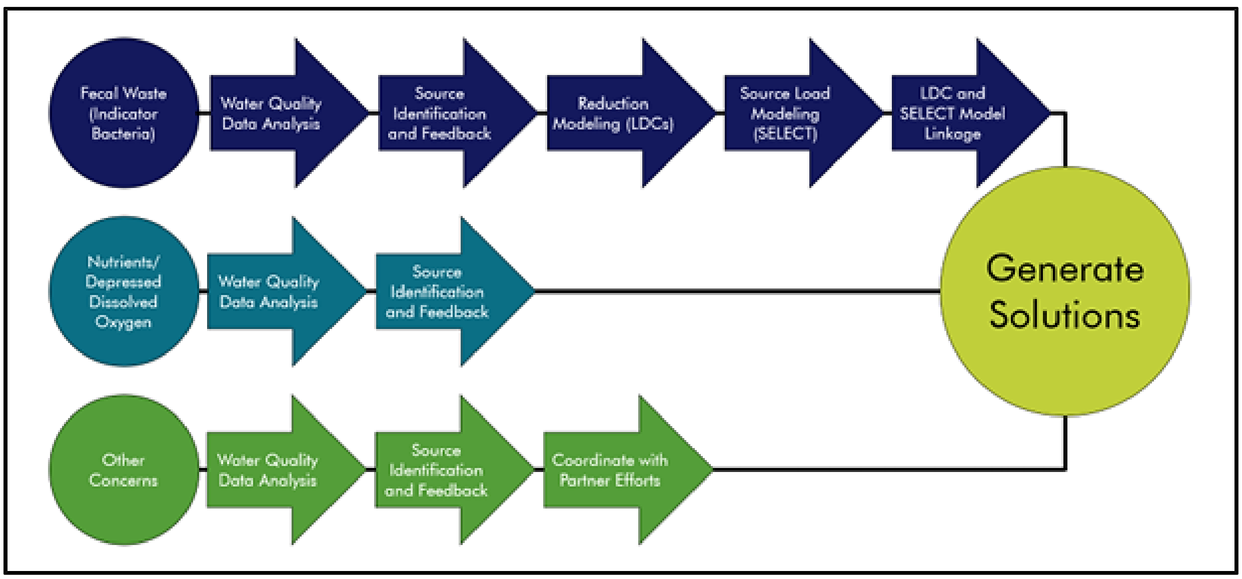


Figure 20 - Pollutant source investigation flow chart

Water Quality Goals

The applicability of each step to different pollutants/conditions of concern is based on the water quality goals established by the stakeholders (see Section 1) and is noted in parentheses for each step.

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

[27] 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://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/final_clear_creek_wpp_bacteria_modeling_report.pdf.

wastewater treatment plants, and sanitary sewer overflow (SSO) events. 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 as measured by indicator bacteria (*E. coli* and Enterococcus) generated in the watershed using computer models guided by local knowledge and feedback. These efforts identified the potential total fecal bacteria loads, mix of sources responsible, and variation between different areas of the watershed.
- **Reduction/Improvement modeling (fecal waste)** — 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* levels (see Section 4).
- **Source and improvement linkage (fecal waste)** — As the primary focus and sole impairment in the watershed, 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 do not 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[28]; 3) discharge monitoring reports (DMRs) and sanitary sewer overflow (SSO) data from wastewater treatment facilities (WWTFs); 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*[29] 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.

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[30]. Most monitoring stations are sampled by CRP partners, including H-GAC[31]. Waterways are inherently dynamic systems, and water quality at any given time can vary greatly dependent on conditions at the time[32]. 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. 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 Clear Creek system is heavily monitored, with 17 active monitoring stations: six on the main body (3 on 1101, 3 on 1102), and 11 on tributaries (five on 1101 tributaries, 6 on 1102 tributaries) as shown in Figure 21 and Table 7. Data for most stations[33] are

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[28] While staff looked at volunteer data from Texas Stream Team sites in the watershed, this data was treated as wholly anecdotal, and not combined or otherwise used with quality assured monitoring data for modeling or assessment purposes.

[29] Available on the project website at: https://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/clear_creek_water_quality_trends_report_phase_1_final.pdf.

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

[31] 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/

[32] For this section, 24-hour DO data is discussed. 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.

[33] Station 179298 on Cow Bayou 1101C was added for 2019 only, and station 18636 on Unnamed Tributary of Mary's Creek was added in 2021. Both have limited data.

representative of ten years of sampling and are enough to describe the conditions during the study period.

Table 6 - CRP monitoring station locations in the Clear Creek watershed

Station	Segment or Tributary Designation	Site Location
Clear Creek Tidal		
11446	1101	Clear Creek Tidal at State Highway 3 near Webster
16573	1101	Clear Creek Tidal at the confluence with Clear Lake, League City
16576	1101	Clear Creek Tidal at Brookdale Drive, League City
16611	1101A	Magnolia Creek at West Bay Area Blvd., League city
16493	1101B	Chigger Creek at FM 528, Friendswood
*17928**	*1101C*	*Cow Bayou at NASA Road 1, Webster*
16475	1101D	Robinson's Bayou at FM 270
18591	1101F	Unnamed Tributary of Clear Creek Tidal at I-45, Webster
Clear Creek Above Tidal		
11450	1102	Clear Creek at FM 2351, Friendswood
11452	1102	Clear Creek at Telephone Road, South Houston
20010	1102	Clear Creek Above Tidal at Yost Road, Pearland
16677	1102A	Cowart Creek at Castlewood Drive, Friendswood
16473	1102B	Mary's Creek at Mary's Crossing, North Friendswood
17068	1102C	Hickory Slough at Robinson Drive, Pearland
21925	1102D	Turkey Creek at Beamer Road, Friendswood
18639	1102F	Mary's Creek Bypass at East Broadway Street, Pearland
*18636**	*1102G*	*Unnamed Tributary of Mary's Creek at Thalerfield Drive*

* - Refer to Footnote 33 regarding data from these sites.

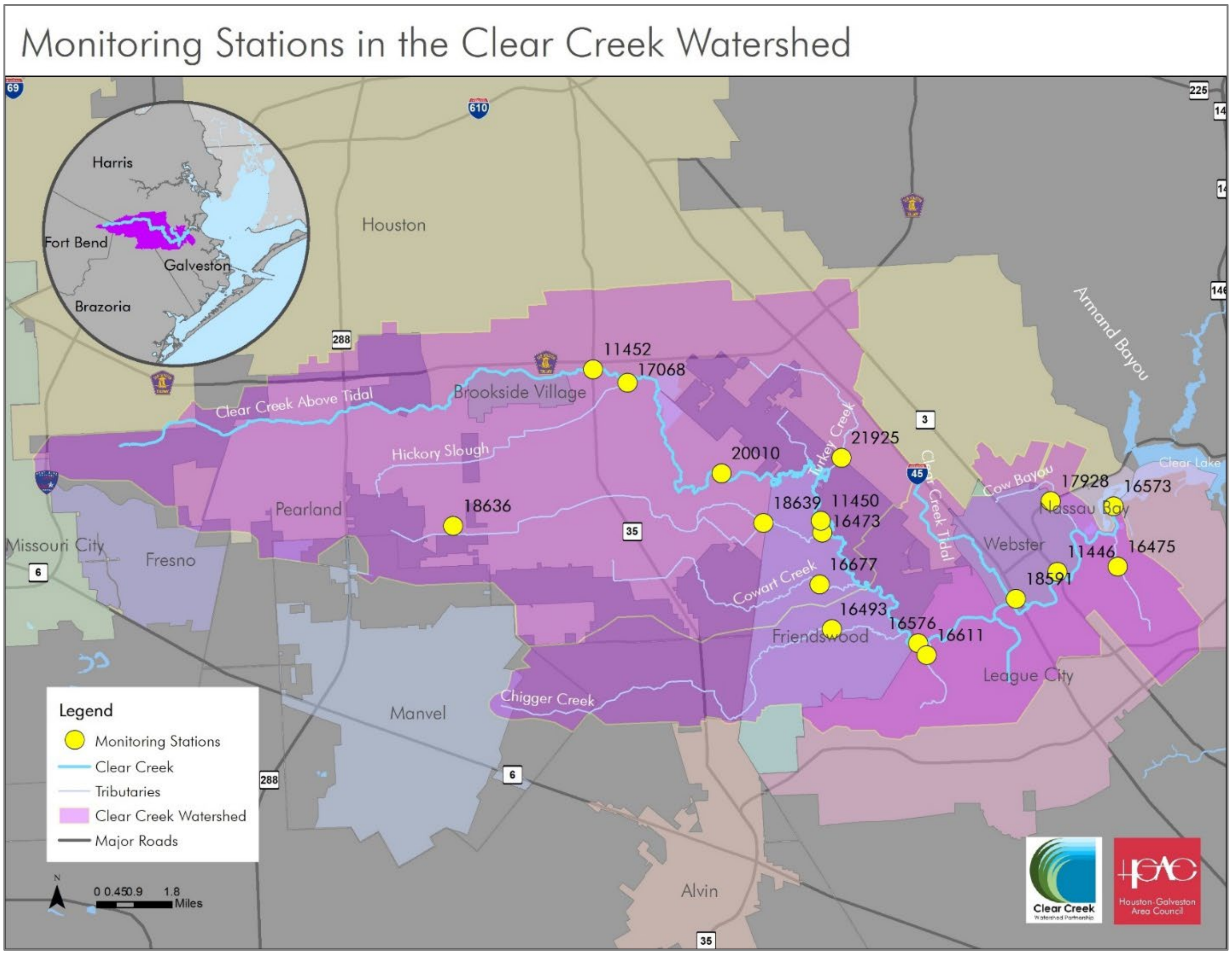

Figure 21 - Monitoring Stations of the Clear Creek Watershed

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) and Enterococcus* – bacterial indicators of the presence of fecal wastes, and indicators of the safety of waterways for human recreation. *E. coli* is used for freshwater systems like Clear Creek Above Tidal, and Enterococcus is used for tidally influenced/marine systems like Clear Creek Tidal.
- *DO, grab* – an indicator of the ability of the waterway to support aquatic life.
- *DO, 24*-hour – an indicator of the ability of the waterway to support aquatic life throughout the daily cycle.
- *Temperature* – an indicator of a waterway's ability to hold oxygen, and a means for correlating other indicators to conditions in the waterways.

- *pH* – an indicator of the acidity or basicness of water, which may affect aquatic life and other uses.
- *Chlorophyll-a* – an indicator of aquatic plant productivity and action, which can indicate areas in which algal blooms or elevated nutrient levels are present, and thus potentially depressed DO.
- *Nitrate Nitrogen* – an indicator of nitrogen contribution to nutrient levels (and DO impacts).
- *Ammonia (NH_3-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 over time.
- *Total Phosphorus* – an indicator of nutrient levels, especially in relation to potential for algal blooms and depressed DO in elevated levels.

The analyzed data covers 3,825 samples from the 17 stations over a period between 2014-2020 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[34] on both the individual station and segment level, with attention to any unclassified tributaries which may be experiencing water quality issues.

Monitoring Analysis

Tabular summaries of ambient monitoring data are shown in Appendix B. This dataset is from TCEQ's Surface Water Quality Monitoring Information System, and the period of record is designed to generally reflect that of the load duration curves mentioned in Section 4[35].

[34] The description of the water quality analyses in this section is a summary of the more exhaustive details on goals, methods, data sufficiency, process, and outcomes available in the Water Quality Data Collection and Trends Analysis Report available on the project website at: https://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/clear_creek_water_quality_trends_report_phase_1_final.pdf.

[35] These results are not wholly comparable to that of the 2022 Texas Integrated Report which uses a different period of record and assessment attainment by Assessment Unit. The 2022 Texas Integrated Report examined surface water data collected (2013-2020), and this analysis uses data collected from 2014-2020.

Water Quality Parameter Sufficiency and Trends

By examining all data for all parameters collected from surface water samples in the Clear Creek watershed and how measurements for those parameters have changed over time, trends in the data were determined. While some sites had limited data, there were sufficient samples to characterize the segments overall and individual AUs or tributaries. Table 8 indicates the parameters in the main channels of Segments 1101 and 1102 and the unclassified tributaries of the systems for which there are statistically significant trends[36]. Some trends, especially for the main channel, are not consistent across the whole segment or tributary, though the issues related to the constituents of primary concern (particularly *E. coli* and Enterococcus) are relatively consistent. The broadest view of the system's trends is that there are few statistically significant trends in either improvement or degradation. Of the 120 instances (parameter by segment/tributary) reviewed, only 10 instances indicated a statistically significant improvement, and only 5 showed statistically significant degradation over the whole period of time represented by the dataset. Most importantly, there were no statistically significant trends in either *E. coli,* Enterococcus, or DO.

Relationship to Flow

Parameter measurements and their relationships to flow conditions were considered in this analysis. Further work on the relationship between flow, bacteria, and DO was completed as part of the model development explained in Section 4. According to the results of the models, surface water in the Clear Creek watershed is likely impacted by nonpoint source pollution. This is indicated by fecal indicator bacteria concentrations that are observed to increase with flow magnitude.

[36] The trends represented here do not consider stations for which there were fewer than 10 samples for any given parameter. These stations were excluded from the analysis for lack of sufficient data.

Table 7 - Trends Analyses by Parameter, 2014-2020

Parameter	Improving	No Change	Deteriorating
Ammonia-N	4	9	.
Chlorophyll-*a*	.	1	.
Dissolved Oxygen (24-hour Mean/ Grab Screening Level)	.	14	.
Dissolved Oxygen (24-hour Minimum / Grab Minimum)	.	2	.
E. Coli	.	11	.
Enterococci	.	3	.
Instantaneous Flow	.	10	1
Nitrate-N	.	13	.
Temperature	.	12	1
Total Phosphorus	.	13	.
Total Suspended Solids	.	11	2
pH	1	11	1

Ambient Data Analysis Summary

Of the ambient water quality parameters observed, geomean values for fecal indicator bacteria levels consistently exceeded state water quality standards across most waterways. Of the 17 stations evaluated for either *E. coli* or Enterococcus, only station 16573 and 18591 on tributary 1101F (Unnamed Tributary) of the Tidal segment did not exceed the geomean for the cumulative review of the data period[37]. The cumulative samples for each segment were in excess of the respective criteria. More importantly, a review of maximum and minimum values indicated a wide range, with significant peaks across most waterways.

In looking at seasonality of fecal bacteria values, there was little differentiation in the Tidal segment, although fall geomeans were relatively lower on both stations with *E. coli* data. In the Above Tidal segment, winter was the period of highest geomeans for all waterways. Many waterways had their second highest seasonal geomeans in spring, but this was less universal (only 4 of 7 waterways followed this trend).

DO levels were less frequently an issue for waterways of the system, but still persistent throughout the data period. In a review of DO grab samples collected in the Tidal segment,

[37] However, in a review of samples by seasons, both of these stations exceeded the geomean in at least one cumulative assessment of a season's data.

only two tributary stations had neither exceedances of the minimum standard or the screening level. Two stations had no minimum criteria exceedances but exceeded the screening level between 7.1 to 17.8% of the time. The other five stations exceeded both the minimum and screening level standards by ranges of 3.6% to 19.7% and 10.1% to 37.5%, respectively. In the Above Tidal segment, three stations had neither minimum no screening level exceedances; two had screening level exceedances (ranging from 5.9% to 23.5%) but no minimum exceedances; and five had both minimum exceedances (ranging from 2.3% to 60% on 1102G) and screening level exceedances (ranging from 4.7% to 80%). While the Above Tidal had fewer stations with exceedances, some of the highest rates of exceedances are found in that part of the system. Seasonally, there was not a significant difference in distribution (or sufficient exceedances) of minimum criteria exceedances between seasons to identify any seasonal patterns for each segment. However, looking at the entire system overall, summer had higher rates of exceedance, while winter had the lowest rate.

Nutrients and other parameters also seem to pose a challenge to water quality in the Clear Creek Watershed. While there were few if any exceedances for temperature (0%) or pH (0.8% in 1101) in either segment, Nitrate was an issue for both the Tidal (with 50% of main channel values and 100% in 1101A), and Above Tidal (with 1102, 1102B, -D, and -F having exceedances that ranged from 42.9% to 71.4%.) Total Phosphorus also exhibited widespread exceedances in all of the main channel and tributary assessments in the Tidal (ranging from 10.7% to 92.9%) and Above Tidal (ranging from 3.1% to 76.5%)

Overall, the results indicated that while most parameters did not show appreciable change in levels over the time period of the data, significant and persistent water quality issues remain for most of the waterways of the system.

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 two active TST sites in the Clear Creek watershed. Project staff reviewed the data from these sites and inactive sites 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 but was not used in any quality-assured modeling or water quality analyses for this project.

Wastewater Treatment Facility Discharge Data

Discharges from wastewater treatment facilities (WWTFs) are regulated by Texas Pollutant Discharge Elimination System (TPDES) permits from TCEQ which require stringent limits for effluent quality. Human waste has a relatively high potential to cause human illness[38], so identifying trends in permit exceedances for fecal bacteria 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. At the time of this study[39], there are 21 permitted WWTFs with 22 outfalls in the Clear Creek Watershed (as indicated in Figure 22 and Appendix C).

Discharges from WWTFs are monitored on a regular basis (with a frequency dependent on facility size and other factors). The data from these required sampling events are submitted to (and compiled by) TCEQ as DMRs. As with any self-reported data, there is an expectation that some degree of uncertainty or variation from conditions may occur, but these DMRs are the most comprehensive data available for evaluating WWTFs in the watershed.

Project staff evaluated five years of DMRs from TCEQ, reported between 2016 and 2021[40]) by WWTF permit holders in the Clear Creek watershed. Five parameters common to most WWTF permits were assessed including: Fecal Bacteria (*E. coli* or Enterococcus), Total Suspended Solids (TSS), ammonia nitrogen (NH_3-N), DO, and five-day carbonaceous biochemical oxygen demand ($CBOD_5$). While some parameters are themselves constituents of concern, all are indicators of the presence or potential presence of untreated/improperly treated waste[41]. The parameter evaluations were based on the regulatory permit limits specific to each facility, and consider the number of exceedances by each facility, in each year, in each segment, and as a percentage of the total samples.

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[38] 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 https://www.mdpi.com/2073-4441/12/2/327.

[39] Greater detail about the methods and results for the DMR analyses can be found in the Water Quality Data Collection and Trends Analysis Report available on the project website at: https://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/clear_creek_water_quality_trends_report_phase_1_final.pdf.

[40] 2021 data was not complete at the time of the analysis but was considered along with the previous 5 years.

[41] In consideration of the nutrient loading capacity of the facilities, it should be noted that some nutrient parameters are not standard facility 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 facilities as nutrient loading sources for non-permit limit parameters.

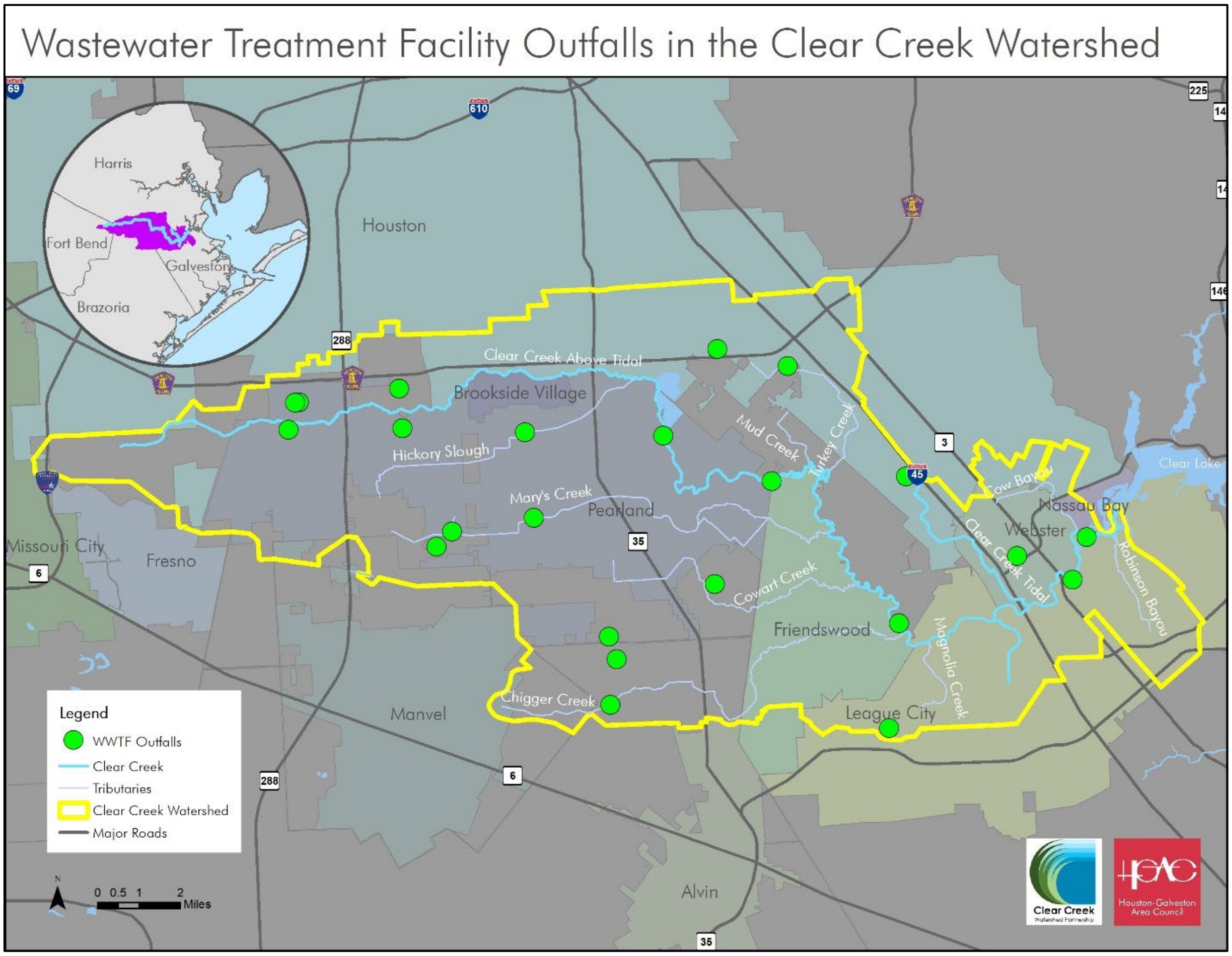

Figure 22 - WWTF outfalls in the Clear Creek watershed

Fecal Indicator Bacteria

Effluent discharge from WWTFs is assessed for compliance with the TPDES permitted limits. For this analysis, DMR data were compared to TPDES permit limits for fecal indicator bacteria across segments, facility types, years, and seasons. The values for exceedances of geomean and single sample limits in Table 9 were calculated for each facility depending on their specific permit limits. Plants in both the Tidal and Above Tidal segments that reported fecal indicator bacteria are included in these analyses.

Table 8 - Fecal bacteria exceedances, 2016-2021

Parameter	Number of Plants	Percentage of Plants
Plants in DMR dataset	19	100%
Plants report bacteria	18	95%
Less than 1% violations	12	67%
1% to 5% violations	5	28%
5% to 10% violations	1	6%
Exceedances of geomean	1	6%
Exceedances of single grab	8	44%

Overall, the results of the analyses of DMR fecal bacteria data indicated that the total number of exceedances reported was small relative to the total number of DMR reports submitted for the period of 2016 to 2021 (9 out of 501 records, or 1.8%). Further, only 1 facility out of 61 exceeded the bacteria standard in >5% of their samples. Maximum grab values more commonly exceeded than geomean limits which suggests high variability in the data.

Seasonality of exceedances was reviewed, with most exceedances (21 of 29) in the spring and summer months. Evaluations of facility size relative to number of exceedances revealed that larger plants (5-10 million gallons a day permitted discharge) had the most violations of any size category for single sample standards. This may be in part due to relative frequency of monitoring, wherein large facilities monitor more frequently. However, the small number of overall violations makes both the seasonal and plant size analyses not significant indicators of past or future performance.

While WWTFs may be appreciable contributions under certain conditions and in localized areas, the DMR analysis indicated that they are not likely a significant driver of segment bacteria impairments due to the comparatively few exceedances. However, due to the relatively higher risk of pathogens from human waste, and proximity to developed areas, WWTF exceedances are still a point of concern for stakeholders.

Dissolved Oxygen

DO levels in WWTF effluent help indicate the efficiency of treatment processes. DO is generally more stable in effluent than it can be in ambient conditions because it is less subject to natural processes and variation in insolation. DO is measured in milligrams per liter (mg/L), and the permit limits can vary based on the receiving water body and other factors. Unlike other contaminants, DO limits are based on a minimum, rather than maximum level, and represent a grab sample as opposed to a 24-hour monitoring event. Generally, permit limits for the data reviewed ranged between 4-6 mg/L. Evaluations for compliance with the permit limits were for all records, between years, and by season. 19 plants reported DO results during this period. The outcomes are summarized in the tables below. Table 10 summarizes the overall statistics of DO data reported by WWTFs in the Clear Creek watershed.

Table 9 - DO exceedances, 2016-2021

Parameter	Number	Percent of Records
Plants in DMR dataset	19	100%
Plants that report DO	18	95%
Total Records	1347	100%
Total Exceedances	1	<1%

Only 1 sample fell below the minimum standard, making additional analyses by year, size, or season irrelevant. However, these values may not accurately represent DO dynamics in the Clear Creek Watershed. Due to the findings of this analysis, it is unlikely that low DO levels in the waterways of the Clear Creek Watershed are being driven by WWTF effluent. As with the results of the bacteria analysis, it is important to note that periodic impacts to DO levels may occur on a localized level but may not be well represented in this broad analysis.

While the impacts of WWTFs on DO levels may not be a chronic or widespread issue in the watershed, an analysis of DO values reported in DMRs is still a critical component of this project especially as it pertains to identifying localized impacts. In addition, the levels of direct oxygen-demanding constituents ($CBOD_5$ and ammonia-nitrogen) present in wastewater discharges can have a more prolonged downstream impact on instream DO concentrations than effluent DO concentrations.

Total Suspended Solids

To determine the efficiency of wastewater treatment in removing solids, TSS is evaluated. Bacteria use suspended particles as a protected growth medium and can therefore occur in greater concentrations when TSS is high. Additionally, TSS can be useful as an indicator that inefficient treatment may have led to other waste products (nutrients, *etc.*) being elevated in effluent. Permit limits for TSS include a concentration based (average) limit in mg/L and a total weight-based limit in pounds per day. Both average and maximum monitored results exist for most facilities. Evaluations for compliance with concentration and total weight permit limits were made for the overall dataset and for annual and seasonal data. The summary of reports made for TSS measurements, and the number of exceedances of the concentration and weight limits are presented in Table 11 below.

Table 10 - DMR TSS exceedance statistics, 2016-2021

Category	Number	Percent of Records
Plants in DMR dataset	19	100%
Plants reporting TSS	18	95%
Total Records	4,041	100%
Total Exceedances	42	1.0%
Total Exceedances, Concentration Average (mg/L)	21	50% of exceedances
Total Exceedances, Concentration Maximum (mg/L)	5	12% of exceedances
Exceedances, Weight Average (kg/d)	16	38% of exceedances

Compared to the total number of reports submitted between 2016 and 2021, the total frequency of exceedance is very small (approximately 1%). Viewing the data annually, there is a slight trend in both weight (average) and concentration (average), with exceedances increasing in the latter years of the range. Seasonally, winter saw the most exceedances, and fall the least. However, the very small number of exceedances limits the usefulness of these analyses. Though periodic, local impacts may not be captured by these results, water quality throughout the Clear Creek watershed is unlikely to be impacted by TSS from WWTFs at the watershed level. Despite this, observing TSS in WWTF effluent is still worth considering when moving forward with best management practices (BMPs) for water quality. As mentioned previously, TSS is often correlated with nutrient and bacteria levels, and can be tracked as a measure of WWTF improvement.

Ammonia Nitrogen

Ammonia nitrogen is a component that indicates negative impacts to water quality due to nutrient loading. Further, it can be toxic to humans and wildlife. Deficiencies in wastewater treatment that lead to improperly treated sewage entering waterways can be indicated by elevated levels of ammonia nitrogen. Similar to TSS, concentration and weight measurements are used to assess compliance of ammonia nitrogen levels with permit limits. In Table 12 below, the results of samples reported to be in exceedance of the limits as reported between 2016 and 2021 are summarized.

Table 11 - Ammonia nitrogen exceedances, 2016-2021

Category	Number	Percent of Records
Plants in DMR dataset	19	100%
Plants reporting TSS	18	95%
Total Records	4041	100%
Total Exceedances	154	3.8%
Total Exceedances, Concentration Average (mg/L)	40	26% of exceedances
Total Exceedances, Concentration Maximum (mg/L)	31	20% of exceedances
Exceedances, Weight Average (kg/d)	83	54% of exceedances

The results of the analyses of ammonia nitrogen reported by Clear Creek watershed WWTFs show that exceedances were rare, representing only 3.8% of all samples, but were more excessive than other constituents. However, the exceedances for all categories did not follow any specific annual pattern and did not show a trend linearly across the period of data. This indicates that WWTFs are generally operating within permit limits and that ammonia inputs from WWTFs are not likely a chronic issue of importance for Clear Creek waterways. Periodic, localized impacts may not be as apparent when using a broad scope analysis. Ammonia nitrogen may still have use as an indicator of WWTF efficiency much in the same way as TSS and will therefore continue to be considered for best management practices in the watershed.

Oxygen Demand

$CBOD_5$ measures the depletion of oxygen over time by biological processes and indicates the efficiency of treatment. It is not a pollutant itself but is informative of the water quality of effluent from WWTFs. In Table 13 below, the exceedances of concentration and weight limits for $CBOD_5$ in relation to the total number of reported values are summarized.

Overall, $CBOD_5$ exceedances were exceedingly rare in this DMR dataset compared to the other observed parameters, representing less than 1% of all samples. While the small subset of exceedances limits the usefulness of these analyses, there was a trend toward more exceedances in later years of the time period, but little meaningful season variation, other than relatively few exceedances occurring in the summer months.

Table 12 - DMR $CBOD_5$ exceedance statistics, 2014-2019

Category	Number	Percent of Records
Facilities in DMR Dataset	61	
Facilities Reporting $CBOD_5$	61	
Total Records	8,164	
Exceedances of Concentration	17	0.2%
Exceedances of Weight	11	0.1%
Total Exceedances	28	0.3%

From this analysis, it can be assumed that WWTFs are not likely a chronic source of poor $CBOD_5$ values in the waterways of the Clear Creek watershed. As with previous analyses however, it should be noted that determining periodic and localized impacts may require further investigation.

Discharge Data Analysis Summary

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

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

Sanitary Sewer Overflows

Unlike treated WWTF effluent, SSOs represent a high, if episodic risk, because they can have concentrations of bacteria several orders of magnitude higher than treated effluent. Untreated sewage can contain large volumes of raw fecal matter, making it a significant health risk where SSOs are sizeable and/or chronic issues. The causes of SSOs vary from human error to infiltration of rainwater into sewer pipes. Data used for these analyses is self-reported and may vary in quality. Even in the best of circumstances, the ability to accurately gauge SSO volumes or even occurrences in the field 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 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[42].

This study considered six years of TCEQ SSO violation data for 2016-2021[43]. There were 338 SSO records from 12 of the 19 plants with collection systems considered for the watershed area. Of those 12 plants, eight plants had more than five SSOs, and of those eight plants, six plants had 10 or more SSOs. Three plants had a 6-year total in excess of 75 SSOs each. The numbers and volumes of SSOs are indicated in Table 14.

Table 13 - Number and volume of SSOs, by plant size

Category	Number of plants	Number of SSOs	% of SSOs	Volume of SSOs in gallons	% of SSO Volume
Plants in SSO dataset	12	338	100%	3,010,610	100.0%
Plants with <5 SSOs	4	10	3%	30,050	1.0%
Plants with 5-10 SSOs	2	17	5%	76,250	2.5%
Plants with 10-30 SSOs	3	68	20%	1,295,407	43.0%
Plants with 30-90- SSOs	3	243	72%	1,608,453	53.5%

Volume of SSOs corresponded roughly with numbers, but with the plants in the 10-30 SSO range represented with disproportionately large volumes. Plants with the largest number of SSOs still made up the largest volume, but disproportionately smaller than the numbers they represented. On an individual plant scale, the percentages vary even more greatly. The top two plants whose number of SSOs represent roughly half of all SSOs by number, only represent 5% of the total SSO volume, whereas the plant with the third largest number of SSOs represented nearly half the total SSO volume. It should be noted that the period this assessment covers includes Hurricane Harvey in 2017, as well as other high profile flooding events, which impacted this area with storm surge and heavy flooding. Some portion of the volumes represented here are due to those storms, and it is likely a large volume of wastewater from SSOs during the storms is unaccounted for due to the conditions

[42] For example, fats, oils, and grease collecting in lift station motors 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.
[43] When the report was compiled, the 2021 dataset was not yet complete.

in the field. There was not a significant increase or decrease in number or volume of SSOs over time.

In reviewing the causes of SSOs, potential causes were grouped into four main categories: Weather, Malfunctions, Blockages, or Other/Unknown. Table 15 indicates the percentage of SSOs by number and volume attributed to each cause.

Table 14 - Causes of SSOs by number and volume

Cause	% of SSOs by Number	% of SSO Volume
Weather	27.2%	38.9%
Malfunctions	24.8%	53.5%
Blockages	43.5%	4.5%
Other/Unknown	4.4%	2.9%

While blockages were the largest cause category, they represented only a small amount of the total volume. Both Weather and Malfunctions led to much larger volumes being released, representing 92.6% of all volume, but only 52% of all SSOs. The data showed a strong relationship to event in 2017 coinciding with or resulting from Hurricane Harvey impacts. Seasonally, the number of SSOs was distributed fairly equally, while volume was heavily weighted toward spring incidences, representing 60.5% of all volume.

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

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

Other Water Quality Studies

The Clear 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 is 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:

Clear Creek TMDLs

TCEQ developed a series of TMDLs for Clear Creek and its tributaries[44] that are addressed in the much broader Implementation Plan for Seventy-two Total Maximum Daily Loads for Bacteria in the Houston-Galveston Region being implemented by the Bacteria Implementation Group[45]. Prior TMDLs for chlordane and volatile organic compounds (primarily related to the Brio Superfund site) were also developed and are currently either complete or in implementation. The bacteria TMDLs focus singly on bacteria, and its Implementation Plan does not have a granular focus on the Clear Creek Watershed. This WPP is intended to complement that effort, expanding the scope of the pollutants reviewed and the specificity of the recommendations for this area.

Summary of Water Quality Analyses

The review of water quality data for the Clear Creek watershed provided a better understanding of the character of water quality issues in these systems and will inform subsequent stakeholder decisions. The primary questions answered were in regard to 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, but increasing levels and ubiquity of issues with some other constituents. Compared to future growth projections, it is likely that increased development in the watershed will continue to alter the balance of pollutant sources and change the hydrologic processes and time frames by which pollutants reach the waterways in precipitation events.

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 streams that may be effluent dominated. There were few statistically significant relationships between exceedance of water quality standards and WWTF permit limits, or

[44] Available for review at: https://www.tceq.texas.gov/waterquality/tmdl/nav/42-houstonbacteria/42-houstonbig-tmdlplan#clear

[45] More information on the Implementation Plan and the Bacteria Implementation Group can be found at https://www.tceq.texas.gov/waterquality/tmdl/nav/42-houstonbacteria/42-houstonbig-tmdlplan.

incidences of SSOs, and seasonal change other than expected relationships evident in DO levels in ambient conditions. SSOs were present in all areas of the watershed, in numbers that were relatively high for comparative areas, likely owing to the relative age of systems within some areas of the watershed and the relative vulnerability of much of the area to high rainfall events and periodic flooding.

Overall, water quality in these watersheds faces many challenges, but is within the range which may be successfully addressed through best management practices under a watershed-based plan. With continued growth of the watershed continuing to push into the few remaining areas to the west and south, while existing densely developed areas continue to age, the implication for future water quality is likely negative without intervention. Subsequent efforts should be made to identify causes and sources of the primary constituent of concern (indicator bacteria), and to characterize nutrient sources further to identify areas within the project watersheds most vulnerable to pollutant loadings and/or best suited for siting of solutions.

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. Notable sources of other contaminants or stakeholder concerns were also considered.

Fecal Waste Source Identification

Waste from all warm-blooded animals is a potential source of fecal bacteria contamination. The indicator species *E. coli* and Enterococcus are not necessarily themselves the source of potential health impacts; however, they signify the presence of fecal waste and the host of other pathogens associated with it. 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"[46]. The results of the survey shaped further analysis under the source modeling efforts of the project.

[46] For greater detail on the source survey and subsequent bacteria modeling outcomes, please refer to the Water Quality Modeling Report, available online at:

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 true even in a developed watershed like Clear Creek with less natural land cover. 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** — Existing data was used to generate information on discrete (usually permitted) sources. Data sources included[47]:
  - WWTF outfall locations and DMRs (TCEQ outfall locations and DMR records)
  - 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)
  - County-level agricultural census data (United States Department of Agriculture's Census of Agriculture)
- **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 as the basis of populating diffuse sources whose assumptions were tied to specific land cover types in modeling efforts.
- **Imagery Reconnaissance** — Staff utilized aerial imagery, online map assets (Google Maps, Google Maps Street View, Google Earth) and stakeholder feedback to identify any specific locations, specific sources, or issues to raise with stakeholders for further clarification. Examples of this include:
  - Presence of recreational uses
  - Evidence of hydrologic changes/erosion

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https://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/final_clear_creek_wpp_bacteria_modeling_report.pdf

[47] More information on data sources and quality objectives can be found in the project quality assurance project plan (QAPP) and modeling report, available online on the project website at: https://clearcreekpartnership.weebly.com/project-documents.html.

  - 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 areas of the far west and mid-south of the watershed)
  - Signs of streambank stability
  - Signs of wildlife activity in riparian corridors
  - General character of remaining 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 and Work Group meetings
  - One-on-one meetings with local stakeholders
  - One-on-one meetings with state and regional experts/agencies (*e.g.*, the Texas Parks and Wildlife Department (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.

The source survey (Table 16) includes an assessment of the likely prominence of each of the general categories, based on preliminary understandings, rather than the modeled outcomes or final stakeholder feedback. These estimations reflect the current status of the watershed, and some sources may be expected to change in the future, as was assessed by the modeling effort. The results of the fecal waste source survey were used to guide the development of the source modeling.

Table 15 - Fecal waste source survey

Category	Source	Origin	Estimated Extent
Human Waste	WWTFs	Improperly treated sewage from permitted outfalls	Minor to Moderate (locally)
	OSSFs	Failing OSSFs	Minor (locally)
	SSOs	Untreated sewage from wastewater collection systems	Minor to Moderate (locally)
	Direct Discharge	Untreated wastes from areas without OSSF or WWTF service	Minor
	Land Deposition	Improperly use of sewage sludge	Minor
Agriculture	Cattle	Runoff or direct deposition	Minor
	Horses	Runoff or direct deposition	Minor to Moderate (locally)
	Sheep & Goats	Runoff or direct deposition	Minor
	Pigs	Runoff	Minor
	CAFOs	Improperly treated discharge from permitted facilities	Not Expected
Wildlife	Deer	Runoff or direct deposition	Minor to Moderate (locally)
	Birds	Direct deposition	Minor, No Formal Data
	Bats	Direct deposition	Minor, No Data
	Other Animals[48]	Runoff or direct deposition	Moderate, No Data
Domestic Animals	Dogs (pets)	Runoff	Major
	Dogs (feral)	Runoff	Minor to Moderate (locally)
	Cats (pets)	Runoff	Not Expected to Minor
	Cats (feral)	Runoff	Minor to Moderate (locally)
Invasive Animals	Feral Hogs	Runoff or direct deposition	Moderate
Other	Dumping	Runoff or direct deposition	Minor (locally)
	Sedimentation	Erosion or mining operations	Not Applicable[49]

[48] Other Animals is used throughout this document as a means of designating all wildlife populations for which sufficient data does not exist and could not be assessed (unlike colonial birds and bat colonies), and for accounting for potential small loads from feral pet populations. Stakeholder decisions regarding an assumption for this source is discussed in greater detail in its corresponding section.

[49] While not a source of fecal bacteria, suspended sediment in waterways can decrease 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*[50] was being generated by each source, and how those sources were distributed in the watershed.

Spatially Explicit Load Enrichment Calculation Tool

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) is a Geographic Information System (GIS)-based analysis approach developed by the Spatial Sciences Laboratory and the Biological and Agricultural Engineering Department at Texas A&M University[51]. 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[52] estimates are not intended to represent the amount of *E. coli* actually transmitted to the water, as the stock version of 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

[50] In order to ensure consistency in approach between the two segment modeling approaches, *E. coli* loads were estimated for both, despite the different instream fecal bacteria indicators. Load reductions were generated specific to each indicator for the respective segments. The source load reduction calculations are based on percentage reductions, rather than absolute numbers. Therefore, all source load reductions are given in *E. coli*.

[51] Additional information about the stock version of SELECT can be found at: http://ssl.tamu.edu/media/11291/select-aarin.pdf

[52] 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 the fate and transport of pollutants.

the riparian corridor. Realistically, loads generated adjacent to the waterways are more likely to contribute to instream conditions. However, SELECT 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 solutions 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[53]. 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 Clear Creek watershed is primarily built out but will continue to experience developmental change in the coming years. Sources estimated based on data collected as of the year 2020[54] 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 2050 in 5-year intervals[55]. Land use change is a primary driver for estimating changes in source contribution, and spatial distribution of loads[56].

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

[54] References to "current" modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.

[55] 2050 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.

[56] 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,

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 identifying and siting solutions. 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 reduction percentages derived from the models explained in Section 4 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 23).

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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 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.

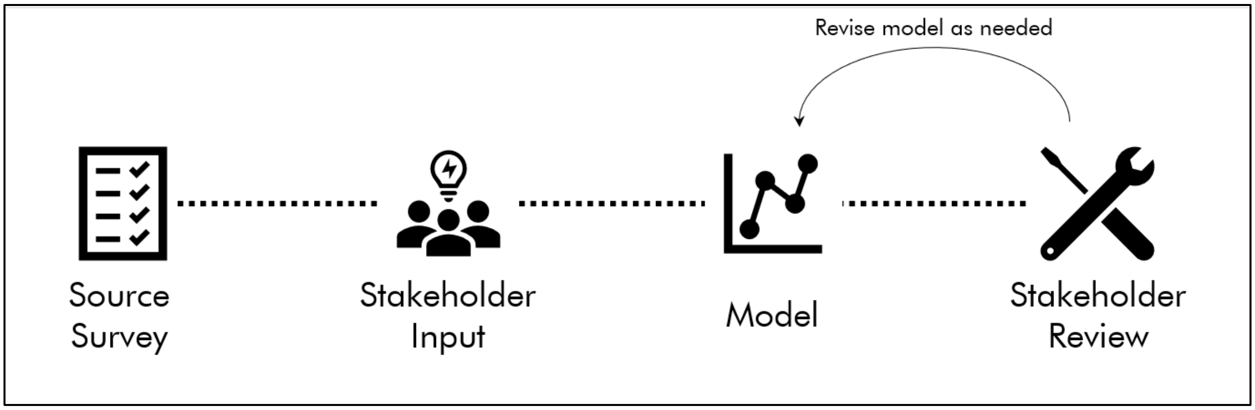

Figure 23 - SELECT modeling process

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[57]. The map for each specific source is 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. A 300-foot buffer around each waterway (appearing as a series of lines on the map) displays loading in these areas separate from the greater land area using the same color scale. Note that major waterways are represented in blue for spatial reference. Colors associated with the loading value within the riparian buffer for each subwatershed are consistent but are partially obscured by the main channel vectors.

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.

Wastewater Treatment Facilities

Wastewater utilities serve a number of communities throughout the watershed and occur in various sizes and capacities. For areas outside city boundaries, centralized waste treatment is most commonly managed by municipal utility districts and other districts. Discharge monitoring report data for fecal indicator bacteria was available from TCEQ for 19 of the 21 WWTFs in the watershed and was incorporated into the SELECT model. Size

[57] For example, 1.0E+12 is equivalent to 1.0×10^{12}, or 1 trillion. E+9 would be billions, E+6 millions, *etc.*

of WWTFs vary greatly throughout the watershed and ranged between capacities of less than 0.1 MGD to 12 MGD. Stakeholders noted that age of wastewater systems in the watershed varied greatly, with newer development in the Pearland and Friendswood areas, and older development in the aspects of the watershed in Harris County and in older areas of Galveston County.

WWTFs in the Clear Creek watershed are not expected to be major contributors to the daily average fecal indicator bacteria loading overall. However, as the risks associated with human waste processed by WWTFs can be considerable in the event of improper treatment or other localized incidents, it is important to consider estimates of potential WWTF loadings in the overall SELECT model. These estimates are derived by multiplying the total discharge capacity of each facility by the state water quality standard for fecal bacteria[58]. For future projections, models continued to estimate fecal bacteria loads at the state standard but adapted flow rates to reflect the projected increase in the number of households within service area boundaries. As many facilities discharge well below their maximum permitted rates, this results in a potential overestimation of fecal bacteria loading from this source. As noted previously, this method is still deemed appropriate for this watershed in order to account for exceedances or variations throughout daily discharges that could have greater impacts to public health.

Current[59] WWTF loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into Clear Creek are represented in Figure 24. Loads were applied at the buffer area loading rate to reflect direct outfalls. For future projections, discharges were assumed to be at the standard. Future flows were increased proportionally to projected household increase within the existing service area boundaries.

Color intensity indicates loading severity relative to the other streams and may not be directly comparable between this modeled parameter and the remaining sources examined with SELECT analyses. Actual loading estimates by subwatershed are represented in Table 17. In Figure 25, forecasted total watershed loads from WWTFs are plotted in five-year increments through the year 2050. WWTF flows and loadings increase slightly through 2050, but they remain a minor contributor to overall potential loading. Currently, areas outside existing service area boundaries and known or planned developments are assumed to be served by OSSFs, including future development.

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[58] While the existing TMDL requires that all permitted WWTFs in the Clear Creek watershed achieve a permit concentration standard of 63 cfu/100mL of *E. coli*, the 126 cfu/100mL standard was used to estimate conservative potential WWTF loadings.
[59] References to "current" modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.

Depending on the extent to which development includes centralized sanitary sewer, OSSF numbers may need to be reduced.

Table 16 - Wastewater facility outfalls and loadings by subwatershed

Subwatershed*	# of Outfalls	*E. coli* Load Estimate (Current)	Subwatershed Percent of Total WWTF Load
1	4	7.36E+09	9.4%
2	1	7.43E+07	0.1%
3	2	8.30E+09	10.6%
4	1	8.45E+09	10.8%
5	1	8.77E+09	11.2%
6	3	8.29E+09	10.5%
7	2	1.33E+08	0.2%
8	0	0.00E+00	0.0%
9	1	3.40E+09	4.3%
10	4	3.38E+10	43.0%
11	0	0.00E+00	0.0%
12	0	0.00E+00	0.0%
13	0	0.00E+00	0.0%
Total	**19**	**7.86E+10**	**100.0%**

*See Figure 6 for subwatershed names and location

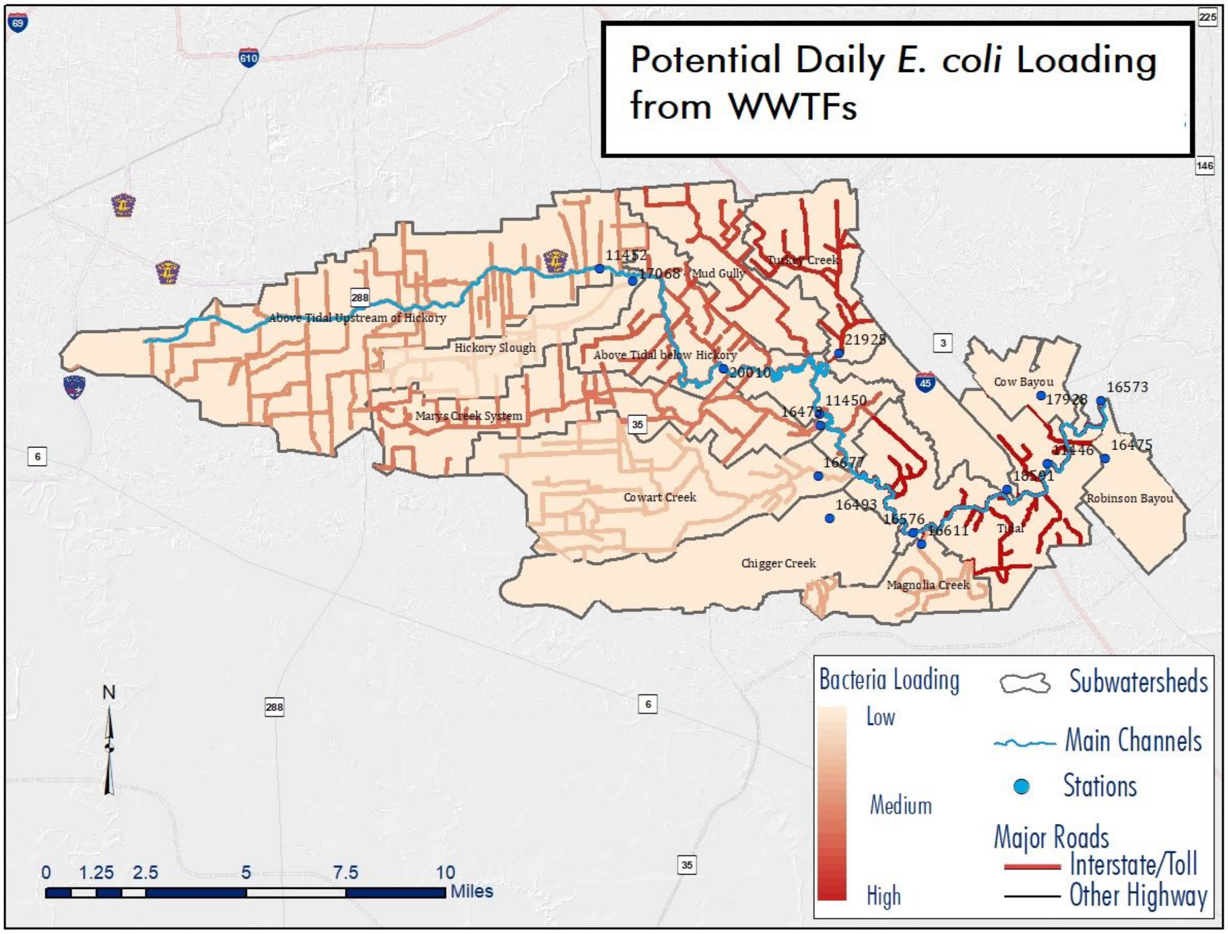

Figure 24 - *E. coli* loadings from WWTFs by subwatershed

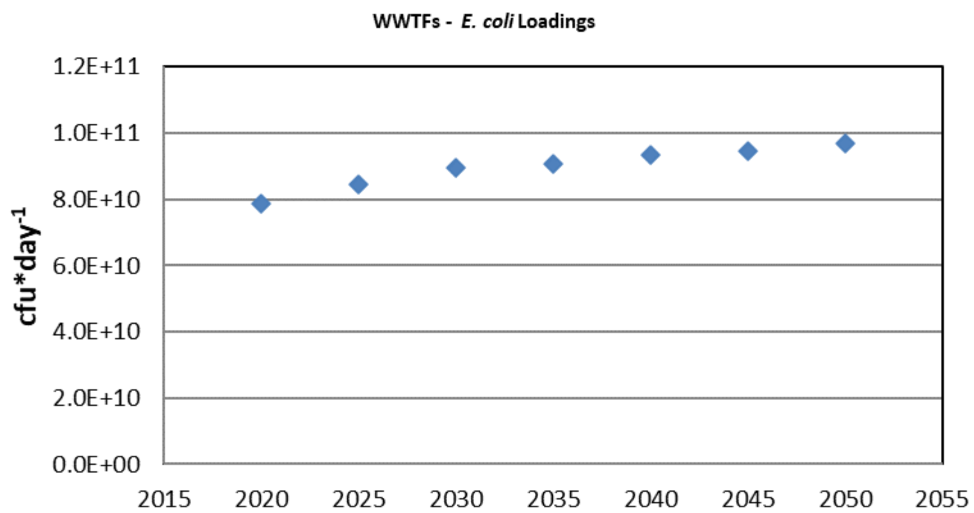

Figure 25 - Future *E. coli* loadings from WWTFs

On-site Sewage Facilities

Failing or improperly maintained OSSFs can be significant sources of fecal bacteria, and are a common 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 remaining outlying areas of the watershed rely on centralized wastewater. While OSSFs in the project area are generally more closely regulated than in some areas of the H-GAC region, the inherently distributed maintenance for those systems is a concern for future water quality as systems continue to age. Systems in this area are a mix of traditional septic systems and other treatment technologies.

Permitted OSSF data were taken from existing spatial data compiled by H-GAC from authorized agents[60]. 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, whether permitted or unpermitted. Project staff discussed failure rate with authorized agents for the area, as well as the Partnership and Human Waste work groups. 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 2050.

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

[60] Data is collected under a 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.

Figure 26 shows the current[61] loading distributions for OSSFs in the watersheds, relative to each subwatershed's contribution. Figure 27 indicates the change in loading over time, through 2050. Table 18 indicates the OSSF source loading estimates by subwatershed.

[61] References to "current" modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.

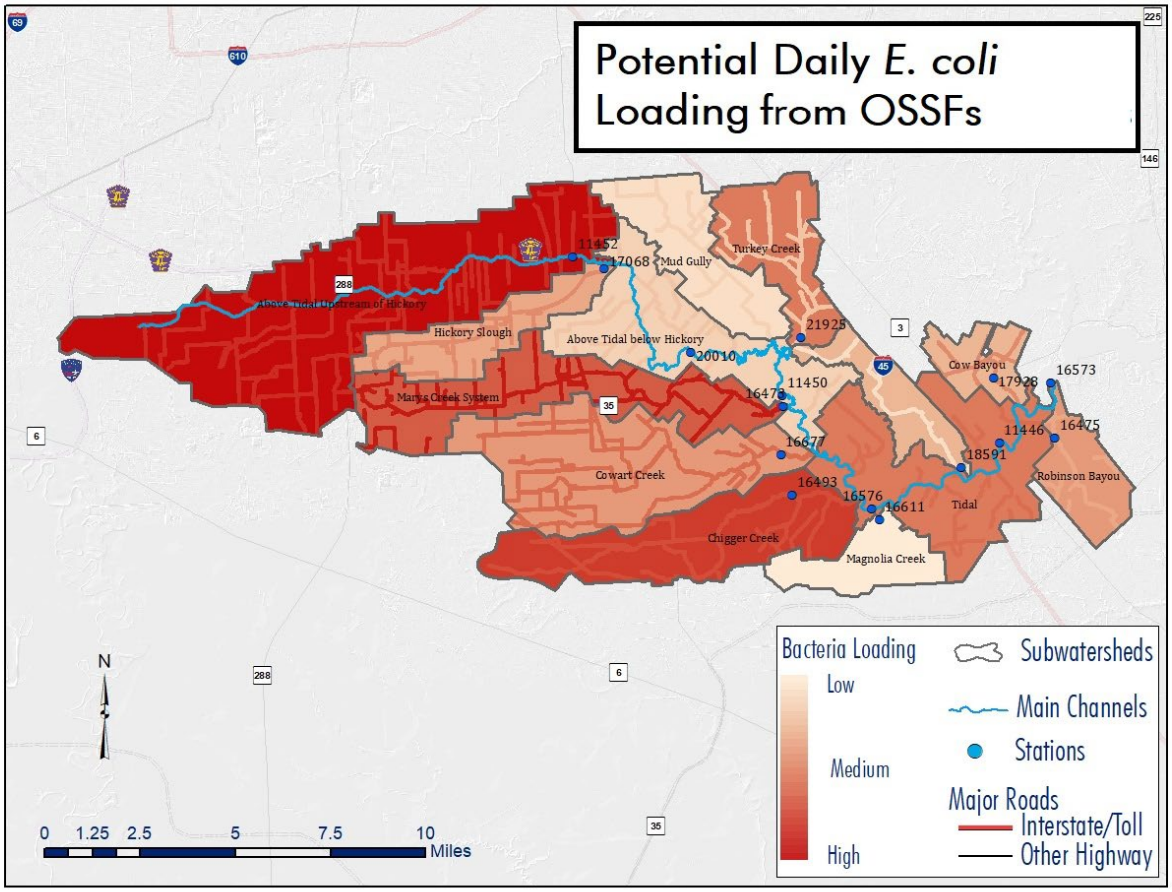

Figure 26 - *E. coli* loadings from OSSFs by subwatershed

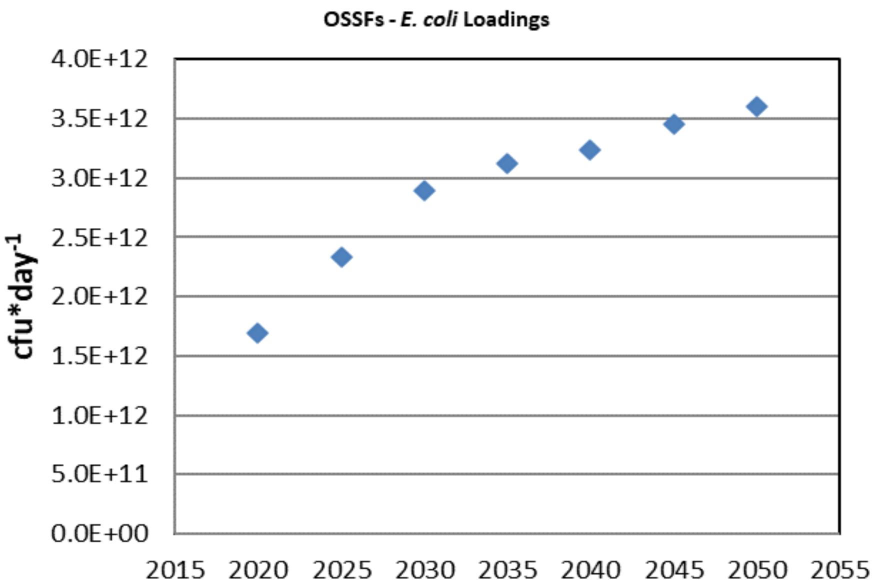

Figure 27 - Future *E. coli* loadings from OSSFs

Table 17 - OSSFs and loadings by subwatershed

Subwatershed	OSSFs Outside Buffer	OSSFs Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Total *E. coli* Load	Subwatershed Percent of Total Load
1	2976	478	2.76E+11	1.77E+11	4.53E+11	26.8%
2	452	139	4.19E+10	5.16E+10	9.35E+10	5.5%
3	59	56	5.51E+09	2.08E+10	2.63E+10	1.6%
4	43	16	4.03E+09	5.80E+09	9.83E+09	0.6%
5	585	72	5.43E+10	2.68E+10	8.11E+10	4.8%
6	1096	723	1.02E+11	2.68E+11	3.70E+11	21.9%
7	483	157	4.48E+10	5.81E+10	1.03E+11	6.1%
8	1242	286	1.15E+11	1.06E+11	2.21E+11	13.1%
9	0	0	0.00E+00	0.00E+00	0.00E+00	0.0%
10	583	205	5.41E+10	7.61E+10	1.30E+11	7.6%
11	393	14	3.65E+10	5.12E+09	4.16E+10	2.5%
12	305	122	2.83E+10	4.51E+10	7.34E+10	4.3%
13	477	116	4.43E+10	4.29E+10	8.72E+10	5.2%
TOTAL	**8694**	**2384**	**8.06E+11**	**8.83E+11**	**1.69E+12**	**100%**

As indicated in Figure 27, OSSF loadings are expected to continue to increase through 2050, with the addition of households in undeveloped areas, outside of wastewater service areas. For the sake of this analysis, areas outside known or planned wastewater service areas were assumed to be reliant on OSSFs. However, additional sewage system development in these areas in the future may reduce the number of OSSFs in new development. While OSSFs are not required to be routinely inspected, new systems must be permitted and have regular maintenance. A 10% failure rate is currently being used for all years, based on stakeholder feedback, although the stakeholders indicated that this be checked regularly as some systems continue to age. An increase in assumed failure rate may be necessary if on the ground conditions warrant.

Pet Waste

Domestic and feral dog populations are a significant contributor to fecal bacteria contamination in the greater Houston region, especially in densely 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[62] 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 American Veterinary Medical Association's statistical data for Texas. Apartment ownership rates do not always match home ownership rates, and the high number of apartment households in the watershed might skew the estimation of dog populations. Project staff conducted a study of six apartment complexes in urban and suburban areas and determined that there was an average of approximately 0.48 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. 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 population will be developed under the WPP, but for the sake of the model, dog waste is tied to the 0.6 assumption.

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 fecal bacteria from dog waste continues to increase through 2050. 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 the ecosystem, 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 30% reduction in pet 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.

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

Dog fecal bacteria loads were derived for milestones at every five years starting with current conditions. Figure 28 shows the current[63] loading distributions for dogs in the watersheds. Figure 29 indicates the change in loading over time, through 2050. Table 19 indicates the actual dog source loading estimates by subwatershed.

Table 18 - Dogs and loadings by subwatershed

Subwatershed	Dogs Outside Buffer	Dogs Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Total *E. coli* Load	Subwatershed Percent of Total Load
1	12,683	4,034	4.44E+12	5.65E+12	1.01E+13	20.8%
2	2,412	848	8.47E+11	1.19E+12	2.04E+12	4.2%
3	7,343	2,178	2.57E+12	3.05E+12	5.62E+12	11.6%
4	7,864	1,247	2.75E+12	1.74E+12	4.49E+12	9.3%
5	4,428	813	1.55E+12	1.14E+12	2.69E+12	5.6%
6	8,388	2,373	2.93E+12	3.33E+12	6.26E+12	12.9%
7	3,903	1,146	1.37E+12	1.60E+12	2.97E+12	6.1%
8	3,222	647	1.13E+12	9.03E+11	2.03E+12	4.2%
9	2,259	649	7.91E+11	9.10E+11	1.70E+12	3.5%
10	9,562	1,649	3.35E+12	2.31E+12	5.66E+12	11.7%
11	590	40	2.07E+11	5.58E+10	2.63E+11	0.5%
12	4,445	898	1.55E+12	1.26E+12	2.81E+12	5.8%
13	3,279	484	1.15E+12	6.78E+11	1.83E+12	3.8%
Total	**70,378**	**17,007**	**2.46E+13**	**2.38E+13**	**4.84E+13**	**100%**

[63] References to "current" modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.

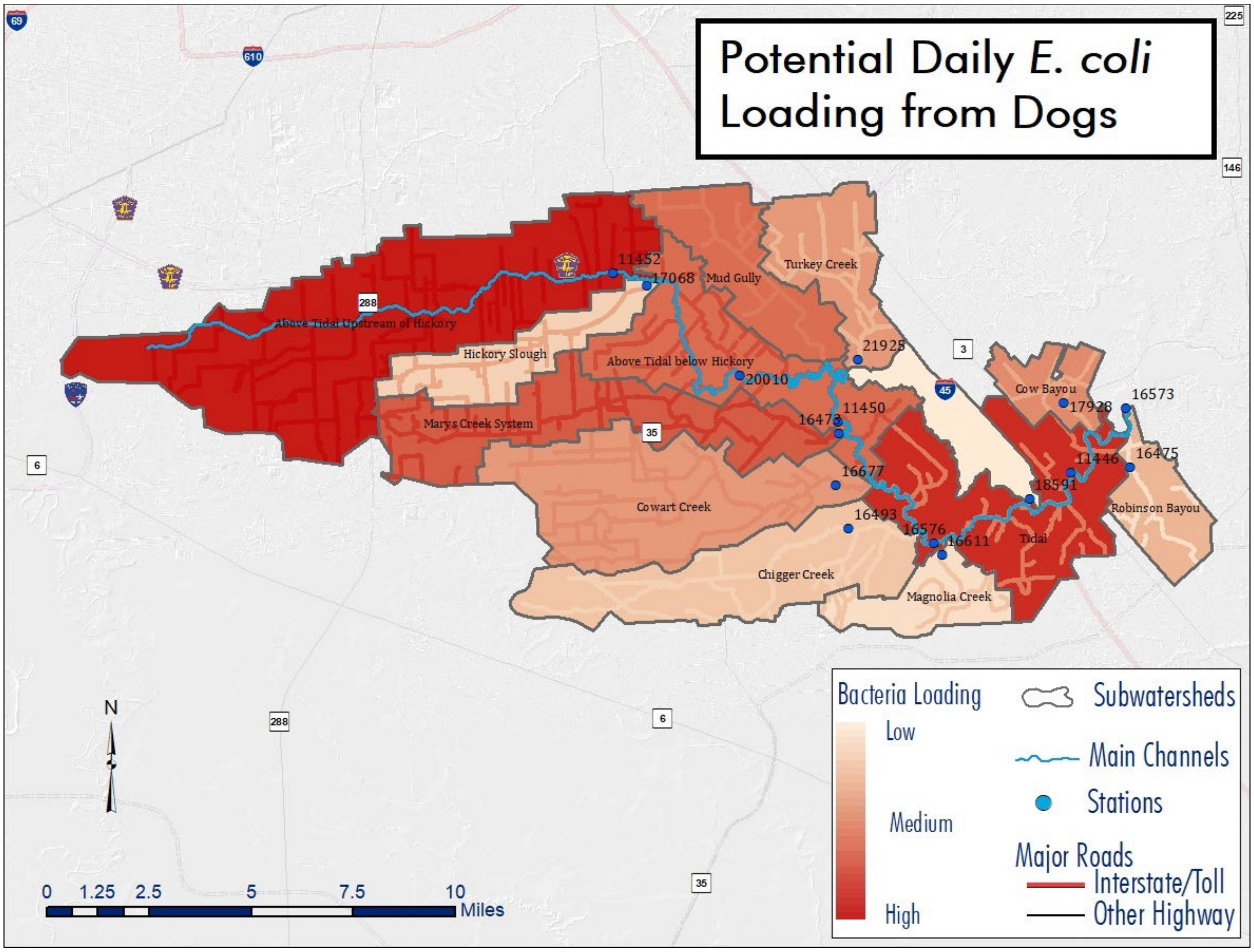

Figure 28 - *E. coli* loadings from dogs by subwatershed

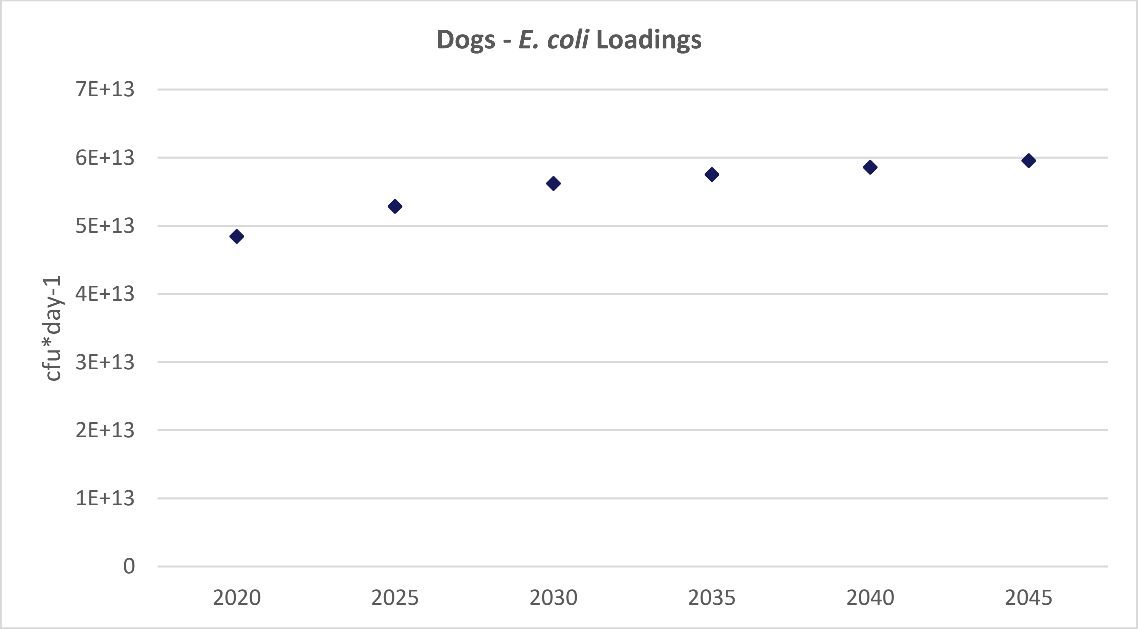

Figure 29 - Future *E. coli* loadings from dogs

Cattle

Cattle production has been historically present in parts of the watershed, and production is currently concentrated primarily in the undeveloped and rural areas in the headwaters and southern portions of the watershed. Developmental pressure, weather events (*e.g.*, the 2011 drought), and other market forces have led to a marked decline in agricultural production in general in the Clear Creek Watershed. Initial estimates of cattle populations for the watershed were based on the latest (2017) livestock census data from the United States Department of Agriculture's (USDA's) National Agricultural Statistics Service (NASS). Because the data for cattle is not specific to the watershed area, cattle were assumed to be equally distributed throughout applicable land cover (grassland and pasture/hay) in each county. H-GAC generated the ratio of each county's portion of the watershed's acreage in appropriate land cover types to the acreage of the entire county. This ratio was then applied to county cattle populations, to establish the number of cattle proportional to the size of the watershed acreage in that county. This approach ensures that the density of cattle in a county's applicable land cover acreage 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 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. There are no CAFOs in the watershed.

Cattle fecal bacteria loads were then derived for milestones at every five years starting with current conditions. Table 20 indicates the actual cattle source loading estimates by subwatershed. Figure 30 shows the current[64] loading distributions for cattle in the watersheds. Figure 31 indicates the change in loading over time, through 2050.

Cattle production and presence in the watersheds is expected to continue to decrease, leading to a corresponding decrease in potential fecal bacteria load. 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.

[64] References to "current" modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.

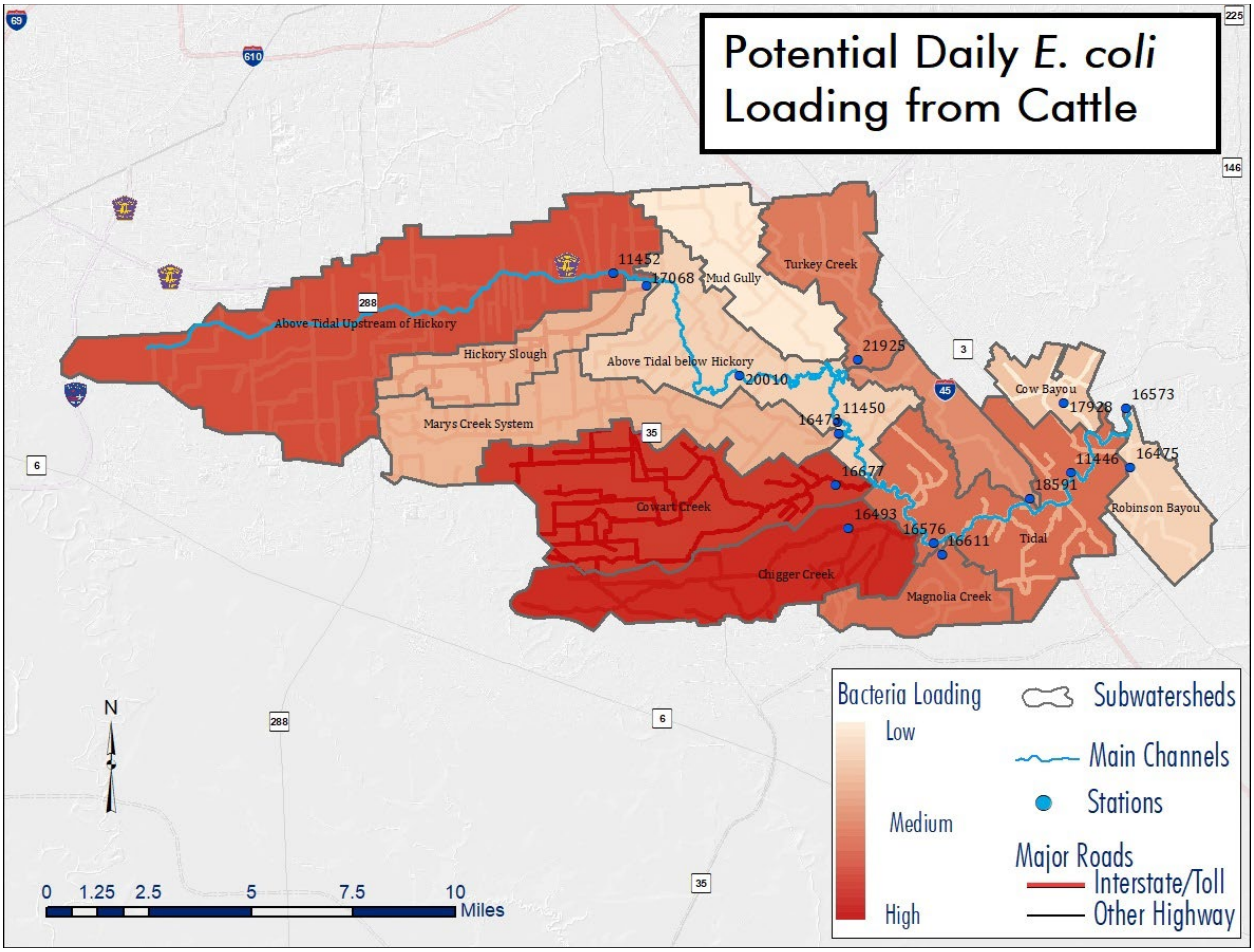

Figure 30 - *E. coli* loadings from cattle by subwatershed

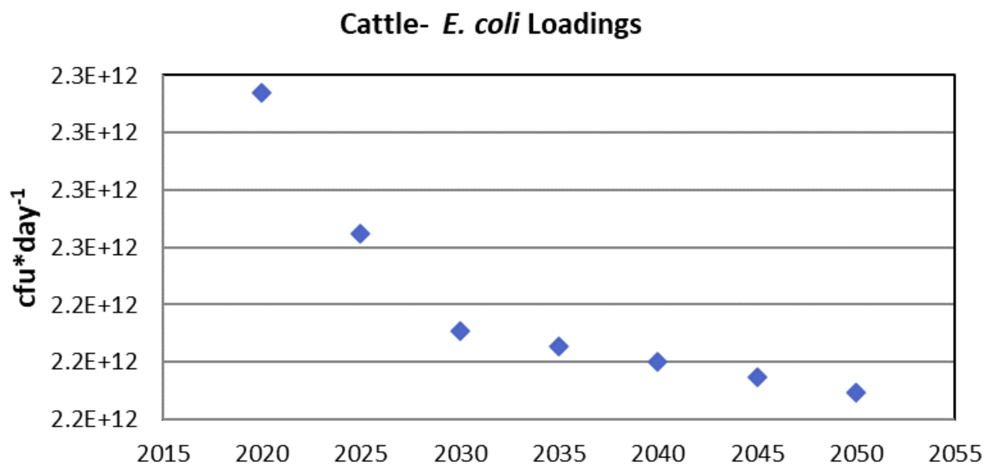

Figure 31 - Future *E. coli* loadings from cattle

Table 19 - Cattle and loadings by subwatershed

Subwatershed	Cattle Outside Buffer	Cattle Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Total *E. coli* Load	Subwatershed Percent of Total Load
1	396	73	2.67E+11	1.98E+11	4.65E+11	20.1%
2	31	10	2.10E+10	2.81E+10	4.91E+10	2.1%
3	12	7	8.36E+09	1.98E+10	2.82E+10	1.2%
4	2	1	1.02E+09	2.30E+09	3.32E+09	0.1%
5	63	13	4.25E+10	3.62E+10	7.87E+10	3.4%
6	32	9	2.15E+10	2.55E+10	4.70E+10	2.0%
7	430	179	2.90E+11	4.84E+11	7.74E+11	33.5%
8	459	115	3.10E+11	3.12E+11	6.22E+11	26.9%
9	73	14	4.92E+10	3.67E+10	8.59E+10	3.7%
10	65	10	4.39E+10	2.61E+10	7.00E+10	3.1%
11	47	11	3.20E+10	2.85E+10	6.05E+10	2.6%
12	20	0	1.35E+10	9.86E+06	1.35E+10	0.7%
13	16	2	1.09E+10	6.63E+09	1.75E+10	0.8%
Total	**1646**	**444**	**1.11E+12**	**1.20E+12**	**2.31E+12**	**100.0%**

Horses

Unlike cattle populations in the watershed, horses have straddled the divide between rural areas and suburban/exurban development. Horse populations are found in both traditional rural settings and in less densely developed areas, where recreational[65] horse ownership was noted. Primary modes of ownership include traditional rural populations accompanying existing agricultural operations, and 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.

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, and then with the work group and Partnership.

[65] "Recreational" is used here in comparison to horses that are part of an agricultural operation or property.

Horse fecal bacteria loads were then derived for milestones at every five years starting with current conditions. Figure 32 shows the current[66] loading distributions for horses in the watersheds. Figure 33 indicates the change in loading over time, through 2050. Table 21 indicates the actual horse source loading estimates by subwatershed. As with cattle and other livestock, horse populations are expected to decline as development pushes further into rural areas. However, the extent of reduction is expected to be somewhat less as exurban acreage developments continue to support small horse populations.

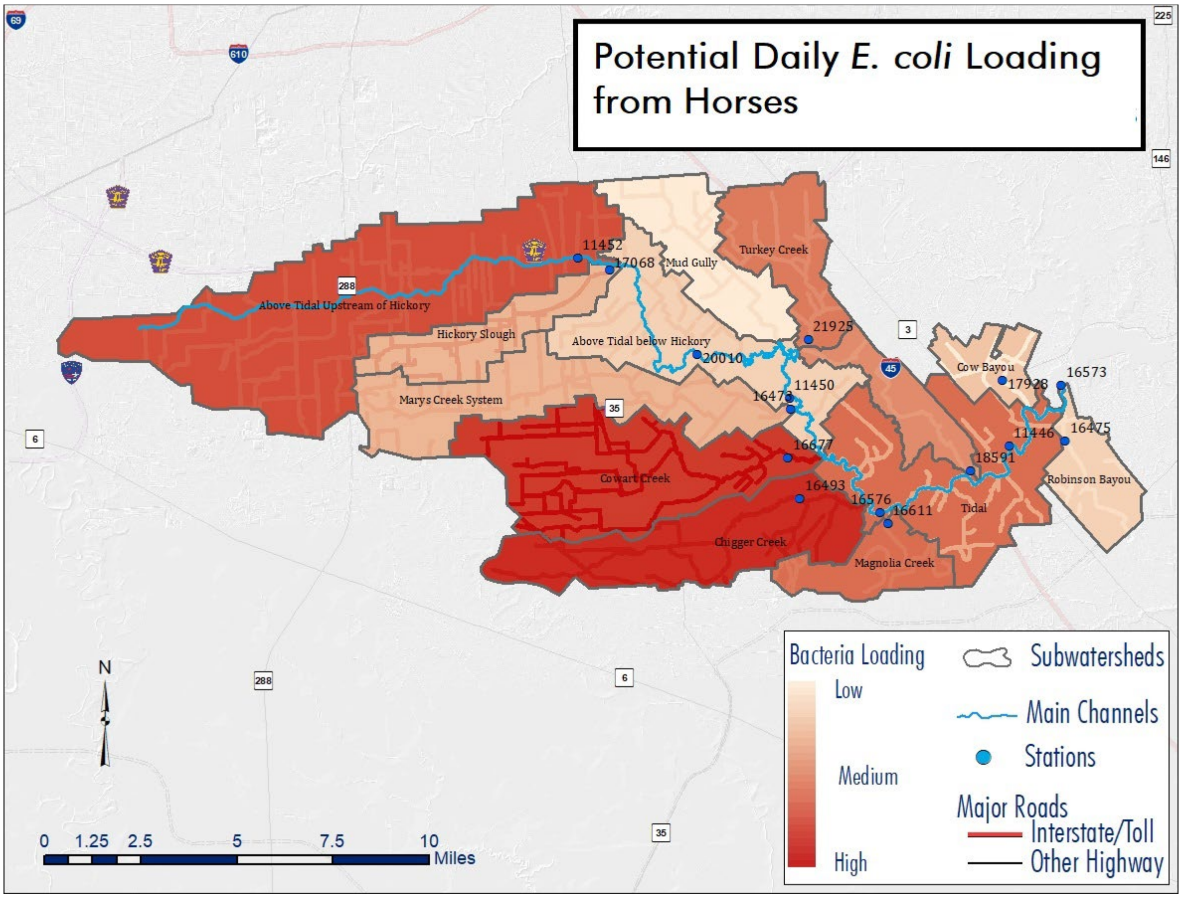

Figure 32 - *E. coli* loadings from horses by subwatershed

[66] References to "current" modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.

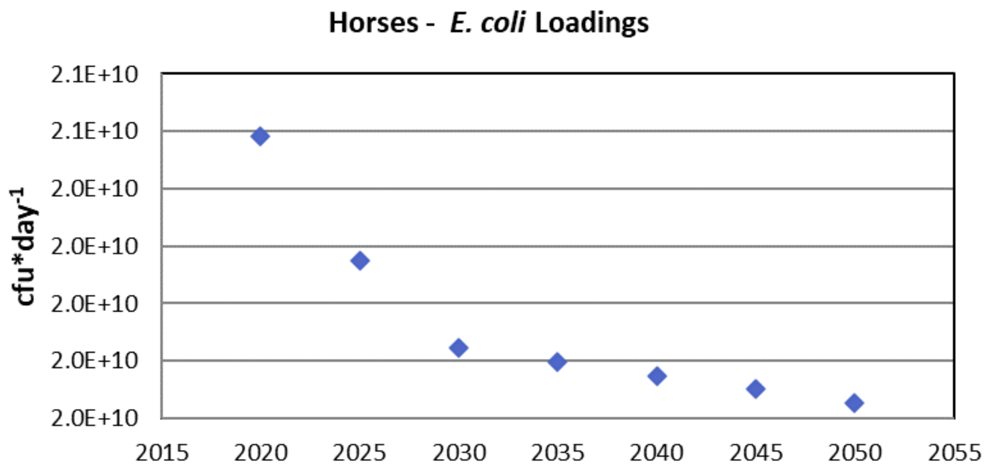

Figure 33 - Future *E. coli* loadings from horses

Table 20 - Horses and loadings by subwatershed

Subwatershed	Horses Outside Buffer	Horses Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Total *E. coli* Load	Subwatershed Percent of Total Load
1	45	8	2.37E+09	1.76E+09	4.13E+09	20.1%
2	4	1	1.87E+08	2.50E+08	4.37E+08	2.1%
3	1	1	7.44E+07	1.76E+08	2.50E+08	1.2%
4	0	0	9.07E+06	2.05E+07	2.96E+07	0.1%
5	7	2	3.78E+08	3.22E+08	7.00E+08	3.4%
6	4	1	1.91E+08	2.26E+08	4.17E+08	2.0%
7	49	20	2.58E+09	4.30E+09	6.88E+09	33.4%
8	52	13	2.75E+09	2.77E+09	5.52E+09	26.8%
9	8	2	4.38E+08	3.26E+08	7.64E+08	3.7%
10	7	1	3.90E+08	2.32E+08	6.22E+08	3.0%
11	5	1	2.85E+08	2.53E+08	5.38E+08	2.6%
12	2	0	1.20E+08	8.77E+04	1.20E+08	0.6%
13	2	0	9.65E+07	5.90E+07	1.56E+08	0.8%
Total	**186**	**50**	**9.88E+09**	**1.07E+10**	**2.06E+10**	**100.0%**

Sheep and Goats

Sheep and goat populations represent a smaller portion of the livestock in the watershed, but still retain a small 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 fecal bacteria loads were then derived for milestones at every five years starting with current conditions. Figure 34 shows the current[67] loading distributions for sheep and goats in the watersheds. Table 22 indicates the actual sheep and goat source loading estimates by subwatershed. Figure 35 indicates the change in loading over time, through 2050.

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.

[67] References to "current" modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.

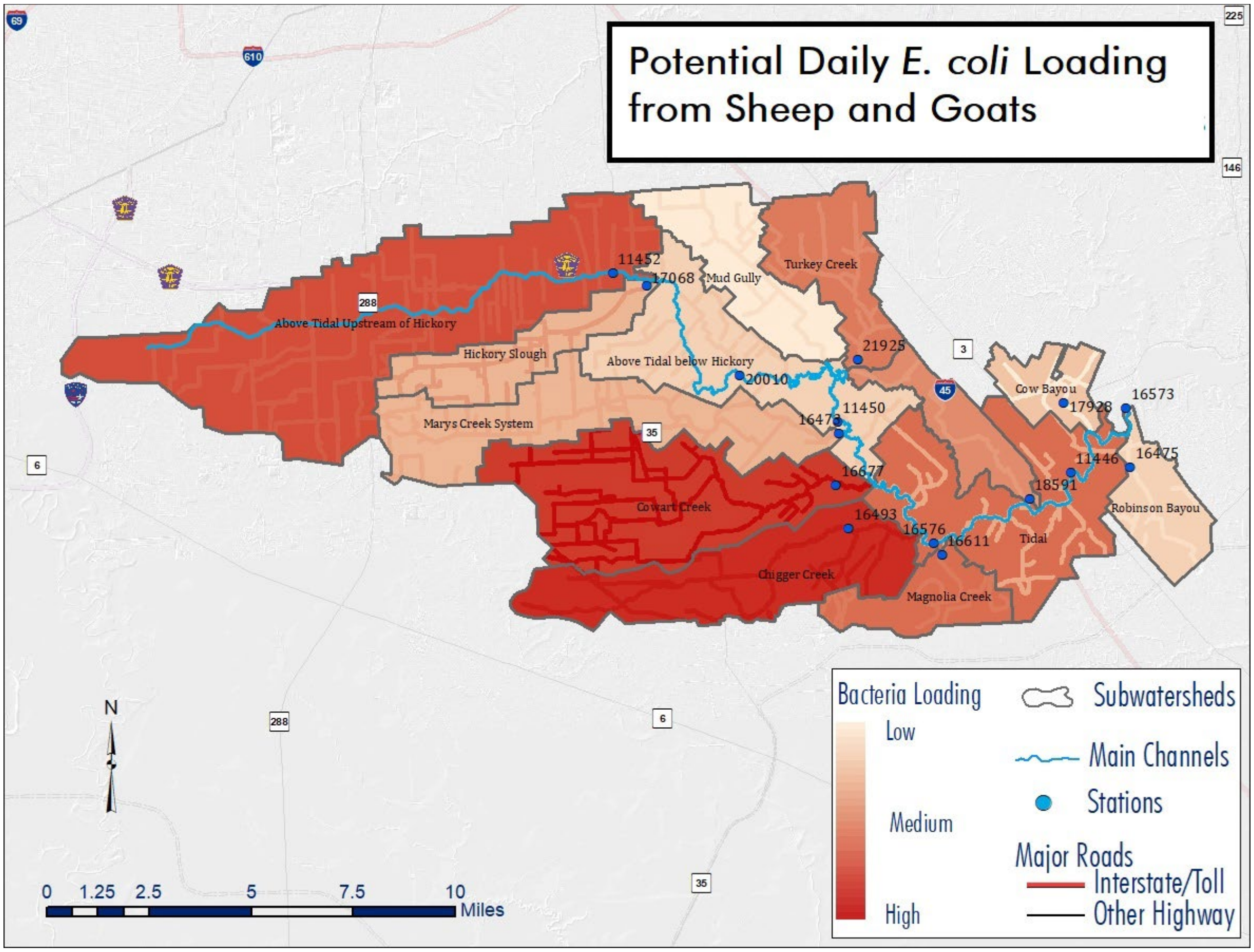

Figure 34 - *E. coli* loadings from sheep and goats by subwatershed

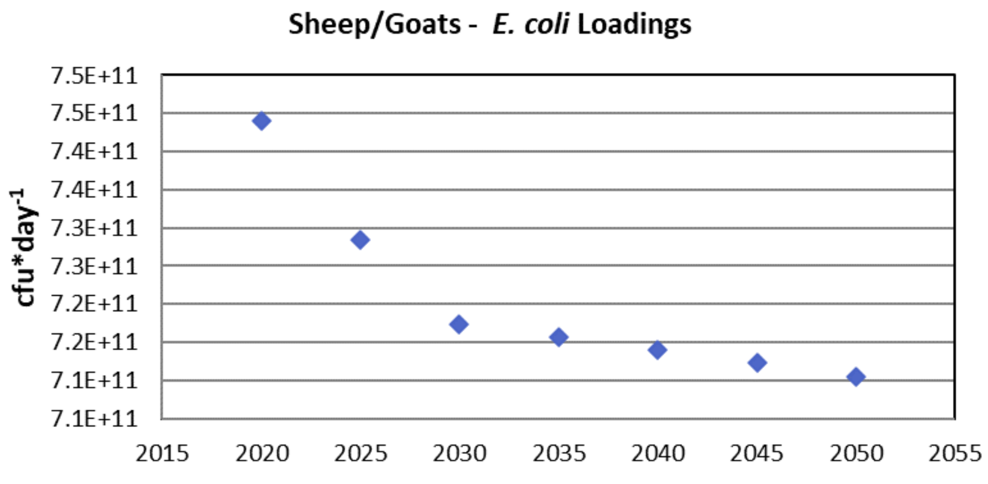

Figure 35 - Future *E. coli* loadings from sheep and goats

Table 21 - Sheep and goat loadings by subwatershed

Subwatershed	Sheep & Goats Outside Buffer	Sheep & Goats Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Total *E. coli* Load	Subwatershed Percent of Total Load
1	38	7	8.59E+10	6.38E+10	1.50E+11	20.2%
2	3	1	6.76E+09	9.03E+09	1.58E+10	2.1%
3	1	1	2.69E+09	6.36E+09	9.05E+09	1.2%
4	0	0	3.28E+08	7.40E+08	1.07E+09	0.1%
5	6	1	1.37E+10	1.16E+10	2.53E+10	3.4%
6	3	1	6.91E+09	8.19E+09	1.51E+10	2.0%
7	41	17	9.33E+10	1.56E+11	2.49E+11	33.5%
8	44	11	9.96E+10	1.00E+11	2.00E+11	26.8%
9	7	1	1.58E+10	1.18E+10	2.76E+10	3.7%
10	6	1	1.41E+10	8.38E+09	2.25E+10	3.0%
11	5	1	1.03E+10	9.16E+09	1.95E+10	2.6%
12	2	0	4.33E+09	3.17E+06	4.33E+09	0.6%
13	2	0	3.49E+09	2.13E+09	5.62E+09	0.8%
Total	**158**	**42**	**3.57E+11**	**3.87E+11**	**7.44E+11**	**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 other area watersheds.

The starting point for estimating deer populations is the use of density projections derived from TPWD's Resource Management Unit (RMU) 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.

Deer fecal bacteria loads were derived for milestones at every five years starting with current conditions. Figure 36 shows the current[68] loading distributions for deer in the watersheds. Table 23 indicates the actual deer source loading estimates by subwatershed. Figure 37 indicates the change in loading over time, through 2050.

[68] References to "current" modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.

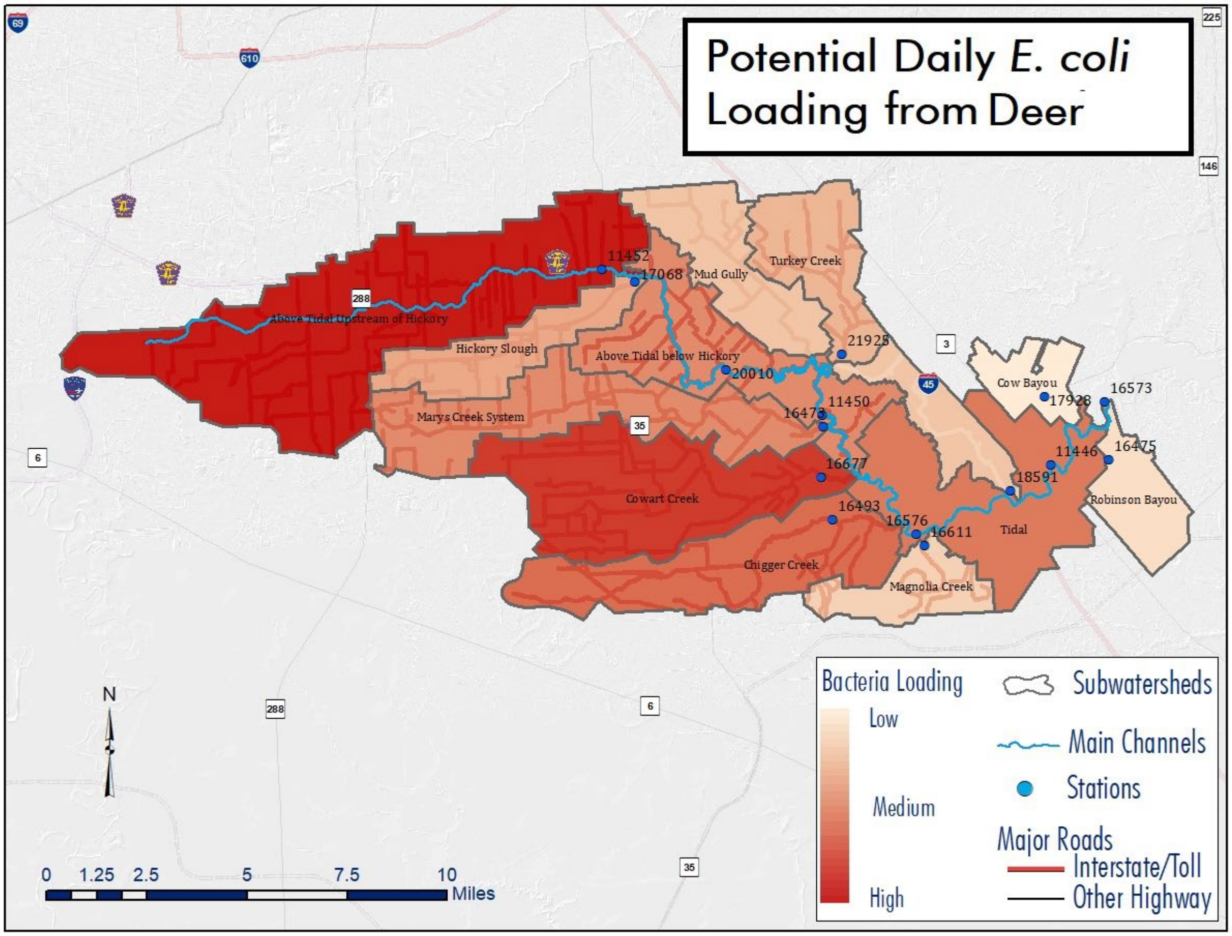

Figure 36 – *E. coli* loadings from deer by subwatershed

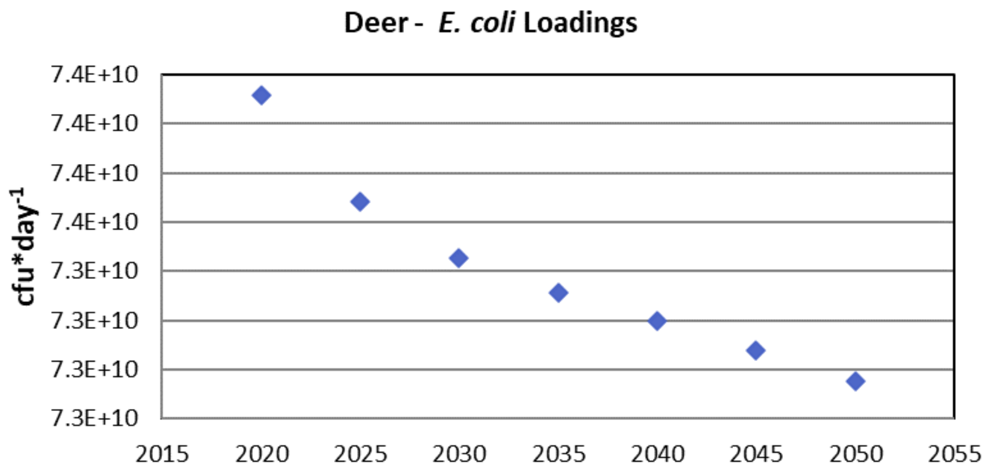

Figure 37 - Future *E. coli* loadings from deer

Table 22 - Deer and loadings by subwatershed

Subwatershed	Deer Outside Buffer	Deer Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Total *E. coli* Load	Subwatershed Percent of Total Load
1	177	54	7.76E+09	9.50E+09	1.73E+10	23.4%
2	32	12	1.42E+09	2.12E+09	3.54E+09	4.8%
3	60	25	2.61E+09	4.32E+09	6.93E+09	9.4%
4	27	8	1.17E+09	1.32E+09	2.49E+09	3.4%
5	30	10	1.33E+09	1.68E+09	3.01E+09	4.1%
6	59	23	2.58E+09	4.07E+09	6.65E+09	9.0%
7	111	39	4.86E+09	6.91E+09	1.18E+10	16.0%
8	90	26	3.94E+09	4.49E+09	8.43E+09	11.4%
9	24	8	1.04E+09	1.38E+09	2.42E+09	3.3%
10	67	17	2.94E+09	2.91E+09	5.85E+09	7.9%
11	25	6	1.08E+09	1.07E+09	2.15E+09	2.9%
12	10	4	4.48E+08	7.71E+08	1.22E+09	1.7%
13	24	6	1.04E+09	1.00E+09	2.04E+09	2.8%
Total	**736**	**238**	**3.22E+10**	**4.15E+10**	**7.37E+10**	**100.0%**

Feral Hogs

Feral hogs (*Sus scrofa*) 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 Extension (AgriLife) were used as initial assumptions. Based on accounts from landowners at the edge of developed areas, 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 AgriLife literature values[69] 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 fecal bacteria loads were derived for milestones at every five years starting with current conditions. Table 24 indicates the actual feral hog loading estimates by subwatershed. Figure 38 indicates the change in loading over time, through 2050. Figure 39 shows the current[70] loading distributions for feral hogs in the watersheds.

Future conditions reflect a slight reduction in hog populations and loading. 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

[69] From numbers in https://agrilifetoday.tamu.edu/wp-content/uploads/2019/10/sp-472.pdf and http://feralhogs.tamu.edu/files/2011/05/FeralHogFactSheet.pdf.

[70] References to "current" modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.

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.

Table 23 - Feral hogs and loadings by subwatershed

Subwatershed	Feral Hogs Outside Buffer	Feral Hogs Within Buffer	*E. coli* Load Outside Buffer	*E. coli* Load Within Buffer	Total *E. coli* Load	Subwatershed Percent of Total Load
1	15	4	1.65E+10	1.62E+10	3.27E+10	24.6%
2	1	0	1.55E+09	1.97E+09	3.52E+09	2.6%
3	3	2	3.03E+09	7.75E+09	1.08E+10	8.1%
4	1	0	8.14E+08	7.14E+08	1.53E+09	1.1%
5	3	1	2.91E+09	4.65E+09	7.56E+09	5.7%
6	1	0	1.16E+09	1.68E+09	2.84E+09	2.1%
7	9	4	9.83E+09	1.64E+10	2.62E+10	19.7%
8	10	3	1.11E+10	1.33E+10	2.44E+10	18.4%
9	3	1	2.80E+09	2.77E+09	5.57E+09	4.2%
10	3	2	3.87E+09	7.30E+09	1.12E+10	8.4%
11	2	0	2.25E+09	1.91E+09	4.16E+09	3.1%
12	0	0	4.39E+08	4.61E+08	9.00E+08	0.7%
13	1	0	6.74E+08	8.33E+08	1.51E+09	1.1%
Total	52	17	5.70E+10	7.59E+10	1.33E+11	100.0%

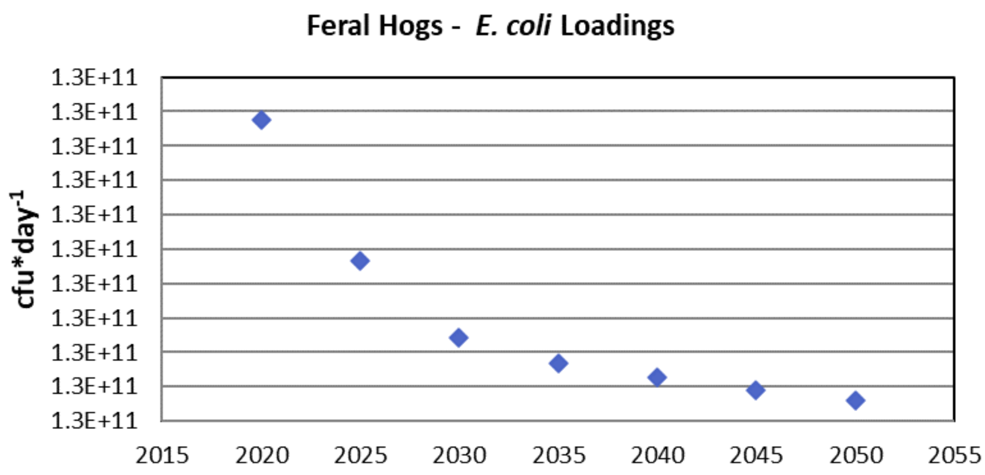

Figure 38 - Future *E. coli* loadings from feral hogs

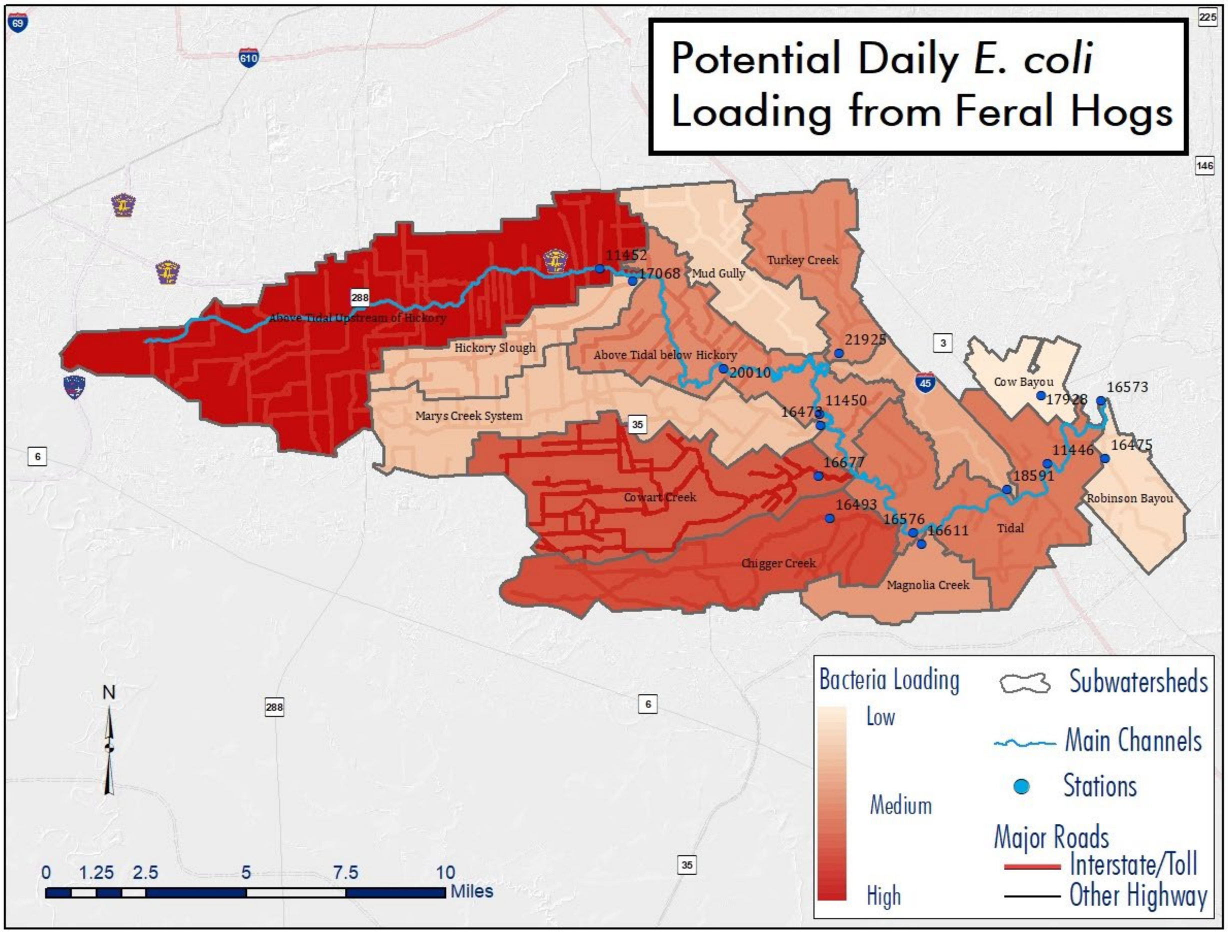

Figure 39 - *E. coli* loadings from feral hogs by subwatershed

Other Animals

The primary missing element discussed by the stakeholders was the impact of animals and 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, and to consider the context of limited potential means to address it. A limited fecal bacteria source tracking (BST) effort at one location close to the end of the

Tidal segment[71] offered some insights into non-domestic animal contributions, showing upwards of 47% of the samples analyzed were broadly wildlife, of which 29% were non-avian, and 18% were avian. Another 31% of the samples were unidentified. While this data points to a strong contribution from wildlife, the effort was linked to a single site, over a single year, using an indicator (*E. coli*) not used for tidal systems. No equivalent data exists for other stations in the watershed. The great deal of uncertainty about the applicability of this data did not fit the data quality objectives of this project. However, it provides a snapshot of a potentially greater than expected wildlife contribution.

Additionally, 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 other animals in some form might produce a less defensible estimation. In review of the source tracking information from the Texas Water Resources Institute (TWRI) study and other studies from more rural watersheds[72] 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 Clear Creek. To ensure that the estimate was conservative and reflected the developmental character of the area, contributions from other animals was assumed to be equivalent to 20% of the total load for the watershed. The value was generated by finding the total for all other sources, assuming that total to represent 80% of the actual total, and then considering the remaining 20% to be other animals. The stakeholders also felt that the extent of urban wildlife and other animals known in the watershed suggested that this load should be applied to all subwatersheds, rather than just rural 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. The Other Animals values are reflected in the final load estimation in Table 25 of this report.

[71] Monitoring was conducted by the Texas Water Resources Institute as part of their report, *Bacterial Source Tracking (BST) on Tributaries of Trinity and Galveston Bays* (August 2020), available online at https://twri.tamu.edu/media/5472/tr-528.pdf.

[72] 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).

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 intervention 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 20% other wildlife load estimate.

Human Waste – Direct Discharges

Stakeholders discussed the presence of some homeless individuals in some areas. 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 best management practices (BMPs), including Water Quality Management Plans (WQMPs), *etc.*

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 Central Flyway migratory 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.

Previous WPP efforts have evaluated the potential impact of waterfowl in terms of duration, potential fecal bacteria 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 fecal bacteria 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. The limited BST evidence indicated avian wildlife may make up an appreciable portion of the load (18%), but the lack of individualized source data for this watershed relegates their potential load to be included within assumptions for the Other Animals category.

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.

Other Animals

Anecdotal reports from stakeholders, known area species, and observed species during field reconnaissance indicate coyote, rabbit, skunk, many rodent species, nutria, beaver, raccoon, opossum, armadillo, and other common mammals are present in the watershed in appreciable numbers. However, little data exists to characterize their contributions. Their contributions cannot be individually assessed but are considered to be part of the 20% other wildlife load.

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 separately 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 were located. In a review of other regional WPPs, feral cat populations were generally included as part of diffuse urban stormwater and were not 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 20% Other Animals load. Some local governments have specifically targeted feral cat populations.

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 fecal bacteria levels. The primary focus of dumping concerns was trash and other aesthetic and regulatory issues. Some specific sites were identified but not particularly strongly associated with fecal waste.

Sediment

Sand and gravel mining operations are common in the riparian corridors of the area watersheds but are less common on much of Clear Creek. However, there are a few small operations in the watershed. Mining operations are not a source of fecal bacteria, so no modeled estimation can be completed. In some areas, runoff from new development is notable during high runoff events. Excess sediment is common in the waterways, which can provide shelter for fecal bacteria and decrease insolation that may lead to die-off in the water column, can impact DO levels, and can have pronounced hydrologic impacts on flow. These effects are already an aspect of the in-stream conditions described under the LDCs, in that recorded fecal bacteria levels reflect the end product of these ambient factors as well as other fate and transport aspects. Excess sediment introduced into the channel can foster the survival of fecal bacteria from other sources, making it an indirect source for fecal bacteria that might have otherwise not survived. The considerations regarding sediment will be dealt with in the WPP.

SSOs

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, fecal bacteria 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[73].

Records of SSOs within the watersheds were derived from five years of TCEQ data. 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[74]. All SSOs related to a WWTF and receiving stream segment in the

[73] More information on the character and distribution of SSOs is available in the project Water Quality Data Collection and Trends Analysis Report at https://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/clear_creek_water_quality_trends_report_phase_1_final.pdf.

[74] 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.

watershed area[75] were used to characterize this source. Loading values were based on a consideration of the causes identified for SSOs in the watershed, of which over a third were primarily dilute (rainwater charger releases) or moderate. Concentrations of fecal bacteria can vary greatly based on the composition of sewage at the time of the SSO. EPA literature values[76] 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 and integrate them into other source loading estimates stems from their (usually) episodic nature. SSOs in the watershed areas were not generally found to be chronic loads, but rather, acute. Therefore, when they are active their 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 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 intent was to focus on any identified problem areas as localized, acute sources to prioritize for remediation in the WPP.

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[77]; 2) their peak volumes and

[75] Collection systems can straddle watershed boundaries, and WWTFs outside the watershed may have systems partially within it. However, without spatially explicit data on SSO locations, SSOs from systems discharging outside the watershed could not be included.

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

[77] Quantitative microbial risk assessment studies, including work in the Leon River and elsewhere (Gitter, Anna, et al. (2020) "Human Health Risks Associated with Recreational Waters: Preliminary Approach of Integrating Quantitative Microbial Risk Assessment with Microbial Source Tracking", Water 12:327-342. https://www.mdpi.com/2073-4441/12/2/327) have indicated that sources with equivalent loads may have pronounced differences in expected microbial risk, with human sources being the most potentially problematic.

concentrations are underrepresented here; and 3) they can be pronounced localized sources in areas where direct human contact is more likely (developed areas).

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 in different areas of the watershed. The approaches of reducing pet waste to reflect waste bag usage, and the inclusion of a 20% load for Other Animals 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.

Table 25 indicates the estimated current potential loads for all sources. Table 26 shows the estimated potential load for each milestone year, by source. The target year for the plan, 2035, is accented in red. Figure 40 shows the change in total load between 2020 and 2050. Figures 41 and 42 show the relative change in source contributions between current and future conditions, respectively.

Absent a concerted effort to address fecal bacteria sources, the projections indicate that total fecal bacteria load in the watershed will continue to increase through 2050, as well as the target date of 2035. Between current conditions and those projected for 2050, the mix of sources shifts away from some of the legacy agricultural activity toward a growing predominance of sources associated with developed areas.

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 solutions. 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 is a recommended consideration in the future to further characterize sources, identify location-specific challenges, and refine the linkage between source loads and instream conditions.

Table 24 - Current Fecal Bacteria Daily Average Loadings by Source and Subwatershed

Sub-watershed	OSSF	WWTFs	Dogs	Cattle	Horses	Sheep and Goats	Deer	Feral Hogs	Other Animals	Total Daily Load in *E. coli*
SW1	4.53E+11	7.36E+09	1.01E+13	4.65E+11	4.14E+09	1.5E+11	1.73E+10	3.27E+10	2.80E+12	**1.40E+13**
SW2	9.35E+10	74340198	2.03E+12	4.91E+10	4.37E+08	1.58E+10	3.54E+09	3.52E+09	5.49E+11	**2.75E+12**
SW3	2.63E+10	8.3E+09	5.62E+12	2.81E+10	2.5E+08	9.05E+09	6.93E+09	1.08E+10	1.43E+12	**7.14E+12**
SW4	9.83E+09	8.45E+09	4.5E+12	3.32E+09	29538490	1.07E+09	2.49E+09	1.53E+09	1.13E+12	**5.66E+12**
SW5	8.1E+10	8.77E+09	2.69E+12	7.87E+10	7E+08	2.53E+10	3.01E+09	7.56E+09	7.23E+11	**3.62E+12**
SW6	3.7E+11	8.29E+09	6.26E+12	4.69E+10	4.18E+08	1.51E+10	6.65E+09	2.84E+09	1.68E+12	**8.39E+12**
SW7	1.03E+11	1.33E+08	2.97E+12	7.74E+11	6.88E+09	2.49E+11	1.18E+10	2.62E+10	1.04E+12	**5.18E+12**
SW8	2.21E+11	0	2.03E+12	6.21E+11	5.53E+09	2E+11	8.43E+09	2.44E+10	7.78E+11	**3.89E+12**
SW9	0	3.4E+09	1.7E+12	8.59E+10	7.64E+08	2.76E+10	2.42E+09	5.57E+09	4.56E+11	**2.28E+12**
SW10	1.3E+11	3.38E+10	5.66E+12	6.99E+10	6.22E+08	2.25E+10	5.85E+09	1.12E+10	1.48E+12	**7.41E+12**
SW11	4.16E+10	0	2.62E+11	6.05E+10	5.38E+08	1.95E+10	2.14E+09	4.16E+09	9.76E+10	**4.88E+11**
SW12	7.34E+10	0	2.81E+12	1.35E+10	1.2E+08	4.33E+09	1.22E+09	9.01E+08	7.27E+11	**3.63E+12**
SW13	8.72E+10	0	1.83E+12	1.75E+10	1.56E+08	5.62E+09	2.04E+09	1.51E+09	4.85E+11	**2.42E+12**
Total	**1.69E+12**	**7.86E+10**	**4.84E+13**	**2.31E+12**	**2.06E+10**	**7.44E+11**	**7.38E+10**	**1.33E+11**	**1.34E+13**	**6.69E+13**
Percent of Total Load	**2.53%**	**0.12%**	**72.44%**	**3.46%**	**0.03%**	**1.11%**	**0.11%**	**0.20%**	**20.0%**	**100.0%**

Table 25 – Daily Average Fecal Bacteria Loadings by Source for all Milestone Years

Category	Source	2020	2025	2030	2035[78]	2040	2045	2050
Human Waste	OSSFs	1.69E+12	2.33E+12	2.9E+12	3.12E+12	3.23E+12	3.46E+12	3.6E+12
	WWTFs	7.86E+10	8.45E+10	8.94E+10	9.06E+10	9.33E+10	9.47E+10	9.69E+10
Pets	Dogs	4.84E+13	5.29E+13	5.62E+13	5.75E+13	5.86E+13	5.96E+13	6.05E+13
Livestock	Cattle	2.31E+12	2.26E+12	2.23E+12	2.23E+12	2.22E+12	2.21E+12	2.21E+12
	Horses	2.06E+10	2.01E+10	1.98E+10	1.98E+10	1.97E+10	1.97E+10	1.97E+10
	Sheep / Goats	7.44E+11	7.28E+11	7.17E+11	7.16E+11	7.14E+11	7.12E+11	7.11E+11
Wildlife and Feral Hogs	Deer	7.38E+10	7.35E+10	7.34E+10	7.34E+10	7.33E+10	7.32E+10	7.32E+10
	Feral Hogs	1.33E+11	1.31E+11	1.3E+11	1.29E+11	1.29E+11	1.29E+11	1.29E+11
	Other Animals	1.34E+13	1.34E+13	1.34E+13	1.34E+13	1.34E+13	1.34E+13	1.34E+13
Total		**6.69E+13**	**7.18E+13**	**7.57E+13**	**7.73E+13**	**7.84E+13**	**7.96E+13**	**8.07E+13**

[78] 2035, accented in red, is the target year for this WPP.

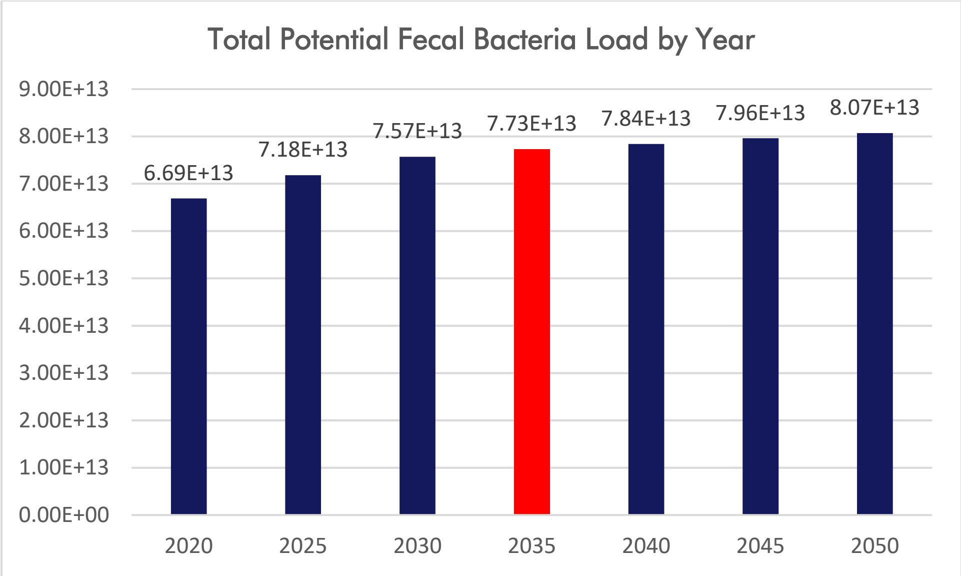

Figure 40 - Total Potential Daily Load, 2020-2050

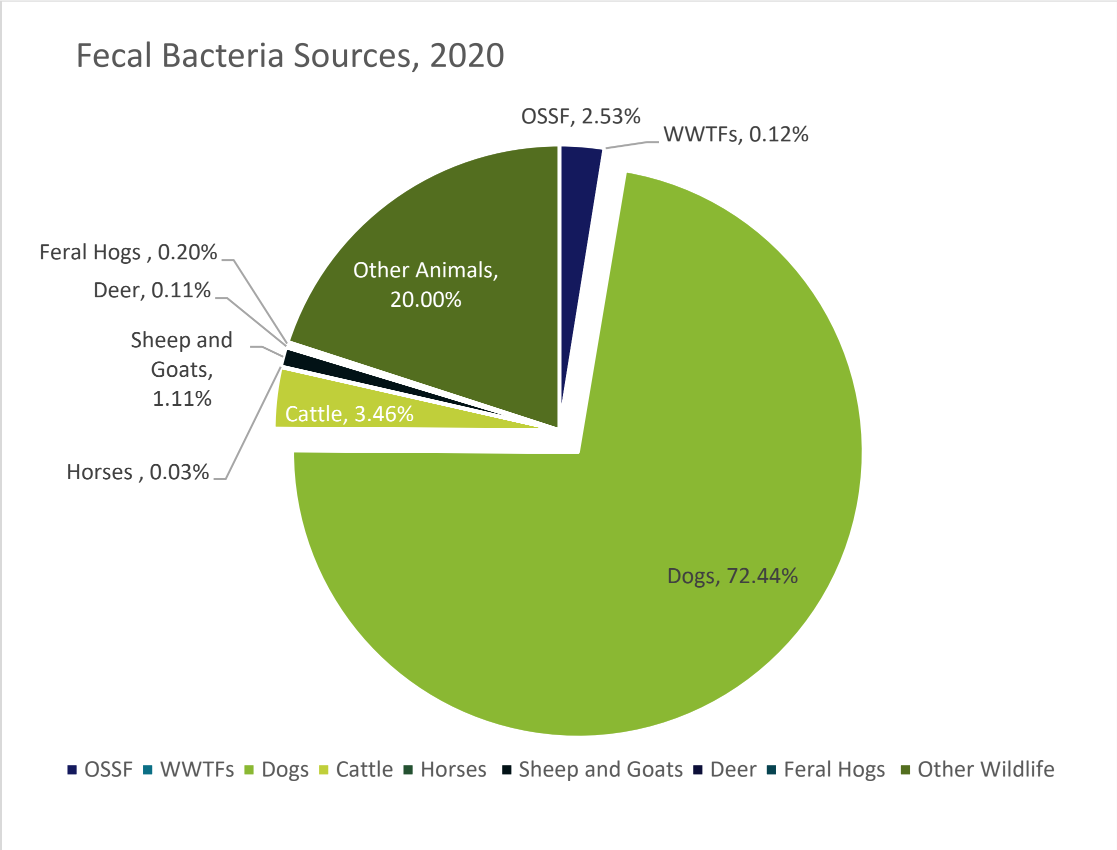

Figure 41 - Fecal Bacteria Source Profile, 2020

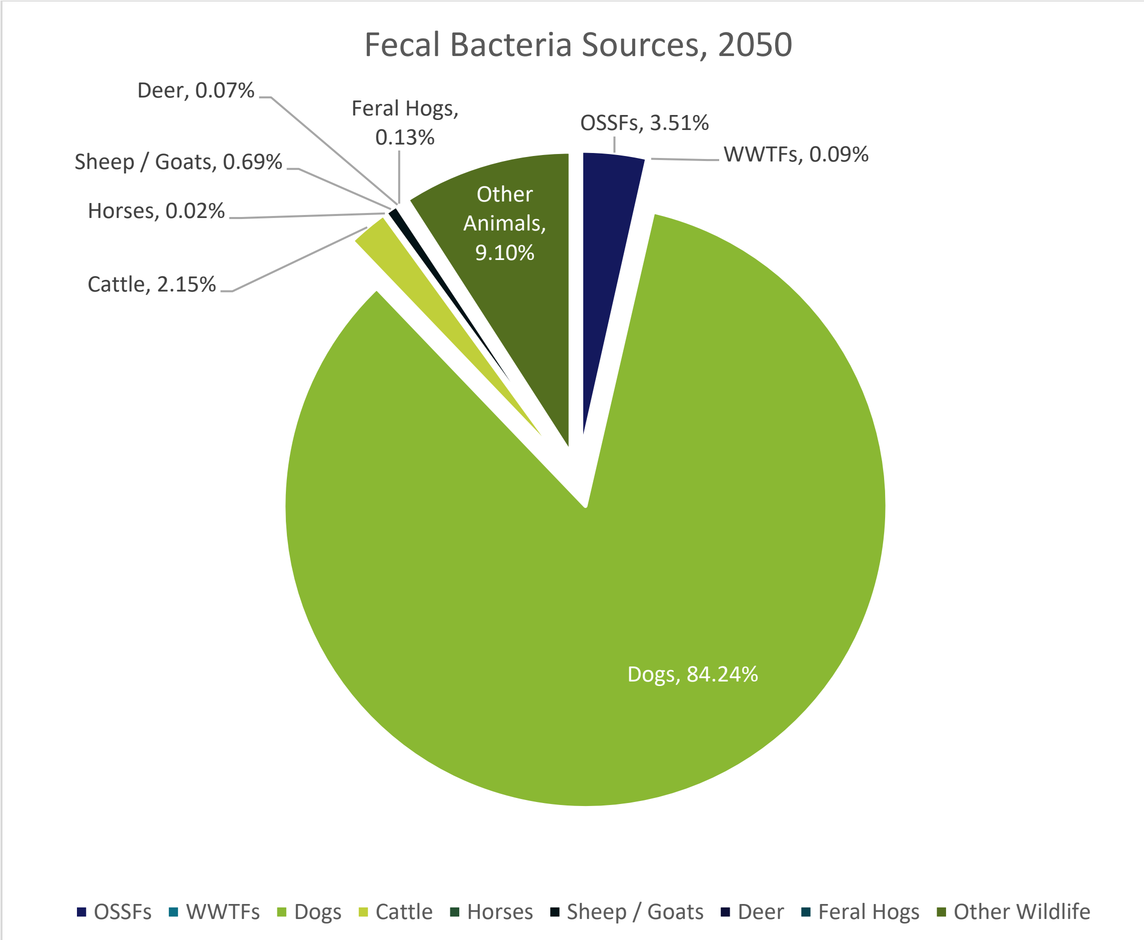

Figure 42 - Fecal Bacteria Source Profile, 2050

Nutrient Source Characterization

Adequate dissolved oxygen (DO) is essential for supporting aquatic communities. 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 nutrient inputs from human use (*e.g.*, landscaping and agricultural fertilizers) are sources that 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 which depresses levels of oxygen available for other aquatic life. 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 DO in the context of the water quality goals they established as part of the water quality analysis and improvement goals established by load duration curve analysis (Section 4). Because many of the sources of nutrients overlap with sources of fecal waste[79], the Partnership focused its investigation efforts on identifying potential solutions and specific areas of concern. In the recommended solutions (Section 5), potential impacts and areas of priority are noted.

Figure 43 - Urbanized riparian banks on a tributary of Clear Creek

[79] 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

Section 4. Improving Water Quality

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. In addition to the source modeling, the Partnership conducted a water quality modeling effort[80] to determine the amount of improvement needed. The purpose of this effort was to establish how much of each parameter (*E. coli* and Enterococcus) needed to be reduced to meet their respective SWQSs and determine percentage-based DO improvement goals. **Load duration curves** (LDCs) were used in combination with the observed water quality data to determine these results. Based on these analyses, assessments of land cover and pollution sources, and the locations of points at which future compliance would be measured, different attainment areas were identified within the total watershed. Unique improvement goals were generated specific to the magnitude and composition of pollutant sources estimated for each attainment area.

Load Duration Curves for *E. coli*, Enterococcus, and Dissolved DO

Pollutants can enter the water body from discrete sources or from nonpoint sources in different flow conditions. The amount of water flowing through a water body can affect concentrations of pollutants. LDCs use observed water quality and flow data (see Section 3) to indicate the difference between observed levels of pollutants[81] 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. These 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 44). More importantly, the curve indicates under what flow conditions, and by how much, the observed pollutant levels exceed the allowable load. Areas in which the load duration curve line exceeds the

[80] For greater detail on the modeling for *E. coli* discussed in this section, please refer to the Water Quality Modeling Report on the project website at: https://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/final_clear_creek_wpp_bacteria_modeling_report.pdf

[81] As a system with both freshwater and tidal/marine aspects, both *E. coli* (in the freshwater Above Tidal segment 1102) and *Enterococcus* (in the marine-influenced Tidal segment 1101) indicator bacteria were used, specific to their respective segments.

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. LDCs in tidal areas like Segment 1101 require a consideration of tidal flows and use a regression of salinity data in observed water quality to calculate a tidal flow if the salinity contribution and delta were significant. For the purpose of DO, the analysis focused on percentage improvement needed rather than reduction, as DO is not a pollutant that can be reduce, but rather, a condition.

The amount in which the observed loads exceed the allowable loads is the basis for developing improvement goals.

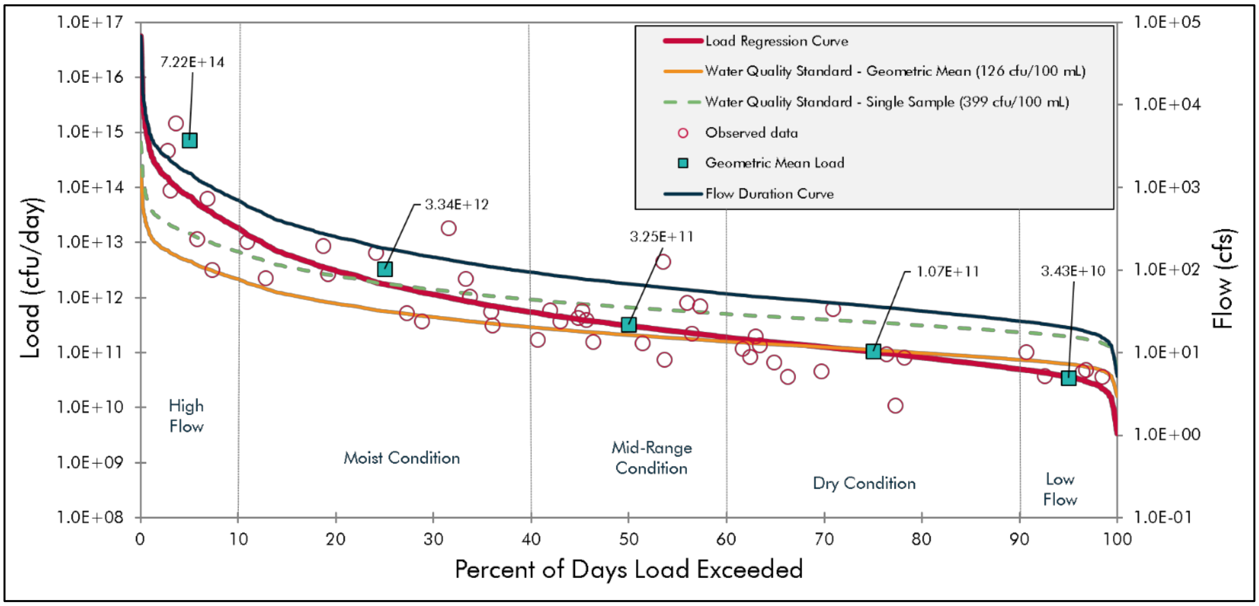

Figure 44 - Example of a load duration curve for *E. coli*

Data Development

Project staff developed LDCs for *E. coli* and Enterococcus at several monitoring stations throughout the Clear Creek watershed. The purpose of the LDCs was to identify which flow conditions demonstrated exceedances, and to generate reduction goals.

Site Selection

Site selection for LDCs was based on support for a mix of considerations, including known water quality conditions[82], the need for long-term assessment of progress toward the water quality standard, projected needs for solution 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 (DMRs), and sanitary sewer overflow (SSO) information, water quality in the project watershed indicated that conditions in both the assessed tributaries and main channel of two segments of Clear Creek (Above Tidal, Segment 1102; Tidal, Segment 1101) had a degree of variability and potential for continued exceedance. A single station would not be representative of the variability of water quality and flow conditions based on the water quality review. Therefore, 15 LDC locations (Table 27 and Figure 45 were chosen to represent varying conditions in the system, including the relatively large number of unclassified tributaries. Six of the stations are on the main stem (three in each segment), and nine are on the various tributaries (five in Clear Creek Tidal, Segment 1101, and four in Clear Creek Above Tidal, Segment 1102). Main stem locations were chosen to allow consideration of water quality before and after inputs of some large tributaries. 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 data would be available for long-term assessment, potential LDC locations were drawn from existing Clean Rivers Program monitoring stations, which will provide ongoing data. Flow from all the sites either correspond directly to USGS stream gauges with flow data or were derived using an area ratio formula from the stream gauge data. Tidal sites with significant salinity fluctuation considered tidal volumes in the development of their flows. The existing sites were found to be sufficient to characterize conditions in the waterways, as affirmed by the stakeholders. In general, the most downstream station was chosen to be representative of a subwatershed area.
- *Solution Siting Requirements* - As discussed previously, LDCs were chosen in part to reflect geographic variability. A greater number of LDC locations is beneficial to support the use of modeling results to scale and site recommended solutions (i.e., solution requirements and recommendations can be refined to the subwatershed level based on

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

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 Clear Creek Watershed Partnership.

Selected LDC Locations

Based on these considerations, project staff conducted all 15 LDC site analyses, a selection of which would be used to generate fecal bacteria load reduction targets and DO improvement goals for attainment areas. The final LDC sites, from headwaters to mouth, are indicated in Figure 45 and Table 27.

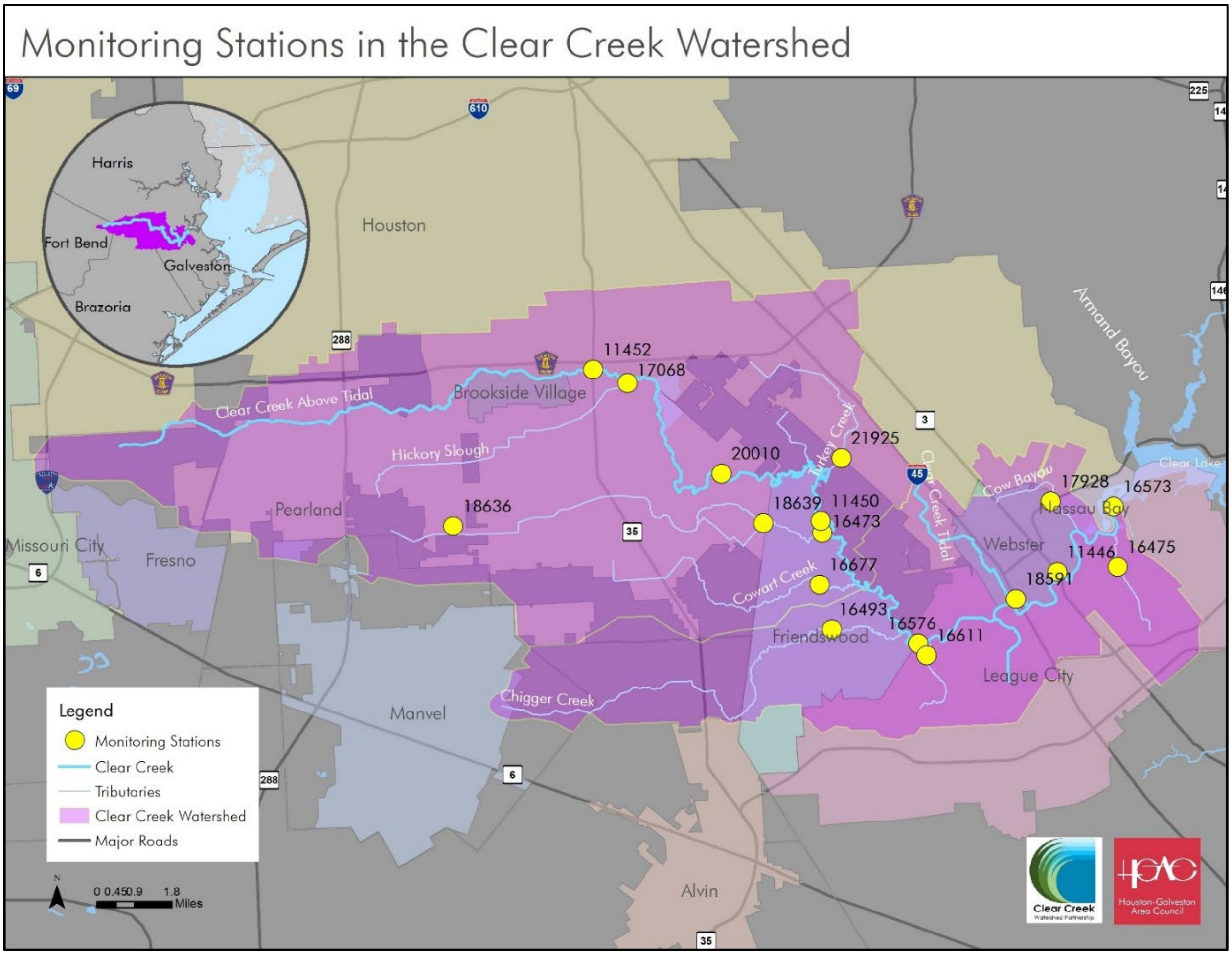

Figure 45 - Monitoring sites and LDC locations

Table 26- LDC Locations

Waterway	LDC Site	USGS Gauge	Sub-watershed	Assessed Area of Segment
1102, Clear Creek Above Tidal	11452	08076997	1	The main stem site represents the headwaters of the segment, prior to the influence of its major tributaries.
1102C, Hickory Creek	17068	08076997	2	
1102, Clear Creek Above Tidal	20010	08076997	3	This main stem site is upstream of the confluence of several suburban tributaries, in a developed area.
1102D, Turkey Creek	21925	08076997	5	
1102, Clear Creek Above Tidal	11450	08076997	3,4	This main stem site is between the confluence of Turkey Creek and Mary's Creek.
1102B/F, Mary's Creek	16473	08076997	6	
1102A, Cowart's Creek	16677	08076997	7	
1101B, Chigger Creek	16493	08076997	8	
1101, Clear Creek Tidal	16576	08077600	10	This main stem site represents the boundary conditions between the Above Tidal and Tidal segments.
1101A, Magnolia Creek	16611	08076997	9	
1101F, Unnamed Tributary	18591	08076997	11	
1101, Clear Creek Tidal	11446	08077600	10	This main stem site represents a transition to the wider waterway the creek will become as it nears its confluence with Clear Lake at the end of the system.
1101C, Cow Bayou	17928	08076997	12	
1101D, Robinson Bayou	16475	08076997	13	
1101, Clear Creek Tidal	16573	08077600	10	This main stem site nominally represents the conditions at the end of the system, located within the confluence with Clear Lake.

Data Development

LDCs require a sufficient amount of ambient water quality data, as well as flow data (with continuous flow data being preferable). Flow for all 15 of the Clear Creek LDC sites was developed from corresponding USGS gauges. There are two USGS stream gauges in the Clear Creek watershed:

- **08076997** – This above tidal gauge has actual flow measurements in cubic feet per second (cfs), and was used, after application of a direct drainage area ratio, to represent the relative area drained by each station. This gauge was also used for the tributaries in the tidal segment, after application of both the drainage area ratio consideration and the tidal salinity regression and consideration.
- **08077600** – This tidal segment gauge has only gauge height in feet (with a small subset of hourly cfs measurements). This data was converted into flow values by running a linear regression of recorded gauge height and observed cfs measurements. Continuous flow values were then interpolated from gauge heights, area ratios were applied, and tidal flows were considered, to represent flows at the main stem tidal sites.

Flow for the tidal stations other than 18591, 18576, 18573, and 11446 were developed using a consideration of tidal impacts and volumes. 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 were available for all 15 stations[83]. There were a sufficient number of fecal indicator bacteria monitoring records for each station to develop LDCs. Most stations had at least 7 years of monitoring results from which to draw (between 30-40 fecal indicator bacteria samples each). Stations 16677, 18591, and 21925 had fewer results than the other stations, but there were no alternate stations available for these three tributaries. The data was sufficient to develop LDCs, regardless. For fecal indicator bacteria, 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.

[83] 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 at https://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/clear_creek_water_quality_trends_report_phase_1_final.pdf.

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.

LDCs for DO were also developed in the same manner and are presented alongside the fecal bacteria LDCs. Some stations (11452, 20010) did not have sufficient data to develop DO LDCs. After a review of where DO issues existed in the waterway, and available data, DO LDCs were limited to stations 11446, 16473, 16475, 16576, 17068, 17928, 18591, and 21925.

Load Duration Curve Implementation

Both the requisite flow and constituent sample data was sufficient to develop LDCs for all locations. The subsequent selection of representative stations from this list as endpoints of attainment areas representing distinct areas of the watershed will continue to support future revisions and the adaptive management process of evaluating WPP success. Full profiles for each LDC site are included in the Bacteria Modeling Report[84].

Load Duration Curve Analysis Summary

Results of LDC analyses for Clear Creek have been reviewed internally and subjected to thorough stakeholder analysis. H-GAC staff discussed these results with stakeholders at partnership meetings and in more focused conversations. Stakeholder support and positive feedback support confidence in the estimated fecal bacteria reduction targets and DO improvement goals for the Clear Creek watershed.

Overall, the results indicated that fecal bacteria levels varied widely throughout the system. Stations in the tributaries and headwaters areas of the creek exhibited a stronger relationship between high flows and high fecal bacteria concentrations. However, as the creek broadened in the tidal segment, bacteria levels were more consistently in excess of the standard, but with less variation between flow regimes. This is potentially an indication of the strong influence of nonpoint sources on an episodic basis in the former, and the cumulative impact of the sources in the watershed, as well as the more stable profile of a larger waterbody, in the latter. Regardless, it is clear that fecal bacteria contamination is consistent throughout the system, even as it may vary in extent and relationship to flow. While the results of the confluence station (16573) at the end of the system indicate that the impact on Clear Lake is likely as a source of chronic load in most conditions, but acute impact in high flow conditions, the generally higher levels in the tidal segment pose a

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[84] For more information, please refer to the Water Quality Modeling Report on the project website at: https://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/final_clear_creek_wpp_bacteria_modeling_report.pdf

concern given its proximity to the most densely developed areas and potential recreational sites.

In the interpretation of the DO results it should be noted that even though many LDCs throughout the system indicated that DO levels did not require improvement in most if any flow categories, this evaluation may skew the impact of outliers. The TCEQ assessment of several of the unclassified tributaries and assessment units of the main stem indicated concerns and impairments related to various standards or screening levels regarding DO levels based on the outlying exceedances. The data also naturally skew toward high DO samples because monitoring is not conducted at night, when the daily DO cycle leads to lower DO levels in some conditions.

The design for generating single target reductions[85] for each subwatershed or group of subwatersheds was based on a compromise between the worst-case scenario (highest possible reduction need in any flow category, specific to each LDC station/attainment area) versus the least conservative approach (average reduction needed based on all flow conditions, general to each watershed). 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 of the segments and their assessed tributaries.

- *Under this approach, a station that showed a need for reductions in its LDC during High, Moist, and Midrange conditions, but no reduction in Dry Conditions of Low Flows, would establish a reduction target by finding the weighted average of the percent reductions for High, Moist, and Midrange conditions.*

Table 28 represents the current single-number fecal bacteria percent reduction targets[86] for the modeled subwatersheds. Results were developed for the furthest downstream LDC in subwatersheds with multiple monitoring stations. No specific percentage improvement goals were developed for DO, but the range of improvement (from highest to lowest flow categories,) is also represented in the table. The range of values demonstrates the need

[85] As opposed to up to five modeled reduction values, representing one for each flow category.

[86] These targets do not consider the potential impacts of upstream subwatersheds meeting their reduction targets (i.e., subwatershed 3 includes cumulative loads from subwatersheds 1,2, and 4, as may be affected by growth and decline during transport prior to reaching station 11450. Realistically, if the preceding subwatersheds made great strides in reducing fecal waste, subwatershed 3, downstream, should show a decrease because it no longer receives that cumulative load from upstream. However, the reduction target for subwatershed 3 does not assume prior targets were met, as a conservative approach.

for multiple points of consideration rather than a single, overall target for the watershed. The range also demonstrates that even weighted targets indicate most areas in the system need moderate to high levels of fecal bacteria reduction.

Table 27 - LDC results by monitoring station

LDC Station	Waterway	Subwatersheds	Weighted Average Fecal Bacteria Reduction Target (%)	DO Improvement Goal Range (% improvement)
11452	1102 Clear Creek Above Tidal	1	51.3%	No LDC developed
17068	1102C, Hickory Creek	2	63.5%	No improvement needed in any flows
20010	1102, Clear Creek Above Tidal	3	*Reduction for SW3 set at Station 11450*	No LDC developed
11450	1102 Clear Creek Above Tidal	3 (inclusive of 4)	65.0%	No LDC developed
21925	1102D, Turkey Creek	5	55.0%	No improvement needed in any flows
16473	1102B/F Mary's Creek	6	57.9%	No improvement needed in any flows
16677	1102A, Cowart's Creek	7	68.3%	No LDC developed
16493	1102B, Chigger Creek	8	66.2%	No LDC developed
16611	1101A, Magnolia Creek	9	69.9%	No LDC developed
16576	1101, Clear Creek Tidal	10	*Reduction for SW10 set at Station 11446*	No improvement needed in any flows
16573	1101, Clear Creek Tidal	10	*Reduction for SW10 set at Station 11446*	No LDC developed
11446	1101 Clear Creek Tidal	10	60.7%	No improvement needed in any flows
18591	1101F, Unnamed Tributary	11	24.5%	No improvement needed in any flows
17928	1101C, Cow Bayou	12	84.8%	No improvement needed in any flows
16475	1101D, Robinson Bayou	13	81.2%	No improvement needed in any flows

Model Linkage

The LDC results provided the basis for setting the weighted fecal bacteria reduction goals[87] for fecal bacteria, in the form of percentage reductions of instream loading (for source loads in *E. coli*). The percent reduction targets developed under the LDCs were applied directly to the source loads from SELECT 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 (illustrated in Figure 46) relies on using the percent reductions in place of absolute numbers to help bridge the gap between source loads and instream loads (assuming a linear relationship between sources, processes impacting transmission, and the resulting instream loads) and the gap between reductions based on enterococcus instream loads and *E. coli* source loads. The percent reduction from the LDCs, rather than absolute number of fecal bacteria to reduce, is used for the linkage.

While real world conditions may not always follow a true linear relationship, there were several factors that help reduce the uncertainty for this model approach: 1) the implementation of a buffer for this SELECT analysis helped to conceptually account for the fate and transport of source loads outside the riparian areas; 2) the level of precision provided by further fate and transport modeling was expected to be beyond the level of information needed for the decisions facing the stakeholders; 3) this approach mirrors other WPP efforts in the state and region; and 4) the focus on accessible, efficient modeling based on decision-making needs was established between H-GAC, TCEQ, and the stakeholders at the start of the project. While this approach includes a level of uncertainty because of factors the models do not consider (die-off and regrowth, filtration, *etc.* as part of transmittal of runoff from source to stream), the primary use of the outcomes will be to guide implementation. In a densely populated watershed, for a project life of over a decade, and with implementation likely to be adapted as things progress, the outcomes were sufficient to set the general source reduction goals. Additional fate and transport

[87] For DO, no further linkage to sources was calculated due to the lack of improvement needed in the LDCs, and the inability to conduct SELECT source modeling of the multiple potential precursors to low DO conditions. Based on the LDC results, where negative values indicate no improvement is needed and additional assimilative capacity may be present, DO conditions at all the DO LDC sites had additional assimilative capacity in all flow conditions. However, the data represents ambient sampling, and not 24-hour DO, so variation in conditions is likely to happen throughout the daily cycle. Additionally, DO conditions on tributaries with less flow may vary more widely than those in the main stem. However, this should not be taken to indicate there is no concern about DO or its precursors. As indicated in Section 5, many recommended solutions for fecal bacteria are also inclusive of potential improvements to, and consideration of, DO. Based on both stakeholder input and ambient water quality data analysis, DO remains a concern for the ongoing effort to improve water quality in the Clear Creek system.

modeling would add precision to estimates but would not likely be of much additional benefit to the stakeholders in their preliminary selection of solutions, and would still be subject to the same underlying level of uncertainty in source estimation. The estimation of future reductions was based on including any increase in load to the current conditions' reduction (i.e., assuming assimilative capacity of the waterway was an average constant).

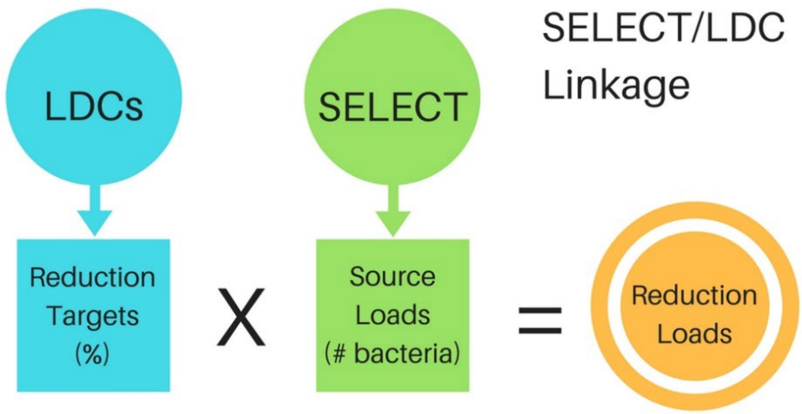

Figure 46 - Model linkage between SELECT and LDCs

To apply this linkage to develop current and future reduction targets, the stakeholders had to determine whether attainment of water quality standards should be measured at all points in the watershed, or at a selection of points that conglomerate subwatersheds into broad "attainment areas" of similar character and condition.

Attainment Areas

In developing improvement goals, the Partnership considered whether a single, watershed-wide goal for fecal bacteria, goals for each subwatershed, or grouped subwatersheds representing attainment areas were appropriate. Based on the varied character of the watershed, the lack of good separating points/stations to group similar subwatersheds, and to provide for better monitoring of project progress, the Partnership elected to set separate goals for each subwatershed area encapsulated by a station at which an LDC was completed, with the exception of lumping subwatersheds 3 and 4[88].

The monitoring stations and their associated LDCs and improvement goals for these areas will be the primary focus of measuring water quality achievements under the WPP.

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[88] For the development and distribution of recommended solutions discussed in Section 5, estimates are presented at the segment level, inclusive of all subwatersheds in the segment. Where subwatersheds are specific priorities, they are noted individually.

E. coli Source Load Reduction Goals

With the establishment of the attainment areas, the Partnership developed specific *E. coli* reduction targets for current[89] and target year (2035). The first step was to identify a single percentage improvement goal based on the LDCs for each attainment area.

The design for generating single target percent reductions for each attainment area[90] 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. The equation below demonstrates the calculation used to determine this average, where *W* represents the weighting factor (percent of flows) at high flow (*H*), moist (*M*), mid-range (*MR*), dry (*D*), and low flow (*L*) conditions, and *R* represents the reduction value required at each rate of flow. In the formula, all flows are represented; for each LDC only the flow categories where reduction was needed would be represented.

$$\text{Weighted Average Reduction} = \frac{WHRH + WMRM + WMRRMR + WDRD + WLRL}{WH + WM + WMR + WD + WL}$$

For example, Station 16611 is the station whose LDC and monitoring represent tributary 1101A, Magnolia Creek. At the high flow category which represents the top 10% of flows, an *E. coli* reduction of 89% is recommended. *E. coli* observed in the next 30% of flows (moist conditions) require a reduction of 79% and *E. coli* observed in the following 20% of flows (mid-range conditions) require a 69% reduction. *E. coli* observed in dry conditions comprising the following 30% of flows require a 62% reduction. Lastly, low flow conditions representing the final 10% of flows require a 49% reduction. The calculation for the weighted average reduction for Station 11314 is shown below:

$$\text{Weighted Average Reduction} = \frac{(10 \times 89) + (30 \times 79) + (20 \times 69) + (30 \times 62) + (10 \times 49)}{10 + 30 + 20 + 30 + 10}$$

$$\text{Weighted Average Reduction} = \frac{890 + 2370 + 1380 + 1860 + 490}{100}$$

$$\text{Weighted Average Reduction} = \frac{6990}{100} = 69.9$$

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[89] References to “current” modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.

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

This formula was applied to the representative stations for all subwatershed attainment areas to develop the final weighted average reduction goals, shown previously in Table 28. These percent reductions could then be applied to the source loads from SELECT to determine corresponding source load reductions.

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 to be executed over a 5 to 15-year period. The existing projections developed during the SELECT analyses allowed the stakeholders to target any of the five-year milestone dates between 2020 and 2050. 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 2050, whereas a more long-term plan would have to rely on less certain predictions[91]. The Partnership and project staff agreed to target the year 2035, allowing a long-term focus to account for watershed change, while focusing on meaningful interim action. For a WPP approved in 2023, this would represent a 12-year plan life.

Allocating Reductions

The mix of sources present in the watershed, and the differing number of solutions for each source 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[92] relative contribution (rather than 2035). Project staff proposed the first option as an initial guide for the calculation of reduction targets, with the understanding that the WPP would stress opportunistic implementation in addition to adaptive management strategies that will be most feasible in the short term. The proportional allocation was modeled for the

[91] 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.
[92] References to "current" modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.

subwatershed/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. 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 estimations as of the year 2020, and for the 2035 milestone year (Table 29). The load reductions needed by each source for each of the segments was also projected for conditions in 2035 (Table 30).

Table 28 - Current and 2035 source load reduction targets

Sub-watershed(s)	Weighted *E. coli* percent reduction target (current[93])	Current Source Load	Current Source Load Reduction Target	Incremental load 2020-2035[94]	2035 Source Load Reduction Target[95]
1	51.3%	1.40E+13	7.19E+12	3.36E+12	1.06E+13
2	63.5%	2.75E+12	1.74E+12	-8.93E+10	1.66E+12
3,4	65.0%	1.28+13[96]	8.32E+12	4.90E+11	8.81E+12
5	55.0%	3.62E+12	1.99E+12	-3.04E+09	1.99E+12
6	57.9%	8.39E+12	4.85E+12	-1.70E+11	4.69E+12
7	68.3%	5.18E+12	3.54E+12	2.76E+12	6.30E+12
1102, Total	*64.1%*	*4.67E+13*	*2.76E+13*	*6.35E+12*	*3.40E+13*
8	66.2%	3.89E+12	2.58E+12	2.64E+12	5.22E+12
9	69.9%	2.28E+12	1.59E+12	5.75E+11	2.17E+12
10	60.7%	7.41E+12	4.50E+12	3.41E+11	4.84E+12
11	24.5%	4.88E+11	1.20E+11	4.93E+11	6.13E+11
12	84.8%	3.63E+12	3.08E+12	-1.54E+11	2.93E+12
13	81.2%	2.42E+12	1.97E+12	1.54E+11	2.12E+12
1101, Total	*74.1%*	*2.01E+13*	*1.38E+13*	*4.05E+12*	*1.79E+13*

[93] References to "current" modeled conditions throughout this document refer to 2020 estimations, based on the available data at the time of the modeling effort.
[94] The incremental load represents the difference between the 2035 load and the 2020 load without BMPs. See the next footnote for explanation of its use in generating 2035 source reduction load target.
[95] The 2035 reduction target is generated by through the equation $C_r+(F_l-C_l)$; 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 2020 and 2035 is added to whatever existing reduction load exists in 2020. 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.
[96] Current source load is generated by summing the source loads for the subwatersheds within the attainment area.

Table 29 - Source load reductions by segment and source, 2035

Segment		OSSF	WWTF	Dogs	Cattle	Horses	Sheep & Goats	Deer	Feral Hogs	Other Animals	Total Reduction
1102	Source Load	2.04E+12	4.39E+10	3.98E+13	1.43E+12	1.28E+10	4.61E+11	5.13E+10	8.45E+10	9.21E+12	**5.31E+13**
	% of total Source Load	3.85%	0.08%	74.88%	2.70%	0.02%	0.87%	0.10%	0.16%	17.34%	**100.00%**
	Reduction Load	1.31E+12	2.81E+10	2.55E+13	9.19E+11	8.17E+09	2.95E+11	3.28E+10	5.41E+10	5.90E+12	**3.40E+13**
1101	Source Load	1.07E+12	4.67E+10	1.78E+13	7.91E+11	7.03E+09	2.54E+11	2.21E+10	4.49E+10	4.19E+12	**2.42E+13**
	% of total Source Load	4.44%	0.19%	73.40%	3.27%	0.03%	1.05%	0.09%	0.19%	17.34%	**100.00%**
	Reduction Load	7.94E+11	3.46E+10	1.31E+13	5.85E+11	5.21E+09	1.88E+11	1.63E+10	3.32E+10	3.10E+12	**1.79E+13**
Total	Source Load	3.12E+12	9.06E+10	5.75E+13	2.23E+12	1.98E+10	7.16E+11	7.34E+10	1.29E+11	1.34E+13	**7.73E+13**
	% of total Source Load	4.03%	0.12%	74.42%	2.88%	0.03%	0.93%	0.09%	0.17%	17.34%	**100.00%**
	Reduction Load	2.09E+12	6.09E+10	3.86E+13	1.49E+12	1.33E+10	4.81E+11	4.93E+10	8.69E+10	9.00E+12	**5.19E+13**

Representative Units and Scaling Implementation

The source load reduction targets represent reductions needed by each source in each segment. In order to determine what the source load reduction targets meant in terms of the scaling of solutions, representative units for sources were used. Representative units simplify the conceptualization of load reduction targets by converting source load values in colony forming units (cfu)/day to practical units. Table 31 shows the total number of units that would need to be addressed in each segment in 2035 was calculated by dividing the target load reductions by the per-unit *E. coli* load of each source (*e.g.*, one representative unit for dog waste is equal to the daily *E. coli* load produced by one dog[97]). This approach helps illustrate and plan for the scale of implementation. All units to address are rounded up to the nearest whole unit.

Table 30 - Representative units to address by 2035, by segment

Source	Representative Unit	Representative Unit Daily Load (cfu/day)[98]	Units to Address by 2035, 1101	Units to Address by 2035, 1102	Units to Address by 2035, Total
WWTFs	1 million gallons of effluent per day	4.77E+09	8	6	14
OSSFs	1 failing OSSF	3.71E+09	1,055 (214)	1,951 (353)	3,006
Dogs	(waste of) 1 dog	2.50E+09	5,256	10,184	15,440
Cattle	(waste of) 1 cow	2.70E+09	217	341	558
Horses	(waste of) 1 horse	2.10E+08	25	39	64
Sheep/ Goats	(waste of) 1 sheep or goat	9.00E+09	21	33	54
Deer	*(waste of) 1 deer*	*1.75E+08*	*0 (94)*	*0 (189)*	*0*
Feral Hogs	(waste of) 1 feral hog	4.45E+09	8	13	21
Other Animals	*NA*	*NA*	*(0)*	*(0)*	*0*

As can be seen, the number of units to address from the Other Animals category and deer are zeroed out in this chart. In discussions with the stakeholders, deer were not expected to be a source that could easily be addressed, and there was little interest to do so. Similarly, the load from Other Animals cannot likely be directly addressed. To ensure

[97] In the SELECT analyses using the buffer approach, the instream load contributed by each source varies by proximity to the waterway. However, when calculating representative units, no spatial distinction was made in calculating the number of units to be addressed. A representative unit for a dog may represent a single dog in the buffer area, or the waste of four dogs outside the buffer area (where it is reduced to 25% of potential load.)

[98] Daily loads associated with each source are adapted from Teague *et al*. 2009: https://ssl.tamu.edu/media/11291/select-aarin.pdf

implementation is sufficient to cover these sources, their reduction loads were assigned to OSSFs. Preliminary numbers to address are shown in parentheses, prior to this conversion.

While SSOs were not included in source and reduction calculations, per prior discussion of their episodic nature, addressing them is an expectation as a source of primary concern. Activities to address SSOs will help meet the WWTF requirements.

The solutions for livestock are based on the implementation of TSSWCB Water Quality Management Plans (WQMPs), similar conservation plans or other Farm Bill funded activities through USDA Natural Resources Conservation Service (NRCS) programs, or voluntary efforts by agricultural producers. 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 Soil and Water Conservation Districts (SWCDs) in this and previous projects to develop an assumed average number of livestock units (30) to be served by each plan. The assumption for this watershed includes consideration of the small agricultural presence in the watershed, and lack of known large herds/operations. 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 32). The actual load reduction value for each plan will differ depending on the mix of livestock involved (given their different representative unit loading values).

Table 31 - Agricultural plans needed to address livestock loads by 2035

Segment	Total Livestock Units to Address	Total Plans
1101	263	9
1102	413	14

Source Load Reduction Summary

The findings of the fecal bacteria modeling efforts for Clear Creek reinforce the image of a watershed that's heavily influenced by developed areas and sources, with some lingering agricultural presence. 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 build out its remaining areas in the coming years. While the watershed will experience less change in source loads and profile than other area watersheds with less existing development, future conditions are still an important consideration for stakeholder decisions.

The persistent and pervasive need for fecal bacteria source reduction throughout the watershed highlights the need for intervention through the WPP and other means. Water quality issues will persist 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 solutions. For these purposes, the level of uncertainty and precision of the results was deemed to be acceptable by the stakeholders, with the exception of the desire for additional microbial source tracking. While source tracking or other DNA source tracking analyses were not a function of this project, it should be a consideration in the future to further characterize sources, identify location-specific challenges, and refine the linkage between source loads and instream conditions. Further refinement of results may be needed in the future as conditions change.

Figure 47 - Avian wildlife (White Ibis) in the Clear Creek Watershed

Section 5: Recommended Solutions

Section 5. Recommended Solutions

Sources of pollution in the Clear Creek watershed are widespread, diverse, and expected to persists into 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 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.

Identifying Solutions

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.

Stakeholders reviewed a wide range of potential solutions, starting with those identified in existing projects[99] and ongoing local efforts[100]. The diversity of pollutant sources in the watershed required that stakeholders consider an equally wide range of potential solutions sufficient to address each source[101] in proportion to the prominence of the source. This palette of potential solutions served as a starting point for local customization and

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[99] Including previous WPPs and TMDL I-Plans conducted in other watersheds, as well as the I-Plan for the Bacteria Implementation Group, which covers the Clear Creek TMDL assessment for fecal bacteria (https://www.h-gac.com/bacteria-implementation-group/studies/clear-creek)

[100] Including planned or potential activities of local government partners like the HCFCD; NGOs like the Bayou Land Conservancy; regional efforts like USACE flood mitigation studies; private developers, and others.

[101] Solutions to address the Deer and Other Animals categories were not considered under this process, based on stakeholder feedback or regulatory restriction.

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 discussions focused primarily on 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 enhancement or supplementation 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;
- Provided more detailed information for future consideration;
- 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.

Recommended Solutions

In developing solutions, the stakeholders considered the purpose of the solution, the scope of its implementation, the responsible parties[102], the period in which it would be

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

implemented[103], 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 2030. 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 E.

Figure 48 - Degraded riparian area in the Clear Creek watershed

[103] The period represented for each solution is the timeframe within the initial 12-year implementation window between an assumed approval in 2023 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.

Wastewater Treatment Facilities and Sanitary Sewer Overflows

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 priority 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, utility districts, water control and improvement districts (WCIDs), private utilities, and other entities are actively engaged in these efforts and have had noteworthy success. Across the watershed, 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 following solutions were identified by the stakeholders for WWTFs and SSOs:

- WWTF 1 — Support Local Utility Improvement Efforts
- SSO 1 — Remediate Infrastructure
- 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 E.

WWTF 1 – Support Local Utility Improvements

Purpose: To support, through funding identification and/or development, appropriate advocacy, or other means, local utilities seeking to expand and utilize resources to improve wastewater utility function.

Description: The Partnership will work with local utilities to promote remediation of facilities 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 facilities and infrastructure. No specific problem facilities were identified in the watershed characterization, but as systems age, problem areas may arise.

Priority Area(s): Watershed-wide, but with specific focus on older systems such as those in older communities of subwatersheds 4 and 5.

Responsible Parties	Period	Contaminant(s) Addressed	Status
Utilities; Cities; 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 and development or regional facilitation. Financial resources needed for this recommendation are highly variable, but include utility staff time costs, and infrastructure costs as warranted.	Costs involved with WWTF system improvements 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.*) or related funding through disaster mitigation programs like Community Development Block Grants, *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 as systems in the watershed continue to age. The relatively small number of plants in the watershed and mix of ages allows for a greater focus on supporting supplementary efforts by local utility partners.

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

No specific problem areas were identified by stakeholders, but as systems age, problem areas may arise.

Priority Area(s): Watershed-wide, but with specific focus on older systems such as those in older communities of subwatersheds 4 and 5.

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

Technical and Financial Resources Needed	Estimated Costs and Funding
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 as listed in Appendix E, 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 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 relatively consolidated nature of service in the watershed means costs per utility are likely similar to 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.

SSO 2 – Consider Additional Preventative Measures

Purpose: To enhance operations and infrastructure capacity to help prevent SSOs.

Description: Utilities will consider enhancing their operations and preparations for mitigating SSOs by implementing one or more of the following solutions (if not already in place):

- Evaluate and enhance lift station[104] 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[105] for problem systems.

Priority Area(s): Watershed-wide

Responsible Parties	Period	Contaminant(s) Addressed	Status
Utilities	Ongoing-2030	Bacteria, Nutrients	Enhance existing efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
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.	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 (Appendix E).

Bacteria Reduction Capability
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.

[104] 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.

[105] Information on this program can be accessed at https://www.tceq.texas.gov/compliance/investigation/ssoinitiative.

On-site Sewage Facilities

Failing OSSFs are a priority source due to high risks to human health associated with untreated human waste, 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, attempt to prevent future failures through education and outreach to the community and licensed professionals, and direct intervention to economically disadvantaged households through programs such as a Supplemental Environmental Program (SEP)[106]. OSSF funding through H-GAC is currently being provided by a TCEQ approved SEP, the Harris County District Attorney's Office, and private funders. In order to qualify, homeowners with failing OSSFs must reside in an eligible county and have a combined income below 80% of the median for the county.

These solutions are in addition to the existing requirements of watershed counties, including mandatory maintenance contracts for systems and other authorized agents, and the enforcement thereof. It should be recognized that county and authorized agent efforts are the primary foundation for all other efforts. The following supplementary solutions were identified by the stakeholders:

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

In addition to management measures geared at educating stakeholders about their OSSF system (see Section 6), Management Measures OSSF 1 and 3 recommend the repair, replacement, or conversion to sanitary sewer of 3,006 systems by acquiring programmatic resources and funding to address high priority systems. These management measures will also be used to support TCEQ's Coastal Nonpoint Source Pollution Control Program by prioritizing systems in the coastal zone boundary that are failing and/or if their system is by nitrogen-limited waters. A detailed OSSF Geographic Information System-based inventory database was completed by TCEQ in 2017, in support of the Texas Coastal Nonpoint Source Program. Further, education on system operation and maintenance as well as proper installation, inspection, and repair procedures should be delivered.

All subwatersheds are targeted by these strategies, with a focus on the developing areas of subwatershed 5. Educational elements (*e.g.*, homeowner workshops) are included in the discussion of education and outreach activities in Section 6.

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[106] H-GAC's SEP is used to remediate, repair, pump, or decommission OSSFs for homeowners making less than 80% of the Area Median Income. More information is available at https://www.h-gac.com/on-site-sewage-facilities.

Actual implementation will be opportunistic and will seek to emphasize priorities noted in each OSSF solution. Proposed siting of OSSF projects within the watershed to be implemented by 2035 is shown in Table 33.

Table 32 - Proposed siting for OSSF solutions to be implemented by 2035

Attainment Area	Units to Address, Total	Priority Subwatersheds
Segment 1101	1,055	1,6
Segment 1102	1,951	8

<table>
<tr><th colspan="4">OSSF 1 – Remediate Failing OSSFs</th></tr>
<tr><td colspan="4">Purpose: Reduce bacteria and nutrient contributions from failing OSSFs through physical remediation.</td></tr>
<tr><td colspan="4">Description: H-GAC will work with watershed counties and OSSF owners to inspect and remediate eligible failing systems through pumping, repair, replacement, or abandonment/conversion to sanitary sewer. The Partnership will promote the use of the 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.


Priority Area(s): Subwatersheds 1,6, and 8 and older systems watershed wide.</td></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant(s) Addressed</th><th>Status</th></tr>
<tr><td>H-GAC; Homeowners; Counties (enforcement); Utilities (for conversion projects)</td><td>Ongoing-2035</td><td>Bacteria, Nutrients</td><td>Expansion of existing efforts (e.g., H-GAC OSSF SEP, residential maintenance)</td></tr>
<tr><th colspan="3">Technical and Financial Resources Needed</th><th>Estimated Costs and Funding</th></tr>
<tr><td colspan="3">Technical resource needs include data on OSSF locations from H-GAC's regional OSSF database, the counties and authorized agents, and 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 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.

While these estimations include all costs of directly mediating failing systems, it is assumed that some systems in developing or re-developing areas will be supplanted by wastewater service in new development.</td><td>Estimated costs are an average[107] of $5,500 per unit, with a total cost of $16,533,000 for 3,006 systems.

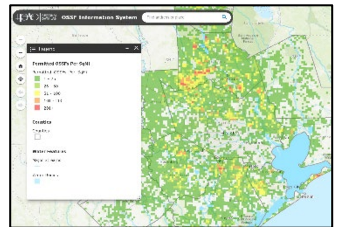
Funding Sources include routine homeowner maintenance costs, as supplemented by H-GAC SEP and other grant programs (CWA §319(h), etc.).</td></tr>
<tr><th colspan="4">Bacteria Reduction Capability</th></tr>
<tr><td colspan="4">Remediating failing OSSFs is assumed to remove 100% of their daily load. Full implementation of this solution will meet the bacteria reduction goal for OSSFs by 2035.</td></tr>
</table>

[107] 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.

OSSF 2 – Improve Spatial Data

Purpose: Inform decisions about prioritizing OSSF remediation.

Description: H-GAC will work with watershed counties and other local partners to continue to collect spatial data on OSSF locations as part of H-GAC's existing OSSF spatial database[108]. The partners will update and improve designations for priority remediation areas based on the data and other factors (e.g., growth, developmental trends).



Priority Area(s): Watershed-wide.

Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; Counties; Special Districts; 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, OSSFs in riparian or flood-prone areas, and those in older communities.	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.

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

OSSF 3 – Convert to Sanitary Sewer

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

Description: Local partners 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. Priority should be given to failing systems, and this recommendation only applies where sanitary service is available/feasible.

Priority Area(s): Properties in subwatersheds with existing sanitary sewer systems; developing areas in subwatersheds 1, 8 and 7.

Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; Counties; Special Districts; Utilities; Homeowners	Ongoing-2035	Bacteria, Nutrients	Expansion of existing efforts

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources include available staff at local governments, H-GAC, and watershed 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 is expected that a good number of conversions may result from development of master-planned communities or other new development, or redevelopment 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. Funding sources include expected routine costs from homeowner, as supplemented by grant funding or municipal funding where appropriate and available.

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

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 extent of urban areas in the Clear Creek Watersheds makes these solutions especially important to consider.

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[109]. The recommendations of this WPP are not designed to supplant the existing efforts of the MS4s in the watershed. They are intended to supplement those activities, which form the basis of stormwater quality management in the area[110]. MS4 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 the following solutions:

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

Points of focus of this category include education and outreach activities, as reflected in Section 6. Implementation will target the urbanized portions of the watershed, especial in communities with aging infrastructure. 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

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

[110] 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.

Group[111] (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 or local stakeholders.

Siting of riparian buffers or other mitigation measures should take into account other uses for our urban corridors, including flood mitigation. 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.

Figure 49 - Inlet marker on storm drain

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

Urban Stormwater 1 – Install Stormwater Inlet Markers and Signage

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, homeowners' associations (HOAs), and neighborhoods, and/or the use of signage in public areas. Local organizations (*e.g.*, Harris County's Stormwater Inlet Marking program[112]) have existing programs for this purpose. This solution reflects partners' intent to continue or expand programs. Inlet markers and/or signage 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.

Priority Area(s): Urbanized areas of the watershed, especially those with aging infrastructure.

Responsible Parties	Period	Contaminant(s) Addressed	Status
Harris County; Local Governments; Special Districts; HOAs; Local Volunteers	Ongoing with focus on 2023-2027	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, local government/organization funding, CWA §319(h) grant funding, neighborhood HOA funding, or private foundation funding. The Partnership will seek additional funding to support interested communities.	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. Signage is variable by type and size. Funding sources include existing programs (Harris County provides marking kits upon registration), utility revenues, or non-governmental organization (NGO) partner funds.

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

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

Urban Stormwater 2 – 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 high bacterial loads and coordination of follow-up to anything found would be efforts above and beyond permit requirements. The models for this recommendation are similar to previous efforts by many organizations in the Galveston Bay Watershed to identify high bacteria load streams. This effort can be paired with monitoring activities and would focus on areas with appreciable impairment or other indicators of potential illicit connections, *etc.*

Priority Area(s): Riparian areas of AUs with impairments; urbanized areas.

Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; MS4s; Counties; TCEQ	Ongoing with focus on 2023-2027	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 counties 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 (Section 6).	Estimated costs include hourly costs of $50-60 for staff time and overhead. Total costs depend on scale of effort. A $30,000 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, sediment, and trash by identifying potential sources, which would then be referred to responsible enforcement jurisdictions.

Urban Stormwater 3 – Promote and Implement Riparian Buffers and Urban Trees			
Purpose: To reduce pollution from runoff by maintaining or restoring riparian buffers where appropriate and increasing urban tree canopy.			
 **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, 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. **Priority Area(s):** Riparian buffers throughout the watershed; trees planted in appropriate plantable areas in urban subwatersheds, with a focus on tree equity between communities and riparian areas, and native species.			
Responsible Parties	**Period**	**Contaminant(s) Addressed**	**Status**
MS4s; Local Governments; Special Districts; Texas A&M Forest Service (forestry technical support); NGOs; Landowners; Business community	Ongoing-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[113]. Agency partners like the Texas A&M Forest Service, and 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.			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.			

[113] 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, including those available at:
https://tfsweb.tamu.edu/LandownerAssistance

Urban Stormwater 4 – Promote Low Impact Development and Green Infrastructure

Purpose: To reduce pollutants in stormwater flows through infrastructure that mimics or improves on natural hydrology.

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 providing model materials on our website, coordinating 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 downstream especially in areas of new development.

Priority Area(s): New development and redevelopment; public facilities in urban areas.

Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; MS4s; Counties; Local Governments; Special Districts	Ongoing with focus on 2023-2027	Bacteria, Nutrients, Sediment, Trash	New or expanded effort

Technical and Financial Resources Needed	Estimated Costs and Funding
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.	Cost estimates for promotion are included in the general duties of a watershed coordinator (see Section 7), 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.*)

Bacteria Reduction Capability

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.

Pet Waste

Waste from both pet and feral dogs is a substantial source of bacteria and nutrients in the Clear 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. Stakeholders recommended the following solutions:

- 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
- 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 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.

Figure 50 - Resident walking a dog in the Dr. Ned and Fay Dudney Clear Creek Nature Center

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 50 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 Challenger 7 Park, other neighborhoods, and county parks, other recreational areas, and new development. Temporary stations at large events are another potential supplement to this effort. This work will be coordinated with municipal and other planning efforts, including the ongoing Clear Creek Master Plan process.

Priority Area(s): Parks, neighborhoods and other high traffic areas, apartment complexes

Responsible Parties	Period	Contaminant(s) Addressed	Status
Counties; Local Governments; HOAs; Apartment Complexes	Focus on 2024-2028 for installation; 2029-2035 for 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 participate in H-GACBuy[114] cooperative purchasing	Estimated costs for 50 pet stations include installation costs of $200 per station, $50 in bags, $200 in labor and materials (total $22,500). Maintenance is estimated at $400/year per station ($220,000 for 14-year period). The total cost is $242,500. Costs for mobile stations at events are variable. Funding sources include local government tax or utility revenues, HOA fees, or grants from CWA §319(h) or other sources.

Bacteria Reduction Capability

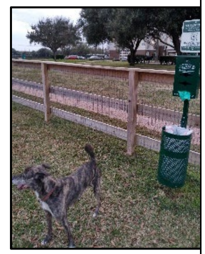
The number of dogs impacted by this solution will vary based on the location. An average of 50 dogs a day per station served was chosen based on stakeholder description of high-traffic area parks and assumptions from similar WPPs. Assuming half of the dog's daily waste is served, full implementation of this solution would yield 2,500 dogs, or 1,250 representative units, addressed. This would represent a daily bacteria reduction of 3.13E+12 in riparian areas (300-foot buffer), and 7.81+11 in areas outside the buffer based on SELECT assumptions.

[114] 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 and are well utilized (*e.g.*, Bark Park at Countryside, Friendswood Dogsafe Park, Lake Nassau Park Dog Park, Lucky Leash Dog Park, Independence Dog 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 with strong amenity focuses are also potential opportunities for expanded parks. Priority areas are based on highest potential use/traffic and population served.



Priority Area(s): New developments, public spaces near riparian areas

Responsible Parties	Period	Contaminant(s) Addressed	Status
Counties; Local Governments; HOAs; Developers; Special Districts	One new park, 2024-2030; another park, 2030-2035	Bacteria, Nutrients	New and expanded effort

Technical and Financial Resources Needed	Estimated Costs and Funding
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.	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 \$100,000 to \$500,000. Funding sources include municipal or HOA 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 and Neuter Events

Purpose: To reduce feral dog populations through reproductive controls.

Description: Spay and neuter programs are an effective means of curbing unwanted pet populations[115]. 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.

Priority Area(s): Urbanized areas, downstream attainment area

Responsible Parties	Period	Contaminant(s) Addressed	Status
Service provider (such as SPCA[116] or similar); Local Partners	2023-2035, every 6 years (2)	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 from a combination of local government or HOA 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[117]. 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[118]. 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[119].

[115] This effort is aimed at voluntary spaying and neutering of pet populations. Due to the controversy surrounding trap/neuter/release programs and impacts on native wildlife, the Partnership did not have a consensus on application of this effort to feral populations.

[116] Society for the Prevention of Cruelty to Animals (SPCA)

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

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

[119] 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.  **Priority Area(s):** Urbanized areas, neighborhoods adjacent to waterways			
Responsible Parties	**Period**	**Contaminant(s) Addressed**	**Status**
Local Governments; Special Districts; HOAs; Apartment Complexes	Ongoing-2030	Bacteria, Nutrients	New effort
Technical and Financial Resources Needed			**Estimated Costs and Funding**
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.			Cost estimates for developing new ordinances or outreach materials will vary by scope and type. However, H-GAC maintains model materials on its website[120] as do partners like Harris County[121]. Costs for increased enforcement will vary based on the entity involved and scope of enforcement. Funding sources for developing new enforcement or materials are 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.			

Dogs are a substantial portion of the modeled source load for Clear Creek. While they are concentrated most densely in the most heavily urban 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

[120] http://www.h-gac.com/pet-waste-pollutes/default.aspx
[121] For example, https://www.cleanwaterways.org/Portals/73/downloads/brochures/dogWaste_bro_hiresCS2.pdf

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. The number of representative units whose waste will be addressed in each segment is included in Table 34[122].

Table 33 - Number of dogs whose waste will be addressed by 2035, by segment

Segment	Units to Address, Total
1101	5,256
1102	10,184

Agriculture

Agriculture maintains a small, declining presence in the watershed. Legacy agricultural areas in the western and south-central areas of the watershed (primarily subwatersheds 1,7,and 8) maintain populations of livestock in addition to row crops and fallow fields. 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 Texas A&M University AgriLife Extension (AgriLife Extension) and Texas A&M University AgriLife Research (AgriLife Research) in coordination with local producers and conservation efforts on agricultural lands by NGOs and private interests. 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

[122] The number of dog waste units designated to be addressed by subwatershed is based on each subwatershed's proportional contribution to the total pet waste load for its segment area. This proportion is applied to the reduction load for the segment area and divided by the load per unit to produce the number of units per subwatershed. As with other sources, the focus of implementation will continue to be on siting solutions 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.

benefits that well-run agricultural lands provide. A large component of the efforts for this watershed will be discussed as educational activities in Section 6.

The solutions selected by the stakeholders include promoting and implementing voluntary, site-specific management plans for individual operations. The efforts will focus on implementing multiple solutions where appropriate. The focus areas for the solutions below are subwatersheds 1, 7, and 8, and operations in other areas.

- Agricultural Operations 1 — Promote voluntary land management plans including TSSWCB WQMPs, NRCS Conservation Plans, and similar efforts
- Agricultural Operations 2 — Maintain or restore riparian buffers

Figure 51 - Cattle in Clear Creek Above Tidal

Agricultural Operations 1 – Promote Voluntary Land Management Plans

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

Description: Both the USDA 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 SWCD that is customized to fit the needs of their operation. The USDA 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 reduce 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[123] including but not limited to filter strips, riparian buffers, prescribed grazing, and providing alternative shade and water. More information on the practices is included in Appendix D. Similarly, the USDA NRCS offers conservation planning services through its Conservation Technical Assistance (CTA) program[124] 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[125].

Priority Area(s): Agricultural areas concentrated in north Harris County, headwaters attainment area

Responsible Parties	Period	Contaminant(s) Addressed	Status
TSSWCB; SWCDs; USDA NRCS; Agricultural Producers/Landowners	Ongoing-2035	Bacteria, Nutrients, Sediments, Pesticides	Ongoing and expanded effort

Technical and Financial Resources Needed	Estimated Costs and Funding
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 are 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.	Estimated costs for WQMPs include up to $15,000 per WQMP in financial incentives, 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.

Bacteria Reduction Capability

[123] For more information, see: https://www.tsswcb.texas.gov/programs/water-quality-management-plan
[124] For more information, see: https://www.nrcs.usda.gov/getting-assistance/conservation-technical-assistance
[125] For more information, see: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/

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.

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, buffers help serve ecological and flood mitigation purposes. Buffers along drainage conveyances should be appropriate to the needs of the conveyance.

In addition to WQMPs and conservation plans, potential methods of implementation include the utilization of conservation easements held by land trusts, voluntary individual landowner implementation, or participation in a USDA NRCS Farm Bill program (*e.g.*, EQIP or similar).

Priority Area(s): Riparian areas, subwatersheds 1,6,7, and 8.

Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners/producers (on a voluntary basis); NGOs; Agricultural Agencies	Ongoing-2035	Bacteria, Nutrients, Organic Wastes, Pesticides, Flooding	Expanded existing effort

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; USDA 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.

<table>
<tr><th colspan="4">Agricultural Operations 3 – Implement Horse Manure Composting Program</th></tr>
<tr><td colspan="4">Purpose: To reduce transmission of wastes from non-agricultural horses through collection and composting of wastes.</td></tr>
<tr><td colspan="4">Description: Recreational horse (i.e., horses not attached to an agricultural operation) ownership is prevalent in the watershed, with several 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 stabling operations throughout the watershed. Other local watersheds have identified this as a potential program, making a regional approach possible for economy of scale.

Priority Area(s): Stabling operations throughout the watershed; subwatersheds 1,6,7 and 8.</td></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant(s) Addressed</th><th>Status</th></tr>
<tr><td>Horse Owners; Stabling Operations; Commercial Facilities</td><td>Ongoing-2035</td><td>Bacteria, Nutrients</td><td>New 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 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 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.</td><td>Costs estimates assume existing staff capacity (at $40-$50 total hourly cost per employee) and resources (vehicles).

Funding sources include local government revenue, private commercial investment, and manure compost sales.</td></tr>
<tr><th colspan="4">Bacteria Reduction Capability</th></tr>
<tr><td colspan="4">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.</td></tr>
</table>

[128] For more, see: https://agrilifeextension.tamu.edu/asset-external/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 Animals

Feral hogs are a potential source of bacteria in watersheds, especially those with networks of riparian corridors connecting rural, suburban, and urban areas. Within the 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[132] 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 effective methods 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 public open space areas in which feral hog damage is a potent incentive for landowner participation. Reduction of feral hogs is expected to derive directly from landowner efforts and local and state government eradication efforts, as supported by partner agencies through information and technical services. While estimated feral hog numbers are low for this watershed, continued development in adjacent watersheds may push populations into the Clear Creek area.

While the WPP does not specifically seek to address deer and other wildlife species, 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 for these solutions is watershed-wide, with special attention paid to localized hog problems, or conservation opportunities may exist in the watershed. To one degree or another, hog, deer, and other animal populations are found throughout the project area. For feral hogs, deer, and other animals, stakeholders recommended the following solutions:

- Feral Hogs 1 — Remove feral hogs
- Feral Hogs 2 – Manage feeding
- Wildlife 1 — Conserve or restore upland habitat

[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.
[132] Included in the safety margin.

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

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 on voluntary efforts from individual landowners, but the Partnership recommends abatement activities on behalf of local governments, as appropriate.

Priority Area(s): Watershed-wide with a specific focus on large public open spaces.

Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners; Local Governments; Special Districts; Agricultural Agencies (technical support)	Ongoing-2035	Bacteria, Nutrients	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 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 local governments or 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.	To reduce an estimated 21 hogs, 5 traps would be needed (assuming each trap serves to reduce five hogs). With an average cost of $1,000 for a medium sized trap, this would represent an annual cost of $5,000[133], 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.

[133] 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. Costs vary from single animal small box traps at $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.

Feral Hogs 2 – Manage Feeding

Purpose: To encourage landowners to mitigate wildlife concentrations near riparian buffers and avoid attracting invasive species.

Description: This solution seeks to encourage voluntary implementation of exclusionary devices around deer feeders to deter invasive species such as feral hogs[134]. These measures are especially recommended near riparian areas to avoid concentrating invasive species populations and their waste near waterways. The primary focus of this effort is on voluntary efforts from individual landowners across the watershed.

Priority Area(s): Populated areas near riparian buffers

Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners; Agricultural Agencies (technical support)	Ongoing-2035	Bacteria, Nutrients	New effort

Technical and Financial Resources Needed	Estimated Costs and Funding
Technical resources needed for this solution are advice and support for landowners, and participation from the landowners themselves. The primary agency providing technical support on wildlife and feral hog issues is 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 by the landowners on a voluntary basis. No grant funds have been identified to supplement these contributions.	Costs for 100 feet of 28” fencing vary between $250-S300 depending on materials, and do not include landowner time. Funding for these measures would come from property owners. No specific grant resources were identified for this solution.

Bacteria Reduction Capability

This solution is not intended to directly impact sources but is expected to generally reduce feral hog and other wildlife time in riparian areas by discouraging the formation of resident populations of invasive species. Due to the wide variety of species this may impact, and the potential variety of lands involved, no specific reduction potential can be generated.

[134] For more information, see: https://wildpigs.nri.tamu.edu/media/1153/l-5533-using-fences-to-exclude-feral-hogs-from-wildlife-feeding-stations.pdf

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 to provide suitable habitat for wildlife 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.

Priority Area(s): Ecologically appropriate areas in all subwatersheds.

Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners; NGOs; Local Governments; Agricultural Agencies (technical support); Developers	Ongoing-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.*, Galveston Bay Foundation), agricultural agencies, and local governmental staff (*e.g.*, county precincts already involved in habitat conservation in parks and public areas like the Cities of Houston and Pearland). 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 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
  - Trash 1 – Implement a Trash Bash Site
- 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 watershed but may include open space areas in the watershed in general. Areas appropriate for restoration activities in more developed areas may also be targeted for conservation activities (*e.g.*, increasing tree canopy, restoring riparian vegetation). Conservation practices recommended by this WPP are wholly limited to voluntary landowner decisions supported by resources and technical expertise from local government, landowners, conservation NGOs, and the Partnership. The focus in this category is improving water quality and promoting ancillary benefits like habitat value and flood mitigation, by maintaining or restoring ecosystem services from conserved land. A variety of successful, model conservation activities exist in the watershed.

While few chronic problem dumping sites were identified, 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.

Flooding is a primary concern for the Clear Creek communities, and the subject of extensive local, state, and federal study and investment. 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.

<table>
<tr><th colspan="4">Conservation and Land Management 1 – Riparian Buffers</th></tr>
<tr><td colspan="4">Purpose: To reduce transmission of bacteria, nutrients, trash, and sediment to waterways by maintaining or implementing vegetated buffers in riparian corridors.</td></tr>
<tr><td colspan="4">Description: This solution is supplementary to Urban Stormwater 3 – Promote and Implement Urban Riparian Buffers and Agricultural Operations 2 – Maintain and Restore 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 headwaters area.

Priority Area(s): Current and new developments, headwaters area</td></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant(s) Addressed</th><th>Status</th></tr>
<tr><td>Landowners; NGOs; Counties; Local Governments; Special Districts; Agricultural Agencies</td><td>Ongoing, with focus on 2024-2028</td><td>Bacteria, Nutrients, Sediment, Flooding</td><td>Expansion of existing efforts</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 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.</td><td>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[135].

Funding sources include local government revenues (public buffers), landowner funding, or NGO/local partner funding.</td></tr>
<tr><th colspan="4">Bacteria Reduction Capability</th></tr>
<tr><td colspan="4">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%[136].</td></tr>
</table>

[135] Available at: http://www.h-gac.com/riparian-buffer-tool/default.aspx
[136] See references under Agricultural Operations 2

Conservation and Land Management 2 – Voluntary Conservation

Purpose: To reduce transmission of bacteria, nutrients, trash, and sediment to waterways through voluntary land conservation.

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 riparian and/or ecologically valuable areas in the watershed, in conjunction with local partner efforts. Wetlands and coastal prairie in the watershed are priority land cover types due to the overlapping benefits the provide for flood mitigation.

Priority Area(s): Riparian areas, ecologically valuable areas, areas of benefit to flood mitigation.

Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners; NGOs; Counties; Local Governments; Special Districts; Agricultural Agencies	Ongoing-2035	Bacteria, Nutrients, Sediment, Flooding	Expansion of existing 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 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[137], 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.

[137] Projects of note in the watershed include local government projects identified as part of H-GAC Regional Conservation Initiative (https://www.h-gac.com/regional-conservation/priority-project-list); existing conservation efforts by prominent NGOs (e.g., Galveston Bay Foundation, Coastal Prairie Conservancy, etc.), and current partnership opportunities being sought with USDA NRCS and other federal funding sources.

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[138], 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 forestry programs to identify adjacent efforts and practices that would address fecal waste and other concerns. This solution will include Partnership support for existing forestry efforts by local governments in the area, NGOs, 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. Key focuses will be coordinating with new development to promote increased tree canopy where appropriate and identifying opportunities to increase tree equity by assessing needs of disadvantaged communities in the watershed.

Priority Area(s): Opportunistic placement with a focus on urbanized areas and disadvantaged communities.

Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners; NGOs; Counties; Local Governments; Special Districts; Agricultural Agencies; Developers	Ongoing, with focus on 2024-2028 to prevent degradation	Bacteria, Nutrients, Sediment, Flooding	Expansion of existing efforts

Continued on Next Page

[138] Based on preliminary iTree Hydro modeling by Texas A&M Forest Service in similar area watersheds (e.g., Cypress Creek, Spring Creek), 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 area.

<table>
<tr><th colspan="2">Conservation and Land Management 3 – Increase Tree Canopy, Continued</th></tr>
<tr><th>Technical and Financial Resources Needed</th><th>Estimated Costs and Funding</th></tr>
<tr><td>Technical resources needed for this solution include the existing programmatic resources and staff expertise of the partners identified above. Additional iTree 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 HCFCD and the Texas A&M Forest Service Green Futures program 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.</td><td>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.</td></tr>
<tr><th colspan="2">Bacteria Reduction Capability</th></tr>
<tr><td colspan="2">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.</td></tr>
</table>

The watershed has extensive existing conservation activity from local governments, NGOs, and other local partners. Additionally, many of the recreational planning efforts and flood mitigation efforts in the watershed include natural elements. Ongoing efforts by these 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 role in the future use of natural systems for water quality and flood mitigation. Specific focuses of these voluntary conservation measures include preserving coastal prairie areas, preserving or restoring forested riparian areas on public lands, establishing 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 and Green Infrastructure recommendation to the extent existing facilities in developed areas can add natural elements.

<table>
<tr><th colspan="4">Illegal Dumping 1 – Report Chronic Dump Sites and Consider Increased Enforcement</th></tr>
<tr><td colspan="4">Purpose: To reduce trash in waterways at chronic dump sites by encouraging reporting and increased enforcement.</td></tr>
<tr><td colspan="4">Description: This solution is intended to augment existing county and local efforts to reduce illegal dumping in the following ways:
• Encouraging reporting (see Section 6 for outreach elements)
• Coordinating between the Partnership and local enforcement to ensure reporting for sites
• Consider using cameras to identify dumpers[139]
The solution targets the downstream area, where problem areas were identified by the stakeholders. The primary focus of this solution is chronic dump sites, with emphasis on those adjacent to or near waterways.


Priority Area(s): Areas with reported dumping watershed-wide.</td></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant(s) Addressed</th><th>Status</th></tr>
<tr><td>Counties; Local Governments; H-GAC; Landowners</td><td>Ongoing-2035</td><td>Trash</td><td>New and expanded efforts</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 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.</td><td>Cost estimates include the incremental costs to local enforcement, which will be dependent on extent of use; Prior camera programs have spent approximately $500- $2,000 a unit for high end equipment and maintenance.

Funding sources include local government revenues and solid waste grant programs.</td></tr>
<tr><th colspan="4">Bacteria Reduction Capability</th></tr>
<tr><td colspan="4">This solution is not expected to directly address bacteria, although it may be an ancillary benefit.</td></tr>
</table>

[139] 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.

<table>
<tr><th colspan="4">Trash 1 – Trash Reduction Event</th></tr>
<tr><td colspan="4">Purpose: To reduce trash in waterways in conjunction with existing programs.</td></tr>
<tr><td colspan="4">Description: This solution is intended to engage the public in a visible trash reduction effort by implementing a Rivers, Lakes, Bays ‘N Bayous Trash Bash[140] (Trash Bash) event or similarl effort in the watershed.

Priority Area(s): Urban riparian area in a local park(s).
</td></tr>
<tr><th>Responsible Parties</th><th>Period</th><th>Contaminant(s) Addressed</th><th>Status</th></tr>
<tr><td>H-GAC; local site coordinator; or local government</td><td>Ongoing-2035</td><td>Trash</td><td>New effort and/or expansion of existing efforts</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 needed for this solution are limited to staff expertise in developing and implementing trash reduction events. The Trash Bash program is established in the region but lacks a site in this watershed. Resources needed for other reduction events (e.g., Keep Pearland Beautiful’s Don’t Mess With Texas Trash-Off event)

New Trash Bash sites require a startup cost and volunteers.</td><td>New Trash Bash sites estimate a $5,000 startup cost, in addition to the value of volunteer time for site coordination. Costs for other reduction events will vary by size and extent of the event.

Funding sources include local government revenues or other local partner funding, with support from existing organizations.</td></tr>
<tr><th colspan="4">Bacteria Reduction Capability</th></tr>
<tr><td colspan="4">This solution is not expected to directly address bacteria, although it may be an ancillary benefit.</td></tr>
</table>

140 https://www.trashbash.org/

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 common issue in the Clear Creek Watershed. In addition to area-wide studies by the United States Army Corps of Engineers (USACE) and consortiums of local partners (including the Lower Clear Creek and Dickinson Bayou Watershed Study[141]), there are several flood mitigation projects underway such as the HCFCD's 2018 Bond Program projects[142] and other local capital programs. This solution is recommended in conjunction with Urban Stormwater E3 in Section 6. 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 and priority land cover like wetlands or considerations in these projects. The Partnership will seek to coordinate with new development on water quality features for drainage and detention, as appropriate.

Priority Area(s): Areas where flood planning and projects are active

Responsible Parties	Period	Contaminant(s) Addressed	Status
HCFCD; Special Districts; Local Governments; Counties; NGOs	Ongoing-2035	Bacteria, Nutrients, Sediment, Flooding	Current and expanded efforts

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 HCFCD are already actively engaged in these projects. Other potential points of coordination include the Regional Flood Mitigation Committee[143] and the 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 existing H-GAC funding, 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[144] 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

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[141] https://www.leaguecity.com/LCCDB

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

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

[144] Including studies from Virginia (Clary, J., R. Pitt, and B. Steets, eds. 2014. *Pathogens in Urban Stormwater Systems*. Reston, VA: ASCE. 289 pp.), and national documentation from EPA https://www.epa.gov/system/files/documents/2021-11/bmp-wet-ponds.pdf.

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 and disaster recovery funding opportunities in the future;
- Texas Water Development Board Flood Infrastructure Fund; and
- Various Federal Emergency Management Agency (FEMA) disaster mitigation programs.

Solutions Summary

The recommended solutions presented in this section are intended to meet the *E. coli* reduction goals defined in Section 4 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, which 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.

Section 6: Education and Outreach

Section 6. Education and Outreach

Engaging 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 benefits from shared resources with adjacent efforts from practice areas like forestry, flood mitigation, recreation planning 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.

General Outreach

The Partnership is one of many organizations working toward similar goals in the watershed but focused primarily on 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 supplant existing efforts but will support them however possible while seeking opportunities to expand or enhance links to water quality and the goals of the WPP.

Maintaining the Partnership

The Partnership will maintain its varied composition and strong local commitments through continued facilitation of an active group by H-GAC[145] 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 once a year or as needed),
- Dissemination of information regarding WPP activities among stakeholders through e-mail, newsletters, and/or other appropriate channels (*e.g.*, website, social media), and
- Individual meetings with strategic partners to maintain commitments and coordinate efforts.

Building the Brand, Broadening the Audience

The Partnership must maintain visible representation of its specific goals in the eyes of the public and increase the audience it reaches. To accomplish these goals, the Partnership will:

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

[145] Throughout this and following sections, references to H-GAC involvement after the successful development of the WPP should be assumed to refer to H-GAC and/or a successive facilitating organization.

- Expand the intended audiences to include key groups like HOAs, apartment complexes, potential corporate partners, recreation enthusiasts, *etc*.

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 which the Partnership will carry out by:

- Participating in and collaborating with groups like the Texas Watershed Coordinator's Roundtable, Galveston Bay Estuary Program, Clean Rivers Program, and others,
- Supporting other area watershed efforts and TMDL efforts in the H-GAC region,
- Identifying and/or pursuing funding opportunities that would assist local partners in opportunities of shared interest,
- Coordinating directly with forestry, conservation, and flood mitigation programs in the area, and
- Seeking additional data necessary to inform stakeholder decisions or evaluate progress[146].

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 the entities listed in Table 35[147].

Table 34 - Outreach partners

Outreach Partner	Focus Areas
Academic institutions (*e.g.*, University of Houston – Clear Lake)	Environmental topics
Bayou Preservation Association	Conservation, water quality, outreach, citizen science, recreation, invasive species management, flood mitigation, trash reduction
Brazoria County	Household Hazardous Waste collection, general environmental education

[146] The item of greatest interest to the stakeholders was expanded use of microbial/fecal source tracking.

[147] 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
City of Houston	Source water protection, urban forestry, utility education, general environmental education
City of Pearland	General environmental education, Stormwater outreach, FOG outreach
City of Friendswood	General environmental education, Stormwater outreach, SSO outreach
City of League City	Stormwater, general environmental education, outdoor environmental education
City of Nassau Bay	Stormwater, trash reduction/recycling, flood preparedness
Clear Creek Environmental Foundation	Trash cleanup events
Coastal Prairie Conservancy	Conservation, general environmental education
Fort Bend County	Illegal dumping, recycling/HHW
Galveston Bay Estuary Program	Galveston Bay, source water protection
Galveston Bay Foundation	Habitat, conservation, general environmental education, etc.
Galveston County	OSSFs, general environmental education
Galveston County Health District	Illegal dumping, general environmental education, stormwater
Gulf Coast Authority	Trash reduction, recycling/HHW, general environmental education
Harris County, HCFCD, and Harris County Precincts	Riparian corridors, stormwater, outreach, recreation, OSSFs, illegal dumping, animal control, environmental enforcement, flood mitigation
Houston Area Urban Forestry Council	Urban forestry, industry best practices
Houston Audubon	Conservation, wildlife, recreation
Houston Canoe Club	Recreation, conservation, outreach
Houston Wilderness	Gulf-Houston Regional Conservation Plan, outreach
Houston-Galveston Area Council	Watershed management, water quality, forestry, public outreach, OSSFs, trash reduction, flood mitigation, resilience, coastal communities, etc.
Local HOAs (multiple)	Resident outreach, pet waste, inlet marking
Local MUDs/Special Districts (multiple)	Utilities, stormwater, outreach
Local Soil and Water Conservation Districts (Harris, Coastal Plains, Waters Davis)	Agriculture, land management programs
AgriLife Extension/AgriLife Research/Texas Water Resources Institute	Agriculture, OSSFs, water quality, land management, feral hogs, riparian buffers
Texas A&M Forest Service	Forestry
Texas Commission on Environmental Quality	Water quality, wastewater, nonpoint source pollution
Texas Master Naturalists	Environmental education and outreach, habitat
Texas Parks and Wildlife Department	Wildlife, habitat, water quality
Texas State Soil and Water Conservation Board	Agriculture/silviculture, nonpoint source pollution, water quality, conservation
Texas Stream Team	Water quality, volunteering
The Nature Conservancy	Urban forestry, conservation, habitat, water resources
State and Federal Elected Officials	Constituent outreach, environmental events
United States Army Corps of Engineers, Galveston	Flood mitigation, water quality modeling

Outreach Partner	Focus Areas
United States Department of Agriculture, Natural Resources Conservation Service	Agriculture, land management, habitat, conservation
United States Department of Agriculture, United States Forest Service	Forestry

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.

Wastewater and Sanitary Sewer Overflows

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 regional Galveston Bay Cease the Grease[148] campaign already exist. The Partnership seeks to promote these programs and maintain model materials[149] 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[150]. The promotion will take place throughout the implementation period, and model materials will be added in the first two years 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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[148] For more information, see: http://ceasethegrease.net/

[149] 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.*

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

On-site Sewage Facilities

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 three years throughout the project period. Costs for these efforts range from $1000+ per workshop (inclusive of staff time) 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 and Brazoria County hold annual OSSF workshops for local OSSF practitioners. The Partnership will support the county with publicity and participation as appropriate and seek to support other local workshop efforts as well. This activity will happen throughout the implementation period.

OSSF E3 – Provide Model Educational Materials 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 – Signage at Remediation Sites

H-GAC works with the Harris County District Attorney's Office, private contributors, and TCEQ to provide funding to remediate failing OSSFs as part of a Supplemental Environmental Project and related effort 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.

Urban Stormwater

Education and outreach elements[151] 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[152]. 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[153] 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 efforts by 5 volunteers by 2035.

Urban Stormwater E2 – Promote Urban Forestry as a Solution[154]

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[155] they produce. 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 iTree modeling completed by Texas A&M Forest Service to quantify tree benefits and inform stakeholder choices in other regional watershed projects. The Partnership will seek to coordinate with ongoing urban forestry projects and programs, including those of the City of Houston and other local cities, the HCFCD, 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

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[151] 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.

[152] Except for promoting LID, urban forestry, coordination with flood mitigation, or other efforts as indicated in Section 5.

[153] For more information, see: https://h-gac.com/texas-stream-team/

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

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

[156] For more information, see: https://www.haufc.org/

link[157]. Model materials will be hosted 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], H-GAC's Regional Conservation Initiative, 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.

Urban Stormwater E3 – Engage with Urban Flood Mitigation Efforts[159]

Flood mitigation was a primary concern for many of the stakeholders, and a number of efforts of varying scale and scope are underway or planned. In addition to potentially impacting flow and transmission of pollutants in the watershed, these efforts may offer the opportunity to influence the inclusion of water quality-oriented practices in the design of mitigation activities. Additionally, coordinating with these efforts allows the Partnership to reach a broader range of potential partners. Current projects include The Lower Clear Creek and Dickinson Bayou Watershed Study[160], several projects being developed by the HCFCD[161], and many programs and projects of local municipal partners.

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 Bag Dispensers at Local Events

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.

[157] Specific urban forestry practices and technical resources are available from the Texas Forest Service at: http://texasforestservice.tamu.edu/abouturbanandcommunityforestry/
[158] For more information, see: https://www.gulfhoustonrcp.org/
[159] This effort is recommended in conjunction with Flooding 1 in Section 5. This recommendation reflects the outreach aspects of the coordination.
[160] More information can be found online at https://www.leaguecity.com/LCCDB.
[161] More information can be found online at https://www.hcfcd.org/Activity/Active-Projects/Clear-Creek.

For an 11-year implementation period, assuming 4 outreach events per year, this would equate to a cost of $3,300.

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 or a linked website[162]. Materials will be developed in the first two years of implementation and maintained/updated indefinitely.

Agriculture

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 – Promote the Lone Star Healthy Streams Program and Similar Education Efforts

Texas A&M AgriLife Extension and the Texas State Soil and Water Conservation Board host a variety of agricultural education programs, but specific in area and topic through County Extension Agents, and statewide programs like the Lone Star Healthy Streams program[163]. 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.

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

[162] Including https://www.h-gac.com/pet-waste-pollutes.
[163] More information is available at https://lshs.tamu.edu/.

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, and future elements of regional conservation plans in agricultural areas, including the H-GAC Regional Conservation Initiative[164] program.

Feral Hogs

Feral Hog abatement is a strong concern for properties throughout the watershed, but especially along riparian corridors. Existing outreach programs through 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[165] 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 AgriLife Extension in the watershed counties 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.

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 USDA 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, recreation, 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.

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[164] For more information, see: https://www.h-gac.com/regional-conservation

[165] For more information, see: http://lshs.tamu.edu/workshops/

Land Management E1 – Promote Riparian Buffers and Voluntary Conservation

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[166] for landowners. Resources will be developed/obtained and hosted during the first year of implementation. The Partnership will seek to promote the Texas Water Resources Institute (TWRI) Texas Riparian and Stream Ecosystem Education Program and Urban Riparian and Stream Restoration Program[167] and 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

AgriLife Extension's Texas Watershed Stewards[168] program is an effective way of developing knowledge among the local communities of watershed issues and actions they can take. The Partnership will work with AgriLife to bring the program to the watershed 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 the Regional Conservation Initiative, Gulf-Houston Regional Conservation Plan, the Clear Creek Master Plan, efforts of local NGOs like the Galveston Bay Foundation and the Coastal Prairie Conservancy, and other local efforts that may have implications or opportunities for riparian-oriented conservation in the watershed.

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. Counties and other local jurisdictions will continue to enforce dumping issues. In addition, the Partnership recommends the following actions.

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[166] For more information, see: https://www.h-gac.com/riparian-buffer-tool
[167] For more information, see: http://texasriparian.org/riparian-education-program/
[168] For more information, see: https://tws.tamu.edu/

Trash and Illegal Dumping E1 – Trash Bash Site

The Texas Rivers, Lakes, Bays N' Bayous Trash Bash[169] is an annual trash reduction and community outreach event that takes place throughout the region. Thousands of volunteers participate at a network of sites, where outreach materials and education about water quality accompany the trash reduction elements. The cleanups focus on areas adjacent to local waterways. 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.

[169] For more information, see: http://www.trashbash.org/

Section 7: Implementation

Section 7. Implementation

The manner of implementing the concerns, ideas, and commitment that went into developing this WPP into tangible action and results was of primary concern to the Partnership. 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.

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 infeasible 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 space actions and resource needs throughout 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, conservation, and forestry projects in the watershed and region.

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 Clear Creek watershed. The ongoing support of a 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 human health risk[170], pet wastes are a prominent source of fecal bacteria and nutrients. 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 is 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

[170] 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: https://www.mdpi.com/2073-4441/12/2/327.

area (in the form of partner messaging, relevant online venues, or other appropriate means). Additionally, the Partnership will work to expand the message to specific target audiences, including apartment complexes, HOA/POAs, *etc*.

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.

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.

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

While this effort is focused mainly on issues related to water quality, many of the primary grant funding sources (as referenced in Appendix E) currently available to local partners focus on resiliency and flood mitigation, a water quantity issue. 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 (HCFCD and others) and actively participating, as appropriate, in public processes linked to the flood mitigation efforts.

Conservation

The 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.

Forestry

Inclusion of urban forestry practices and an increase in urban forest canopy would have a dramatic impact on stormwater runoff in the watershed. Urban forestry is a growing focus in the region, as evidenced by its inclusion in large scale planning efforts like the City of Houston's 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 HCFCD, CenterPoint Energy, Texas Department of Transportation, corporate partners, 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[171].

Project staff have been engaged with local partners in all these pursuits, and the Partnership will continue to participate and actively promote water quality considerations and appropriate areas of the watershed within these efforts.

Figure 52 - Environmental education at the City of Pearland's Delores Fenwick Nature Center

[171] For more information, see: https://tfsweb.tamu.edu/partnership/#:~:text=The%20Texas%20Forests%20and%20Drinking,important%20and%20interdependent%20natural%20resource

Timelines for Implementation

Implementation of this WPP is intended to take place over a 12-year initial implementation timeframe (2023-2035). 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.

Interim Milestones for Measuring Progress

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. Additional information about each solution, its intended implementation, and estimated costs can be found in Sections 5 and 6[172]. 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 36). This table will be updated as part of future WPP updates, after each implementation phase, or as needs warrant.

Figure 53 - Wildlife Viewing at the Dr. Ned and Fay Dudney Nature Center

[172] 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 35 - Interim milestones for solutions and outreach activities

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
General (N/A)	General – Watershed Coordinator	Retain a Watershed Coordinator to manage day-to-day coordination, pursue resources, and guide implementation	Partnership[176]	2024 – The Partnership assesses facilitation during early implementation	2024 – Funding application is made for a 2025 start date	2025 – Watershed Coordinator position retained	2028 – Partnership reassess facilitation need after early implementation
Wastewater Treatment Facilities (N/A)	WWTF 1 – Support Local Utility Improvement Efforts	Improve treatment of sewage and infrastructure	Utilities; Cities; Counties	2026 – 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	
Wastewater Treatment Facilities (N/A)	*WWTF E1 – Promote FOG Awareness*	*Reduce SSOs by affecting utility customer behavior regarding FOG*	*Partnership; Utilities*	*2024– Model materials identified and added to website; distribute printed*	*2035 – Consistent promotion with partners throughout*		

[173] Numbers in parentheses indicate the estimated relative units that will be addressed by the solutions for each target as calculated in Tables 31 and 32. All numeric targets (*i.e.*, number of dogs) refer to representative units. Actual units addressed may change based on pollutant removal efficiency, location, *etc.*

[174] 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.

[175] Outreach and education elements are designated with italics throughout this table.

[176] 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."

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
				materials at local events	*implementation period*		
	WWTF E2 – Promote Floodwater Contact Awareness	*Reduce exposure to bacteria by educating residents about floodwater contact*	*Partnership; Counties; Special districts*	*2024 – Model materials identified and added to website; distribute printed materials at local events*	*2035 – Consistent promotion with partners throughout implementation period*		
Sanitary Sewer Overflows (N/A)	SSO 1 – Remediate Infrastructure	Reduce contamination from human fecal waste by reducing overflows from WWTF collection systems	Utilities	2028 – 5 fewer SSOs occurred than average since 2023	2035 – 10 fewer SSOs occurred than average since 2020 over implementation period		
	SSO 2 – Consider Additional Preventative Measures	Improve infrastructure capacity, operations, and preventive measures to reduce SSOs	Utilities	2030 – At least 3 utilities have reviewed and/or upgraded backup capacity or other measures	2035 – At least 3 additional utilities have reviewed and upgraded backup capacity or other measures		
On-site Sewage Facilities (3,006)	OSSF 1 – Remediate Failing OSSFs	In conjunction with OSSF 3, address failing OSSFs	H-GAC; Homeowners; Counties (enforcement); Utilities (for conversion projects)	2030 – First half of OSSFs addressed, or failures prevented	2035 – Second half of OSSFs addressed, or failures prevented		

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	OSSF 2 – Improve and Update Spatial Data	Improve OSSF location spatial data to guide remediation efforts	H-GAC; Counties; Special Districts; Utilities	2024 – Partners have reviewed and commented on existing spatial data, which is revised accordingly	2030 – Authorized Agents have continued to provide new data regularly	2035 – Authorized Agents have continued to provide new data regularly	
	OSSF 3 – Convert to Sanitary Sewer	In conjunction with OSSF 1, address failing OSSFs	H-GAC; Counties; Special Districts; Utilities; Homeowners	2030 – First half of OSSFs addressed, or failures prevented	2035 – Second half of OSSFs addressed, or failures prevented		
	OSSF E1 – Hold Residential OSSF Workshops	*Empower homeowners and real estate inspectors to identify the signs of failing/failed OSSFs and promote proper OSSF management to avoid failures*	*H-GAC; Partnership; AgriLife Extension*	*2030 – 2 workshops held*	*2035 – 2 additional workshops held*		
	OSSF E2 – Participate in County-wide OSSF Workshop for Practitioners	*Harris and Brazoria County's OSSF workshops provides a point of coordination with practitioners*	*Partnership; Harris County, Brazoria County*	*2035 – Annual meetings[177] have been held; Partnership participated*			
	OSSF E3 – Promote Model Educational Materials	*Provide model educational materials online to facilitate education by other organizations*	*Partnership*	*2024 – Model materials identified and added to website; distribute printed*	*2035 – Consistent promotion with partners throughout*		

[177] This education and outreach measure is an activity of Brazoria and Harris counties. The counties may change the nature or frequency of these meetings in the future.

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
				materials at local events	*implementation period*		
	OSSF E4 – Texas Well Owner Network Events	*Educate well owners about potential risks from OSSFs and potential contamination of drinking water wells*	*Partnership; TWRI; AgriLife Extension; TSSWCB*	*2025 – First TWON event held*	*2032[178] – Second TWON event held*		
	OSSF E5 – Signage at Remediation Sites	*Use OSSF remediation sites as outreach to neighbors via signage*	*H-GAC; Harris County; TCEQ*	*2035 – Signage placed at OSSF remediation locations*			
Urban Stormwater (N/A)	Urban Stormwater 1 – Install Stormwater Inlet Markers	Raise awareness and shift behavior of residents served by stormwater systems to reduce pollutants entering drains/waterways	Harris County; Local Governments ; Special Districts; HOAs; Local Volunteers	2028 – At least 2 neighborhoods have markers added	2035 – At least 2 additional neighborhoods have markers added		
	Urban Stormwater 2 – Investigate Drainage Channels	Locate potential sources of pollutants in urban channels[179]	H-GAC; Partnership; MS4s; Counties; TCEQ	2024 – Potential priority areas and grant resources identified	2028 – Pilot project completed; at least 1 round completed, field reconnaissance project	2035 – At least 1 additional round completed, field reconnaissan ce project	

[178] These workshops are expected to occur in 7-year intervals which do not align with usual milestone intervals.
[179] 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.

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	Urban Stormwater 3 – Promote and Implement Urban Riparian Buffers	Reduce pollutants in urban sheet flow and erosion through vegetative barriers; this strategy coincides with Agricultural Operations 2, Conservation and Land Management 1	MS4s; Local Governments ; Special Districts; Texas A&M Forest Service (forestry technical support); NGOs; Landowners	2028 – At least 1 urban riparian project completed	2035 – At least 1 additional urban riparian project completed; Partnership consistently promotes riparian buffers		
	Urban Stormwater 4 – Promote Low Impact Development and Green Infrastructure	To reduce pollutants in stormwater flows through promoting and implementing infrastructure that mimics or improves on natural hydrology	H-GAC; MS4s; Counties; Local Governments ; Special Districts	2024 – LID/green infrastructure materials developed and hosted on website	2035 – At least 1 demonstration project installed		
	Urban Stormwater E1 – Expand Texas Stream Team Participation	*Supplement existing monitoring data with volunteer sites and empower volunteers to acts as water quality ambassadors*	*H-GAC; Partnership; TST Partners*	*2028 – 5 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; this strategy coincides with Conservation and Land Management 3*	*Partnership; Texas A&M Forest Service; H-GAC*	*2022 – Model materials identified and hosted online; distribute printed materials at local events*	*2026 – Revised modeling completed to support forestry measures' effectiveness*	*2030 – Coordination and promotion consistent message*	

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	Urban Stormwater E3 – Engage with Urban Flood Mitigation Efforts	*Coordinate with flood mitigation efforts to accent water quality features.*	*Partnership; H-GAC; Counties; Local Governments*				
Pet Waste (15,440)	Pet Waste 1 – Install Pet Waste Stations	Reduce wastes by facilitating use of bags in public areas	Counties; Local Governments ; HOAs; Apartment Complexes	2028 – At least 20 pet waste stations installed	2035 – At least 20 additional stations installed; all stations maintained throughout the implementation period		
	Pet Waste 2 – Expand Dog Parks	Increase availability of controlled dog recreation areas to sequester wastes in public areas	Counties; Local Governments ; HOAs; Developers; Special Districts	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 of pets	Service provider (such as SPCA or similar); Local Partners	2028 – 1 spay/neuter event held	2035 – Second spay /neuter event held		
	Pet Waste 4 – Consider Additional Enforcement	Reduce dog waste by promoting voluntary consideration of enforcement mechanisms	Local Governments ; Special Districts; HOAs; Apartment Complexes	2028 – The Partnership will have worked with at least 5 local partners to promote enforcement	2035 – The Partnership will have worked with at least 5 more local partners to		

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
					promote enforcement		
	Pet Waste E1 – Handheld Pet Waste Bag Dispensers at Local Events	*Educate residents about impacts of dog waste and reduce waste in stormwater*	*Partnership; H-GAC*	*2028 – Distribution of 1,200 dispensers at 24 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*	*Partnership*	*2028 – 4 visits held*	*2035 – 5 additional visits held*		
	Pet Waste E3 – Promote Model Educational Materials	*Provide model materials to facilitate other organizations' education efforts*	*Partnership*	*2024 – Model materials identified and added to website; distribute printed materials at local events*	*2035 – Consistent promotion with partners throughout implementation period*		
Agricultural Operations (676)	Agricultural Operations 1 – Promote Voluntary Land Management Plans	Address waste from livestock units through WQMPs, Conservation Plans or other agricultural plans	TSSWCB; SWCDs; USDA NRCS; Agricultural Producers/Landowners	2030 – First half of plans (or plans representing half of the reduction load) addressed by the solution	2035 – Second half of plans (or plans representing half of the reduction load) addressed by the solution		

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	Agricultural Operations 2 – Maintain or Restore Riparian Buffers	In conjunction with, or in supplement to, Agricultural Operations 1, install or maintain riparian buffers in agricultural areas to reduce transmission of pollutants; this strategy coincides with Urban Stormwater 3, and Conservation and Land Management 1	Landowners/ producers (on a voluntary basis); NGOs; Agricultural Agencies	2030 – At least 2 rural properties have riparian projects, at least 1 is agricultural	2035 – At least 2 additional rural properties have riparian projects, at least 1 is agricultural		
	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*	*Partnership; TSSWCB; AgriLife Extension*	*2024 – Needs, potential local partners identified; Materials developed and reviewed locally; hosted online; distribute printed materials at local events*	*2035 – Consistent promotion with partners throughout implementation period*		

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	Agricultural Operations E2 – Hold Agricultural Resources Workshops	*Promote agricultural programs by facilitating one on one meetings with landowners*	*Partnership; TSSWCB; AgriLife Extension; USDA NRCS*	*2025 – First workshop held*	*2030[180] – Second workshop held*	*2035[181] – Third workshop held*	
	Agricultural Operations E3 – Support Local Agricultural Conservation	*Increase conservation efforts by lending support and coordination to local partners pursuing opportunities*	*Partnership; USDA NRCS; Other local conservation partners*	*2025 – Collaborate with at least 1 local 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*	
Feral Hogs (21)	Feral Hogs 1 – Remove Feral Hogs	Implement trapping/other removal programs to remove feral hogs from the watershed, reduce pollutants/ancillary damages	Landowners; Local Governments ; Special Districts; Agricultural Agencies (technical support)	2028 – Develop or augment trapping program with local partners	2035 – Expand program to additional properties		

[180] These workshops are expected to occur in 3-year intervals which do not align with usual milestone intervals.
[181] See Footnote **Error! Bookmark not defined.**.

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	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*	*AgriLife Extension; TSSWCB; Partnership*	*2028 – First workshop has been held*	*2035 – Second workshop has been held*		
	Feral Hogs E2 – Feral Hog Management Workshop	*Educate local stakeholders to promote feral hog reduction*	*AgriLife Extension; TSSWCB; Partnership*	*2025 – First workshop has been held*	*2030 – Second workshop has been held*	*2035 – Third workshop has been held*	
Wildlife (N/A)	Wildlife 1 – Restore Upland Habitat	Restore upland habitat to provide wildlife alternative areas and reduce concentration in riparian zones	Landowners; NGOs; Local Governments; Agricultural Agencies (technical support); Developers	2030 – Develop at least 1 acre or greater restoration project	2035 – Develop at least 1 acre or greater restoration project		
Conservation and Land Management (N/A)	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	Landowners; NGOs; Counties; Local Governments; Special Districts;	2028 – At least 1 property has a riparian project	2035 – At least 1 additional property has a riparian project		

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
		Conservation); this strategy coincides with Urban Stormwater 3, and Agricultural Operations 2	Agricultural Agencies				
	Conservation and Land Management 2 — Voluntary Conservation	Promote voluntary conservation to reduce pollutants from developed areas	Landowners; NGOs; Counties; Local Governments; Special Districts; Agricultural Agencies	2028 – At least one 1+ acre property has a conservation project	2035 – At least 2 additional properties have conservation projects		
	Conservation and Land Management 3 – Increase Tree Canopy	Reduce storm flow runoff and generate additional ecosystem services by expanding tree canopy in appropriate areas; this strategy coincides with Urban Stormwater E2	Landowners; NGOs; Counties; Local Governments; Special Districts; Agricultural Agencies; Developers	2025 – Develop additional iTree modeling and 5-year planting priorities	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*	*Partnership; TWRI; TSSWCB/TCEQ (granting)*	*2027 – Workshop held*	*2030 – Another workshop held*		

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
	Conservation and Land Management E2 – Texas Watershed Stewards	*Educate stakeholders on water quality/watershed issues*	*TWRI; Partnership*	*2027 – Workshop held*	*2030 – Additional workshop held*		
Conservation and Land Management (N/A)	*Conservation and Land Management E3 – Conservation Coordination*	*Promote and help coordinate conservation efforts in the watershed*	*Partnership; NGOs; USDA NRCS; Other local conservation partners*	*Ongoing; Partnership has been active in all appropriate conservation initiatives in the watershed*			
Trash and Illegal Dumping (N/A)	Illegal Dumping 1 – Report Chronic Dump Sites and Consider Increased Efficiency	Promote enforcement efforts to reduce chronic dumping sites	Counties; Local Governments; H-GAC; Landowners	2025 – Identify dumping sites and enforcement priorities with local partners	2028 – Address at least 1 chronic site	2035 – Address at least 1 additional chronic site	
	Trash 1 – Implement a Trash Bash Site	Reduce trash through reduction events	H-GAC; Local site sponsor	2026 – Establish a site within the watershed	2035 – Maintain the site throughout the period		
	Trash and Illegal Dumping E1 – Trash Bash Site	*Educate participants on water quality issues at trash reduction events*	*H-GAC; Partnership; Local Site Sponsor*	*Ongoing (annual event)*			
Flooding (N/A)	Flooding 1 – Coordinate with Ongoing Flood Mitigation Efforts	Promote water quality features as supplementary elements in flood mitigation studies and projects	HCFCD; Texas General Land Office (GLO); USACE; Special	2025 – Identify flood mitigation priority projects for water quality enhancements	2035 – Partnership or successor maintains presence in flood mitigation		

Target[173]	Solutions[174]	Overall Implementation Goal[175]	Responsible Parties	Milestone 1	Milestone 2	Milestone 3	Milestone 4
			Districts; Local Governments ; Counties; NGOs		projects through public processes, comments, *etc.*		

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

Section 8. 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, by achieving programmatic milestones (Section 7), and by generally maintaining active engagement and effort by local stakeholders. Water quality monitoring data and other monitoring or reported data related to TPDES 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 and others will conduct long-term ambient surface water quality monitoring in Clear Creek. TST volunteers are an additional source of supplemental data[182]. The Partnership will also evaluate compliance by permitted wastewater dischargers using DMR and SSO data reported to TCEQ. Special studies, including microbial/fecal source tracking or other DNA-based categorization of *E. coli* or host species, are recommended to be used to supplement these ongoing data collection efforts. The combination of ambient surface water quality data, permitted discharge data, and other sources will be used by the Partnership to understand the end result of WPP actions or developmental change 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 including ambient, DMR and SSO data analyses as shown in the *Water Quality Data Collection and Trends Analysis Report*[183] will be conducted by the Partnership at the end of every phase of implementation through 2035, or as necessary in interim periods.

Clean Rivers Program Data

Ongoing CRP monitoring in Clear Creek and its tributaries includes twenty long-term sites (six on Clear Creek, and 14 on tributaries). All sites are monitored at least quarterly. The current sites are listed in Table 19 and shown in Figure 6, both in Section 3 of this document.

[182] Stream team data will be used for qualitative assessment, and not as part of formal quantitative assessments of water quality.

[183] Available on the project website at: https://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/clear_creek_water_quality_trends_report_phase_1_final.pdf.

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 stations of each of the subwatershed areas for this WPP are the ultimate focus of evaluation. However, attention will also be given to other tributary stations to evaluate whether additional attention or modeling is needed to isolate other areas of the watershed. Monitoring will be conducted under an approved quality assurance project plan (QAPP).

Additional Data

In addition to 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.

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 subwatershed area and the WWTF/SSO 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 warm-blooded animals (not including deer) for which there was insufficient data as part of the safety margin category. 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[184]. Absent any microbial source tracking data for the Clear Creek watershed, and in consideration of its more developed character, a conservative estimate of 20% of total source load in current conditions was assigned to the Other Animals category which includes undocumented 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 developed areas like this watershed. The Partnership will work with Texas A&M University, 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.

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[185] that use genetic information to identify the origins of biological pollutants present in a water body. Identification of *E. coli* is based on the genetic detection of bacteria strains specific to different animal types in surface water samples. MST can help characterize uncertainties in modeling efforts (*e.g.*, undocumented wildlife) and provide 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 as needed in the Clear Creek Watershed, with an intended focus on specified areas during narrow time frames for purposes such as illicit discharge detection, understanding localized spikes, *etc.* The Partnership recognizes the potential value of these tools for guiding decisions when opportunity and resources allow.

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[184] 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) …". Accessed 5/21/2021 at: http://leonriver.tamu.edu/media/1110/final-leon-wpp.pdf

[185] 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.

Hydrologic Impacts on Water Quality

Several large studies and efforts are currently evaluating various aspects of the hydrology/hydraulics within the Clear Creek system and in adjacent watersheds. Additionally, there is significant investment 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.

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 37). Ultimate success in the waterways of the Clear 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 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, quantitative goal of the WPP is to achieve and maintain compliance with SWQSs at the representative stations for each of the attainment areas. A secondary goal is to ensure source reduction by meeting TPDES permit limits. Therefore, the primary indicators of success are listed below.

- The status of the waterways on the most current Texas 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.*), are the main benchmarks of success. 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 will also indicate successful implementation.

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 rather than a broad survey of instream quality.

Programmatic Achievement

The ability to maintain the Partnership, fund implementation, and put solutions in place are qualitative 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 36 - Indicators of success

Goal	Indicator of Success	Source of Identification
Quantitative, Compliance with SWQSs	Fully support all designated uses	CRP data; Texas Integrated Report status
	Comply with TPDES permit limits	WWTF DMR/SSO
Qualitative, Implementation of 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 38).

Table 37 - 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.
Periodic Review	Every other year, or at another other frequency agreeable to the participants, the Partnership will review progress made during that period 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 five years, 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, forestry, flood mitigation, *etc.*)
Continuity Review	Two years prior to 2035, the Partnership will discuss during its Periodic 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.

Figure 54 - WPP forms a pathway to a cleaner Clear Creek

Appendices

Appendix A. WPP Information Checklist

Elements in the table below correspond to the nine 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[186].

Table 38 - Guide to watershed protection plan information

Segment Information	
Name of Water Body	Clear Creek Tidal (Segment 1101); Clear Creek Above Tidal (Segment 1102)
Assessment Units	1101_01-04; 1101A_01; 1101B_01,02; 1101C_01; 1101D_01,02; 1101E_01; 1101F_01; 1102_01-05; 1102A_01,02; 1102B_01; 1102C_01; 1102D_01; 1102E_01; 1102F_01; 1102G_01
Impairments Addressed	Contact recreation/*E. coli;* 24hr. Dissolved Oxygen/Aquatic Life
Concerns Addressed	Nitrate, Total Phosphorus, Dissolved Oxygen (grab), Chlorophyll-*a*, Ammonia, Impaired Habitat
Element	**Report Section(s) and Page Number(s)**
Element A: Identification of Causes and Sources	
1. Sources identified, described, and mapped	Section 3 • Water quality analysis and point source contribution descriptions; Appendix B and C; more information on water quality and wastewater sources, respectively. • Formal source descriptions, modeled loadings, and maps of spatial distribution
2. Subwatershed sources	Section 3 • Sources are described in terms of their general spatial distribution and loads by subwatersheds
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 • Description of water quality data and links to the project water quality report Section 3 • Discussion of water quality monitoring analyses, point source data analyses, and data sources • Description of sources and loadings with references to data used Section 4 • Description of LDCs and data sources. • Application of data sources to load reduction goals discussed Section 8 • Discussion of data sources to be used for evaluating success

[186] For more information, see: https://www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters

Element	Report Section(s) and Page Number(s)
4. Data gaps identified	Section 3 • In general, discussion of uncertainty in various modeling and data approaches Section 4 • Discussion of DO precursors Section 8 • 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 • Description of linkage of environmental goal (via LDC reductions) to source loads (via SELECT estimations) • Summarized specifically in **Tables 27-30.**
2. Load reductions linked to sources	Section 4 • Description of linkage of environmental goal (via LDC reductions) to source loads (via SELECT estimations) • Summarized specifically in **Tables 27-30.**
3. Model complexity is appropriate	Section 3 • Description of modeling approach (p. 61-63 specific to SELECT); link to project modeling report; pp. 62 contains specific description of rationale for modeling approach • Results of modeling indicated above in B1/B2 Section 4 • Description of LDC modeling approach • Description of LDC and LDC/SELECT linkage
4. Basis of effectiveness estimates explained	Section 4 • Description of use of representative units Section 5 • Solution effectiveness/reduction efficiency discussed in the bottom of each recommended solution page
5. Methods and data cited and verifiable	Section 3 • Throughout; 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; data for load reduction goals discussed, links to project modeling report included
Element C: Management Measures Identified	
1. Specific management measures are identified	Section 5 • Specific measures described, including technical and financial support needed, roles and responsibilities, *etc.* Section 6 • Specific educational measures described, including responsible parties
2. Priority areas	Section 5 • Discussion of priority areas for each category of specific focus Section 6 • General description of intended audiences/areas for educational activities
3. Measure selection rationale documented	Section 5 • Specific description of guiding principles for selection and selection process

Element	Report Section(s) and Page Number(s)
	• Summary of selection process and intention Section 6 • Description of Partnership's goals for selected educational measures
4. Technically sound	Section 5 • Specific measures described, including technical detail Section 6 • Specific educational measures described Section 7 • 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 • Technical assistance needs detailed for each measure in their one-page summaries
2. Estimate of financial assistance	Section 5 • Financial assistance needs detailed for each measure in their one-page summaries Appendix D • List of potential funding sources related to measures in this WPP
Element E: Education/Outreach	
1. Public education/information	Section 6 • Description of public outreach activities
2. All relevant stakeholders are identified in outreach process	Section 1 • Description of initial outreach, forming the Partnership, links to Public Participation Plan for the project Section 6 • Description of public outreach activities including existing partners/roles and focus areas
3. Stakeholder outreach	Section 1 • Description of initial outreach, forming the Partnership, links to Public Participation Plan and Stakeholder Outreach Report for the project
4. Public participation in plan development	Section 1 • Description of initial outreach, forming the Partnership, links to Public Participation Plan and Stakeholder Outreach Report for the project Section 3 • Description of Partnership process in identifying sources and assumptions Section 4 • Description of stakeholder choices in reduction linkage, load allocation, *etc.* Section 5 • Description of stakeholder participation in measures selection Section 6 • Description of stakeholder decisions on outreach strategies Section 7 • Description of stakeholder input on implementation strategies Section 8 • Description of the Partnership's role in determining how the project evaluates success
5. Emphasis on achieving water quality standards	Section 1 • Description of specific water quality goals for the project/Partnership

Element	Report Section(s) and Page Number(s)
	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).
6. Operation and maintenance of solutions	Section 5 • 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 • Implementation schedule
2. Schedule is appropriate	Section 7 • Implementation schedule
Element G: Milestones	
1. Milestones are measurable and attainable	Section 7 • Milestones described for all measures
2. Milestones include completion dates	Section 7 • Milestones described for all measures
3. Progress evaluation and course correction	Section 8 • Describes all methods used to evaluate success for the project; pp. 194-195 specifically describes adaptive management processes
4. Milestones linked to schedule	Section 7 • 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 • Describes evaluation criteria and data sources used to evaluate both water quality and programmatic milestones.
3. Data and models identified	Section 8 • 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. Section 8 evaluation criteria also assume this date.
5. Review of progress toward goals	Section 8 • Details the methods that will be used to evaluate progress regarding water quality • Details the methods that will be used to evaluate progress regarding programmatic means
6. Criteria for revision	Section 8 • Describes the indicators of success and adaptive management process
7. Adaptive management	Section 8 • Describes the adaptive management process
Element I: Monitoring	
1. Description of how monitoring used to	Section 8 • Describes the monitoring plan and other potential data sources

Element	Report Section(s) and Page Number(s)
evaluate implementation	
2. Monitoring measures evaluation criteria	Section 8 • Describes the indicators of success, including water quality/monitoring outcomes
3. Routine reporting of progress and methods	Section 8 • Describes both the monitoring process and its reporting/evaluation, as well as the project evaluation and formal reviews process with the Partnership
4. Parameters are appropriate	Section 8 • Describes the monitoring program
5. Number of sites is adequate	Section 8 • Describes the monitoring program
6. Frequency of sampling is adequate	Section 8 • Describes the monitoring program
7. Monitoring tied to QAPP	Section 8 • Describes the monitoring program • Describes the potential use of other data sources
8. Can link implementation to improved water quality	Section 8 • Discusses the monitoring program • Discussed water quality indicators of success

Appendix B. Ambient Water Quality Analysis Results

The tables presented in this Appendix are summaries for a greater amount of information available in the Water Quality Data Collection and Trends Analysis Report[187] developed for this WPP project. Shaded records represent a geomean in excess of the applicable standard or screening level.

E. coli

Table 39 - *E. coli* monitoring summary, 2014-2020

Station ID	Total records	Segment	Max.	Min.	Geomean	Seasonal Geomeans			
						Summer	Winter	Fall	Spring
11446	0	1101	NA	NA	NA	NA	NA	NA	NA
16573	0	1101	NA	NA	NA	NA	NA	NA	NA
16576	0	1101	NA	NA	NA	NA	NA	NA	NA
1101 combined	0	1101	NA	NA	NA	NA	NA	NA	NA
16611	26	1101A	24000	52	405.47	597.31	476.68	230.11	441.33
16493	27	1101B	24000	16	219.85	224.67	609.50	152.87	111.95
17928	0	1101C	NA	NA	NA	NA	NA	NA	NA
16475	0	1101D	NA	NA	NA	NA	NA	NA	NA
18591	27	1101F	6500	1	56.87	31.19	79.77	56.93	67.75
11450	22	1102	10000	10	267.31	124.04	259.23	433.24	429.97
11452	23	1102	1800	9	142.92	81.25	199.26	89.25	283.03
20010	27	1102	7300	10	170.36	155.57	579.44	73.76	125.05
1102 combined	72	1102	10000	9	184.84	116.18	313.30	131.31	228.65
16677	13	1102A	16000	20	400.42	235.85	1172.72	240.47	458.11
16473	27	1102B	20000	38	449.62	296.63	1110.04	159.31	734.10
17068	26	1102C	6500	2	88.83	118.68	249.27	24.63	92.85
21925	17	1102D	24000	52	229.87	138.19	864.33	116.36	238.17
18639	17	1102F	14000	10	280.92	355.60	626.44	151.37	215.58
18636	5	1102G	24000	46	384.08	46.00	24000.00	288.44	91.00

[187] Available online at https://clearcreekpartnership.weebly.com/uploads/9/6/6/3/9663419/clear_creek_water_quality_trends_report_phase_1_final.pdf.

Enterococcus

Table 40 - Enterococcus monitoring results, 2014-2020

Station ID	Total records	Segment	Max.	Min.	Geomean	Seasonal Geomeans			
						Summer	Winter	Fall	Spring
11446	22	1101	20000	10	95.27	43.32	66.58	359.94	91.58
16573	38	1101	2800	10	30.28	11.49	65.00	32.65	27.40
16576	27	1101	4100	10	39.93	39.04	67.21	30.42	30.63
1101 combined	87	1101	20000	10	44.09	28.09	66.26	54.01	35.61
16611	15	1101A	24000	110	491.44	1586.22	586.44	312.10	179.36
16493	15	1101B	24000	10	93.03	133.56	303.52	25.26	52.81
17928	26	1101C	24000	10	154.20	129.67	187.74	105.21	233.85
16475	28	1101D	24000	10	87.66	127.87	24.91	144.64	128.17
18591	15	1101F	24000	10	25.28	10.00	30.66	17.32	69.99
11450	1	1102	180	180	180.00	NA	180.00	NA	NA
11452	0	1102	0	0	NA	NA	NA	NA	NA
20010	15	1102	2300	20	157.61	149.64	358.73	74.49	127.97
1102 combined	16	1102	2300	20	158.93	149.64	312.51	74.49	127.97
16677	0	1102A	0	0	NA	NA	NA	NA	NA
16473	15	1102B	4000	41	221.77	233.72	586.79	85.79	162.14
17068	15	1102C	2900	10	117.05	77.36	144.42	80.56	189.95
21925	4	1102D	2300	39	158.34	73.00	2300.00	96.00	39.00
18639	4	1102F	1600	10	47.19	31.00	1600.00	10.00	10.00
18636	4	1102G	24000	41	268.63	84.00	24000.00	63.00	41.00

Dissolved Oxygen (Grab Samples)

Table 41 - Summary of dissolved oxygen (grab) monitoring, 2014-2020

Station ID	Total records	Segment	Geomean	Criteria, Minimum	Exceedances, Minimum	Percent Exceedance, Minimum	Criteria, Screening Level	Exceedances, Screening Level	Percent Exceedances, Screening Level
11446	118	1101	5.4547386	3	0	0.0%	4	21	17.8%
16573	99	1101	6.4150118	3	5	5.1%	4	10	10.1%
16576	147	1101	4.9363468	3	8	5.4%	4	29	19.7%
1101 combined	364	1101	5.4753701	3	13	3.6%	4	60	16.5%
16611	28	1101A	6.0973975	3	0	0.0%	4	0	0.0%
16493	28	1101B	7.9315831	2	0	0.0%	3	0	0.0%
17928	71	1101C	4.6164025	3	14	19.7%	4	26	36.6%
16475	48	1101D	4.8401001	3	9	18.8%	4	18	37.5%
18591	28	1101F	6.1400205	3	0	0.0%	5	2	7.1%
11450	27	1102	6.392768	3	0	0.0%	5	0	0.0%
11452	25	1102	6.3198417	3	1	4.0%	5	2	8.0%
20010	34	1102	6.3649017	3	1	2.9%	5	2	5.9%
1102 combined	86	1102	6.3604874	3	2	2.3%	5	4	4.7%
16677	15	1102A	7.8181367	2	0	0.0%	3	0	0.0%
16473	37	1102B	6.988524	3	0	0.0%	4	0	0.0%
17068	27	1102C	5.930844	3	1	3.7%	5	4	14.8%
21925	17	1102D	5.2137862	3	0	0.0%	5	4	23.5%
18639	17	1102F	7.24334	3	0	0.0%	5	1	5.9%
18636	5	1102G	2.8069624	3	3	60.0%	5	4	80.0%

DO Grab Minimum (Seasonal)

Table 42- Seasonal assessment of DO grab samples by minimum criteria, 2014-2020

Station ID	Total records	Segment	Criteria, Minimum	Minimum exceedances by Season			
				Summer	Winter	Fall	Spring
11446	118	1101	3	0	0	0	0
16573	99	1101	3	3	0	0	2
16576	147	1101	3	0	4	2	2
1101 combined	364	1101	3	3	4	2	4
16611	28	1101A	3	0	0	0	0
16493	28	1101B	2	0	0	0	0
17928	71	1101C	3	6	0	5	3
16475	48	1101D	3	5	0	3	1
18591	28	1101F	3	0	0	0	0
11450	27	1102	3	0	0	0	0
11452	25	1102	3	0	0	0	1
20010	34	1102	3	0	0	0	1
1102 combined	86	1102	3	0	0	0	2
16677	15	1102A	2	0	0	0	0
16473	37	1102B	3	0	0	0	0
17068	27	1102C	3	0	0	0	1
21925	17	1102D	3	0	0	0	0
18639	17	1102F	3	0	0	0	0
18636	5	1102G	3	1	0	2	0
Total, all	**771**			**15**	**4**	**12**	**11**
1101	**567**			**14**	**4**	**10**	**8**
1102	**204**			**1**	**0**	**2**	**3**

Other Parameters (Tidal 1101)

Table 43 - Summary of analysis of other parameters in Clear Creek Tidal (1101)

Parameter	Criteria	Units	Geomeans and Percent of Samples Exceeding Standards in the Tidal Segment (1101)					
			1101	1101A	1101B	1101C	1101D	1101F
			Geomean (% Exceed)	Geomean (% Exceed)	Geomean (% Exceed)	Geomean (% Exceed)	Geomean (% Exceed)	Geomean (% Exceed)
Temperature	35	Degrees Celsius	22.18 (0.0%)	20.62 (0%)	19.69 (0%)	21.74 (0%)	20.15 (0%)	19.81 (0%)
pH	9 (high)/ 6.5(low)	NA	7.77 (0.8%)	7.39 (0%)	7.84 (0%)	7.93 (0%)	7.84 (0%)	7.67 (0%)
Ammonia	0.33/0.46[188]	mg/L	0.16 (4.5%)	0.15 (3.6%)	0.13 (3.6%)	0.16 (7.7%)	0.15 (6.3%)	0.16 (3.6%)
Nitrate	1.95/1.10[189]	mg/L	1.64 (50.0%)	11.07 (100%)	0.08 (0%)	NA	0.24 (0%)	0.13 (0%)
Total Phosphorus	0.69/0.66[190]	mg/L	0.59 (41.4%)	1.44 (92.9%)	0.15 (10.7%)	0.35 (19.2%)	0.24 (15.6%)	0.22 (21.4%)
Chlorophyll-*a*	21	ug/L	8.52 (18.2%)	NA	NA	NA	NA	NA

[188] The 0.33 mg/L level applies to 1101A and 1101B. All other waterways use 0.46 mg/L.
[189] The 1.95 mg/L level applies to 1101A and 1101B. All other waterways use 1.10 mg/L.
[190] The 0.69 mg/L level applies to 1101A and 1101B. All other waterways use 0.66 mg/L.

Other Parameters (Above Tidal 1102)

Table 44 - Summary of analyses of other parameters in Clear Creek Above Tidal (1102)

Parameter	Criteria	Units	Geomeans and Percent of Samples Exceeding Standards in the Above Tidal Segment (1102)						
			1102	1102A	1102B	1102C	1102D	1102F	1102G
Temperature	35	Degrees Celsius	21.54 (0%)	20.19 (0%)	20.25 (0%)	18.50 (0%)	20.71 (0%)	21.16 (0%)	21.99 (0%)
pH	9 (high)/ 6.5(low)	NA	7.67 (0%)	7.67 (0%)	7.67 (0%)	7.67 (0%)	7.67 (0%)	7.67 (0%)	7.67 (0%)
Ammonia	0.33	mg/L	0.18 (22.9%)	0.27 (31.3%)	0.19 (25.0%)	0.12 (3.7%)	0.35 (47.1%)	0.19 (23.5%)	0.12 (0%)
Nitrate	1.95	mg/L	1.95 (55.6%)	0.17 (0%)	1.86 (42.9%)	0.13 (0%)	3.29 (71.4%)	2.18 (57.1%)	1.18 (0%)
Total Phosphorus	0.69	mg/L	0.78 (60.9%)	0.16 (3.1%)	0.87 (67.9%)	0.24 (14.8%)	0.83 (76.5%)	0.90 (58.8%)	0.30 (20.0%)
Chlorophyll-*a*	14.1	ug/L	3.35 (2.2%)	NA	NA	NA	NA	NA	NA

Appendix C. Wastewater Treatment Facilities

Table 45 - Permitted Wastewater Facilities in the Clear Creek Watershed

Permittee	Permit Number
H & R Realty Investments LLC	WQ0012680001
Aqua Utilities Inc	WQ0012822001
City Of Pearland	WQ0012295001
Brazoria County MUD No 3	WQ0012332001
City Of Pearland	WQ0010134002
City Of Pearland	WQ0010134007
City Of Pearland	WQ0010134008
City Of Pearland	WQ0010134010
City Of Houston	WQ0010495075
City Of Houston	WQ0010495079
Yes Companies LLC	WQ0012849001
Syntech Chemicals Inc	WQ0003593000 (outfalls 001 and 002)
Gulf Coast Authority	WQ0011571001
MHP Utility Systems Inc	WQ0015237001
Harris County WCID 89	WQ0012939001
City Of Webster	WQ0010520001
City Of Nassau Bay	WQ0010526001
City Of League City	WQ0010568008
City Of League City	WQ0010568005
Land Baron Holdings LLC	WQ0016030001
The Landing at Pearland Ltd	WQ0015972001
Cullen RV Resort LLC[191]	*WQ0016309001*
Preserve at Friendswood LLC[192]	*WQ0016284001*

[191] This permit application is still pending, and was added after the completion of data analyses for this project.
[192] This permit application was granted in late 2023, after data analysis for this project was complete. The current permitted flow (0.05MGD) is not anticipated to change any projections related to flow, loading, or BMP recommendations. This flow is accounted for as part of future projections in modeled years other than baseline.

Appendix D. Agricultural Best Management Practices

This appendix details the typical practices implemented in WQMPs and similar agricultural land management projects[193]. Emphasis for this WPP is put on practices that reduce animal wastes or impede transmission of wastes to water.

Table 46 - Agricultural best management practices

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.
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.

[193] 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 E. 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.

Table 47 - Potential funding sources

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 (Mitigation/Disaster Recovery)	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	FEMA/Texas Division of Emergency Management	Disaster resilience
WQMP	TSSWCB	Agricultural best practices
Regional Conservation Partnership Program	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

Grant Program	Grantor	Uses
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
Inflation Reduction Act/Bipartisan Infrastructure Law funded programs	Multiple	Multiple, including forestry, water quality, *etc.*