

A WATERSHED PROTECTION PLAN FOR THE

GREENS BAYOU WATERSHED

Photo Credit: Todd Running



Greens Bayou Watershed Protection Plan

Developed for Greens Bayou Watershed, Segments 1006 and 1016 of the San Jacinto River Basin, by the Houston-Galveston Area Council on behalf of the Greens Bayou Watershed Partnership.

May 2026

Water Body	Segment	Assessment Units
Houston Ship Channel Tidal	1006	03 and 05
Halls Bayou	1006D	01 and 02
Big Gulch	1006F	01
Spring Gully	1006H	01
Unnamed Tributary of Halls Bayou	1006I	01
Unnamed Tributary of Halls Bayou	1006J	01
Greens Bayou	1016	01, 02 and 03
Garners Bayou	1016A	01 and 02
Unnamed Tributary of Greens Bayou	1016B	01
Unnamed Tributary of Greens Bayou	1016C	01
Unnamed Tributary of Greens Bayou	1016D	01

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Steering Committee

The Greens Bayou 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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Texas Stream Team

Texas Water Resources Institute

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USDA Natural Resources Conservation Service

USDA U.S. Forest Service

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Abbreviations List

AgriLife Extension	Texas A&M University AgriLife Extension
AgriLife Research	Texas A&M University AgriLife Research
AU	Assessment Unit
BIG	Bacteria Implementation Group
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
CFU	Colony Forming Unit(s)
CRP	Clean Rivers Program
CWA	Clean Water Act
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
<i>E. coli</i>	<i>Escherichia coli</i>
EQIP	Environmental Quality Incentive Program
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FOG	Fats, Oils, and Grease
GBEP	Galveston Bay Estuary Program
GIS	Geographic Information System
HCFCDD	Harris County Flood Control District
H-GAC	Houston-Galveston Area Council
HOA	Homeowners Association
HSC	Houston Ship Channel
I-Plan	Implementation Plan
LDC	Load Duration Curve
LID	Low Impact Development
MGD	Million Gallons per Day
mL	Milliliters
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NGO	Non-governmental Organization
NHD+	National Hydrography Dataset Plus
NRCS	(USDA) Natural Resources Conservation Service
OSSF	On-Site Sewage Facility
Partnership	Greens Bayou Watershed Partnership
pH	Measure of acidity or alkalinity
QAPP	Quality Assurance Project Plan
SELECT	Spatially Explicit Load Enrichment Calculation Tool

SEP	Supplemental Environmental Project
SPCA	Society for the Prevention of Cruelty to Animals
SSO	Sanitary Sewer Overflow
SWCD	Soil and Water Conservation District
SWQMIS	Surface Water Quality Monitoring Information System
SWQS	Surface Water Quality Standards
TCEQ	Texas Commission on Environmental Quality
Texas Integrated Report	<i>Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)</i>
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
USDA	United States Department of Agriculture
USGS	United States Geological Survey
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 website¹. They include:

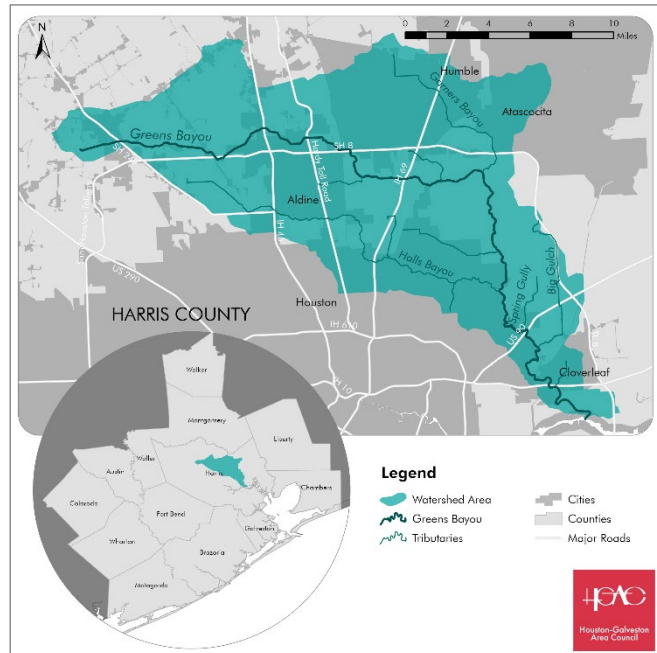
- **Quality Assurance Project Plan** – the quality assurance document detailing the manner and methods in which project modeling efforts were conducted to ensure results reflect project data quality objectives.
- **Acquired Data Analysis Summary Report** – a detailed report on analyses of various water quality data used to characterize the conditions in the project area waterways.
- **Bacteria Modeling Report** – a detailed summary of the development, implementation, and results of the bacteria modeling efforts.
- **Public Outreach Report** – a summary of the efforts and activities conducted by the Houston-Galveston Area Council to engage and inform project stakeholders, key partners, and general watershed audiences.

¹ Visit <http://www.eastforkpartnership.weebly.com/> to learn more.

Executive Summary

The Greens Bayou Watershed

Greens Bayou flows east and south from its headwaters near the crossing of State Highway 249 and the Sam Houston Tollway. The Greens Bayou watershed is composed of the drainage area of the classified segments Greens Bayou Above Tidal (1016) and Houston Ship Channel Tidal (1006), as well as smaller unclassified segment tributaries including Halls Bayou (1006D), and a network of natural and manmade drainage channels. This watershed area spans approximately 208 square miles within Harris County. Land cover in the watershed is mostly developed with the exception of some forested and woody wetland areas clustered around the waterways that run through the area. This area and its waterways represent an essential part of supporting local communities and economies, recreation, fisheries, and a diverse ecosystem.



Water Quality Challenges

High levels of fecal waste, indicated by the presence of Enterococci and *Escherichia coli* (*E. coli*) bacteria, are prevalent throughout the Greens Bayou watershed. Elevated levels of fecal waste in area waterways can be a result of both human activities, such as overflow from sanitary sewers and on-site sewage facilities, as well as natural influences like waste from native wildlife and invasive species. Harmful pathogens associated with fecal waste can impact public health.

Water quality is sampled in the Greens Bayou and its tributaries at least quarterly at 27 active monitoring stations, providing the basis for assessing the health of the system. As in past years, the 2024 *Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)* (a summary of water quality in Texas waterways) indicates that Greens Bayou Above Tidal (1016) has a contact recreation impairment due to levels of fecal indicator bacteria that exceed the state water quality standard. Tributaries to the Greens Bayou including Halls Bayou (1006D) and Garner's Bayou (1016A) also show high levels of bacteria.

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 entities and regulation. Primary sources of concern are mismanaged pet waste and pollution from failing on-site sewage facilities. Pollutant sources related to human activity will continue to increase as area growth drives future development in the watershed, exacerbating the existing situation. The watershed protection plan (WPP) project estimates indicate that necessary reductions of bacteria loads range from 53% to 89%.



Local concerns over the future of the Greens Bayou 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 and Texas Commission on Environmental Quality facilitated the formation and efforts of the Greens Bayou Watershed Partnership (Partnership), a group of local stakeholders representing residents, government, industry, agricultural land owners, 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. Stakeholders reviewed and revised results and used them to inform decisions about potential solutions. Specific focus was given to reducing fecal waste, which can directly impact human health. 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, outreach and advocacy 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 following table is a guide to the contents of the WPP. Additional information on specific items can be found in Appendix A.

Watershed Protection Plan Content Guide

WPP Section	Description	EPA Element	Location
Section 1 – Project Background	An introduction to the watershed planning process for the Greens Bayou	NA	pp. 1-8, Appendix A
Section 2 – Watershed Characterization	A summary of the physical (geography, climate, etc.), human (land use, political geography), and water quality characteristics of the watershed	NA	pp. 8-24, Appendix B
Section 3 – Identifying Pollutant Sources	An evaluation of water quality data, stakeholder knowledge, and modeling results to identify and characterize causes and sources of pollution	<ul style="list-style-type: none"> • Element A – Identify the causes and sources of pollution 	pp. 25-74, Appendix B
Section 4 – Improving Water Quality	Establishing the amount of reduction in pollutant source loads needed to achieve water quality goals	<ul style="list-style-type: none"> • Element B – Estimate of load reductions 	pp. 75-91
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	<ul style="list-style-type: none"> • Element C – Description of management measures • Element D - Estimate of technical and financial resources needed 	pp. 92-127, Appendices C and D
Section 6 – Education, Outreach and Advocacy	An outline of the education, outreach and advocacy efforts that will increase public awareness of the WPP and support its implementation	<ul style="list-style-type: none"> • Element E – Information and Public Education Component 	pp. 128-139
Section 7 – Implementation	The schedules for implementation, and measurable milestones for tracking progress	<ul style="list-style-type: none"> • Element F – Schedule for implementation • Element G – Interim measurable milestones 	pp. 140-151
Section 8 – Evaluating Success	An overview of the criteria and data that will be used to evaluate the success of implementation efforts	<ul style="list-style-type: none"> • Element H – Criteria for successful implementation • Element I – Monitoring component to evaluate effectiveness 	pp. 152-158

Section 1

Project Background



Photo Credit: Rachel Windham

Section 1. Project Background

Background

The Greens Bayou Watershed Partnership (Partnership) developed this watershed protection plan (WPP) to address water quality issues in Greens Bayou 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. Land use, natural processes, and the way these things change over time, influence the quality of the water that flows over the watershed and into its water bodies (Figure 1²).

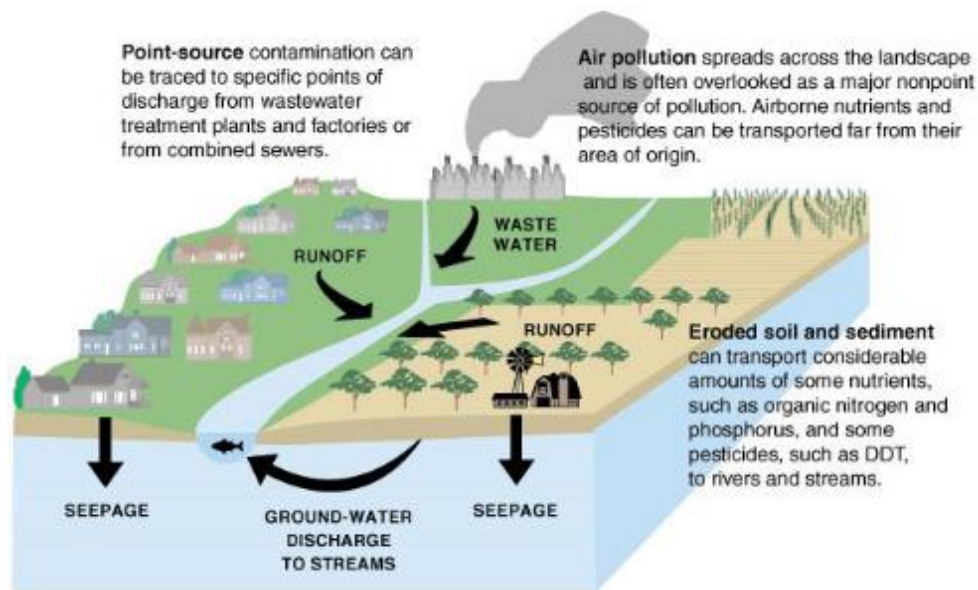


Figure 1. Pollution sources in a watershed

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

² Image courtesy of United States Geological Survey

fundamental aspect of watersheds limits the ability of individual political entities to wholly address sources of contamination in their waterways.

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

- Reflecting the connection between land and water.
- Coordinating multi-jurisdictional efforts to focus on shared priorities.
- 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, most WPPs follow the United States Environmental Protection Agency's (EPA) nine element model³, 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 waterways⁴. 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 recommendations. Stakeholders can include residents, elected officials, local governments, landowners, agricultural land owners, recreation enthusiasts, businesses,

³ 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>

⁴ 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).

and community groups. WPPs are best served by a diverse group of stakeholders who can represent the different interests in the watershed.

Funding for WPP development in Texas is often provided through federal Clean Water Act (CWA) grants that are administered by the Texas Commission on Environmental Quality (TCEQ) or Texas State Soil and Water Conservation Board (TSSWCB), and matching funds or in-kind time from local stakeholders.

A Watershed Protection Plan for Greens Bayou

Water quality issues in the Greens Bayou system (Segments 1006 and 1016) and local concern over the impact of future changes in the watershed were the impetus for undertaking a watershed-based plan. Previous projects in the greater Houston-Galveston area, including West Fork San Jacinto River and Lake Creek WPP, the Cypress Creek WPP, the Spring Creek WPP, Clear Creek WPP, East Fork San Jacinto River WPP and various other TMDLs in the area established widespread local interest and commitment to address water quality⁵. The desire to evaluate these areas on a local level for the Greens Bayou, and to consider other local concerns, led to the formation of the Partnership in 2024. 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 and sedimentation were at the forefront of local considerations.

The Greens Bayou 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) and was funded through EPA CWA §319(h) and CWA §320 grants administered locally by 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 the Partnership and serves as guidance for future implementation activities. Using the watershed planning model, this plan is based on local decision-making supported by local knowledge, robust public participation, and technical and scientific analysis. The Partnership held six full Partnership meetings between December 2024 and May 2026 to discuss and provide feedback on a variety of water quality issues⁶ (**Table 1**). Representation from a diverse range of local stakeholders

⁵ More information on these projects can be found at: <https://www.h-gac.com/watershed-based-plans/>

⁶ More information on the individual meetings and process can be found on the project website at: <http://www.greensbayoupartnership.weebly.com/>

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 plan⁷.

Table 1. Meetings of the Greens Bayou Watershed Partnership

Date	Meeting Type	Topics
Dec. 12, 2024	Partnership (hybrid; in-person option at North Houston District Office)	Project introduction, water quality data review, and invitation to nominate Steering Committee
Mar. 13, 2025	Partnership (hybrid; in-person option at North Houston District Office)	Steering Committee formation, water quality analysis, pollution source model review and discussion
Jul. 23, 2025	Partnership (hybrid; in-person option at North Houston District Office)	Discussion of suggested model revisions and brief introduction of water quality improvement strategies
Nov. 19, 2025	Partnership (hybrid; in-person option at North Houston District Office)	Further discussion of workgroup suggested model revisions and continued discussion of implementation strategy selection guided by source-specific bacteria reduction targets
Jan. 29, 2026	Partnership (hybrid; in-person option at North Houston District Office)	Selection of implementation strategies to include in the WPP and discussion of details related to each strategy such as responsible parties and milestones
May 14, 2026	Partnership (virtual)	Review of draft WPP and discussion of final edits before submission to TCEQ

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 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.

Water Quality Goals

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

- *Plan for 2035* — The stakeholders balanced the need to account for future growth in this developing watershed with the potential uncertainty of future projections

⁷ See: https://greensbayoupartnership.weebly.com/uploads/1/3/0/7/130710643/50226_greens_ppp_final.pdf

past a 10-year window. Based on the level of water quality issues, the likely continued pollution pressures 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 areas.

- *Reduce fecal waste* — Potential fecal pathogens, as measured by the bacteria Enterococci and *Escherichia coli* (*E. coli*)⁸ as indicators of fecal waste, are the primary focus of the Partnership due to their potential impact on human health, presence as an impairment for many of the segments of the watershed, and relationship to causes and sources within the scope of the voluntary WPP effort. The focus of this WPP is to reduce excess levels of human and animal waste in the water for the sake of public health, recreational economy, and regulatory compliance with SWQS criteria for primary contact recreation. This goal involves identifying and quantifying potential causes and sources of fecal waste and developing recommended best practices sufficient to meet modeled reduction goals. **The priority goal of the WPP is to improve and maintain fecal indicator bacteria levels at or below the contact recreation standard (primary contact recreation 1).**
- *Address other stakeholder concerns* — The WPP model allows for the consideration of other local water quality issues outside SWQS impairments and concerns. No modeling or specific quantification was conducted for stakeholder concerns, but the goal of the project remains to support or selectively implement related best practices to reduce issues as appropriate. Specific concerns include trash and illegal dumping and impacts from hydrologic issues in the watershed.

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 Greens Bayou 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.

⁸ Throughout this WPP, “bacteria” should be taken to mean Enterococci or *E. coli* in their roles as indicators of fecal waste and its associated pathogens in water rather than specifically attributing potential health impacts to individual bacteria species.

- *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 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 supports rather than supplant them.
- *Coordination is key* — This WPP will coordinate its aims and recommendations with hydrologic and environmental mitigation activity already occurring in the watershed.
- *Education, outreach and advocacy are vital* — Education, outreach and advocacy are important implementation elements of the WPP and are essential to future success. The Partnership will be transparent and build relationships with the community at every feasible opportunity.

Section 2

Watershed Characterization

Photo Credit: Rachel Windham

A photograph of a stream flowing through a lush, green landscape. The stream is surrounded by tall grasses and wildflowers, including purple and yellow blooms. In the background, there are trees and a clear blue sky. A small white pipe or structure is visible in the water near the right bank.

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

Regional Context

The watershed area of Greens Bayou spans approximately 208 square miles entirely contained within Harris County (**Figure 2**). Cities such as Houston, Cloverleaf, Aldine, Atascocita and Humble intersect or are completely contained within the watershed area. Greens Bayou and its network of tributaries drain into the Houston Ship Channel (HSC).

Watershed Delineation

The Greens Bayou watershed was delineated using a combination of existing data, map review, and field observations. The primary watershed and subwatershed delineations were developed from National Hydrography Dataset Plus (NHD+) watershed layers, with minor adjustments to reflect conditions on the ground, segregate tributaries, and normalize subwatershed size. NHD+ data were compared with United States Geological Survey (USGS) Hydrologic Unit Code 12 and 10 data, and other local sources. Compared to aeriels and known hydrologic boundaries, the NHD+ data were closest to expected actual drainage patterns in this system. Staff conducted map surveys using online mapping and limited field reconnaissance to confirm assumptions.

Subwatersheds were further delineated from a selection of existing and continuing water quality monitoring stations to ensure the ability to evaluate these areas during the implementation of the WPP. Considerations for the selection of the stations were their ability to represent different areas of the watershed, the natural hydrologic elements of the watershed (e.g., major tributaries), 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.

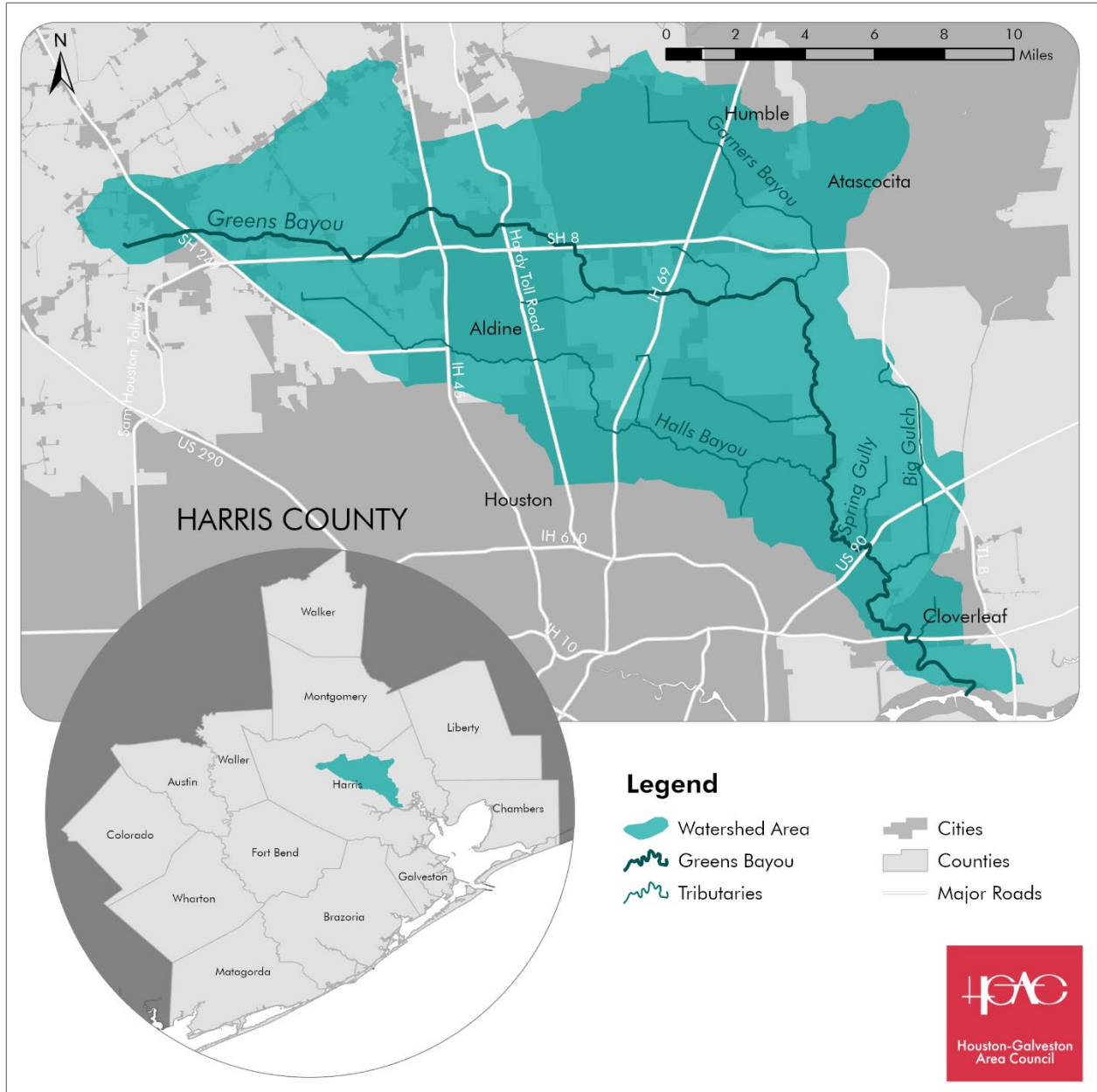


Figure 2. Regional context for the Greens Bayou watershed

Stream Network and Drainage Area

Greens Bayou flows east and south from its headwaters near the crossing of State Highway 249 and the Sam Houston Tollway (Figure 3). The Greens Bayou watershed is composed of the drainage area of the classified segments Greens Bayou Above Tidal (Segment 1016) and HSC Tidal (Segment 1006, units 03 and 05), as well as smaller unclassified segment tributaries including Halls Bayou (Segment 1006D), Garners Bayou (Segment 1016A), and a network of natural and manmade drainage channels. They include: Big Gulch (Segment 1006F), Spring Gully (Segment 1006H), Unnamed Tributary

of Halls Bayou (Segment 1006I), Unnamed Tributary of Halls Bayou (Segment 1006J), Unnamed Tributary of Greens Bayou (Segment 1016B), Unnamed Tributary of Greens Bayou (Segment 1016C), and Unnamed Tributary of Greens Bayou (Segment 1016D).

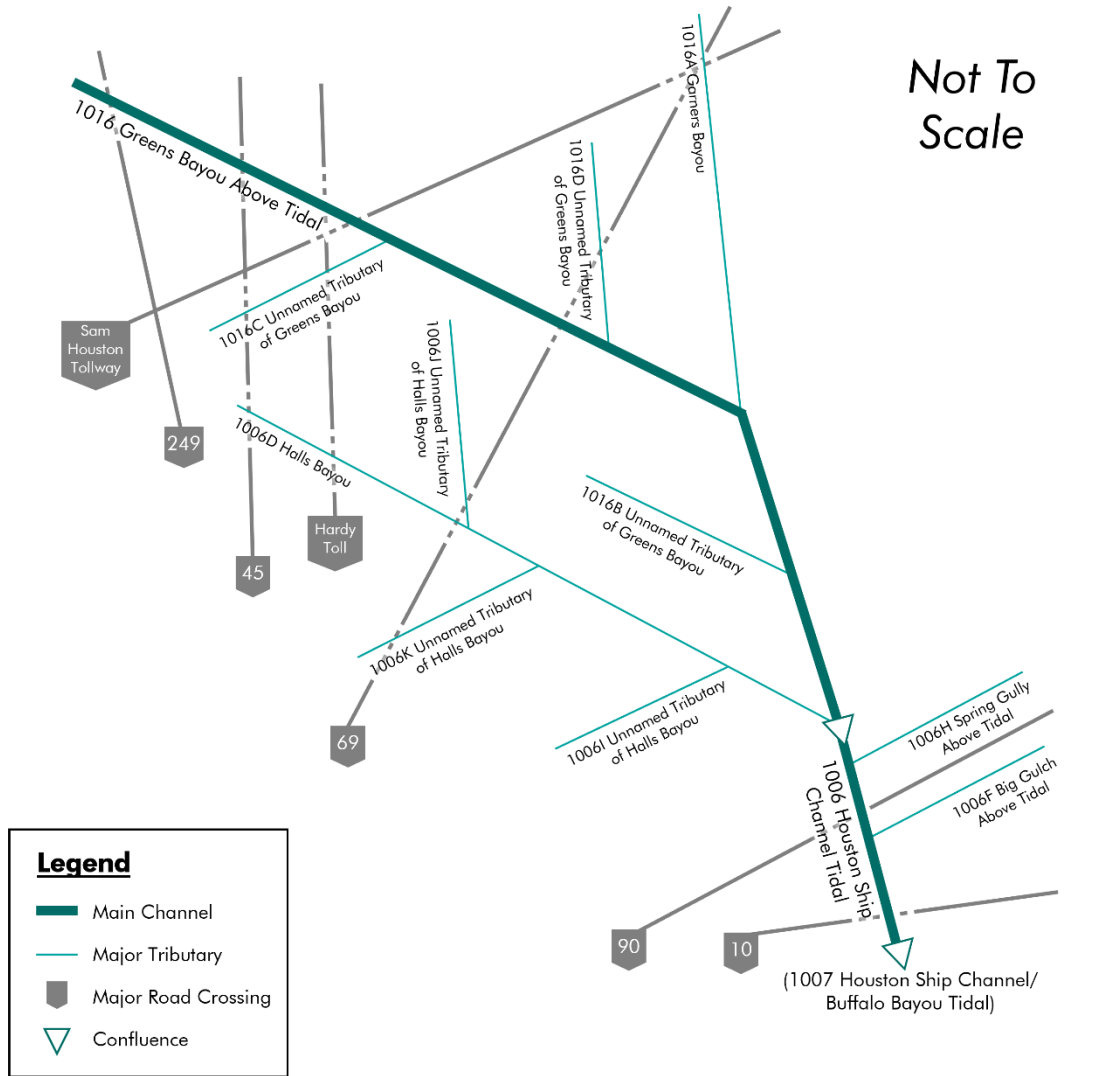


Figure 3. Stream network diagram

The full drainage network of the Greens Bayou watershed includes natural streams, modified waterways, and manmade drainage (channels and storm sewer systems) of varying size. (Figure 4). Each of Greens Bayou’s primary tributaries (Halls Bayou and Garners Bayou) are themselves networks of smaller tributaries and drainage conveyances.

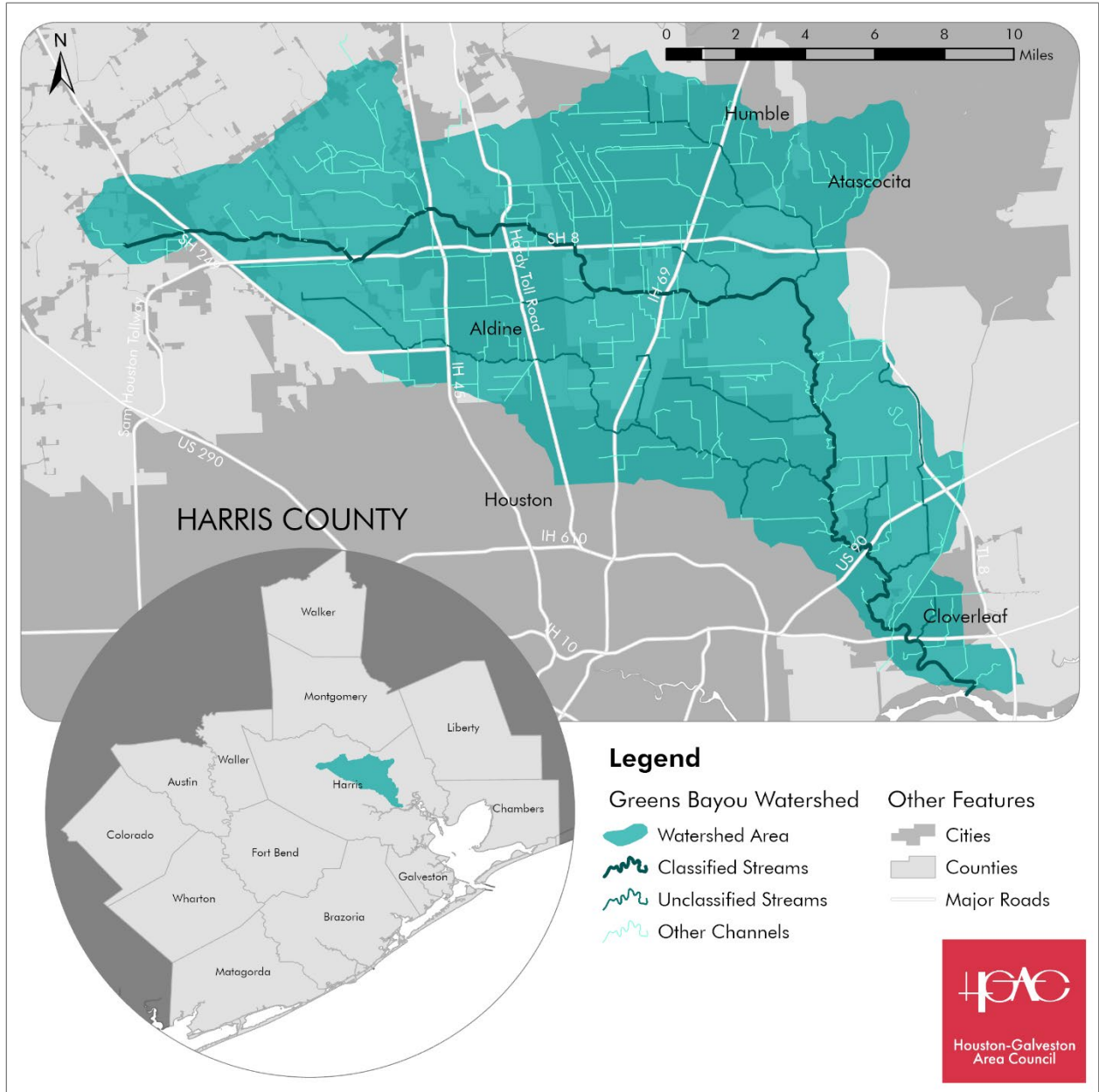


Figure 4. Hydrology in the Greens Bayou watershed

Political Geography

The watershed includes portions of Harris County Commissioner Precincts 1, 2 and 3. Representation at the national level includes United States House of Representatives Districts 02, 18, 29, 36, and 38 (in addition to the United States Senate general representation). Representation at the state level includes Texas House of Representatives Districts 126, 127, 130, 139, 140, 141, 142, 143, 145, and 148; and Texas State Senate Districts 4, 6, 7, 13 and 15. In addition, the watershed overlaps the service area of a variety of other districts and authorities, including the Coastal Water Authority, North Houston District, Harris County Flood Control District (HCFCD), and Harris County SWCD.

Physical and Natural Characteristics

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

Topography

Elevation generally decreases from northwest to southeast, and from headwaters toward the drainage pathways. There is a 60-meter difference between the highest and lowest points⁹ 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 annual precipitation between 2006 and 2020 monitored at the National Oceanic and Atmospheric Administration station in Tomball, Texas measured 49.07 inches with the most rainfall occurring in the summer and the least occurring in the winter¹⁰. However, drought events can have appreciable effect on the area, as evidenced in the 2011 drought. Throughout this period, water elevations fell to record levels throughout the state. Even though the watershed is not directly adjacent to the coast, the area is still well within the range of hurricanes and other large storms coming in from the Gulf of Mexico.

⁹ Based on United States Geological Survey Digital Elevation Model 10-meter resolution spatial data.

¹⁰ Accessed 3/12/2026 at: <https://www.ncei.noaa.gov/access/us-climate-normals/#dataset=normals-annualseasonal&timeframe=15&location=TX&station=US1TXHRR043>

Soils

Loamy and silty soils¹¹ are found throughout the Greens Bayou watershed (**Figure 5**). Soils in the central portion of the watershed tend to be more coarse. Finer sediments are common on the fringes of the above tidal portion of the watershed and throughout the tidal portion. In the Houston-Galveston region, erosion of soils is prominent in the alluvial sediments along waterways.

Habitat and Wildlife

The Greens Bayou watershed is fairly homogenous in that it only overlaps two designated ecoregions¹² (areas of similar climate, habitat, and landscape). The watershed is within the Northern Humid Gulf Coastal Prairies (EPA Level IV ecoregion 34a) and Flatwoods (EPA Level IV ecoregion 35f) under the broader Western Gulf Coastal Plain (EPA Level III ecoregion 34) and South Central Plains (EPA Level III ecoregion 35) designations.

Despite the developed land cover characteristic of the majority of the watershed, this landscape hosts a diverse array of animal and plant species. Moderate winter temperatures and the location of the watershed in the Central Flyway for migratory birds support a dense and varied community of bird species year-round. Local bird species include wading birds (e.g., great blue heron, white ibis), a wide variety of passerine species, and several raptors (e.g., red-tailed hawk, bald eagle, barred owl). Typical mammal species include white-tailed deer, Virginia opossum, raccoons, coyotes, eastern grey squirrels, striped skunks, nine-banded armadillos, and numerous species of rodents and bats. The watershed is also home to many common reptiles and amphibians, including *Nerodia* water snakes, red-eared slider turtles, and bullfrogs.

Of particular concern to the watershed are some of its invasive species. In addition to exotic plants (e.g., Chinese tallow) and various invasive animals, feral hogs (*Sus scrofa*) are a growing issue for the Houston region and are present in the Greens Bayou watershed. Feral hogs threaten native wildlife species through direct competition for food and destruction of habitat. Large feral hog populations can cause damage on agricultural lands and are also a nuisance for suburban and exurban residential areas. Hogs tend to congregate in and around water bodies, causing damage to the riparian corridor and depositing fecal waste directly into the water body.

¹¹ 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 3/12/2026 at: <https://websoilsurvey.nrcs.usda.gov/>. Soil survey dates and methods can differ from jurisdiction to jurisdiction and across time periods.

¹² Based on EPA Level III (broad) and Level IV (more specific) Ecoregion data accessed on 3/12/2026 at: <https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states>

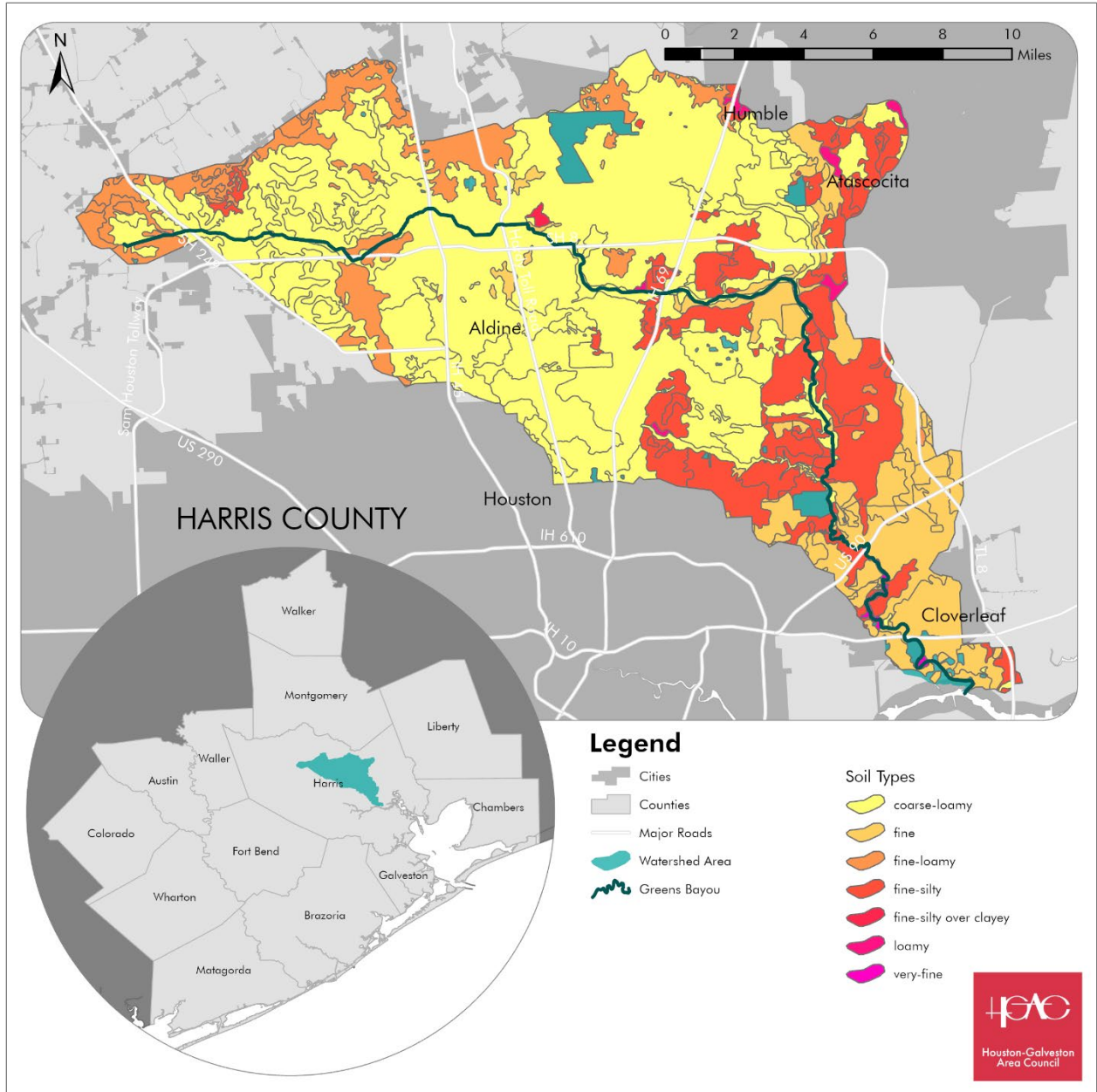


Figure 5. Soils in the Greens Bayou watershed

Land Cover and Development

The mixture of natural landscapes in the Greens Bayou watershed determines the density and transmission of pollutant sources, and considerations for implementing solutions.

Land Cover

Land cover in the watershed is mostly developed with the exception of some forested and woody wetland areas clustered around the waterways that run through the area (**Figure 6**). Developed land uses make up the vast majority (81.6%) of the total area of the watershed followed by natural areas (16.2%). The remaining area consists of agricultural land cover (**Table 2**)¹³. The mix of land cover and uses in different areas of the watershed emphasizes the WPP should 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.

Table 2. Land cover as a percentage of watershed area

Land Cover Category	Percentage of Watershed Area
Open Water	0.8%
Developed – Open Space	12.2%
Developed – Low Intensity	20.5%
Developed – Medium Intensity	32.0%
Developed – High Intensity	16.9%
Barren Lands	0.6%
Deciduous Forest	0.2%
Evergreen Forest	3.9%
Mixed Forest	0.3%
Shrub/Scrub	0.0%
Herbaceous	0.6%
Hay/Pasture	1.8%
Cultivated Crops	0.4%
Woody Wetlands	9.6%
Emergent Herbaceous Wetlands	0.2%

¹³ Data for this analysis represents 15-class data produced by H-GAC in 2022.

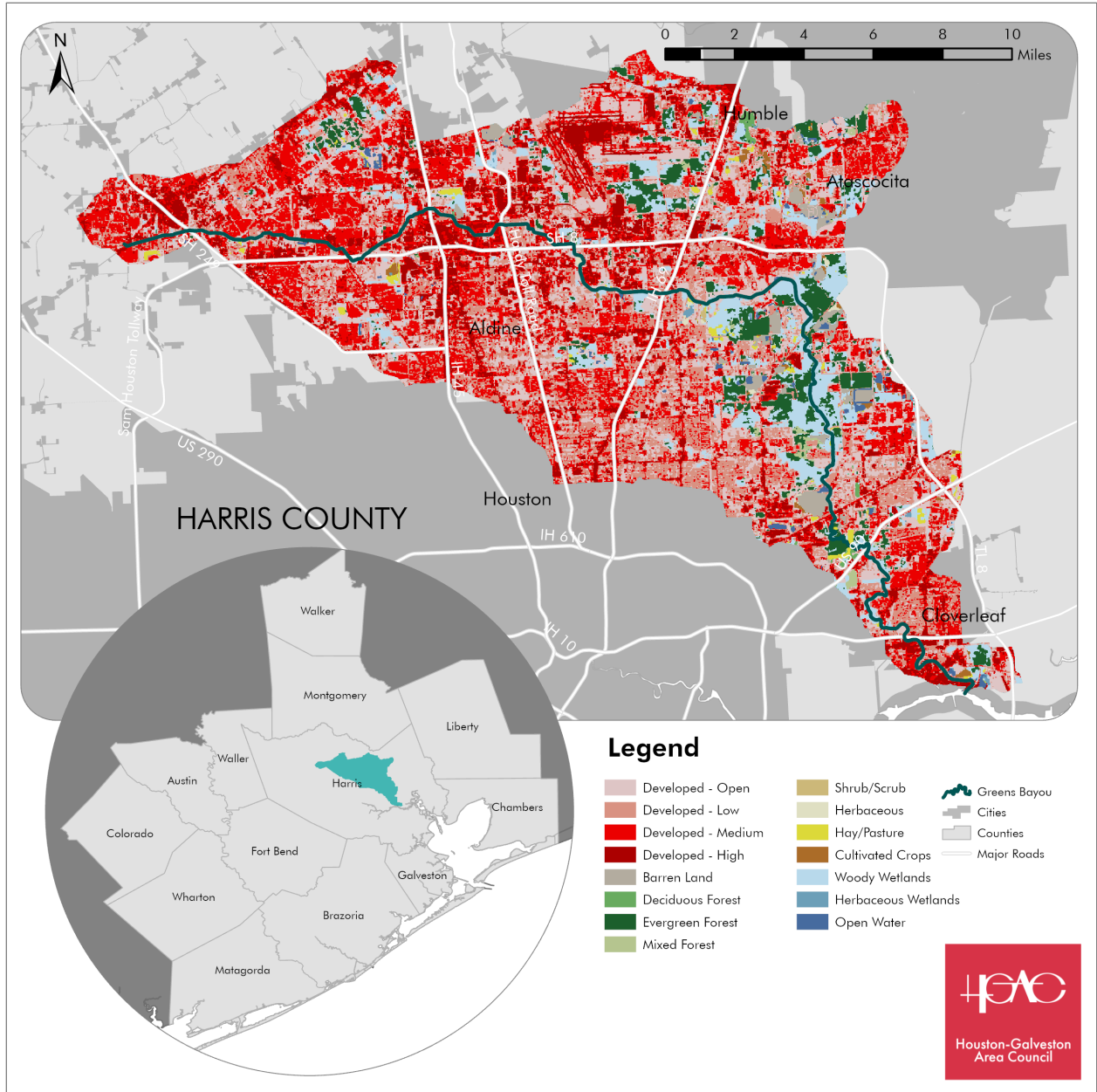


Figure 6. Land cover in the Greens Bayou watershed

Agriculture

Summary assessments below were derived from the United States Department of Agriculture (USDA) 2022 Census of Agriculture State and County profiles for Texas¹⁴.

- **Harris County** – Harris County saw a 19% decrease in the number of farms, and an 11% decrease in the amount of land under production since 2017. Market value of sold products increased by 76% in the same period. Most farms in the county are under 180 acres (93%) and many are under 50 acres (80%). However, there are several operations of 1,000 acres or larger. Current production value is heavily weighted toward crops (82%) as opposed to livestock (18%), but this is not reflected by total acreage for each type, with pastureland making up 49% of the total farmland, and cropland (38%) and other uses being smaller shares, proportionally. Only 8% of farmland is irrigated. These numbers apply to the whole of the county and are not representative of the portion of Harris County overlapped by the watershed. Rather, this information is listed to provide context.

Recreation

Greens Bayou is a popular destination for a variety of recreational activities. Many of the over 2,345 acres of parks and natural areas within the watershed are adjacent to the bayou system and are points of access for recreation.

Water Quality

For the State of Texas' water quality assessments of its water bodies, water quality parameters are strictly defined and tied to the uses associated with 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 SWQSSs. Under the delegated authority of the CWA, TCEQ develops the SWQSSs and is responsible for ensuring they are met. The intent of the standards is to

¹⁴ Accessed on 3/12/2026 at:
https://www.nass.usda.gov/Publications/AgCensus/2022/Online_Resources/County_Profiles/Texas/

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

	<p>The aquatic life use designation reflects the ability of the waterways to support aquatic ecosystems and habitat. Compliance with this use is determined by the availability of Dissolved Oxygen (DO) and an assessment of the diversity and health of existing ecological communities (fish, macrobenthics, and their habitat). High levels of chlorophyll-<i>a</i>, and elevated levels of nutrients can indicate potential issues related to low DO.</p>
	<p>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 (<i>E. coli</i> and Enterococci) are used as indicators of the potential contamination level from fecal pathogens.</p>
	<p>The public water supply use designation assessment of compliance 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.</p>
	<p>The general use designation reflects the overall health of the waterway as measured by criteria for temperature, pH, chloride, sulfate, and other parameters.</p>

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 Greens Bayou watershed are Segment 1016 (Greens Bayou Above Tidal) and parts of Segment 1006 (HSC Tidal). Major tributaries or waterways of interest within these classified segments are delineated as subordinate unclassified segments. Other contributing waterways and drainage networks also contribute to the system but are either not designated as unclassified segments 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., 1016_01 for Greens Bayou Above Tidal, AU 1). AUs in the Greens Bayou system (Table 4; Figure 7) include:

Table 4. Greens Bayou segments and AUs

Water Body	Segment	Assessment Units
HSC Tidal	1006	03 and 05
Halls Bayou	1006D	01 and 02
Big Gulch	1006F	01
Spring Gully	1006H	01
Unnamed Tributary of Halls Bayou	1006I	01
Unnamed Tributary of Halls Bayou	1006J	01
Greens Bayou	1016	01, 02 and 03
Garners Bayou	1016A	01 and 02
Unnamed Tributary of Greens Bayou	1016B	01
Unnamed Tributary of Greens Bayou	1016C	01
Unnamed Tributary of Greens Bayou	1016D	01

Assessments are made based on data collected under the state’s Clean Rivers Program (CRP) and other quality-assured data. TCEQ conducts assessments every two years for the state’s water bodies, reviewing the previous seven years of data against the designated uses for the waterways. The results are included as part of TCEQ’s Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d) (Texas Integrated Report) which is produced every two years. The results of the assessments of the Greens Bayou AUs only reflect ambient surface water quality, not the quality of tap water provided by utilities in the watershed, which is not the focus of this WPP.

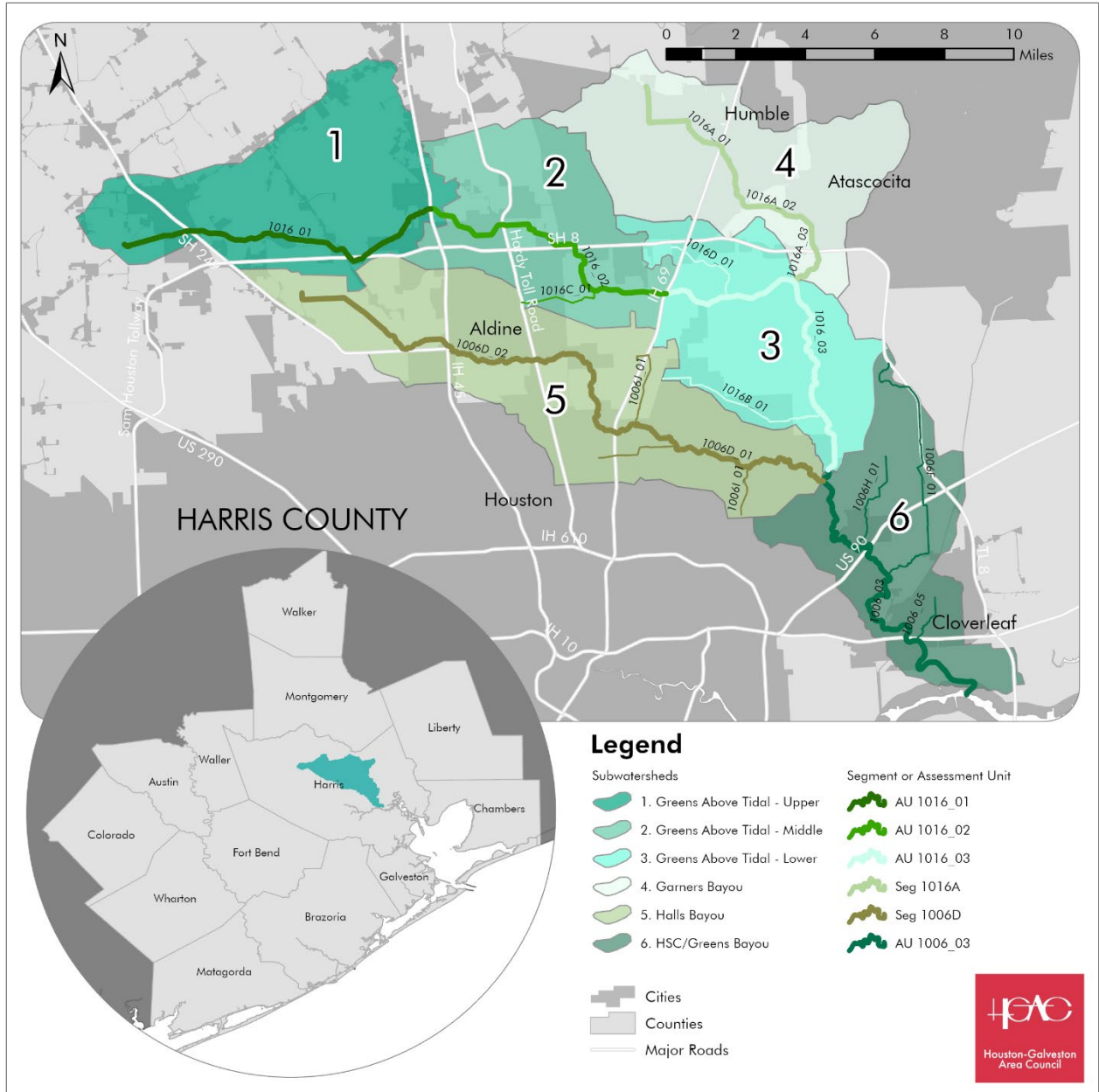


Figure 7. Subwatersheds, segments and AUs in the Greens Bayou watershed

State of the Water

The water quality of the Greens Bayou 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 data¹⁵, 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 SWQs, 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 Greens Bayou and its tributaries is typical of challenges seen in other water bodies in the area¹⁶.

According to the 2024 version of the Texas Integrated Report, current assessed water quality issues in the Greens Bayou and its assessed tributaries include elevated levels of fecal indicator bacteria (**Table 5**). The contact recreation impairment exists across many of the watershed's AUs and is the primary focus of this WPP.

¹⁵ 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 Analysis Summary Report* available on the website for this WPP project at: https://greensbayoupartnership.weebly.com/uploads/1/3/0/7/130710643/50226_3.3_prelimwqdataanalysisreport_final.pdf

¹⁶ References to assessments and water quality status refer, unless otherwise noted, to the 2024 *Texas Integrated Report*, the most current report available at the time of publication.

Table 5. Impairments and concerns in the Greens Bayou watershed, 2024

Segment	AU(s)	Parameter	Use	Category or Level of Concern
1006	03	PCBs and Dioxin	Fish Consumption	NS, 5c
		Total Phosphorus and Nitrate	General	CS
1006	05	PCBs and Dioxin	Fish Consumption	NS, 5c
		Total Phosphorus and Nitrate	General	CS
1006D	01	Nitrate and Total Phosphorus	General	CS
		<i>E. coli</i>	Recreation	NS,4a
1006D	02	Total Phosphorus and Nitrate	General	CS
		<i>E. coli</i>	Recreation	NS, 4a
1006F	01	<i>E. coli</i>	Recreation	NS, 4a
1006H	01	<i>E. coli</i>	Recreation	NS, 4a
1006I	01	Dissolved oxygen grab	Aquatic life	CS
		<i>E. coli</i>	Recreation	NS, 4a
1006J	01	Dissolved oxygen grab	Aquatic life	CS
		<i>E. coli</i>	Recreation	NS, 4a
1016	01	Total Phosphorus and Nitrate	General	CS
		<i>E. coli</i>	Recreation	NS, 4a
1016	02	Total Phosphorus, Nitrate, Ammonia	General	CS
		<i>E. coli</i>	Recreation	NS, 4a
1016	03	Total Phosphorus and Nitrate	General	CS
		<i>E. coli</i>	Recreation	NS, 4a
1016A	02	Total Phosphorus and Nitrate	General	CS
		<i>E. coli</i>	Recreation	CN
1016A	03	Total Phosphorus, Nitrate, Ammonia	General	CS
		<i>E. coli</i>	Recreation	NS, 4a
1016B	01	<i>E. coli</i>	Recreation	NS, 4a
1016C	01	Dissolved oxygen grab	Aquatic life	CS
		Total Phosphorus, Nitrate, Ammonia	General	CS
		<i>E. coli</i>	Recreation	NS, 4a
1016D	01	Dissolved oxygen grab	Aquatic life	NS, 5c
		Dissolved oxygen grab	Aquatic life	CS
		Total Phosphorus and Ammonia	General	CS
		<i>E. coli</i>	Recreation	NS, 4a

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

Illegal dumping and ambient trash from stormwater are not reported by the stakeholders to be a widespread issue in the watershed, but implementation measures related to trash management are incorporated in this WPP as a precaution.

Flooding

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.

Conservation of Natural Areas/Function

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

Photo Credit: Rachel Windham



Section 3. Identifying Potential Pollutant Sources

The process of identifying, characterizing, and quantifying potential 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 Greens Bayou 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 potential causes and sources of pollution to meet the needs of the stakeholders¹⁷.

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 and discharge data from wastewater treatment facilities (WWTFs). 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/fecal indicator bacteria generated in the watershed using computer models guided by local knowledge and feedback. These efforts identified the potential total fecal loads, mix of potential sources responsible, and variation between different areas of the watershed.

¹⁷ More detailed information on the development of this investigation methodology and selection of models can be found in the Bacteria Modeling Report, located at: https://greensbayoupartnership.weebly.com/uploads/1/3/0/7/130710643/50226_4.3_bacteria_modeling_report_final.pdf

- **Reduction/Improvement modeling (fecal waste, DO)** — H-GAC worked with the Partnership to estimate the amount of improvement needed to meet water quality standards for various areas in the waterway. Results were generated by computer models using then-current water quality monitoring data. These processes generated the percent reduction for fecal indicator bacteria 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 fecal indicator bacteria. This process applied the percent reduction targets from the improvement modeling to fecal indicator bacteria 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 wastewater¹⁸ 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, and 3) discharge monitoring reports (DMRs) and sanitary sewer overflow (SSO) data from WWTFs. While these analyses are summarized here, greater detail on the methods and results can be found in the *Water Quality Data Analysis Summary Report*¹⁹ 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.

¹⁸ Report on the Second Five-Year Review of EPA's Recreational Water Quality Criteria (May 2023).

<https://www.epa.gov/system/files/documents/2023-05/2023-5year-review-rwqc-factsheet.pdf>

¹⁹ Available on the project website at:

https://greensbayoupartnership.weebly.com/uploads/1/3/0/7/130710643/50226_3.3_prelimwqdataanalysesreport_final.pdf

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 CRP²⁰. Most monitoring stations are sampled by CRP partners²¹. Waterways are inherently dynamic systems, and water quality at any given time can vary greatly dependent on conditions at the time. However, a history of 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 are an important source of information for informing stakeholder decisions.

The Greens Bayou system is heavily monitored, with 14 active monitoring stations: seven on the main body, five on Winters Bayou (1003A), one on Nebletts Creek (1003B), and one on Boswell Creek (1003C; **Figure 8; Table 6**).

Table 6. CRP monitoring station locations in the Greens Bayou watershed

Segment Number	Segment Name	Stations
1006	HSC Tidal	11279, 16664, 16981, 18363, 21008
1006D	Halls Bayou	11126, 11127, 15862, 15863, 15864, 17490, 17491
1006F	Big Gulch	16662
1006H	Spring Gully	16663
1006I	Unnamed Tributary of Halls Bayou	16666
1006J	Unnamed Tributary of Halls Bayou	16665
1016	Greens Bayou	11369, 11370, 11371, 11376, 13778, 17495
1016A	Garners Bayou	11125, 16589
1016B	Unnamed Tributary of Greens Bayou	16590
1016C	Unnamed Tributary of Greens Bayou	22090
1016D	Unnamed Tributary of Greens Bayou	16676

²⁰ More information about this state-wide water quality monitoring program can be found at:

<https://www.tceq.texas.gov/waterquality/clean-rivers>

²¹ 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/>

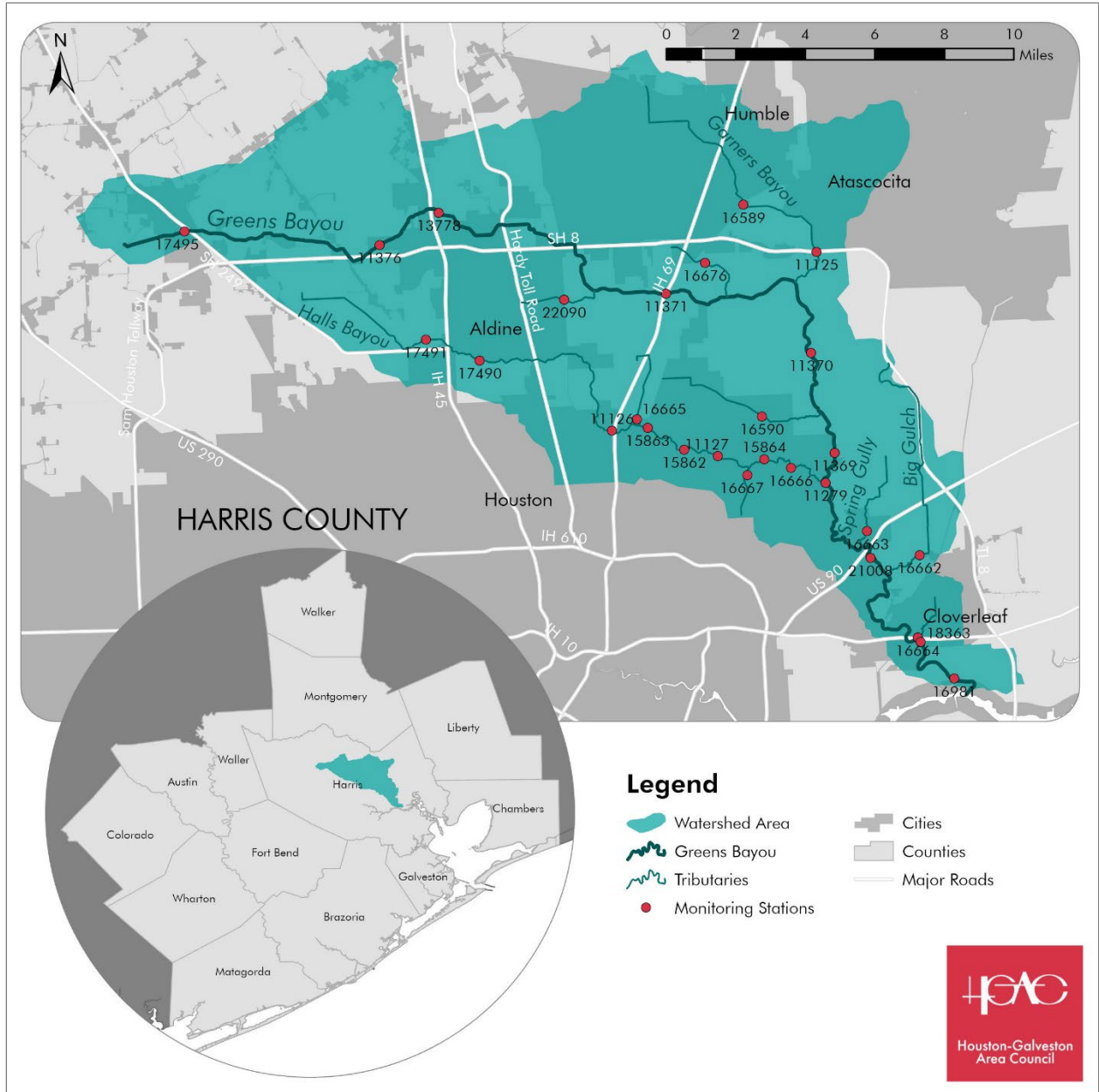


Figure 8. Greens Bayou watershed monitoring stations

Constituents of Concern

Routine ambient water quality monitoring under 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 were selected for in-depth analysis. The parameters reviewed were:

- **Enterococci and *E. coli***— bacterial indicators of the presence of fecal wastes, and of the safety of waterways for human recreation.

- **Dissolved Oxygen (DO) (grab)** — an indicator of the ability of the waterway to support aquatic life.
- **Temperature** — an indicator of a waterway’s ability to hold oxygen, and a means for correlating other indicators to conditions in the waterways.
- **pH** — an indicator of the acidity or alkalinity of water, which may affect aquatic life and other uses.
- **Chlorophyll-*a*** — an indicator of aquatic plant productivity and action, which can indicate areas in which algal blooms or elevated nutrient levels are present, and thus potentially depressed DO.
- **Nitrate and Nitrite** — a measure of nitrogenous compounds and indicator of nutrient levels (and thus potential DO impacts).
- **Ammonia Nitrogen** — a measure of specific nitrogenous compound that can impact aquatic life and is an indicator of nutrient levels and potentially of improperly treated sewage effluent.
- **Total Phosphorus** — an indicator of nutrient levels, especially in relation to potential for algal blooms and depressed DO in elevated levels.
- **Total Suspended Solids (TSS)** — a measure of the number of suspended particles in water that indicates the potential of light infiltration in the water column and the presence of particulate matter which fecal indicator bacteria may use as substrate.

The analyzed data covers 2011 to 2021 to show a broad historic view. Note that this is not the same time period used by TCEQ for the Texas Integrated Report assessment. 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.
- Trends in water quality conditions, including any observable seasonal patterns.

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

Monitoring Analysis

A summary of ambient data for each segment of the Greens Bayou watershed, represented as the geomean of each parameter for data from TCEQ’s Surface Water Quality Monitoring Information System (SWQMIS) collected between 2020 and 2024 (

Table 7). These results are not directly comparable to that of the *2024 Texas Integrated Report* which uses a different period of record (2015 to 2022) and assessment methodology for determination of Texas SWQS attainment.

Table 7. Water quality monitoring geometric mean results by segment, 2020 to 2024

Parameter	Criteria	Unit	Houston Ship Channel, 1006	Halls Bayou, 1006D	Big Gulch, 1006F	Spring Gully, 1006H	Unnamed Tributary Of Halls Bayou, 1006I	Unnamed Tributary Of Halls Bayou, 1006J	Greens Bayou, 1016	Garners Bayou, 1016A	Unnamed Tributary Of Greens Bayou, 1016B	Unnamed Tributary Of Greens Bayou, 1016C	Unnamed Tributary Of Greens Bayou, 1016D
Ammonia Nitrogen	0.33	mg/L	0.19	0.14	-	0.06	-	0.08	0.17	0.13	0.06	0.28	0.18
DO, grab	Various	mg/L	4.88	5.91	5.66	6.29	5.08	4.95	6.90	6.49	6.43	3.71	3.61
<i>E. coli</i>	126	CFU/100mL	272.41	975.42	258.10	237.28	1,926.50	340.43	466.42	320.07	217.94	2,877.48	1,365.98
Enterococci	35	CFU/100mL	56.50	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
Instantaneous Flow	NA	Cubic Feet Per Second	No Data	19.04	No Data		No Data	7.48	35.08	21.03	No Data	No Data	0.86
Nitrate Nitrogen	1.95	mg/L	4.20	5.44	No Data	0.10	No Data	0.15	5.80	5.16	0.36	1.90	0.22
pH	9 (high) 6.5(low)	NA	7.45	7.55	7.42	7.04	7.74	7.56	7.66	7.48	7.55	7.46	7.36
Temperature	NA	Degrees Celsius	22.93	22.80	22.40	21.54	21.09	21.04	23.89	23.12	21.68	21.98	21.60
Total Phosphorus	0.69	mg/L	0.60	1.71	No Data	0.14	No Data	0.21	1.51	1.80	0.04	0.75	0.38

Note: Results shaded in gray indicate geomeans that exceed criteria or screening levels, while cells with no shading represent results that comply with criteria or screening levels. Italicized values indicate the data are not being compared to criteria or screening levels. This trend analysis does not reflect analysis or conclusions from the *Texas Integrated Report*.

Water Quality Parameter Trends

By examining all parameters collected from surface water samples in the Greens Bayou watershed and how measurements for those parameters have changed over time, statistically significant ($p < 0.0545$) trends in the data were determined. The results shown in **Table 8** only indicate significant improvements or worsening trends. Results for parameters with stable trends over time are not represented. Consequently, parameter measurements that remained consistently above water quality standards (such as *E. coli*) throughout the study period are not captured by this summary.

Relationship to Flow

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

Ambient Data Analysis Summary

Of the ambient water quality parameters observed, geomean values for fecal indicator bacteria levels measured between 2020 and 2024 exceeded state water quality standards most frequently. All segments observed in this analysis showed geomean values for fecal indicator bacteria exceeding criteria levels. In the trend analysis of data collected between 2020 and 2024, *E. coli* levels show signs of significant improvement on an unnamed tributary of Greens Bayou (1016D). However, bacteria levels are so far above the standard, that this trend is not expected to continue to the point of compliance with the geomean standard without action. All other segments showed stable trends for bacteria, however, this was due to regular observed exceedances of the geomean standard.

Nutrients also continue to pose a challenge to water quality in the Greens Bayou watershed. Total phosphorous and nitrate nitrogen geomeans exceeded screening levels on Halls Bayou (1006D), Greens Bayou (1016), and Garners Bayou (1016A). Nitrate nitrogen was also high on HSC Tidal (1006), and phosphorous was high on an unnamed tributary of Greens Bayou (1016C). All significant trends related to nutrient concentrations in segments throughout the watershed indicate deteriorating conditions especially for total phosphorous.

Table 8. Greens Bayou Watershed significant water quality trends by segment, 2020 to 2024

Segment	Parameter	Trend
HSC Tidal, 1006	DO	Improving
HSC Tidal, 1006	pH	Improving
HSC Tidal, 1006	Temperature	Deteriorating
HSC Tidal, 1006	Total Phosphorus	Deteriorating
HSC Tidal, 1006	Total Suspended Solids	Improving
Halls Bayou, 1006D	DO	Improving
Halls Bayou, 1006D	pH	Improving
Halls Bayou, 1006D	Temperature	Deteriorating
Halls Bayou, 1006D	Total Phosphorus	Deteriorating
Halls Bayou, 1006D	Total Suspended Solids	Improving
Big Gulch, 1006F	Ammonia-N	Improving
Spring Gully, 1006H	DO	Improving
Spring Gully, 1006H	pH	Improving
Unnamed Tributary of Halls Bayou, 1006I	DO	Improving
Unnamed Tributary of Halls Bayou, 1006J	Instantaneous Flow	Deteriorating
Unnamed Tributary of Halls Bayou, 1006J	pH	Improving
Greens Bayou, 1016	Ammonia-N	Deteriorating
Greens Bayou, 1016	DO	Improving
Greens Bayou, 1016	pH	Improving
Greens Bayou, 1016	Temperature	Deteriorating
Greens Bayou, 1016	Total Phosphorus	Deteriorating
Greens Bayou, 1016	Total Suspended Solids	Improving
Garners Bayou, 1016A	DO	Improving
Garners Bayou, 1016A	pH	Improving
Garners Bayou, 1016A	Total Phosphorus	Deteriorating
Unnamed Tributary of Greens Bayou, 1016C	Nitrate-N	Deteriorating
Unnamed Tributary of Greens Bayou, 1016C	Total Phosphorus	Deteriorating
Unnamed Tributary of Greens Bayou, 1016D	Ammonia-N	Improving
Unnamed Tributary of Greens Bayou, 1016D	DO	Deteriorating
Unnamed Tributary of Greens Bayou, 1016D	<i>E. coli</i>	Improving

Another parameter of interest in this watershed is DO. Though the criteria for DO varies depending on the waterway, Section 307.10 Appendix D in the Texas Administrative Code indicates that DO levels in two unnamed tributaries of Greens Bayou (1016C and 1016D) were below the criteria. The trend analysis of data collected between 2020 and 2024 indicates a significantly worsening trends for DO on Segment 1016D. However, improving trends for DO were observed on tidally influenced segments such as HSC Tidal (1006), Halls Bayou (1006D), Spring Gully (1006H), an unnamed tributary of Halls Bayou (1006I), Greens Bayou (1016) and Garners Bayou (1016A).

Texas 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) community scientists 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. While there are currently no active TST sites in the Greens Bayou watershed, stakeholders have expressed interest in establishing a TST site to help identify WPP effectiveness going forward.

Wastewater Treatment Facility Discharge Data

Discharges from WWTFs are regulated by Texas Pollutant Discharge Elimination System (TPDES) permits from TCEQ which require stringent limits for effluent quality and 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.

Human waste can cause human illness, so identifying trends in permit exceedances for fecal indicator 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 analysis, there were 138 permitted outfalls in the Greens Bayou watershed (**Figure 9; Appendix B. Wastewater Treatment Facilities**). Of these, 119 submitted DMRs. Project staff evaluated²² bacteria results compiled in these DMRs

²² For more detail, see the Water Quality Data Analysis Summary Report on the project website at: https://eastforkpartnership.weebly.com/uploads/1/3/0/7/130710643/30143_3.2_acquired_data_analysis_report_final.pdf

reported between 2020 and 2024 by WWTF permit holders in the Greens Bayou watershed.

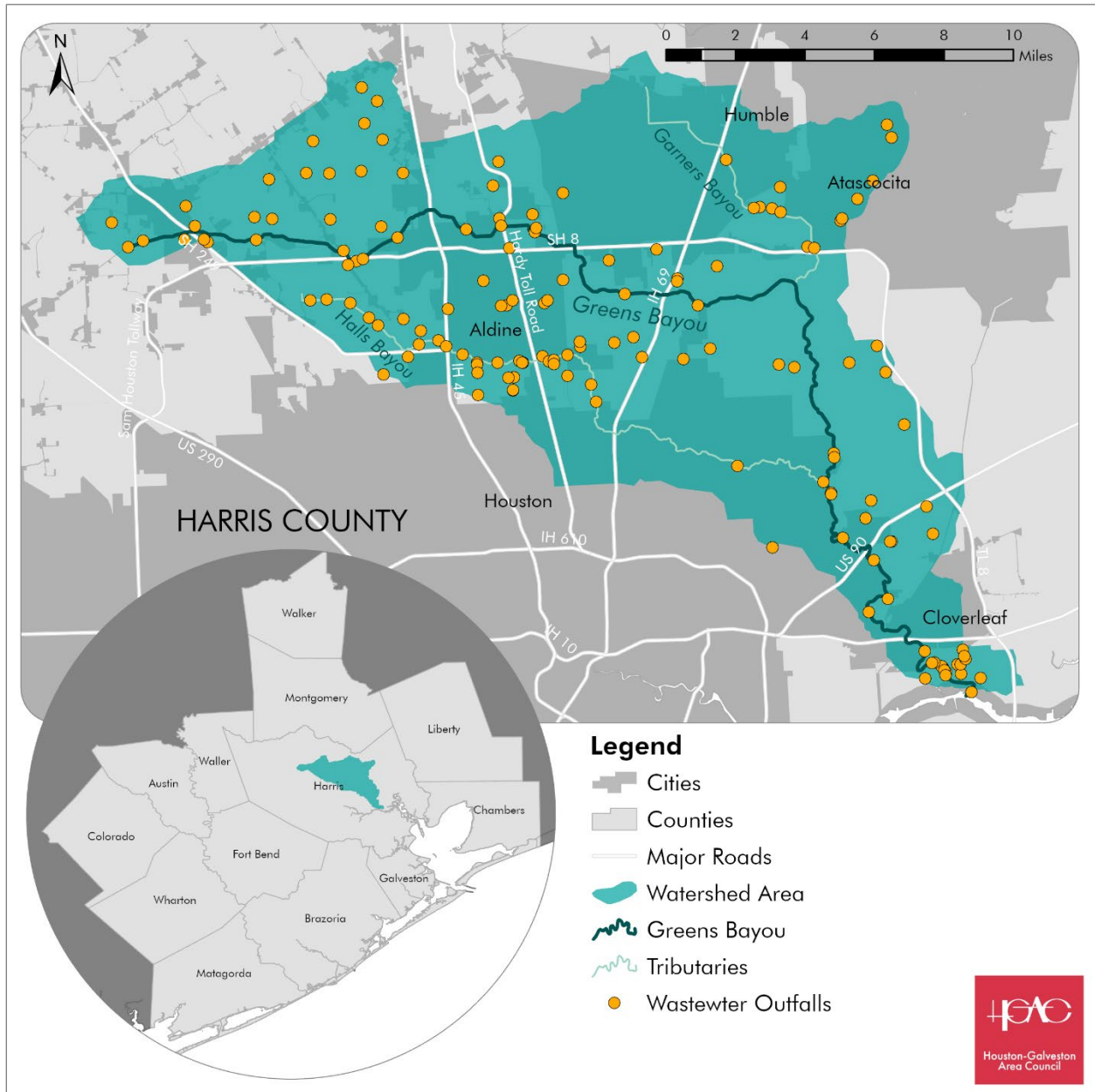


Figure 9. WWTF outfalls in the Greens Bayou watershed

Bacteria

Effluent discharge from WWTFs is assessed for compliance with the TPDES permit limits. For this analysis, DMR data were compared to TPDES permit limits for bacteria across segments, facility types, years, and seasons. The values for exceedances of geomean and single sample limits were calculated for each facility depending on their specific permit limits. In the case of the indicator bacteria *E. coli* and Enterococci, the permitted

geomean standard is 126 CFU/100 mL and 35 CFU/100 mL, respectively, whereas the grab sample standard is 399 CFU/100 mL and 130 CFU/100 mL, respectively. Several facilities in the watershed have more stringent fecal indicator bacteria limits (e.g., 63 cfu/100mL) than SWQS (126 cfu/100 mL) because of TMDL requirements. For this project, staff evaluated bacteria data associated with WWTF permits, from the same time period as the most recently available ambient water quality data, January 2020 through December 2024, and compliance with permit limits for bacteria were compared across segments, plant types, years, and seasons. However, when the WWTF bacteria loading was estimated in the Spatially Explicit Load Enrichment Calculation Tool (SELECT) process, an assumed effluent concentration of 126 cfu/100 mL was used for all facilities to get a high-end estimate for bacteria loading that the stakeholders felt was more appropriate.

Overall, the results of the DMR bacteria data analyses indicate that the total number of exceedances reported was small relative to the total number of DMR reports submitted for the period of 2020 to 2024 (53 out of 2,019 records; **Table 9**). Maximum single grab values exceeded the standard on 45 of those reports and geomean limits were exceeded eight times. The disparity between the number of samples exceeding the geomean standard compared to samples exceeding the grab standard could indicate high variability in the data. Higher rates of exceedance from specific sites may be overshadowed by the broad scope of this analysis.

Table 9. DMR bacteria exceedance statistics, 2020 to 2024

Parameter	Number of Facilities	Percent of Facilities	Percent of Reports
Facilities in DMR Dataset	119		
Facilities Reporting Bacteria	2,019		
Total Records	217		
Exceedances of Geomean	8		0.4%
Exceedances of Single Grab	45		2.2%
Total Exceedances	53		2.6%

Temporal analysis indicated that with the exception of 2020, the number of annual exceedances per year appeared to increase. The rate of exceedance by plant size was also considered as part of this analysis. Plant size refers to the amount of volume in millions of gallons per day (MGD) that each WWTF is permitted to discharge. From the data analyzed, grab samples generally exceed the standard at a higher rate than geomeans. The highest single-year percent exceedances occurred in 2024 in the 1-5 MGD category for both geomean (2.5%) and grab samples (10.0%).

Discharge Data Analysis Summary

Overall, the results of the analyses of DMR 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 2020 to 2024 (53 out of 2,019 records). Exceedances for both grab samples and geomean appear to have been increasing since 2021. While WWTFs may be appreciable contributors to pollution under certain conditions in localized areas, the DMR analysis indicates that they are not likely a significant driver of segment bacteria impairments in the Greens Bayou watershed due to the comparatively few exceedances. However, due to the relatively higher risk of pathogens from human waste, and proximity to developed areas, WWTF exceedances are likely still a point of concern for stakeholders.

Sanitary Sewer Overflows

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

This study considered five years of TCEQ SSO violation data from January 2020 through December 2024. There were 714 SSO records from 37 plants considered for the Greens Bayou watershed, which were broken down by year and cause, for number and volume.

There was not a strong trend in number of SSOs over time for the five years examined (**Table 10**). In terms of cause by number, the general category of blockages accounted for 42.9% of reported SSOs, weather accounted for 29.5%, malfunctions accounted for 27.0%, and 0.6% were attributed to unknown causes.

Table 10. Number of annual SSO events

CAUSE	2020	2021	2022	2023	2024
Weather	20	21	18	43	108
Rain / Inflow / Infiltration	20	20	18	43	97
Severe Freezing Weather	-	1	-	-	11
Malfunctions	63	39	17	55	18
WWTF Operation or Equipment Malfunction	26	19	10	6	10
Power Failure	-	-	1	43	-
Lift Station Failure	4	3	3	1	1
Collection System Structural Failure	33	17	3	5	7
Equipment Failure	-	-	-	-	-
Blockages	100	70	86	10	39
Blockage in Collection System- Other Cause	31	15	20	-	7
Blockage in Collection System- Fats/Grease	68	49	65	10	30
Blockage Due to Rags/Wipes	1	6	1	-	2
Unknown Cause	-	1	2	-	1
Total	183	131	123	108	166

While number of SSO events informs how frequently these overflows impact the basin, volume of overflow is an indicator of the magnitude of impact. Of the total volume of overflows reported from 2020 to 2024, weather related events were responsible for 59.2% of reported overflows, malfunctions contributed 25.7%, blockages comprised 15.0%, and unknown causes led to the remaining 0.1% (Table 11). It should be noted that 86.1% of all weather related overflow volume was reported in 2024 in connection with extreme weather events such as a derecho and Hurricane Beryl which both affected the greater Houston area.

Table 11. Annual SSO events by volume (in gallons)

CAUSE	2020	2021	2022	2023	2024
Weather	3,483.5	8,041.0	1,429.0	94,537.0	663,193.0
Rain / Inflow / Infiltration	3,483.5	7,041.0	1,429.0	94,537.0	565,122.0
Severe Freezing Weather	-	1,000.0	-	-	98,071.0
Malfunctions	48,460.0	103,950.0	8,717.0	128,211.0	45,493.0
WWTF Operation or Equipment Malfunction	41,371.0	25,643.0	3,762.0	1,930.0	3,762.0
Power Failure	-	-	50.0	94,537.0	-
Lift Station Failure	2,200.0	3,000.0	3,000.0	5,000.0	41,220.0
Collection System Structural Failure	4,889.0	75,307.0	1,905.0	26,744.0	511.0
Equipment Failure	-	-	-	-	-
Blockages	15,500.0	90,827.5	50,619.5	19,994.0	17,457.0
Blockage in Collection System- Other Cause	9,014.0	11,070.0	3,896.0	-	1,196.0
Blockage in Collection System- Fats/Grease	6,486.0	79,561.0	46,693.5	19,994.0	16,261.0
Blockage Due to Roots/Rags/Debris	0.0	196.5	30.0	-	0.0
Unknown Cause	-	0.0	500.0	-	500.0
Total	67,443.5	202,818.5	61,265.5	242,742.0	726,643.0

SSO Report Data Analysis Summary

The highest volume of flows relative to other years occurred in 2024, but there was not a strong annual trend in number of SSOs. In terms of general cause, blockages accounted for the highest number of events respective to the other general categories of weather, malfunctions, and unknown causes. In terms of volume, extreme weather events concentrated in 2024 contributed the highest overflows observed between 2020 and 2024.

While these data are useful, it should be noted that they are 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, and 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 cause 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 waterways of Greens Bayou and other surrounding watersheds.

Summary of Water Quality Analyses

This review of water quality data is foundational for understanding and characterizing water quality concerns in the Greens Bayou watershed, and for informing subsequent stakeholder decisions. The analyses answered questions regarding the sufficiency of the data, the extent and severity of water quality trends, seasonality of water quality issues, and the potential impact of wastewater effluent and SSOs.

Data collected between January 2020 and December 2024 were used to determine what parameters of water quality are of greatest concern and the extent to which their impacts have been observed throughout the waterways. As indicated in the *2024 Texas Integrated Report* results for this watershed, a geomean analysis of the SWQMIS dataset identified high levels of fecal indicator bacteria as the most pervasive impact to water quality throughout the waterways. Further, elevated nutrient (nitrate nitrogen and total phosphorous) levels were also highlighted as concerns in segments such as Halls Bayou (1006D), Greens Bayou (1016), and Garners Bayou (1016A). Depressed DO levels were observed on two of the unnamed tributaries to Greens Bayou (1016C and 1016D). Slight discrepancies between the geomean analyses in this report and the results of the *2024 Texas Integrated Report* are most likely due to the incomplete temporal overlap of datasets observed for each report.

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

An analysis of SSO reports from the watershed indicated that for the number of SSO events, blockages were among the most common for the general cause categories, while weather contributed to the highest volumes of overflow. However, it is important to note that while only one cause is usually listed on the report, multiple compounding factors can lead to SSOs. Ultimately, causes listed in SSO reports are prone to a degree of subjectivity as opposed to more quantitative measurements. While the episodic overflow volumes reported during these events are relatively small compared to the scale of effluent produced by WWTFs, SSO inputs are of particular concern due to the untreated nature of the sewage associated with them and the subsequent risk to human health.

As populations in the watershed continue to grow, the balance of pollutant sources and current hydrologic processes could be altered significantly in the coming years. These

changes could result in further water quality impacts without intervention. Subsequent efforts should be made to identify causes and sources of the primary parameter of concern (indicator bacteria), and to characterize nutrient sources further to identify areas within the project watershed most vulnerable to pollutant loadings and/or best suited for the implementation of management strategies.

Potential Source Identification

Using the information generated through the water quality data analyses, the next step in characterizing the watershed was to evaluate potential causes and sources of pollution. 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.

Fecal Waste Source Identification

Waste from all warm-blooded animals is a potential source of fecal indicator bacteria contamination. Fecal indicator bacteria are not necessarily themselves the source of potential health impacts; however, they signify the presence of fecal waste as well as a host of other pathogens associated with fecal waste. 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.

Source Survey

Characterizing fecal waste pollution in watersheds, and development of analyses to estimate potential loading, requires a consideration of potential sources. In any watershed with a mix of land uses, fecal waste can be produced by a broad mix of sources; this is especially true in a large, diverse watershed like the Greens Bayou. 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 included²³:

²³ More information on data sources and quality objectives can be found in the project quality assurance project plan, available online on the project website at:

https://greensbayoupartnership.weebly.com/uploads/1/3/0/7/130710643/50226_modelingqapp_qtrak24-307_executed.pdf

- 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)
- SSOs (TCEQ SSO database)
- **Land Cover Analysis** — Staff reviewed both national and local (H-GAC proprietary) land cover datasets to determine the mix of land cover types within the whole 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.
- **Stakeholder Feedback** — Stakeholder engagement was a primary focus of the source survey. Local knowledge was a key aspect of understanding source composition in the area. Project staff engaged stakeholder consideration of sources through:
 - Direct discussion of sources at Partnership meetings.
 - Direct discussion of sources at source-based Work Group meetings.
 - 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).

In general, stakeholder feedback upheld staff expectations of usual sources, and helped refine extent and scale of expected source contributions (*e.g.*, presence of deer in developed areas, hog activity levels). The ultimate selection of sources to include in the model was based on stakeholder decisions and affirmation of H-GAC's proposed modeling methodology, through the revision process.

Estimating Fecal Indicator Bacteria 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 fecal indicator bacteria was being generated by each source, and how those sources were distributed in the watershed.

Spatially Explicit Load Enrichment Calculation Tool

SELECT is a Geographic Information System-based analysis approach developed by the Spatial Sciences Laboratory and the Biological and Agricultural Engineering Department at Texas A&M University²⁴. The intent of this tool is to estimate the total potential fecal indicator bacteria 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 fecal indicator bacteria 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 load²⁵ estimates are not intended to represent the amount of fecal indicator bacteria actually transmitted to the water, as the model does not account for the natural processes that may reduce pollutants on their way to the water, or the relative proximity of sources to the waterway.

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

- **Buffer Approach** — The basic SELECT model assumes all fecal indicator bacteria generated within a watershed will have the same impact on instream loads. For example, loads generated two miles from a waterway are assumed equal to equivalent loads generated within the riparian corridor. However, in real situations loads generated adjacent to the waterways are more likely to contribute to instream conditions. In addition, SELECT does not provide a means by which to model fate and transport factors, so if a particular source is located farther from the waterway, it may be overrepresented compared to a source located adjacent to the waterway. For example, if OSSFs in a watershed produced 50 units of waste, but were located far from the water, while livestock in a waterway produced the same amount of waste, but in the riparian corridor, SELECT would treat these potential loads as equal. For stakeholders making decisions on prioritizing BMPs and sources, this is a false equivalency. To strike a balance between project focus on simple but effective modeling and a desire to understand the potential impact

²⁴ Additional information about SELECT can be found at: <http://ssl.tamu.edu/media/11291/select-aarin.pdf>

²⁵ 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.

of transmission, this modification 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 waterway²⁶. 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 Greens Bayou watershed is forecasted to experience developmental change. Sources estimated based on data collected as of the year 2022²⁷ are expected to expand in the future. Therefore, fecal indicator bacteria reductions based on current conditions would be inadequate to meet future needs. This modification of SELECT uses regional demographic projection data to estimate future conditions through 2050 in 5-year intervals²⁸. Land use change is the primary driver for estimating changes in source contribution, and spatial distribution of loads²⁹. Future loading predications do not account for pollutant reductions actions that may take place as a result of implementing this WPP.

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

²⁶ Buffer percentages were based on previously approved WPPs and reviewed on multiple occasions with project stakeholders.

²⁷ References to “current” modeled conditions throughout this document refer to 2022 estimations, based on the available data at the time of the modeling effort.

²⁸ 2050 represents the extent of H-GAC regional demographic model projections at the time of analysis.

²⁹ All future projections have some level of uncertainty that cannot be wholly controlled for. The H-GAC Regional Growth Forecast (<http://www.h-gac.com/regional-growth-forecast/default.aspx>) demographic model projections are widely used in the region and in similar WPPs, and thus considered the best available data for making these projections. Some wildlife sources have additional levels of uncertainty because the model assumes that change between land uses eliminates populations tied to the former land use. However, there are 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 are 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.

analysis and its eventual use as a prioritization tool for selecting BMPs. The goal of the SELECT modeling in this WPP effort, other than the general characterization of source loading, is to aid in prioritizing which sources to address by showing their relative contributions and locations. The loads generated by SELECT are combined with 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.
- 4) Stakeholder review of results and model revision as necessary (**Figure 10**).

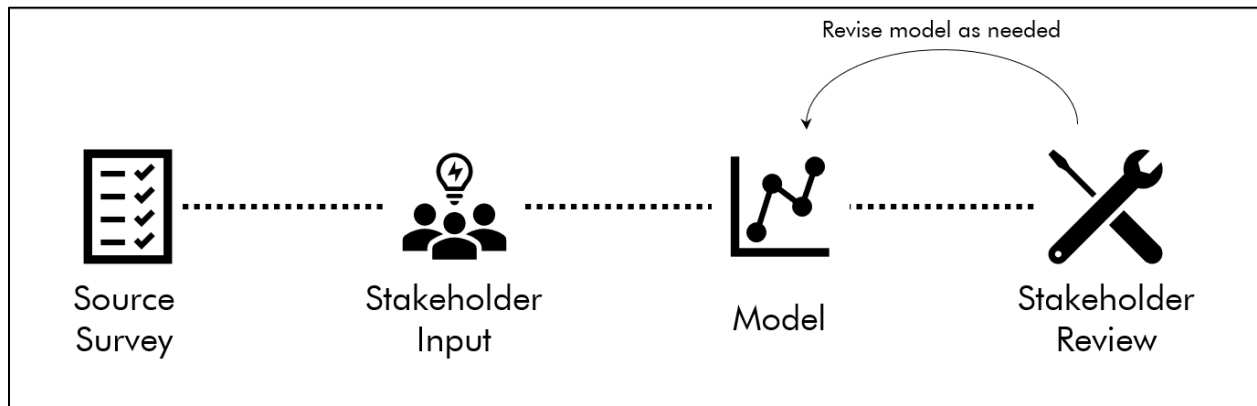


Figure 10. SELECT modeling process

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 billions of fecal indicator bacteria per day.

The maps display both relative loading by area within a subwatershed (riparian areas versus areas outside the riparian) and between subwatersheds with color intensity indicating loading severity relative to the other subwatersheds. Larger subwatersheds will have larger loads, all things being equal. Load density maps help equalize discrepancies in subwatershed size. Due to these factors, and that map colors are not tied to absolute loads, it should be noted that the spatial results are not directly comparable between the modeled sources.

The maps also reflect the use of the buffer approach. A 300-foot buffer around each waterway (appearing as a series of lines forming the watershed stream network on the maps) 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.

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 commonly managed by municipal utility districts and other districts. Considering all types of WWTFs, 119 permitted facilities with discharge monitoring report data are found within the watershed boundary of Greens Bayou. Size of WWTFs vary throughout the watershed and range between capacities of less than 0.1 millions of gallons per day (MGD) to 10 MGD.

WWTFs in the Greens Bayou watershed are not expected to be major contributors to fecal indicator bacteria loading. 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. As loads were estimated to reflect the impacts of direct outfalls, all results are indicated within the buffer zone surrounding the watershed stream network. 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 to account for exceedances or variations throughout daily discharges that could have greater impacts to public health.

In the Greens Bayou watershed, fecal bacteria loading from WWTFs is most prevalent in the Garners Bayou subwatershed where WWTF densities and sizes are greater (**Table 12**). Forecasted total watershed loads from WWTFs were plotted in five-year increments through the year 2050 and indicate that fecal indicator bacteria loading will double over the next two decades if no BMPs are implemented (**Figure 11**). As loads were estimated solely from outfall data within the riparian buffer, all spatial results are indicated within the buffer zone surrounding the watershed stream network (no data are available for the land area beyond the buffer; **Figure 12**).

Table 12. WWTF outfalls and bacteria loadings in billion cfu/day by subwatershed

Subwatershed*	# of Outfalls	Load Estimate in Billion cfu/day	Subwatershed Percent of Total Load
Greens Above Tidal - Upper (SW1)	24	2.38	17%
Greens Above Tidal - Middle (SW2)	14	2.41	18%
Greens Above Tidal - Lower (SW3)	12	2.79	20%
Garners Bayou (SW4)	14	4.73	34%
Halls Bayou (SW5)	43	1.09	8%
HSC Tidal/Greens Bayou (SW6)	10	0.43	3%
Total	117	13.83	100%

*See Figure 7 for subwatershed names and location

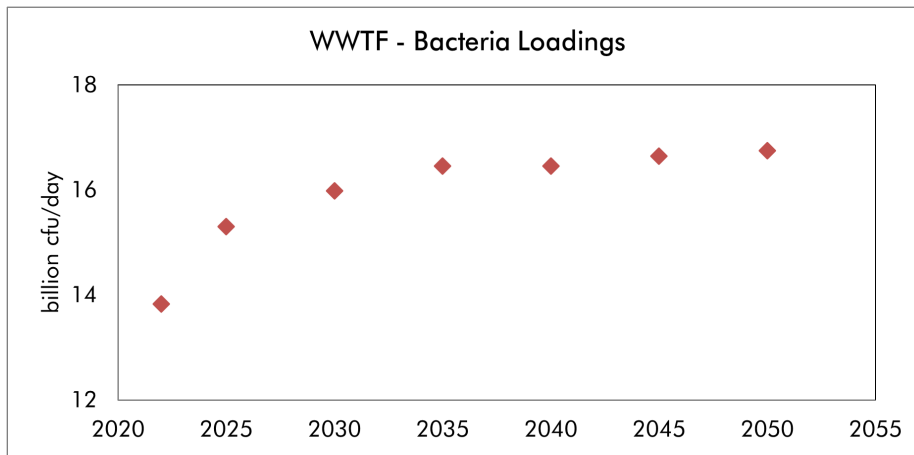


Figure 11. Future bacteria loadings from WWTFs

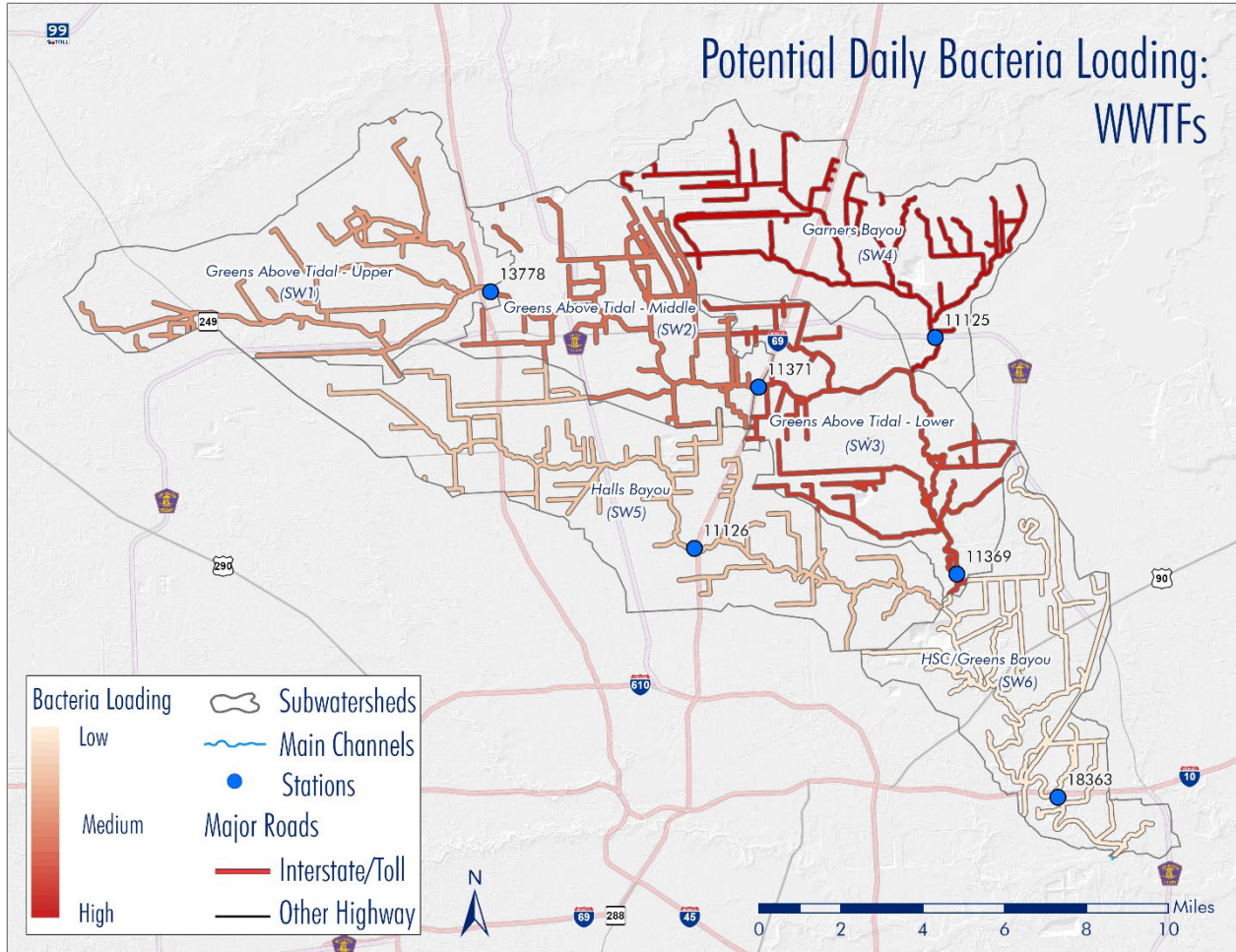


Figure 12. Bacteria loadings from WWTFs by subwatershed

On-site Sewage Facilities

While centralized wastewater treatment is more common in developed areas, OSSFs are more likely to be used in parts of the watershed outside service area boundaries such as suburban and rural communities. OSSFs, both conventional and aerobic systems, are efficient and effective ways to manage wastewater, however, aging or improperly maintained units run the risk of failing and becoming significant sources of fecal bacteria and nutrients to waterways.

OSSF distribution throughout the Greens Bayou watershed was estimated using the spatial data of permitted systems collected under a federal 604(b) grant agreement between H-GAC and TCEQ, and quality assured under the auspices of that contract³⁰. This dataset is not comprehensive as some data may be subject to insufficiencies such as a lack of geocoding. This uncertainty is accounted for in the SELECT model through an

³⁰ Use of this acquired data is detailed in the project modeling QAPP for this project available for review at <https://greensbayoupartnership.weebly.com/documents.html>.

estimation of any unrecorded or otherwise unpermitted OSSFs in the watershed area based on land use. Regardless of permit information, OSSFs throughout the watershed were estimated by assessing the number of occupied parcels outside wastewater service area boundaries. Loading rates observed from improperly maintained and failed systems were used to estimate total load contribution from OSSFs. Literature values for OSSF failure rates range between 10 and 15%³¹. Due to the history of OSSF failures in this watershed area as documented in a study by WaterEngineers, Inc. on behalf of the East Aldine Management District³², a slightly more aggressive estimate of 20% failure rate was applied to the number units indicated by the current dataset and for each of the five-year interval projections through 2050. After seeing the results of this estimate, the Partnership suggested increasing the estimated failure rate to 30%. The Halls Bayou subwatershed (SW5) is a known hotspot for failing OSSFs, so an even higher failure rate of 50% was applied to the number of OSSFs within the subwatershed's boundaries.

With these adjustments, estimated OSSF loadings are highest in the Halls Bayou subwatershed as shown in **Table 13**. In **Figure 13**, forecasted total watershed loads from OSSFs are plotted in five-year increments through the year 2050. Current OSSF loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into the Greens Bayou are represented in **Figure 14**.

As with WWTFs, understanding the potential impacts of OSSF pollution is critical to the development of the WPP as the health risks associated improperly treated human waste are far greater than those associated with other sources.

³¹ Reed, Stowe & Yanke, LLC. 2001. Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-site Sewage Facility Systems in Texas. Texas On-site Wastewater Treatment Council.

³² See: https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/2002483472_Aldine.pdf

Table 13. OSSFs and bacteria loadings in billion cfu/day by subwatershed

Subwatershed	OSSFs Outside Buffer	OSSFs Within Buffer	Load Outside Buffer in Billion cfu/day	Load Within Buffer in Billion cfu/day	Subwatershed Percent of Total Load
Greens Above Tidal - Upper (SW1)	4,268	421	1,187.57	468.57	29%
Greens Above Tidal - Middle (SW2)	390	46	108.52	51.20	3%
Greens Above Tidal - Lower (SW3)	4,152	181	1,155.29	201.45	24%
Garners Bayou (SW4)	631	40	175.58	44.52	4%
Halls Bayou (SW5)	3,695	320	1,713.56	593.60	30%
HSC Tidal/Greens Bayou (SW6)	1,466	181	407.91	201.45	10%
TOTAL	14,602	1,189	4,748.43	1,560.79	100%

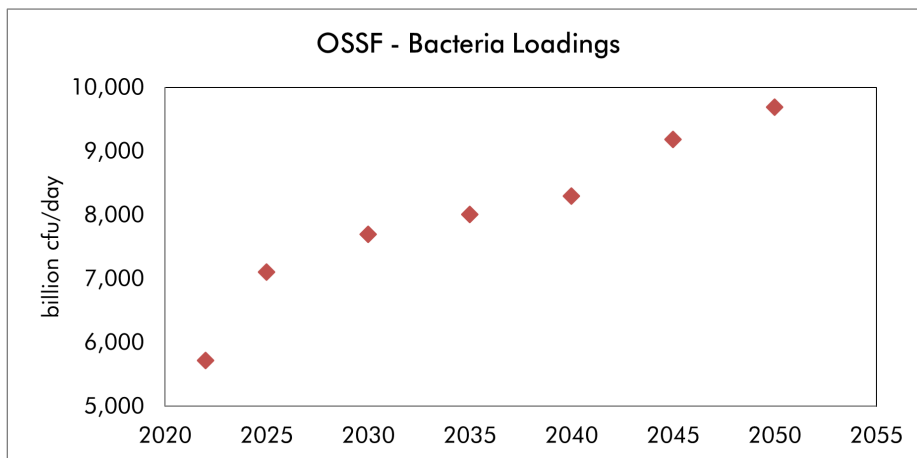


Figure 13. Future bacteria loadings from OSSFs

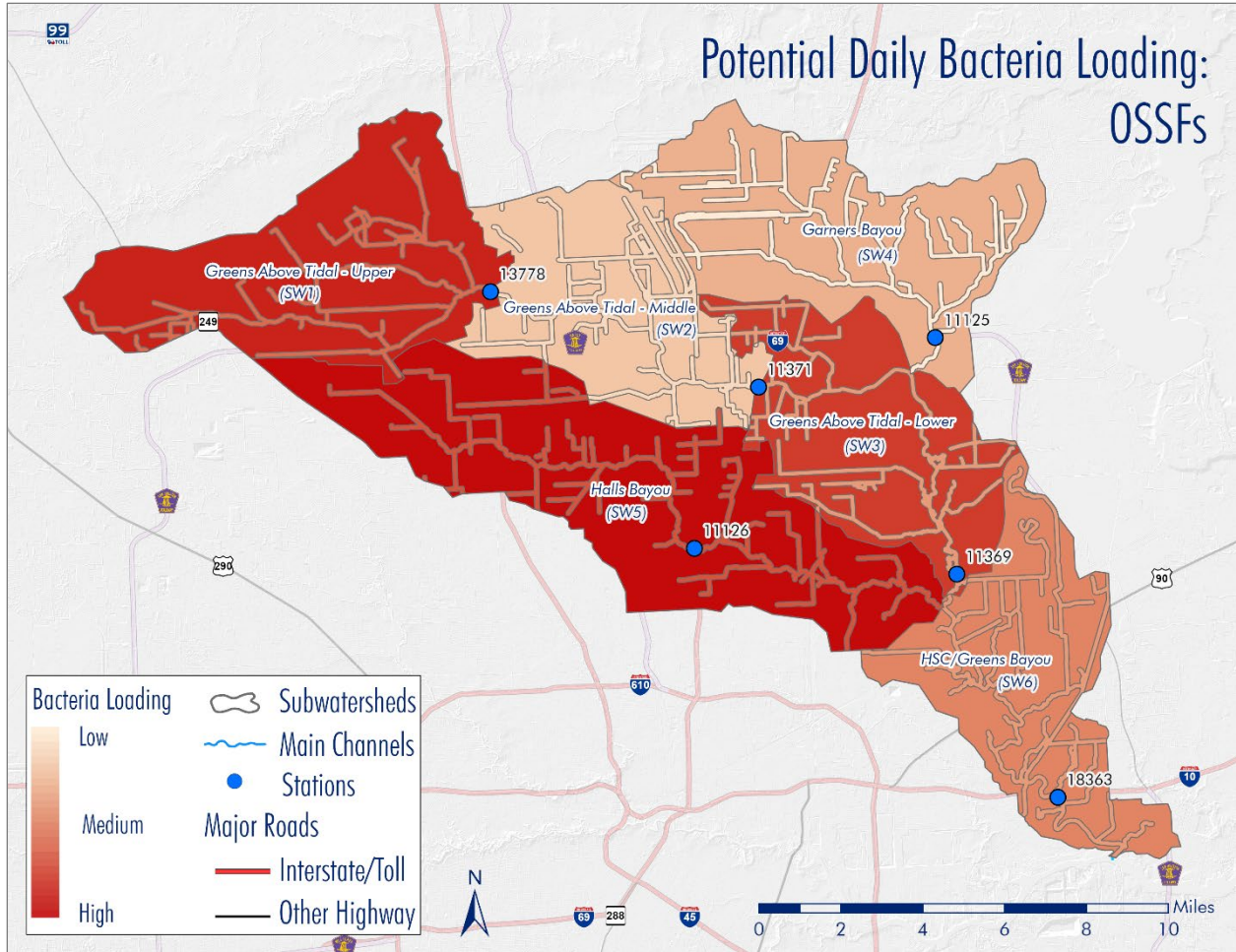


Figure 14. Bacteria loadings from OSSFs by subwatershed

Pet Waste

Domestic and feral dog populations are significant contributors to fecal bacteria contamination in densely developed areas and are a common source of loading in the greater Houston region. Waste from other domestic pets (e.g., cats) is typically managed through collection in waste receptacles, whereas dog waste is more likely to be deposited directly into the environment.

For SELECT analysis, fecal bacteria loading from dog populations was estimated by assessing pet ownership. At the time of this analysis, statistical data for Texas established by the American Veterinary Medical Association³³ estimated a density of 0.6 dogs per household. This value was applied to current household data and future projections through 2050. After seeing the results of this analysis, the Partnership suggested adjusting the household density of dogs down to 0.4. Additionally, stakeholders provided

³³ For more information, see: <https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx>

insights on recent efforts to control pet waste already underway in the watershed including development of pet waste station infrastructure and community use of waste bags. To account for this, the estimated load based on 0.4 dogs per household was further reduced by 20%. This reduction has been applied in other WPP projects.

Loading estimates by subwatershed are represented in **Table 14**. Dog ownership, and therefore dog waste, is most densely concentrated in the subwatershed of Halls Bayou. In **Figure 15**, forecasted total watershed loads from dogs are plotted in five-year increments through the year 2050. Current dog loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into the Greens Bayou are represented in **Figure 16**. As the human population of the watershed increases in the coming years, dog populations and related pollution will also increase

Table 14. Dogs and bacteria loadings in billion cfu/day by subwatershed

Subwatershed	Dogs Outside Buffer	Dogs Within Buffer	Load Outside Buffer in Billion cfu/day	Load Within Buffer in Billion cfu/day	Subwatershed Percent of Total Load
Greens Above Tidal - Upper (SW1)	16,234	1,061	8,116.80	2,121.60	29%
Greens Above Tidal - Middle (SW2)	5,527	528	2,763.40	1,056.00	11%
Greens Above Tidal - Lower (SW3)	3,616	444	1,808.20	888.00	8%
Garners Bayou (SW4)	4,606	298	2,302.80	596.00	8%
Halls Bayou (SW5)	16,967	1,255	8,483.60	2,509.60	32%
HSC Tidal/Greens Bayou (SW6)	5,628	755	2,814.20	1,509.60	12%
Total	52,578	4,340	26,289.00	8,681.80	100%

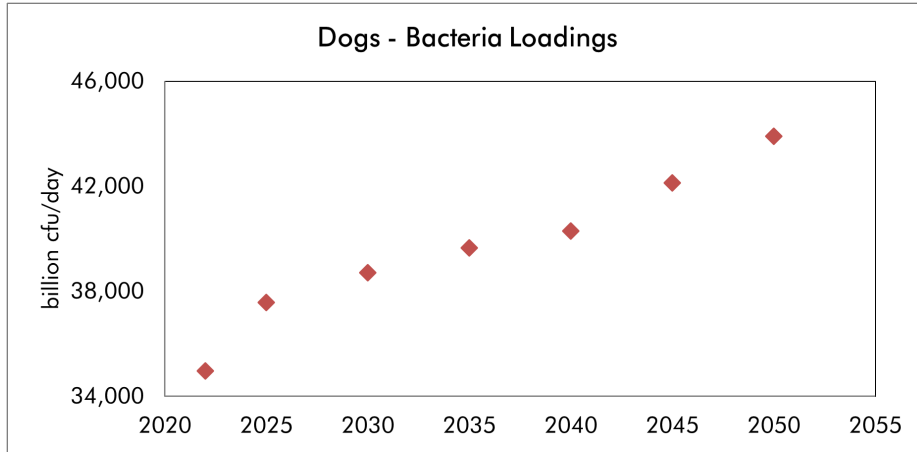


Figure 15. Future bacteria loadings from dogs

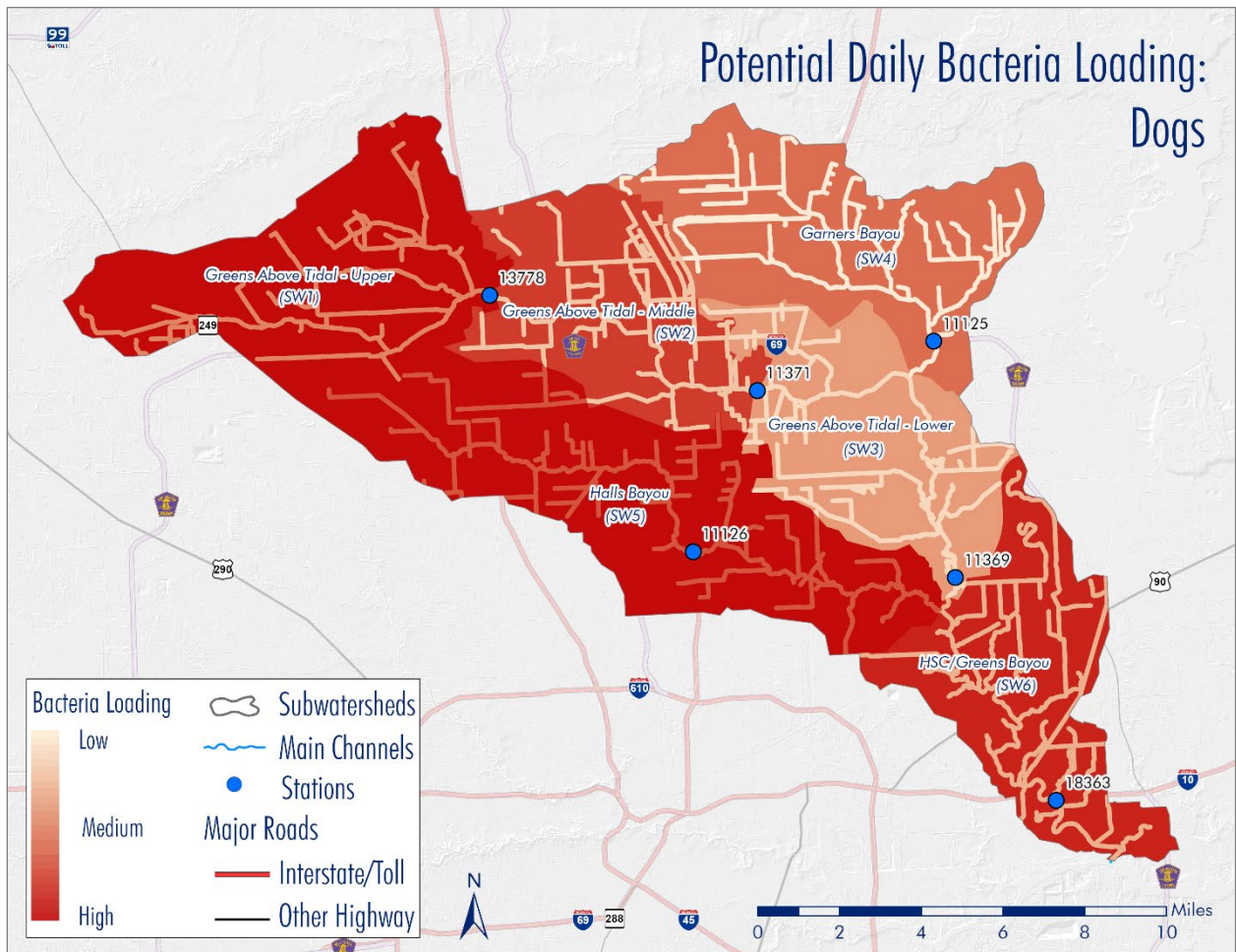


Figure 16. Bacteria loadings from dogs by subwatershed

Cattle

Cattle populations can contribute to fecal bacteria contamination in waterways through agricultural runoff and through direct deposition to the waterway. Some studies indicate that cattle fecal contamination presents a health risk comparable to that of human fecal contamination^{34, 35, 36}. Agricultural land, grassland, and pastures supporting cattle populations are most common in the western reaches of the watershed with smaller concentrated areas of these land cover types distributed throughout. National livestock populations including cattle were most recently assessed in a 2022 census by the USDA. Census data are available by county and are not specific to the watershed area. To estimate cattle in the Greens Bayou watershed, a ratio of Harris county's portion of the watershed's acreage in appropriate land cover types to that of the respective whole county was applied to agricultural census data. This approach ensures that the density of cattle in a county's applicable land cover acreage (hay/pasture) was the same as the density in the watershed's applicable land use acreage. In addition, reductions were made from the current (2022) calculation for each of the subsequent five-year intervals in order to reflect declining livestock populations observed throughout the state at a rate proportional to the difference in 2017 and 2022 agricultural census values. This adjustment is further supported by growing trends in development leading to limited availability of agricultural land in future years. More details on how the method was adjusted are described in **Appendix F**.

Loading estimates by subwatershed are represented in **Table 15**. In **Figure 17**, forecasted total watershed loads from cattle are plotted in five-year increments through the year 2050. Current cattle loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into the Greens Bayou are represented in **Figure 18**. Cattle loads from the Lower Greens Bayou Above Tidal subwatershed are greater compared to other subwatersheds due to the highest concentration of suitable land cover. Projections of future fecal bacteria loading by cattle decrease over the next 25 years. This rate of decline reflects statewide trends in decreasing livestock populations.

³⁴ See Soller et al., 2010 (<https://www.sciencedirect.com/science/article/abs/pii/S0043135410004367>)

³⁵ See Soller et al., 2014 (<https://www.sciencedirect.com/science/article/abs/pii/S0043135414005934>)

³⁶ See Munns et al., 2016 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4809568/pdf/pone.0151673.pdf>)

Table 15. Cattle and bacteria loadings in billion cfu/day by subwatershed

Subwatershed	Cattle Outside Buffer	Cattle Within Buffer	Load Outside Buffer in Billion cfu/day	Load Within Buffer in Billion cfu/day	Subwatershed Percent of Total Load
Greens Above Tidal - Upper (SW1)	45	6	30.18	15.98	11%
Greens Above Tidal - Middle (SW2)	17	9	11.39	23.02	8%
Greens Above Tidal - Lower (SW3)	91	41	61.51	110.05	42%
Garners Bayou (SW4)	59	13	39.53	33.99	18%
Halls Bayou (SW5)	24	6	16.11	15.86	8%
HSC Tidal/Greens Bayou (SW6)	36	11	24.52	28.64	13%
Total	272	86	183.24	227.54	100%

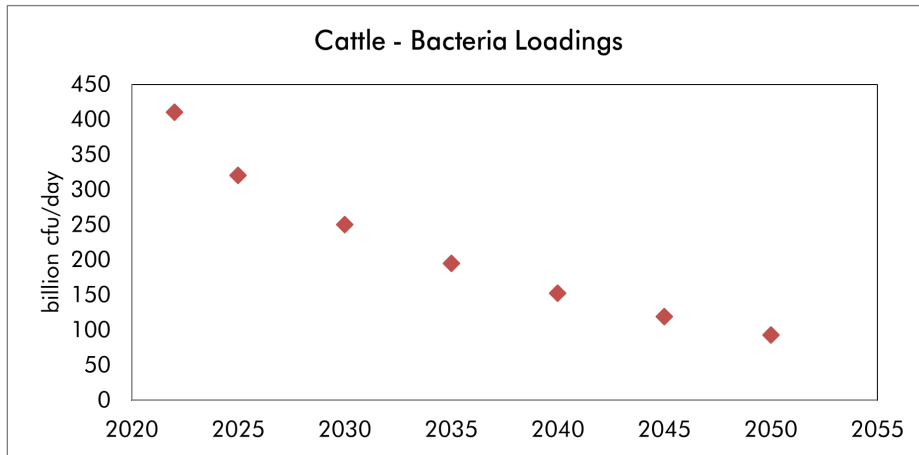


Figure 17. Future bacteria loadings from cattle

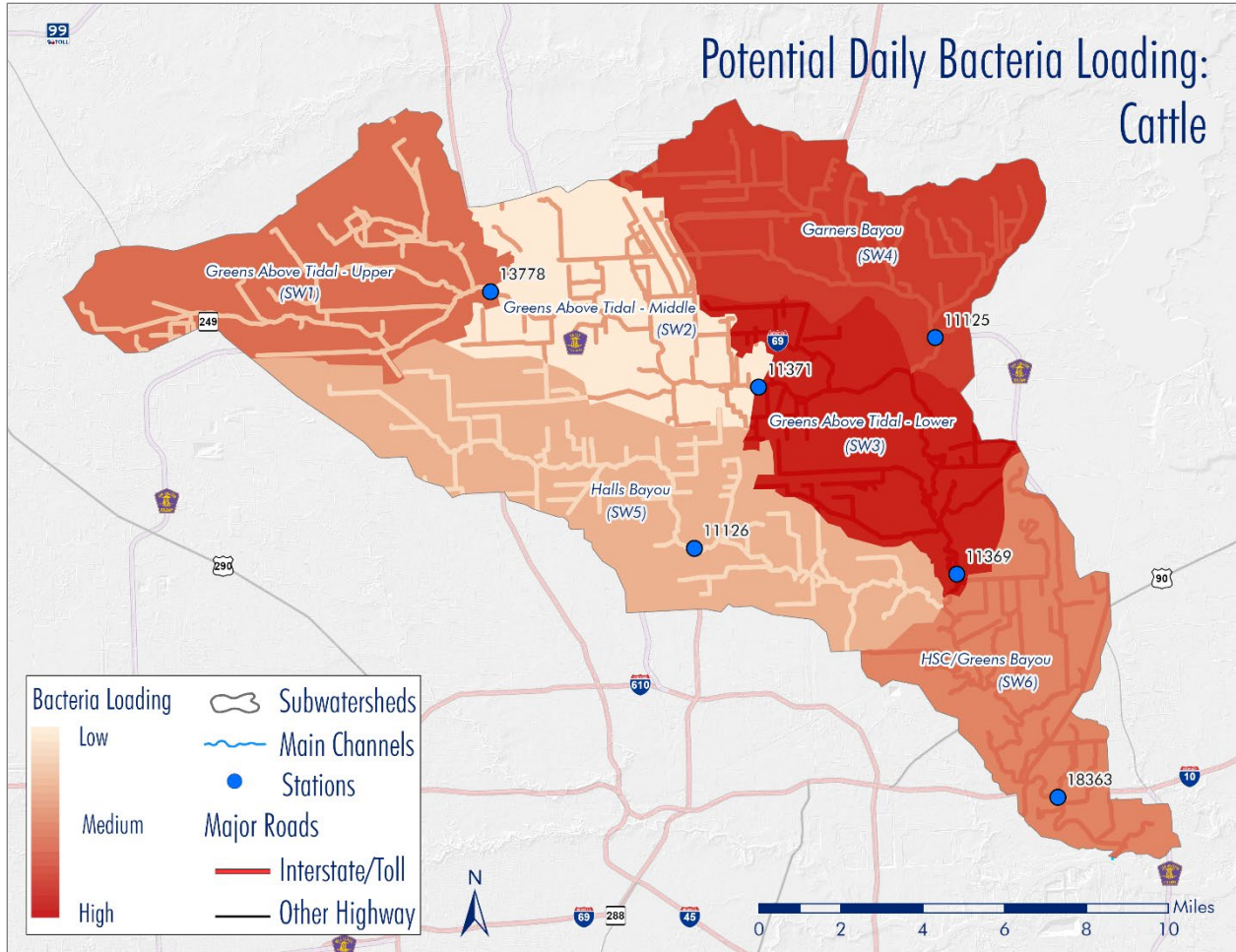


Figure 18. Bacteria loadings from cattle by subwatershed

Horses

Like cattle, horse population estimates were calculated based on agricultural census data modified by the ratio of watershed area of relevant land use types to total county area and adjusted for percent reductions proportional to those observed between 2017 and 2022 USDA census values (see **Appendix F**). This method assesses only the horses designated for livestock use in the watershed. Horses owned for recreational purposes may not be well represented by these estimates.

Loading estimates by subwatershed are represented in **Table 16**. In **Figure 19**, forecasted total watershed loads from horses are plotted in five-year increments through the year 2050. Current horse loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into the Greens Bayou are represented in **Figure 20**. As with cattle, horse bacteria loading is highest in the Lower Greens Bayou Above Tidal subwatershed. The rate of decline expected by 2050 is similar to estimations for cattle and reflects statewide trends in decreasing livestock populations.

Table 16. Horses and bacteria loadings in billion cfu/day by subwatershed

Subwatershed	Horses Outside Buffer	Horses Within Buffer	Load Outside Buffer in Billion cfu/day	Load Within Buffer in Billion cfu/day	Subwatershed Percent of Total Load
Greens Above Tidal - Upper (SW1)	10	1	0.5	0.26	11%
Greens Above Tidal - Middle (SW2)	4	2	0.19	0.38	8%
Greens Above Tidal - Lower (SW3)	19	9	1.01	1.81	42%
Garners Bayou (SW4)	12	3	0.65	0.56	18%
Halls Bayou (SW5)	5	1	0.26	0.26	8%
HSC Tidal/Greens Bayou (SW6)	8	2	0.4	0.47	13%
Total	58	18	3.01	3.74	100%

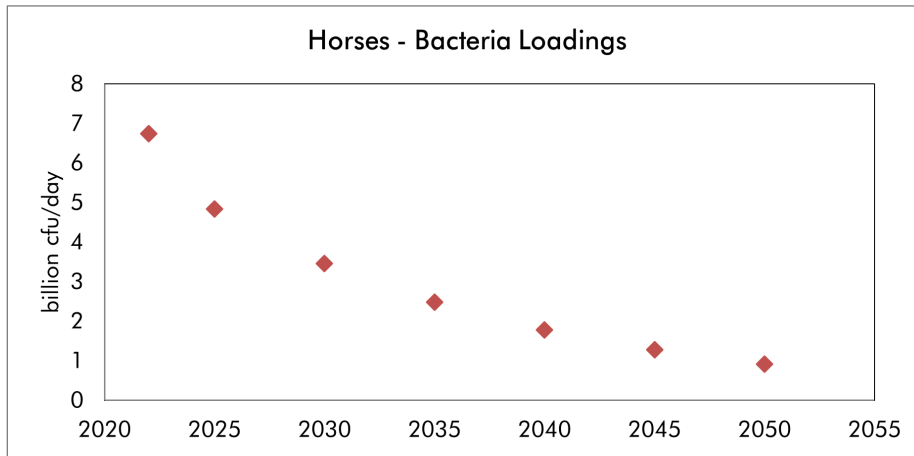


Figure 19. Future bacteria loadings from horses

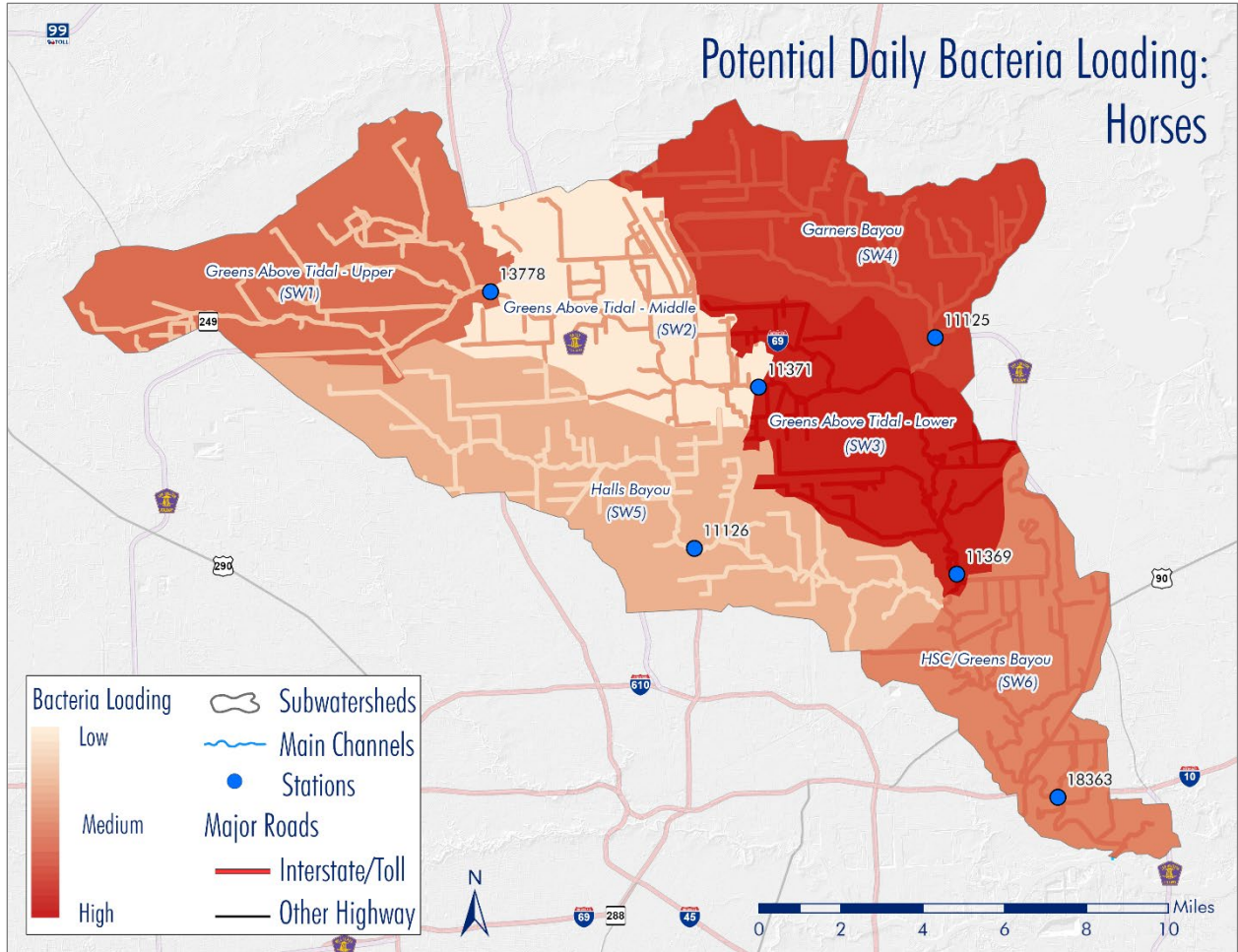


Figure 20. Bacteria loadings from horses by subwatershed

Sheep and Goats

Sheep and goat populations represent a smaller portion of the livestock in the watershed, but still retain a presence in rural areas. Both animal populations are grouped into a single statistic in the agricultural census. To estimate the size of these populations, the same method used for cattle and horses was applied to agricultural census data for sheep and goats.

Loading estimates by subwatershed are represented in **Table 17**. In **Figure 21**, forecasted total watershed loads from sheep and goats are plotted in five-year increments through the year 2050. Current sheep and goat loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into the Greens Bayou are represented in **Figure 22**. Sheep and goat bacteria loading bears a strong special similarity to cattle and horse bacteria loading with the highest concentration occurring in the Lower Greens Bayou Above Tidal subwatershed. As with other agricultural animals, sheep and goat populations are expected to decline as a result of statewide trends in decreasing livestock populations.

Table 17. Sheep and goats and bacteria loadings in billion cfu/day by subwatershed

Subwatershed	Sheep & Goats Outside Buffer	Sheep & Goats Within Buffer	Load Outside Buffer in Billion cfu/day	Load Within Buffer in Billion cfu/day	Subwatershed Percent of Total Load
Greens Above Tidal - Upper (SW1)	8	1	18	9.53	11%
Greens Above Tidal - Middle (SW2)	3	2	6.79	13.73	8%
Greens Above Tidal - Lower (SW3)	16	7	36.68	65.64	42%
Garners Bayou (SW4)	11	2	23.57	20.27	18%
Halls Bayou (SW5)	4	1	9.61	9.46	8%
HSC Tidal/Greens Bayou (SW6)	7	2	14.62	17.08	13%
Total	49	15	109.27	135.71	100%

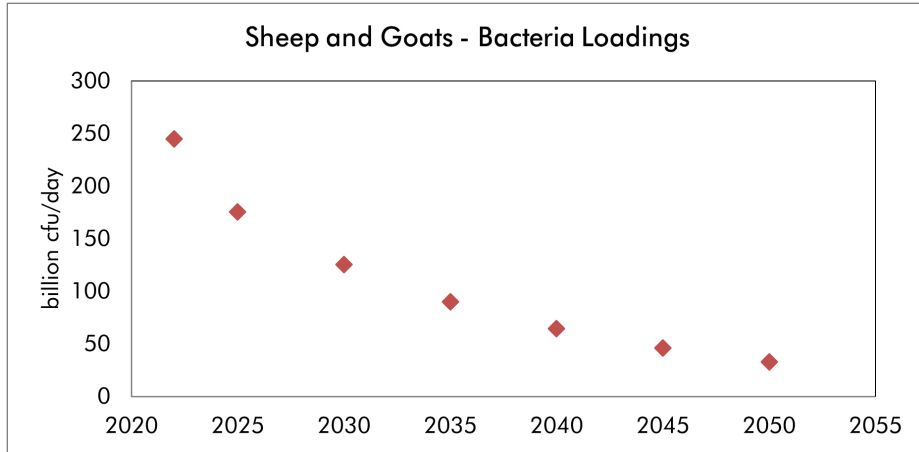


Figure 21. Future bacteria loadings from sheep and goats

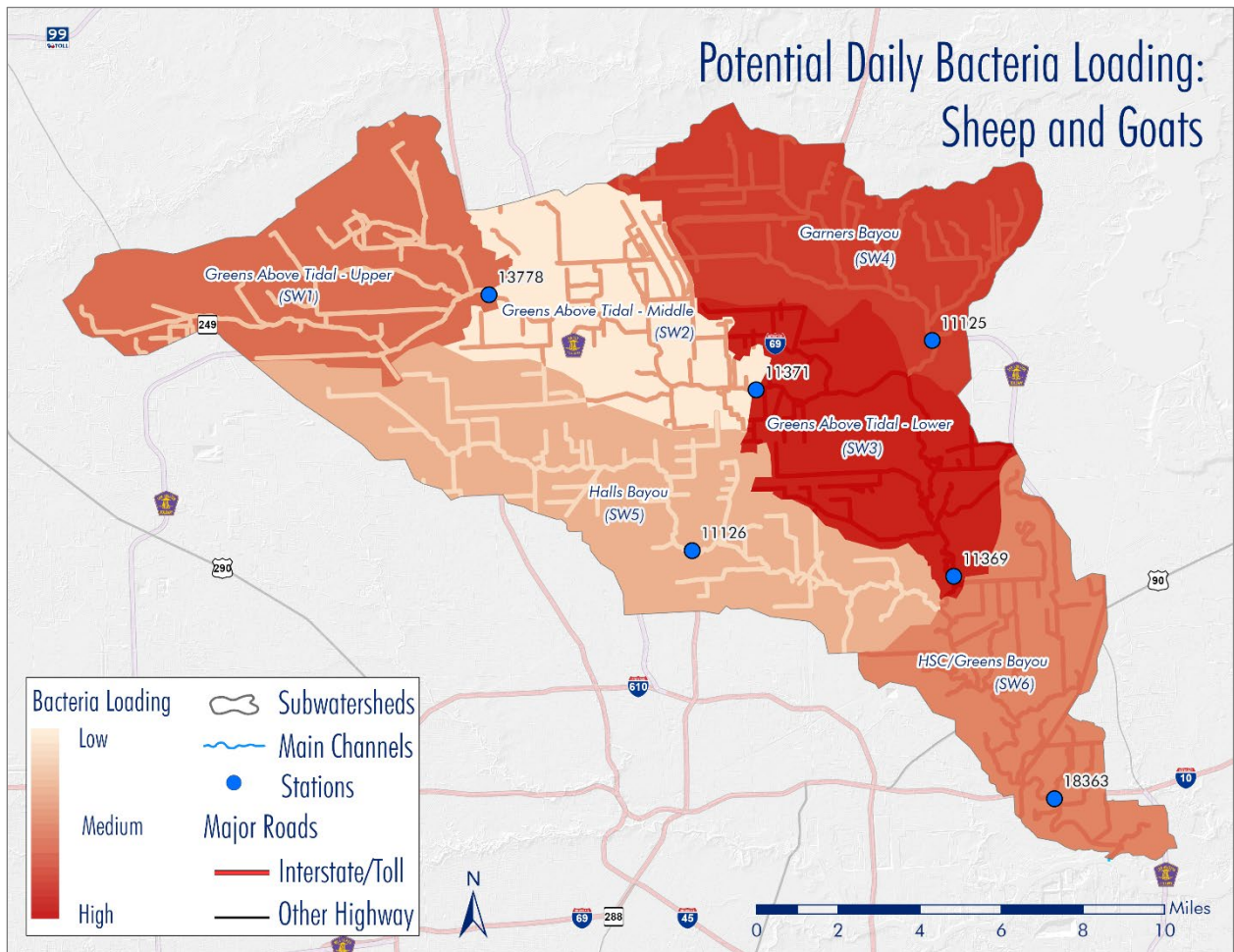


Figure 22. Bacteria loadings from sheep and goats by subwatershed

Deer

Forests and open areas in the less developed areas of the watershed provide ample habitat area for white-tailed deer. However, deer are among the few species that are adaptable to the encroachment of developed areas. Loss of natural areas may lead deer to explore larger lots of suburban and light urban development as alternative habitat. Because of this, forested areas and open and low intensity developed areas were considered as possible deer habitat for the purposes of load estimation. To estimate deer populations and their associated fecal bacteria loading potential, resource management unit population density data accessed from the TPWD³⁷ assuming one deer for every 40.2 acres of forest, shrubland and open developed areas were used. In low intensity developed areas, deer density was assumed to be one deer for every 80.4 acres. After consulting with stakeholders, this lower density of one deer per 80.4 acres was applied in additional land cover areas including pasture and grassland, wetlands, and barren land. This change was made as stakeholders agreed that deer populations are most concentrated in forested areas but noted seeing deer in areas also used by feral hog populations. Even with this updated approach, population dynamics are not well represented with respect to movements between land cover types and possible increases in density of natural areas after the built environment extends into previously undeveloped spaces.

Loading estimates by subwatershed are represented in **Table 18**. In **Figure 23**, forecasted total watershed loads from deer are plotted in five-year increments through the year 2050. Current deer loading distributions throughout the watershed as well as relative load contribution from each of the subwatersheds draining into the Greens Bayou are represented in **Figure 24**. Estimated deer bacteria loadings were highest in Garners Bayou and Lower Greens Bayou Above Tidal subwatersheds. As the SELECT model only accounts for gains and losses of fecal bacteria load pressures, migration between parcels could be underestimated. Despite their ability to adapt to more developed land areas when faced with the loss of natural habitat, deer populations in the Greens Bayou watershed are predicted to slightly decrease over time.

³⁷ Personal communication with Alan Cain, White-tailed Deer Program Leader, TPWD

Table 18. Deer and bacteria loadings in billion cfu/day by subwatershed

Subwatershed	Deer Outside Buffer	Deer Within Buffer	Load Outside Buffer in Billion cfu/day	Load Within Buffer in Billion cfu/day	Subwatershed Percent of Total Load
Greens Above Tidal - Upper (SW1)	61	8	2.66	1.44	7%
Greens Above Tidal - Middle (SW2)	43	15	1.89	2.56	8%
Greens Above Tidal - Lower (SW3)	211	50	9.22	8.75	32%
Garners Bayou (SW4)	216	38	9.44	6.64	28%
Halls Bayou (SW5)	61	5	2.68	3.22	11%
HSC Tidal/Greens Bayou (SW6)	84	25	3.65	4.38	14%
Total	676	141	29.54	26.99	100%

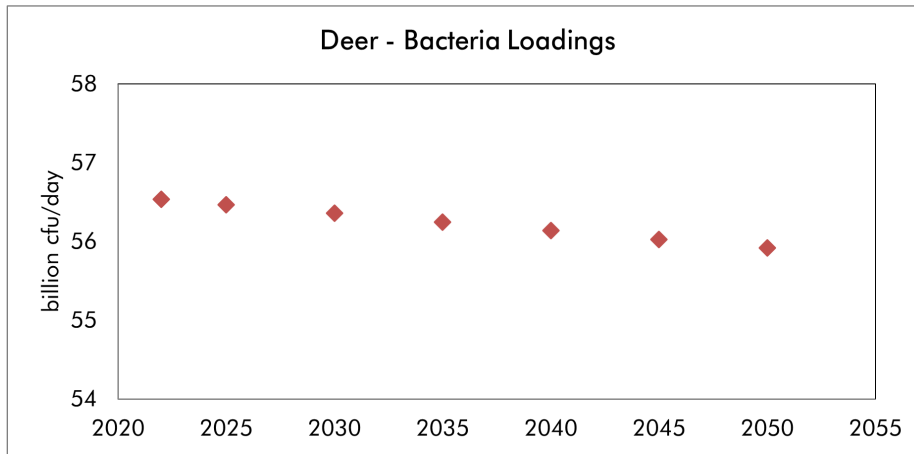


Figure 23. Future bacteria loadings from deer

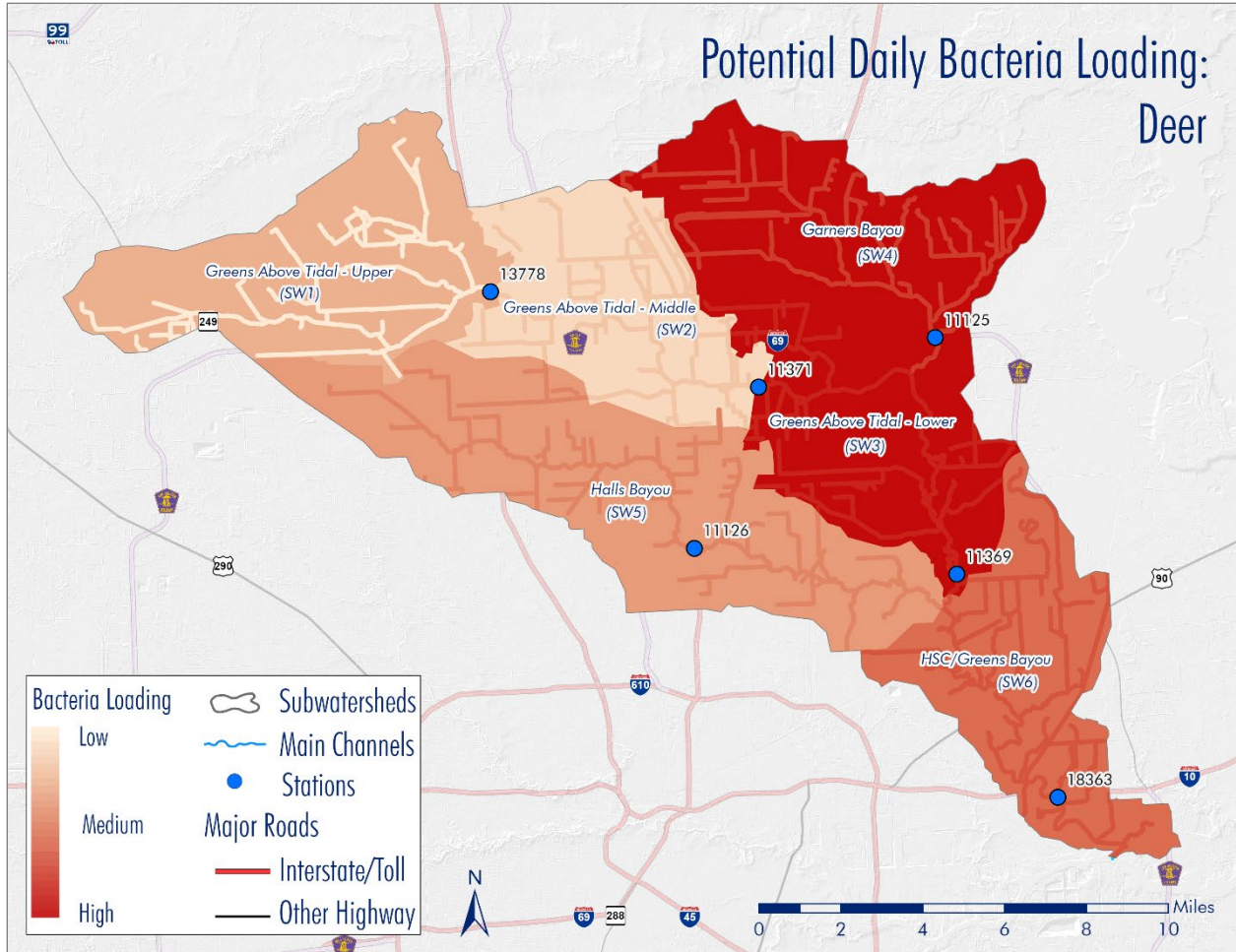


Figure 24. Bacteria loadings from deer by subwatershed

Feral Hogs

In the Houston-Galveston region feral hogs (*Sus scrofa*) are an invasive species that negatively impact agriculture, wildlife species and their habitats, and human landscapes. Efforts to control feral hogs have been carried out by communities within the Greens Bayou watershed that have already recognized the environmental pressures associated with their populations. Feral hogs are of particular concern as carriers of diseases that can be dangerous to domestic livestock, pets, and humans. These animals are known to use land around waterways as shelter and transportation corridors between food resources and can generate large volumes of waste where they concentrate.

Though they occur in the highest densities along riparian corridors and other natural areas, feral hogs are pervasive and can be found in all land cover types aside from heavily developed areas and open water. Population density estimates used in the SELECT model for feral hog source loads referenced land cover types in the watershed area based on Texas A&M University AgriLife Research (AgriLife Research) literature

values³⁸. Though initial estimates accounted for hogs in all land cover areas excluding development and open water, stakeholder feedback about observed hog behaviors and migration in the watershed led to two important changes. First, hog densities were assumed to follow a gradient from heavy densities in more natural land cover type to lighter densities with increasing proximity to development (**Table 19**). Second, though no feral hog populations were assumed outside the riparian buffer in medium and high intensity developed areas, half of the lowest density estimate was applied within the riparian buffer in those land types.

Table 19. Feral hog population density by land cover type

Land Cover Type	# Hogs per Square Mile Outside Buffer ¹	# Hogs per Square Mile Inside Buffer ²
Wetlands	16.4	16.4
Forest and Shrubland	16.4	16.4
Grassland	16.4	16.4
Pasture	12.7	12.7
Cultivated Cropland	12.7	12.7
Barren Land	12.7	12.7
Developed Open Space	8.9	8.9
Low Intensity Developed	8.9	8.9
Medium Intensity Developed	None	4.45
High Intensity Developed	None	4.45

¹ In SW3 and SW4, the highest density (16.4 per square mile) was used in all land cover types except medium and high intensity developed areas outside the riparian buffer

² In SW3 and SW4, the highest density (16.4 per square mile) was used in all land cover types inside the riparian buffer

After reviewing the results of initial calculations referencing Table 19, the Partnership suggested increasing the estimated density of feral hogs within the Garners Bayou (SW4) and Lower Greens Bayou Above Tidal (SW3) subwatersheds to the maximum (16.4 per square mile) in all land cover types except medium and high intensity development outside the buffer, and all land cover types including medium and high intensity development within the buffer.

Loading estimates by subwatershed are represented in **Table 20**. In **Figure 25**, forecasted total watershed loads from feral hogs are plotted in five-year increments through the year 2050. Current feral hog loading distributions throughout the watershed as well as

³⁸ For more information, see:

<http://agrillife.org/feralhogs/files/2010/04/FeralHogPopulationGrwothDensityandHervestinTexasedited.pdf>

relative load contribution from each of the subwatersheds draining into the Greens Bayou are represented in **Figure 26**. Potential fecal bacteria loading by feral hogs was estimated to be highest in the Garners Bayou and Lower Greens Bayou Above Tidal subwatersheds. Future projections of feral hog loads predict a steady decline in magnitude as time progresses. However, the SELECT model does not account for the adaptability of feral hog populations that have anecdotally been observed to redistribute or condense when faced with the loss of their preferred habitats. Therefore, without literature support or evidence from local stakeholders, the estimates presented in this SELECT model should be considered conservative.

Table 20. Feral hogs and bacteria loadings in billion cfu/day by subwatershed

Subwatershed	Feral Hogs Outside Buffer	Feral Hogs Within Buffer	Load Outside Buffer in Billion cfu/day	Load Within Buffer in Billion cfu/day	Subwatershed Percent of Total Load
Greens Above Tidal - Upper (SW1)	104	33	142.73	182.43	11%
Greens Above Tidal - Middle (SW2)	55	32	75.28	174.15	9%
Greens Above Tidal - Lower (SW3)	211	78	290.6	429.82	25%
Garners Bayou (SW4)	205	81	281.75	444.45	25%
Halls Bayou (SW5)	146	44	200.99	244.15	16%
HSC Tidal/Greens Bayou (SW6)	109	47	149.24	260.28	14%
Total	830	315	1140.59	1735.28	100%

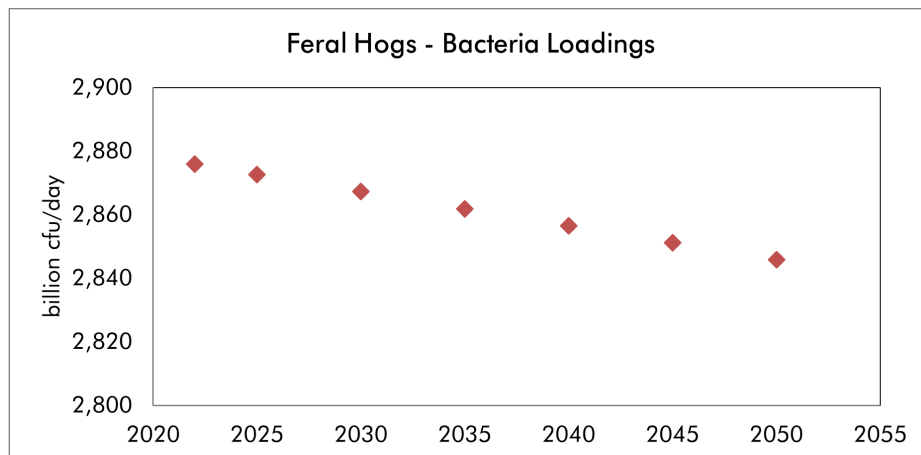


Figure 25. Future bacteria loadings from feral hogs

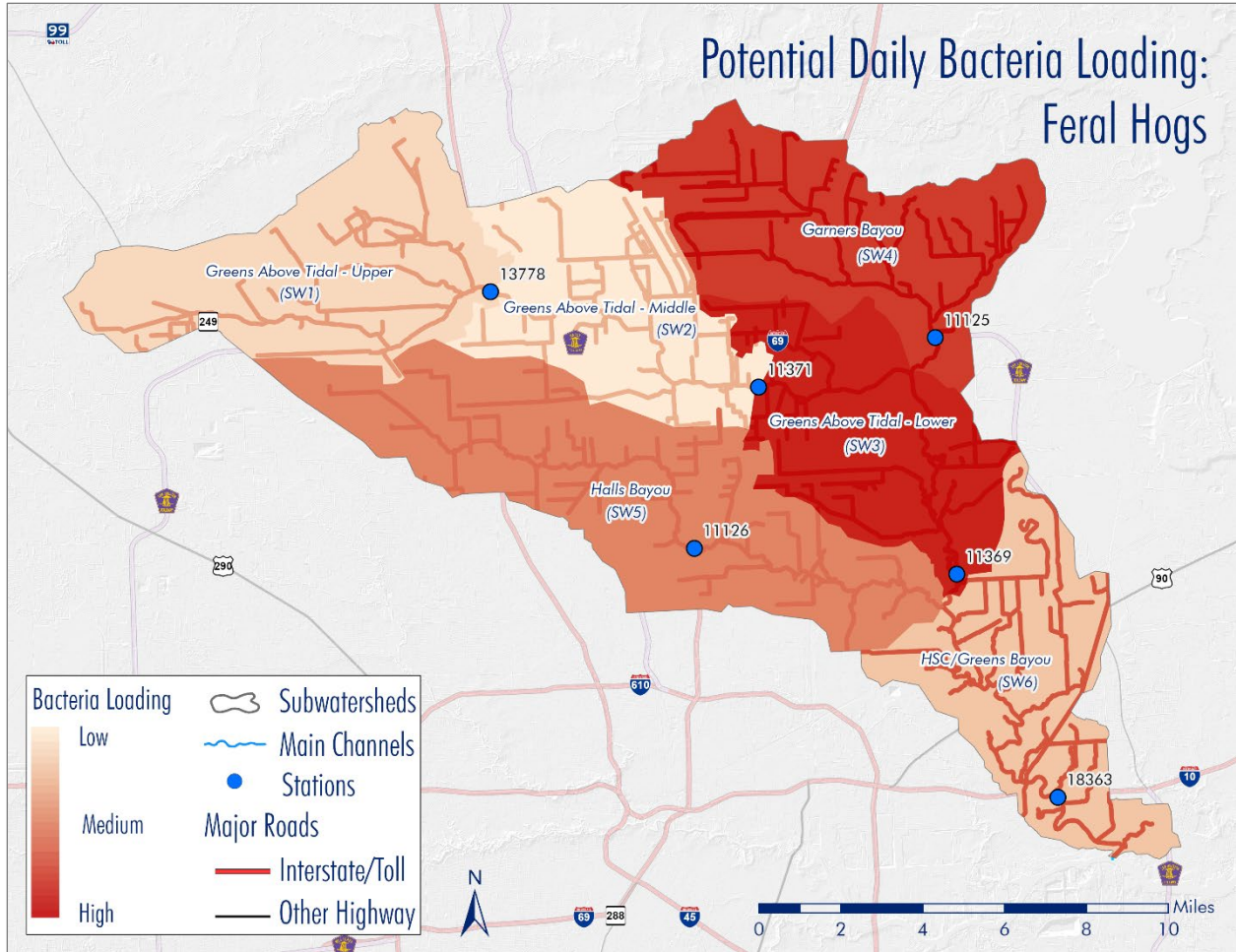


Figure 26. Bacteria loadings from feral hogs by subwatershed

Other Sources of Fecal Waste

Other sources that are not specifically included in the SELECT estimates are still potential targets of mitigation as part of the WPP, especially on a localized scale, depending on the source being discussed. While some of the wildlife populations discussed were not specifically modeled, their contributions are included in this project in the 10% other sources load estimate.

- **SSOs**

Though SSOs occur episodically, they represent a high-risk vector for fecal bacteria contamination because they can have concentrations of fecal bacteria several orders of magnitude higher than treated effluent. Untreated sewage can contain large volumes of raw fecal waste, making it a significant health risk where SSOs are sizeable or chronic issues. Events are self-reported and may vary in quality. Descriptions of frequencies, causes, durations, and volumes of SSOs may be subject to logistical inadequacies such as unknown duration of discharge, and inability to accurately gauge discharge volume. Actual SSO volumes and

incidences are generally expected to be greater than reported due to these fundamental challenges.

After reviewing data compiled in SSO reports submitted by permit holders in the Greens Bayou watershed³⁹, SSO events were not found to follow any specific spatial, seasonal, or annual pattern. Blockages accounted for the highest number of events respective to the other general categories of weather, malfunctions and unknown causes. Extreme weather events contributed to the highest volume of SSOs between 2020 and 2024.

Due to the episodic nature and spatial inconsistency of SSO events, fecal bacteria load from this source is not expected to have an appreciable long-term impact on the overall loading for the watershed and was excluded from SELECT model analysis. Though the estimations of SSO impacts in this watershed are not represented by SELECT models, they are no less important to consider in the overall assessment of fecal bacteria loading. The most extreme method of estimating fecal bacteria loads from SSOs would be to calculate loading based on EPA literature values⁴⁰ suggested for general causes related to each event multiplied by the highest observed volumes of discharge recorded for each cause. A more conservative method would be to calculate the average daily volume of discharge and use that as the multiplier for cause related load estimates. In other area watershed projects, stakeholders elected to refrain from the aforementioned calculations and treat SSOs as a separate, high-priority item for inclusion in the management strategies outlined in the WPP. SSO data regarding unique events impacting stream segments within the watershed area over the most recent five years of reports provided by TCEQ were used in these assessments. The Greens Bayou watershed stakeholders elected to adopt this method as well.

- **Human Waste – Direct Deposition**

In other watershed projects, potential impacts from unhoused communities and areas not serviced by centralized or localized wastewater treatment were considered. Based on stakeholder feedback, the populations represented by these groups were not found to be large enough to have appreciable impact.

- **Land Deposition of Sewage Sludge**

In the event that improper use of manure spreading or violations of sludge application have occurred in the watershed area, action would be required to

³⁹ For more detail, see the Water Quality Data Analysis Summary Report on the project website at: https://greensbayoupartnership.weebly.com/uploads/1/3/0/7/130710643/50226_3.3_prelimwqdataanalysesreport_final.pdf

⁴⁰ As referenced at: https://www3.epa.gov/npdes/pubs/csossoRTC2004_AppendixH.pdf

intervene and reduce the resulting fecal bacteria loading impacts. No such activity is known in the Greens Bayou watershed; however, these impacts would likely be addressed in BMPs for agricultural sources of pollution.

- **Concentrated Animal Feeding Operations (CAFO)s**

No active CAFOs are in operation within the Greens Bayou watershed.

- **Birds**

The greater Houston area is well known as part of the great Central Flyway migration path used by various bird populations. Many migratory bird species only utilize the land area for short periods of time while in transit, but migratory waterfowl and resident species represent longer-term populations, especially in coastal marshes. Similar watershed projects have evaluated the potential impact of waterfowl in terms of duration, potential fecal bacteria load, and other considerations, and found them to not be significant sources to be modeled. Colonial birds such as swallows have been identified by other watershed projects as potential sources of fecal bacteria load. Unfortunately, little or no data are available to characterize the impacts of fecal bacteria loading from colonial bird sources or to implicate colonial bird influenced fecal bacteria loading as a significant health risks to the watershed community. Beyond lack of data, relatively small fecal bacteria loads and health risks associated with bird waste compared to human sources further reduce the significance of bird waste impacts. General lack of management strategies available to deal with wild birds have limited the emphasis of this source as a meaningful component of management efforts in similar projects.

- **Bats**

Though bats are present in the watershed area, only large colonies of these animals are estimated to have an appreciable impact on water quality. No known nesting sites of significant size or density have been indicated in the Greens Bayou watershed.

- **Other Sources/Wildlife**

Specific data for wildlife such as coyotes, opossums, rodents, wild cats, skunks, raccoons, and other mammals are not widely available. Similar watershed projects have recognized these wildlife animals as potentially appreciable contributors to fecal bacteria loads but lacked a reasonable method for quantifying their potential impacts. One method of improving understanding of wildlife impacts in the Greens Bayou watershed would be to implement fecal bacteria source tracking or assessments of genetic material found in waterways to

identify species depositing fecal waste in and around water bodies. Data collected with this method in other watersheds showed that wildlife impacts are significant⁴¹ and should be incorporated into fecal bacteria reduction strategies. As no such data are presently available for the watershed area of the Greens Bayou, the understanding of wildlife species in this watershed will be largely informed by anecdotal information provided by stakeholders and general estimations decided by stakeholder input. In a nearby watershed project on Clear Creek, a novel approach assumed wildlife impacts to be equivalent to a conservative 20% of the other modeled loads assessed in the watershed. The value was generated by finding the total for all quantified sources in all subwatersheds, setting that total as 80% of the total load, and then assuming other sources/wildlife to be the other 20%. The stakeholders of the Greens Bayou watershed also elected to employ this method. However, to reflect the likelihood of loss of wildlife habitat as development expands in the watershed, stakeholders opted not to assume a consistent additional 20% contribution from wildlife in projections for 2025 onward. Rather, the 2022 20% calculated value was repeated in all subsequent projections. Stakeholders reviewed these results and agreed that other sources/wildlife are an important component of bacteria loading in the Greens Bayou but were reluctant to attribute a firm percentage to their influence. However, recognizing that sources beyond wildlife with little data for quantification estimates are at play in this watershed, stakeholders opted to retain this 20% addition to the total estimated load and refer to it more generally as other sources/wildlife.

- **Cats**

Domestic dogs are included in the SELECT model analysis as a concern of particular interest to the watershed due to the likelihood of improperly managed dog waste deposited outdoors making its way to streams via runoff. Domestic cat waste management, however, is typically handled indoors and restricted to litter boxes. Therefore, pet waste from cats was not estimated as part of this project. Feral cats, however, can be a local source when found in sufficiently dense urban populations, though very little data exists to quantify these impacts. Generally, impacts from feral cats may be accounted for in other loading assumptions such as diffuse urban stormwater or as part of the impacts from other sources/wildlife.

- **Dumping**

⁴¹ 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>) and a similar analysis (<https://oaktrust.library.tamu.edu/handle/1969.1/149197>) conducted for the Lampasas and Leon Rivers showed comparable results.

Illegal dumping is not typically a widespread or appreciable contributor to fecal bacteria loads in watersheds as these events occur locally or episodically. Dumping will still be important for stakeholders to consider addressing in the WPP in terms of aesthetic and other regulatory issues.

Summary of Fecal Indicator Bacteria Source Modeling Results

SELECT analyses indicated the highest loads from the total mix of modeled sources are concentrated in the Halls Bayou subwatershed because of pressures from dog waste and OSSFs (

Table 21). There is also a pronounced concentration of loading in the Upper Greens Bayou Above Tidal subwatershed associated with the same pressures.

Without taking action to reduce fecal bacteria sources in the watershed, loads will continue to increase by 2050 (**Table 22**).

Proportions of each source considered in this analysis as part of a total estimated load are shown in **Figure 27** and **Figure 28** for 2022 and 2050, respectively.

Table 21. Current bacteria loadings in billion cfu/day by source and subwatershed

Source	Greens Above Tidal - Upper (SW1)	Greens Above Tidal - Middle (SW2)	Greens Above Tidal - Lower (SW3)	Garners Bayou (SW4)	Halls Bayou (SW5)	HSC Tidal/Greens Bayou (SW6)	% Total Load
OSSFs	1,656.14	159.72	1,356.75	220.10	2,307.16	609.37	11.00%
WWTFs	2.38	2.41	2.79	4.73	1.09	0.43	0.00%
Dogs	10,238.40	3,819.40	2,696.20	2,898.80	10,993.20	4,323.80	62.00%
Cattle	46.16	34.41	171.56	73.52	31.98	53.16	1.00%
Horses	0.76	0.56	2.82	1.21	0.52	0.87	0.00%
Sheep & Goats	27.53	20.52	102.32	43.85	19.07	31.70	1.00%
Deer	4.09	4.45	17.97	16.08	5.90	8.03	0.00%
Other Sources/Wildlife	3,075.16	1,072.73	1,267.71	996.12	3,451.02	1,359.22	20.00%
Feral Hogs	325.17	249.43	720.42	726.20	445.14	409.52	5.00%
Total	15,375.79	5,363.65	6,338.53	4,980.60	17,255.08	6,796.11	100.00%
% per SW	27.00%	10.00%	11.00%	9.00%	31.00%	12.00%	100.00%

Table 22. Bacteria loadings in billion cfu/day by source for all milestone years

Source	2022	2025	2030	2035	2040	2045	2050
OSSFs	5,715.63	7,103.26	7,698.44	8,011.84	8,295.65	9,184.94	9,692.00
WWTFs	13.83	15.30	15.99	16.46	16.46	16.64	16.75
Dogs	34,969.80	37,582.60	38,712.80	39,648.00	40,286.60	42,130.60	43,902.80
Cattle	410.79	320.65	250.29	195.37	152.50	119.04	92.92
Horses	6.74	4.84	3.47	2.49	1.78	1.28	0.92
Sheep/ Goats	244.99	175.48	125.69	90.02	64.48	46.18	33.08
Deer	56.54	56.47	56.36	56.25	56.14	56.03	55.92
Feral Hogs	2,875.87	2,872.63	2,867.24	2,861.86	2,856.51	2,851.17	2,845.86
Other Sources/ Wildlife	11,073.55	11,073.55	11,073.55	11,073.55	11,073.55	11,073.55	11,073.55
Total	55,367.75	59,204.78	60,803.82	61,955.84	62,803.67	65,479.44	67,713.79

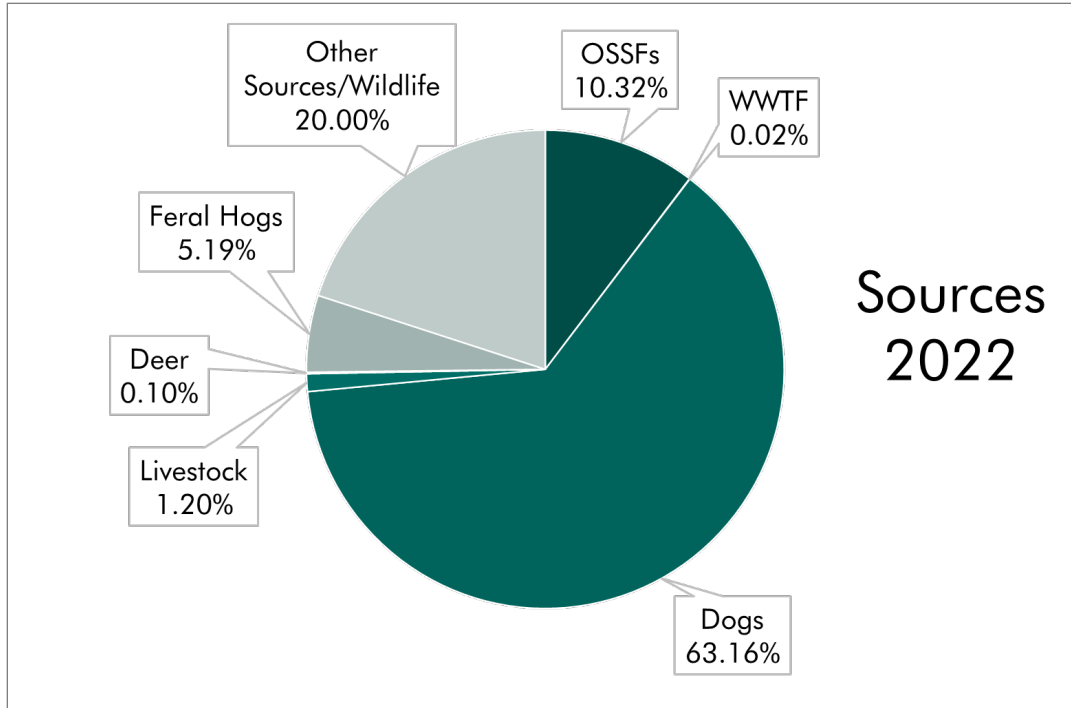


Figure 27. Bacteria source profile, 2022

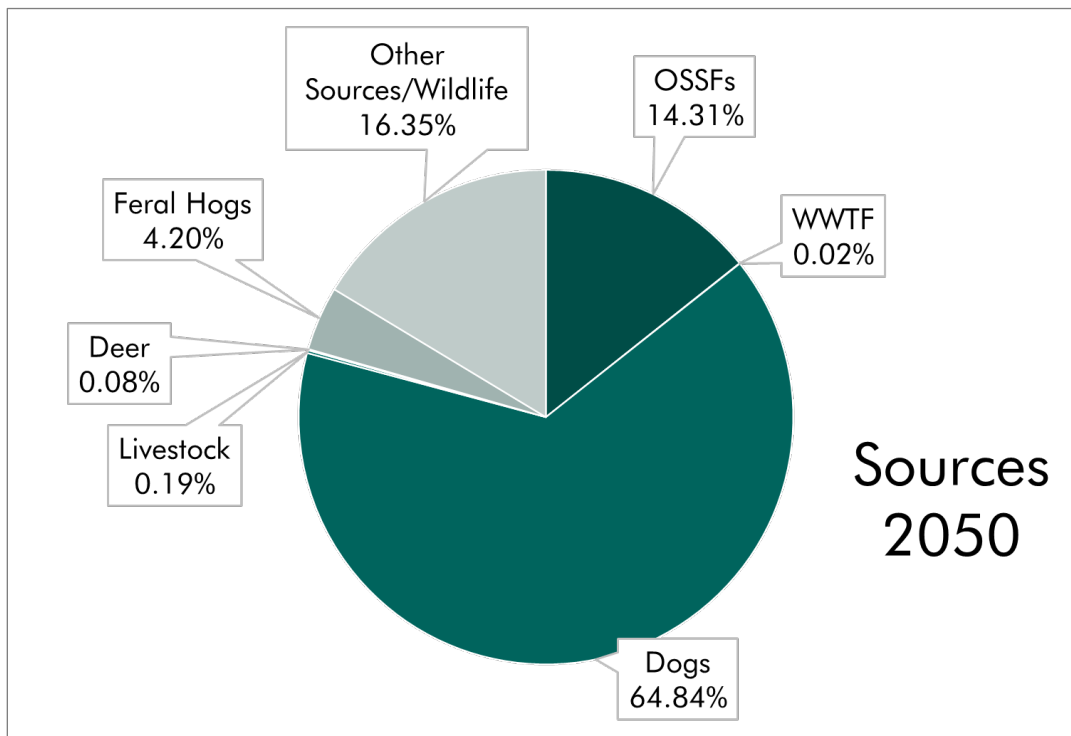


Figure 28. Bacteria source profile, 2050

Implications of Fecal Waste Source Characterization Findings

The results of SELECT models generated for this report indicate different causes of fecal bacteria in different areas of the watershed dictated by a complex mix of sources, which are predicted to shift in coming years. Among these sources, pet waste was determined to be the dominant pollutant in both current and projected scenarios. The increasing loads highlight the need for intervention through the WPP and other means. Current water quality issues will be compounded by future loads, leading to degrading water quality through the planning period absent any effort to the contrary.

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

Other Concerns

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

Trash

Trash in the waterways was considered as a concern, especially in denser urban areas of the downstream watershed, where trash enters through stormwater and sheet flow. Project staff identified ongoing efforts in the watershed that would be important points of coordination, with the intent of including trash in water quality conversations, and vice versa.

Flooding

The potential use of natural infrastructure as supplement to flood mitigation projects, the conservation of open space, and the inclusion of water quality concerns in flood project design are all areas of needed coordination during the implementation of this WPP.

Section 4

Improving Water Quality



Photo Credit: Rachel Windham

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. The Partnership conducted a water quality modeling effort⁴² to determine the amount of improvement needed for fecal indicator bacteria. The purpose of this effort was to establish how much fecal indicator bacteria needed to be reduced to meet the SWQS. LDCs were used in combination with 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 subwatersheds were identified within the total watershed. Unique improvement goals were generated specific to the magnitude and composition of pollutant sources estimated for each subwatershed.

Load Duration Curves for Fecal Indicator Bacteria

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 data (see Section 3) to determine the difference between observed levels of pollutants in a waterway and the levels at which the applicable water quality standards would be met, which 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, which 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 an LDC, which shows how the actual load of a pollutant in the water changes in different flow situations (an example LDC is shown in **Figure 29**). 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 LDC line exceeds the maximum allowable load curve line indicate that the standard is not being met in those flow conditions. If exceedances are primarily observed in low flow conditions, point sources such as direct flow from outfalls are likely drivers of pollution. This is because even without natural flows or storm conditions leading to runoff, a direct source such as an outfall is contributing to high surface water concentrations of bacteria. If exceedances are observed primarily in high flow conditions, nonpoint sources which are more diffuse and harder to trace but are

⁴² For greater detail on the modeling for *E. coli* discussed in this section, please refer to the Bacteria Modeling Report on the project website at: https://eastforkpartnership.weebly.com/uploads/1/3/0/7/130710643/30143_4.3_bacteria_modeling_report_final.pdf

likely to be delivered to the waterway in storm events via runoff can drive the trend in pollution. Point sources may still be contributing to pollution during high flow conditions, but could be masked by a strong nonpoint source influence. In situations where there is a mix of flow conditions related to exceedances, or in which contaminants exceed the allowable limit in all conditions, a mix of point and nonpoint sources is likely. The amount in which the observed loads exceed the allowable loads is the basis for developing improvement goals.

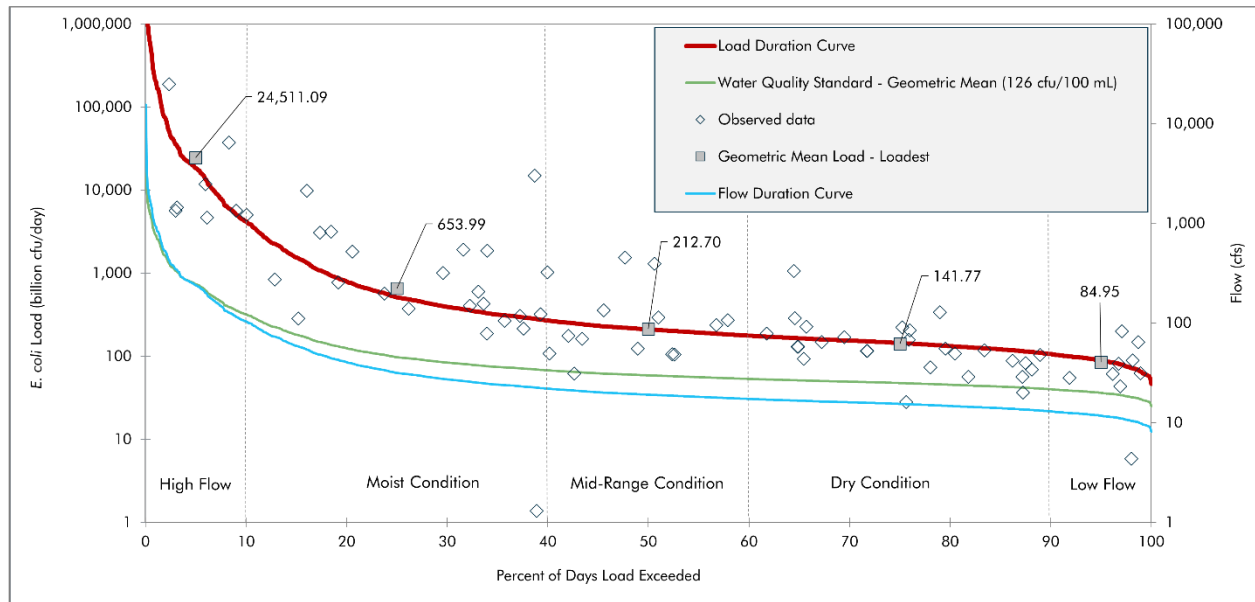


Figure 29. Example of an LDC for fecal indicator bacteria

Data Development

Project staff developed LDCs for fecal indicator bacteria at several monitoring stations throughout the Greens Bayou watershed to identify which flow conditions demonstrated exceedance, and generate goals for fecal indicator bacteria reduction.

Site Selection

Site selection for LDCs was based on support for several considerations, including known water quality conditions⁴³, the need for long-term assessment of progress toward the water quality standard, projected needs for BMP siting decisions, and stakeholder input.

- *Known Water Quality Conditions* — Based on a review of historical ambient water quality trends, WWTF DMRs, and SSO information, water quality in the project watershed indicated that conditions in the assessed tributaries and main channel

⁴³ For more information, see the Water Quality Data Analysis Summary Report on the project website at: https://eastforkpartnership.weebly.com/uploads/1/3/0/7/130710643/30143_3.2_acquired_data_analysis_report_final.pdf

both had a degree of variability and potential for continued exceedance. A single station would not be representative of the variability of conditions based on the water quality review. Therefore, several LDC locations were chosen to represent varying conditions along the waterway. One station on each AU with an impairment or concern was selected to assess water quality throughout the watershed. This design allowed 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 sufficient periods of record and continued data availability, locations of monitoring data used for LDC analyses were selected based on their periods of record, water quality conditions, availability of corresponding stream flow data, and representativeness of smaller drainage areas within the greater watershed known as subwatersheds. Data from CRP stations and associated USGS gages (**Table 23** and **Figure 30**) selected for LDC analysis include:
 - **Greens Above Tidal - Upper (SW1)** – the drainage area of Assessment Unit (AU) 1016_01, the upper third of Greens Bayou Above Tidal. Like the rest of the subwatersheds, land cover in this subwatershed is densely developed. This waterbody represents the headwaters of Greens Bayou Above Tidal. This area is represented by Station 13778 (Greens Bayou at Knobcrest Drive) and stream flow was assessed from USGS gage 08075900.
 - **Greens Above Tidal - Middle (SW2)** – the drainage area of AU 1016_02, the middle third of Greens Bayou Above Tidal. This area is represented by USGS gage 08076000 which was used to measure flow at Station 11371 (Greens Bayou at US 59).
 - **Greens Above Tidal - Lower (SW3)** – the drainage area of AU 1016_03, the lower third of Greens Bayou. While still a heavily developed area, forest and wetland land cover types are more prevalent compared to other subwatersheds. This area is represented by Station 11369 (Greens Bayou at Tidwell Road). This station is not represented by a USGS gage, but because it occurs on the same water body as a gaged station (11371), stream flow was estimated by applying a drainage area ratio⁴⁴. To do this, the drainage area

⁴⁴ See Appendix 1 in Asquith, W., Roussel, M., and Vrabel, J. 2006. Statewide analysis of the drainage-area ratio method for 34 streamflow percentile ranges in Texas (No. 2006-5286). USGS. 51 pp.: <https://pubs.usgs.gov/sir/2006/5286/pdf/sir2006-5286.pdf>

of 11371 was compared to that of 11369 to determine a ratio to use as a multiplier for daily mean stream gage measurements taken at 11371.

- **Garners Bayou (SW4)** – the drainage area of Segment 1016A, which is made up of the full length of Garners Bayou. While still a heavily developed area, forest and wetland land cover types are more prevalent compared to other subwatersheds. Ambient data for this area are represented by Station 11125 (Garners Bayou at SH Loop 8). This station is represented by USGS gage 08076180.
 - **Halls Bayou (SW5)** – the drainage area of Halls Bayou (Segment 1006D), a tributary to Greens Bayou. Ambient data for this area are represented by Station 11126 (Halls Bayou at Jensen Drive). This station is represented by USGS gage 08076500.
 - **HSC Tidal/Greens Bayou (SW6)** – the drainage area of the tidal portion of Greens Bayou (AU 1006_03). Ambient data were collected from Station 18363 (Greens Bayou at Market Street). As with Station 11369 in SW3, stream flow data were assessed by applying a drainage area ratio. However, as the station is tidally influenced, the reference gage data was taken from a nearby watershed of similar size and geography on Goose Creek in Baytown, TX (08067525). Additionally, a seawater flow adjustment formula was applied using regression values between flow and salinity collected at 18363.
- *BMP Siting Requirements* — As discussed previously, LDCs were chosen in part to reflect geographic variability. A greater number of LDC locations is beneficial to compare with modeling results to scale and site solutions (*i.e.*, solution requirements can be refined to the subwatershed level based on the specific reduction needs of the LDC assessment area in which the subwatershed falls).
 - *Stakeholder Input* — Project staff built the aforementioned considerations into a set of LDC locations, which were reviewed with stakeholders in the preliminary meetings of the Partnership.

Table 23. LDC site information

LDC Site	CRP Station	USGS Gage	Assessed Area	Number of Bacteria Samples
Greens Bayou at Knobcrest Drive	13778	08075900	Subwatershed 1	85
Greens Bayou at US 59	11371	08076000	Subwatershed 2	86
Greens Bayou at Tidwell Road	11369	No Gage	Subwatershed 3	95
Garners Bayou at SH Loop 8	11125	08076180	Subwatershed 4	80
Halls Bayou at Jensen Drive	11126	08076500	Subwatershed 5	86
Greens Bayou at Market Street	18363	No Gage	Subwatershed 6	35

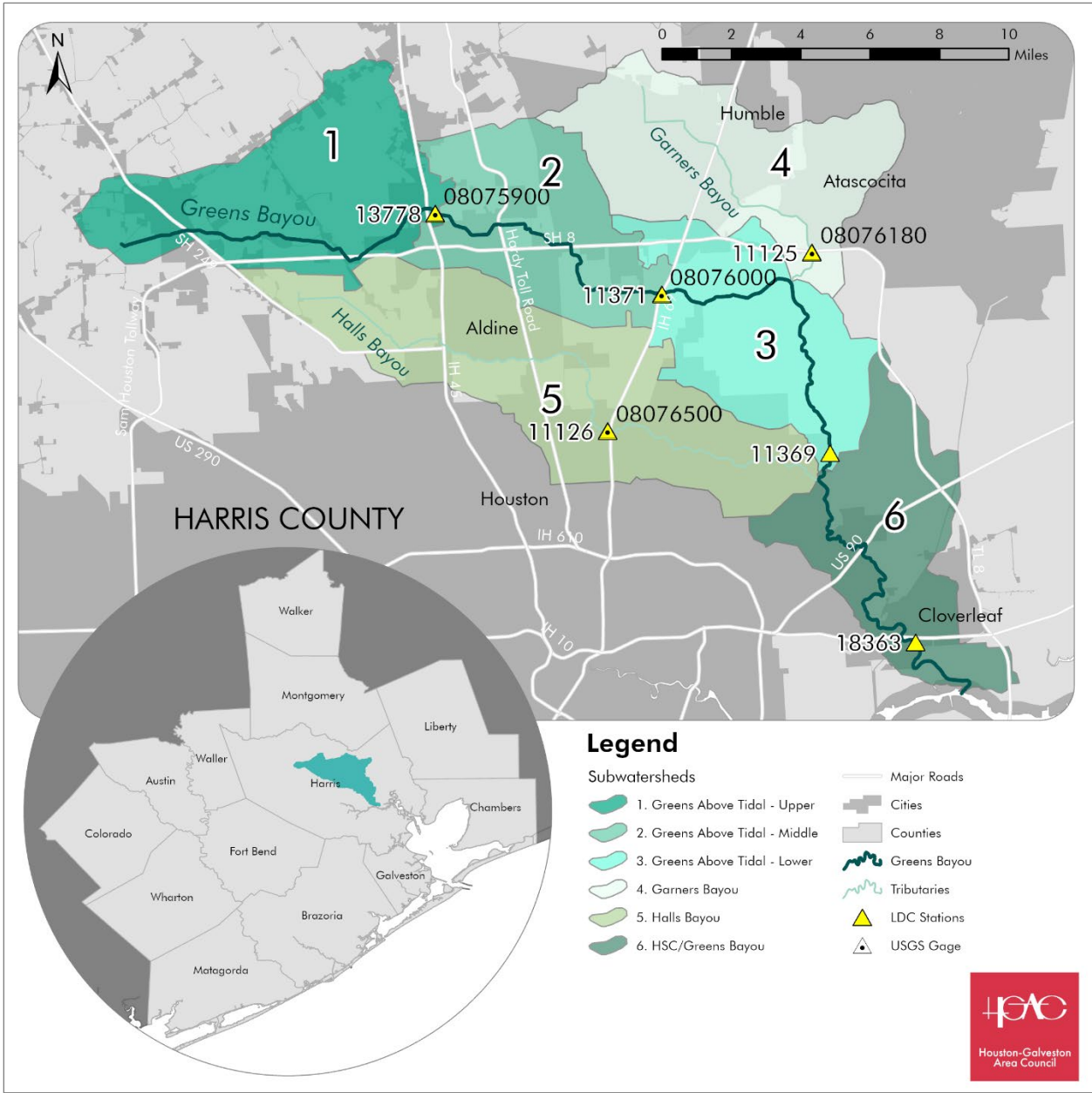


Figure 30. LDC sites

Quality Assurance

Quality-assured ambient water quality data from CRP monitoring were available for all five stations. All stations on the main stem of Greens Bayou have at least 10 years of data available and range from 35 to 95 samples for bacteria (Table 23).

In addition to ambient water quality data, streamflow data is also required (with continuous flow data being preferable) to produce LDCs. Four of the Greens Bayou watershed LDC sites (13778, 11371, 11125 and 11126) have corresponding USGS

gages. For Stations 11369 and 18363, drainage area ratios were used to estimate flow. Because Station 18363 is also tidally influenced, a seawater flow adjustment was factored into its flow estimation. These processes were reviewed internally and with project stakeholders and found to be sufficient for the quality objectives of the project.

Load Duration Curve Implementation

Both the requisite flow and constituent sample data were sufficient to develop LDCs for all locations and will likely continue to support future revisions and the adaptive management process of evaluating WPP success. Results of the LDC analyses were reviewed internally and with project stakeholders. No issues with the data development and implementation were identified based on quality assurance review and feedback. Full profiles for each LDC site are included in the Bacteria Modeling Report⁴⁵.

Load Duration Curve Analysis Summary

Results of LDC analyses for the Greens Bayou were reviewed internally and subjected to stakeholder analysis. H-GAC staff discussed these results with stakeholders at Partnership meetings and in more focused, one-on-one conversations. Stakeholder support and positive feedback support confidence in the estimated levels of fecal bacteria loadings and reduction targets for the Greens Bayou watershed.

LDC analyses of fecal bacteria loads at all sites throughout the watershed indicated a need for considerable reductions in high flow through dry conditions (**Table 24**).

⁴⁵ For more information, please refer to the Bacteria Modeling Report on the project website at: https://greensbayoupartnership.weebly.com/uploads/1/3/0/7/130710643/50226_4.3_bacteria_modeling_report_final.pdf

Table 24. Summary of LDC results

LDC Location	Area Represented	Findings
Greens Above Tidal - Upper (13778)	Segment 1016; Subwatershed 1	The results of LDC analyses for bacteria at Station 13778 indicate a need for significant reductions in <i>E. coli</i> geomean loads expressed in billion colony forming units per day (cfu/day) at all five levels of flow conditions.
Greens Above Tidal - Middle (11371)	Segment 1016; Subwatershed 2	The results of LDC analyses for Station 11371 indicate that fecal bacteria require reduction in all five flow conditions. Comparative to Station 13778, reduction levels at Station 11371 were lower especially for mid-range through low flow conditions. This indicates that nonpoint sources of fecal bacteria loading are of greater concern at this site.
Greens Above Tidal - Lower (11369)	Segment 1016; Subwatershed 3	The results of LDC analyses for Station 11369 show that reductions in fecal bacteria are recommended for all flow conditions excluding low flow.
Garners Bayou (11125)	Segment 1016A; Subwatershed 4	The results of LDC analyses for Station 11125 indicate that considerable <i>E. coli</i> reductions are needed in all five flow conditions.
Halls Bayou (11126)	Segment 1006D; Subwatershed 5	The results of LDC analyses for Station 11126 indicate that exceedances of the <i>E. coli</i> water quality standard were observed in all periods of flow, however, a reduction of only 2% is indicated in low flow conditions.
HSC Tidal/Greens Bayou (18363)	Segment 1006; Subwatershed 6	The results of LDC analyses for Station 18363 exceedances of the Enterococci water quality standard were observed in all periods of flow excluding low flow conditions.

Improvement Goals for *E. coli*

The LDCs provided the basis for setting improvement goals for *E. coli* in the form of percent reductions of instream loading.

E. coli Source Load Reduction Goals

The Partnership developed specific bacteria reduction targets for each of the six subwatersheds for both current and target year (2035) conditions. The first step was to identify a single improvement goal based on the LDCs for each subwatershed.

The design for generating single target reductions for each subwatershed⁴⁶ 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 subwatershed.

⁴⁶ As opposed to the modeled reduction values for each flow category.

Calculations were completed to determine the weighted average reduction:

$$\text{Weighted Average Reduction} = \frac{WhRh + WmRm + WmrRmr + WdRd + WIRI}{Wh + Wm + Wmr + Wd + WI}$$

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.

For example, Station 11125 represents the Garners Bayou subwatershed. At the high flow category which represents the top 10% of flows, an E. coli reduction of 96% is recommended. E. coli observed in the next 30% of flows (moist conditions) require a reduction of 83% and E. coli observed in the following 20% of flows (mid-range conditions) require a 72% reduction. Finally, E. coli observed in dry conditions comprising the following 30% of flows require a 67% reduction and E. coli observed in the lowest 10% of flows (low flow conditions) require a 58% reduction. For stations with negative reductions indicated in the low flow category, no values are factored into the calculation for the last weighted average category. The calculation for the weighted average reduction for Station 11125 is shown below:

$$\text{Weighted Average Reduction} = \frac{(10 \times 96) + (30 \times 83) + (20 \times 72) + (30 \times 67) + (10 \times 58)}{10 + 30 + 20 + 30 + 10}$$

$$\text{Weighted Average Reduction} = \frac{960 + 2,490 + 1,440 + 2,010 + 580}{100}$$

$$\text{Weighted Average Reduction} = \frac{7,480}{100} = 74.8$$

This method was used to determine the weighted average fecal bacteria reduction needed at all other LDC stations throughout the watershed (**Table 25**).

Table 25. Bacteria load reduction goals by percentage of load

Subwatershed	LDC Station	Subwatershed #	Weighted Average Bacteria Reduction Target
Greens Above Tidal - Upper	13778	1	89%
Greens Above Tidal - Middle	11371	2	61%
Greens Above Tidal - Lower	11369	3	53%
Garners Bayou	11125	4	75%
Halls Bayou	11126	5	70%
HSC Tidal/Greens Bayou	18363	6	63%

Model Linkage

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

With the model linkage established, calculating bacteria 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 2022 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 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 predictions⁴⁷. 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 2027, this would represent an 8-year plan life.

Allocating Reductions

The mix of sources present in the watershed, and the shift of relative contribution through 2050, posed a challenge for allocating how reduction targets would be met. Stakeholders considered several options, including: 1) targeting all sources proportional to their contribution (e.g., if in 2035, source X made up 30% of the total load, then 30% of the reduction value would be met by addressing that source); 2) allocating reduction subjectively based on potential solutions; and 3) allocating reduction based on current relative contribution (rather than 2035). Project staff proposed the first option as an initial

⁴⁷ 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.

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 whole watershed and subwatersheds, with the proposed allocations to focus on the subwatersheds. Stakeholders affirmed the proposal.

Based on these decisions, project staff generated reduction targets for each subwatershed, and source. Overall reduction targets for each of the subwatersheds 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 2022, and for the 2035 milestone year (**Table 26**). The load reductions needed by source for each of the three subwatersheds, were also determined for conditions in 2035 (**Table 27, Table 28, and Table 29**).

Table 26. 2022 and 2035 source load reduction targets

Subwatershed	Weighted Average Bacteria Reduction Target	2022 Total Source Load (Billion cfu/day)	2022 Source Load Reduction Target (Billion cfu/day)	Incremental Load 2022 to 2035 (Billion cfu/day ⁴⁸)	2035 Total Source Load Reduction Target (Billion cfu/day ⁴⁹)
Greens Above Tidal – Upper (SW1)	89.00%	15,375.79	13,684.45	1,504.71	15,189.16
Greens Above Tidal – Middle (SW2)	61.00%	5,363.65	3,271.82	49.60	3,321.43
Greens Above Tidal – Lower (SW3)	53.00%	6,338.53	3,359.42	2,402.94	5,762.36
Garners Bayou (SW4)	75.00%	4,980.60	3,735.45	1,246.42	4,981.86
Halls Bayou (SW5)	70.00%	17,255.08	12,078.55	594.00	12,672.55
HSC Tidal/Greens Bayou (SW6)	63.00%	6,796.11	4281.55	790.43	5,071.98

⁴⁸ The incremental load represents the difference between the 2035 load and the 2022 load. Negative loads represent reductions in source loads outside of BMPs due to projected land use changes in the watershed. These negative values were retained in place of zero values because of the ultimate decrease in reduction targets for 2035 relative to 2022. See the next footnote for explanation of its use in generating 2035 source reduction load target.

⁴⁹ The 2035 reduction target is generated by through the equation $C_r + (F_i - C_i)$; where C_r = current source reduction load, F_i = future total source load, and C_i = current total source load. In essence, the incremental load generated between 2022 and 2035 is added to whatever existing reduction load exists in 2022. This approach is used because LDCs cannot estimate future reduction percentages, and because it is assumed the waterway will not have additional assimilative capacity in 2035.

Table 27. Load reduction targets by source for the Upper Greens Bayou Above Tidal subwatershed, 2035

Source	Percent Total Load, 2035	Proportion of 2035 Load Reduction Target (Billion cfu/day)
OSSFs	11.49%	1,745.33
WWTFs	0.02%	2.42
Dogs	68.14%	10,350.64
Cattle	0.13%	19.75
Horses	0.00%	0.25
Sheep and Goats	0.06%	9.10
Deer	0.02%	3.65
Other Sources/Wildlife	18.22%	2,767.04
Feral Hogs	1.92%	290.96
Total	100.00%	15,189.14

Table 28. Load reduction targets by source for the Upper Greens Bayou Above Tidal subwatershed, 2035

Source	Percent Total Load, 2035	Proportion of 2035 Load Reduction Target (Billion cfu/day)
OSSFs	3.06%	101.58
WWTFs	0.05%	1.51
Dogs	71.97%	2,390.36
Cattle	0.30%	10.04
Horses	0.00%	0.13
Sheep and Goats	0.14%	4.63
Deer	0.08%	2.72
Other Sources/Wildlife	19.82%	658.20
Feral Hogs	4.58%	152.27
Total	100.00%	3,321.44

Table 29. Load reduction targets by source for the Upper Greens Bayou Above Tidal subwatershed, 2035

Source	Percent Total Load, 2035	Proportion of 2035 Load Reduction Target (Billion cfu/day)
OSSFs	30.30%	1,745.81
WWTFs	0.04%	2.28
Dogs	45.38%	2,614.91
Cattle	0.93%	53.79
Horses	0.01%	0.68
Sheep and Goats	0.43%	24.78
Deer	0.21%	11.79
Other Sources/Wildlife	14.50%	835.67
Feral Hogs	8.20%	472.64
Total	100.00%	5,762.35

Table 30. Load reduction targets by source for the Garners Bayou subwatershed, 2035

Source	Percent Total Load, 2035	Proportion of 2035 Load Reduction Target (Billion cfu/day)
OSSFs	6.42%	319.67
WWTFs	0.10%	5.00
Dogs	64.79%	3,228.00
Cattle	0.56%	27.97
Horses	0.01%	0.36
Sheep and Goats	0.26%	12.89
Deer	0.26%	12.81
Other Sources/Wildlife	16.00%	796.94
Feral Hogs	11.60%	578.23
Total	100.00%	4,981.87

Table 31. Load reduction targets by source for the Halls Bayou subwatershed, 2035

Source	Percent Total Load, 2035	Proportion of 2035 Load Reduction Target (Billion cfu/day)
OSSFs	11.37%	1,441.13
WWTFs	0.01%	0.83
Dogs	66.56%	8,434.95
Cattle	0.09%	11.27
Horses	0.00%	0.14
Sheep and Goats	0.04%	5.19
Deer	0.03%	4.35
Other Sources/Wildlife	19.31%	2,446.51
Feral Hogs	2.59%	328.18
Total	100.00%	12,672.55

Table 32. Load reduction targets by source for the HSC Tidal/Greens Bayou subwatershed, 2035

Source	Percent Total Load, 2035	Proportion of 2035 Load Reduction Target (Billion cfu/day)
OSSFs	12.04%	610.53
WWTFs	0.01%	0.32
Dogs	64.07%	3,249.69
Cattle	0.33%	16.90
Horses	0.00%	0.22
Sheep and Goats	0.15%	7.79
Deer	0.11%	5.35
Other Sources/Wildlife	17.92%	908.71
Feral Hogs	5.37%	272.48
Total	100.00%	5,071.99

Representative Units and Scaling Implementation

To determine what the source load reduction targets meant in terms of the scaling of solutions, representative units were used. Representative units simplify the conceptualization of load reduction targets by converting load values in cfu/day to practical units. The total number of units that would need to be addressed in each subwatershed 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 pet waste is equal to the daily *E. coli* load produced by one dog; **Table 33**, **Table 34**, and **Table 35**). The per-unit *E. coli* loads from each source are largely adapted from Teague *et al.*, 2009⁵⁰. All units are rounded up to the nearest whole unit. In 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. This conservative method of converting target load reductions to representative units could over-represent reductions to be made in areas outside the buffer.

Table 33. Representative units to address by 2035 for the Upper Greens Bayou Above Tidal subwatershed

Source	Representative Unit	Representative Unit Daily Load (billion cfu/day)	Units to Address by 2035
OSSFs	1 failing OSSF	3.71	488
WWTFs	1 million gallons of effluent	4.77	0.5
Dogs	(waste of) 1 dog	2.50	5,230 ⁵¹ (4,160)
Cattle	(waste of) 1 cow	2.70	6
Horses	(waste of) 1 horse	0.21	1
Sheep & Goats	(waste of) 1 sheep or goat	9.00	1
Deer	(waste of) 1 deer	0.18	NA (20)
Feral Hogs	1 feral hog	4.45	63

⁵⁰ See: <https://ssl.tamu.edu/media/11291/select-aarin.pdf>

⁵¹ Dog waste unit numbers are increased to cover deer and other sources/wildlife reduction loads in this subwatershed per stakeholder preference. Because there is no representative unit for other sources/wildlife, that reduction value is not shown. Equivalent reduction values for dogs are added to the total representative units. The number in parentheses represents the number of dogs whose waste would be required to be addressed if deer and other sources/wildlife loads were not converted into equivalent values. Similarly, the number in parentheses for deer units to address represents the number of deer whose waste would be required to be addressed if the load had not been converted to equivalent dog waste units.

Table 34. Representative units to address by 2035 for the Middle Greens Bayou Above Tidal subwatershed

Source	Representative Unit	Representative Unit Daily Load (billion cfu/day)	Units to Address by 2035
OSSFs	1 failing OSSF	3.71	27
WWTFs	1 million gallons of effluent	4.77	0
Dogs	(waste of) 1 dog	2.50	1,224 ⁵² (963)
Cattle	(waste of) 1 cow	2.70	3
Horses	(waste of) 1 horse	0.21	0
Sheep & Goats	(waste of) 1 sheep or goat	9.00	0
Deer	(waste of) 1 deer	0.18	NA (15)
Feral Hogs	1 feral hog	4.45	34

Table 35. Representative units to address by 2035 for the Lower Greens Bayou Above Tidal subwatershed

Source	Representative Unit	Representative Unit Daily Load (billion cfu/day)	Units to Address by 2035
OSSFs	1 failing OSSF	3.71	479
WWTFs	1 million gallons of effluent	4.77	0
Dogs	(waste of) 1 dog	2.50	1,381 ⁵³ (1,043)
Cattle	(waste of) 1 cow	2.70	16
Horses	(waste of) 1 horse	0.21	2
Sheep & Goats	(waste of) 1 sheep or goat	9.00	2
Deer	(waste of) 1 deer	0.18	NA (67)
Feral Hogs	1 feral hog	4.45	106

Table 36. Representative units to address by 2035 for the Garners Bayou subwatershed

Source	Representative Unit	Representative Unit Daily Load (billion cfu/day)	Units to Address by 2035
OSSFs	1 failing OSSF	3.71	87
WWTFs	1 million gallons of effluent	4.77	1
Dogs	(waste of) 1 dog	2.50	1,615 ⁵⁴ (1,285)
Cattle	(waste of) 1 cow	2.70	8
Horses	(waste of) 1 horse	0.21	1
Sheep & Goats	(waste of) 1 sheep or goat	9.00	1
Deer	(waste of) 1 deer	0.18	NA (74)
Feral Hogs	1 feral hog	4.45	132

⁵² See Footnote 51.⁵³ See Footnote 51.⁵⁴ See Footnote 51.

Table 37. Representative units to address by 2035 for the Halls Bayou subwatershed

Source	Representative Unit	Representative Unit Daily Load (billion cfu/day)	Units to Address by 2035
OSSFs	1 failing OSSF	3.71	397
WWTFs	1 million gallons of effluent	4.77	0
Dogs	(waste of) 1 dog	2.50	4,345 ⁵⁵ (3,376)
Cattle	(waste of) 1 cow	2.70	3
Horses	(waste of) 1 horse	0.21	0
Sheep & Goats	(waste of) 1 sheep or goat	9.00	0
Deer	(waste of) 1 deer	0.18	NA (25)
Feral Hogs	1 feral hog	4.45	73

Table 38. Representative units to address by 2035 for the HSC Tidal/Greens Bayou subwatershed

Source	Representative Unit	Representative Unit Daily Load (billion cfu/day)	Units to Address by 2035
OSSFs	1 failing OSSF	3.71	168
WWTFs	1 million gallons of effluent	4.77	0
Dogs	(waste of) 1 dog	2.50	1,663 ⁵⁶ (1,300)
Cattle	(waste of) 1 cow	2.70	5
Horses	(waste of) 1 horse	0.21	1
Sheep & Goats	(waste of) 1 sheep or goat	9.00	1
Deer	(waste of) 1 deer	0.18	NA (30)
Feral Hogs	1 feral hog	4.45	61

Because the other sources/wildlife category does not have a representative unit, it was not included in these tables. Reduction targets for deer and other sources/wildlife were converted into equivalent dog waste units in each subwatershed to account for negligible instream loads expected from these sources.

Source Load Reduction Summary

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

Uncertainty is present in 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

⁵⁵ See Footnote 51.

⁵⁶ See Footnote 51.

taken in the context of their use in characterizing fecal waste pollution on a broad scale, and for scaling and siting BMPs. For these purposes, the level of uncertainty and precision of the results was deemed to be acceptable by the stakeholders. Further refinement of results may be needed in the future considering changing conditions.

Section 5

Recommended Solutions



Photo Credit: Rachel Windham

Section 5. Recommended Solutions

Sources of pollution in the Greens Bayou watershed are widespread, diverse, and expected to increase in the future. Without intervention, water quality will likely continue to degrade. Identifying a path forward that details a comprehensive approach for addressing these water quality issues is a necessary step in linking stakeholder concerns to achievable results. While the situation is challenging, potential solutions 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 fecal indicator bacteria reductions 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, outreach and advocacy 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, outreach and advocacy 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 projects⁵⁷ and ongoing local efforts⁵⁸. The diversity of pollutant sources in the watershed required that stakeholders consider an equally wide range of potential solutions sufficient to address each source⁵⁹ in proportion to the prominence of the source. This palette of potential solutions served as a starting point for local

⁵⁷ Including previous WPPs and TMDL Implementation Plans conducted in other watersheds, as well as the Implementation Plan for the Bacteria Implementation Group, under whose auspices the Greens Bayou TMDL project now rests.

⁵⁸ Including planned or potential activities of local government partners like the Harris County Precincts and HCFCD; NGOs like the Bayou Land Conservancy; regional efforts like USACE studies; private developers, and others.

⁵⁹ Deer, migratory birds, and other wildlife for which no feasible solutions existed were not considered under this process, based on stakeholder feedback or regulatory restriction.

customization and development of area-specific actions. Recommendations were discussed at multiple meetings of the Partnership. In the interim, the topic-specific Work Groups refined ideas and added expertise in the form of recommendations to the Partnership for further discussion. The discussions focused primarily on solutions to reduce fecal waste loads, with the assumption that most of the fecal waste solutions proposed would also benefit 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 fecal indicator bacteria 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.
- Were related to or supplemental to flood mitigation efforts.
- Had a strong outreach and education component or tie-in.
- Were focused on areas most adjacent to waterways.

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 parties⁶⁰, the period in which it would be implemented⁶¹, 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 fecal indicator bacteria. The solutions will be implemented together, or in phases, such that they cumulatively address the fecal indicator bacteria reduction goals for each source. Estimated costs reflect the period through 2035. The solutions identified in this section are for direct structural or programmatic elements. Solutions related to education, outreach and advocacy for each source category are highlighted in Section 6. While solutions are intended to be implemented in all appropriate subwatersheds, proportional to the load from the subwatersheds, specific focus areas are indicated for each source category. Focus areas identify the subwatersheds for which a set of solutions is most applicable. For all solutions the Partnership, as an ongoing point of coordination facilitated by H-GAC or a successor agency, is assumed to be a supporting party, though the level of support will differ based on the solution. Additional information on potential funding mechanisms is included as **Appendix D**.

⁶⁰ Throughout this section, references to categories (Utilities, Districts) are made unless a specific party is named.

⁶¹ The period represented for each solution is the timeframe within the implementation window between an assumed approval in 2027 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 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 municipal utility districts, water control and improvement districts, private utilities, and other entities are actively engaged in these efforts and have had noteworthy success. For example, an estimated \$52 million project known as North Corridor Consolidation Package 4 is underway to expand wastewater capacity, retire aging facilities, improve system reliability, and support community growth near the George Bush Intercontinental Airport⁶². Additionally, a consent decree between the City of Houston, EPA and the State of Texas was approved in 2021 to provide \$9 billion in improvements to upgrade Houston's aging wastewater system and keep up with Houston's rapidly growing population⁶³.

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


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:

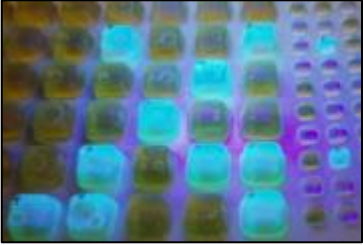
- WWTF 1 — Address problem facilities and consider regionalization.
- WWTF 2 — Recommend increased testing.
- SSO 1 — Remediate infrastructure.

⁶² See: <https://www.engagehouston.org/north-corridor-consolidation-package-4>

⁶³ See: <https://www.houstonpublicworks.org/wastewater-cd>

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

WWTF 1 – Address Aging Facilities; Consider Regionalization			
<p>Purpose: To increase oversight of facilities with discharge violations, and potentially consolidate operations where appropriate to increase economies of scale and phase out outdated treatment infrastructure.</p>			
<p>Description: The Partnership will work with local authorized agents and interested 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 Harris County 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.</p>			
<p>Priority Area(s): Watershed-wide</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
Utilities; Cities; Utility District Operators; Harris County	Ongoing-2035	Bacteria	Expands existing effort; potential enhancement to existing operations
Technical Resources Needed		Estimated Costs and Funding	
Sufficient utility staff to address system elements, and Partnership support for funding identification.		Costs involved with WWTF rehabilitation or regionalization are highly variable and not estimated individually here.	
Financial Resources Needed		Potential funding sources include tax or utility revenue, Texas Water Development Board (TWDB) loans or grants, or other applicable grant programs (USDA Rural Utilities Service, etc.).	
Highly variable but include utility staff time costs and infrastructure costs as warranted.			
Bacteria Reduction Capability			
This activity directly reduces bacteria and additional concerns such as nutrients stemming from poorly treated effluent. Because there is not a significant pattern of exceedance existing already among watershed WWTFs, future reductions cannot be quantified as they will be dependent on the future state of infrastructure. The primary reduction potential for this task is as a preventative measure.			

WWTF 2 – Recommend Increased Testing			
Purpose: To increase oversight of certain facilities and enhance nutrients data through increased voluntary testing.			
<p>Description: The Partnership will recommend additional bacteria testing to local utilities that do not have daily testing requirements in their TPDES permit. The intent of the increased voluntary testing is to expand the ability to identify operations that would benefit from additional resources. Infrequent testing may mask issues, especially in smaller facilities with less consistent loading. The Partnership also recommends that utilities consider voluntary testing, as appropriate, for a wider suite of nutrients, such as total phosphorus and nitrogenous compounds. These data would help establish the potential impacts of effluent on nutrient loading to the waterway and potentially help prepare facilities for future permit changes, including future statewide additions of other nutrient criteria by TCEQ.</p>			
<p>Priority Area(s): Watershed-wide</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
Utilities; Partnership	Ongoing-2035	Bacteria	Expands existing effort
Technical Resources Needed		Estimated Costs and Funding	
Sufficient utility staff to handle increased voluntary testing.		Testing costs are highly variable by the frequency of testing and costs specific to the individual entity involved. Potential funding sources are expected to be tax or utility revenues of the utility.	
Financial Resources Needed			
Incremental costs of sampling and analysis, dependent on the frequencies and constituents involved.			
Bacteria Reduction Capability			
This activity does not directly reduce bacteria; it provides information for decision-makers to address current or future operations to directly reduce pollutants.			

SSO 1 – Remediate Infrastructure

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

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

- Prioritizing rehabilitation of problem elements/areas.
- Considering additional funding for rehabilitation where appropriate.
- Pursuing additional grant or loan funding to expand resources for rehabilitation.



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

Priority Area(s): Watershed-wide

Responsible Parties	Period	Contaminant(s) Addressed	Status
Utilities	Ongoing-2035	Bacteria	Expands existing effort
Technical Resources Needed		Estimated Costs and Funding	
Sufficient staff capacity for investigating problem areas and implementing capital projects or operational adjustments. For grant projects, staff grant administration capacity would be needed.		Estimated costs for addressing SSOs are highly variable depending on the extent of the issues, size of the system, and nature of the causative factor. Example costs from other regional WPPs include mid-sized cities who spend \$1,000,000-\$5,000,000/year on addressing aging collection system infrastructure. The distributed nature of service in the watershed means costs per utility are likely lower than this estimate, but in conglomerate amount to appreciable investment. Potential funding sources include tax or utility revenue, loans/grants from TWDB, resiliency-based funding sources from federal agencies as listed in Appendix D, and traditional commercial loan or bond opportunities.	
Financial Resources Needed			
Typically borne by utilities directly, through rate revenue or <i>ad valorem</i> tax revenue. 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.			
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.			

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. In the Greens Bayou watershed, aging and failing OSSFs have been of particular concern. However, many measures are already underway to address these concerns. The East Aldine District has undertaken water and sewer projects to convert communities serviced by OSSF to sanitary sewer and recently approved an additional \$1.7 million funding partnership with Harris County Water Control and Improvement District No. 74 to pursue further water infrastructure improvements⁶⁴. These efforts and the estimated impacts of continued improvements were not captured in the modeling analysis used to estimate loading from failing OSSFs. Therefore, the calculations in this WPP represent an overestimation.

Regardless, this source is a priority for stakeholders in the Greens Bayou watershed. The general intent of the Partnership was to prioritize failing systems identified by age and spatial clustering 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 the Supplemental Environmental Project (SEP)⁶⁵. SEP funding is being provided by both TCEQ and the Harris County District Attorney's Office. 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 Harris County, 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 — Convert OSSFs to sanitary sewer where appropriate.
- OSSF 3 — Improve and update spatial data to identify priority areas.

Educational elements (e.g., homeowner workshops) are included in the discussion of education, outreach and advocacy activities in Section 6.


⁶⁴ See: <https://aldinedistrict.org/2026/03/east-aldine-board-approves-1-7m-water-partnership-advances-projects-aligned-with-community-action-plan/>

⁶⁵ H-GAC's SEP is used to remediate, repair, pump, or decommission OSSFs for homeowners making less than 80% of the Area Median Income.


Actual implementation will be opportunistic and will emphasize priorities noted in each OSSF solution. Proposed siting of OSSF projects within the watershed to be implemented by 2035 is shown in **Table 39**. As mentioned previously, work is already underway to remediate failing OSSFs in East Aldine which was not captured in the modeling analysis, therefore units in the table represent an overestimation.


Table 39. Proposed siting for OSSF solutions to be implemented by 2035

Subwatershed	Units to Address
Greens Above Tidal - Upper	488
Greens Above Tidal - Middle	27
Greens Above Tidal - Lower	479
Garners Bayou	87
Halls Bayou	397
HSC Tidal/Greens Bayou	168
TOTAL	1,646

OSSF 1 – Remediate Failing OSSFs			
Purpose: Reduce bacteria and nutrient contributions from failing OSSFs through physical remediation.			
<p>Description: H-GAC will work with Harris County and OSSF owners to inspect and remediate failing systems through pumping, repair, replacement, or abandonment/conversion to sanitary sewer. H-GAC will use 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.</p>			
<p>Priority Area(s): Watershed-wide with a focus on Halls Bayou (Subwatershed 5)</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; Homeowners; Harris County (enforcement); Utilities (for conversion projects)	Ongoing-2035	Bacteria	Expands existing effort
Technical Resources Needed		Estimated Costs and Funding	
Data on OSSF locations from H-GAC’s regional OSSF database, Harris County, and local utilities/special districts, who may also provide violation information as appropriate. Remediation will be conducted by H-GAC, the homeowner, or another party; enforcement and referrals will be provided by the other responsible parties. Inspections will be conducted as needed by authorized entities based on existing ordinance or other authority.		Estimated costs are an average ⁶⁶ of \$5,500 per unit, with a total cost of \$9,053,500 for 1,646 systems.	
Financial Resources Needed		Potential funding sources include routine homeowner maintenance costs, as supplemented by H-GAC SEP and other grant programs (CWA §319(h), etc.).	
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.			
Bacteria Reduction Capability			
Remediating failing OSSFs is assumed to remove 100% of their daily load. Full implementation of this solution will meet the bacteria reduction goal for OSSFs by 2035.			

⁶⁶ 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 – Convert to Sanitary Sewer			
Purpose: Convert old and/or failing OSSFs to sanitary sewer service where available and appropriate.			
<p>Description: Local partners, in coordinating with funding sources like H-GAC’s SEP for OSSF remediation, 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.</p>			
<p>Priority Area(s): Watershed-wide with a focus on Halls Bayou (Subwatershed 5)</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; Harris County; Special Districts; Utilities; Homeowners	Ongoing-2035	Bacteria	Expands existing effort
Technical Resources Needed		Estimated Costs and Funding	
Available staff at local governments, H-GAC, and Harris County 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.		Estimated costs of converting a residence to sewer service are \$3,000-\$5,000. No specific number of OSSFs is slated for this specific action (see OSSF 1). Potential funding sources for continued work in this focus area include expected routine costs from homeowner, as supplemented by H-GAC SEP or CWA §319(h) grant funding.	
Financial Resources Needed			
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 in abandoned OSSFs as development of master-planned communities displaces existing residences.			
Bacteria Reduction Capability			
This solution is expected to provide 100% removal rate by actively converting systems to alternate service.			

OSSF 3 – Improve Spatial Data			
Purpose: Inform decisions about prioritizing OSSF remediation.			
Description: H-GAC will work with Harris County and other local partners to continue to collect spatial data on OSSF locations as part of H-GAC’s existing OSSF spatial database ⁶⁷ . The partners will update and improve designations for priority remediation areas based on the data and other factors (e.g., growth and developmental trends).			
Priority Area(s): H-GAC region			
Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; Regional Counties; Special Districts; Utilities	Ongoing-2035	Bacteria	Expands existing effort
Technical Resources Needed		Estimated Costs and Funding	
Existing staff capacity at H-GAC and partner agencies. H-GAC currently maintains the database as part of a CWA §604(b) grant project with TCEQ. No additional technical resources are needed for this aspect of the task.		Estimated costs include existing funding of staff time, which is variable depending on workload for this element.	
Financial Resources Needed		Potential funding sources are the ongoing H-GAC CWA §604(b) grant and local partner staff time.	
Staff time from local partners to continue submittal and review of OSSF data, and to coordinate with H-GAC on maintaining/updating priority areas for H-GAC SEP and other funding in the watershed. Specific focus will be given to economically disadvantaged households and OSSFs in riparian or flood-prone areas.			
Bacteria Reduction Capability			
This solution does not directly reduce fecal waste pollution but is designed to better inform other solutions (OSSF 1 and OSSF 2; OSSF homeowner workshops) to enhance their effectiveness.			

⁶⁷ Available for review online at: <http://datalab.h-gac.com/ossf/>

Stormwater

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

The primary means for addressing these sources in most of the urban areas of the watershed are the Municipal Separate Storm Sewer System (MS4) permits through TCEQ's General Permit (TXR040000). The permits require stormwater utilities to address sources of pollutants they may discharge to impaired waterways⁶⁸. The recommendations of this WPP are designed to supplement rather than supplant the existing efforts of the MS4s in the watershed⁶⁹. MS4 activities are likely to have the most impact on bacteria levels in the downstream area. In addition to MS4 permit activities, the stakeholders recommended:

- Urban Stormwater 1 — Install stormwater inlet markers.
- Urban Stormwater 2 — Investigate drainage channels for illicit discharges.
- Urban Stormwater 3 — Promote low impact development.

Points of focus of this category include education, outreach and advocacy activities, as reflected in Section 6. Implementation will target the urbanized portions of the watershed. 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 maker 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 2 is a recommendation for the broader Bacteria Implementation Group⁷⁰ (BIG) area⁷¹, and active projects are currently underway which may serve as valuable


⁶⁸ More information on the permits can be found at: <https://www.tceq.texas.gov/permitting/stormwater>

⁶⁹ 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.


⁷⁰ The BIG is an ongoing TMDL effort addressing fecal indicator bacteria for a number of segments in the H-GAC region, including Greens Bayou. The WPP 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>

⁷¹ See Appendix E for map of the BIG area.


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.

Urban Stormwater 1 – Install Stormwater Inlet Markers			
Purpose: To increase public visibility of stormwater drains as vectors for pollution.			
<p>Description: This solution involves installation of stormwater inlet markers or other permanent messaging such as casting on manhole covers, where appropriate for local governments, special districts, homeowners associations (HOAs), and neighborhoods. Local organizations (e.g., the HCFCD’s Stormwater Inlet Marking program⁷²) have existing programs for this purpose. This solution reflects partners’ intent to continue or expand programs. Inlet markers will be installed based on the requirements of the specific jurisdictions. The intent is to utilize this as a project to engage local volunteers in coordination with outreach efforts.</p>			
<p>Priority Area(s): Watershed-wide</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
Local Governments; Special Districts; HOAs; Local Volunteers	Ongoing-2035	Bacteria, Trash	New or expanded effort
Technical Resources Needed		Estimated Costs and Funding	
Staff capacity to train volunteers and manage installation programs. This capacity already exists in the watershed.		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. Potential funding sources include existing programs, local government/organization funding, CWA §319(h) grant funding, neighborhood HOA funding, or private foundation funding.	
Financial Resources Needed			
Costs of staff time in installation or managing volunteers and the costs of the inlet markers.			
Bacteria Reduction Capability			
This activity is expected to have an indirect impact on bacteria and trash by providing structural outreach to residents. No specific reduction efficiency is assumed.			

⁷² 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.			
<p>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 TCEQ/Galveston Bay Estuary Program (GBEP) projects⁷³ identifying high bacteria load streams in the Houston urban area. This effort can be paired with monitoring activities.</p>			
<p>Priority Area(s): Watershed-wide</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; Non-Profit Organizations; Local Governments	Early; Ongoing-2035	Bacteria, Trash	New or expanded effort
Technical Resources Needed		Estimated Costs and Funding	
Staff capacity in investigation of water and drainage channels. Enforcement data and knowledge from Harris County and other jurisdictions would aid in choosing sites and channels.		Estimated costs include \$40-50/hour for staff time and overhead. Total costs depend on scale of effort. A \$20,000 project could fund 200-300 hours of field investigation and follow-up.	
Financial Resources Needed		Potential funding sources include grants (CWA §319(h), GBEP, etc.), collaborations with MS4s, or existing partner resources.	
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).			
Bacteria Reduction Capability			
This activity is expected to have an indirect impact on bacteria and trash by identifying potential sources, which would then be referred to responsible enforcement jurisdictions.			

⁷³ The Top 5/Least 5 project, among others, was a GBEP and H-GAC partnership project to detect potential sources of contamination in highly contaminated waterways, and those close to meeting the standard. The project was successful in identifying sources for several waterways in excess of MS4 permit requirements in the area, through targeted monitoring and reconnaissance.

Urban Stormwater 3 – Promote Low Impact Development			
<p>Purpose: To reduce pollutants in stormwater flows through infrastructure that mimics or improves on natural hydrology.</p>			
<p>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 in areas of new development.</p>			
<p>Priority Area(s): New developments</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
H-GAC; Local Governments; Special Districts; Developers	Ongoing-2035	Bacteria, Trash	New or expanded effort
Technical Resources Needed		Estimated Costs and Funding	
Staff capacity to facilitate discussions for promotion and staff capacity among local partners to implement LID projects.		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. Potential funding sources include local government revenues with potential grant supplement (CWA §319(h), etc.).	
Financial Resources Needed			
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.			
Bacteria Reduction Capability			
This activity is expected to have a direct impact on bacteria and trash by providing structural barriers. However, reduction capacity is dependent on the practices used. No specific reduction is assumed for this activity.			

Pet Waste

Waste from both pet and feral dogs is a substantial source of bacteria and nutrients in the Greens Bayou 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 Lower Greens Bayou subwatershed 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.


The Partnership's goal is to address dog waste proportional to the number of dogs in any subwatershed, but special attention will be given to riparian areas and high-use public facilities. Proposed siting of pet waste projects within the watershed to be implemented by 2035 includes additional units to convert in order to cover reduction loads from deer and other sources/wildlife, as noted in Section 4. In **Table 40**, the number of dog waste units designated to be addressed by subwatershed is divided by the estimated reduction in load per BMP unit to produce the number of BMP units needed per subwatershed. An average use rate of 50 dogs per day per pet waste station was chosen based on stakeholder description of high-traffic area parks in this and other watershed projects. An additional assumption estimates that only half of the average dog's daily waste would be disposed of in a public pet waste station for an equivalent of 25 dog waste units addressed per pet waste station per day. The Partnership recommends the expansion of these elements to any appropriate areas where opportunities exist, including smaller HOA and private parks. As with other sources, the focus of implementation will continue to be on siting BMPs opportunistically to generate the greatest bacteria reduction for each segment area. Therefore, actual implementation in each subwatershed may differ from these targets based on opportunities and changing conditions in the watershed.


Table 40. Proposed siting for pet waste solutions to be implemented by 2035

Subwatershed	Dog Waste Units to Address	Pet Waste Station Equivalent
Greens Above Tidal - Upper	5,230	209
Greens Above Tidal - Middle	1,224	49
Greens Above Tidal - Lower	1,381	55
Garners Bayou	1,615	65
Halls Bayou	4,345	174
HSC Tidal/Greens Bayou	1,663	67
TOTAL	15,458	619

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.			
<p>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. Pet waste stations 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 neighborhoods, county parks, other recreational areas, and new development. Temporary stations at large events are another potential supplement to this effort.</p> <p>Priority Area(s): Parks, neighborhoods and other high traffic areas, Halls Bayou (Subwatershed 5)</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
Local Governments; HOAs; Apartment Complexes	Ongoing-2035	Bacteria	Expands existing effort
Technical Resources Needed		Estimated Costs and Funding	
Adequate staffing commitment to install and maintain the sites, which functions within the scope of the partners’ existing capabilities.		Estimated costs for 500 pet stations include installation costs of \$200 per station, \$50 in bags, \$200 in labor and materials (total \$225,000). Maintenance is estimated at \$300/year per station (\$1,200,000 for an eight-year period). The total cost is \$1,425,000. Costs for mobile stations at events are variable.	
Financial Resources Needed			
Purchase of the stations and initial materials; installation and ongoing maintenance 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 ⁷⁴ cooperative purchasing.		Potential funding sources include existing funding from local partners, local government tax or utility revenues, or grants from CWA §319(h) or other sources.	
Bacteria Reduction Capability			
The number of dogs impacted by this solution will vary based on the location. An average of 50 dogs a day per station served was chosen based on stakeholder description of high-traffic area parks. Assuming half of the dog’s daily waste is served, full implementation of this solution would yield 3,000 dogs, or 1,500 representative units, addressed. This would represent a daily bacteria reduction of 3,750 billion cfu/day in riparian areas (300-foot buffer), and 625 billion cfu/day in areas outside the buffer based on SELECT assumptions.			

⁷⁴ More detail about H-GAC’s cooperative purchasing program can be found online at: <https://www.hgacbuy.org/>

Pet Waste 2 – Expand Dog Parks			
<p>Purpose: To provide additional areas for dog owners to bring dogs, to sequester waste and increase the likelihood of owners picking up waste.</p>			
<p>Description: This solution would entail partners developing dog park/areas at their properties or developing new specific dog parks. Heavily used recreation areas and other parks adjacent to waterways are prime locations for dog parks or off-leash areas with waste stations. New 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.</p>			
<p>Priority Area(s): Existing recreation areas near waterways, new developments</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
Local Governments; HOAs; Developers; Apartment Complexes	Middle; goal to establish one new park by 2035	Bacteria	New effort
Technical Resources Needed		Estimated Costs and Funding	
Sufficient staff capacity for park owners to evaluate potential expansion of dog areas, manage capital projects, and/or seek funding.		Cost estimates for new park acquisition in area plans range from \$500,000 to \$1,000,000+, whereas development of new facilities in existing parks range from \$50,000 to \$300,000. Potential funding sources include municipal revenues, CWA §319(h) grant funding, TPWD park grant funding, or foundation grants.	
Financial Resources Needed			
Reflect the stages for which technical resources are needed. 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.			
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.			
<p>Description: Spay and neuter programs are an effective means of curbing feral and unwanted pet populations⁷⁵. The Partnership will work with a spay and neuter provider, such as Society for the Prevention of Cruelty to Animals (SPCA), to hold local spay and neuter events or promote local services to pet owners through local governments, special districts, NGOs, and HOAs. Potential models include existing spay and neuter programs in Harris County and NGOs like Friends For Life⁷⁶.</p>			
Priority Area(s): Watershed-wide			
Responsible Parties	Period	Contaminant(s) Addressed	Status
Service provider; Local Partners	Ongoing, goal to have one event every 5 years	Bacteria	New effort
Technical Resources Needed		Estimated Costs and Funding	
<p>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.</p>		<p>Costs estimates for spay/neuter education events are \$5,000 per event, (\$15,000 total) and spay/neuter costs are \$40-\$150 per animal⁷⁷.</p>	
Financial Resources Needed		<p>Potential funding sources include pet owners, local partners or non-profit funding, and grants.</p>	
<p>Funding for the spay/neuter events. 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.</p>			
Bacteria Reduction Capability			
<p>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 with an average litter size of seven puppies, yielding up to thousands of dogs in five years or less⁷⁸. Even with a low feral survival rate, this is an appreciable, if not directly quantifiable, reduction. The reduction of each average litter represents a 17.5 billion cfu daily source load reduction⁷⁹.</p>			


⁷⁵ Harris County has an existing Trap, Neuter, Release program for community (feral) cats. More details are available at: <https://www.countypets.com/Pet-Resources/Community-Cat-Program>

⁷⁶ More information on a model program by this NGO to curb pet populations in underserved communities can be found at: <https://friends4life.org/programs-and-events/fix-houston/>

⁷⁷ Based on cost estimates provided by the Houston Humane Society, available online at: <https://www.houstonhumane.org/clinic/spay-neuter>

⁷⁸ <https://dogpages.net/health/how-many-puppies-do-dogs-have>

⁷⁹ 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 restrictions.			
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): Residential areas			
Responsible Parties	Period	Contaminant(s) Addressed	Status
Local Governments; Special Districts; HOAs; Apartment Complexes	Ongoing-2035	Bacteria	New effort
Technical Resources Needed		Estimated Costs and Funding	
Limited technical resources are required for this solution. Model materials already exist and can be adapted as needed. 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 ⁸⁰ as do partners like Harris County. Costs for increased enforcement will vary based on the entity involved and scope of enforcement.	
Financial Resources Needed		Potential 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.	
Primarily an issue for increased enforcement costs if active vs. passive enforcement is conducted. Otherwise, costs are limited to staff time in developing and seeking approval for additional restrictions.			
Bacteria Reduction Capability			
This solution is not a direct intervention, but a reinforcement or expansion of restrictions that serve to prevent pet waste.			

⁸⁰ See: <http://www.h-gac.com/pet-waste-pollutes/default.aspx>

Agriculture

Agricultural areas in the watershed are limited and may consist largely of hobby farms throughout residential areas. 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, AgriLife Extension, and AgriLife Research in coordination with local landowners and conservation efforts on agricultural lands by the Bayou Land Conservancy and other NGOs. The intent of these solutions is to provide financial assistance or technical resources for local landowners to make voluntary improvements to their property and operations. These improvements are designed to be beneficial to the landowner and to water quality. These recommendations recognize the benefits that well-run agricultural lands provide.


The solutions for livestock are based on the implementation of TSSWCB Water Quality Management Plans (WQMPs) and similar conservation plans through USDA Natural Resources Conservation Service (NRCS). Section 5 provides details on these solutions. To translate the number of livestock units to address into number of plans, project staff worked with TSSWCB and the local SWCDs in this and previous projects to develop an assumed average number of livestock units (50) to be served by each plan. The number of plans is then derived by dividing the number of livestock units by the average units per plan and rounding to the nearest whole representative plan. Because the total number (**Table 41**) of estimated livestock waste units to address throughout the Greens Bayou watershed is nearly equal to this average (51), one plan could be implemented to make the needed livestock waste reduction target. The actual load reduction value for plans will differ depending on the mix of livestock involved (given their different representative unit loading values).

Table 41. Livestock units to address by 2035 by subwatershed

Subwatershed	Total Livestock Units to Address
Greens Above Tidal - Upper	8
Greens Above Tidal - Middle	3
Greens Above Tidal - Lower	20
Garners Bayou	10
Halls Bayou	3
HSC Tidal/Greens Bayou	7
TOTAL	51

The solutions selected by the stakeholders include promoting and implementing voluntary, site-specific management plans for individual farms. The efforts will focus on implementing multiple solutions where appropriate.


- Agricultural Operations 1 — Develop land management plans including TSSWCB WQMPs and USDA NRCS Conservation Plans.
- Agricultural Operations 2 — Implement other land management techniques through financial assistance and technical programs.

Agricultural Operations 1 – WQMPs and Conservation Plans			
<p>Purpose: Provide technical and financial assistance to agricultural land owners to plan and implement land management practices that benefit water quality.</p>			
<p>Description: Both the USDA NRCS and TSSWCB offer agricultural land owners technical and financial assistance for “on-the-ground” implementation. To receive financial assistance from TSSWCB, the landowner must develop a WQMP with the local SWCD that is customized to fit the needs of their operation. 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 control bacteria contributions to the waterways, with a focus on areas adjacent to riparian corridors. Based on site-specific characteristics, plans will include one or more of TSSWCB’s approved practices⁸¹ 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 C. Similarly, USDA NRCS offers conservation planning services through its Conservation Technical Assistance program⁸² 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 USDA NRCS expertise and financial assistance. In addition to WQMPs and Conservation Plans, USDA NRCS offers a broad range of other land and habitat management programs⁸³.</p>			
<p>Priority Area(s): Rural areas</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
TSSWCB; SWCDs; USDA NRCS; Agricultural Landowners	Ongoing-2035	Bacteria	Expands existing effort
Technical Resources Needed		Estimated Costs and Funding	
<p>The expertise of TSSWCB and USDA NRCS staff involved with their respective programs, and the local knowledge of the agricultural land owners. 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.</p>		<p>Estimated costs for WQMPs include up to \$30,000 per WQMP in financial incentives, with the landowner share of costs being variable. USDA NRCS Conservation Plan costs are estimated at \$2,000-\$3,000 in agency staff time, with landowner costs being variable.</p>	
Financial Resources Needed		<p>Potential funding sources include existing programs (TSSWCB and USDA NRCS) and landowner funding.</p>	
<p>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. Resources for USDA NRCS conservation plans and financial assistance programs include USDA NRCS staff time and related costs, funding from EQIP and other programs, and contribution from the landowner. The funding for these costs is expected to come directly from the respective parties. WQMPs or other plans addressing an average of 50 livestock units will need to be implemented (Table 41).</p>			
Bacteria Reduction Capability			
<p>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.</p>			

⁸¹ For more information, see: <https://tsswcb.texas.gov/sites/default/files/files/programs/water-quality-management-plan/fy24-practice-list-final9.18.pdf>

⁸² For more information, see: <https://www.tsswcb.texas.gov/index.php/programs/soil-and-water-conservation-assistance>

⁸³ For more information, see: <https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/>

Agricultural Operations 2 – Maintain or Restore Riparian Buffers			
Purpose: To reduce transmission of pollutants by slowing and filtering runoff from agricultural areas.			
<p>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.</p> <p>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).</p> <p>Priority Area(s): Riparian areas</p>			
Responsible Parties	Period	Contaminant(s) Addressed	
Landowners (on a voluntary basis); NGOs; Agricultural Agencies	Ongoing-2035	Bacteria	Expands existing effort
Technical Resources Needed			Estimated Costs and Funding
Staff capacity at support agencies to provide services and knowledge to landowners.			<p>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.</p> <p>Potential funding sources include established programs and property owner contributions.</p>
Financial Resources Needed			
<p>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.</p>			
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% ⁸⁴ to 95% ⁸⁵ .			

⁸⁴ 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.

⁸⁵ Larsen, R.E. et al. 1994. Water Quality Benefits of Having Cattle Manure Deposited Away from Streams. *Biosource Technology* Vol. 48 pp 113-118. See: <https://www.sciencedirect.com/science/article/abs/pii/096085249490197X>

Feral Hogs, Deer, and Other Wildlife

Feral hogs are a potential source of bacteria in watersheds, especially those with large undeveloped areas. Within this general category of wildlife and non-domestic animals, feral hogs are the primary focus of this WPP because of their relatively high bacteria concentration, other damages they create, and the availability of feasible solutions to address them⁸⁶. Other animals included in this WPP's estimates of loading for deer and other sources/wildlife⁸⁷ 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 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, as supported by partner agencies through information and technical services, although the Partnership recommends that local and state governments consider active involvement in feral hog reduction efforts.

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


The focus 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 wildlife populations are found throughout the project area. For feral hogs, deer, and other wildlife, stakeholders recommended the following solutions:

- Feral Hogs 1 — Remove feral hogs.
- Wildlife 1 — Conserve or restore upland habitat.


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

⁸⁶ 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.

⁸⁷ Included under the category Other Sources/Wildlife.

Feral Hogs 1 – Remove Feral Hogs			
<p>Purpose: To encourage landowners and local governments to directly reduce feral hog populations through trapping and hunting.</p>			
<p>Description: This solution reduces 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.</p>			
<p>Priority Area(s): Watershed-wide</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners; Local Governments; Special Districts; Agricultural Agencies (technical support)	Early; Ongoing-2035	Bacteria	Expands existing effort
Technical Resources Needed		Estimated Costs and Funding	
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.		<p>To reduce an estimated 1,861 hogs, 372 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 a total cost of \$372,000⁸⁸, not inclusive of staff/landowner time.</p> <p>Funding sources include local government and property owners. No specific grant resources were identified for this solution.</p>	
Financial Resources Needed			
Staff time and related costs of the partner agencies, and the cost of implementing solutions borne primarily by the landowners on a voluntary basis. Potential other resources include leasing property to hog hunting at a potential net gain of costs.			
Bacteria Reduction Capability			
This solution nominally reduces feral hog waste by a maximum daily <i>E. coli</i> load of 4.45 billion cfu/day 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.			

⁸⁸ 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 \$4,000-\$5,000. Costs do not include time, feed, and other elements. The estimate given should be considered conservative due to the capability of feral hog populations to breed rapidly up to (or beyond) the carrying capacity of the areas they inhabit. Rates of removal below 75% are not likely to have a net reduction of feral hog populations.

Wildlife 1 – Conserve or Restore Upland Habitat			
Purpose: To encourage landowners, NGOs, and local governments to conserve and restore upland habitat to relieve wildlife pressures on riparian areas.			
Description: This solution encourages 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): Watershed-wide			
Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners; NGOs; Local Governments; Agricultural Agencies (technical support); Developers	Ongoing-2035	Bacteria, Nutrients, Sediment, Flooding	Expands existing effort
Technical Resources Needed		Estimated Costs and Funding	
Staff capacity for pursuing and implementing voluntary conservation projects or ecosystem restoration. Potential technical resources include existing NGOs in the watershed (e.g., Bayou Land Conservancy), agricultural agencies, and local governmental staff.		Cost estimates vary based on scale and type of conservation or restoration and area.	
Financial Resources Needed		Potential funding sources include agricultural agencies (e.g., USDA NRCS Farm Bill programs), other grants, and local governmental or non-governmental organization (NGO) funding (including private donation and in-kind donation of land value from property owners).	
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.			
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 BMPs 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.
- Trash/Illegal Dumping
 - Illegal Dumping 1 — Report chronic dump sites and consider increased enforcement.
- Flooding
 - Flooding 1 — Coordinate with ongoing flood mitigation efforts.

Conservation and land management activities relate to conserving or developing natural barriers to pollutants entering the water body. These solutions are approached on a voluntary basis. Prioritization is placed on areas adjacent to riparian corridors in the 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 from local government, landowners, and conservation NGOs (e.g., Bayou Land Conservancy), and the Partnership. This WPP makes no recommendations concerning recreational trails or development; its sole focus in this category is improving water quality by maintaining or restoring ecosystem services from conserved land. A variety of successful, model conservation activities exist in the watershed.

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

Flooding is another concern for the Greens Bayou community. The focus of this WPP will be to coordinate with and support the advancement of flood mitigation activities, with an eye toward advocating for inclusion of water quality features.

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

Conservation and Land Management 1 – Riparian Buffers and Urban Forestry			
<p>Purpose: To reduce transmission of bacteria, nutrients, trash, and sediment to waterways by maintaining or implementing vegetated buffers in riparian corridors and to reduce heat and slow runoff in urban areas.</p>			
<p>Description: This solution is supplementary to Agricultural Operations 2 – Maintain and Restore Riparian Buffers, with a focus on non-agricultural areas.</p> <p>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). As forestry is an important component of any watershed plan, the Partnership also endorses the maintenance and planting of trees in urbanized areas. 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.</p>			
<p>Priority Area(s): Watershed-wide</p>			
Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners; NGOs; Harris County; Local Governments; Special Districts; Agricultural Agencies	Ongoing-2035	Bacteria, Flooding	Expands existing effort
Technical Resources Needed		Estimated Costs and Funding	
Existing programmatic resources and staff expertise of the partners identified above.		Cost estimates are variable depending on type, size, and location of buffer/forest. Savings in maintenance (mowing, etc.) may counter some potential costs. H-GAC offers a riparian buffer planning tool for landowners to estimate potential costs ⁸⁹ . Potential funding sources include local government revenues (public buffers), landowner funding, or NGO/local partner funding.	
Financial Resources Needed			
Staff resources and landowner contributions previously detailed for the other versions of this solution. Other costs include opportunity costs related to lost property value.			
Bacteria Reduction Capability			
This solution’s efficiency will vary greatly based on the type, 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% ⁹⁰ .			

⁸⁹ Available at: <http://www.h-gac.com/riparian-buffer-tool/default.aspx>

⁹⁰ 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 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.

Priority Area(s): Watershed-wide


Responsible Parties	Period	Contaminant(s) Addressed	Status
Landowners; NGOs; Harris County; Local Governments; Special Districts; Agricultural Agencies	Ongoing-2035	Bacteria, Flooding	Expands existing effort

Technical Resources Needed	Estimated Costs and Funding
Existing programmatic resources and staff expertise of the partners identified above.	Cost estimates are variable depending on type, size, and location of properties. Tax savings may offset potential lost land value in easements. Potential funding sources include new grant sources; developer funding or in-kind value for land set-asides or remediation; and additional investment by public and private partners.
Financial Resources Needed	
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.	


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 (development, etc.) determine the difference in potential transmission.

Developers in the watershed stand to play a large role in the future use of natural systems for water quality and flood mitigation. Specific focuses of these voluntary conservation measures include establishing wetland areas in wet or dry detention facilities or including wetland plantings in mitigation ponds along the floodplain corridor. Wetland areas in detention or mitigation facilities can add water quality improvement using existing infrastructure. These recommendations are also relevant for the Urban Stormwater 3 – Promote Low Impact Development recommendation to the extent existing facilities in developed areas can add natural elements.

Illegal Dumping 1 – Report Chronic Dump Sites and Consider Increased Enforcement			
Purpose: To reduce trash in waterways at chronic dump sites by encouraging reporting and increased enforcement.			
Description: This solution is intended to augment existing county and local efforts to reduce illegal dumping in the following ways: <ul style="list-style-type: none"> • Encouraging reporting (see Section 6 for outreach elements). • Encourage merchants to install shopping cart wheel locks. • Coordinating between the Partnership and local enforcement to ensure reporting for sites. • Consider using cameras to identify dumpers⁹¹. 			
The primary focus of this solution is chronic dump sites, with emphasis on those adjacent to or near waterways.			
Priority Area(s): Watershed-wide			
Responsible Parties	Period	Contaminant(s) Addressed	Status
Harris County; Local Governments; H-GAC; Landowners	Early; Ongoing-2035	Trash	New or expanded effort
Technical Resources Needed		Estimated Costs and Funding	
Local enforcement capacity, especially through Harris County, 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.		Cost estimates include the incremental costs to local enforcement, which will be dependent on extent of use; prior camera programs have spent approximately \$500- \$1,000 a unit for high end equipment and maintenance.	
Financial Resources Needed		Potential funding sources include local government revenues and solid waste grant programs.	
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.			
Bacteria Reduction Capability			
This solution is not expected to directly address bacteria, although it may be an ancillary benefit.			

⁹¹ While not currently funded, H-GAC and other local partners have successfully utilized camera systems for illegal dumping curtailment in the past. The relatively low cost of camera systems provides an efficient way to monitor problem areas.

Flooding 1 – Coordinate with Ongoing Flood Mitigation Efforts			
<p>Purpose: To promote water quality elements in flood mitigation projects and share resources among adjacent efforts.</p>			
<p>Description: Flooding is a common issue in the Houston-Galveston Area region. In addition to area-wide studies by the United States Army Corps of Engineers (USACE) and HCFCD⁹², there are several flood mitigation projects underway such as the HCFCD’s 2018 Bond Program projects⁹³.</p> <p>This solution focuses on areas where flood planning and projects are active and coordinates WPP efforts with flood mitigation efforts, including the promotion of water quality elements or considerations in these projects. The Partnership will seek to coordinate with new development on water quality features for drainage and detention, as appropriate.</p> <p>Priority Area(s): Areas where flood planning and projects are active</p>			
Responsible Parties	Period	Contaminant(s) Addressed	
HCFCD; Special Districts; Local Governments; Harris County; NGOs	Ongoing-2035	Bacteria, Flooding	Expands existing effort
Technical Resources Needed		Estimated Costs and Funding	
Continued facilitation of the Partnership would help provide the technical skills needed to coordinate water quality efforts, 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 ⁹⁴ and the San Jacinto River Regional Flood Planning Group.		<p>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.</p> <p>Potential funding sources include new grants for WPP implementation (CWA §319(h), etc.) or local partner contributions.</p>	
Financial Resources Needed			
Staff time for coordination.			
Bacteria Reduction Capability			
<p>This solution is expected to 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 studies⁹⁵ have shown appreciable impacts of wet bottom detention and other mitigation practices that incorporate infrastructure of natural elements on nutrients and, to a lesser degree, <i>E. coli</i>.</p>			

⁹² Including the San Jacinto Regional Watershed Master Drainage Plan. More information can be found at: <https://www.hcfcd.org/Activity/Active-Projects/San-Jacinto-River/C-17-San-Jacinto-River-Watershed-Study>

⁹³ The updated status of projects under the 2018 Bond Program can be found at: <https://www.harriscountyfemt.org/cb>
⁹⁴ <http://www.h-gac.com/board-of-directors/advisory-committees/regional-flood-management-committee/default.aspx>

⁹⁵ Including studies from North Carolina (https://www.researchgate.net/publication/228647472_Indicator_Bacteria_Removal_in_Storm-Water_Best_Management_Practices_in_Charlotte_North_Carolina), and Virginia (Clary, J., R. Pitt, and B. Steets, eds. 2014. *Pathogens in Urban Stormwater Systems*. Reston, VA: ASCE. 289 pp.), among others.

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

- TWDB Flood Infrastructure Fund.
- Various Federal Emergency Management Agency (FEMA) disaster mitigation programs.

Solutions Summary

The recommended solutions presented in this section are intended to meet the bacteria 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 subwatershed.

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, Outreach and Advocacy

Section 6. Education, Outreach and Advocacy

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 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 number 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 forestry, flood mitigation, and conservation. When implementing solutions, public engagement efforts will build on the work of adjacent programs wherever appropriate and cross-promote water quality messages through platforms such as the Partnership website, public meetings, and materials distributed at partner events.

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 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 WPP goals.

Maintaining the Partnership

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

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

Building the Brand

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

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

Coordination

The Partnership is one of many watershed-based groups in the area, state, and nation. Finite resources and overlapping areas of interest make coordination of partner efforts a vital part of the WPP which the Partnership will carry out by:

- Participating in and collaborating with groups like the Texas Watershed Coordinator's Roundtable, Regional Watershed Coordinators Steering Committee, GBEP, CRP, and others.
- Supporting other area efforts like the various TMDL projects represented by the Houston Area BIG.
- Identifying and/or pursuing funding opportunities that would assist local partners in opportunities of shared interest.
- Obtaining additional data necessary to inform stakeholder decisions or evaluate progress⁹⁶.

Existing Outreach in the Watershed

Many local stakeholder organizations and regional, state, and national organizations have ongoing education efforts in the watershed (**Table 42**⁹⁷). The Partnership recognizes the value of these ongoing programs to positively impact water quality and public awareness in the WPP area and is committed to coordinating with and supporting their efforts.

⁹⁶ Specific examples identified in the project include wildlife loading estimates, and spatial data for features like pipelines and new development.

⁹⁷ 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 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 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.

Table 42. Outreach partners

Outreach Partner	Focus Areas
AgriLife Extension/AgriLife Research/ Texas Water Resources Institute	Agriculture, OSSFs, water quality, land management, feral hogs, riparian buffers
Bayou Preservation Association	Conservation, water quality, outreach, citizen science, recreation, invasive species management, flood mitigation, trash reduction
City of Houston	Source water protection
GBEP	Galveston Bay, source water protection
Greens Bayou Coalition	Outreach, flood mitigation, recreation, restoration trash reduction
Harris County, HCFCD	Riparian corridors, stormwater, outreach, recreation, OSSFs, illegal dumping, animal control, environmental enforcement, flood mitigation
Houston Advanced Research Center	Research, urban forestry, water quality
Houston Audubon	Conservation, wildlife, recreation
Houston Canoe Club	Recreation, conservation, outreach
Houston Wilderness	Gulf-Houston Regional Conservation Plan, outreach
H-GAC	Watershed management, water quality, forestry, public outreach, OSSFs, trash reduction
Houston Sierra Club	Conservation, water quality, forestry, outreach, recreation
Local HOAs	Resident outreach, pet waste, inlet marking
Municipal Utility Districts/Special Districts	Utilities, stormwater, outreach
Lone Star Chapter of the Sierra Club	Conservation, outreach
Other Cities and Communities	Utilities, stormwater, outreach, resident outreach
Texas A&M Forest Service	Forestry
TCEQ	Water quality, wastewater, nonpoint source pollution
Texas Invasive Species Institute	Education, outreach, and conservation
Texas Master Naturalists	Environmental education and outreach, habitat
TPWD	Wildlife, habitat, water quality
TSSWCB	Agriculture/silviculture, nonpoint source pollution, water quality, conservation
TST	Water quality, volunteering
The Nature Conservancy	Urban forestry, conservation, habitat, water resources
SWCDs	Agriculture, land management programs
State and Federal Elected Officials	Constituent outreach, environmental events
USACE, Galveston	Flood mitigation, water quality modeling
USDA, NRCS	Agriculture, land management, habitat, conservation
USDA, US 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 support water quality goals. The Partnership recommends the following activities as supplementary actions under this WPP.

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

FOG issues are a source of SSOs and operational challenges for local wastewater utilities. Programs like the San Jacinto River Authority's No Wipes in the Pipes (Patty Potty)⁹⁸ and the regional Galveston Bay Cease the Grease⁹⁹ campaign already exist. The Partnership will promote these programs and maintain model materials¹⁰⁰ on its website, social media, and at outreach events in appropriate translations. Local partners will promote the message through their online presence, utility bills, or through established programs¹⁰¹. The promotion will take place throughout the implementation period.

SSO E1 – Increase Public SSO Reporting

The Partnership will increase community knowledge by providing educational resources on how to report SSO events by working with local utilities to develop and disseminate materials in appropriate translations to constituents. This action will take place throughout the implementation period.

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

⁹⁸ For more information, see: <http://www.pattypotty.com/>

⁹⁹ For more information, see: <http://ceasethegrease.net/>

¹⁰⁰ 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.

¹⁰¹ These efforts are in addition to existing management of utility functions.

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

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

OSSF E3 – Provide Model Educational Materials Online

In addition to existing educational materials from Harris County, AgriLife Extension, and local governments, the Partnership will host or promote materials on its website in appropriate translations. 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 include an OSSF message related to water well siting. The expected frequency is once every seven years.

OSSF E5 – Signage at Remediation Sites

H-GAC works with the Harris County District Attorney's Office and TCEQ to provide funding to remediate failing OSSFs as part of SEP 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 elements¹⁰² for urban stormwater will include efforts aimed at both MS4 structures and diffuse flow off the land directly into waterways in urban areas. Much of the education and outreach for the former is conducted by the MS4 permit holders under the TPDES stormwater permits. For these areas, the Partnership will coordinate and support, but will not add additional elements¹⁰³. 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

TST¹⁰⁴ volunteers provide valuable information on local conditions in areas where there is no existing CRP monitoring. The role volunteers play as ambassadors to their community

¹⁰² 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.

¹⁰³ Except for promoting LID, as indicated in Section 5.

¹⁰⁴ For more information, see: <https://h-gac.com/texas-stream-team/>

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 five volunteers by 2035.

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 such as 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 a 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 can serve as event giveaways to raise awareness and cost approximately \$1.50 each. A standard giveaway would be 50 dispensers per outreach event, on average.

Pet Waste E2 – School Visits

Elementary-age children are good candidates for educational programs and can influence activities of their parents. The Partnership also recognizes the value of expanding education efforts to older students. H-GAC or other local partners will visit local schools (at least once per 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 Educational Materials Online

In addition to existing educational materials from local partners, the Partnership will host or promote materials on its website. Materials will be developed in appropriate translations 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 SWCDs, TSSWCB, AgriLife extension, USDA NRCS, and other agricultural partners in promoting their programs in the watershed. The Partnership recommends the following actions.

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

The Partnership will work with the agricultural agencies to identify existing source material and develop educational materials specific to operations 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 at least once every three years. The workshops will have representation from agricultural and other land management agencies (TSSWCB, AgriLife Extension, 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 Framework¹⁰⁵ 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 will promote these elements through the project 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 Extension Lone Star Healthy Streams¹⁰⁶ program by promoting the Feral Hog Resource manual and hosting a workshop in the watershed at least twice during the implementation period, subject to AgriLife Extension availability.

Feral Hogs E2 – Feral Hog Management Workshop

The Partnership will work with AgriLife Extension in Harris County to host local feral hog management workshops at least once every five years, based on AgriLife Extension availability.

¹⁰⁵ For more information, see: <https://www.h-gac.com/regional-conservation>

¹⁰⁶ For more information, see: <http://lshs.tamu.edu/workshops/>

Deer and Other Wildlife

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

Wildlife E1 – Homeowner Education Materials and Mailing

The Partnership will work with AgriLife Extension to promote the distribution of materials for homeowners that provide education on how to use exclusionary devices to deter invasive species, such as feral hogs, from using deer feeders. The materials will be hosted online and made available at outreach events in the priority areas of the watershed. The Partnership will work with local HOAs and other community groups to include the message in existing communication networks (HOA newsletters, etc.).

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 (e.g., Bayou Land Conservancy preserves), recreation, and flood retention. The key focus for water quality is lands adjacent to the waterways. The Partnership will support and promote voluntary projects and programs however appropriate and recommends the following outreach activities as a specific action under this WPP.

Land Management E1 – Promote Riparian Buffers

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 tool¹⁰⁷ for landowners. Resources will be developed/obtained and hosted within the first year of implementation. The Partnership will promote the Texas Water Resources Institute (TWRI) Texas Riparian and Stream Ecosystem Education Program and Urban Riparian and Stream Restoration Program¹⁰⁸ and similar workshops from AgriLife Extension. The

¹⁰⁷ For more information, see: <https://www.h-gac.com/riparian-buffer-tool>

¹⁰⁸ For more information, see: <http://texasriparian.org/riparian-education-program/>

programs will focus on fecal waste remediation in this watershed and will be held once every five years. Funding is currently provided by CWA §319(h) grants and attendee fees.

Land Management E2 – Texas Watershed Stewards

AgriLife Extension’s Texas Watershed Stewards 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 Extension to bring the program to the watershed on an expected frequency of once 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 will continue to participate meaningfully in the Gulf-Houston Regional Conservation Plan, the H-GAC Regional Conservation Initiative, 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. Harris County and other local jurisdictions will continue to enforce dumping issues. In addition, the Partnership recommends the following actions.

Trash and Illegal Dumping E1 – Encourage Bayou Clean-ups

Clean-up events such as the Texas Rivers, Lakes, Bays N’ Bayous Trash Bash¹⁰⁹ reduce trash and engage the community. During these events, upwards of hundreds of volunteers attend each site. This provides an opportunity to promote water quality education and distribute outreach materials accompany trash cleanup activities. The Partnership will participate in efforts to directly engage the public on visible examples of water pollution and will provide accompanying water quality messages.

¹⁰⁹ For more information, see: <http://www.trashbash.org/>

Advocacy

Throughout the development of this plan, the Partnership emphasized the importance of advocacy as a tool for carrying out the strategies laid out in the WPP. It is the intent of the Partnership to continue to use their collective leverage as prominent stakeholders in the watershed to support the measures in this WPP and related efforts working to improve water quality in Greens Bayou and its tributaries in collaboration with partners outlined in **Table 42**. Early priorities identified by the Partnership include supporting watershed entities seeking assistance from sources such as TWDB to expand opportunities to convert communities serviced by OSSF to sanitary sewer, and advocating for additional funding for animal control operations in watershed cities and counties.

Section 7

Implementation



Photo Credit: Rachel Windham

Section 7. Implementation

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

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 and some were focused on specific areas of the watershed. 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 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 and implemented on a voluntary basis.
- Siting of solutions that consider local needs and conditions, but overall favor areas closest to waterways.
- An opportunistic approach that is flexible enough to maximize resources and opportunities.
- Timelines that consider the changing mix of sources through the implementation period.
- An integrated approach that uses education, outreach and advocacy 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.
- A special focus on coordinating implementation activities with flood mitigation, source water protection, conservation, and forestry projects in the watershed and region.

Locally Based Watershed Coordinator

Implementing, maintaining, evaluating, and adapting the ongoing and proposed solutions are essential to the success of this project and the future of water quality in the Greens Bayou watershed. A local watershed coordinator will be necessary to guide

implementation, education, and outreach solutions as the focal point for coordinating these efforts for the WPP. The watershed coordinator will work with local partners to seek opportunities to implement solutions and to find common priorities. The watershed 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 is crucial for success and should be one of the primary roles of the position. The watershed coordinator will also work to secure funding to facilitate implementation activities and coordinate with partner efforts following the initial implementation phase facilitation provided by H-GAC. 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.

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 (**Appendix D**) currently available to local partners focus on resiliency and flood mitigation, a water quantity issue. To continue WPP visibility and tie water quality messages to flood mitigation efforts, the Partnership will maintain a strong coordination with local partners (HCFCD and others) and actively participate, as appropriate, in public processes linked to the flood mitigation efforts.

Conservation

The strong tradition of conservation in the watershed and existing organizational capacity among local governments and NGOs provides an opportunity to enhance water quality through ecosystem services. The Partnership will actively engage with and support conservation initiatives in the watershed and help represent the unique character and needs of the watershed in regional initiatives. Current efforts include the Gulf-Houston

Regional Conservation Plan (Houston Wilderness), the H-GAC Regional Conservation Initiative, and others.

Forestry

Supporting forestry practices is critical in this watershed. Regional efforts include:

- Large scale planting programs by the HCFCD, CenterPoint Energy, Texas Department of Transportation, and others.
- Significant research and restoration work by Texas A&M Forest Service and conservation NGOs.
- Broad regional partnerships (e.g., Texas Forests and Drinking Water Partnership¹¹⁰).

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.

Timelines for Implementation

Implementation of this WPP is intended to take place over an eight year initial timeframe (2027-2035). Some of the recommended solutions and outreach elements are intended for the whole implementation period, while some are intended for specific portions of 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 supported 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 6¹¹¹. 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 43**). The milestones will be updated as part of future WPP updates.

¹¹⁰ For more information, see:

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

¹¹¹ 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 43. Interim milestones for solutions and outreach activities

Target ¹¹²	Solutions ¹¹³	Overall Implementation Goal ¹¹⁴	Responsible Parties	Initial Implementation Phase Milestone	2028 Milestone	2031 Milestone	2035 Milestone
General (N/A)	Watershed Coordinator	Retain a Watershed Coordinator to manage day-to-day coordination, pursue resources, and guide implementation	Partnership ¹¹⁵	Funding application is made for a 2026 start date	Partnership reassess facilitation need	Partnership reassess facilitation need	Partnership reassess facilitation need
Wastewater Treatment Facilities (N/A)	1 – Address Aging Facilities and Consider Regionalization	Improve treatment of sewage	Utilities; Cities; Special Districts	N/A	At least 1 WWTF made operational/ structural changes resulting in effluent improvement	At least 1 additional WWTF made operational/ structural changes resulting in effluent improvement	At least 1 additional WWTF made operational/ structural changes resulting in effluent improvement
	2 – Recommend Increased Testing (voluntary)	Enhance monitoring to better characterize effluent	Utilities; Partnership	N/A	Partnership worked with at least 1 plant to identify capacity for increased testing	Partnership worked with at least 1 additional plant to identify capacity for increased testing	Partnership worked with at least 1 additional plant to identify capacity for increased testing
	<i>E1 – Promote FOG Awareness</i>	<i>Reduce SSOs by affecting utility customer behavior regarding FOG</i>	<i>Partnership; Utilities</i>	<i>Materials identified and added to website in appropriate translations; distribute printed materials at local events</i>	<i>Consistent promotion with partners throughout implementation period</i>	<i>Consistent promotion with partners throughout implementation period</i>	<i>Consistent promotion with partners throughout implementation period</i>
Sanitary Sewer Overflows (N/A)	1 – Remediate Infrastructure	Reduce contamination from human fecal waste by reducing overflows from WWTF collection systems	Utilities	N/A	1 fewer SSO occurred than average since 2026	1 fewer SSO occurred than average since 2028	1 fewer SSO occurred than average since 2031

¹¹² Numbers in parentheses indicate the estimated relative units that will be addressed by the solutions for each target as calculated in **Table 33**, **Table 34**, and **Table 35**.

¹¹³ 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.

¹¹⁴ Target goals are based on **Table 33**, **Table 34**, and **Table 35**, and may vary based on opportunity, resources, and regulatory changes in the future. All numeric targets (i.e., number of dogs) refer to representative units. Actual units addressed may change based on pollutant removal efficiency, location, etc. Outreach and education elements are designated with italics.

¹¹⁵ 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 ¹¹²	Solutions ¹¹³	Overall Implementation Goal ¹¹⁴	Responsible Parties	Initial Implementation Phase Milestone	2028 Milestone	2031 Milestone	2035 Milestone
Sanitary Sewer Overflows (N/A)	E1– Increase Public SSO Reporting	Enhance reporting by increasing public visibility and community knowledge	H-GAC; Partnership; Utilities	Materials identified and added to website in appropriate translations; distribute printed materials at local events	Partnership works consistently with local utilities to develop and disseminate materials	Partnership works consistently with local utilities to develop and disseminate materials	Partnership works consistently with local utilities to develop and disseminate materials
On-site Sewage Facilities (1,646)	1 – Remediate Failing OSSFs	In conjunction with OSSF 2, address failing OSSFs	H-GAC; Homeowners; Harris County; Utilities	N/A	First third of OSSFs addressed, or failures prevented	Second third of OSSFs addressed, or failures prevented	Final third of OSSFs addressed, or failures prevented
	2 – Convert to Sanitary Sewer	In conjunction with OSSF 1, address failing OSSFs	H-GAC; Harris County; Special Districts; Utilities; Homeowners	N/A	First third of OSSFs addressed, or failures prevented	Second third of OSSFs addressed, or failures prevented	Final third of OSSFs addressed, or failures prevented
	3 – Improve Spatial Data	Improve OSSF location spatial data to guide remediation efforts	H-GAC; Harris County; Authorized Agents	Partners have reviewed and commented on existing spatial data, which was revised accordingly	Authorized Agents continue to provide new data regularly	Authorized Agents continue to provide new data regularly	Authorized Agents continue to provide new data regularly
	E1 – Hold Residential OSSF Workshop	<i>Empower homeowners and real estate inspectors to identify the signs of failing/failed OSSFs and promote proper OSSF management to avoid failures</i>	H-GAC; Partnership; AgriLife Extension	N/A	5 workshops held	5 additional workshops held	5 additional workshops held
	E2 – Participate in County-wide OSSF Workshop for Practitioners	<i>Harris County’s annual OSSF workshop provides a point of coordination with practitioners</i>	Partnership; Harris County; Montgomery County	N/A	Partnership participates in annual meetings ¹¹⁶	Partnership participates in annual meetings	Partnership participates in annual meetings

¹¹⁶ This education and outreach measure is an activity of Harris County. The county may change the nature or frequency of these meetings in the future.

Target ¹¹²	Solutions ¹¹³	Overall Implementation Goal ¹¹⁴	Responsible Parties	Initial Implementation Phase Milestone	2028 Milestone	2031 Milestone	2035 Milestone
On-site Sewage Facilities (1,646)	E3 – Promote Educational Materials	Provide educational materials online to facilitate education by other organizations	H-GAC; Partnership; Utilities	Materials identified and added to website in appropriate translations; distribute printed materials at local events	Partnership works consistently with local utilities to develop and disseminate materials	Partnership works consistently with local utilities to develop and disseminate materials	Partnership works consistently with local utilities to develop and disseminate materials
	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	First event held ¹¹⁷	N/A	Second event held	If available, third event held
	E5 – Signage at Remediation Sites	Use OSSF remediation sites as outreach to neighbors via signage	H-GAC; Harris County; TCEQ	N/A	Signage placed at OSSF remediation locations	Signage placed at OSSF remediation locations	Signage placed at OSSF remediation locations
Urban Stormwater (N/A)	1 – Install Stormwater Inlet Markers	Raise awareness and shift behavior of residents served by stormwater systems to reduce pollutants entering drains/waterways	Local Governments; Special Districts; HOAs; Local Volunteers	N/A	At least 1 neighborhood has markers added	At least 1 additional neighborhood has markers added	At least 1 additional neighborhood has markers added
	2 – Investigate Drainage Channels	Locate potential sources of pollutants in urban channels ¹¹⁸	H-GAC; Non-Profit Organizations; Local Governments	N/A	Priority areas and grant resources identified; at least 1 field reconnaissance project completed	At least 1 additional field reconnaissance project completed	At least 1 additional field reconnaissance project completed
	3 – Low Impact Development	To reduce pollutants in stormwater flows through promoting and implementing infrastructure that mimics or improves on natural hydrology	H-GAC; Developers; Local Governments; Special Districts	LID materials developed and hosted on website in appropriate translations	N/A	At least 1 LID demonstration project installed	N/A

¹¹⁷ These workshops are expected to occur in 7-year intervals which do not align with usual milestone intervals.

¹¹⁸ 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 ¹¹²	Solutions ¹¹³	Overall Implementation Goal ¹¹⁴	Responsible Parties	Initial Implementation Phase Milestone	2028 Milestone	2031 Milestone	2035 Milestone
Urban Stormwater (N/A)	E1 – Expand Texas Stream Team Participation	Supplement existing monitoring data with volunteer sites and empower volunteers to act as water quality ambassadors	H-GAC; Partnership; TST Partners	N/A	1 volunteer added	2 additional volunteers added	2 additional volunteers added
Pet Waste (15,458)	1 – Install Pet Waste Stations	Reduce waste by facilitating use of bags in public areas	Local Governments; HOAs; Apartment Complexes	N/A	At least 100 pet waste stations installed and maintained throughout the implementation period	At least 200 additional stations installed and maintained throughout the implementation period	At least 200 additional stations installed; all stations maintained throughout the implementation period
	2 – Expand Dog Parks	Increase availability of controlled dog recreation areas to sequester waste in public areas	Apartment Complexes; Local Governments; HOAs; Developers	N/A	N/A	1 new dog park area developed	N/A
	3 – Promote Spay and Neuter Events	Reduce pollutants from feral populations through voluntary population control	Service provider (such as SPCA or similar); Local Partners	N/A	1 spay/neuter event held	1 spay/neuter event held	1 spay/neuter event held
	4 – Consider Additional Enforcement	Reduce dog waste by promoting enforcement	Local Governments; Special Districts; HOAs; Apartment Complexes	N/A	Worked with at least 1 local partner to promote enforcement	Worked with at least 1 additional local partner to promote enforcement	Worked with at least 1 additional local partner to promote enforcement
	E1 – Handheld Pet Waste Bag Dispensers at Local Events	Educate residents about impacts of dog waste and reduce waste in stormwater	Partnership; H-GAC	N/A	Distribution of 500 dispensers at 10 local events	Distribution of 500 dispensers at 10 additional local events	Distribution of 500 dispensers at 10 additional local events
	E2 – School Visits	Educate children on pet waste and other water quality issues	H-GAC	N/A	5 visits held	5 additional visits held	5 additional visits held

Target ¹¹²	Solutions ¹¹³	Overall Implementation Goal ¹¹⁴	Responsible Parties	Initial Implementation Phase Milestone	2028 Milestone	2031 Milestone	2035 Milestone
Pet Waste (15,458)	E3 – Promote Educational Materials	Provide materials to facilitate other organizations’ education efforts	H-GAC; Partnership; Local Partners	Materials identified and added to website in appropriate translations; distribute printed materials at local events	Partnership works consistently with local partners to develop and disseminate materials	Partnership works consistently with local partners to develop and disseminate materials	Partnership works consistently with local partners to develop and disseminate materials
Agricultural Operations (51)	1 – WQMPs and Conservation Plans	Address waste from 2,427 livestock units through 50 WQMPs, Conservation Plans, or other agricultural plans	TSSWCB; SWCDs; USDA NRCS; Agricultural Landowners	N/A	One third of the reduction load addressed by active plan	One third of the reduction load addressed by active plan	One third of the reduction load addressed by active plan
	2 – Maintain or Restore Riparian Buffers	In conjunction with, or supplemental to Agricultural Operations 1 and Conservation and Land Management 1, install or maintain riparian buffers in agricultural areas to reduce transmission of pollutants	Landowners (on a voluntary basis); NGOs; Agricultural Agencies	N/A	At least 1 rural property has a riparian project	At least 1 additional rural property has a riparian project	At least 1 additional rural property has a riparian project
	<i>E1 – Develop and Implement Education Measures and Materials for Livestock Operations (non-CAFO)</i>	<i>Develop specific recommendations for agricultural operations to reduce contributions from these sources</i>	<i>Partnership; TSSWCB; AgriLife Extension</i>	<i>Identify needs and potential local partners</i>	<i>Materials developed in appropriate translations and reviewed locally; hosted and disseminated</i>	<i>Materials hosted and disseminated</i>	<i>Materials hosted and disseminated</i>
	<i>E2 – Hold Agricultural Resources Workshops</i>	<i>Promote agricultural programs by facilitating one on one meetings with landowners</i>	<i>Partnership; TSSWCB; AgriLife Extension; USDA NRCS</i>	<i>N/A</i>	<i>First workshop held¹¹⁹</i>	<i>Second workshop held</i>	<i>Third workshop held</i>

¹¹⁹ These workshops are expected to occur in 3-year intervals which do not align with usual milestone intervals.

Target ¹¹²	Solutions ¹¹³	Overall Implementation Goal ¹¹⁴	Responsible Parties	Initial Implementation Phase Milestone	2028 Milestone	2031 Milestone	2035 Milestone
Agricultural Operations (51)	<i>E3 – Support Local Agricultural Conservation</i>	<i>Increase conservation efforts by lending support and coordination to local partners pursuing opportunities</i>	<i>Landowners; Partnership; USDA NRCS; Other local conservation partners</i>	N/A	<i>Collaborate with at least 1 partner on a project proposal</i>	<i>Collaborate with at least 1 additional partner on a project proposal</i>	<i>Collaborate with at least 1 additional partner on a project proposal</i>
Feral Hogs (469)	1 – Remove Feral Hogs	Implement trapping/other programs to remove feral hogs from the watershed, reduce pollutants/ancillary damages	Landowners; Local Governments; NGOs; Forest Service	Develop or augment trapping program with local partners	Expand program to at least 1 property	Expand program to at least 1 additional property	Expand program to at least 1 additional property
	<i>E1 – Lone Star Healthy Streams Workshops and Feral Hog Resource Manual</i>	<i>Educate local stakeholders to promote feral hog reduction</i>	<i>AgriLife Extension; TSSWCB; Partnership</i>	N/A	<i>First workshop held</i>	<i>Second workshop held</i>	<i>Third workshop held</i>
Wildlife (N/A)	1 – Restore Upland Habitat	Restore upland habitat to provide wildlife alternative areas and reduce concentration in riparian zones	Landowners; NGOs; Local Governments; Agricultural Agencies	N/A	N/A	Develop at least 1 acre or greater restoration project	N/A
	<i>E1 – Homeowner Education Materials and Mailing</i>	<i>Distribute exclusionary device materials for homeowners</i>	<i>H-GAC; Partnership; AgriLife Extension; HOAs; Local Partners</i>	<i>Materials identified and added to website in appropriate translations; distribute printed materials at local events</i>	<i>Partnership works consistently with local partners to develop and disseminate materials</i>	<i>Partnership works consistently with local partners to develop and disseminate materials</i>	<i>Partnership works consistently with local partners to develop and disseminate materials</i>
Conservation and Land Management (N/A)	1 – Riparian Buffers	In conjunction with, or supplemental to Land Management 2 and Agricultural Operations 2; Promote riparian buffers in all land uses to reduce transmission of pollutants	Landowners; NGOs	N/A	At least 1 property has a riparian project	At least 1 additional property has a riparian project	At least 1 additional property has a riparian project

Target ¹¹²	Solutions ¹¹³	Overall Implementation Goal ¹¹⁴	Responsible Parties	Initial Implementation Phase Milestone	2028 Milestone	2031 Milestone	2035 Milestone
Conservation and Land Management (N/A)	2 – Voluntary Conservation	Promote voluntary conservation to reduce pollutants from developed areas	Landowners; NGOs	N/A	At least one 1+ acre property has a conservation project	At least 1 additional property has conservation projects	At least 1 additional property has conservation projects
	<i>E1 – Promote Riparian Buffers (Tools and Workshops)</i>	<i>Reduce pollutant loads by promoting riparian buffer areas</i>	<i>Landowners; Partnership; TWRI; TSSWCB/TCEQ</i>	N/A	<i>First workshop held</i>	<i>Second workshop held</i>	<i>Third workshop held</i>
	<i>E2 – Texas Watershed Stewards</i>	<i>Educate stakeholders on water quality/watershed issues</i>	<i>AgriLife Extension</i>	N/A	<i>First workshop held</i>	<i>Second workshop held</i>	<i>Third workshop held</i>
	<i>E3 – Conservation Coordination</i>	<i>Promote and help coordinate conservation efforts in the watershed</i>	<i>Partnership; NGOs; USDA NRCS; Local conservation partners</i>	N/A	<i>Active in at least 1 conservation initiative in the watershed</i>	<i>Active in at least 1 additional conservation initiative in the watershed</i>	<i>Active in at least 1 additional conservation initiative in the watershed</i>
Trash and Illegal Dumping (N/A)	1 – Report Chronic Dump Sites and Consider Increased Efficiency	Promote enforcement efforts to reduce chronic dumping sites	Local Governments; Residents; Landowners	N/A	Identify dumping sites and enforcement priorities with local partners	Address at least 1 chronic site	Address at least 1 additional chronic site
	<i>E1 – Encourage Bayou Clean-ups</i>	<i>Reduce trash and educate participants on water quality issues</i>	<i>H-GAC; Partnership;</i>	N/A	<i>Establish at least 1 clean-up site</i>	<i>Ongoing (annual events)</i>	<i>Ongoing (annual events)</i>
Flooding (N/A)	1 – Coordinate with Ongoing Flood Mitigation Efforts	Promote water quality features as supplementary elements in flood mitigation studies and projects	Partnership	Identify flood mitigation priority projects for water quality enhancements	Maintains presence in flood mitigation projects through public processes, comments, etc.	Maintains presence in flood mitigation projects through public processes, comments, etc.	Maintains presence in flood mitigation projects through public processes, comments, etc.

It should be noted that developing and ensuring funding to cover the cost of implementation activities without current funding sources is a primary challenge and focus for the successful implementation of a WPP. While the WPP recognizes the need for support from a watershed coordinator and local partners to identify funding resources, and emphasizes an opportunistic approach to utilizing funding sources, funding will be the primary determining factor in the pace and extent of implementation.

Section 8

Evaluating Success



Photo Credit: Rachel Windham

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 observable changes in water quality in the watershed and by achieving programmatic milestones (Section 7). Water quality monitoring data and other monitoring or reported data related to 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 will be 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

The combination of ambient surface water quality data, permitted discharge data, and other sources (as appropriate) will be used by the Partnership to understand the result of WPP actions on the project waterways. CRP partners and others will conduct long-term ambient surface water quality monitoring in the Greens Bayou watershed, and TST volunteers are an additional source of supplemental data¹²⁰. The Partnership will also evaluate compliance by permitted wastewater dischargers using DMR and SSO data reported to TCEQ. Special studies, including microbial source tracking (MST) or other DNA-based categorization of fecal indicator bacteria or host species, may be used to supplement these ongoing data collection efforts if the Partnership deems them necessary in the future. 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 *Acquired Data Analysis Report*¹²¹ will be conducted by the Partnership at the end of every phase of implementation or as necessary in interim periods.

Clean Rivers Program Data

Ongoing monitoring in the Greens Bayou watershed includes 27 long-term sites that are all monitored at least quarterly (**Table 6** and **Figure 8**).

The quality-assured data from these sampling efforts are the primary means for evaluating compliance with SWQs and will serve as the primary indicator of success

¹²⁰ TST data will be used for qualitative assessment, and not as part of formal quantitative assessments of water quality.

¹²¹ Available on the project website at:

https://greensbayoupartnership.weebly.com/uploads/1/3/0/7/130710643/50226_3.3_prelimwqdataanalysesreport_final.pdf

under this WPP. The ambient parameters sampled are the same as those sampled during the WPP development project.

While data from all the stations will be reviewed, the most downstream stations of each of the subwatersheds (**Figure 7**) for this WPP are the ultimate focus of evaluation. However, special attention will also be given to tributary stations to evaluate whether additional attention or modeling is needed to isolate the tributaries. Monitoring will be conducted under an approved quality assurance project plan (QAPP).

Additional Data

In addition to CRP 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 and the WWTF permit data will be the primary points 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 in which additional data was warranted to ensure informed future decisions by the Partnership. These proposed 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 fecal indicator bacteria load totals assume a conservative additional load for warm-blooded animals (not including deer) for which there were insufficient data as part of the other sources/wildlife category. This source has been found to be a contributor to instream loads in some other watersheds, especially in more rural areas. One study cited a figure of 41 to 55%, but this is an overestimate due to the inclusion of feral hogs

together with wildlife¹²². Absent any MST data for the Greens Bayou 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 sources/wildlife category. However, additional data, in either the form of fecal source tracking information or wildlife population data estimates or established statewide wildlife loading assumptions based on land cover, could refine those estimates. This need is especially relevant given the propensity for wildlife to use stream corridors to traverse developing areas like this watershed. The Partnership will work with 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.

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 methods¹²³ that use genetic information to identify the origins of biological pollutants present in a water body. Identification of fecal indicator bacteria 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 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 Greens Bayou 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.

¹²² For example, the WPP 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 3/17/26 at: <https://brazos.org/Portals/0/Documents/WPP/Leon-WPP-Final.pdf>

¹²³ 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 Greens Bayou system and in adjacent watersheds. Additionally, there is significant investment planned for flood mitigation activities that may change flow patterns in these waterways. The potential for these factors to influence water quality conditions is unknown. While flood mitigation measures are expected to have a relatively positive impact (e.g., settling of pollutants in wet bottom detention basins), water quality impacts have not been a primary focus of the ongoing efforts. The Partnership does not have a specific recommendation, other than ongoing coordination with these efforts, but expressed an interest in subsequent research that might help predict water quality impacts. H-GAC, EPA, and USACE are currently involved in a Watershed Management Optimization Support Tool¹²⁴ modeling effort that may provide additional detail prior to, or immediately after, the approval process for this WPP. This information will help guide future decisions and WPP updates, but additional research will likely be needed given the scale of potential flood mitigation efforts in and around the watershed.

Indicators of Success

The Partnership identified key criteria for success for use in evaluating the progress of the WPP. The success indicators are used to measure the effectiveness of the implementation effort and the pace of progress (**Table 44**). Ultimate success in the waterways of the Greens Bayou watershed is found in achieving the water quality goals of the stakeholders. However, the changing nature of the watershed may mask some achievements in early years, as pollutant sources continue to increase rapidly even as implementation begins. However, the future focus of the WPP takes these considerations into account. To ensure that progress can be evaluated against this background, programmatic metrics will also be used as indicators of successful progress.

Table 44. Indicators of success

Goal	Indicator of Success	Source of Identification
Quantitative, Compliance with SWQSSs	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 milestones)	Partnership records; MS4 Annual Reports; partner information
	Implementation funded sufficiently	Funding sources identified and acquired
	Maintain the Partnership	At least annual meetings held

¹²⁴ See: <https://www.epa.gov/ceam/wmost>

Compliance with Water Quality Standards

The primary, quantitative goal of the WPP is to achieve and maintain compliance with SWQs at the representative stations for each of the subwatersheds. A secondary goal is to ensure source reduction by meeting TPDES permit limits. Therefore, the primary indicators of success are:

- The status of the waterways on the most current Texas Integrated Report, with specific focus on the SWQs for contact recreation standard (bacteria criteria for primary contact recreation 1). Success is measured by fully supporting all uses, and progress in abating concerns.
- A positive or stable trend in WWTF compliance, as indicated in the DMRs/SSOs.

While the goal of the WPP is to move water quality toward compliance, the changing nature of the watershed may mean that in interim years, a reduction of projected degradation will also be considered as interim progress. Based on known development and current trends, northward growth spanning toward the headwaters area is likely to continue to be strong but not necessarily linear. 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 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.
- Acquisition of funding levels and technical resources sufficient to realize implementation goals.

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 and is designed to be flexible to changing conditions. The WPP will be put through 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 45).

Table 45. Adaptive management process

Component	Description
Ad hoc review	Each partner responsible for implementing any activity will do due diligence in evaluating the continuing effectiveness of the activity. This review happens on an informal or project-specific basis. Partners are encouraged to share any insights on what is working well or what is working poorly with the Partnership at large. Facilitation staff will talk regularly with partners to assess progress.
Annual Review	Every year the Partnership will review progress made during that year during a public meeting. The results of the annual reviews will be summarized for dissemination to the stakeholders and the WPP may be amended as needed.
Formal WPP Reviews	The Partnership will conduct a formal review and revision of the WPP as appropriate. This process will include at least a 30-day review period and an open public meeting. If necessary, the result of the review will be an amended WPP. Criteria for review will include but not be limited to: <ul style="list-style-type: none"> • Stakeholder feedback on implemented solutions and resources (stakeholders). • Water quality data summary of segment conditions (H-GAC or successor watershed coordinator). • Review of progress in meeting programmatic milestones. • Progress in complementary efforts (MS4 permits, etc.).
Continuity Review	Two years prior to 2035, the Partnership will discuss during its Annual Review how it will plan for the next period of implementation (if needed). At this time, the Partnership will identify any modeling, data analysis and collection, or other information needed to make further projections for future implementation periods.

Appendices



Photo Credit: Rachel Windham

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 CWA §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*¹²⁵.

Table A. 1 Guide to watershed protection plan information

Segment Information	
Name of Water Body	HSC Tidal (Segment 1006) and Greens Bayou (Segment 1016)
Assessment Units	1006_03, 1006_05, 1006D_01, 1006D_02, 1006F_01, 1006H_01, 1006I_01, 1006J_01, 1016_01, 1016_02, 1016_03, 1016A_01, 1016A_02, 1016B_01, 1016C_01, and 1016D_01
Impairments Addressed	Primary contact recreation/ <i>E. coli</i>
Concerns Addressed	<i>E. coli</i>
Element	Report Section(s) and Page Number(s)
Element A: Identification of Causes and Sources	
1. Sources identified, described, and mapped	Section 3 <ul style="list-style-type: none"> water quality analysis and point source contribution descriptions. formal source descriptions, modeled loadings, and maps of spatial distribution.
2. Subwatershed sources	Section 3 <ul style="list-style-type: none"> sources are described in terms of their general spatial distribution and loads by subwatersheds. Table 21 summarizes all loadings by subwatershed.
3. Data sources are accurate and verifiable	Section 2 <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> description of LDCs and data sources. application of data sources to load reduction goals discussed. Section 8 <ul style="list-style-type: none"> discussion of data sources to be used for evaluating success.
4. Data gaps identified	Section 3 <ul style="list-style-type: none"> discussion of uncertainty in various modeling and data approaches. Section 4 <ul style="list-style-type: none"> discussion of DO precursors. Section 8 <ul style="list-style-type: none"> specific discussion of additional data sources that may be helpful (other wildlife estimations, BST/MST, etc.)
Element B: Expected Load Reductions	

¹²⁵ For more information, see: <https://www.epa.gov/nps/handbook-developing-watershed-plans-restore-and-protect-our-waters>

1. Load reductions achieve environmental goal	<p>Section 4</p> <ul style="list-style-type: none"> description of linkage of environmental goal (via LDC reductions) to source loads (via SELECT estimations) Summarized specifically in Table 26 through Table 33.
2. Load reductions linked to sources	<p>Section 4</p> <ul style="list-style-type: none"> description of linkage of environmental goal (via LDC reductions) to source loads (via SELECT estimations) summarized specifically in Table 26 through Table 33..
3. Model complexity is appropriate	<p>Section 3</p> <ul style="list-style-type: none"> description of modeling approach; link to project modeling report; contains specific description of rationale for modeling approach. Results of modeling indicated above in B1/B2. <p>Section 4</p> <ul style="list-style-type: none"> description of LDC modeling approach. description of LDC and SELECT linkage.
4. Basis of effectiveness estimates explained	<p>Section 4</p> <ul style="list-style-type: none"> description of use of representative units. <p>Section 5</p> <ul style="list-style-type: none"> solution effectiveness/reduction efficiency discussed in the bottom of each recommended solution page.
5. Methods and data cited and verifiable	<p>Section 3</p> <ul style="list-style-type: none"> 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. <p>Section 4</p> <ul style="list-style-type: none"> data for load reduction goals discussed, links to project modeling report included.
Element C: Management Measures Identified	
1. Specific management measures are identified	<p>Section 5</p> <ul style="list-style-type: none"> specific measures described, including technical and financial support needed, roles and responsibilities, etc. <p>Section 6</p> <ul style="list-style-type: none"> specific educational measures described, including responsible parties.
2. Priority areas	<p>Section 5</p> <ul style="list-style-type: none"> discussion of priority areas for each category of specific focus. <p>Section 6</p> <ul style="list-style-type: none"> general description of intended audiences/areas for educational activities.
3. Measure selection rationale documented	<p>Section 5</p> <ul style="list-style-type: none"> specific description of guiding principles for selection and selection process. summary of selection process and intention. <p>Section 6</p> <ul style="list-style-type: none"> description of Partnership's goals for selected educational measures.
4. Technically sound	<p>Section 5</p> <ul style="list-style-type: none"> specific measures described, including technical detail. <p>Section 6</p> <ul style="list-style-type: none"> specific educational measures described. <p>Section 7</p> <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> technical assistance needs detailed for each measure in their one-page summaries.
2. Estimate of financial assistance	Section 5 <ul style="list-style-type: none"> financial assistance needs detailed for each measure in their one-page summaries. Appendix D <ul style="list-style-type: none"> List of potential funding sources related to measures in this WPP.
Element E: Education/Outreach	
1. Public education/information	Section 6 <ul style="list-style-type: none"> description of public outreach activities.
2. All relevant stakeholders are identified in outreach process	Section 1 <ul style="list-style-type: none"> description of initial outreach, forming the Partnership, links to Public Participation Plan for the project. Section 6 <ul style="list-style-type: none"> description of public outreach activities including existing partners/roles and focus areas
3. Stakeholder outreach	Section 1 <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> description of initial outreach, forming the Partnership, links to Public Participation Plan and Stakeholder Outreach Report for the project. Section 3 <ul style="list-style-type: none"> description of Partnership process in identifying sources and assumptions (specific to each source, pp. 65-89). Section 4 <ul style="list-style-type: none"> description of stakeholder choices in reduction linkage, load allocation, etc. Section 5 <ul style="list-style-type: none"> description of stakeholder participation in measures selection. Section 6 <ul style="list-style-type: none"> description of stakeholder decisions on outreach strategies. Section 7 <ul style="list-style-type: none"> description of stakeholder input on implementation strategies. Section 8 <ul style="list-style-type: none"> description of the Partnership's role in determining how the project evaluates success.
5. Emphasis on achieving water quality standards	Section 1 <ul style="list-style-type: none"> description of specific water quality goals for the project/Partnership. All Other Sections <ul style="list-style-type: none"> 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 BMPs	Section 5 <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> implementation schedule.

2. Schedule is appropriate	Section 7 <ul style="list-style-type: none"> • implementation schedule.
Element G: Milestones	
1. Milestones are measurable and attainable	Section 7 <ul style="list-style-type: none"> • milestones described for all measures.
2. Milestones include completion dates	Section 7 <ul style="list-style-type: none"> • milestones described for all measures.
3. Progress evaluation and course correction	Section 8 <ul style="list-style-type: none"> • describes all methods used to evaluate success for the project; specifically describes adaptive management processes.
4. Milestones linked to schedule	Section 7 <ul style="list-style-type: none"> • 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 <ul style="list-style-type: none"> • describes evaluation criteria and data sources used to evaluate both water quality and programmatic milestones.
3. Data and models identified	Section 8 <ul style="list-style-type: none"> • 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. Section 4 bases load reductions on this timeline. Section 5/6 recommendations are based on the 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 <ul style="list-style-type: none"> • 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 <ul style="list-style-type: none"> • describes the indicators of success and adaptive management process.
7. Adaptive management	Section 8 <ul style="list-style-type: none"> • describes the adaptive management process.
Element I: Monitoring	
1. Description of how monitoring used to evaluate implementation	Section 8 <ul style="list-style-type: none"> • describes the monitoring plan and other potential data sources.
2. Monitoring measures evaluation criteria	Section 8 <ul style="list-style-type: none"> • describes the indicators of success, including water quality/monitoring outcomes.
3. Routine reporting of progress and methods	Section 8 <ul style="list-style-type: none"> • describes both the monitoring process and its reporting/evaluation, as well as the project evaluation and formal reviews process with the Partnership (Table 43, etc.).
4. Parameters are appropriate	Section 8 <ul style="list-style-type: none"> • describes the monitoring program.
5. Number of sites is adequate	Section 8 <ul style="list-style-type: none"> • describes the monitoring program.

6. Frequency of sampling is adequate	Section 8 <ul style="list-style-type: none">• describes the monitoring program.
7. Monitoring tied to QAPP	Section 8 <ul style="list-style-type: none">• describes the monitoring program under CRP QAPP.• describes the potential use of other data sources.
8. Can link implementation to improved water quality	Section 8 <ul style="list-style-type: none">• discusses the monitoring program.• discusses water quality indicators of success.

Appendix B. Wastewater Treatment Facilities

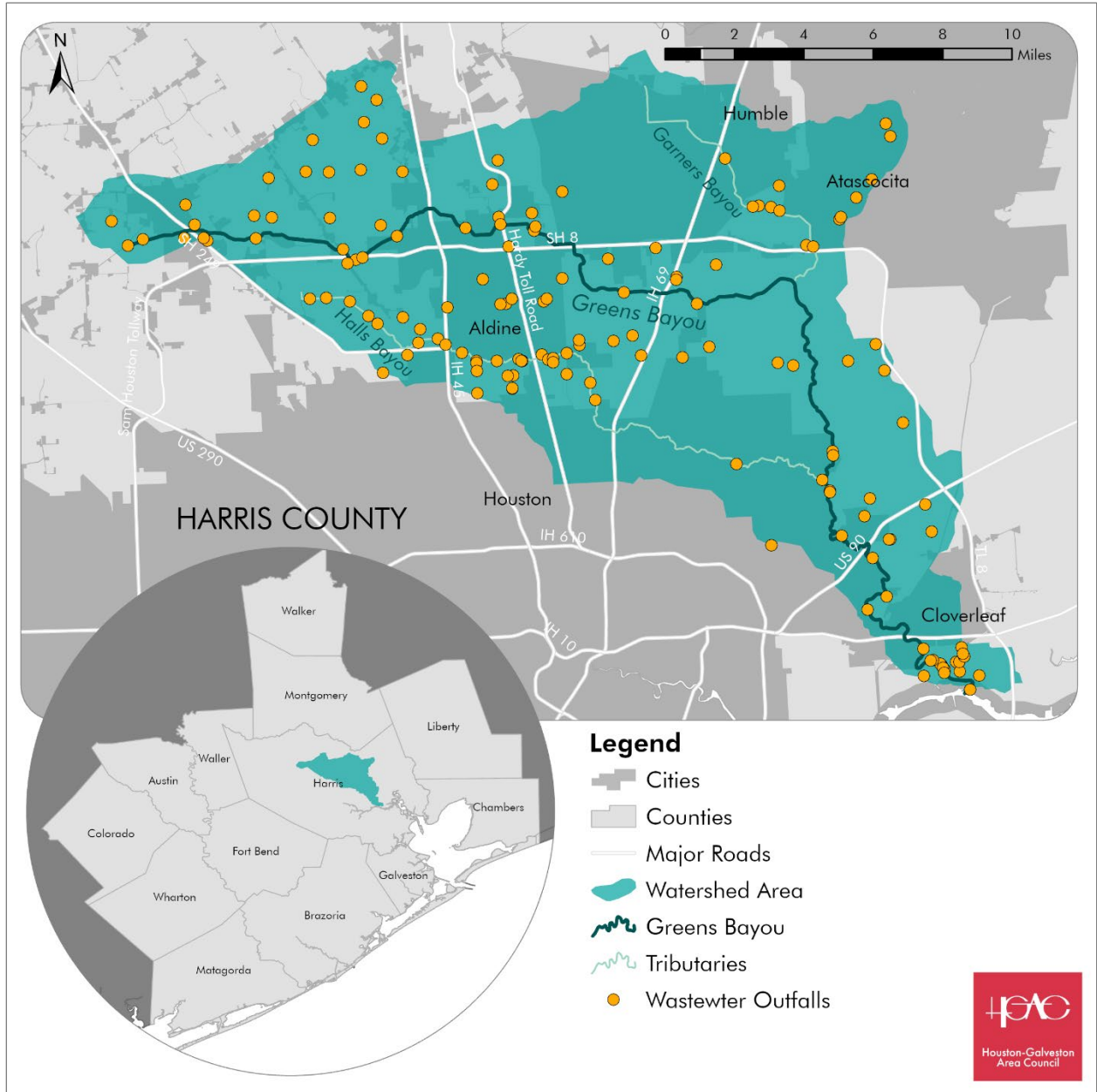
Table B. 1 Greens Bayou watershed WWTF permittees at study initiation

Permittee	TPDES #	EPA Permit #
ARKEMA INC	WQ0000445000	TX0007064
SYNGENTA CROP PROTECTION LLC	WQ0000749000	TX0007439
WOODLOCH MHP LLC	WQ0011673001	TX0063860
AQUA TEXAS INC	WQ0011701001	TX0068683
HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 150	WQ0011863001	TX0072893
SAMPOGNA PROPERTIES LP	WQ0014966001	TX0132519
CHAMPS WATER CO	WQ0011739001	TX0069582
SUNBELT FRESH WATER SUPPLY DISTRICT	WQ0011791001	TX0071382
HYDRIL USA MANUFACTURING LLC	WQ0011794001	TX0071251
FOREST HILLS MUD	WQ0011807001	TX0071820
HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 8	WQ0011727001	TX0075698
PR-PARK RIDGE APARTMENTS LLC	WQ0016359001	TX0144657
SASOL CHEMICALS USA LLC	WQ0000485000	TX0005584
HARRIS COUNTY MUD 86	WQ0012065001	TX0078824
ALDINE ISD	WQ0012070002	TX0094188
HOOKS MOBILE HOME PARK LTD	WQ0012083001	TX0078883
HARRIS COUNTY MUD 180	WQ0012127001	TX0079529
NRG TEXAS POWER LLC	WQ0001031000	TX0006386
NORTHWEST HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 24	WQ0012655001	TX0092312
KARBALAI RITA LAURA REDOW	WQ0012692001	TX0092711
GREENS PARKWAY MUD	WQ0012754001	TX0093475
UNITED STRUCTURES OF AMERICA INC	WQ0012765001	TX0093556
US STEEL OILWELL SERVICES LLC	WQ0004690000	TX0126292
BAYOU FOREST VILLAGE INC	WQ0012259001	TX0084531
MELROSE MHP LLC	WQ0012261001	TX0084671
ALI MOHAMMAD SOLHJOU	WQ0012261002	TX0119610
HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 200	WQ0012294001	TX0085413
NORTH GREEN MUD	WQ0012206001	TX0083381
YES COMPANIES LLC	WQ0012218001	TX0083429
HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 189	WQ0012237001	TX0083712
AMC FACILITIES LP	WQ0014882001	TX0083836
NRG TEXAS POWER LLC	WQ0001039000	TX0006408
RITA LAURA REDOW KARBALAI	WQ0012399001	TX0087785
STONETOWN WOODGATE LLC	WQ0012414001	TX0088102
UA HOLDINGS 1994-5 LP	WQ0012000001	TX0077062
EXPLORER PIPELINE COMPANY	WQ0004965000	TX0133141
CSA LIMITED INC	WQ0004084000	TX0063878

Permittee	TPDES #	EPA Permit #
MCCARTY ROAD LANDFILL TX LP	WQ0004134000	TX0119326
HOUSTON FMC-IREIC LLC AND FMC TECHNOLOGIES INC	WQ0002611000	TX0029564
ALI MOHAMMAD SOLHJOU	WQ0014277001	TX0124265
CITY OF HOUSTON	WQ0010495016	TX0063053
AQUA TEXAS INC	WQ0013870001	TX0119067
TEXAS WATER UTILITIES LP	WQ0013882001	TX0070769
KARBALAI, RITA LAURA REDOW	WQ0013955001	TX0094935
CITY OF HOUSTON	WQ0010495077	TX0063037
CITY OF HOUSTON	WQ0010495078	TX0034916
CITY OF HOUSTON	WQ0010495100	TX0055310
CITY OF HOUSTON	WQ0010495101	TX0020478
CITY OF HOUSTON	WQ0010495122	TX0103721
CITY OF HOUSTON	WQ0010495126	TX0113131
CITY OF HOUSTON	WQ0010495133	TX0084875
CITY OF HOUSTON	WQ0010495148	TX0101460
CITY OF HOUSTON	WQ0010495150	TX0025291
SOUTHERN WATER CORP	WQ0010610001	TX0030988
HARRIS COUNTY WCID NO 74	WQ0010679001	TX0023825
ALDINE INDEPENDENT SCHOOL DISTRICT	WQ0013609001	TX0115797
NITSCH AND SON UTILITY COMPANY INC	WQ0010419001	TX0070611
LA CASITA HOMES LLC	WQ0013709001	TX0103071
NADIJA BALABAN SULYUKMANOV AND ALBERT FARHATOVICH SULYUKMANOV	WQ0013749001	TX0122521
WILLIAM DONALD SMITH	WQ0013770001	TX0124257
HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 304	WQ0013564001	TX0097225
HARRIS CO MUD 278	WQ0013037001	TX0097071
HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 278	WQ0013037002	TX0127124
ROVING MEADOWS UTILITIES INC	WQ0013084001	TX0097527
MAXEY ROAD WSC	WQ0013503001	TX0105406
HINOJOSA RENE	WQ0013559001	TX0095761
TRINITY RCT GP LLC	WQ0012450001	TX0088650
VAITHI DEVELOPMENT INC	WQ0012527001	TX0090069
WESTFIELD MOBILE HOME COMMUNITY LTD	WQ0012555001	TX0090492
CHAMPS WATER CO	WQ0012571001	TX0090506
HOUSTON METRO RV PARK INC	WQ0012617001	TX0091651
HARRIS COUNTY MUD 202	WQ0012631001	TX0091901
RETERRA CORPORATION AND 1503 HADEN ROAD LLC	WQ0000662000	TX0005576
SUNBELT FRESH WATER SUPPLY DISTRICT	WQ0010236001	TX0021253
SASSON ELI GRAVRIEL	WQ0011414002	TX0033189
BLUE BELL MANOR UTILITY CO INC	WQ0011473001	TX0066478
HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 109	WQ0011533001	TX0058963

Permittee	TPDES #	EPA Permit #
JACKIE DIANE POWELL	WQ0003007000	TX0103578
HUMBLE PARTNERS LIMITED PARTNERSHIP	WQ0011161001	TX0020320
HARRIS COUNTY MUD NO 148	WQ0011818003	TX0131482
DOUGLAS UTILITY CO	WQ0011200001	TX0031461
EMERALD FOREST UD	WQ0011201001	TX0027324
EL DORADO UTILITY DISTRICT	WQ0011302001	TX0025623
LOCHINVAR GOLF CLUB	WQ0014891001	TX0131555
ROYALWOOD MUNICIPAL UTILITY DISTRICT	WQ0010608002	TX0062952
RITA LAURA REDOW KARBALAI	WQ0014217001	TX0123579
SUNBELT FRESH WATER SUPPLY DISTRICT	WQ0010812001	TX0021270
NORTH FOREST MUD	WQ0010905001	TX0058424
TRAIL OF THE LAKES MUNICIPAL UTILITY DISTRICT	WQ0011901001	TX0074021
HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 33	WQ0011904001	TX0074136
MILLS ROAD MUD	WQ0011907002	TX0075132
BAHRAM SOLHJOU	WQ0012882001	TX0094986
HOLY TRINITY EPISCOPAL SCHOOL OF GREATER HOUSTON INC	WQ0014897001	TX0125326
HOA KHUONG BUI AND CHUONG ANH NGUYEN	WQ0014921002	TX0135364
VAM USA LLC	WQ0015026001	TX0084093
HARRIS COUNTY MUD NO 400	WQ0014419001	TX0125661
AQUA UTILITIES INC	WQ0010694001	TX0027707
FALLBROOK UTILITY DISTRICT	WQ0010919001	TX0021237
MOUNT HOUSTON ROAD MUNICIPAL UTILITY DISTRICT	WQ0011154001	TX0023515
TIDWELL WASTEWATER UTILITY LLC	WQ0014320001	TX0124702
WEST ROAD WSC & MCDONALDS CORP	WQ0002761000	TX0092037
GREENWOOD UTILITY DISTRICT	WQ0011061001	TX0020800
LAKE HOUSTON PINES APARTMENTS LLC	WQ0015204001	TX0135062
HARRIS COUNTY MUD NO 191	WQ0014447001	TX0090476
SMITH INTERNATIONAL INDUSTRIAL SUBDIVISION WATER SUPPLY AND SEWER CORP	WQ0002453000	TX0084298
WILLIAM EMMETT HARTZOG JR	WQ0015001001	TX0133001
HARTZOG LINDA DIANNE	WQ0012918001	TX0095508
ESMERALDA SANJUAN	WQ0012919001	TX0099171
RANKIN ROAD WEST MUD	WQ0012934001	TX0097047
AQUA TEXAS INC	WQ0012996001	TX0096679
SUNBELT FRESH WATER SUPPLY DISTRICT	WQ0010518001	TX0021261
HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 49	WQ0011919002	TX0074446
GSL WELCOME BP 32 LLC	WQ0015545001	TX0137529
BRIXMOR GA MOUNT HOUSTON TX LP	WQ0014144001	TX0120189
HARRIS COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO 109	WQ0011026002	TX0033243
CHRISTIAN TABERNACLE OF HOUSTON INC	WQ0014513001	TX0126594

Permittee	TPDES #	EPA Permit #
HARRIS COUNTY MUD NO 400	WQ0014812001	TX0129666
RANKIN PARK MAINTENANCE & UTILITIES CO INC	WQ0014621001	TX0127957
KINDER MORGAN PETCOKE LP	WQ0003244000	TX0106542
SOLMAX GEOSYNTHETICS LLC	WQ0003402000	TX0103616
UNDINE TEXAS ENVIRONMENTAL LLC	WQ0003792000	TX0100935
BC HUMBLE ENTERPRISES LLC	WQ0014874001	TX0067539
CHAMPS WATER CO	WQ0011158001	TX0032085
BRENNTAG SOUTHWEST INC	WQ0004884000	TX0116076
SUNBELT FRESH WATER SUPPLY DISTRICT	WQ0011231001	TX0021245
HARRIS COUNTY MUD 5	WQ0011238002	TX0026344
AQUA TEXAS INC	WQ0011255001	TX0032034
CITY OF HUMBLE	WQ0010763002	TX0034401
HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 412	WQ0014527001	TX0126756
12750 ALDINE WESTFIELD LP	WQ0015868001	TX0140171
HARRIS COUNTY MUNICIPAL UTILITY DISTRICT NO 11	WQ0011351001	TX0111767
MIDWAY WATER UTILITIES INC	WQ0010436001	TX0032093
GREENSPORT SHIP CHANNEL PARTNERS LP	WQ0000509000	TX0008524
HARRIS COUNTY MUD NO 422	WQ0015889001	TX0140350
SUNNY FLEA MARKET INC	WQ0016160001	TX0142883
NORTHWEST HARRIS COUNTY MUNICIPAL UTILITY DISTRICTS 21, 22 AND 23	WQ0012144001	TX0079821
KALEIDOSCOPE YOUTH DEVELOPMENT SERVICES INC	WQ0013581001	TX0118931
ALI MOHAMMAD SOLHJOU	WQ0016028001	TX0141615



Appendix C. Agricultural Best Management Practices

This appendix details the typical practices implemented in WQMPs and similar agricultural land management projects¹²⁶. Emphasis for this WPP is put on practices that reduce animal wastes or impede transmission of wastes to water.

Table C. 1 Agricultural BMPs

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.

¹²⁶ Technicians work with local landowners to design WQMPs on a site-specific basis. More information about WQMPs, standard practices, and related TSSWCB programs can be found at <https://www.tsswcb.texas.gov/programs/water-quality-management-plan>.

Appendix D. Potential Funding Resources

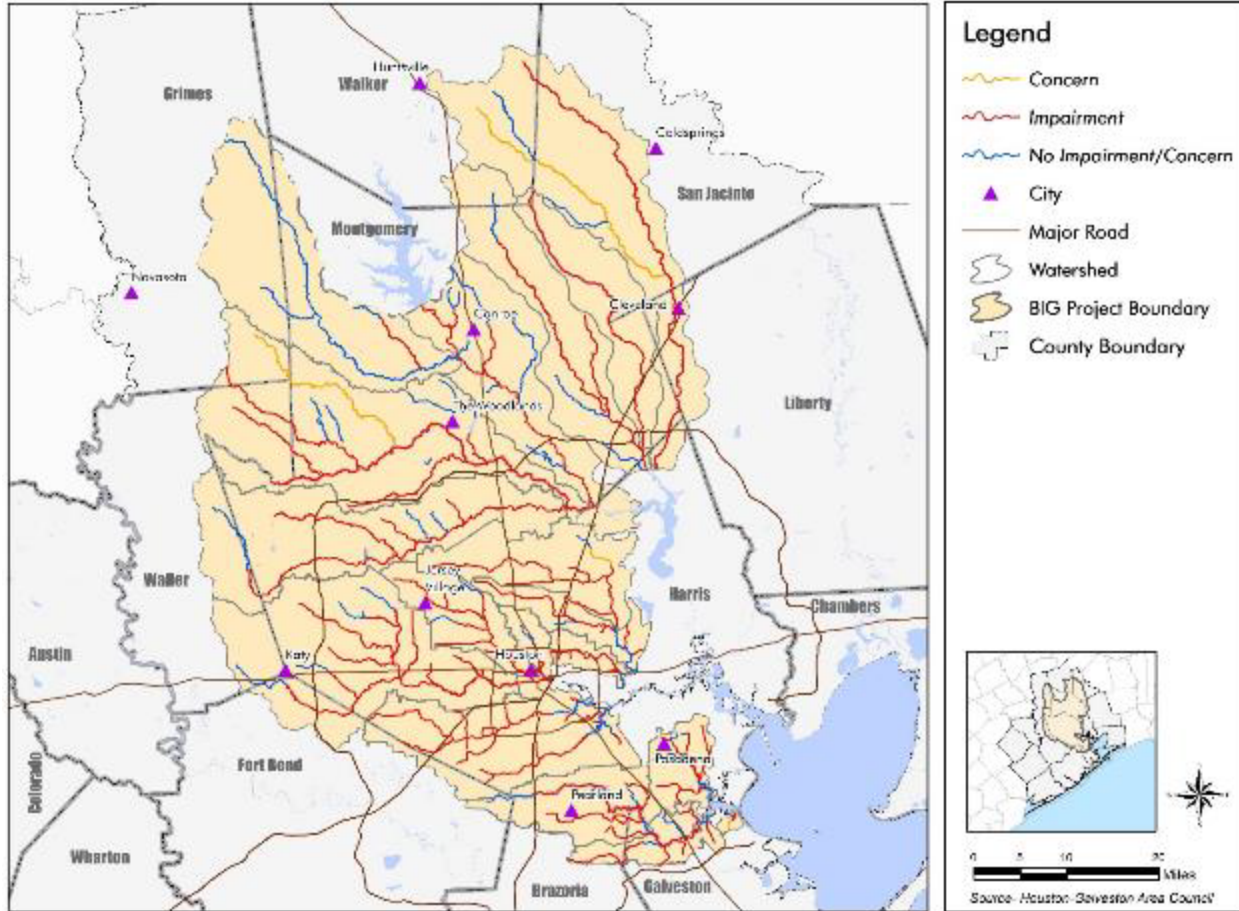
This appendix contains examples of funding resources, by category, that may be utilized to implement aspects of this WPP's recommendations. These resources represent potential external sources of funding other than existing or local contributions (*ad valorem* tax revenue, landowner contributions, etc.). The Partnership will continue to track, evaluate, and match grant sources for potential implementation activities as part of the ongoing facilitation of this WPP.

Table D. 1 Potential funding sources

Grant Program	Grantor	Uses
CWA §319(h) Nonpoint Source grants	TCEQ, TSSWCB	Multiple implementation and outreach activities
CWA §604(b) WQMP 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	Texas General Land Office/ United States Department of Housing and Urban Development	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
Land and Water Conservation Fund	US Forest Service	Conservation
Various grant programs	US Fish and Wildlife Service	Conservation, habitat restoration, wetlands restoration, endangered species

Grant Program	Grantor	Uses
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.

Appendix E. Map of the BIG Area



Appendix F. Livestock Population Estimation Adjustment

A decline in livestock populations was observed across Harris County as reported in National Agricultural Statistics Service agricultural census data collected by the USDA between 2017 and 2022¹²⁷. Adjustments were made to the calculations for future livestock populations of cattle, horses, and sheep and goats using the following steps:

- 1) Calculate the percent change between 2017 and 2022 USDA census values for cattle, horses, and sheep and goats by county.

Table F. 1 Percent reduction in animal populations between 2017 and 2022 USDA agricultural census by county

	Harris
Cattle	22%
Horse	28%
Sheep & Goats	28%

- 2) Starting point (2022) estimations for livestock population and loading estimates were not altered from those discussed in the project's Bacteria Modeling Report¹²⁸.
- 3) To estimate changes in livestock populations in five-year intervals out to 2050 for use in estimating associated bacteria loads, the population estimate (*pe*) for the previous interval was multiplied by the animal-specific percent reduction factor and subtracted from the previous interval's *pe*. For example:

$$2025 \text{ pe} = 2022 \text{ pe} - (2022 \text{ pe} \times \text{percent reduction factor})$$

$$2030 \text{ pe} = 2025 \text{ pe} - (2025 \text{ pe} \times \text{percent reduction factor})$$

$$2035 \text{ pe} = 2030 \text{ pe} - (2030 \text{ pe} \times \text{percent reduction factor})$$

$$2040 \text{ pe} = 2035 \text{ pe} - (2035 \text{ pe} \times \text{percent reduction factor})$$

$$2045 \text{ pe} = 2040 \text{ pe} - (2040 \text{ pe} \times \text{percent reduction factor})$$

$$2050 \text{ pe} = 2045 \text{ pe} - (2045 \text{ pe} \times \text{percent reduction factor})$$

- 4) The resulting population and loading estimates are shown in **Section 3**.

¹²⁷ Accessed on 3/19/2026 at: <https://www.nass.usda.gov/AgCensus/>

¹²⁸ More detailed information can be found in the Bacteria Modeling Report, located at: https://greensbayoupartnership.weebly.com/uploads/1/3/0/7/130710643/50226_4.3_bacteria_modeling_report_final.pdf