Highland Bayou Coastal Basin Watershed Protection Plan

Highland Bayou, Highland Bayou Diversion Canal, Marchand Bayou, Moses Bayou, and Unnamed Tributary of Moses Lake

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Final Report

By Texas Community Watershed Partners
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Prepared for:
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Texas Commission on Environmental Quality
17041 El Camino Real
Suite 210
Houston, Texas 77058

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By:
Texas Community Watershed Partners
Texas A&M University
Houston, Texas 77058

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Abbreviations

µg/L	micrograms per liter
ALU	Aquatic life uses
AU	Assessment Unit
AVMA	The American Veterinary Medical Association
AWEP	Agricultural Water Enhancement Program
BMP	Best Management Practices
BNSF	Burlington Norther and Santa Fe Railway
BOD	biological oxygen demand
BST	Bacteria Source Tracking
CAD	County Appraisal District
C-CAP	Coastal Change Analysis Program
CCTV	closed-circuit television
CDBG	Community Development Block Grants
CELCP	Coastal and Estuarine Land Conservation Program
CFU	Colony Forming Units
CIAP	Coastal Impact Assistance Program
CMP	Texas Coastal Management Program
CRP	Conservation Reserve Program
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund
DO	Dissolved Oxygen
EE	Environmental education
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentive Program
FDC	Flow Duration Curve
FOG	Fats, Oils, and Grease
GBAN	Galveston Bay Action Network
GBCOW	Galveston Bay Coalition of Watersheds
GBEP	Galveston Bay Estuary Program
GBF	Galveston Bay Foundation
GCDD2	Galveston County Drainage District 2
GCHD	Galveston County Health District
GI	Green Infrastructure
GIS	Geographic Information System
H-GAC	Houston-Galveston Area Council
HOA	Homeowners Association
I/I	Infiltration and inflow
IS	Impervious surface
KAST	Kills and Spills Team
Lbs	pounds
LDC	Load Duration Curve

LF	linear feet
LID	Low Impact Development
LIP	Landowner Incentive Program
mg/L	milligram per liter
MGD	million gallons per day
mL	milliliter
MOU	memorandum of understanding (maintenance agreement)
MS4	Municipal Separate Storm Sewer Systems
MUD	Municipal Utility District
NOAA	National Oceanic and Atmospheric Agency
NRCS	Natural Resource Conservation Service
OSSF	Onsite Sewage Facility
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SSO	Sanitary Sewer Overflow
SSOI	Sanitary Sewer Overflow Initiative
SSS	Sanitary Sewer System
SWQ	Surface Water Quality
SWQM	Surface Water Quality Monitoring
SWW	Stormwater Wetlands
TCEQ	Texas Commission on Environmental Quality
TCWP	Texas Coastal Watershed Program
TFRLCP	Texas Farm and Ranch Lands Conservation Program
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas Surface Water Quality Standards
TWDB	Texas Water Development Board
TX GLO	Texas General Land Office
UH	University of Houston

Executive Summary

This plan covers several coastal watersheds in southern mainland Galveston County within the Highland Bayou Coastal Basin including Highland Bayou, Marchand Bayou, Highland Bayou Diversion Canal, Moses Bayou, and an unnamed tributary of Moses Lake. Each of these waterways flows into a portion of Galveston Bay and is influenced by tidal fluctuation. This portion of Galveston County is rapidly developing, adding pressure to already precarious bayou systems. Local communities rely on the bayous for stormwater and flood conveyance as well as for fishing, recreation, and ecotourism.

Problem Statement

Water quality monitoring for the project area bayous indicates high levels of fecal coliform bacteria and low levels of dissolved oxygen. The upper reaches of Highland Bayou, all of Marchand Bayou, and all of the diversion canal, Moses Bayou, and the unnamed tributary of Moses Lake have higher than acceptable levels of fecal coliform bacteria. Portions of Highland Bayou and Marchand Bayou also show low levels of dissolved oxygen in the water under certain circumstances. Due to these impairments, all stream segments discussed are included on the State of Texas impaired waterbodies list. With this listing comes a need to improve the water quality and restore the health of each bayou. This watershed protection plan (WPP) is a stakeholder-led project facilitated by the Texas A&M AgriLife Extension Service to restore water quality and repair watershed health within the project area.

Plan Overview

This WPP was developed as a result of the water quality impairment listing discussed above and included extensive stakeholder involvement spanning several years. Through a series of meetings, on-going dialogue, data collection and review, and group prioritization, a number of voluntary actions were determined and described. These actions describe management strategies and practices for local communities, drainage districts, wastewater operators, elected officials, and homeowners to implement. Even with all of the resources and knowledge poured into this WPP, bayous are dynamic systems that continue to change, and it is essential this Plan be dynamic as well. This WPP should be viewed as a living document, to be updated and revisited as needed for continued relevance in the project watersheds.

Pollutant Sources

Local experts and credible data were used to identify sources of pollution for the project area. These include domesticated dogs, cattle, feral hogs, failing on-site sewage facilities, sanitary sewer overflows, wastewater treatment facilities, and stormwater runoff. Stakeholders also expressed concerns about the water flow in Highland Bayou. There is a general consensus that improving flow in the bayou will improve flushing of the system and therefore improve water quality and health.

Recommended Actions

In addition to determining sources of pollution, local stakeholders determined appropriate and realistic actions to mitigate these sources. Twelve actions were prioritized and 26 additional project ideas documented. The 12 actions can be grouped into seven topic areas.

Sanitary Sewers

Wastewater facilities and infrastructure within the project area are aging and is often undersized due to increased development and populations. Management measures include upgrading sanitary systems and educating residents on proper disposal of household items including wipes, fats, oils, and grease (FOG) that frequently clog sewer pipes.

Flow in Highland Bayou

Over time, changes made to the main channel of Highland Bayou, and the construction of the diversion canal have dramatically altered flow in Highland Bayou. Stakeholders prioritized measures to increase flow and flushing of Highland Bayou to improve stream health.

Pet Waste

A large number of residents own pets, especially dogs. This measure is focused on educating residents on the need to clean up after their pets.

Stormwater Management

As development continues in the project area watersheds, stormwater management is a growing need. Measures include mapping, maintaining, and improving infrastructure; incorporating new techniques including green infrastructure practices, and updating ordinances that protect the stormwater conveyance system.

Natural Areas

Stakeholders will encourage the identification, protection, preservation, and enhancement of natural areas for their ecosystem services. This includes both public and private lands.

On-Site Sewage Facilities

The diversion canal and Moses Bayou watersheds have large concentrations of on-site sewage facilities (OSSFs). It is well known locally that heavy clay soils do not allow traditional drain fields to function well, and that homeowners are not savvy about maintenance for new aerobic systems. Many opportunities exist for educating OSSF owners, so these systems function well.

Feral Hogs

Undeveloped areas in Galveston County have growing feral hog populations, but landowners have few local resources to assist with management. This measure is

focused on bringing educational resources to local landowners in a meaningful and useful way, so that the hog population can be suppressed.

Education and Outreach

Execution of this WPP and improving watershed health depends on more than just the individuals and organizations involved in the WPP process. Continual education efforts and materials are essential throughout the project area to ensure success. Several management measures focus specifically on educational efforts, but education is needed as a component of each action. A wide variety of audiences will be engaged from elected officials to homeowners, landowners, and pet owners. A mixture of in-person and digital media will be needed to reach various groups and meet individuals where they are while encouraging behavior change.

Goals of the WPP

The primary goal of this WPP is to provide locally derived solutions to improve water quality and stream health in the project area bayous, resulting in removal of all segments from the State of Texas Impaired waterbodies listing. Interim goals were identified to measure progress throughout the process, and to allow for course correction if needed to reach the goal of fully functional bayou systems throughout the project area.

Introduction

Why a Watershed Protection Plan?

A watershed protection plan (WPP) is a stakeholder-driven, voluntary plan of action to address water quality issues in the watershed. Stakeholders bring to the planning process their local knowledge of their watershed, communities and projects. It is imagined that a voluntary plan developed through sustained stakeholder participation will lead to individual ownership and follow-through activities that will have a positive impact on the area's water quality. A U.S. Environmental Protection Agency (EPA) approved WPP also opens opportunities to bring in state and federal support for these projects. The WPP document is a community resource, compiling in one place the wide range of factors impacting water quality, estimated pollution loads and reductions, specific stakeholder concerns, and potential pathways for action. The plan includes narratives about how these issues and concerns relate and fit within the larger picture.

Figure 1. Highland Bayou Diversion Canal.

What is a Watershed?

A watershed is an area of land drained by a water body, such as a river or bayou. As stormwater flows over the land, it collects into a system of ditches, creeks, bayous, and ultimately Galveston Bay. The water, from the time it hits the ground, transports all water-borne compounds it encounters along the way, such as bacteria, chemicals, paint, oil, sediment, fertilizers, lawn clippings, sewage, litter, and more. A popular misconception by average citizens is that stormwater is treated by the "City." This is not true. Stormwater is not sent to wastewater treatment plants and instead flows into larger and larger stormwater systems and then into the bayou, untreated. What we do on the land ends up in the bayou. A watershed approach is a holistic way to deal with all the land-based factors that impact stormwater before it flows into the bayou.

Project Area

The Highland Bayou, Highland Bayou Diversion Canal, Marchand Bayou, Moses Bayou, and unnamed tributary of Moses Lake watersheds are in Galveston County's southern mainland within the larger Highland Bayou Coastal Basin (Figure 2). The basin is bounded to the north by Dickinson Bayou, and on the west by Halls Bayou. Waterways

within the basin drain easterly and southerly into the tidal bays of Lower Galveston Bayou and West Bay. Communities in the coastal basin include the cities of Santa Fe, Hitchcock, La Marque, Texas City, and Bayou Vista. Marchand Bayou is a tributary that flows into Highland Bayou, which then drains into Jones Bay and the West Bay of Galveston Bay (Figure 2). The Highland and Marchand bayous watershed cover almost 23 square miles of land.

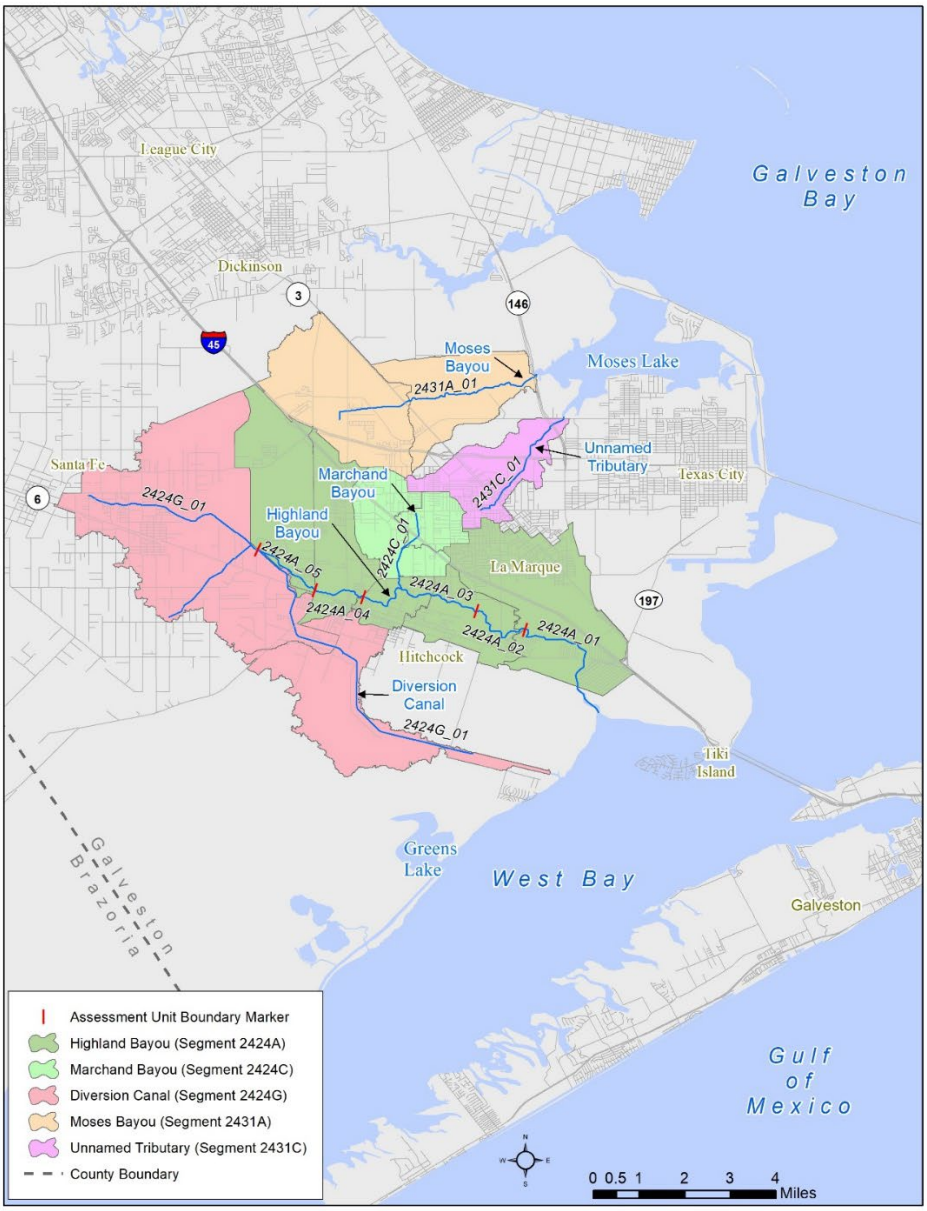


Figure 2. Project watersheds and TCEQ AUs.

The Highland Bayou Diversion Canal was constructed in the 1970s, intercepting the headwaters of Highland Bayou at a point near Jack Brooks Park, and diverting it

southward through old Basford Bayou and into West Bay. These historical headwaters are now considered the diversionary canal watershed and are separate from the Highland Bayou Watershed.

Moses Bayou flows from upstream of State Highway 3, 1.4 miles east into Moses Lake, a sub-bay of Lower Galveston Bay.

The unnamed tributary of Moses Lake flows from upstream of State Highway 3, 0.45 miles into the southern arm of Moses Lake.

Within the study area, the topography is flat (Figure 3) and drained by a system of ditches and drainage infrastructure maintained by the communities and Drainage Districts. Land in the study area is a mix of residential, industrial, and undeveloped lands, including farms, coastal prairies, wetlands, and estuaries (Figure 4).

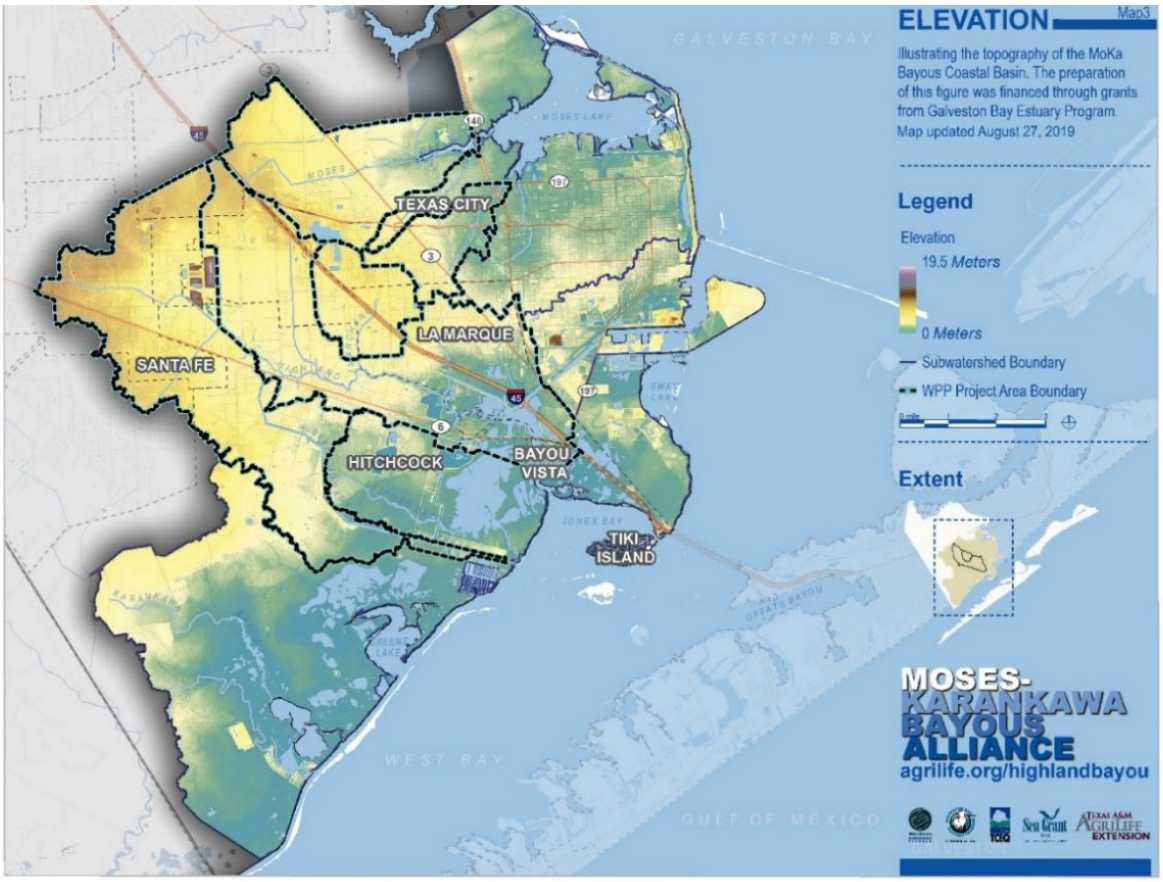


Figure 3. Elevation in the Highland Bayou Coastal Basin.

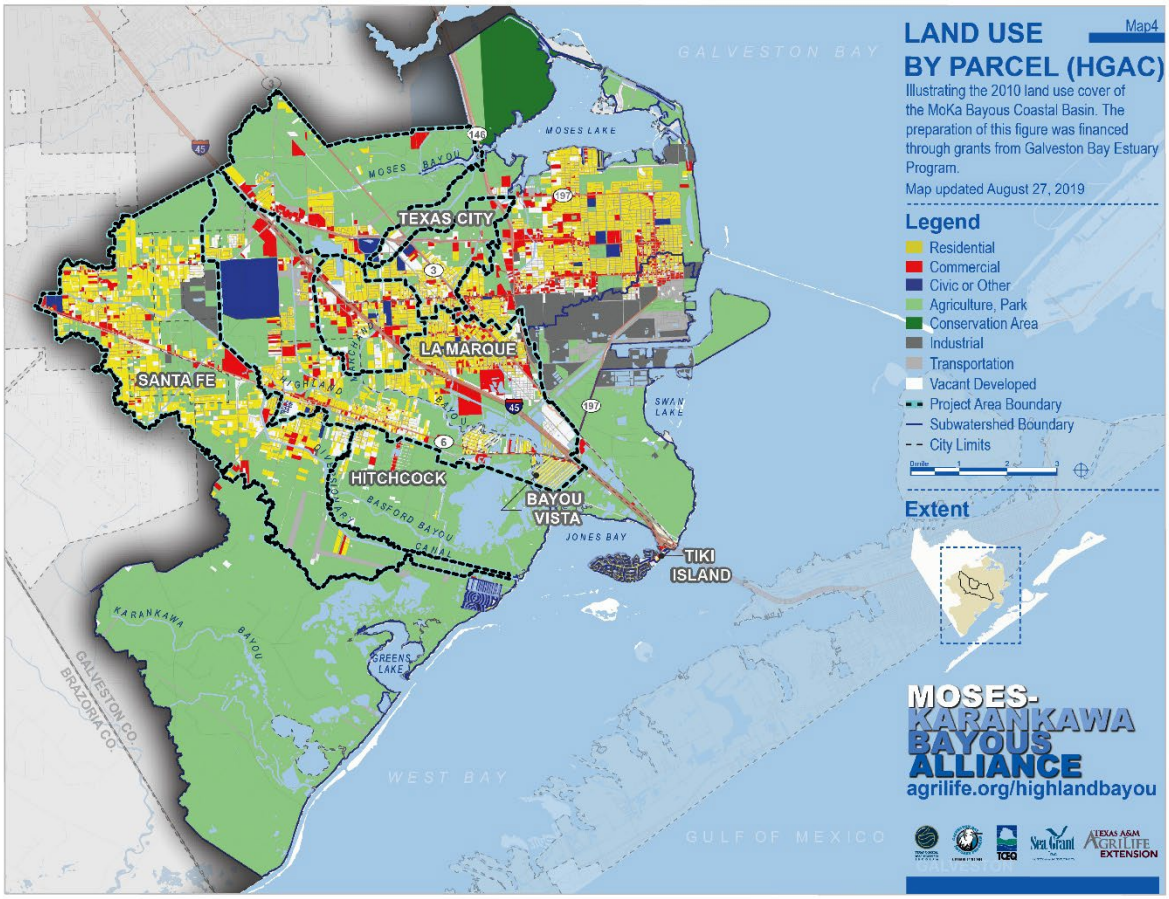


Figure 4. Parcel land use in the Highland Bayou Coastal Basin.

In 2012, the Highland Bayou Watershed Characterization Report[1] was prepared in anticipation of this WPP. The Report includes historical background about the habitats and communities in the basin. It includes summaries of physical and natural features in the watershed, along with observed and measured water quality conditions. The report also includes details about land development and demographic trends in the watershed.

Elements of a Successful WPP

EPA identified nine elements as critical pieces of a WPP to achieve water quality improvements (Table 1). A WPP must address these elements before it can be approved by EPA and thus be eligible for Clean Water Act (CWA) Section 319-funding for

[1] agrilife.org/highlandbayou/project-data-2/highland-bayou-characterization/

implementation projects. Other funding sources must also be obtained for a successful outcome.

Table 1. EPA nine elements of a WPP.

EPA Nine Elements of a Watershed Protection Plan	
Element A. Identify Causes and Sources of Impairment	Identify the causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions. Sources that need to be controlled should be identified at a significant subcategory level along with estimates of the extent to which they are present in the watershed.
Element B. Expected Load Reductions	Estimate load reductions expected from management measures.
Element C. Proposed Management Measures	Describe the nonpoint source management measures that will need to be implemented to achieve load reductions and include a description of the critical areas in which those measures will be needed to implement this plan.
Element D. Technical and Financial Assistance Needs	Estimate the amount of technical and financial assistance, associated costs, and authorities that will be relied upon to implement this plan.
Element E. Information, Education, and Public Participation	Include an information and education component to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.
Element F. Implementation Schedule	Prepare a schedule for implementing the nonpoint source management measures identified in this plan that are reasonably expeditious. For this plan, a 10-year time horizon is used for load reduction estimates.
Element G. Milestones	Prepare interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.
Element H. Load Reduction and Evaluation Criteria	Set forth water quality or other environmental criteria that can be used to determine whether loading reductions are achieved over time and if substantial progress is being made toward attaining water quality standards.
Element I. Monitoring	Propose a monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item H above.

Stakeholder Working Group

The stakeholder working group was essential in developing this WPP; community stakeholders, regional organizations, and state agencies comprise the working group. Details of this process are in Element E. This group identified and shared their concerns along with specific projects and project ideas that are the basis for this plan.

Project Significance and Background

Regulatory Standards and Water Quality

All major waterbodies in Texas are classified into basins and segments by TCEQ. All waterbodies for this WPP are in Basin 24, "Bays and Estuaries," which includes all Texas bayous and inland surface waters that are tidally influenced by the Gulf of Mexico. The TCEQ segment IDs are numbered using the subbasin ID: for example, Highland and Marchand Bayous are 2424A and 2424C, respectively. The segments are divided into assessment units (AUs), the smallest unit of analysis used by TCEQ to assess water quality. AUs for the project area are in Table 2. The catchment areas defined by these AUs are in Figure 2.

Each stream segment has a designated use and an associated water quality standard for each use. The primary use for waterways in the WPP is primary contact recreation, the most stringent use class after drinking water sources. TCEQ assesses water quality in each segment using the standards and methods described in the 2010 Guidance for Assessing and Reporting Surface Water Quality (SWQ) in Texas. When an evaluation of water quality samples results in a set number of exceedances, the agency determines that the segment has failed water quality standards. Water quality assessments are based upon a rolling seven-year period and are updated every two years. The latest assessment was released in 2020. Water quality sampling events must be from at least two years, and no more than two-thirds of the samples can be assessed from any one year. At least 10 samples are needed to calculate a use attainment, although smaller sample sizes can be considered.

303(d) Listing

The federal CWA requires that states identify and list segments that do not attain their designated water quality standards. The name "303(d)" refers to the section of the federal CWA that describes the process states must use to list impaired waterways (i.e., waterways that do not meet state water quality standards). TCEQ publishes the Texas 303(d) list in the Texas Integrated Report—Texas 303(d) List. Segments on the list are identified by the segment ID, the type of impairment, and the pollutant resulting in the impairment. Highland, Marchand, and Moses bayous, the diversion canal, and the unnamed tributary are currently listed on the 303(d) list of impaired waters, and this is the impetus behind the funding for this WPP (Table 2).

The 2014 Texas Integrated Report was the most current iteration when WPP development began and was therefore used to inform stakeholder decisions and is referenced in this document instead of the more recent 2020 Report. According to the 2014 Texas Integrated Report, Highland Bayou AUs have been on the 303(d) list since 2002 for bacteria levels. Marchand Bayou (2424C_01) was first listed in 2002; and Highland Bayou segment 2424A_01 was also listed as "concerned" for low dissolved oxygen (DO). The Integrated report also lists causes for each impairment. For project area waterbodies these are nonpoint sources (EPA code 141), "Urban Runoff/Storm Sewers" (EPA code 177), and "Source Unknown" (EPA code 140). All waterbodies in the project area are expected to meet the bacteria contract recreation standard of 35 colony forming units (CFU)/100 milliliters (mL) set forth by the EPA. Those that do not meet this standard are considered "not supporting."

Table 2. AU and assessment from the 2014 Integrated Report.

Assessment Unit	Bacteria – Contact Recreation	Dissolved Oxygen – Aquatic Life Use
Highland Bayou 2424A_01	Fully Supporting	Screening level concern – DO grab
Highland Bayou 2424A_02	Not Supporting	Use concern – DO 24-hour minimum
Highland Bayou 2424A_03	Not Supporting	Screening level concern- DO grab Use concern – DO 24-hour minimum
Highland Bayou 2424A_04	Not Supporting	Use concern – DO 24-hour minimum
Highland Bayou 2424A_05	Not Supporting	Not supporting – 24-hour average and minimum
Marchand Bayou 2424C_01	Not Supporting	Not supporting – DO 24-hour minimum
Diversion Canal 2424G_01	Not Supporting	Screening level concern – DO grab
Moses Bayou 2431A_01	Not Supporting	Fully supporting
Unnamed Tributary 2431C_01	Not Supporting	Fully supporting

Pollutant of Concern – Bacteria

All project area waterbodies are listed on the 303(d) list of impaired waters for high levels of fecal coliform bacteria. Bacteria can enter the bayou from point sources like wastewater treatment plants and nonpoint sources such as sewage collection systems, pet waste, urban runoff, and wildlife. These sources are described more in Element A. Bacteria usually enter waterways attached to sediment or other particles. Reductions in sediment loads could reduce bacteria loads.

High bacteria levels are a public health risk, which can result in human sickness. Bacterial infections occur through ingestion of water containing bacteria or via contact through cuts, the nose, eyes, and ears. Infections from waterborne bacteria can result in rashes, flu-like symptoms, nausea, diarrhea, vomiting, and gastroenteritis. In the elderly or infant populations with weakened immune systems, severe cases of bacterial infection can result in chronic illness and death. The National Water Quality Inventory lists bacteria as the leading cause of water quality impairment in rivers and streams in the United States (Environmental Protection Agency, 2000).

Many species of bacteria exist in contaminated water, but not all can be measured or counted. Water quality analysis tests for specific bacteria species, referred to as indicator bacteria. The presence of indicator bacteria implies the presence of other bacteria in the water. In the case of tidally influenced waterways, the indicator Enterococcus bacterium is used. These bacteria are present in the intestines of warm-blooded animals and indicate the presence of human or animal waste in the water. E. coli is used as the fecal bacteria indicator in freshwater segments. The TCEQ limit for Primary Contact Recreation is 126 CFU per 100 mL for E. coli in freshwater segments and 35 CFU per 100 mL for Enterococcus in saltwater segments (Texas Administrative Code Section 307.7)

Observed values for Enterococcus in Highland, Marchand, and Moses Bayous, the diversion canal, and the unnamed tributary exceed Primary Contact Recreation limits established by TCEQ. Recreational uses include primary contact recreation such as swimming and other activities that have a high likelihood of ingesting some water.

Pollutants of Concern – Low DO and Nutrients

Low DO

Oxygen levels are a measure of overall health and the ability of waterways to support aquatic life. Low DO is not itself a pollutant, but it is correlated with excessive levels of nutrients and other pollutants. DO in water increases when aquatic plants and algae use sunlight and produce oxygen. Oxygenated water sustains other living organisms. For this reason, Texas regulatory limits for DO are defined as a standard for Aquatic Life Uses (ALU). In healthy water quality conditions, DO concentrations should be between 7-10 milligrams per liter (mg/L), depending on the salinity and temperature. The minimum regulatory standard for DO in segments designated with a “High” ALU is 4.0 mg/L for freshwater segments and 3.0 mg/L for saltwater segments. Below these levels, aquatic species are stressed and can die (discussion below).

Fish kills are sudden die offs of large numbers of fish and are observed or reported every year in the watershed. Many species of the Gulf fisheries spend phases of their life cycle in the bayous before migrating to Galveston Bay or the open waters of the Gulf. The water quality of the Bayous is tied to the health of fish populations along the Gulf Coast. Along the Upper Texas Coast, low DO is the most common cause for fish

kills. Many aquatic organisms cannot survive when the oxygen levels fall below 2 mg/L for any significant period, and sensitive organisms or life stages cannot survive very long below 4 mg/L. TCEQ requires the DO level in a 24-hour period to be greater than 3mg/L and the average one-day average value to be above 4 mg/L.

Low DO Correlated to Nutrients and Other Phenomena

It is highly likely that nonpoint source pollution is a factor explaining observed low levels of DO. Nutrients including nitrates and phosphorus come from a variety of activities and sources, including fertilizers, untreated sewage from sanitary sewer overflow (SSO) discharges, organic decomposition, and even atmospheric deposition. Runoff rich in nutrients promotes excessive growth of algae and other plant life in the water. In turn, the eventual decay of the algae starts a chemical process that consumes and sometimes depletes oxygen from the water, resulting in a condition called eutrophication.

Evidence of these processes is seen in the water quality data analyzed in the 2012 Characterization Report, particularly through measurements for biological oxygen demand (BOD), chlorophyll-a, phosphorus, and nitrogen. For example, algal blooms, which can be observed as a milky green coloration in the water, are indicated by measurements of chlorophyll-a. Of 96 tests for chlorophyll-a, 27 tests showed values exceeding the state limit of 21 micrograms per liter (µg/L). Only three of those occurred during the cool weather season. Because algae use phosphate as a growth nutrient, phosphate levels decline during summertime algae blooms and rebound during the cool season. This indicates that algae consume phosphorus nutrients in the water during the high growth season, lowering observed levels. Low algae growth in the cool season may explain the increase in measured phosphorus during the cool months.

Ammonia

Ammonia is very soluble in water. It is a primary and secondary plant nutrient, promoting excessive plant growth and eventual eutrophication of the waterway. Elevated levels of ammonia can interfere with fish health. Ammonia is produced in natural settings through decomposition of biological matter. Residential sources of ammonia are fertilizer and cleaning products.

Nitrates

Nitrate is a form of nitrogen usable by plant species. Nitrate can interfere with animal health by binding to blood and blocking the uptake of oxygen. In freshwater aquatic systems the limiting nutrient for plant growth is phosphorus, whereas in saline aquatic systems nitrate is the limiting nutrient. Algal blooms may occur at concentrations greater than 0.1 mg/L. Excessive nitrogen can promote plant and algal growth, resulting in eutrophic conditions, clogging of water channels, and lowered aesthetic quality. Sources from agriculture include animal waste, fertilizer, and irrigation return flows. Residential sources include septage, fertilizer, and pet waste. Industrial sources

include water treatment plants and production activities relating to glass making, fertilizer, petrochemicals, and meat processing.

Orthophosphate/Total Phosphorus

Phosphorus is a commonly occurring element, and it can be found naturally in various chemical states and in combination with other elements. Orthophosphate refers to the water-soluble form of phosphorus. Total phosphate includes organic P, precipitates, colloidal phosphorus, and phosphorus adsorbed to suspended solids and sediment. Soluble forms of phosphorus do not persist in the environment for much longer than five days, when they become incorporated into soil or taken up by plant life. There are several pathways for phosphorus to move through the environment, but phosphorus adsorption to the surfaces of suspended solids may account for a sizable portion of phosphorus transport. If soluble forms such as orthophosphate are measured in the environment, they are likely recent and indicate a nearby source, such as wastewater treatment plants, septic systems, and/or crops. Excessive phosphorus promotes excessive plant growth. Sources of phosphorus are fertilized fields and lawns, and domestic wastewater.

Chlorophyll-a

Chlorophyll is a green chemical compound found in algae and other plant life. It is the basic molecule in plant-based photosynthesis. The compound exists in several forms, but the most prevalent is chlorophyll-a. Its measurement in water provides a direct measure of phytoplankton in the water and provides a proxy measurement for other pollutants like nitrates and phosphorus. Excessive growth of algae can result in eutrophication and cause fish kills. High levels of chlorophyll can arise from anthropogenic sources of nitrogen and phosphorus.

Physical Conditions

Levels of oxygen in the water are the result of several factors, but perhaps not all of them resulting from runoff. For example, cold water can hold more oxygen than warm water, a condition that can partially account for the seasonality of oxygen levels in the waterways. At the freezing point (0°C), fully saturated water can hold 14mg/L, a difference of 6.0 mg/L compared with what water can hold at 70°F (21°C), 8.0mg/L. Because Highland Bayou, like most coastal bayous, is a slow moving warm-water bayou, naturally depressed levels of DO might be the norm, although the “normal” level in a bayou in its pristine state is not understood, and there is disagreement among experts about what that figure would be for waterways like Highland Bayou.

Methods

Element A: Identify Sources of Impairments and Loads

Stormwater Runoff is a Fingerprint of the Land

Water pollutants originate from both point and nonpoint source pollution on the land. Point sources have an identifiable origin such as a pipe or ditch from an industrial or commercial process discharging directly into a waterway. Discharges from point sources are usually covered by federal and state regulations and permits. Stormwater nonpoint source pollution, also commonly called runoff pollution, refers to diffuse sources of pollution originating from multiple locations, such as lawns, roadways, homes, and businesses. Runoff from nonpoint sources is commonly understood to include fertilizers, insecticides, oils, sediment, and bacteria. Each nonpoint source might be small, but when considered together, they can exceed the pollution contribution from point sources. In fact, in many watersheds around the country, nonpoint source pollution is the leading cause of water quality problems.

This means that how land is used determines what we see in the water. Development, for example, impacts both the quantity and the quality of stormwater runoff. Impervious surfaces alter stormwater runoff patterns and are a key indicator of loading and overall watershed health (Figure 5). Impervious surfaces include all hard surfaces, such as roofs, driveways, parking lots, roadways, and even compacted soil. Due to changes in surface cover, developed or urbanized areas exhibit higher stormwater pollutant levels when compared with their predevelopment runoff levels. As the amount of impervious surface cover increases in the watershed, the water quality of receiving water bodies degrades. For example, two neighboring properties, one developed and one undeveloped, may receive the same amount of rainfall but exhibit different runoff characteristics. The undeveloped property will allow water to infiltrate into the ground while the developed property sees increased runoff.

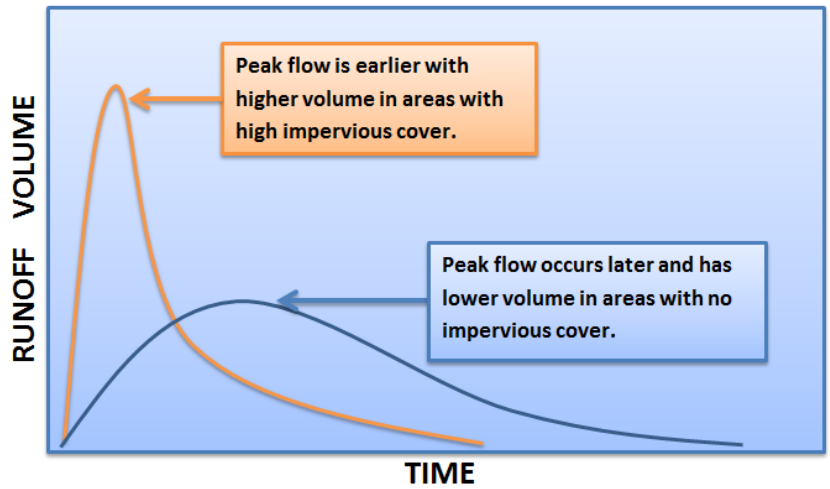


Figure 5. Generalized hydrograph of areas with and without impervious surface cover.

Stakeholder concerns about water quality were gathered and can be grouped into four categories: wastewater; flow and dredging; urbanization and development; and agriculture, wildlife, and natural areas.

Flow and dredging (technically, hydrologic changes) is an unusual category for a WPP and is not itself a source of pollutant loading. However, many stakeholders expressed concerns about the flow condition in Highland Bayou, and some of them believe that improved flow and flushing could have a positive impact on water quality. Stakeholders also noted habitat fragmentation throughout the project area and recognized the result of breaking up larger undeveloped lands and habitat loss from development as a threat to wildlife populations. Individual properties within watersheds do not function as separate, isolated components but as a single, integrated natural system. Significant alteration of individual properties can disrupt the functioning of the watershed.

Table 3 summarizes the nonpoint sources stakeholders identified as likely contributors to nonpoint source loads in the watershed.

Table 3. Pollutants of concern by source.

Source	Bacteria	Nutrients [1]	Sediment
Wastewater			
Wastewater Treatment Facilities (WWTF)	x	x	
Sanitary Sewer Systems	x	x	
Septic Systems (OSSFs)	x	x	
Urbanization and Development			
Urban Stormwater Runoff	x	x	x
Construction Runoff			x
Lawn Care and Landscaping		x	x
Litter and Illegal Dumping		x	
Pets	x	x	
Agriculture/Wildlife/Natural Areas			
Feral Hogs	x		

Source	Bacteria	Nutrients [1]	Sediment
Livestock and Pasture	x	x	x
Wildlife and Non-Domestic Animals	x	x	x
Streambank Erosion		x	x

[1] Nutrients—nitrogen and phosphorus compounds.

Wastewater

Permitted WWTFs

There are four permitted WWTFs in the project area. (Figure 6). The Galveston County Municipal Utility District (MUD) 12 wastewater treatment plant (WWTP) and La Marque's Westside WWTP discharge into Highland Bayou. Galveston County Water Control Improvement District (WCID) 8, and the city of Hitchcock WWTF discharge into the diversion canal. The city of Hitchcock and La Marque's Westside facility has recently doubled its discharge authorized by TCEQ to a volume not to exceed an annual average flow of six million gallons per day (MGD). The Galveston County MUD 12 facility, considered a minor source, is authorized to discharge a daily average flow at a volume not to exceed 0.4 MGD. WCID #8 is also making improvements to add aeration to its process and possibly updating their outfall location, which would replace existing older infrastructure. While the city of Hitchcock's WWTP discharges to the diversionary canal, much of the associated collection system occurs within the Highland Bayou Watershed.

In the last five years, La Marque has had three TCEQ inspections and Galveston County MUD 12 has had two, none resulting in enforcement actions. Two formal enforcement actions were reported for the city of Hitchcock. There have been nine reported effluent exceedances for both Hitchcock and La Marque and one for Galveston County MUD 12 between July 31, 2012 and July 31, 2015. The Enterococci daily maximum threshold exceeded only one month for both the city of Hitchcock and Galveston County MUD 12. Other effluent parameters remain within discharge limits: nitrogen (ammonia total, as nitrogen), BOD, and flow.

The Galveston County Health District (GCHD) Water Pollution Services Program offers quarterly inspections of WWTP operations for compliance with state and federal regulations as a contract and have assisted Hitchcock and La Marque as recently as 2015. For the city of La Marque in fiscal year 2015, the GCHD reported an annual average removal rate for ammonia nitrogen of 88%, which exceeds the monthly removal rate of 85% required by the permit. The average Enterococci quantity was 1.53 CFU/100mL.

WWTP effluent is considered a point source of pollution, highly regulated through the Texas Pollutant Discharge Elimination System (TPDES) program. Due to the episodic

nature of discharges that exceed established thresholds for bacteria and other contaminants, stakeholders expressed greater concern for releases from the sanitary sewer collection system. With additional growth in the basin and extra sewage to treat, it is reasonable to expect volumes to increase accordingly though discharges would be required to remain within the permit limitations.

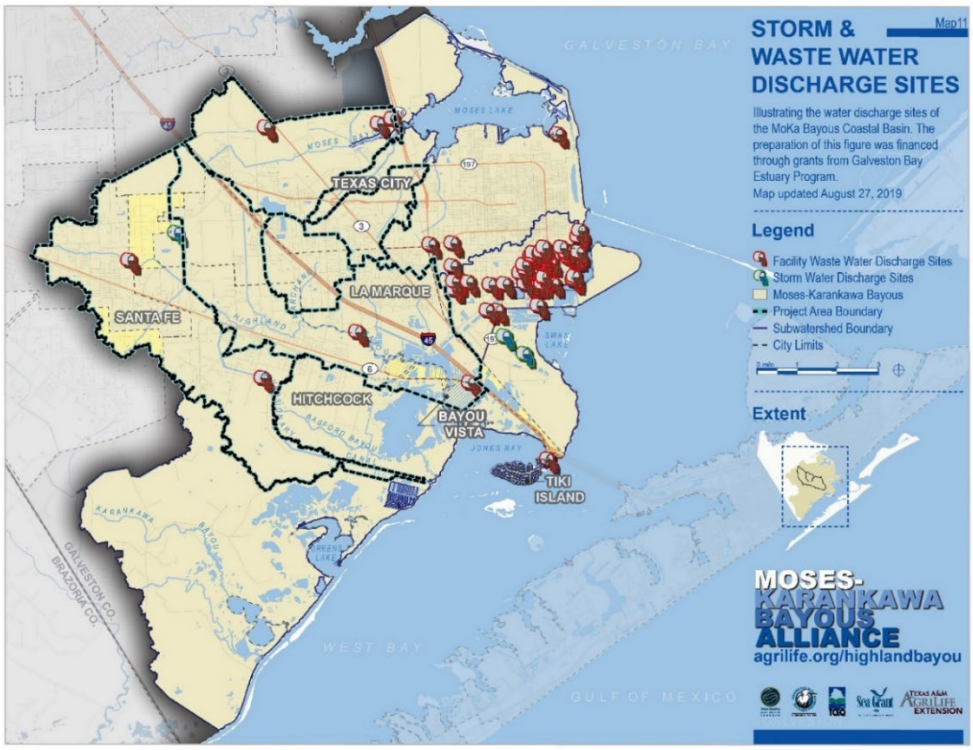


Figure 6. Storm and wastewater discharge sites.

Sanitary Sewer Systems

Collection systems bring sewage from home and businesses to WWTFs. The collection systems include a network of sewer lines, pump stations, and supporting infrastructure. Most areas in the Highland, Marchand, and Moses Bayou watershed are serviced by a collection system. Main lines usually follow highways and roads into neighborhoods, finally connecting to buildings. Anything poured or flushed down a drain flows into the collection system, meaning that sewage is a collection of human waste, urine, paper products, detergents, cosmetics, pharmaceuticals, cleaners, and any other liquids used at home or in businesses. Sanitary sewer overflows (SSO) are releases of untreated sewage from these collection systems. These releases can transmit high levels of bacteria to stormwater runoff. SSOs of certain sizes or happening in certain locations (i.e., near drinking water sources) must be reported by the collection system TPDES permittee. SSOs usually occur as the result of a break, stoppage, or exceedance of capacity in the sanitary sewer conveyance system. If not directly discharged into the bayou, the overflows typically drain to the stormwater

conveyance system and are transported to the bayou by stormwater runoff. Load reduction estimates are included in Element B. Since most of the project area is serviced by a collection system, reductions are allocated on a prorated share of population in each watershed AU.

Septic Systems

OSSFs, commonly referred to as septic systems, are a standard method for treating home and business sewage on site. This is particularly true in areas of low population density. The largest clusters of permitted OSSFs are in and around the city of Santa Fe, with failures likely draining into the diversionary canal. OSSFs are scattered throughout the rest of the project area in small numbers but are not considered a significant source of pollutants for Highland, Marchand, or Moses Bayous or the unnamed tributary. Known OSSF locations are based on permit information. Assumed locations are estimated by identifying structures both without a permitted OSSF and situated outside of a municipal service area boundary for sanitary sewer within the watershed; there is a cluster of OSSFs located near Texas Highway 6 in the parts of unincorporated Galveston County, referred to as Freddiesville and Old Highland Bayou, just west of Bayou Vista (Figure 7). Parts of this area have been recently brought into Hitchcock's collection system service area. GCHD is sometimes contacted by residents reporting leakages from pipes and bulkheads in this area. These reports usually result in a determination that the leakage is connected to abandoned or unpermitted OSSFs.

Failing OSSFs contribute bacteria and nutrients by seepage from failing drain fields or from overflowing systems. Proper operation and maintenance of OSSFs is critical for protecting public health and surface water resources. System owners (i.e., homeowners) are responsible for the proper maintenance of their systems. Aerobic systems require specialized attention, and it is common that owners forget to add chlorine or utilize the wrong chlorine (i.e., pool chlorine). Poor or improper maintenance practices can result in the system becoming unbalanced and nonperforming. With these kinds of failures, aerobic systems could be spraying raw sewage onto the ground. Maintenance agreements when required seem to help this.

Before the mid-1970s, no permit was required to install an onsite septic system in Galveston County, resulting in a legacy of unpermitted and possibly poorly performing or failing systems dotting the landscape. No federal permits are required for installing OSSFs. County regulations now require that the property owner acquire a permit and conduct a site evaluation of water tables and soil permeability, the two factors most likely to contribute to a septic system treatment failure. It is likely that older, unpermitted systems were not designed for the poor soil conditions especially if one assumes that the conventional soil leaching systems were used when they were installed. Most soils in this watershed have shallow water tables and low permeability (Figure 8). During periods of extended wet weather, there is a high probability of soil saturation, when untreated septage could rise to the surface and thence to nearby drainage ditches.

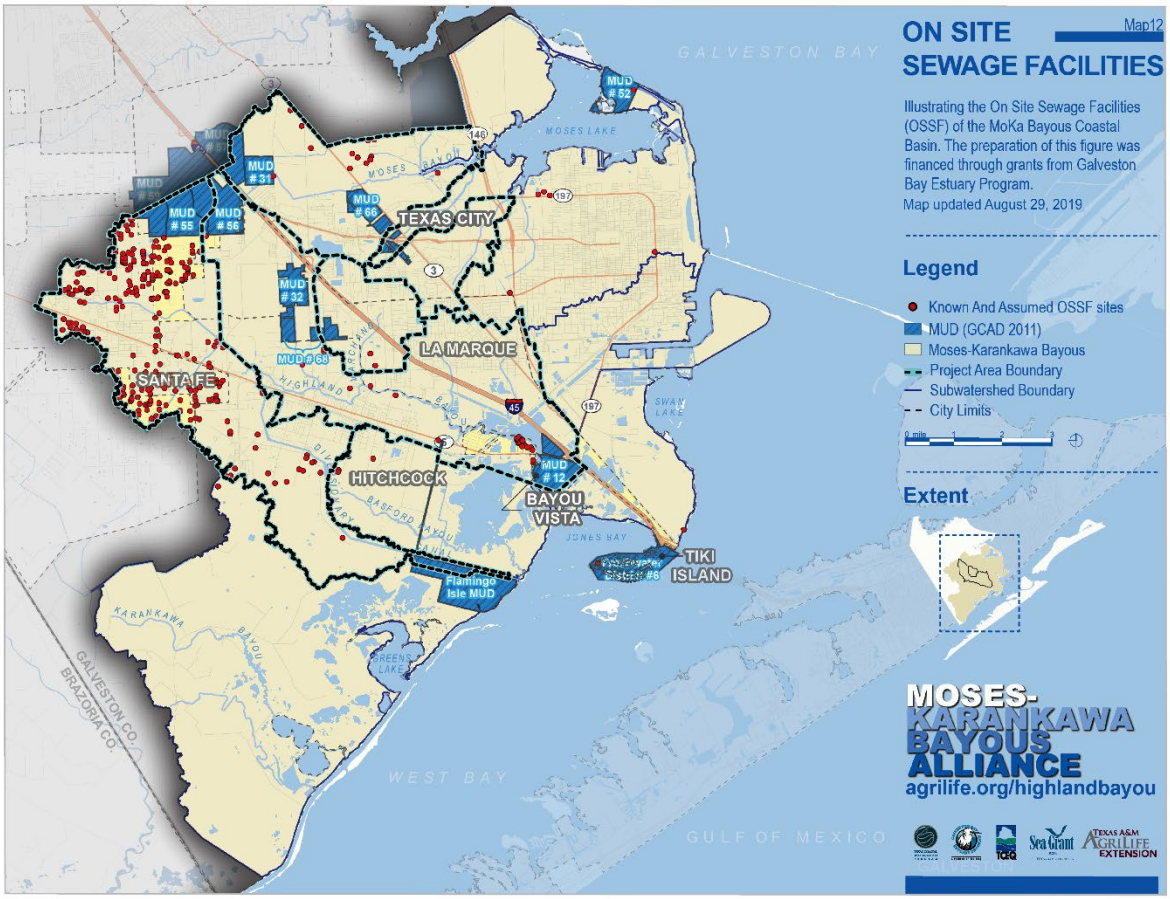


Figure 7. OSSF locations in the Highland Bayou Coastal Basin.

The percentage of permits issued for standard and advanced systems provided in Table 4 shows the movement toward advanced systems in Galveston County (Source: Martin Entringer, GCHD 2008).

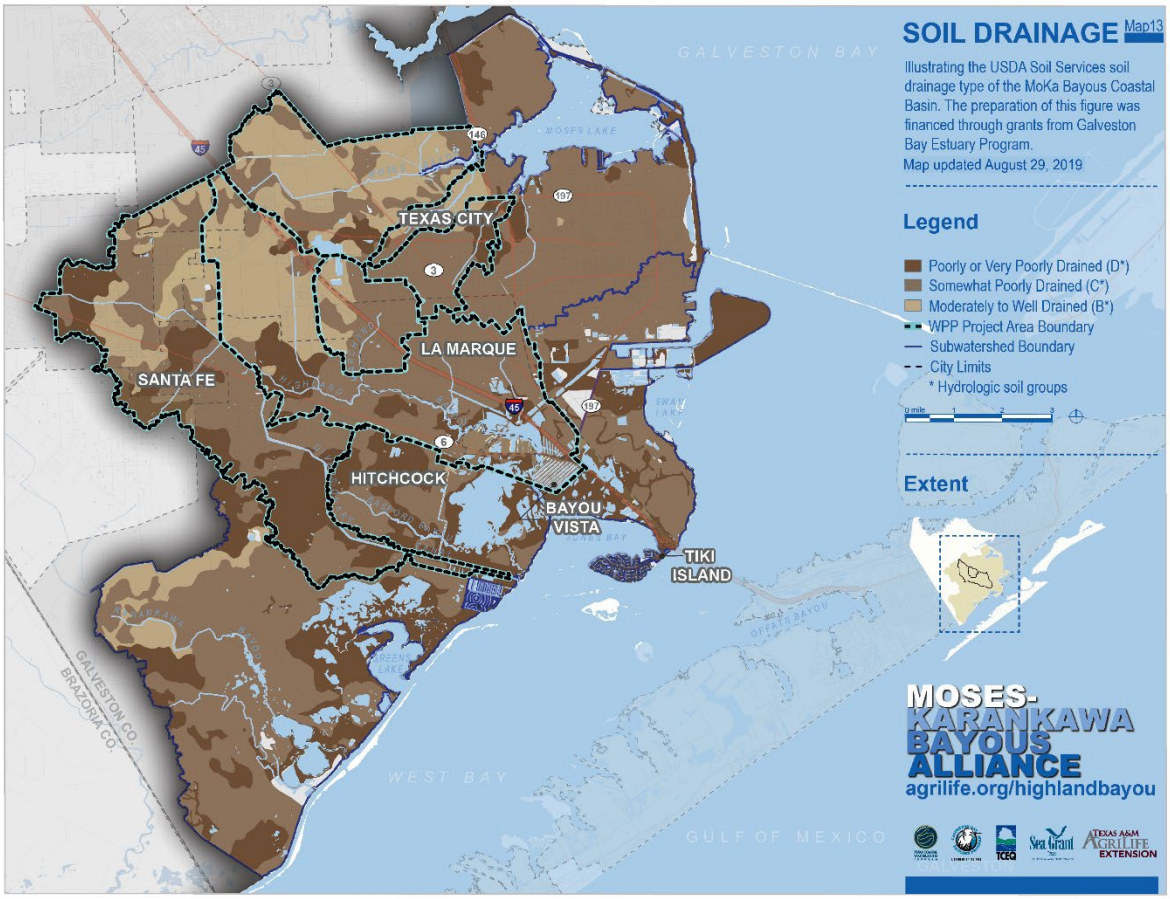


Figure 8. U.S. Department of Agriculture (USDA) soil services soil drainage types.

Table 4. Relative change in Galveston County new OSSF permits from selected years.

Year	Percent standard soil treatment systems	Percent aerobic chlorinated (advanced) systems
1995	84	16
1998	68	32
2003	51	49
2006	23	77

Hydrologic Change – Flow and Dredging

Hydrological change in and of itself is not a pollutant "source," however it may impact loading characteristics in Highland Bayou. Changes in this watershed since the 1970s have resulted in what stakeholders call a very perceptible change in the flow and character of Highland Bayou. Stakeholders believe two forces are responsible for this. The first is the construction of the diversion canal by the U.S. Army Corps of Engineers (USACE) in the early 1970s. Highland Bayou draining the city of Santa Fe was diverted

at a point near Jack Brooks Park and into a constructed canal that now drains through the old Basford Bayou watershed south of Highland Bayou. The intent of the diversionary canal was to reduce flooding in Highland Bayou, but the resulting canal diverted over half of the headwater towards another watershed. Floods do not occur as frequently now in Highland Bayou, but the average flow of water has predictably declined since then.

A second factor has been the steady development of the watershed over the decades. Sediment from development is transported down the drainage ditches and into the bayou. The combination of slower flow and increased accumulation of sediment has, according to stakeholders, resulted in a shallower and more stagnant Highland Bayou. Representatives from Drainage District 2 characterize the local soil as highly erodible, and they spend considerable resources managing and removing sediment from their ditches. The Highland Bayou channel itself, outside of the jurisdiction of the drainage district, has seen sediment accumulate. Several stakeholders shared pictures from decades ago of swimming holes in Highland Bayou that could be fished and used for jumping and swimming, places which now have only inches of stagnant, foul water.

The connection between hydrology and nonpoint source loading is not entirely understood here. Many stakeholders in the watershed believe that an improved flow regime in Highland Bayou would logically result in improved water quality. By dredging sediment from the bayou channel and managing the inflow of sediment, they believe that the bayou's flow conditions, and tidal dynamics would improve. It is the opinion of the project team that the stakeholder group's foremost concern about the bayou's changes over the years is a powerful pathway for engaging community to understand the full range of land-based factors that are impacting the bayou.

Urbanization Activities

Construction

Construction and development activities usually disturb acres of soil surface, which can remain exposed for months or more. Disturbed surfaces include the construction pad, roads, maintenance yards, and newly excavated detention ponds. If not managed properly, erosion at these sites can transport significant sediment into drainage conveyances and eventually waterways. Erosion adds turbidity to the water column, and the accumulation of eroded sediment in waterways removes flow capacity and can harm habitat for aquatic species. As development continues into the watershed, particularly in the Highland Bayou headwaters (AUs 2424A_4 and 2424A_5) and Moses Bayou (AU 2431_1), the potential for sediment erosion is high. While municipal separate storm sewer systems (MS4) rules are supposed to protect against construction site runoff, construction activities are still likely to impact these watersheds.

Litter and Illegal Dumping

Stakeholders expressed concern for litter and illegal dumping near waterways and throughout the surrounding communities. Illegal dumping refers to improper disposal of tires, batteries, cars, boats, construction litter, and similar waste items. The project team has also observed the illegal discharge of RV septic waste directly into the bayou. Problem areas for illegal dumping include vacant properties, dead end streets, the ditches along Interstate 45, and within Highland Bayou Park (stakeholder meeting, 2015). Reducing litter and illegal disposal through clean-up efforts and community education would promote pride and awareness of the surrounding natural environment and good stewardship principals.

Pets

Dogs and cats make a significant contribution to surface water contamination when their fecal material is left on the ground (Environmental Protection Agency, 2001). Pet waste is washed into storm drains, where it eventually enters nearby surface waters bringing bacteria, resulting in conditions where fishing and swimming are not recommended and can lead to illness. Based on the number of homes and average pet ownership rates, it is estimated that there are over 5,000 dogs in the Highland Bayou Watershed alone, (Figure 9). Since the Highland and Marchand Bayou watershed are well developed areas, pet waste is expected to be a large source of contamination for these. Other pets such as horses, hogs, poultry, and rabbits exist in the watershed, but their numbers are not believed to be sizable enough to contribute significantly to bacteria levels.

Lawn Care and Landscaping Practices

Improper management of landscaping debris, fertilizers, and pesticides was a prominent concern of stakeholders. Grass clippings, leaves, mulch and other plant matter swept or blown onto the road, driveway, and storm drains introduce pollution to local waterways. There is a need for public education about water quality impacts associated with landscaping practices. Homeowner education for spraying pesticides was specifically recommended by stakeholders, including how much to use, when to spray in relation to rain events, and for the homeowner to consider nearby waterbodies. Education for lawn contractors was also brought up by stakeholders as essential to reducing the amount of the above-mentioned materials entering surface waters. Taken together, these related activities are a critical source of nonpoint source load in developed areas.

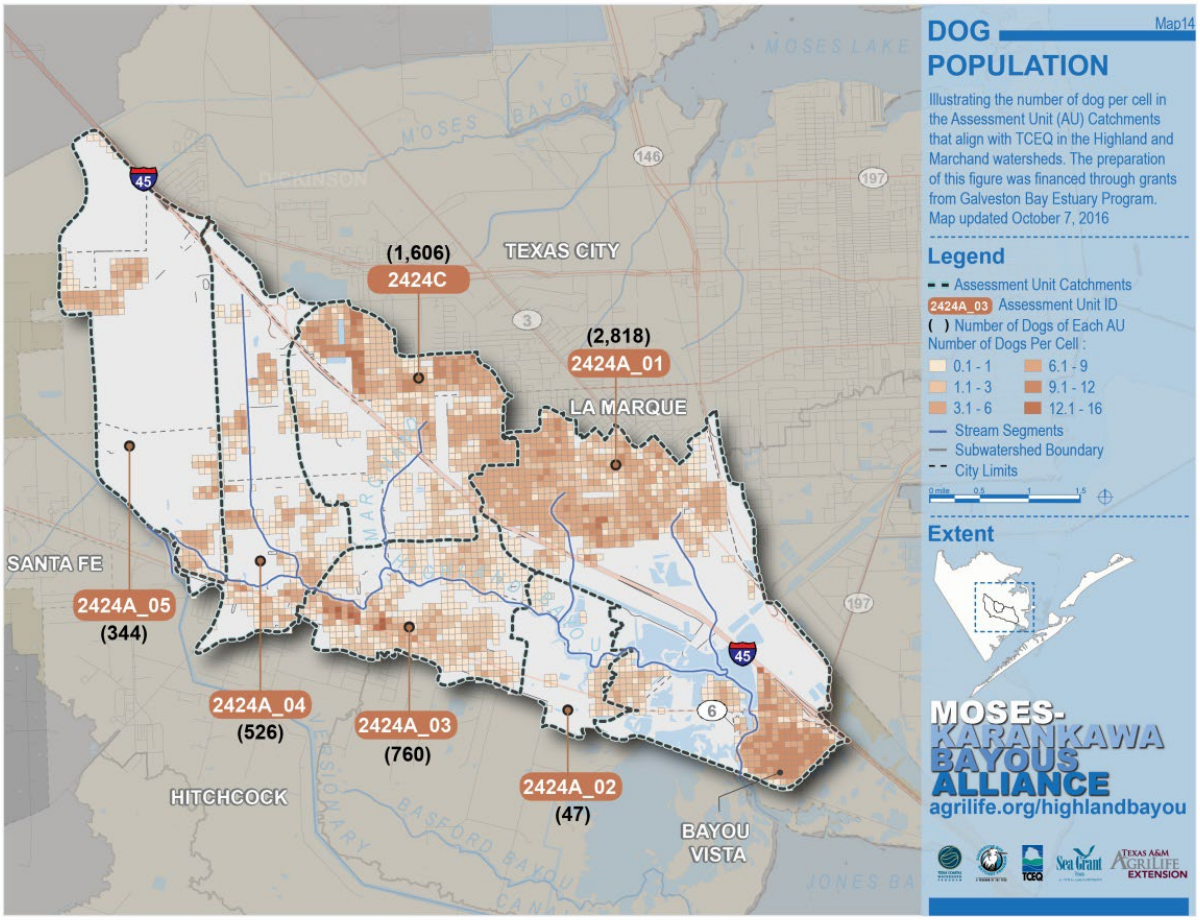


Figure 9. Dog population in the Highland Bayou Coastal Basin.

Urban Stormwater: MS4

MS4s Phase II regulations began in 1999 to regulate the management of nonpoint source pollution from MS4 systems, which refers to the system of stormwater conveyances that transfer stormwater into local waterways. Stormwater runoff is untreated and should not be confused with a centralized sewage treatment system. There are four Phase II regulated MS4s in the watershed, included in Table 5 below. MS4 permittees must address six areas of stormwater management through local laws and enforcement. The primary concern of MS4s is the regulation of construction and post-construction activities, activities that generate disturbed soil surfaces and lead to erosion of sediment into the MS4 and local water ways. MS4 entities must also have a program in place for illegal discharge detection and elimination, referring to non-stormwater discharges into the MS4.

Table 5. Phase II regulated MS4s in the project area.

Regulated Entity Number	Permittee
RN105477434	City of Hitchcock
RN105538763	City of La Marque
RN105604987	Galveston County
RN105550107	City of Santa Fe
RN105479513	City of Texas City

The GCHD Water Pollution Services Program monitors and evaluates stormwater samples for bacteria, DO, pH, chlorine, BOD, and ammonia. Many of the observed exceedances occur within three days of a rainfall event.

Urban Stormwater: Land Use

Land use is how people use the landscape (farm, pave, restore, etc.) and what activities they conduct on that land (commercial, industrial, residential, etc.). Figure 10 illustrates existing land use on a parcel-by-parcel basis in the study area. The Houston-Galveston Area Council (H-GAC) assigned land use categories to data sets maintained by the Galveston County Appraisal District (CAD). Parcel data is primarily maintained for tax purposes, but it can also provide an analysis of how land is used. In addition, not every use is utilized at the same intensity across parcels. Together with information about impervious surface and building density for certain uses, it is possible to estimate how much nonpoint source pollution is generated in each subbasin—this is the approach utilized for nonpoint pollutant load estimates later in this section. Finally, the parcel land use map is useful in understanding where to emphasize certain public education efforts and implementation of management measures.

Urban Stormwater: Land Cover and Impervious Surface

A land use/land cover change analysis was performed as part of this WPP effort (Figure 11), utilizing data from the National Oceanic and Atmospheric Agency (NOAA) Coastal Change Analysis Program (C-CAP) program, 1996-2010. The analysis looks at changes in how land is utilized and how much surface cover has increased from development over time. Table 6 shows the increase in developed acreage in the project area over a 14-year period. Impervious surface cover is the most important factor concerning land use changes and water quality indicators.

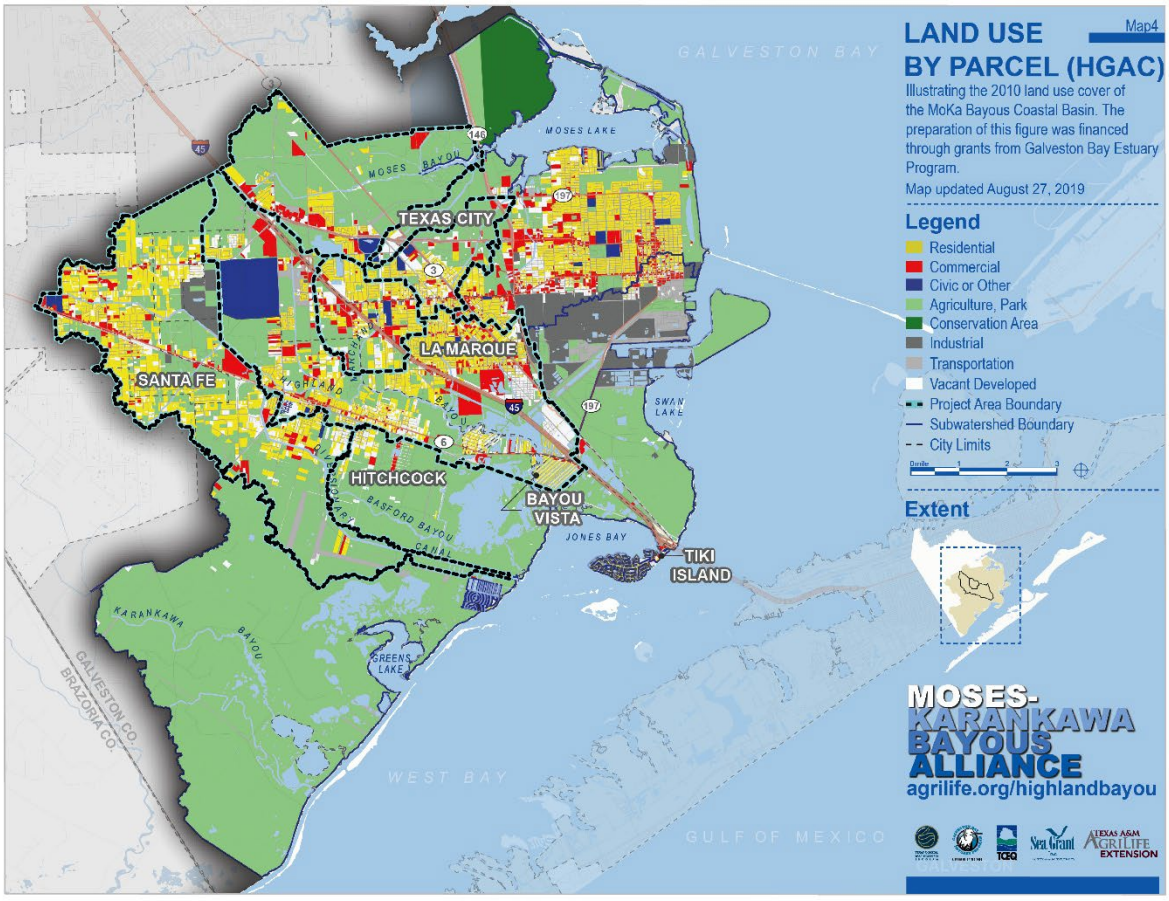


Figure 10. Land use cover in the Highland Bayou Coastal Basin.

Table 6. Increase in developed land, Highland and Marchand Bayous, 1996-2010.

Watershed	Acres developed 1996	Acres developed 2010	Relative % increase
Highland Bayou	4,930	5,312	7.7
Marchand Bayou	1,549	1,658	7.0
Diversionary Canal	5,048	5,266	4.3
Moses Bayou	1,482	1,761	18.8
Unnamed Tributary	1,152	1,200	4.2
Total	**14,161**	**1,200**	**8.4**

Land Cover and Impervious Surface

Highland Bayou saw a 14-year increase of 382 acres in developed land, including a 57-acre increase in high intensity development. Agricultural lands declined by 37 acres; undeveloped vegetated space declined by 164 acres.

The Marchand Bayou watershed saw a 14-year increase of 109 acres of developed land, including a 20-acre increase in high intensity development and a 43-acre increase in

medium intensity development. Pastures and vegetated undeveloped land decreased by 66 and 34 acres respectively.

The diversionary canal watershed saw a 14-year increase of 146 acres of developed land, including a 24-acre increase in high intensity development and a 67-acre increase in medium intensity development. Pastures and vegetated undeveloped land decreased by 28 and 150 acres respectively.

The Moses Bayou watershed saw a 14-year increase of 279 acres of developed land, including an 11-acre increase in high intensity development and a 105-acre increase in medium intensity development. Pastures and vegetated undeveloped land decreased by 87 and 109 acres respectively.

The unnamed tributary saw a 14-year increase of 48 acres of developed land, including an eight-acre increase in high intensity development and a seven-acre increase in medium intensity development. Pastures and vegetated undeveloped land decreased by 18 and 9 acres respectively.

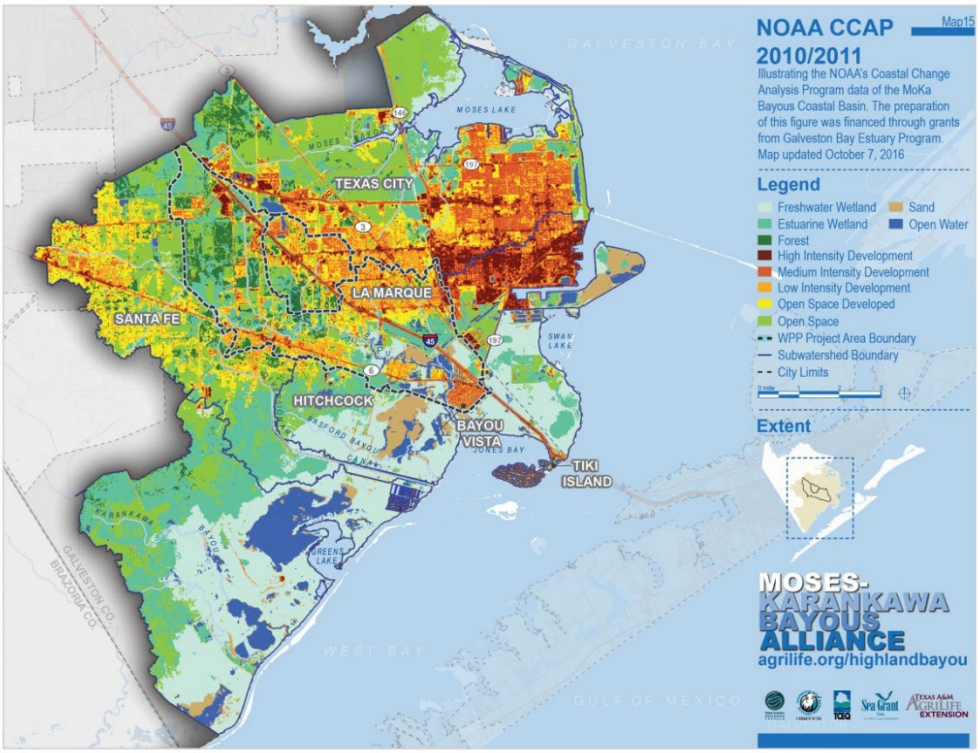


Figure 11. NOAA's C-CAP data for the Highland Bayou Coastal Basin.

Agriculture, Wildlife, and Natural Areas

Livestock

Farm animals such as cattle, horses, and goats contribute to bacterial loading, but they are not considered to be a significant source of bacteria in the project area. Large scale domestic animal facilities or operations are not present in this urban watershed. Approximately 9% of Galveston County is categorized as agricultural by NOAA C-CAP (Figure 11). The 2012 USDA's National Agricultural Statistics Service was reviewed for the cattle and calves' inventory in Galveston County. The total cattle population for the county was 9,772, ranking Galveston County 220 out of 254 Texas counties. Figure 12 illustrates the fragmented nature of grass and pastureland in the project areas, Moses Bayou watershed (MB1 and MB2) has the largest land area dedicated to pasture and grassland, much of which is actively used for cattle grazing.

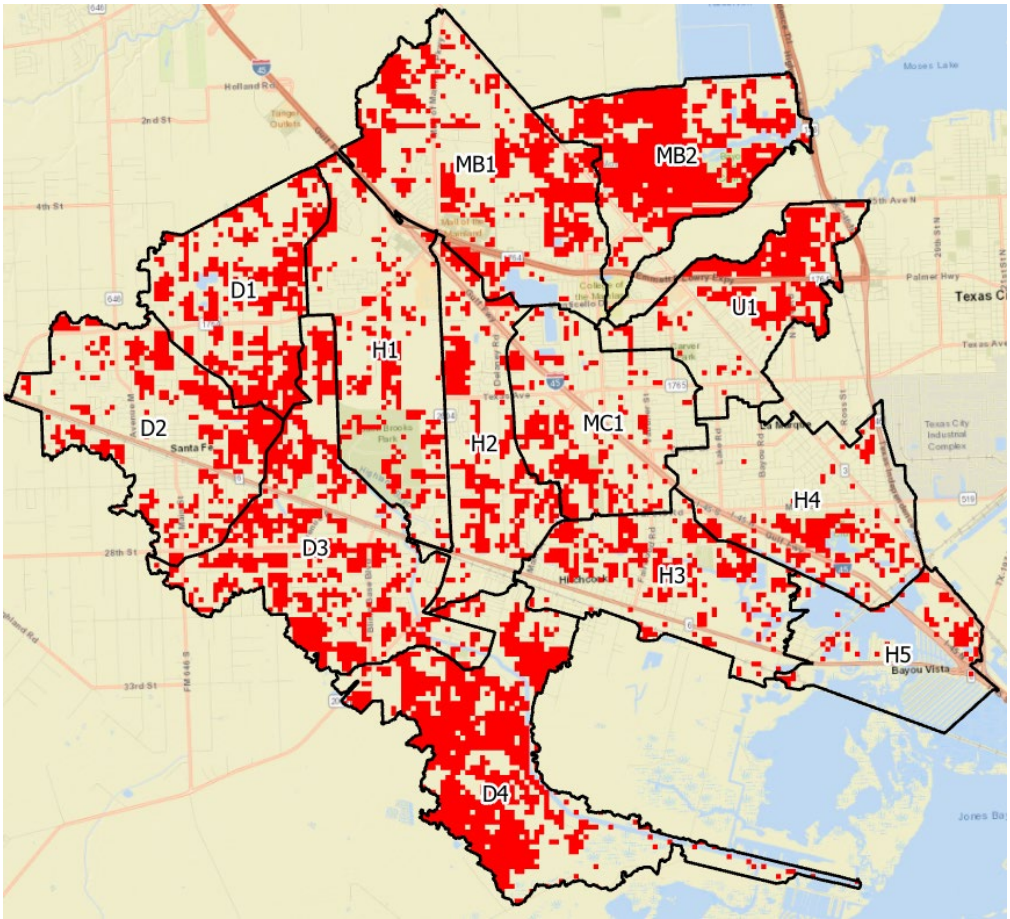


Figure 12. Pasture and grassland areas suitable for livestock.

Wildlife and Non-Domestic Animals

Contributions of bacteria from wildlife are less easily controlled when compared to other sources since these animals move freely over the landscape and some are only

present on a seasonal basis (e.g. migratory birds). Wildlife species in the watershed include deer, raccoon, opossum, squirrels, birds, feral dogs and cats, and others. Stakeholders have reported pigeons in large numbers throughout the canal communities in the lower reach of the watershed. Pigeons are seen at bayou access points and nesting under boat houses. Whereas the population of many wildlife species is unknown, the Texas Colonial Waterbird Census conducted between 1973 and 2006 offers an example of just how many birds may be present in the watershed during different seasons. The census consists of counts for 31 species at colonies along the north Texas Gulf Coast, many of which are observed in the watershed. Colony populations can be highly variable, from a few dozen to tens of thousands and beyond. Such a high volume of birds can significantly impact water quality near these areas. Common wading birds observed are the great blue heron, great egret, snowy egret, tricolor heron, little blue heron, ibises, and roseate spoonbills. Open water birds include royal terns, Caspian tern, least terns, sandwich terns, and neotropic cormorants.

Feral Hogs

Feral hogs are invasive non-domesticated hogs that disturb soils, eat small livestock, and transmit disease. Stakeholders within the watershed have observed wild hogs damaging property. Wild hogs prefer moist bottomland along streams and can be a significant source of soil erosion. As feral hogs consume roots and ground vegetation, they can disturb substantial areas of soil, stripping away any stabilizing ground cover and making the area prone to soil erosion. As hogs continue to trample, eat, and damage crops, they pose a financial burden to agricultural producers. In Texas alone, feral hogs cause an estimated $52 million of damage to agriculture annually and they are increasing in numbers across the state (Timmons, et al., 2012). A combination of pig rooting behavior and deposits of fecal matter increases nitrogen levels in water, impacting water quality.

Feral hogs have established multiple populations throughout the project area. In the Highland Bayou watershed for example, feral hogs are frequently observed in Jack Brooks Park, the University of Houston (UH) Coastal Center, and Mahan Park. Although, exact population numbers are unknown, interviews with stakeholders have indicated their presence is impactful: “Feral hogs use the park as a playground, the UH Coastal Center as a hotel, and the landfill as a buffet.” Trapping efforts have occurred in both Jack Brooks Park and the UH Coastal Center. Management of feral hogs can be difficult for a variety of reasons including their ability to reproduce quickly and their lack of natural predators.

Streambank Erosion

Fallen trees and sediment from drainage ditches have filled sections of Highland Bayou, creating stagnant pools of water in some areas. Trees and brush falling onto the banks are partly a natural process and they provide valuable habitat for aquatic organisms. However, the silting in of culverts and obstruction of flow within the

channel has been a long-standing concern for residents. In 1996 dozens of volunteers removed brush and trash from Highland Bayou during a bayou cleanup effort.

Natural areas in the watersheds of Moses Bayou and the unnamed tributary of Moses Lake are primarily coastal prairie and have many fewer trees than Highland and Marchand Bayous. Therefore, these bayous have few issues related to trees and brush in the water way impeding flow.

Element B: Load Reductions

Bacteria Load Duration Curves (LDC)

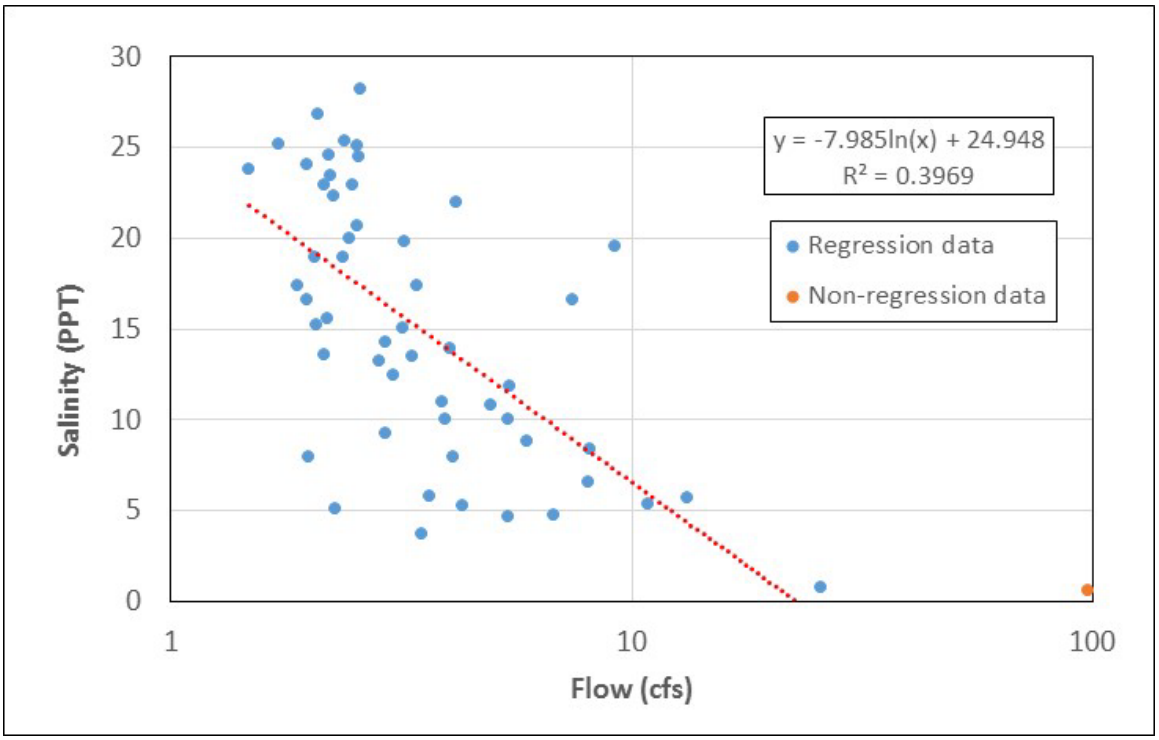
The LDC method allows for estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, the LDC method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment. The LDC method has found relatively broad acceptance among regulatory and nonregulatory communities, primarily due to the simplicity of the approach and ease of application. These communities recognize the frequent information limitations, often associated with bacteria WPPs, which constrain the use of more powerful mechanistic models. The LDC method provides a means to estimate the difference in bacteria loads and relevant criterion and can give indications of broad sources of the bacteria, i.e., point source and nonpoint source.

The modified flow duration curve (FDC)/LDC method as developed in the state of Oregon (ODEQ, 2006) has been used in tidally influenced streams for bacteria WPP and total maximum daily load (TMDL) development as the equivalent of the “standard” FDC/LDC method used for bacteria WPP and TMDL development for nontidal, freshwater streams in Texas and other states. The modified FDC/LDC method adds to the standard approach an additional daily flow volume derived from tidal influences. The approach is based on determining the volume of seawater (salt water) that must be mixed with the volume of freshwater going down the river (bayou) to arrive at the “observed” salinity using a mass balance approach (Hauck and Kannan, 2019A).

The applicability of the modified FDC/LDC method to the bacterially impaired tidal streams in the project area was determined in a precursor study. The findings from that study are reported in Hauck and Kannan (2019).

Stream flow data, and essential component FDCs, is not available for any of the water bodies in this study area. After considering three potential U.S. Geological Survey (USGS) gauge locations, Chocolate Bayou was selected as the most appropriate surrogate and a simple drainage area ratio was used for each watershed in the project area. A basic regression relationship between salinity and flow was determined for

each waterbody. Figure 13 graphically illustrates this relationship with one station within the project area.



This graphical depiction of the salinity to flow relationship is characteristic of those developed for all waterbodies in the project.

Figure 13. Scatter plot of salinity and estimated daily streamflow for station 18593, Highland Bayou Diversion Canal AU 2424G_01.

The 20-year period of Jan. 1, 1998, through Dec. 31, 2017, was used in the development of the FDC for each station. The modified FDC is represented by freshwater plus seawater (Vt) in each figure. The separate freshwater and seawater components to each modified FDC are also provided as separate curves on each graph to show the relative contribution of each to Vt. The FDC for each station varies based on differences in baseflow and tidal influence. For example, station 16488 (Highland Bayou AUs 2424A_01, Figure 14) has more tidal influence as well as a sustained baseflow from the upstream city of La Marque Westside WWTF discharge, whereas station 11415 (Highland Bayou 2424_03, Figure 15) has less tidal influence and no WWTF baseflow.

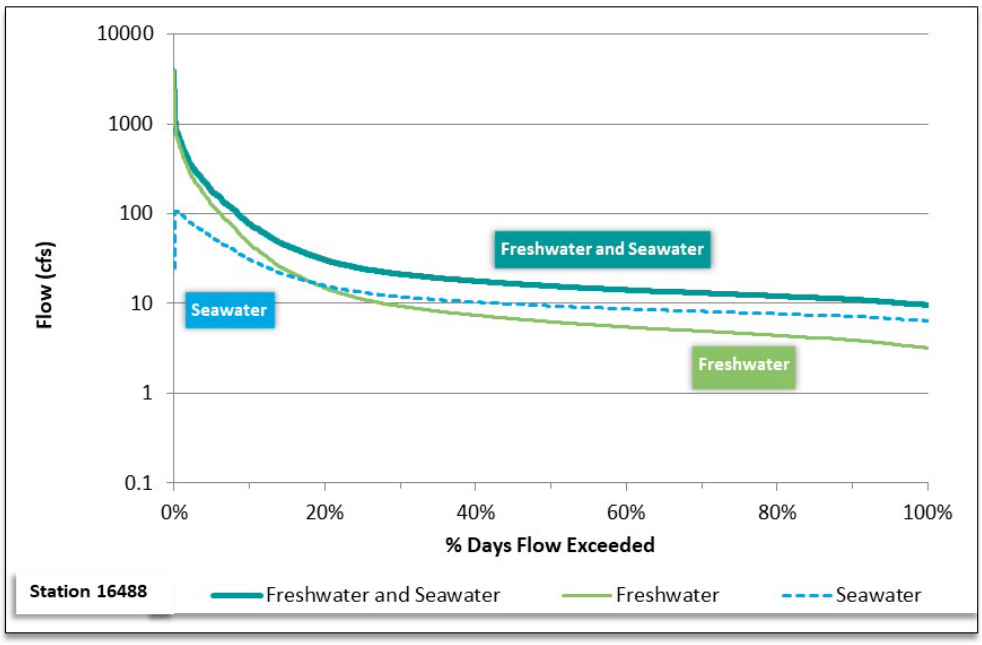


Figure 14. Modified FDC for station 16488, Highland Bayou AU 2424A_01.

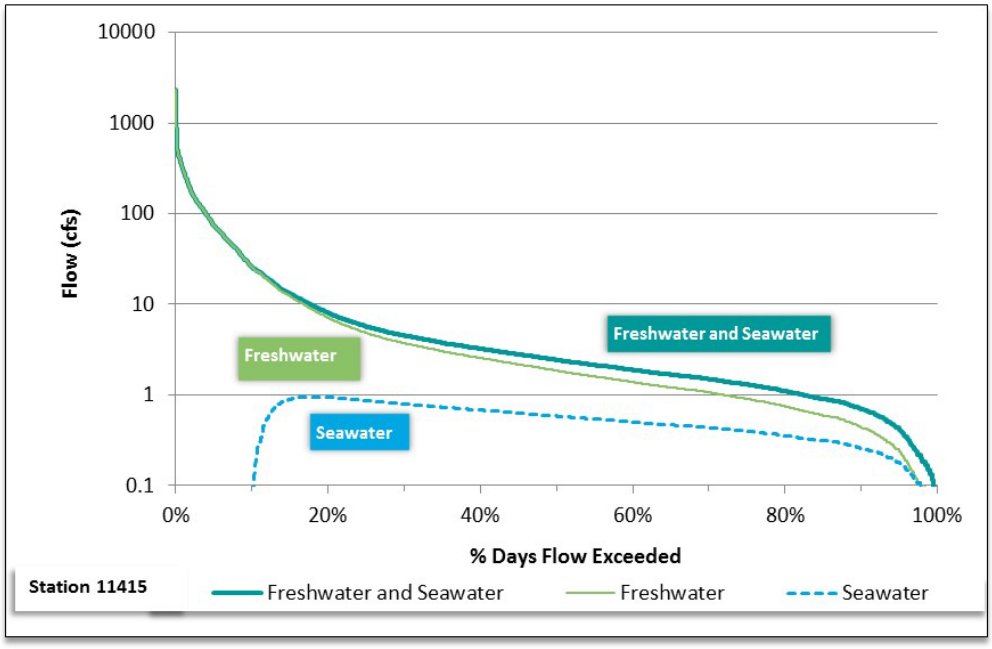


Figure 15. Modified FDC for station 11415, Highland Bayou AU 2424A_03.

Modified LDCs

LDCs provide the following information:

- The allowable in-stream loading of Enterococci—blue line in the graphs below.
- An estimate of the existing loading through data generated using the regression line of observed Enterococci data with estimated flow for the chosen surface water quality monitoring (SWQM) station for each AU—green line in the graphs below.
- An estimate of the amount of reduction in bacteria concentrations required to restore water quality within each of the five flow regimes for each station through the geometric mean of the observed Enterococci data—yellow and red lines line in the graphs below.

High bacteria loadings during high flows are typically associated with nonpoint sources, whereas high bacteria loadings under low flows are typically associated with point sources of pollution.

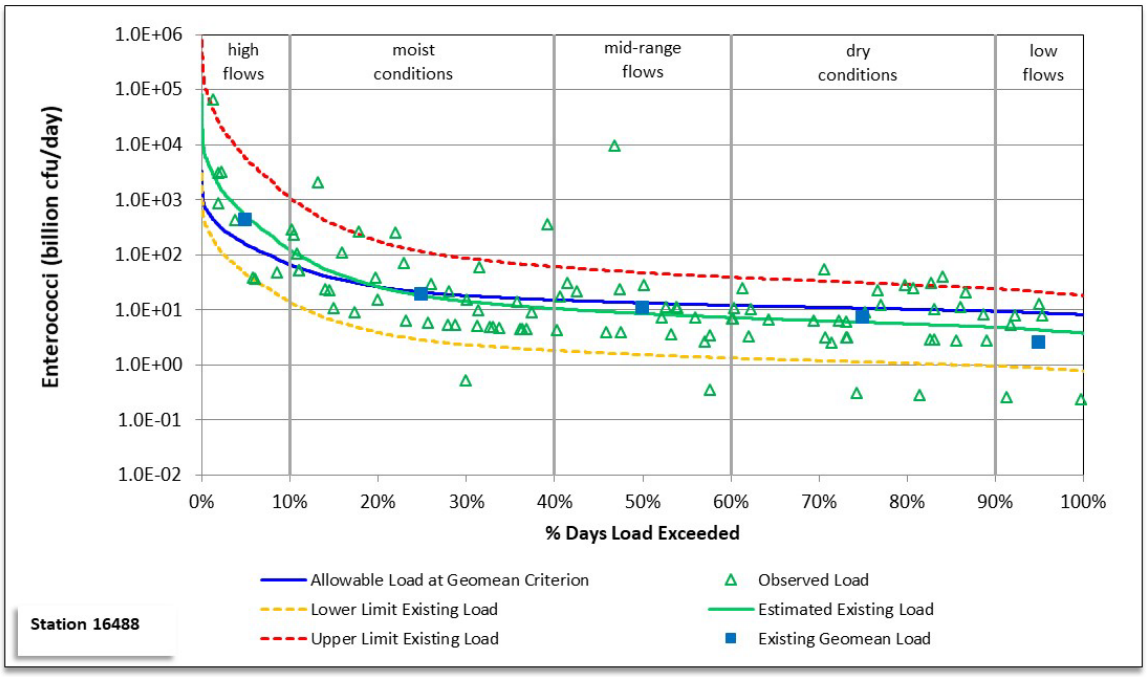


Figure 16. Modified LDC for station 16488, Highland Bayou AU 2424A_01, station nearest the mouth of Highland Bayou.

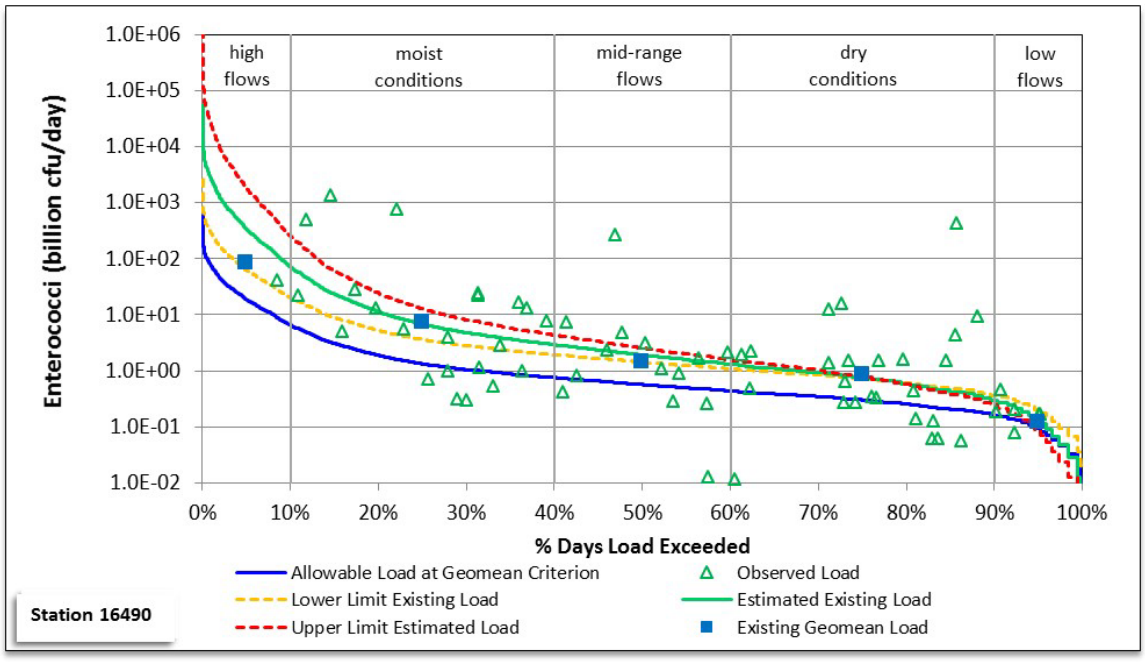


Figure 17. Modified LDC for station 16490, Marchand Bayou AU 2424C_01.

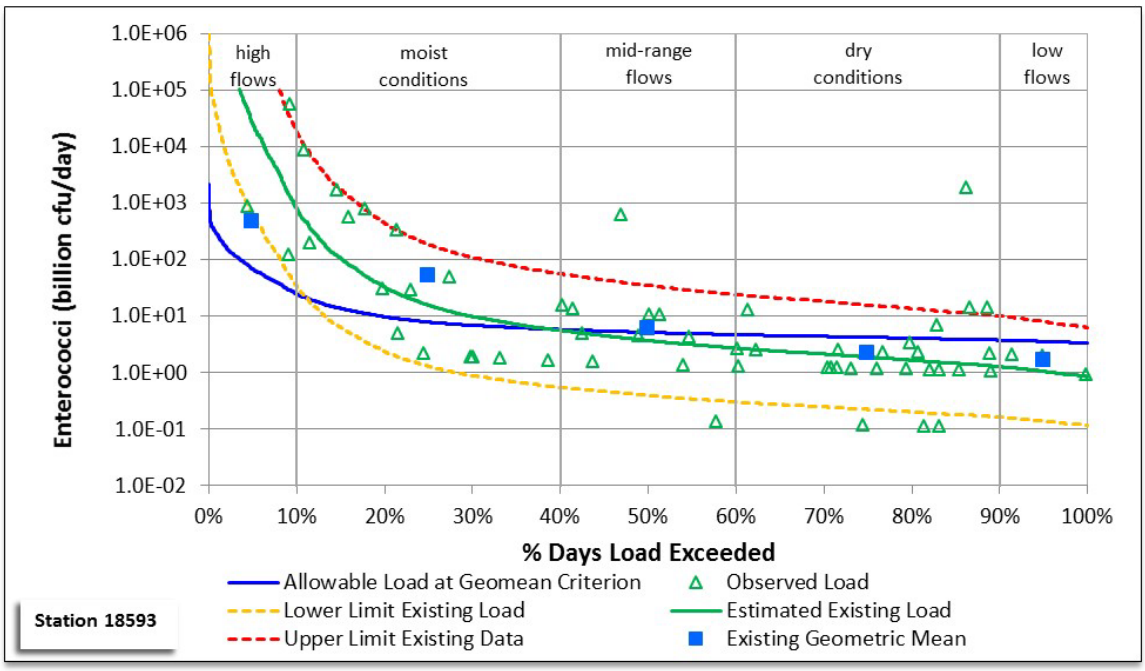


Figure 18. Modified LDC for station 18593, Highland Bayou Diversion Canal AU 2424G_01.

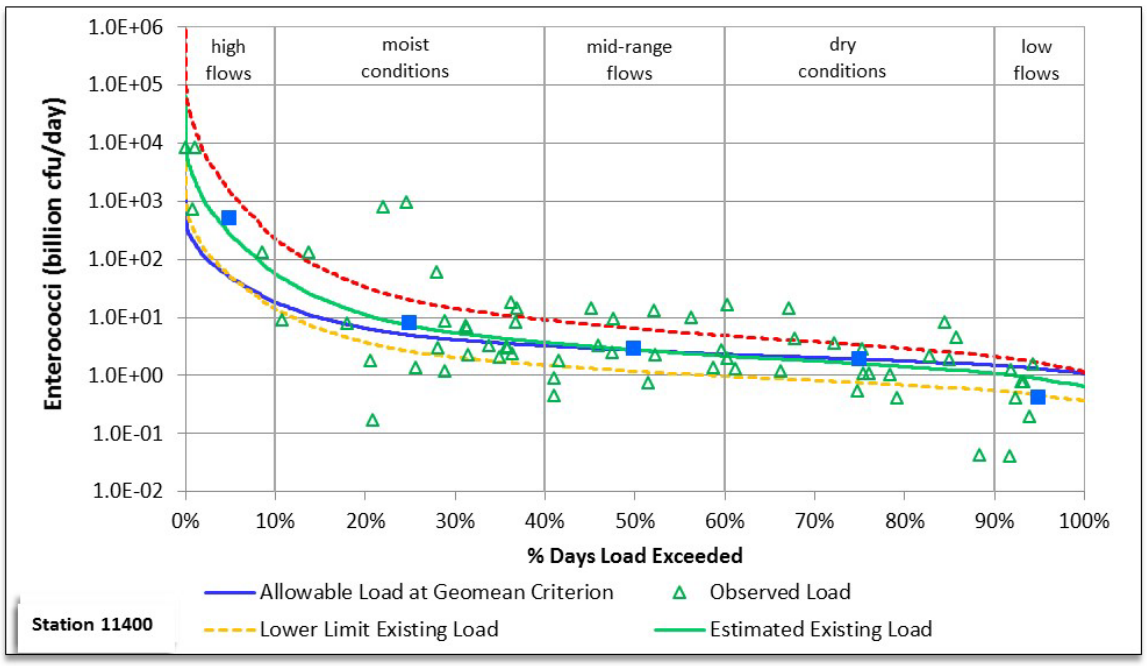


Figure 19. Modified LDC for station 11400, Moses Bayou AU 2431A_01.

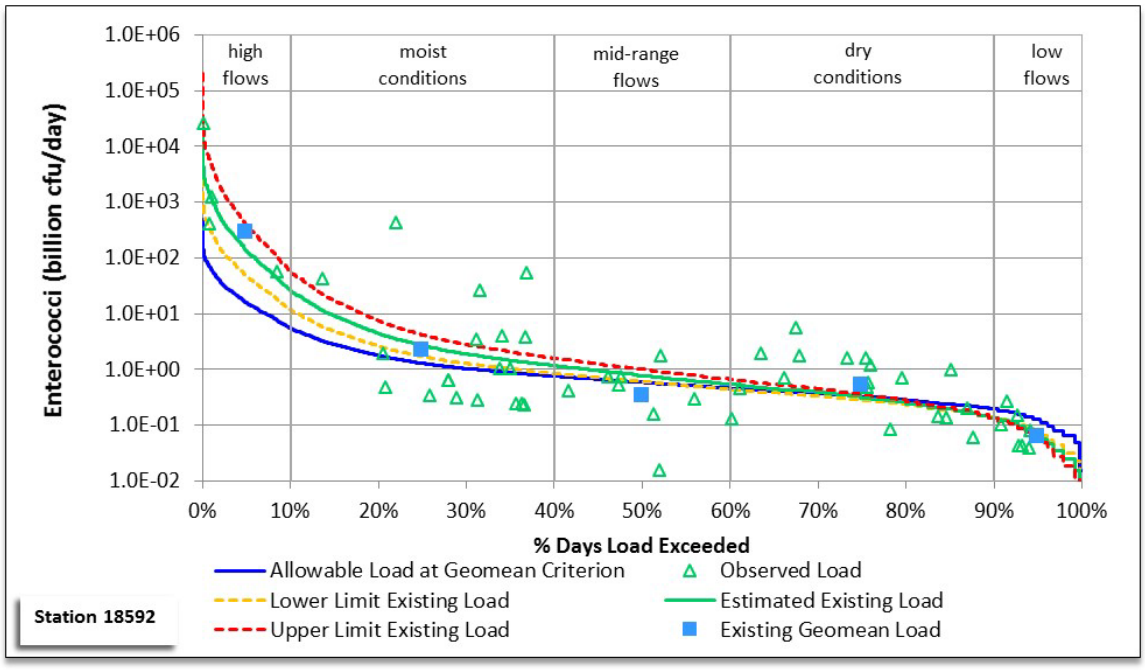


Figure 20. Modified LDC for station 18592, unnamed tributary of Moses Lake AU 2431C_01.

An overall load reduction analyses by flow regime indicates that stormwater runoff drives much of the pollutant loading to these nine AUs in the Highland Bayou Coastal

Basin. The highest percent load reductions for each AU are always for the high flow regime, and, without exception, the amount of reduction required reduces as the flow regimes indicate lower flows. Because the high levels of flow and Enterococci concentrations are associated with the high-flow regime, the percent reduction is not only the greatest for the high-flows regime, but the loads associated with this flow regime are far greater than the sum of the loads associated with the other four flow regimes.

Table 7. Estimated load reductions needed for each AU of the Highland Bayou Coastal Basin.

Flow Condition	Percent Days Load Exceeded	Existing Load (billion cfu/day)	Allowed Load (billion cfu/day)	Reduction Needed to Meet Allowable Load (%)	Needed Daily Load Reduction (billion cfu/day) *	Needed Annual Load Reduction (billion cfu/year) *
			Highland Bayou 2424A_01			
High Flows	2-10	42.008	11.968	71.5%	30.040	10,965
Most Conditions	10-40	8.725	7.848	10.1%	0.877	320
Mid-Range Flows	40-60	1.740	2.695	NA	-0.955	-349
Dry Conditions	60-90	1.801	3.234	NA	-1.433	-523
Low Flows	90-100	0.433	0.885	NA	-0.452	-165
Total	2-100	54.707	26.630	51.3%	28.077	10,248
			Highland Bayou 2424A_02			
High Flows	2-10	42.008	11.968	71.5%	30.040	10,965
Most Conditions	10-40	8.725	7.848	10.1%	0.877	320
Mid-Range Flows	40-60	1.740	2.695	NA	-0.955	-349
Dry Conditions	60-90	1.801	3.234	NA	-1.433	-523
Low Flows	90-100	0.433	0.885	NA	-0.452	-165
Total	2-100	54.707	26.630	51.3%	28.077	10,248
			Highland Bayou 2424A_03			
High Flows	2-10	42.008	11.968	71.5%	30.040	10,965
Most Conditions	10-40	8.725	7.848	10.1%	0.877	320
Mid-Range Flows	40-60	1.740	2.695	NA	-0.955	-349
Dry Conditions	60-90	1.801	3.234	NA	-1.433	-523
Low Flows	90-100	0.433	0.885	NA	-0.452	-165

Flow Condition	Percent Days Load Exceeded	Existing Load (billion cfu/day)	Allowed Load (billion cfu/day)	Reduction Needed to Meet Allowable Load (%)	Needed Daily Load Reduction (billion cfu/day) *	Needed Annual Load Reduction (billion cfu/year) *
Total	2-100	54.707	26.630	51.3%	28.077	10,248
			Highland Bayou 2424A_04			
High Flows	2-10	65.744	3.034	95.4%	62.710	22,889
Most Conditions	10-40	6.701	1.198	82.1%	5.503	2,009
Mid-Range Flows	40-60	0.506	0.238	53.0%	0.268	98
Dry Conditions	60-90	0.261	0.183	29.9%	0.078	28
Low Flows	90-100	0.013	0.018	NA	-0.005	-2
Total	2-100	73.225	4.671	93.6%	68.554	25,022
			Highland Bayou 2424A_05			
High Flows	2-10	56.753	1.751	96.9%	55.002	20,076
Most Conditions	10-40	8.135	0.694	91.5%	7.441	2,716
Mid-Range Flows	40-60	0.770	0.135	82.5%	0.635	232
Dry Conditions	60-90	0.429	0.103	76.0%	0.326	119
Low Flows	90-100	0.024	0.018	25.0%	0.006	2
Total	2-100	66.111	2.701	95.9%	63.410	23,145
			Marchand Bayou AU 2424C_01			
High Flows	2-10	28.772	1.459	94.9% 27.313 9,969		
Most Conditions	10-40	4.018	0.573	85.7%	3.445	1,257
Mid-Range Flows	40-60	0.397	0.115	71.0%	0.282	103
Dry Conditions	60-90	0.229	0.090	60.7%	0.139	51
Low Flows	90-100	0.014	0.009	35.7%	0.005	2
Total	2-100	33.430	2.246	93.3%	31.184	11,382
			Highland Bayou Diversion Canal 2424G_01			
High Flows	2-10	4784.990	5.374	99.9%	4779.616	1,744,560

Flow Condition	Percent Days Load Exceeded	Existing Load (billion cfu/day)	Allowed Load (billion cfu/day)	Reduction Needed to Meet Allowable Load (%)	Needed Daily Load Reduction (billion cfu/day) *	Needed Annual Load Reduction (billion cfu/year) *
Most Conditions	10-40	20.816	2.917	86.0%	17.899	6,533
Mid-Range Flows	40-60	0.772	1.040	NA	-0.268	-98
Dry Conditions	60-90	0.576	1.272	NA	-0.696	-254
Low Flows	90-100	0.106	0.357	NA	-0.251	-92
Total	2-100	4807.260	10.960	99.8%	4796.300	1,750,650
			Moses Bayou 2431A_01			
High Flows	2-10	23.460	3.803	83.8%	19.657	7,175
Most Conditions	10-40	3.732	1.939	48.0%	1.793	654
Mid-Range Flows	40-60	0.565	0.547	3.2%	0.018	7
Dry Conditions	60-90	0.481	0.573	NA	-0.092	-34
Low Flows	90-100	0.087	0.130	NA	-0.043	-16
Total	2-100	28.325	6.992	75.3%	21.333	7,787
			Unnamed Tributary of the Southern Arm of Moses Lake (West) 2431C_01			
High Flows	2-10	11.812	1.229	89.6%	10.583	3,863
Most Conditions	10-40	1.537	0.529	65.6%	1.008	368
Mid-Range Flows	40-60	0.160	0.118	26.3%	0.042	15
Dry Conditions	60-90	0.097	0.099	NA	-0.002	-1
Low Flows	90-100	0.007	0.012	NA	-0.005	-2
Total	2-100	13.613	1.987	85.4%	11.626	4,243

NA—not applicable, no reduction required; * Negative load reductions for some AUs under some flow regimes indicate that the allowable loading was greater than the existing load within those flow regimes. The negative values signify no loading reductions being require, and the negative numbers were left in the table so that the "total" loads across all flow regimes could be computed.

Table 8. Summary of Enterococci data and percent reduction to meet primary contact recreation geometric mean criterion of 35 cfu/100 mL.

Assessment Unit	2014 Assessment*Geometric Mean Concentration of Enterococci data from 12/1/2005 to 11/30/2012 (cfu/100mL)	2014 Percent Reduction	2016 Assessment * Geometric Mean Concentration of Enterococci data from 12/1/2005 to 11/30/2012 (cfu/100mL)	2016 Percent Reduction
2424A_01 Highland Bayou	30.44	NA	27.34	NA
2424A_02 Highland Bayou	45.85	23.7%	ND	ND
2424A_03 Highland Bayou	78.23	55.3%	109.23	68.0%
2424A_04 Highland Bayou	174.79	80.0%	221.06	84.2%
2424A_05 Highland Bayou	184.2	81.0%	303.8	88.5%
2424C_01 Marchand Bayou	139.17	74.9%	196.44	82.2%
2424G_01 Diversion Canal	37.6	6.9%	69.23	49.4%
2431A_01 Moses Bayou	43.53	19.6%	85.68	59.2%
2431C_01 Unnamed Tributary	49.96	29.9%	73.36	52.3%

NA—not applicable, no reduction required; ND—no data; *Data is from the Texas Integrated Report/303(d) list.

Calculated Bacteria Source Loads

Stakeholders identified potential contributors of bacteria within the watershed, and geographic information system (GIS) analysis was applied using the Spatially Explicit Load Enrichment Calculation Tool (SELECT). Available information and stakeholder input were used to estimate potential pollutant loadings based on population estimates, land cover, household locations, and discharge points. These data were used to evaluate potential loadings from livestock, wildlife, feral hogs, domestic pets, wastewater treatment facilities, sanitary sewer overflows, and on-site sewage facilities.

The stakeholder identified sources make up the calculated loadings, but do not represent all sources of bacteria in the watershed. Also, bacteria loading estimates do not account for bacteria fate and transport that occur between where the bacteria

originates and the receiving stream. Because of this, the estimates are likely to represent the high end of loadings into these waterbodies.

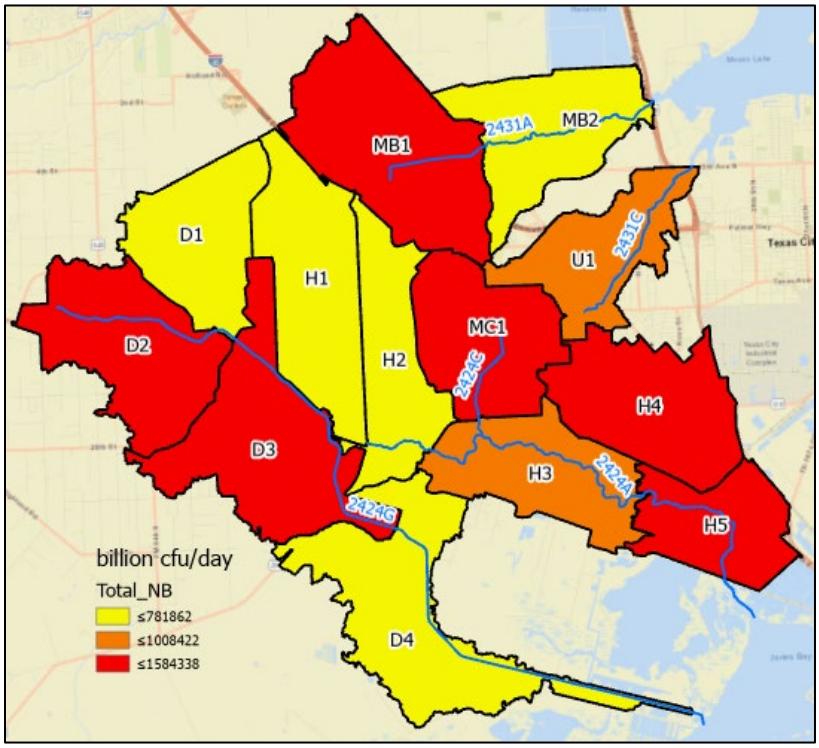


Figure 21. Calculated total daily Enterococcus loading by subwatershed from SELECT analysis.

Table 9. Calculated daily Enterococcus loading by subwatershed.

Subwatershed	Calculated Enterococcus loading (billion cfu/day)
D1- Diversionary Canal 1	715,431
D2- Diversionary Canal 2	1,548,060
D3- Diversionary Canal 3	1,288,469
D4- Diversionary Canal 4	781,862
HB1-Highland Bayou 1	475,583
HB2- Highland Bayou 2	636,081
HB3- Highland Bayou 3	950,918
HB4- Highland Bayou 4	1,584,338
HB5- Highland Bayou 5	1,255,491

MB1- Moses Bayou 1	1,367,927
MB2- Moses Bayou 2	580,949
MC1 -Marchand Bayou 1	1,446,131
U1 – Unnamed Bayou	1,008,422

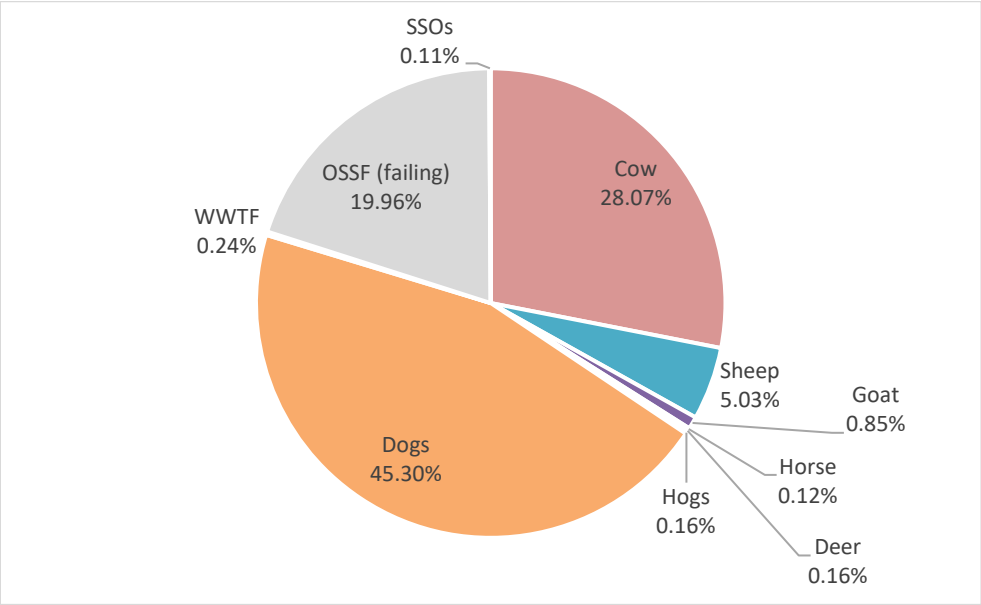


Figure 22. Calculated daily Enterococcus loading by source for all watersheds.

Table 10. Calculated annual Enterococcus loads (billion cfu/year) per watershed from SELECT analysis.

Subwatershed	Cattle	Feral Hogs	Dogs	WWTF	OSSF	SSO	Total
D1- Diversionary Canal 1	5.67×10^{7}	3.06×10^{5}	6.16×10^{7}	0	1.54×10^{7}	0	1.34×10^{8}
D2- Diversionary Canal 2	6.44×10^{7}	3.99×10^{5}	3.38×10^{8}	0	1.75×10^{7}	0	4.20×10^{8}
D3- Diversionary Canal 3	1.09×10^{8}	5.71×10^{5}	1.13×10^{8}	0	3.42×10^{7}	0	2.57×10^{8}
D4- Diversionary Canal 4	1.48×10^{8}	6.87×10^{5}	5.62×10^{7}	1.45×10^{6}	3.34×10^{6}	0	2.11×10^{8}
HB1-Highland Bayou 1	3.55×10^{7}	3.34×10^{5}	8.42×10^{7}	0	1.34×10^{5}	0	1.20×10^{8}
HB2- Highland Bayou 2	3.97×10^{7}	2.8×10^{5}	1.24×10^{8}	0	2.27×10^{6}	0	1.67×10^{8}
HB3- Highland Bayou 3	4.16×10^{7}	3.0×10^{5}	2.00×10^{8}	0	1.03×10^{7}	0	2.52×10^{8}
HB4- Highland Bayou 4	2.44×10^{7}	1.93×10^{5}	4.89×10^{8}	0	1.34×10^{5}	1.58×10^{5}	5.14×10^{8}
HB5- Highland Bayou 5	1.05×10^{7}	8.5×10^{4}	1.14×10^{7}	0	1.34×10^{7}	0	3.55×10^{7}
MC1 -Marchand Bayou 1	3.55×10^{7}	2.53×10^{5}	4.15×10^{8}	0	6.68×10^{5}	0	4.51×10^{8}
Total Highland Bayou and Tributaries							2.57 x 109
MB1- Moses Bayou 1	7.82×10^{7}	4.78×10^{5}	2.92×10^{8}	0	2.00×10^{6}	1.73×10^{5}	3.73×10^{8}
MB2- Moses Bayou 2	1.01×10^{8}	3.9×10^{5}	2.4×10^{7}	0	1.60×10^{6}	0	1.27×10^{8}
Total Moses Bayou							5.0×10^{8}
U1 – Unnamed Bayou	4.77×10^{7}	2.37×10^{5}	2.5×10^{8}	0	4.01×10^{5}	0	2.99×10^{8}

Table 11. Calculated Enterococcus loads by source from SELECT analysis.

Source	Daily Loading (billion cfu/day)	Annual Loading (billion cfu/year)
Cow	2.87×10^{6}	1.05×10^{9}
Deer	1.6×10^{4}	5.87×10^{6}
Hogs	1.62×10^{4}	5.93×10^{6}
Dogs	8.39×10^{6}	3.06×10^{9}
WWTF	1.04×10^{4}	3.82×10^{6}
OSSF (failing)	1.71×10^{6}	6.26×10^{8}
SSOs	7.6×10^{3}	2.77×10^{6}
Total	1.30×10^{7}	4.75×10^{9}

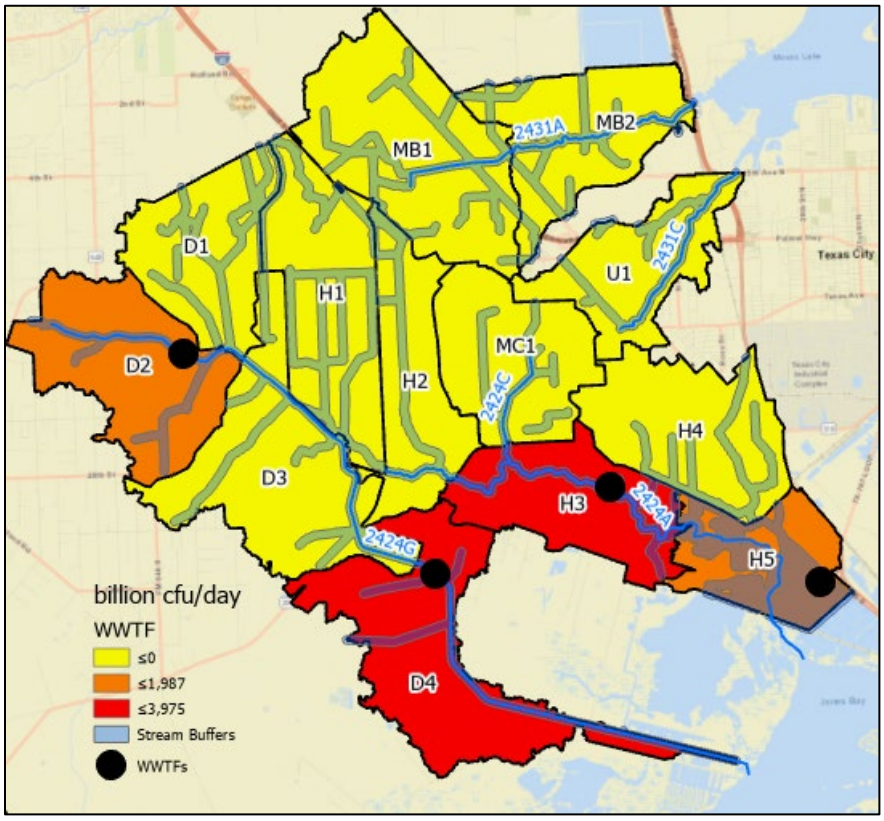


Figure 23. Calculated WWTF loadings by subwatershed from SELECT analysis.

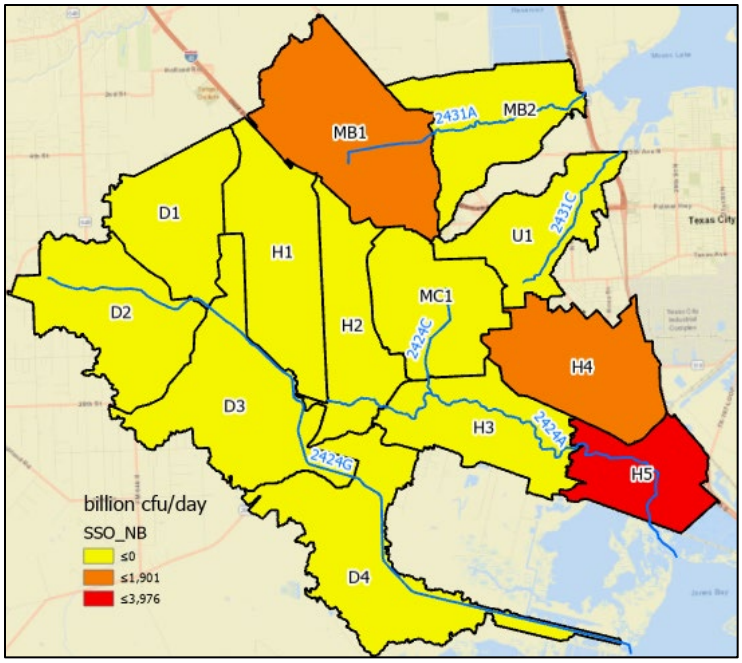


Figure 24. SSO SELECT calculated loadings by subwatershed.

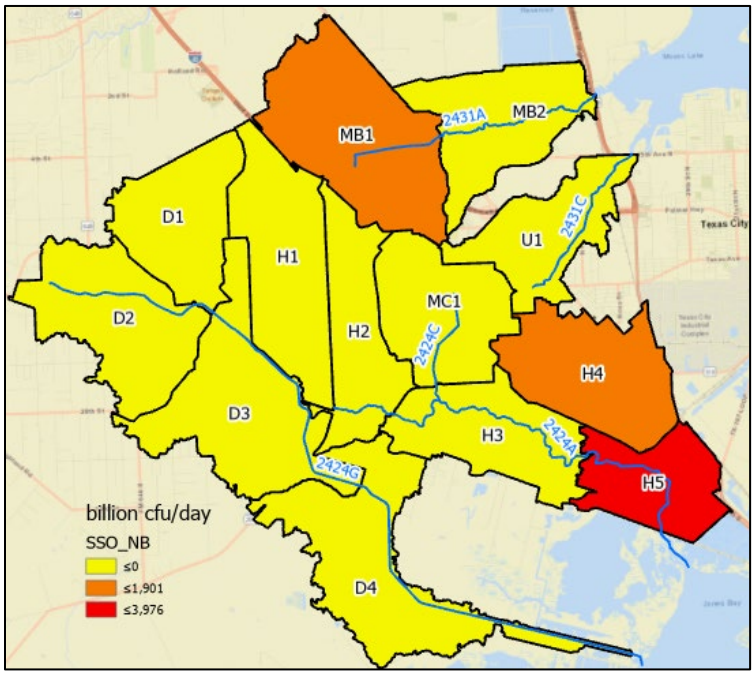


Figure 25. OSSF SELECT calculated loadings by subwatershed.

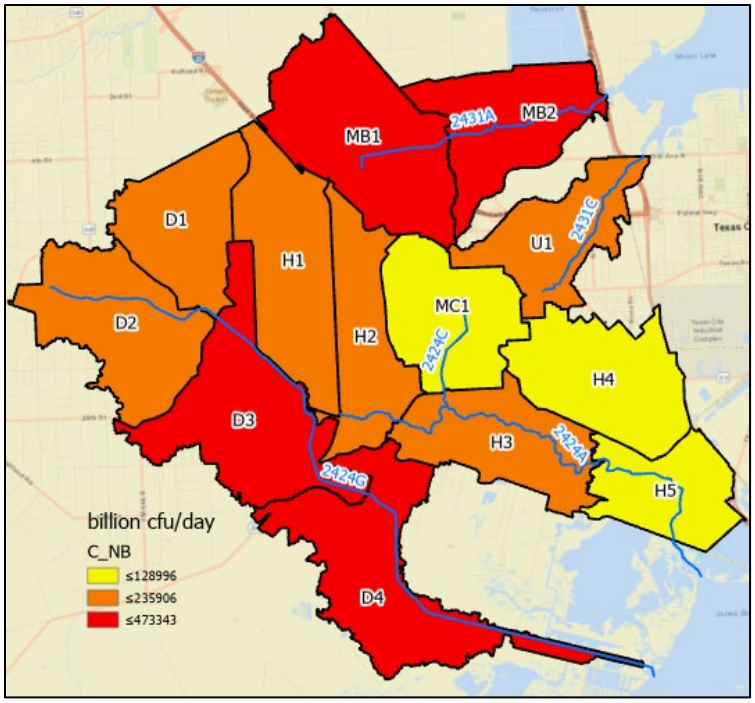


Figure 26. Cattle SELECT calculated loadings by subwatershed.

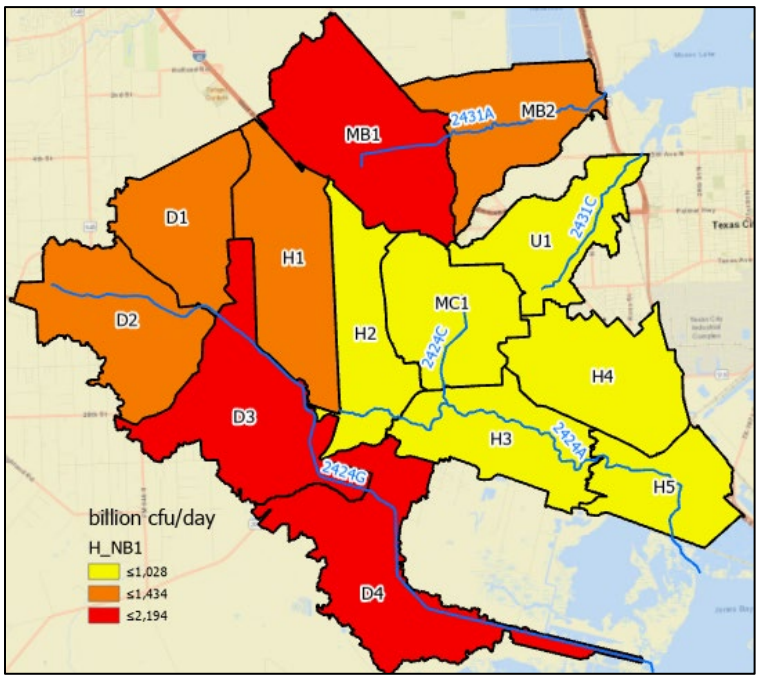


Figure 27. Feral hog SELECT calculated loadings by subwatershed.

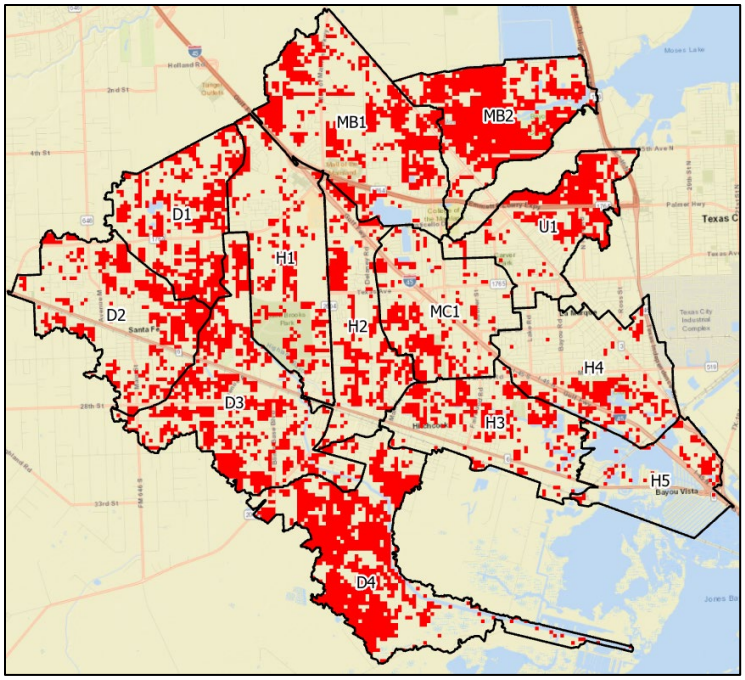


Figure 28. Pasture and grassland suitable for livestock.

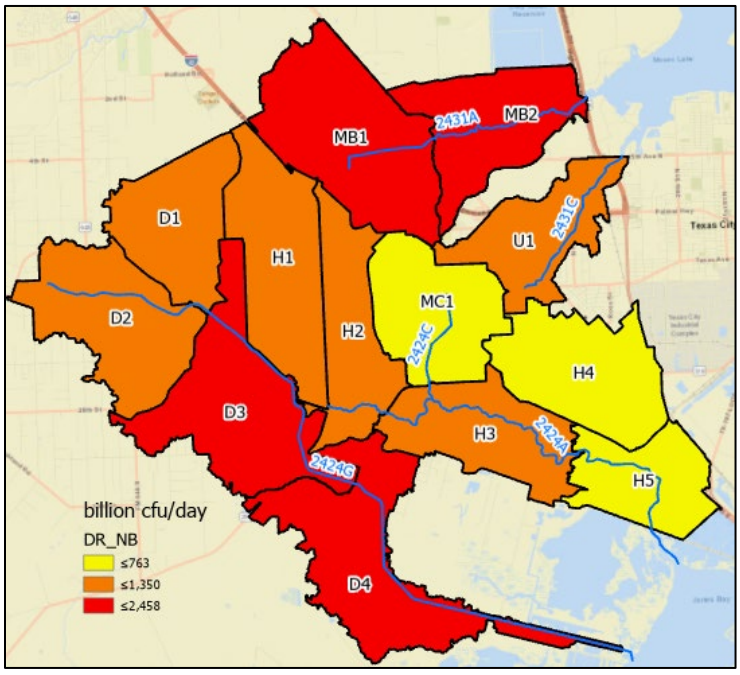


Figure 29. Deer SELECT calculated loadings by subwatershed.

Load Reductions

Load reductions are calculated for three priority management measures (Table 12). For each reduction, a brief narrative about reasoning, assumptions, and calculations is provided, followed by reduction tables for each practice. There is reason to believe that greater reductions could be achieved through the implementation of related practices (i.e., WWTP improvements), or greater implementation participation. Because of this, a brief discussion of Management Measure 2 is also included in this section, though a reduction was not calculated due to lack of needed data.

Table 12. Pollutant of concern by management measure.

Projects	Bacteria	Nitrogen	Phosphorus
SSS Upgrades (MM #1)	x	--	--
Pet Waste Education (MM #5)	x	--	--
Green Infrastructure (GI) (MM #6)	x	x	x
Stormwater Wetlands (MM #6)	x	x	x

Load Reductions from Management Measure 1: Sanitary Sewer Upgrades

The focus of this management measure is the repair of sanitary sewer system (SSS) infrastructure to reduce the number of SSOs leakages and spills into the environment. SSOs are typically due to failures from cracking lines from age, accumulation of fats and grease, clogging from rags and foreign objects, and penetration by tree roots. These failures occur in neighborhoods and along streets, and from there, raw sewage flows into drainage conveyances and eventually the bayou. Actions for this load reduction include replacement of damaged or corroded lines, the point repair of lines at specific locations, man-hole cover upgrades, and the repair of pump or lift stations. These repairs combined, together with improved monitoring technologies, can bring an aging collection system into proper working order and reduce the number of SSO discharges.

For an estimate of load reduction of indicator bacteria from SSS improvements, the reductions are based on SSO discharge figures from the city of La Marque, which is participating in TCEQ's Sanitary Sewer Overflow Initiative (SSOI) program. Other communities like Texas City and Hitchcock have a very similar development style and age, which are likely to translate to comparable collection system characteristics and comparable SSO discharge volumes across much of the watershed. Loads and load reductions can be calculated by pro-rating SSO volumes by population in each AU. This approach points to a known data gap—actual discharge volumes—which could be addressed in part by other WPP management measures.

From April 2011 to March 2013, the city of La Marque reported an estimated 100,000 gallons of SSO discharges. It is assumed that these overflows are from the public side

of the collection system, versus private property sewage lines connecting into the public system (see discussion section below). La Marque has a population of approximately 15,141 residents, compared to 22,008 in the Highland and Marchand Bayous watershed. Prorated by population in incorporated areas, that is, areas likely serviced by a central collection system, results in an average SSO discharge of 73,356 gallons per year in the watershed. Using a low to high range of average concentrations of indicator bacteria in untreated sewage, loads and load reductions can be estimated from these discharges. SSO discharges from the collection system are assumed for purposes of this plan to be a regular leak into the environment, although heavy rainfall events can result in sporadic and high-volume discharges. Similarly, stormwater infiltration from the environment and into the collection system can overwhelm the system's treatment plant, resulting in the untreated discharge of hundreds of thousands of gallons from a single event.

Repair activities. Using estimates of the city of La Marque SSOI upgrade program, we can approximate the types of repairs and potential load reductions achieved from those repairs. The city estimates from its system survey that approximately 25 line points need major repair, 9,350 linear feet (lf) of broken or corroded line need replacement, and approximately 20 lift stations need upkeep at a cost of $1.4 million over 10 years and servicing approximately 15,000 residents (La Marque Meeting Minutes, January 2015). Assuming these repair characteristics hold for the entire watershed, these figures translate to the following watershed-wide repair figures (Table 13).

Table 13. SSS repairs.

Activity	La Marque (pop. 15,141)	Highland Bayou Watershed (pop. 22,008)
Points with major repairs	25	36.7
Line replacement (lf)	9,350	13,718
Lift stations repaired or replaced	20	29

Rate of effectiveness. The city of La Marque SSOI upgrade program utilizes a 10-year program timeline. Ten percent progress per year would result in a complete repair of the system, yet not all needed repairs can be initially known, and new failures will continue to occur elsewhere over the course of 10 years. Combining an 80% repair effectiveness with a 15% failure rate over 10 years, results in a net effective rate of 65% over 10 years, or 6.5% per year using the above repair program. Using these assumptions about repair activities and load reduction, we calculate the following 10-year load reduction of indicator bacteria per AU, utilizing both the low- and high-end bacteria concentrations.

Calculation assumptions

- Reductions assume a 10-year implementation horizon.
- Low *E. coli* concentration of 1.05 x 10^7 and a high value of 1.05 x 10^8 CFUs per 100mL.
- A bacteria conversion factor of 0.278 *Enterococcus* per *E. coli*.
- Effective rate of volume reduction is 65% for 10 years, or 6.5% per year.
- Unreported SSOs from the collection system and from private lines are not factored in but are a known source.
- Wastewater treatment plant SSO discharges are not factored in but are a known source.
- All populations in incorporated areas are assumed to be serviced by a collection system and not by OSSF. GIS was used to allocate population by AU and incorporated areas; see load reduction Table 14.

Calculations

- Low Assumption Load per Gallon SSO = (1.0x10^7 CFU *E. coli* /100ml) * (0.278 *Enterococcus/E. coli*) * (100mL/0.0264172gal) = 1.05x10^8 CFU *Enterococcus*/gallon.
- High Assumption Load per Gallon SSO = (1.0x10^8 CFU *E. coli* /100ml) * (0.278 *Enterococcus/E. coli*) * (100mL/0.0264172gal) = 1.05x10^9 CFU *Enterococcus*/gallon.
- Effective reduction rate = (effective repair rate) – (new failure rate) = (80%) – (15%) = 65%.
- Indicator Bacteria Load Reduction = (Load per gallon) * (Effective rate of volume reduction).
- Percent Reduction = (Load Reduction) / (Total Load).
- Loads and reductions are allocated on a pro-rated share of the incorporated population in each AU (Table 14).

Table 14. Bacteria load and reductions; by population per AU.

	Total	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C_01
Population (incorporated)	22,008	9,243	61	2,919	1,957	1,508	6,320
Share of Population	100%	42.0%	0.3%	13.3%	8.9%	6.9%	28.7%
Share of SSO Gallons per year	73,356	30,808	203	9,729	6,523	5,026	21,066
Annual Load *Enterococcus* from SSO (Low Concentration) (CFU/Gallon = 1.05x10^7)	7.70E+11	3.23E+11	2.13E+09	1.02E+11	6.85E+10	5.28E+10	2.21E+11
Annual Load *Enterococcus* from SSO (High Concentration) (CFU/Gallon = 1.05x10^9)	7.70E+13	3.23E+13	2.13E+11	1.02E+13	6.85E+12	5.28E+12	2.21E+13
Annual Load *Enterococcus* from SSO (in Billion CFUs) (Low Concentration)	770.24	323.49	2.13	102.16	68.49	52.78	221.19
Annual Load *Enterococcus* from SSO (in Billion CFUs) (High Concentration)	77023.8	32348.7	213.5	10215.9	6849.1	5277.7	22118.8
Assumed 10-year Net Effectiveness of Management Measure 1 activities	65%	65%	65%	65%	65%	65%	65%
Bacteria load reduction (in Billions of CFUs) after 10 years (Low Concentration)	-500.7	-210.3	-1.4	-66.4	-44.5	-34.3	-143.8
Bacteria load reduction (in Billion CFUs) after 10 years (High Concentration)	-50065.5	-21026.7	-138.8	-6640.4	-4451.9	-3430.5	-14377.2

	Total	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C_01
Total *Enterococcus* Load from all sources in Billions of CFUs (source Table: A-8)	422,534	175,635	5,396	44,646	54,349	41,936	100,573
Management Measure as percent reduction in load after 10 years (Low Concentration)	0.12%	0.12%	0.03%	0.15%	0.08%	0.08%	0.14%
Management Measure as percent reduction in load after 10 years (High Concentration)	11.85%	11.97%	2.57%	14.87%	8.19%	8.18%	14.30%

Location of SSS repair activities will be prioritized by cities, public works, or MUDs based on competing priorities, resources, and urgency of the repair. In any given year certain neighborhoods will see substantial improvements to their collection system, while other neighborhoods may see no action until years later. From the perspective of a water quality monitoring program in each AU, progress may appear irregular, where some AUs attain large reductions while others realize none. The goal is that after 10 years, SSS repair activities will have been undertaken across most or all AUs, and that the 65% percent net effectiveness will be realized along with associated load reductions.

The reported SSO figures of 100,000 gallons between 2011 and 2013 are for discharges from the public side of the collection system, and do not factor in leakages and failures in private lines that connect into the collection system. La Marque estimates that SSO discharges from the public side of the collection system may represent only 40% of system-wide leakages, meaning that private property lines may constitute 60% of all discharges. Improving private maintenance of private lines could have a substantial impact on the watershed's water quality, possibly accounting for more than a doubling in load reductions from this source. These private lines and their contribution are not included as a management measure in this load reduction section. Other management measures may address the impact of private lines.

Load Reductions from Management Measure 2: Fats, Oils, Grease and Wipes

The focus of this management measure is educating homeowners on the impacts of fats, oils, grease, and wipes on their plumbing and the larger collection system for the community. It is assumed that through education efforts a fraction of homeowners will recognize issues with their home plumbing and see to it that their system is repaired at their personal expense. This reduction depends on a chain of particular events, such that a fraction of homeowners will receive educational material, a fraction of them will recognize an issue with their system, and a fraction will take action to have their pipes

cleared or replaced. While the number of homes may be small, the impact on reducing the volume of raw sewage leaking from private lines could be large.

No attempt is made here to estimate the potential reduction in SSO volumes from private lines connecting to the main collection system. Several key figures are missing, namely a likely estimate for the number of homes with failing private lines, and the volume flowing from the average failure. For total volume of leakages from private lines, an estimate can be made here based on figures from the La Marque study (see above). Prorating the losses reported in La Marque, and applying the 60% volume figure for private lines, there may be over 110,034 gallons of raw sewage leaking from private lines. Applying the reduction assumptions from SSOI improvements to the potential volume reduction from private lines could result in a net reduction of almost 20% across the Highland Bayou watershed.

Through a combination of reporting and homeowner education, it is possible that failing private lines could be identified. However, this is no legal enforcement mechanism to compel a private homeowner to upgrade their system. The most compelling reason for a homeowner is likely the most immediate: overflowing bathrooms and foul odors from the lawn.

Load Reductions from Management Measure 3: Pet Waste Education

The focus of this management measure is on pet owner education and behavior change about pet waste pickup. Pet waste, particularly dog waste, left on a lawn or any outdoor area will eventually be washed away via stormwater and into local waterways, contributing to the Bayou's bacteria load. Through education about the impact and importance of pet waste on water quality, it is assumed that pet owners will act responsibly and pick up their pet's waste and dispose of it in the garbage. Most cat waste is collected in a litter box and disposed of in the garbage.

Using figures on ownership rates from the American Veterinary Medical Association (AVMA) and GIS analysis, the project team estimated the dog population by AU. The AVMA (2012) estimates that 36.5% of households own dogs, and those households have an average of 1.6 dogs. This results in a blended rate of .584 dogs per household. Using these ownership rates and load reduction estimates from pet waste pickup participation rate, and load reduction can be calculated for this management measure. The National People and Pets survey found that around 44% of dog owners stated that they "always" or "sometimes" pick up their dog's waste. For this analysis, we assume 40% of owners pick up dog waste.

Calculation Assumptions

- Reductions assume a 10-year implementation horizon.

- The average dog produces 5.0x10^9 fecal coliform per day.
- A bacteria conversion factor of 0.278 Enterococcus per E. coli, and a bacteria conversion factor of 0.63 E. coli per fecal coliform
- Only 40% of dog waste is picked up; 60% is assumed left outdoors.
- A 20% increase in pick-up rates over 10 years, i.e., 48% pick up rate and 52% leave rate.
- 100% of the bacteria in fecal waste left outdoors will end up in the bayou

Calculations

- Dogs per household = (36.5% of households own dogs) * (1.6 dogs / owning household) = 0.584 dogs / household (Source AVMA, 2012)
- Dogs in watershed = (0.584 dogs / household) * (10,040 households in watershed) = 5,863 dogs in watershed
- Effective load reduction rate = (current load-future load) / (current load) = 60%-52% / 60% = 13.6%
- Load Reduction of Indicator Bacteria in billions = (5.0x10^9 fecal coliform/dog / day) * (0.63 E. coli / fecal coliform) * (0.278 Enterococcus / E. coli)* (365 days / year)*(.136 % effective reduction through increased pick up rates)*(1/1,000,000,000) *(5,963 dogs in watershed) = 24,987 load reduction of indicator bacteria in billions for entire watershed.

Table 15 shows the dog population and load reduction for selected AU (from GIS analysis using Dwelling Units by AU) and shows the allocation of indicator bacteria load reduction and bacteria load reduction as percent of total indicator bacteria load in by AU and the sum for all selected AUs.

Table 15. Bacteria load and reductions; dwelling unit by AU.

	Total	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C _01
Est. Dog Population	5,863	2,707	46	731	505	331	1,544
Percent Allocation by AU	100%	46.2%	0.8%	12.5%	8.6%	5.6%	26.3%
Load *Enterococcus* in	422,534	175,635	5,396	44,646	54,349	41,936	100,573

	Total	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C _01
Billions from All Sources							
Management Measure Load Reduction in Billions	24,987	11,537	196	3,115	2,152	1,411	6,580
Management Measure Load Reduction as Percent of All Sources, Year 2026	5.9%	6.6%	3.6%	7.0%	4.0%	3.4%	6.5%

The cost of education is low compared to other practices and the return on load reductions is potentially high. Several critical facts will determine whether bacteria reductions will exceed or fall short of estimated figures, apart from participation rates. Very little literature exists on the amount of fecal coliform in dog waste, with one study cited by numerous publications on the topic of dog waste, Van der Wel's 1995 journal publication "Dog Pollution." A study by the University of Nevada Cooperative Extension analyzing dog waste around Lake Tahoe found that "fresh feces contained an average of 50 million CFU/gram with a range of two million to 200 million CFU/g." The wide range was "attributed to the highly variable nature of dog food, digestive health and diets" (p.3) (UNV fact sheet, 2008). Twenty-three million was used for calculations in this WPP (see assumptions above).

Bacteria are living organisms and need certain conditions to live and replicate. It is likely that temperature and weather conditions play a significant role on the fate of bacteria as it is transported to waterways from the point of deposition outdoors, and that some amount may never reach the waterway. For example, dry conditions may degrade bacteria quickly. While estimates of dog populations or pick-up rates may reasonably vary by 20 or more percentage points from national averages, the differences in bacterial concentration and the transport dynamics could impact loadings by orders of magnitude.

Load Reductions from Management Measure 6: GI and Stormwater Wetlands (SWW)
The focus of this management measure is on implementing GI practices and SWW. These stormwater management practices mimic natural features by slowing the flow of water and allowing it time to infiltrate into the ground. Load reductions are achieved through a combination of ground infiltration and plant uptake. GI refers to a range of stormwater management practices and in this WPP includes grassed swales, dry and wet infiltration basins, porous pavements, bioretention areas, and sand or vegetated filter strips, and SWW. SWW are constructed ponds that integrate natural wetland vegetation, they are sometimes also called artificial wetlands or constructed wetlands.

In addition to providing water quality benefits, they provide aesthetic value. The rule of thumb for sizing SWW is 1% of the drainage area.

Load reductions are estimated as two calculations, one for GI and one for SWW (Table 16; Table 17). It is assumed that to achieve load reductions, these practices will be implemented in or near existing development over a 10-year implementation horizon. It is also assumed that approximately 20% of the runoff load from existing development will be intercepted by these practices. Existing development includes pollutant load values from land use classes referred to as road, commercial, industrial and all residential classes (0-16 dwelling units per acre). No single GI approach is prescribed here. Rather, the WPP assumes that communities and developers will select from among these options as warranted by site conditions, thus an average figure from all practices is utilized for percent removal rates. Based on figures from over 30 studies, the average percent removal for all practices is 41% for nitrogen, 43% for phosphorus, and 54% for bacteria.

Table 16. Percent reduction for pollutants of concern by green infrastructure practice.

GI Practice	N	P	Bacteria
Grassed Swale	38%	33%	--
Infiltration Basin	54%	60%	82%
Infiltration Trench	56%	58%	82%
Permeable Pavement	69%	59%	--
Bioretention Areas	51%	66%	52%
Water Quality Inlets	11%	6%	5%
Sand and Organic Filter Strips	37%	49%	49%
Vegetated Filter Strips	24%	19%	33%
Dry Detention Basin	32%	29%	67%
Wet Detention Basin	36%	52%	62%
Average Percent Removal Across All Practices	**41%**	**43%**	**54%**

Table 17. Percent reduction for pollutants of concern for SWWs.

GI Practice	N	P	Bacteria
SWWs	35%	47%	72%

Calculation Assumptions

- Reductions assume a 10-year implementation horizon
- Management practices intercept 20% of existing runoff load
- Load and Load reductions do not factor in future growth

- GI load reduction values
    - 41% reduction for nitrogen
    - 43% reduction for phosphorus
    - 60% reduction for bacteria
- SWW load reduction values
    - 35% reduction assumed for nitrogen
    - 47% reduction for phosphorus
    - 72% reduction for bacteria
- Intercepted runoff loads are based on loads from developed acreages

Calculations

- Load mass reduced from developed areas = (load from developed areas) * (Load intercept rate) * (percent removal)
- Percent reduction in total load = (Load Reduction mass from developed areas) / (Existing load from all areas)

Table 18. Nitrogen load reductions from GI practices by AU.

Nitrogen Load Reduction from GI practices	All AUs	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C_01
Load in pounds (lbs.) from Existing Development in AU	42,377	17,963	452	4,481	5,345	3,859	10,277
Load Intercept Rate		20%	20%	20%	20%	20%	20%
Removal Rate		41%	41%	41%	41%	41%	41%
Load Reduction (lbs.)	3,475	1,473	37	367	438	316	843
Total Load for AU	61,304	21,650	1,734	6,657	8,912	9,602	12,749
Percent Reduction for AU	5.7%	6.8%	2.1%	5.5%	4.9%	3.3%	6.6%

Table 19. Phosphorus load reductions from GI practices by AU.

Phosphorus Load Reductions from GI Practices	All AUs	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C_01
Load (lbs.) from Existing Development in AU	5,773	2,517	63	633	685	488	1,387
Load Intercept Rate		20%	20%	20%	20%	20%	20%
Removal Rate		43%	43%	43%	43%	43%	43%
Load Reduction (lbs.)	496	216	5	54	59	42	119
Total Load for AU	8,568	3,041	250	944	1,240	1,351	1,742
Percent Reduction for AU	5.8%	7.1%	2.2%	5.8%	4.8%	3.1%	6.8%

Table 20. Enterococcus load reductions from GI practices by AU.

Enterococcus Load Reductions from GI Practices	All AUs	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C_01
Load (billions) from Existing Development in AU	407,529	172,757	4,384	42,985	51,437	37,332	98,634
Load Intercept Rate		20%	20%	20%	20%	20%	20%
Removal Rate		54%	54%	54%	54%	54%	54%
Load Reduction (billions)	44,013	18,658	473	4,642	5,555	4,032	10,652
Total load (billions) for AU	422,535	175,635	5,396	44,646	54,349	41,936	100,573
Percent Reduction for AU	10.4%	10.6%	8.8%	10.4%	10.2%	9.6%	10.6%

Table 21. Nitrogen load reductions from SWWs by AU.

Nitrogen Load Reductions from SWWs	All AUs	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C_01
Load (lbs.) from Existing Development in AU	42,377	17,963	452	4,481	5,345	3,859	10,277

Nitrogen Load Reductions from SWWs	All AUs	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C_01
Intercept Rate		20%	20%	20%	20%	20%	20%
Removal Rate		35%	35%	35%	35%	35%	35%
Load Reduction (lbs.)	2,966	1,257	32	314	374	270	719
Total Load for AU	61,304	21,650	1,734	6,657	8,912	9,602	12,749
Percent Reduction for AU	4.8%	5.8%	1.8%	4.7%	4.2%	2.8%	5.6%

Table 22. Phosphorus load reductions from SWWs by AU.

Phosphorus Load Reductions from Stormwater Wetlands	All AUs	2424A_01	2424A _02	2424A _03	2424A _04	2424A _05	2424C _01
Load (lbs.) from Existing Development in AU	5,773	2,517	63	633	685	488	1,387
Intercept Rate		20%	20%	20%	20%	20%	20%
Removal Rate		47%	47%	47%	47%	47%	47%
Load Reduction (lbs.)	543	237	6	60	64	46	130
Total Load for AU	8,568	3,041	250	944	1,240	1,351	1,742
Percent Reduction for AU	6.3%	7.8%	2.4%	6.3%	5.2%	3.4%	7.5%

Table 23. Enterococcus load reductions from SWWs by AU.

Enterococcus Load Reductions from SWWs	All AUs	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C_01
Load (billions) from Existing Development	407,529	172,757	4,384	42,985	51,437	37,332	98,634
Intercept Rate		20%	20%	20%	20%	20%	20%
Removal Rate		72%	72%	72%	72%	72%	72%
Load Reduction (billions)	58,684	24,877	631	6,190	7,407	5,376	14,203
Total load (billions)	422,535	175,635	5,396	44,646	54,349	41,936	100,573

Percent Reduction	13.9%	14.2%	11.7%	13.9%	13.6%	12.8%	14.1%

Load reduction and load reduction costs will vary by the practice installed. An average value for all practices was utilized here. The effectiveness of the practices will depend on proper implementation, sizing, and site location. Implementation will be voluntary and undertaken by local public entities, private landowners, or developers. To reiterate, these load reductions are achieved by installing these management measures in a way that intercepts flow from existing developed areas, and not new development. For purposes of water quality monitoring in the basin, load reductions will be offset by load increases from future development in the watershed. One way to stay ahead of this offsetting dynamic is for municipalities to update their subdivision ordinance and site plan reviews to either require these practices as a condition of development or ensure that codes do not inadvertently prohibit developers from utilizing these practices.

Cumulative Load Reductions
Bacteria

Table 24 shows estimated indicator bacteria load reductions from the management measures discussed previously. The high value bacteria concentration for SSO discharges are utilized in this table. It is possible in 10 years, through the adoption of the practices and repair programs, to see a 42% reduction in bacteria from today's load values.

Table 24. Estimated Enterococcus load reductions from four priority management measures by AU.

Enterococcus Load in Billions	All AUs	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C_01
Total Estimated Load	422,534	175,635	5,396	44,646	54,349	41,936	100,573
Load Reduction from SSOI improvements (high bacteria concentration value)	50,065	21,027	139	6,640	4,452	3,430	14,377
Load Reduction from Pet Waste Pick Up Program	24,991	11,537	196	3,115	2,152	1,411	6,580
Load Reduction from Green Infrastructure	44,012	18,658	473	4,642	5,555	4,032	10,652
Load Reduction from Stormwater Wetlands	58,684	24,877	631	6,190	7,407	5,376	14,203
Load Reduction from All Practices	177,752	76,099	1,439	20,587	19,566	14,249	45,812
Reduction as Percent of Total Load	42.1%	43.3%	26.7%	46.1%	36.0%	34.0%	45.6%

DO

Table 25 shows estimated cumulative load reductions in nitrogen and phosphorus from the implementation of proposed GI practices and SWWs. It is possible in 10 years, through the adoption of these practices, to see a 10.5% reduction in nitrogen and a 12.1% reduction in phosphorus. While a reduction in nutrients would be a positive trend, the reduction's impact on the levels of DO is unknown. It is important to remember the 303(d) listing is for low DO and not for specific nutrients.

Table 25. Cumulative nitrogen and phosphorus load reductions from GI practices and SSWs.

Nitrogen (lbs.)	All AUs	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C_01
Total Estimated Load	61,204	21,650	1,734	6,557	8,912	9,602	12,749
Load Reduction from Green Infrastructure	3,474	1473	37	367	438	316	843
Load Reduction from Stormwater Wetlands	2,966	1257	32	314	374	270	719
Total Load Reduction	6,440	2730	69	681	812	586	1562
Reduction as Percent of Total Load	10.5%	12.6%	4.0%	10.4%	9.1%	6.1%	12.3%
Phosphorus (lbs.)	**All AUs**	**2424A_01**	**2424A_02**	**2424A_03**	**2424A_04**	**2424A_05**	**2424C_01**
Total Estimated Load	8,568	3,041	250	944	1,240	1,351	1,742
Load Reduction from Green Infrastructure	495	216	5	54	59	42	119
Load Reduction from Stormwater Wetlands	540	237	6	60	64	43	130
Total Load Reduction	1,035	453	11	114	123	85	249
Reduction as Percent of Total Load	12.1%	14.9%	4.4%	12.1%	9.9%	6.3%	14.3%

Element C: Management Measures

Selecting Management Measures

The project team worked with over 40 stakeholders through a series of workshops, mapping exercises, and one on one interviews to understand what projects have been done in the past, what projects are underway, and what could be done in the future. Stakeholders were asked about activities of any kind that might have an impact on water quality in the watershed. Through this exercise, over 100 specific project ideas were identified. From this pool of project ideas, similar ideas were merged into what became the 38 best management practices (BMP) for the voting exercise.

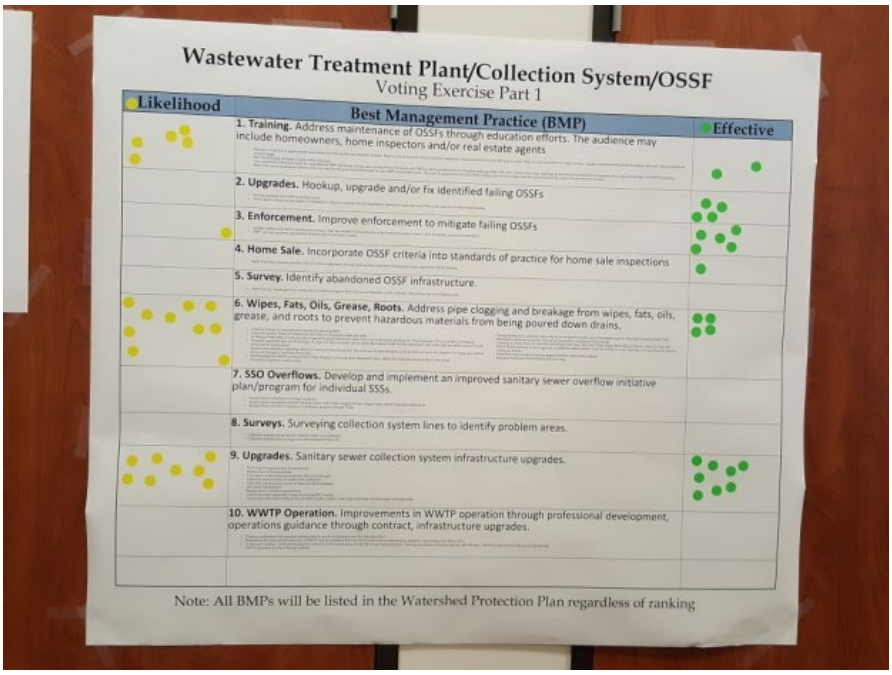


Figure 30. Wastewater management measures poster during the voting exercise.

Participants prioritized the 38 BMPs through a workshop and email voting exercise. Participants were asked to vote their preference based on two considerations—which projects were likely to happen and which projects were likely to be effective. The votes were merged and tallied for each project. After the tally, one more task was required: weighing the votes. Since dots for voting were handed out to participants for each grouping (i.e., wastewater, urbanization, flow, wildlife), and since each group had a different number of management measures, the final votes were weighted to rank management measures across all groups. The final weighted totals were used to rank the management measures; the Top 12 are considered priority for implementation (Table 26). The full list of 38 management measures is in Appendix B.

Table 26. Twelve management measures for implementation as prioritized by stakeholders.

	Management Measures
1	Sanitary Sewer Upgrades
2	Wipes, Fats, Oils, Grease
3	Improved Flow within Highland Bayou
4	Culvert Maintenance at Diversion
5	Pet Waste Education
6	Green Infrastructure and Stormwater Wetlands

	Management Measures
7	Stormwater Infrastructure Assessment
8	Landscaping Debris Ordinances
9	Landowner Conservation Plans
10	Preserve Existing Natural Areas
11	OSSF Training
12	Feral Hog Workshops

The top 12 vote-getting management measures are the priority for implementation and water quality improvement. Details about each management measure are provided below. Stakeholders feel these are the best ways to meet water quality standards; these 12 are the focus of WPP implementation and the project team prepared detailed tables identifying background, goals, objectives, costs, technical resources, timelines, and milestones. The remaining 26 management measures are still considered viable project areas and provide avenues for adaptive management during WPP implementation. To that extent, a brief narrative about project directions and resources is included in Appendix A.

For the 12 management measures, according to the outline of EPA's nine element watershed plan, project details are assigned to their respective elements in this WPP document:

- Element C – Management Measures: Goals, Objectives, Likely Project Lead
- Element D – Financial and Technical Resources: Costs, technical resources, and funding sources
- Element F – Implementation Schedule: Divided into near-, medium- and long-term time horizons.
- Element G – Milestones: Progress points for projects and strategies

Management Measure Definitions

Problem – provides a brief narrative of the problem the management measure is intended to address.

Goals – the primary water quality goals this management measure is intended to achieve.

Approach – the strategy the management measure will use to achieve the goals.

Location – targeted locations for implementing management measures, or if it is a watershed-wide activity.

Objectives – specific phases or steps needed to implement this management measure.

Likely Lead – The organization or agency that is the likely lead for each activity; these include groups mandated to lead efforts and/or organizations involved with developing this WPP. The likely lead entity responsible for each BMP installed is responsible for operations and maintenance. The desire to participate is indicated by inclusion, however additional resources are likely needed for groups to take on this additional role.

Load Reduction Effectiveness – "Low," "Medium," and "High" are used to estimate the impact this action will have on water quality. Priority management measures with a high impact on water quality were used to calculate load reductions in Element B.

Likelihood of Success – The likelihood the strategy has of success attributed to voluntariness, cost, interest, level of difficulty, or other reasons. Also, additional information is needed for successful implementation.

Technical and Financial Needs – Identify resources necessary for implementation, these range from personnel time to infrastructure investments.

Twelve Management Measures

Management Measure #1: Infrastructure Upgrades to the Sanitary Sewer Collection System

Problem: The centralized collection system for WWTFs includes a network of sewer lines, lift stations, and other infrastructure. Sanitary sewer pipes, if broken or malfunctioning, can release raw sewage into the runoff where it flows into streets and stormwater conveyances. These releases of sewage are called SSOs. SSOs associated with FOG and wipes are discussed in Management Measure 6. Infiltration and inflow (I/I) are also contributing factors for SSOs. I/I is caused by unwanted water entering the collection system through manhole covers, sewer cleanouts, illicit connections, or damaged pipes. I/I volumes can overwhelm the collection system and WWTFs. Collection system problems resulting from I/I include: (1) back flooding of sewers into streets and private properties; (2) decreased capacity of the wastewater collection system; and (3) increasing collection system operating costs, e.g. adding to energy, maintenance, and repair costs by extending the running time for pumps and pump stations. SSO discharges may also result in substantial regulatory fines.

For GCHD's Water Pollution Division, the biggest complaint received from residents is sewage overflows, many from centralized sewage systems.

Goals:

- To reduce the volume of raw sewage discharging from failing SSS infrastructure.

Approach: Collection systems need routine maintenance to identify and eliminate SSO and I/I issues. A combination of sewer system surveys, repairs, and monitoring technologies can be utilized to bring a system into proper working order and reduce the release of untreated sewage into neighborhoods and ditches. This may include the replacement of corroded lines, failing lift stations, and repairs at specific line locations. Municipalities in the watersheds are in the process of multi-year infrastructure improvement programs which will reduce the volume of raw sewage flowing into the environment and waterways.

Hitchcock and La Marque have both participated in TCEQ's SSOI program and are in different phases of assessment and implementation. Through the SSOI program, a plan for SSO reduction is submitted to TCEQ including a system inventory, sewer map update, inspections and testing, and system rehabilitation with multiple phases of construction. Video technology is used to survey the collection system and peak flow is measured to identify I/I. La Marque is in the process of issuing substantial capital improvement bonds for their SSO program. The city of Hitchcock completed their SSOI program agreement in 2013 and is continuing system rehabilitation construction activities for SSO reduction. While MUD 12 has not participated in TCEQ's SSOI program, they perform wastewater collection system surveys and report information to TCEQ.

The GCHD offers inspections of WWTP operations for compliance with state and federal regulations as a contract service and have assisted Hitchcock and La Marque as recently as 2015.

Location: Collection system infrastructure for four WWTFs occurs along highways and throughout neighborhoods in Hitchcock, La Marque, Santa Fe, and Bayou Vista. The Galveston County MUD 12 WWTP and La Marque's Westside WWTP discharge into Highland Bayou. While the city of Hitchcock's WWTF discharges to the Highland Bayou Diversionary Canal, much of its collection system is within the Highland Bayou Watershed.

Implementation Objectives

The lead entity for the following objectives will likely be wastewater service providers, such as the city of Hitchcock, city of La Marque, MUD 12, and the city of Texas City.

1. Adopt or update infrastructure management programs to plan and budget for proactive/preventative maintenance activities.
2. Identify areas in the collection system where I/I or aging infrastructure is a problem.
3. Rehabilitate collection system infrastructure to prevent SSOs and I/I.

4. The responsibility of upgrading or repairing private line connections to the wastewater collection system should be performed as necessary by residents with guidance from the wastewater service provider.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: High – Infrastructure repairs and surveying technologies are proven methods for reducing SSOs and leakages.

Likelihood of Success: High – Hitchcock has completed a five-year agreement through the TCEQ SSOI program. La Marque is currently participating in the TCEQ SSOI program. These are existing and new commitments to infrastructure improvements that will improve their collection systems.

Technical and Financial Needs: Each wastewater service provider is responsible for their respective infrastructure improvements, have separate funding and approval processes. Constant maintenance of the collection system is necessary to ensure proper operation and parts can be expensive making ongoing operations a costly undertaking. See Element D for more information.

Management Measure #2: FOG and Wipes in the Sanitary Sewer Collection System
Problem: The accumulation of FOG and wipes is a common problem resulting in SSOs, malfunctions, and failures. As sewer lines clog and eventually break, raw sewage flows into local waterways or occurs as backups into homes and businesses. The issue spans from private lines to the publicly maintained collection system. For private lines, homeowners and commercial customers are responsible for costs associated with blockages on private property. For a blockage on the public side of the collection system, costs can be substantial, and some maintenance costs are passed on by the sewer rate payers. The utility provider may also face regulatory fines for the discharge of SSO volumes into the environment.

Goals:

- Minimize the introduction of SSO raw sewage into local waterways.
- Reduce the deposition of FOG and wipes entering sewer lines.
- Encourage proper disposal practices through education and outreach to residents and commercial entities on items that should not enter their drains.

Approach: *Commercial Practices.* Preventing FOG and wipes will reduce the incidence of blockages and other failures to the SSS and the release of raw sewage. Developing or strengthening regulations and policies that specifically address FOG for food service establishments and other commercial users is a priority. Wastewater treatment providers can employ a variety of requirements for users in their service area including:

Local limits for oil and grease substances from animal or vegetable sources or from hydrocarbon discharges in wastewater to the sewage system:

- a minimum recovery charge per typical blockage incident attributed to the improper disposal of grease,
- outside interceptors for all new or remodeled food service establishments, and
- the development and implementation of a FOG best management plan as well as a grease interceptor cleaning log for food service establishments.

Rules can also be established for licensed waste haulers:

- grease interceptor cleaning practice standards,
- cleaning log requirements, and
- an expectation of communicating pertinent information to personnel of the food service establishment they service.

Public Education: Municipal wastewater entities can improve FOG awareness among their customer base by utilizing existing educational materials. Cease the Grease is a kitchen grease awareness campaign through the Galveston Bay Foundation (GBF) that offers educational materials and an opportunity to learn from neighboring communities through GBF's Cease the Grease workgroup. In addition to keeping FOG out of our drains, GBF publicizes recycling locations for kitchen grease disposal and encourages the establishment of new recycling receptacles. Establishing more convenient recycling receptacles for residents is another way municipalities and other organizations can partner with GBF. Apartment complexes are a good option for pilot efforts as they offer an easy avenue for delivering educational material, measuring participation and surveying participants. Depending on the location and partnerships the organization has in place, GBF can provide various levels of support with acquiring the recycling receptacle, maintaining the unit, or coordinating with the oil hauler.

Educating residents about wipes is important, especially since wipes are marketed to consumers as being flushable. Flushable means that the item can fit through a 4-inch pipe but is interpreted by the consumer to mean that the material should be flushed to the sanitary sewer or is septic safe. Patty Potty is an existing campaign by the San Jacinto River Authority that offers educational materials aiming to improve awareness among residents and businesses about what not to flush down the toilet.

Location: Developed areas of the watershed serviced by a centralized wastewater collection system.

Implementation Objectives

The lead entities for these objectives are wastewater treatment providers including the city of Hitchcock, city of La Marque, city of Santa Fe and MUD 12. Other implementors include county agencies, county commissioners, and nongovernmental organization partners.

1. Regulation and Policy for FOG in commercial settings:
    a. Compile existing regulations within the watershed and share.
    b. Examine, establish, and/or update regulations as necessary to address gaps.
    c. Include enforcement measures.
    d. Perform outreach to promote participation and aid in compliance.
2. Utilize existing educational messaging related to cooking grease – Cease the Grease campaign materials:
    a. Join the Cease the Grease workgroup.
    b. Utilize available online social media materials and website content.
3. Pilot project – establish one Cease the Grease kitchen grease collection station at an apartment complex.
4. Utilize existing educational messaging related to wipes – Patty Potty campaign materials:
    a. Bolster online presence using free Patty Potty materials on social media sites and webpages.
    b. Join the Patty Potty Patrol for access to videos, inserts, and public service announcements. Save Water Texas Coalition members receive a discount. Project ideas include showing a Patty Potty video clip on the topic of flushable wipes in movie theatres (as the San Jacinto River Authority currently does); and setting up a standup cardboard cut-out of Patty Potty with a “don’t flush wipes” message in the city hall lobby.
5. Utilize utility bills for distribution of educational material to homeowners:
    a. Publicize costs for damages to sewer infrastructure to city taxpayers. “Cleaning out wipes that go down the drain is costing tax dollars.” Include a list of annual repairs for pump stations with costs, photos, the dos and don’ts of flushing and drains.
6. Host education and outreach workshops for residents and commercial entities.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Potentially High – If education leads to physical improvement of private lines to public collection system, see Element B for discussion of the data gaps related to this activity. Educational activity if leading to behavior changes would lead to avoided bacterial loads in the future.

Likelihood of Success: High – The educational component is largely available and ready for communities to utilize and educate homeowners and business. The costs and staff time associated with clearing sewer blockages or repairing equipment is significant versus the costs of homeowner education. To maximize existing resources, communities within the watershed should share existing practices and publicity activities with one another.

Technical and Financial Needs: High – The educational component is largely available and ready for communities to utilize and educate homeowners and business. The costs and staff time associated with clearing sewer blockages or repairing equipment is significant versus the costs of homeowner education. To maximize existing resources, communities within the watershed should share existing practices and publicity activities with one another.

Management Measure #3: Stream Flow Within the Highland Bayou Channel
Problem: Flow within the Highland Bayou channel is currently impeded by accumulated sediment introduced to the bayou from urbanization and large storms including Hurricane Ike in 2008. The diversionary canal project in the late 1970s resulted in the most significant alteration to the bayou. The diversion succeeded in its design to provide flood protection for properties in the watershed, but recreational use and habitat quality has declined with the decreased flow and water depth. Detrimental changes to bayou hydrology and water quality are a result.

Streamflow management and maintenance responsibilities including potential modification to the channel were consistent topics of discussion for stakeholders during workgroup meetings. Within the canal communities of Bayou Vista and Omega Bay there is a recognized need for maintenance dredging of Highland Bayou. Many of the canal subdivisions have drafts that are deeper than the main channel of the bayou, 17' in canals versus 4' in the main channel. Several residents have requested debris be removed from the Bayou to improve flow conditions.

The bayou's slow and typically warm conditions provide an ideal environment for bacteria to grow. Increased flow may benefit water quality conditions and decrease the concentration of bacteria present in the bayou.

Goals:

- Improve flow conditions within the Highland Bayou channel by improving channel flow and by removing impediments to flow, such as fallen trees and sediment accumulation.

Approach: Improving the flow within the Highland Bayou channel may be achieved directly through dredging and debris removal activities. Before these activities are approved, further investigation is necessary to establish the scope of the project.

Dredging and debris removal will not reduce future contributions of accumulated sediment and plant debris to the bayou. To accomplish this, the assessment of factors contributing to the decreased flow and introduction of sediment are needed.

Location: Highland Bayou Segment 2424A_01 originating from the headwaters to FM 2004, upstream areas within Jack Brooks Park as well as the residences downstream. Highland Bayou Segments 2424A_01 and 2424A_02 are adjacent to unincorporated Freddiesville, Texas.

Implementation Objectives

The following objectives would be conducted by Galveston County Engineering, in coordination with the USACE for studies and permits. Other potential partners include city of Hitchcock, city of La Marque, MUD 12 and resource agencies.

1. Determine causes of flow reduction by requesting a study to identify contributing factors.
2. Conduct a sediment source study to find the cause of sediment entering the bayou.
3. Selectively remove sediment and clear vegetation from the channel as recommended during assessments performed by the USACE.
4. Selectively remove accumulations of woody debris impeding flow within the channel in residential areas as recommended during assessments performed by the USACE.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Likely to be low, as direct sources are not addressed by this activity. However, it is assumed that an improved flow regimen in the waterway would lead to a reduction in bacteria loading. A load reduction estimate for this management measure is not estimated in Element B.

Likelihood of Success: Medium – As the highest-ranking priority among the stakeholders and a discussion topic that dominated many workgroup meetings, the level of commitment for this management measure is expected to be high. State and federal involvement will be necessary due to regulatory requirements for activities within the bayou channel. These efforts will span the length of the watershed and coordination between several entities will be necessary for successful implementation. The next steps are to prepare for studies. Natural resource agencies have expressed caution be used when modifying stream habitat by removing plant debris that provide beneficial structure for aquatic organisms.

Technical and Financial Needs: Applicants for studies or dredging projects through the USACE may receive project support and financial assistance, though matching funds are a requirement. See Element D for more information.

Management Measure #4: Culvert Dam Maintenance in the Highland Bayou Channel

Problem: Accumulated sediment and plant debris are obstructing the flow of Highland Bayou within Jack Brooks Park. There are two separate locations where culverts are at least partially blocked by accumulated sediment both upstream and downstream of culverts. The culverts represent the intercept point where the diversionary canal drains old Highland Bayou to the south and away from the current channel. Obstruction of flow within the culvert has been a long-standing concern for residents. In 1996, dozens of volunteers removed brush and trash from Highland Bayou during a cleanup effort adjacent to the culverts that comprise the earthen dam in Jack Brooks Park.

The bayou's slow and typically warm conditions provide an ideal environment for bacteria to grow. Increased flow may benefit water quality conditions and decrease the concentration of bacteria present in the bayou. It would not impact the load from bacteria sources.

Goals:

- Improve flow within the Highland Bayou channel, via the culvert.
- Investigate maintenance needs for culverts within Jack Brooks Park.

Approach: Improving the flow within the Highland Bayou channel may be achieved directly through removing sediment and plant debris from the culverts within Jack Brooks Park. Before the culverts can be cleaned out, more information is needed on what maintenance activities are allowed, the process in which work is performed, and which parties are responsible for performing maintenance for these culverts.

Sediment and debris removal will not reduce future contributions of accumulated sediment and plant debris within these culverts. Increased flow could lower bacteria levels through dilution by contributing waters through the dam and culvert.

Location: Highland Bayou at the diversionary canal dam and culverts in Jack Brooks Park.

Implementation Objectives

The following objectives would be conducted by Galveston County Engineering, local municipalities, MUDs, the Texas A&M Agrilife Extension Service, and USACE.

1. Request information from the USACE about culverts to determine maintenance needs (potential removal of sediment and debris) to improve flow.
2. Remove sediment and clear vegetation from culverts.
3. Establish a management/maintenance agreement.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Likely to be low, as direct sources are not addressed by this activity. However, it is assumed that an improved flow regimen in the waterway would lead to increased flow volumes and a concurrent reduction in bacteria concentrations. A load reduction estimate for this management measure is not estimated in Element B.

Likelihood of Success: High – As a top priority among the stakeholders, the level of commitment is expected to be high. More information is needed regarding the need for maintenance in these areas and the parties responsible for maintenance activities. Resource agencies have expressed caution about modifying stream habitat by removing plant debris that provide beneficial structure for aquatic organisms.

Technical and Financial Needs: The USACE provides project support and offers financial assistance, though matching funds are a requirement for applicants. See Element D tables for specific needs.

Management Measure #5: Pet Waste Education

Problem: It is estimated that there are over 5,000 dogs in the project area, generating tons of feces per year. Leaving pet waste in parks, yards or on sidewalks contributes a substantial number of bacteria to surface waters. A single gram of dog feces can carry an estimated 23 million bacteria along with viruses and parasites. Bacteria and other living organisms travel with pet fecal material into our local waterways making it dangerous for swimming and ingesting. On the ground, fecal material can be harmful for children or even other pets. Due to the presence of suburban development within the project watersheds, pet waste is assumed to be a significant source of bacterial contamination.

Goals:

- Reduce bacteria loads from pet waste.
- Encourage pet owners to pick up pet waste by providing pet waste stations in public areas.
- Provide education and outreach to pet owners on proper pet waste management and impact of pet waste on water quality.

Approach: To reduce bacteria loads from pet waste, it is important that waste is disposed of in the garbage and not left on the ground. Since many cats use litter and remain indoors the focus for education is on dogs. Feral or stray animals were discussed separately in Appendix 1.

Existing educational materials will be utilized to improve dog-owner awareness and result in behavior change. The H-GAC and the Texas Coastal Watershed Partners (TCWP) are local entities that have developed pet waste education and outreach materials that are available online. Materials available include fact sheets and posters

that can be utilized in common areas within apartment complexes, public buildings or park bulletin boards.

Pet waste education would be coordinated with the installation of pet waste stations to maximize participation. Pet waste stations with bag dispensers encourage pet owners to pick up after their pets in public areas. Aside from emptying trash cans and refilling bags, the stations require little maintenance. Stakeholders recommended parks with trash cans and regular trash pickup as the most suitable location option.

The Texas A&M AgriLife Extension Service, through the Moses-Karankawa Bayous Alliance, has provided pet waste educational materials at public events within the project area (See Element E). More than 500 pet waste bag dispensers were distributed during these events.

Location: Subwatersheds with the highest population of pets (Table 10). High public-use areas including city parks, county parks, public buildings, and large apartment complexes are best for pet waste stations. High public use areas will be prioritized higher than individual households for educational materials.

Implementation Objectives

Implementors of the following objective include the cities of Hitchcock, La Marque, and Bayou Vista, along with local MUDs, Galveston County, and the Texas A&M Agrilife Extension Service.

1. Distribute pet waste educational materials to residents during public events including H-GAC's Trash Bash, La Marque Bayou Fest, and Hitchcock's Good Ole Days Celebration; at libraries, city hall, and other public facilities; through mailers, utility inserts, Homeowners Association (HOAs), and various civic organizations.
2. Install pet waste stations with bag dispensers in parks and other public spaces.
3. Distribute pet waste bag dispensers to residents during public events including H-GAC's Trash Bash, La Marque Bayou Fest, and Hitchcock's Good Ole Days Celebration; through HOAs and civic organizations.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: High – Bacteria load reductions could be high. Effectiveness will be determined by rates of behavior change among dog-owners. Load reduction estimates are included in Element B.

Likelihood of Success: Medium to High. A sustained education effort is necessary to educate dog-owners in the watershed. While parks and other public areas where owners take their dogs to play and walk are ideal for outreach and deployment of pet waste stations, real load reductions will be seen at the neighborhood level where most

dog owners allow their dogs outside (i.e., yards or neighborhood walks). As with any educational effort, the outcome sought is behavior change, resulting in actual load reductions.

Technical and Financial Needs: Low – Funding and labor for the installation of pet waste stations and for the delivery of education and outreach materials is minimal. Maintenance of the pet waste stations would include staff time within the scope of the participating agencies' capabilities. More information is included in Element D.

Management Measure #6: GI and SWWs

Problem: Impervious and low pervious surfaces alter stormwater runoff behavior, impacting both the quantity and quality of water. Buildings, pavement, and compacted landscapes cover much of the land in suburban communities. Impervious surfaces allow water to flow over the landscape more quickly, prevent opportunities for ground infiltration. This contributes to increased quantities of runoff, and potentially increased flooding. As new development brings additional impervious surface to the watershed, the volume of stormwater runoff will increase unless site development standards change.

Goals:

- Reduce the amount of stormwater runoff entering local waterways by retaining rainfall on site or in neighborhood and regional detention features.
- Treat stormwater runoff using GI and SWWs

Approach: GI consists of designed systems that mimic the natural hydrology of an area, allowing water to infiltrate into the soil and reducing runoff. In addition, GI may reduce some flooding by encouraging infiltration and providing more time for filtration by retaining water during rain events—treating water where it falls. Designs are site specific and can be easily incorporated into new or existing yards, parking lots or landscapes. GI intends to work together with gray infrastructure (roads, bridges, etc.) that makes life possible along the Gulf Coast. Native vegetation should be used when possible as these plants are well adapted to local conditions of prolonged wet and dry spells, requiring little to no additional water once plant populations are established. Rainwater harvesting systems also promote water conservation by providing alternative water resources.

There are several locations in Galveston County providing local GI examples including the city of Dickinson Public Library rain garden, the Ghirardi Family WaterSmart Park in League City, and the Texas City Tanger Outlet Center water conservation measures. Tanger Outlet Center has 11 water cisterns with 90,000 gallons of water storage capacity designed for landscape irrigation. The Ghirardi Family WaterSmart Park in League City showcases eight stormwater BMPs in one location: rain gardens, WaterSmart landscapes, vegetated swales, pervious pavers, a vegetated buffer,

rainwater harvesting, a green roof, and compost for turf grass management. Incorporating GI on public buildings and in public spaces increases their visibility and serves as an educational opportunity to reach both residential and commercial audiences.

Municipalities should consider updating local development codes to ensure that either these kinds of practices are required or at a minimum not prohibited through existing standards. The nearby community of League City proposed an ordinance for Low Impact Development (LID) as an alternative to conventional drainage, detention, and storm water conveyance systems in 2013. Example incentives and regulations to encourage GI for stormwater retrofits are available in the "Retrofit Policies" section of EPA's *Managing Wet Weather with GI Municipal Handbook*[2].

Educating public officials, staff, developers and residents about GI will be necessary to build awareness in the watershed. Online resources are available, including Center for Watershed Protection, EPA's "Soak up the Rain," EPA's "GI Municipal Handbook," and the LID Center located in Maryland. For GI guidance that considers local soil and climate conditions H-GAC offers "Designing for Impact: A Regional Guide to Low Impact Development" and the Texas Community Watershed Partners offers technical assistance through their Green Infrastructure for Texas Program. In 2015 they published the Ghirardi Family WaterSmart Park Stormwater BMP Assessment Report. Communities in the watershed can request rain barrel workshops, through GBF, to educate residents on water conservation and provide participants with a rain barrel they can install the same day.

SWW can be constructed as retrofits of existing detention and conveyance systems, adding beauty, habitat and water quality benefits. They account for variable stormwater flow and provide an alternative to stormwater detention basins. Objectives in approach for promoting SWW include hosting existing workshops that are available and can be offered to public entities and developers. Public entities will be approached to gauge interest in utilizing SWW. Planning and land development ordinances to consider these stormwater detention retrofits into wetlands and incorporate SWW into new development projects may encourage participation.

Location: Developed areas of the project area, including commercial and residential sections of the coastal basin.

Implementation Objectives

[2] www.epa.gov/sites/default/files/2015-10/documents/gi_munichandbook_green_streets.pdf

Implementors of the following objectives include the cities of Hitchcock, La Marque, Bayou Vista, and Santa Fe, along with MUD 12, various state and county agencies, nonprofit organizations, developers, and the Texas A&M Agrilife Extension Service.

1. Update development codes to allow for GI projects during new development and stormwater retrofits; example ordinances are available for reference.
2. GI for public buildings and in public spaces:
    a. Identify public entities interested in utilizing GI.
    b. Design and implement GI projects including rain gardens, permeable pavement, bio-swales, vegetated curb extensions, rainwater harvesting cisterns and WaterSmart landscaping.
3. Educate residents and public entities about GI:
    a. Distribute educational materials about GI practices, how they can be used locally, and their impact on water quality.
    b. Partner with Texas AgriLife Extension Service to host GI workshops, lectures and field trips to educate homeowners, businesses and municipal officials.
    c. Partner with GBF to host rain barrel workshops for residents to promote water conservation.
4. Encourage the use of constructed stormwater treatment wetlands:
    a. Host constructed SWW workshops for public entities and developers.
    b. Identify public entities interested in utilizing stormwater treatment wetlands and establish ordinances to consider these practices.
    c. Retrofit existing stormwater detention facilities into stormwater treatment wetlands where feasible.
    d. Incorporate stormwater treatment wetlands during new development projects.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Medium to High, dependent on design, site selection and maintenance. Effectiveness on load reductions is contingent on use of these practices in areas that intercept runoff load from existing development. Load reductions were calculated and are included in Element B.

Likelihood of Success: Medium – Project timelines require sustained commitment and then maintenance of the features, ideally intermittently. Education is needed for proper site selection and design standards. Garden Clubs may be an avenue for outreach. Misconceptions about these practices are known obstacles to their consideration and use, requiring targeted education. Maintenance needs are expected to be different than for conventional practices but are not expected to be unreasonable. For SWW, the size of the wetland relative to the contributing watershed is the most important determining factor in how well the wetland will function.

Technical and Financial Needs: High – Funding to identify, plan and implement projects; Resource management and technical expertise is needed from partner agencies/organizations.

Management Measure #7: Stormwater Infrastructure Assessment Surveys
Problem: Drainage does not stop at jurisdictional boundaries, but responsibility for infrastructure maintenance does. Sustainability of the stormwater system is critical for proper drainage. A survey would identify, inventory, and map this infrastructure in municipalities, and ideally identify opportunities for improved volume capacity and chances for where water quality practices could be implemented or prevent SSO discharges into the stormwater drainage system.

Stormwater infrastructure includes above and below ground conveyances for stormwater. Drainage District 2 (GCDD2) maintains drainage ditches north of Highland Bayou and include large channels and detention basins. Improvements within GCDD2 are sized and maintained to accommodate runoff anticipated from maximum buildout conditions and using a 100-year rainfall event. The current system of ditches is built out to accommodate this growth, and GCDD2 focuses most of their efforts on maintenance activities. Roadside ditches within city limits are maintained by municipalities. Galveston County Road and Bridge is responsible for construction, repair and maintenance of county streets and drainage systems, and maintains some stream banks within the county. The watershed area south of Highland Bayou is outside GCDD2 and the evaluation of stormwater infrastructure for repair, maintenance and upgrades is performed by several entities in an uncoordinated fashion.

A comprehensive countywide drainage plan was created in 2012 to identify potential drainage and flood control projects both inside and outside of municipalities, following damage during hurricane Ike in 2008. A large database of drainage conditions and facilities across Galveston County was assembled, including representative drainage channel characteristics, estimated culvert capacities, planning level dimensions of proposed projects, and bridge and culvert descriptions. Projects for localized street drainage and storm sewer improvements were not part of the Galveston County Master Drainage Plan because responsibilities are typically covered by local communities and subdivision developers (Klotz, 2012).

Goals:

- Assess stormwater drainage system infrastructure to improve system management and identify maintenance needs and opportunities for where water quality practices could be implemented.

Approach: Stormwater infrastructure inventories could be later utilized to assess and prioritize nonpoint pollution sources. The inventory should identify infrastructure

along with attribute information for asset management purposes; including enough information to allow the local jurisdiction to locate individual structures, record inspection results, prioritize maintenance needs, and issue maintenance work orders. At a minimum, a map of the existing stormwater system should include outfall locations and intercepts with municipally owned conveyances. As new construction occurs, the map should be updated with relevant information. If existing outfalls/intakes are modified, relevant information should be added to the map. An assessment may include assigning risk, determining remaining life, replacement cost, or determining a maintenance schedule. Stormwater system components commonly included in infrastructure inventories include inlets, catch basins, stormwater drainage pipes and conveyances, swales and drainage ditches, culverts, outfalls, streams and receiving water bodies, manholes, weirs, spillways, energy dissipaters, headwalls, structural stormwater controls, and BMPs or structural devices.

Location: All the project areas are serviced by drainage infrastructure.

Implementation Objectives

The organizations responsible for implementing this action include the Galveston County Stormwater Collaborative, local municipalities, Galveston County Engineering, and GCDD2.

1. Compile and review previous storm drainage system studies to determine the scope for an updated assessment.
2. Inventory stormwater infrastructure components:
    a. Establish data objectives, requirements, and the data collection schedule.
    b. Inventory and map public stormwater system.
    c. Develop a plan to maintain and update inventory data.
3. Characterize stormwater system components in the inventory to prioritize improvement needs and pollution prevention measures.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: No load reductions directly from this management measure. Primary benefit is for assessment and planning purposes, leading to the ability to prioritize opportunities for implementation of water quality practices and projects such as SWW or GI.

Likelihood of Success: Medium – The management measure will require coordination between numerous local agencies and departments. Drainage system maintenance needs are ongoing, requiring long-term commitment from participating entities.

Technical and Financial Needs: High – The level of complexity for a stormwater infrastructure inventory will vary between communities, depending on the existing system and resources for inventorying. See Element D.

Management Measure #8: Landscaping and Landscaping Debris Ordinances
Problem: Grass clippings, leaves, mulch and other plant matter swept or blown onto the road, driveway or into storm drains introduce stormwater pollution to local waterways. Yard and household waste contribute nutrients, fertilizers, pesticides, and bacteria to our bayous. Storm drains, streets, and other stormwater drainage infrastructure that are not part of the SSS and stormwater is not treated. Stormwater carries lawn debris and discharges directly to local waterways.

Goals:

- Decrease and minimize the introduction of lawn debris and nutrients into stormwater.

Approach: By preventing landscaping debris from entering stormwater, homeowners and landscaping contractors play a critical role in reducing the pollutant load associated with these materials. Strengthening existing ordinances will ensure that communities have the tools to encourage residents and landscaping contractors to keep lawn debris out of storm drains.

The canal community of Bayou Vista has an ordinance against blowing lawn clippings and other refuse into canals. Bayou Vista residents are encouraged to call and request a warning or ticket be issued if they observe violations. The city of La Marque trains their landscaping contractors in these recommended practices; La Marque does not yet have ordinances to prohibit the disposal of landscaping debris in the stormwater system.

Public education and outreach for landscaping practices are included in Appendix 3. It is important, however, to communicate ordinance requirements to individuals and entities affected to encourage participation.

Location: Entire project area.

Implementation Objectives

The organizations responsible for implementing this management measure include the cities of La Marque, Hitchcock, Texas City, Bayou Vista, and Santa Fe.

1. Develop new or strengthen existing ordinances addressing lawn clipping and landscaping debris management. Example ordinances are widely available for reference.

2. Communicate landscaping ordinance requirements or landscaping best practices to residents and landscaping contractors.
3. Develop enforcement measures for the ordinance including penalties assessed following multiple offenses.
4. Publicize contact information for reporting violations or poor disposal practices.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Low – At this time, these actions are unlikely to result in a sizeable load reduction overall but may provide water quality improvements to localized sections. Preventing lawn clippings and debris from entering waterways will reduce nutrients and the carbon entering the waterway but is unlike to lessen bacteria loads.

Likelihood of Success: Medium – The contribution of landscape clipping and debris into stormwater or directly into the bayou was brought up regularly by stakeholders as an important issue within the project area. The level of commitment for this management measure is expected to be high. At least one community in the project area has an ordinance to address this issue with active participation from residents. When an enforcement component is included in the ordinance, participation increases. In the case of Bayou Vista, enforcement officers play a role in educating residents about the ordinance.

Technical and Financial Needs: Low – Example ordinances are widely available, including from neighboring communities.

Management Measure #9: Landowner Conservation Plans

Problem: Some land management practices can result in soil erosion and the destruction of important natural features such as riparian areas, wetlands, and shorelines. While most landowners are assumed to be good stewards of their property, there are some who may lack the knowledge of good land management practices and landowners may not be aware of the many incentives and BMPs available to them. Landowner participation in conservation and habitat management plans can reduce the number of bacteria and nutrients entering waterways by addressing issues related to water quality, soil erosion and sedimentation.

Goals:

- Increase landowner participation in existing conservation and habitat management plans to decrease bacteria and nutrient loading and enhance water quality within the watershed.

Approach: The Natural Resources Conservation Service (NRCS), Texas State Soil and Water Conservation Board (TSSWCB) and Texas Wildlife Department (TPWD) administer

a variety of voluntary programs which provide landowners with technical and financial assistance to combine sustainable land stewardship activities with land production activities. Conservation and habitat management plans are typically coupled with agricultural activities. The Moses Bayou, diversion canal and unnamed tributary watersheds all have agricultural sectors and private landowners that would be eligible to participate in these programs and stakeholders ranked this item among the top twelve priority measures.

NRCS. Conservation plans developed through NRCS are customized documents that outline the use of BMPs of natural resources on public or private lands. Landowners benefit from NRCS conservation planning through increased productivity of agricultural land by conserving the soil, increasing rangeland health, improving water quality, and managing livestock waste. Conservation plans are also developed to improve habitat for fisheries, upland game birds, and other wildlife. Technical assistance can include engineering designs, operation and maintenance agreements, and information to support federal, state and local permits. Support provided by NRCS instills confidence in the design, implementation, and monitoring of a plan that is voluntary, flexible and specific to the property.

TSSWCB. Local Soil and Water Conservation Districts through TSSWCB develop site-specific Water Quality Management Plans (WQMPs) for landowners upon request. WQMPs provide agricultural producers with traditional, voluntary, incentive-based programs to comply with state water quality laws. Plans include improved land treatment practices, production practices and management and technology measures to achieve a level of pollution prevention or abatement consistent with state water quality standards. By contacting the directors of the soil and water conservation district, a farmer or rancher can get assistance on all phases of conservation. Districts are designed to deliver a local program, based on local needs, that best conserves and promotes the wise use of natural resources. Districts also work with the USDA-Farm Service Agency, Texas Agricultural Extension Service, Texas Forest Service, U.S. Forest Service and others when necessary to assist agricultural landowners/operators meet individual land use needs.

TPWD. Voluntary implementation efforts to establish more desirable wildlife habitat away from the riparian corridor is another approach to reduce bacteria entering local waterways. The Texas Landowner Incentive Program is a collaborative effort through TPWD funded with multiple partnerships to meet the needs of private, nonfederal landowners wishing to enact good conservation practices on their lands for the benefit of healthy terrestrial and aquatic ecosystems.

Location: Large, privately owned properties. Properties adjacent to riparian corridors are considered the most critical.

Implementation Objectives

This management measure will be implemented by the Texas A&M Agrilife Extension Service, NRCS, TSSWCB, TPWD, county agencies, and other resource agencies and organizations.

1. Identify existing conservation and habitat management plans within the watershed.
2. Identify interested landowners to participate in conservation and habitat management plans. Facilitate communication between voluntary programs and potential participants.
    a. Host landowner workshops addressing land management practices.
    b. Distribute educational materials to landowners regarding land stewardship practices.
    c. Develop and implement individual NRCS conservation plans, WQMPs, and landowner incentive program (LIP) participation.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Low to Medium – The agricultural sector in the project area is not as sizeable as in the past, and it continues to decline. Established landowner conservation plans are anticipated to be low in this highly urbanizing area. Success is contingent upon identifying willing landowners with large acreage properties.

Likelihood of Success: Medium – The assistance programs identified above may already have involved landowners within the project area. Additional information is needed to anticipate an increase in participation. Landowners may acknowledge the importance of good land stewardship practices and conservation plans, but financial incentives offered through agency programs are necessary to increase the adoption of these plans. To increase implementation, financial assistance through the assistance programs is the primary need to overcome cost prohibitive obstacles. These are long range planning opportunities and maintenance for continued effectiveness must be considered.

Technical and Financial Needs: Property acquisition can be a very capital-intensive effort. Consideration of recreational opportunities and multi-use developments could be combined with land management and preservation efforts. See Element D.

Management Measure #10: Preserve Existing Natural Areas

Problem: Undeveloped lands allow stormwater to infiltrate into the ground, much more so than in developed areas. Undeveloped natural and agricultural lands are under pressure for development – highways, residential and commercial building sites, and other uses. The decline of natural areas leads to water quality degradation, loss of habitat for wildlife, a decline in scenic beauty and livability for residents. Many stakeholders have expressed concern for the changes in landscape they have observed over the years. Riparian zones are a critical feature of natural areas because they

buffer the flow of runoff to waterways and stabilize soil. Many sections of bayou shoreline have been converted to developed uses and open lawns.

Goals:

- Preserve priority undeveloped lands in their natural state and protect the water quality benefits of undeveloped land.
- Improve land management practices of undeveloped areas by providing education on habitat value for wildlife and water quality.

Approach: Conservation and restoration of coastal prairies, wetlands and other natural areas is an essential component of water quality management. These natural lands slow stormwater runoff and allow nutrients and bacteria to infiltrate into the ground. Targeted land acquisition can protect sensitive areas from developed and maintain its natural cover.

Natural lands are often protected in an uncoordinated and fragmented fashion. A regional planning approach may focus and coordinate conservation, planning and investment efforts to achieve land preservation goals and objectives. Artist Boat, GBF, Audubon Society, Nature Conservancy, and Scenic Galveston are several resource and conservation organizations already acquiring property for preservation in areas in and near the project area. Within the Highland Bayou watershed, the UH Coastal Center manages about 300 acres of highly endangered coastal tallgrass prairie habitat. UH Coastal Center maintains areas of pristine prairie, and, when possible, restores areas invaded by exotic species or disturbed by human activity. UH Coastal Center provides access and equipment to support environmental research and supports outreach activities with public groups.

Back the Bay is an educational campaign through GBEP that aims to engage citizens in the Houston-Galveston region in lifestyle and habitat changes to improve water quality, conserve water, and protect fish and wildlife habitat. Back the Bay provides residents with tips to preserve Galveston Bay and information to understand their connection to the bay. Back the Bay also seeks to involve local governments in voluntary conservation measures.

Communities can protect natural lands and habitat through various regulatory techniques. During the building permit process, communities can require that developers show due diligence with respect to the USACE Section 404 mitigation for destroyed wetlands. This review would enable communities to align mitigation activities with other comprehensive land use planning efforts. The H-GAC Eco-Logical online mapping tool can be used to identify valuable habitat areas.

Landowner conservation plans are covered separately under Management Measure 9.

Location: Acquisition opportunities will be evaluated for undeveloped properties. Properties with portions in the riparian zone should be given preference.

Implementation Objectives

Implementors include local and county municipalities, the Texas A&M Agrilife Extension Service, resource management agencies and organizations, GBEP, GBF, Artist Boat, Houston Wilderness, and others.

1. Support acquisition and conservation of undeveloped natural lands:
    a. Review area conservation plans and consult with resource and conservation organizations to identify protected lands within the watershed.
    b. Identify and prioritize properties with the potential for conservation management.
    c. Acquire undeveloped natural lands and encourage conservation easements.
2. Provide education for public entities and residents on loss of habitat for wildlife utilizing Back the Bay materials and other existing programs.
3. Use regulatory techniques to preserve natural lands:
    a. Require inquiry through the USACE for Section 404 mitigation needs during the building permit process.
    b. Enact ordinances to protect certain trees from removal or discourage developers from cutting down all trees prior to construction.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Low – Preservation of existing natural areas will provide no reduction to current bacteria loads; however, without preservation the bacteria load will increase with the additional impervious surface promised by future development.

Likelihood of Success: Low – Coordination among agencies and conservation groups will be necessary for property acquisition. Priority site selection should include meaningful water quality benefits. The need to mix and match various funding sources can be challenging. Land acquisition costs are high.

Technical and Financial Needs: Property acquisition can be a very capital-intensive effort. Consideration for recreational opportunities and multi-use developments could be combined with land management and preservation efforts. See Element D.

Management Measure #11: OSSF Training
Problem: Homeowner education is the most effective tool for improving OSSF maintenance. Knowledge will help them identify problems and likely prompt them to

properly maintain their systems. The Texas A&M AgriLife Extension Service[3] offers OSSF workshops for homeowners, creates and distributes OSSF educational materials that outline maintenance needs, stresses responsibility towards improving water quality in the bayou, and discusses the health risks and economic burden of illnesses that can be caused by untreated effluent from malfunctioning OSSFs. GCHD has OSSF permitting, fees, and inspection information available on their Consumer Health Services webpage. Additional resources for homeowners include a septic system quiz, a list of OSSF installers, and information on why septic systems fail.

Goals:

- Improve maintenance of OSSFs by educating homeowners about proper OSSF operation and maintenance

Approach: GCHD continues and expands existing OSSF education programs and provides relevant local information on their website and social media platforms.

AgriLife Galveston County Agents work with local entities and AgriLife specialists to hold homeowner training at least once each year.

In addition, this management measure recommends the replacement of 140 systems by acquiring programmatic resources and funding to replace high priority systems. This management measure will also be used to support TCEQ's Coastal Nonpoint Source Pollution Control Program by prioritizing systems in the coastal zone boundary that are failing or if their system is by nitrogen-limited waters. A detailed OSSF GIS-based inventory database was completed by TCEQ in 2017, in support of the Texas Coastal Nonpoint Source Program. Further, education on system operation and maintenance as well as proper installation, inspection, and repair procedures should be delivered.

Location: Throughout the project area with extra attention to the diversion canal, Moses Bayou and the unnamed tributaries watersheds where OSSF concentrations are greatest.

Implementation Objectives

The organizations responsible for implementing this measure include the Texas A&M Agrilife Extension Service, GCHD, GBF, and local municipalities.

1. Galveston County will continue existing OSSF education programs.

[3] ossf.tamu.edu

2. Identify households having OSSFs for a targeted outreach approach.
3. Galveston County undertakes new outreach methods such as mailouts notifying residents of septic online resources.
4. Texas AgriLife Extension Service host free homeowner workshops throughout the project areas.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Medium across the entire project area – Bacteria load reductions could be high in the diversion-canal watershed where the largest number of OSSFs are found, however effectiveness will be determined by rates of behavior change among OSSF owners.

Likelihood of Success: Medium – Success depends on behavior change of individual landowners. Many homeowners only think about their OSSF when it is not functioning, repeated outreach efforts can change this and provide simple steps to better maintain OSSFs.

Technical and Financial Needs: Low – GCHD currently provides OSSF education and resources, additional funding through grants could supplement and expand efforts and target OSSF owners within the project area. Texas AgriLife Extension Service workshops are a low-cost option for training, technical knowledge exists within the system and can be utilized with little to no cost for training.

Management Measure #12: Feral Hog Workshops

Problem: Feral hog populations are known to live in multiple locations within the project area, although numbers have not been estimated. Their ability to disturb the natural soil cover is surprising for people unaware of the damage they can do. Disturbed areas contribute to sediment erosion, and feral hog fecal matter is a likely source of bacteria in the watershed. Feral hogs also reproduce quickly, carry disease, and are a non-native nuisance species. To address this, stakeholders identified hosting feral hog awareness and training workshops to promote education about methods for reducing feral hog populations. In 2013, stakeholders partnered with a neighboring watershed group to host a successful feral hog workshop at Carbide Park, which included free bar-b-q. Other organizations that have experience with these types of activities and which could be involved in future efforts include the Texas A&M AgriLife Extension Service and the UH Coastal Center.

Goals:

- Host feral hog awareness and training workshops to promote the reduction of feral hog populations.

Approach: Texas AgriLife Extension Service partner with Galveston County, Municipalities, GBF and interested groups to host workshops for local landowners about ways to control and decrease feral hog populations.

Location: In the diversion canal watershed and in the upper reaches of the Highland Bayou watersheds which have the largest populations of feral hogs (Table 10).

Implementation Objectives

The Texas A&M Agrilife Extension Service, Galveston County, and local municipalities would be the primary implementors of this measure.

1. Texas AgriLife Extension Service partner with Galveston County, Municipalities, GBF and interested groups to host at least one workshop per year for local landowners.
2. Distribute existing and create new outreach materials.

Estimated Bacteria and/or Nutrient Load Reduction

Reduction Effectiveness: Medium across the entire project area.

Likelihood of Success: Medium – Success is dependent primarily on large landowners managing their property. Feral hogs can be included in conservation plans to help layout long-term strategies. These workshops are an introduction to landowners that can begin conversations about specific actions to reduce feral hog populations.

Technical and Financial Needs: Workshops are low cost as most instructors would be from state or federal agencies, in some cases travel costs might need to be covered. Technical expertise of instructors is needed.

Element D: Technical and Financial Assistance

Successful implementation of this WPP relies on the active participation of local stakeholders, as well as support and assistance from a variety of other sources. The technical expertise, equipment, and staffing required for many priority management measures are beyond the capacity of any one stakeholder alone. Direct support from one or a combination of several sources listed below will be essential to achieve water quality goals in the project area. In Table 29 below, an estimate of associated costs and potential funding sources are listed for each management measure. The implementation of management measures is dependent upon funding and resources.

Potential Funding Sources

A comprehensive narrative of funding sources is provided in Appendix 4, Funding Sources. Funding sources are grouped by federal and state agencies, listed by program name and include eligibility, criteria, and funding limitations. Tables 27 and 28 below list programs discussed in the Appendix 6 narrative.

Electing to pursue a funding source requires a clear understanding of your project scope and requirements and a clear understanding of the sponsor's funding priorities. The two must line up for applications to be a success. Many funding sources (but not all) have a lengthy review process, and the disbursement of funding may not happen for several fiscal quarters after approval, meaning that it can be over a year between submittal of an application and access to funding. Not all funding sources are grants. Some programs offer low interest loans or technical support. Some grants require a local, nonfederal match, which can be a challenge. This is an additional layer to the application that requires match commitments in advance, either in dollars or in-kind contributions such as equipment or staffing.

Education and outreach support programs (a form of technical support) are listed separately in Element E, Education and Outreach, (Table 30). Many of these educational programs are specific to Texas issues and are administered by state and regional agencies. Almost half have some presence in the Houston region and are excellent candidate programs for WPP education objectives.

Table 27. Federal funding source for water quality activities; more information is provided in Appendix 5.

Federal Programs	Agency or Organization
Agricultural Water Enhancement Program	NRCS
Coastal and Estuarine Land Conservation Program	NOAA
Community Development Block Grants (CDBG)	U.S. Department of Housing and Urban Development
Conservation Reserve Program (CRP)	NRCS
Environmental Education Grants	EPA
Environmental Quality Incentive Program	NRCS
Target Watersheds Grant Program	River Network and EPA
WaterSMART: Cooperative Watershed Management Program	US Dept. of the Interior
Water and Environmental Programs	USDA
Wetlands Reserve Program	NRCS

Table 28. State funding sources for water quality activities; more information is provided in Appendix 5.

State Programs	Agency or Organization
Beach Maintenance Reimbursement Fund Program	Texas General Land Office (TX GLO)
Boating Access Grants	TPWD
Clear Water State Revolving Fund (CWSRF)	Texas Water Development Board (TWDB)
Coastal Impact Assistance Program (CIAP)	TX GLO

Economically Distressed Areas Program	TWDB
Landowner Incentive Program (LIP)	TPWD
Recreation Grant Program- Boating Access Grant	TPWD
Recreation Grant Program – Boat Sewage Pump out Grant	TPWD
Reginal Water Supply and Wastewater Facilities Planning Program	TWDB
TCEQ 319 Grant	TSSWCB
Texas Clean River Programs	TCEQ
Texas Coastal Management Program (CMP)	TX GLO
Texas Farm and Ranch Lands Conservation Program	TPWD

Technical and Financial Resources

Table 29 lists likely costs and technical assistance requirements for each management measure and its objectives. It is understood that not all management measures listed are eligible to be funded through CWA 319 funds. Management measures that target point sources were deemed important to the stakeholders and are included to make this a holistic plan. According to Federal Guidelines, if implementation activities go "above and beyond" permit requirements, 319 funds may be used for programs and BMPs, but management measures for point sources cannot be funded with these funds. Required resources are organized by management measures and their objectives.

Table 29. Technical and financial assistance.

Management Measure	Implementation Objective	Cost ($) and Possible Funding Sources	Technical Assistance
MM#1: Infrastructure Upgrades to the Sanitary Sewer Collection System Goal: To reduce the volume of raw sewage discharging from failing SSS infrastructure.	Adopt or update asset management programs to encourage proactive/ preventative maintenance activities	No cost	SSS infrastructure design and capacity standards, plan/program writing for specific community
	Identify areas in the collection system where I/I or aging infrastructure is a problem.	$15,000* CWSRF, CDBG	GIS, infrastructure and design standards
	Rehabilitate collection system infrastructure	$140,000* per year for approx. 2-3 lift stations, 900 linear feet of line replacement, and major line repairs CWSRF, CDBG	SSS infrastructure design and capacity standards; heavy/excavation equipment, professional planning and labor
	Upgrade or repair private line connections to the wastewater collection system. Performed as necessary	To refurbish water and sewer lines for 130 houses and convert 2 old lift stations from gravity to forced main: $500,000*. Potential monetary help in the form of CDBG funds; CWSRF, CDBG	Heavy/excavation equipment, best practices for line maintenance and repairs.
MM2: Wipes and FOG in the Sanitary Sewer Collection System	Regulation and Policy for FOG in commercial settings	No cost, Staff time to compile and report to outreach to city councils	Expertise in drafting and adopting a municipal ordinance or code; potential support from H-GAC, municipalities, MUDS, Texas AgriLife Extension Service, TCWP, GBF
	Compile existing regulations within the watershed and share.	No cost, Staff time to compile and report to outreach to city councils	Expertise in drafting and adopting a municipal ordinance or code; potential support from H-GAC, municipalities, MUDs, Texas AgriLife Extension Service, TCWP, GBF

Management Measure	Implementation Objective	Cost ($) and Possible Funding Sources	Technical Assistance
Goal: To minimize the introduction of SSO raw sewage into local waterways. Reduce the deposition FOG and wipes from entering sewer lines. Encourage proper disposal practices through education and outreach to residents and commercial entities on items that should not enter their drains.	Examine, establish, and/or update regulations as necessary to address gaps.	No cost, Staff time to compile and report to outreach to city councils	Expertise in drafting and adopting a municipal ordinance or code; potential support from H-GAC, municipalities, MUDS, Texas AgriLife Extension Service, TCWP, GBF
	Include enforcement measures	No cost, Staff time to compile and report to outreach to city councils	Work with current staff to understand new requirements and citation process.
	Perform outreach to promote participation and aid in compliance. Focus on the entire watershed and not just the MS4 area if already being reached.	$5,000-$10,000 per year for staff support, printing, and limited travel resources TCEQ 319, CMP	No technical requirements
	Utilize existing educational messaging related to cooking grease – Cease the Grease campaign materials	$5,000-$10,000 onetime cost to compile, ongoing staff time to follow through with campaign, assuming this “piggy backs” with other efforts TCEQ 319, CMP	None
	Join the Cease the Grease workgroup.	No cost	None
	Utilize available online social media materials and website content.	No cost	None
	Pilot project – establish one Cease the Grease kitchen grease collection station at an apartment complex	$850/receptacle (collection station). Does not include maintenance costs. TCEQ 319, CMP	Identify priority location where success of system is high. Disposal contract.
	Utilize existing educational messaging related to wipes – Patty Potty campaign materials.	No cost	None

Management Measure	Implementation Objective	Cost ($) and Possible Funding Sources	Technical Assistance
	Bolster online presence using free Patty Potty materials on social media sites and webpages	No cost, staff time	None
	Join the Patty Potty Patrol for access to videos, inserts, and public service announcements. Save Water Texas Coalition members receive a discount. Project ideas include showing a Patty Potty video clip on the topic of flushable wipes in movie theatres (as the San Jacinto River Authority currently does) and setting up a standup cardboard cut-out of Patty Potty with a "don't flush wipes" message in the City Hall lobby	Variable	None
	Utilize utility bills for distribution of educational material to homeowners. Focus on the entire watershed and not just the MS4 area if already being reached	$0.10/page TCEQ 319, CMP, local funds	None
	Publicize costs for damages to sewer infrastructure to city taxpayers. "Cleaning out wipes that go down the drain is costing tax dollars." Include a list of annual repairs for pump stations with costs, photos, the dos and don'ts of flushing and drains.	$0.10/page TCEQ 319, CMP, local funds	None
	Host education and outreach workshops for residents and commercial entities. Focus on the entire watershed and not	$5,000-$20,000 for staff time and coordination. First time costs are likely to be high; as the	Technical presentation at workshop

Management Measure	Implementation Objective	Cost ($) and Possible Funding Sources	Technical Assistance
	just the MS4 area if already being reached.	workshop becomes routine, costs are expected to fall. TCEQ 319, CMP, local funds	
MM #3: Stream flow within the Highland Bayou Channel Goal: Improve flow conditions within the Highland Bayou channel by improving channel flow and by removing impediments to flow, such as fallen trees and sediment accumulation.	Determine causes of flow reduction by requesting a study to identify contributing factors	Potentially zero cost or partial match (65/35), federal cap at $5,000,000	Section 205 program authority; USACE provides professional expertise, and technical analysis
	Conduct a sediment source study to find the cause of sediment entering the bayou	Potentially zero cost or partial match (65/35), federal cap at $5,000,000	Section 204 program authority; USACE provides professional expertise, and technical analysis
	Selectively remove sediment and clear vegetation from the channel as recommended during assessments performed by the USACE	Potentially zero cost or partial match (65/35), federal cap at $10,000,000	Section 204 program authority; USACE provides professional expertise and technical analysis.
	Selectively remove accumulations of woody debris impeding flow within the channel in residential areas as recommended during assessments performed by the USACE	$150-$1,500/tree CDBG-DR, local funds	Possibly USACE Section 14 program authority; Removal plan, equipment and disposal plan are required
MM #4: Culvert Dam Maintenance in the Highland Bayou Channel	Request information from the USACE about culverts to determine maintenance needs (potential removal of sediment and debris) to improve flow	No cost	None
	Remove sediment and clear vegetation from culverts	Potentially zero cost or partial match (65/35), federal cap at $10,000,000	Heavy equipment to excavate, technical plans to repair culverts if repairs deemed necessary; access to site from County Parks; disposal site for sediment

Management Measure	Implementation Objective	Cost ($) and Possible Funding Sources	Technical Assistance
Goal: To improve flow within the Highland Bayou channel via the culvert and investigate maintenance needs for culverts within Jack Brooks Park.	Establish a management/maintenance agreement.	No cost	Coordination between jurisdictional agencies
MM #5: **Pet Waste Education** Goal: To reduce bacteria loads from pet waste, encourage pet owners to pick up pet waste by providing pet waste stations in public areas, and provide education and outreach to pet owners on proper pet waste management and impact of pet waste on water quality.	Distribute pet waste educational material to residents during public events.	$200 per station + $32 per box of 800 replacement bags annually TCEQ 319, CMP, local funds	None
	Install pet waste stations with bag dispensers in parks and other public spaces	Total of $360 for the installment and bag replacement for each station. TCEQ 319, CMP, local funds	Waste collection agreement/maintenance schedule
	Distribute pet waste bag dispensers to residents during public events	$1,000 for materials biannually TCEQ 319, CMP, local funds	None
	Update development codes to allow for GI projects during new development and stormwater retrofits; example ordinances are available for reference	No cost	Technical expertise in design and site standards for inclusion in drafting of ordinances and practices to match local conditions/resources
	GI for public buildings and in public spaces	$2,000-$100,000 per site, for design and construction. Projects range from minor installations to multi-acre projects. The cost depends on the goals for the property and the projects. Labor costs can be offset with volunteer efforts.	Heavy/Excavation equipment, vegetation, technical designs, acquisition costs, volunteer management

Management Measure	Implementation Objective	Cost ($) and Possible Funding Sources	Technical Assistance
		TCEQ 319, CMP, local funds	
MM #6: **GI and SWW** Goal: To reduce the amount of stormwater runoff entering local waterways by retaining rainfall on site or in neighborhood and regional detention features and to treat stormwater runoff using GI and SWW.	Identify public entities interested in utilizing GI	None	None
	Design and implement GI projects including rain gardens, permeable pavement, bio-swales, vegetated curb extensions, rainwater harvesting cisterns and WaterSmart landscaping	$2,000-$100,000 per site, for design construction. Projects range from minor installations to multi-acre projects. The cost depends on the goals for the property and the projects. Labor costs can be offset with volunteer efforts. TCEQ 319, CMP, local funds	Heavy/Excavation equipment, vegetation, technical designs, acquisition costs, volunteer management
	Educate residents as well as public entities about GI	$1,000 for materials biannually, Total of $2,000/year TCEQ 319, CMP, local funds	Layout, design, and printing
	Distribute educational materials about GI practices, how they can be used locally, and their impact on water quality	$1,000 for materials biannually, Total of $2,000/year TCEQ 319, CMP, local funds	None
	Partner with AgriLife to host GI workshops, lectures and field trips to educate homeowners, businesses and municipal officials	$20,000 TCEQ 319, CMP, local funds	None
	Partner with GBF to host rain barrel workshops for residents to promote water conservation	No fee to request workshops. Participants pay a $35 registration fee. Sponsors can purchase kits for a raffle to encourage attendance.	None
	Encourage the use of constructed stormwater treatment wetlands	$2,000-$10,000 staff time to compile outreach materials and to network/outreach	Design standards, GI practices, Specialized outreach to targeted entities

Management Measure	Implementation Objective	Cost ($) and Possible Funding Sources	Technical Assistance
		TCEQ 319, CMP, local funds	
	Host constructed stormwater wetlands workshops for public entities and developers	$20,000 from scratch for staff and resources, costs could be half or less if presentations are packaged and if outreach is streamlined TCEQ 319, CMP, local funds	Technical presentation at workshop
	Identify public entities interested in utilizing stormwater treatment wetlands and establish ordinances to consider these practices	No cost	Specialized outreach to targeted entities
	Retrofit existing stormwater detention facilities into stormwater treatment wetlands where feasible	$100,000+	Heavy/Excavation equipment, design-construction plans, labor, property acquisition or easements, permitting
	Incorporate stormwater treatment wetlands during new development projects	$1,000-$15,000, cost varies by practice and design, primarily capacity volume, See Appendix 4 for average costs for specific practices by unit TCEQ 319, CMP, local funds	Heavy/Excavation equipment, design-construction plans, labor, property acquisition or easements, permitting
MM #7: Stormwater Infrastructure Assessment Surveys	Compile and review previous storm drainage system studies to determine the scope needed for an updated assessment	No cost	Municipalities; MUDs; County agencies; Drainage districts; Texas AgriLife Extension Service; Resource agencies/organizations
	Inventory stormwater infrastructure components	$60,000* CDBG, CWSRF, local funds	GIS, field surveys, infrastructure and design standards
	Establish data objectives, requirements, and the data collection schedule	Part of above cost	GIS, infrastructure and design standards

Management Measure	Implementation Objective	Cost ($) and Possible Funding Sources	Technical Assistance
Goal: To assess stormwater drainage system infrastructure to improve system management and identify maintenance needs and opportunities for where water quality practices could be implemented.	Inventory and map public stormwater system	Part of above cost	Field survey and staff, knowledge of infrastructure and design standards
	Include a plant to maintain data and update inventory as required	Uncertain	GIS, infrastructure and design standards
	Characterize stormwater system components in the inventory to prioritize improvement needs and pollution prevention measures	Part of the above cost, 30.2	Field survey and staff, knowledge of infrastructure and design standards
MM #8: Landscaping and Landscaping Debris Ordinances Goal: To decrease and minimize the introduction of lawn debris and nutrients into stormwater.	Develop new or strengthen existing ordinances addressing lawn clipping and landscaping debris management. Example ordinances are widely available for reference	No cost	Knowledge of landscaping standards, knowledge of drafting ordinances and compliance
	Communicate landscaping ordinance requirements or landscaping best practices to residents and landscaping contractors.	$1,000 for materials biannually, Total of $2,000/year TCEQ 319, CMP, local funds	None
	Develop enforcement measures for the ordinance including penalties collected following multiple offenses.	No cost	Knowledge of landscaping standards, knowledge of drafting ordinances and compliance
	Publicize contact information for reporting violations or poor disposal practices.	$1,000 for materials biannually, Total of $2,000/year TCEQ 319, CMP, local funds	None

Management Measure	Implementation Objective	Cost ($) and Possible Funding Sources	Technical Assistance
MM #9: **Landowner Conservation Plans** Goal: To increase landowner participation in existing conservation and habitat management plans to decrease bacteria and nutrient loading and enhance water quality within the watershed.	Identify existing conservation and habitat management plans within the watershed	No cost	None
	Identify interested landowners to participate in conservation and habitat management plans. Facilitate communication between organizations with existing voluntary programs with potential participants when appropriate	No cost	Technical knowledge of plan requirements and management practices and standards
	Host landowner workshops addressing land management practices	2 public workshops on land conservation- $50,000; initial costs are high and could be shared across multiple watershed TCEQ 319, CMP, local funds	Technical presentation
	Distribute educational materials to landowners regarding land stewardship practices.	$1,000 for materials biannually, Total of $2,000/year TCEQ 319, CMP, local funds	None
	Develop and implement individual NRCS conservation plans, WQMPs, and LIP participation	$2,000-$25,000 per landowner for implementation Landowners	Technical assistance from NRCS and TSSWCB for plan development
	Support acquisition of undeveloped natural lands for conservation	Cost varies, expected to be a 6-7 figure acquisition, depending on size of property, assuming large properties with meaningful conservation value. Acquisition costs in addition to property costs CIAP, CRP	Legal assistance with title search, acquisition, use restrictions, and easements; technical assistance with habitat and water quality merits of the property; Knowledge of funding sources, grant writing, and grant management.
	Review area conservation plans and consult with resource and conservation organizations to	No cost	Technical knowledge of land management practices and their application

Management Measure	Implementation Objective	Cost ($) and Possible Funding Sources	Technical Assistance
	identify protected lands within the watershed		
MM #10: **Preserve Existing Natural Areas**	Identify and prioritize properties with the potential for conservation management	No cost	Technical assistance with habitat and water quality merits of the property
Goal: To preserve priority undeveloped lands in their natural state and protect the water quality benefits of undeveloped land and improve land management practices of undeveloped areas by providing education on habitat value for wildlife and water quality.	Acquire undeveloped natural lands and encourage conservation easements	Cost varies, expected to be a 6-7 figure acquisition, depending on size of property, assuming large properties with meaningful conservation value. Acquisition costs in addition to property costs CIAP, CRP	Legal assistance with title search, acquisition, use restrictions, and easements; technical assistance with habitat and water quality merits of the property; Technical knowledge of land management practices and their application; Knowledge of funding sources and grant writing, and grant management
	Provide education for public entities and residents on loss of habitat for wildlife utilizing Back the Bay materials and other existing programs	$5,000 per workshop and $1,000 annually for materials TCEQ 319, CMP	Technical presentations at workshops and meetings
	Use regulatory techniques to preserve natural lands	No cost	Technical knowledge of standards for effective ordinance drafting
	Require inquiry through the USACE for Section 404 mitigation needs during the building permit process	No cost	Technical knowledge of standards for effective ordinance drafting
	Enact ordinances to protect certain trees from removal or discourage developers from cutting down all trees prior to construction	No cost	Technical knowledge of standards for effective ordinance drafting

Management Measure	Implementation Objective	Cost ($) and Possible Funding Sources	Technical Assistance
MM# 11: OSSF Training Goal: Improve maintenance of OSSFs by educating homeowners about proper OSSF operation and maintenance	Galveston County will continue existing OSSF education programs.	No cost	GCHD has existing in-house technical expertise
	Identify households having OSSFs for a targeted outreach approach.		GIS technical support
	Galveston County undertakes new outreach methods such as mailouts notifying residents of septic online resources.	$5,000 for design, printing, and postage TCEQ 319, CMP, local funds	GCHD has existing in house technical expertise
	Texas AgriLife Extension Service host free homeowner workshops throughout the project areas	$500/workshop for instructor travel and venue costs TCEQ 319, CMP, local funds	Technical knowledge for instructor
MM #12: Feral Hog Workshops Goal: Host feral hog awareness and training workshops to promote the reduction of feral hog populations	Texas AgriLife Extension Service partner with Galveston County, Municipalities, GBF and interested groups to host at least one workshop per year for local landowners.	$500/workshop for instructor travel and venue costs TCEQ 319, CMP, local funds	Technical knowledge for instructor
	Distribute existing and/or create new outreach materials	No cost for existing publications $2500 per *new* publication to develop, design, and print TCEQ 319, CMP, local funds	None for existing publications Technical knowledge for authors of new publications

*EPA 319 funding supports implementation of management measures if already being done via a permit

Element E: Education and Outreach

Overview

Element E addresses three broad areas of outreach activities in this WPP:

1. Stakeholder outreach and participation refers to the targeted engagement and involvement of watershed stakeholders in the planning process, such as the stakeholder working group.
2. General public education and outreach refers to activities to inform the public about how to become involved and more informed about their watershed, such as websites and community publicity.
3. Programs for Water Quality Education and Awareness refer to implementing WPP management measures that focus on outreach and education, such as homeowner education or feral hog training.

The Importance of Stakeholder Participation

Nonpoint source impairments result from multiple sources spread across a wide area. Individual action is essential, but it will take coordination and cooperation to address them. A broad-based and cross-collaborative strategy for stakeholder involvement is necessary for coordinating different activities and priorities in the basin, and for understanding what resources are available. The Highland Bayou WPP Working Group began in 2012 and was revived in 2015 and 2019 to foster participation in the development and of the recommendations in this WPP. The Working Group consists of stakeholders from multiple state, county, and local agencies, together with private citizens. Their involvement in the planning process and in future years during the implementation phase will be critical.

“Stakeholder” is a term that includes concerned citizens, businesses, municipal officials, and agency representatives, among others. Any individual or agency that could be able to have an impact on the conditions of the bayou is considered a stakeholder. Since these individuals and their organizations have a role in the plan’s implementation, it is important that the plan’s goals and tasks match the abilities and Stakeholder Inspired Plan. Stakeholders were routinely reminded by the project team that the WPP is their plan. As facilitators, the project team’s goal is to bring out the ideas and issues that the group believes are relevant to the WPP. It is the role of stakeholders to provide the recommendations in the plan and determine priorities.

Table 30. Contracted stakeholder groups.

Organization	Title	First Name	Last Name
Artist Boat	Education Program Manager	Amanda	Rinehart
Bayou Vista Resident	Resident /Real Estate Broker	Nick	Stepchinski
City of Bayou Vista	Mayor Pro-Tem	Vaun	Henry
City of Bayou Vista	Mayor	Daniel	Konyha
City of Bayou Vista	Court Clerk	Lisa	Mitchell
City of Bayou Vista	City Secretary	Paula	Eshelman
City of Hitchcock	Engineer	Llarance	Turner
City of Hitchcock	Mayor	Anthony	Matranga
City of Hitchcock	City Secretary	Lucy	Dieringer
City of La Marque	Finance Director	Suzy	Kou
City of La Marque	Emergency Management Coordinator	Charlene	Warren
City of La Marque	City Manager	Carol	Buttler
City of La Marque	Director of Public Works	Les	Rumburg
City of La Marque	Public Works	Chaise	Cary
City of La Marque	WWTP Operations Supervisor	Jason	Hubbell
City of La Marque	Mayor	Bobby	Hocking
City of La Marque City Council	City Council District C	Robert	Michetich
City of Texas City	Engineer	Doug	Kneupper
City of Texas City	Parks Superintendent	Byron	Sefcik
GBEP	Technical Programs Coordinator	Michelle	Krause
GBEP	Water and Sediment Quality/ Monitoring and Research Coordinator/Program Manager	Lisa	Marshall
GBEP	Natural Resource Uses Coordinator	Lindsey	Lippert
GBF	Water Quality Volunteer Coordinator	Sarah	Gossett

Organization	Title	First Name	Last Name
GBF	Water Programs Manager	Nathan	Johnson
Galveston County	Galveston County Commissioner, Precinct 2	Joe	Giusti
GCDD2	Director	Allen	Kuehl
Galveston County Engineering	Assistant County Engineer	Nancy	Baher
Galveston County Engineering	County Engineer	Michael	Shannon
Galveston County AgriLife Extension	County Extension Agent	Phoenix	Rogers
Galveston County AgriLife Extension/ Texas Sea Grant	County Extension Agent	Julie	Massey
GCHD	Air and Water Pollution Services	Taylor	Sanford
GCHD	Consumer Health Manager	Martin	Entringer
GCHD	Air and Water Pollution Manager	Lori	Fitzsimmons-Evans
Galveston County MUD 12	President	Bill	Alcorn
Galveston County MUD 12	Board	Bob	Bassett
Galveston County Parks and Cultural Services	Director	Julie	Diaz
Galveston County Parks and Cultural Services	Operations Manager	Robert	Simoneau
Galveston County Road and Bridge	Director of Road and Bridge	Lee	Crowder
Highland Bayou Estates	Resident Stakeholder	Jim	Bethune
Hitchcock Industrial Development Corporation	Chairman	Harry	Robinson
Hitchcock Industrial Development Corporation	Director of Economic Development	Sabrina	Schwertner
Omega Bay HOA	Vice President	Marcy	Scates
Private Resident	Resident Stakeholder	Tim	O'Connell
Scenic Galveston, INC.	Habitat Restoration Chair	Lalise	Mason

Organization	Title	First Name	Last Name
TCEQ Region 12	Aquatic Scientist in Surface Water Quality Monitoring	Linda	Broach
TCEQ Region 12	Technical Specialist Water Section, former wastewater inspector	Kim	Laird
Texas A&M AgriLife Extension	Assistant Professor and Specialist – Soil Nutrient and Water Resource Management	Jake	Mowrer
Texas A&M AgriLife Extension – Texas Coastal Watershed Program	Extension Program Specialist	Charriss	York
TPWD	Regional Biologist, Water Quality Program	Marty	Kelly
TPWD – Kills and Spills Team (KAST)	KAST Region 3	Stephen	Mitchell
TSSWCB	Regional Watershed Coordinator	Brian	Koch
USACE	Deputy Chief, Project Management Branch	Byron	Williams
USACE	Hydraulic Engineer, H&H/Water Management Branch	Mario	Beddingfield
UH Coastal Center	Director	Steven	Pennings
WCID #19	Operator	Lee	Grundmann
WCID #19	Board of Directors, Secretary	Phil	Harrison

Stakeholder Working Group

Stakeholder outreach began with local governments and agencies and expanded based on their recommendations. This incremental approach to growing the list of stakeholders enabled the project team to bring together from a range of perspectives over 56 individuals (Table 30).

The project team sought out these individuals for one-on-one meetings, to solicit feedback in a way that was otherwise difficult to do in a group setting and where participants were more likely to be guarded. In these meetings stakeholders were also asked which issues are most important for the group to address. The informal, free-form conversation gave the project team a detailed perspective about that stakeholder's role and activities that helped shape the management measures. 56 individuals were contacted, and 40 one-on-one meetings were held.

Stakeholder working group meetings were held in 2015 and 2016 for the initial WPP effort, then again in 2019 to revise the original draft WPP and add additional AUs to the project area. These working group meetings were the primary way for developing and prioritizing recommendations in the WPP.

Figure 31. Stakeholder mapping exercise to compile list of best management practices.

Selecting and Ranking Priority Management Measures

Best Management Practices and program activities for load reductions were ranked by a voting exercise for the stakeholder working group. Using project ideas from the one-on-one interviews, a comprehensive list of all BMPs was created and a dot voting exercise completed by stakeholders to prioritize the BMPs. Through this exercise, the top 12 management measures were determined. This list was compiled without taking into account possible funding sources, which was discussed in future meetings. It is understood that 319 funds cannot be used to meet MS4 permit requirements or other point source regulations.

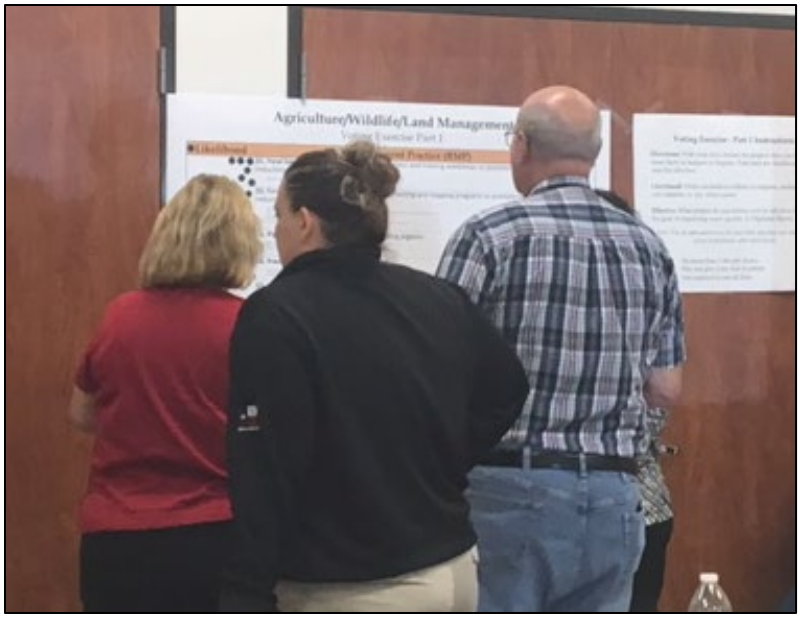


Figure 32. Voting exercise used to rank priority project ideas.

Future Work With the Stakeholder Working Group

The continuation of the WPP stakeholder group will depend on several factors, including funding and related nearby watershed planning projects. The Galveston Bay Coalition of Watersheds (GBCOW), a coalition of watershed groups in Galveston and Brazoria Counties was formed to manage the long-term implementation of watershed-based plans. Stakeholders from this group have been active in the GBCOW and we anticipate many of the management measures in this WPP will be carried out through the work of GBCOW.

The stakeholder working group will continue to exist as an email list, whereby information and project next steps can be communicated to the group. The stakeholder group will likely form working committees to take on specialized projects and tasks in the basin.

WPP Management Measure Outreach Activities

The Highland Bayou Coastal Basin team and stakeholder group will engage in the resources of multiple organizations and programs to support the needs of outreach and environmental awareness for the WPP. The activities listed below are divided by the WPP management measure.

General Outreach

Facebook. A Facebook page, the “Moses-Karankawa Bayous Alliance” was created for the project and planning process. This was a key outreach tool for informing citizens and building awareness about issues in the basin during the initial WPP development phase. The page posted project related information, such as meetings, project status,

events, survey results, relevant news items, and posts that congratulate the work of volunteers and stakeholders.

Website. A Highland Bayou Watershed Protection Plan webpage[4] has been created for the project, which serves as the primary online presence for the Characterization Report and the WPP. The site contains pages where documents, maps and images are stored online and retrieved by the public.

WPP Management Measure Outreach Activities

The WPP project team and stakeholder group will engage the resources of multiple organizations and programs to support the needs of outreach and environmental awareness in the basin.

Education and outreach programs can be implemented through several approaches. Localities can take the initiative by creating their programs or they can partner with existing programs and customize those existing programs to the needs specific to that community.

Four of the 12 management measures have some focus on education and outreach in the project area. management measures with minor outreach activities are not included here.

Management Measure #2: Wipes, FOG

This activity area addresses homeowner awareness about the disposal of waste at home. The disposal of wipes and FOG in sinks and toilets is a major cause of leakages and backups in the municipal sewage system resulting in untreated sewage flowing into the stormwater system. System blockages result in costly repairs borne by the city (and taxpayers) and contribute bacteria and nutrients to local waterways. The primary goal is to educate residents about the proper disposal of these items and the impact improper disposal has on the city's system and ultimately the bayou. The most likely lead agency on this activity are the municipalities in the basin, although GBF and other entities may have programs that complement this activity area.

Program activities include a mix of approaches including inserts in utility bills, Cease the Grease collection supplies, and Patty Potty educational resources for residents and students. Approaches should consider the targeted audience, whether that includes schools, city halls, public parks, or apartment complex mailbox areas, among other locations.

Management Measure #5: Pet Waste Education

Pet waste is a public health issue, and pet owners should be educated about the impacts to health and the environment by not picking up pet waste. Bacteria from pet

[4] agrilife.org/highlandbayou

waste is a known contributor to bacteria levels in waterways. The project team estimates that there are over 5,000 dogs in the watershed, and as Highland Bayou becomes more developed, the number of pets will increase. Education will focus on the connection between pet waste and water quality. Resources for this may include public awareness posters, pet waste pick up bags, and pet waste pick up stations in public areas. Likely lead agencies are Texas A&M AgriLife Service and municipalities.

Management Measure #6: GI and SWW

GI is an emerging practice where developers, through the design of their projects, harness the ability of natural systems to slow down and infiltrate stormwater runoff. This can include simple practices such as planters in parking lots to more sophisticated features like permeable pavement, engineered bioswales and green roofs. Education on this topic should take two approaches. The first is to educate designers and construction firms about the benefits to their bottom line and to the environment of incorporating these practices into their designs. The other approach is to improve public awareness through interpretive signage at demonstration sites about the benefits of these practices. The likely lead agency is Texas A&M AgriLife Extension Service.

Management Measure #12: Feral Hog Workshops

Feral hog populations in the bayou contribute bacteria and sediment into the bayou. Knowing how to manage hog populations, along with state and county regulations, is important. Texas A&M AgriLife Service sponsors a training program for local hunters and residents, although hunting is not allowed within the county. Awareness should be targeted to rural property owners or landowners having or are near large open spaces. Jack Brooks Park and the adjoining UH Coastal Center are known to have feral hog populations. The likely lead agencies are Galveston County parks and Texas A&M AgriLife Service.

Table 31. Education and outreach resources available for management measure activities.

Organization	Program
Artist Boat	Youth Eco-Art Workshop and Adventures
Galveston County/City of Dickinson	County Tire Recycling Program
City of League City Police Department	National Drug Take Back Event
Don't mess with Texas®	Adopt A Highway
Don't mess with Texas®	Trash Off
GBEP	Back the Bay Program
GBF	Cease the Grease
GBF	Dockwalkers
GBF	Galveston Bay Action Network

Organization	Program
GBF	Living Shorelines
GBF	Pump Don't Dump Campaign
GBF	Rain Barrel Workshops
GBF	Water Warriors
H-GAC	Disaster Debris Clearance and Removal Services
H-GAC	H-GAC Texas Stream Team
H-GAC	Illegal Dumping and Camera Sharing Program
H-GAC	Household Hazardous Waste Disposal
H-GAC	OSSF Visual Inspection Training
Houston-Galveston Subsidence District	Water Detective WaterWise Kit
Keep Texas Beautiful	KTB Training
Keep Texas Beautiful	KTB Youth and Education Program
National Wild Turkey Foundation	Hunter Education Program
Potty Patty	Potty Patty Patrol
TCEQ	Sanitary Sewer Overflow Initiative
Texas A&M AgriLife	Bacterial Source Tracking
Texas A&M AgriLife	Feral Hog Bounty Program
Texas A&M AgriLife	Feral Hog Management Seminar
Texas A&M AgriLife (TCWP)	Galveston Coalition of Watersheds
Texas A&M AgriLife	Texas Riparian and Stream Ecosystem Workshop
Texas A&M AgriLife	WaterSmart Program
Texas A&M AgriLife (TCWP)	Wetland Restoration Program
Texas Wildlife Association	Texas Youth Hunting Program
TPWD	Texas Landowner Incentive Program
TWDB	Major Rivers Education Program
TWDB	Rainwater Harvesting Training
TWDB	Water Resource Educator Workshops

Element F and G: Interim Milestones and Implementation Schedule

This WPP identifies strategies for achieving both the implementation schedule and measurable milestones. Milestones are used to benchmark progress in implementing

specific management measures from the 12 priority areas. Implementation of this WPP is divided into three parts: Near (1-2 years), Medium (3-5 years), and Long (6-15 years). Multi-year increments also consider the fact that many of the management measures will be contingent on funding, staffing, and the implementation of new programs, all of which will have initial time demands. Additionally, changes in water quality are often delayed following initial implementation of management measures, and substantial changes generally require several years to be noticeable.

Implementation for the management measures is anticipated to take place over a 15-year timeframe. Table 32 provides targeted implementation timelines and milestones for specific objectives from each management measure, some of these could take longer or less than the estimated timeframes provided. These implementation milestones may need to be adjusted through the adaptive management process if they are found to be unrealistic or ineffective.

Figure 33. Management measure voting exercise results.

Table 32. Management measure implementation schedule.

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
MM #1: Infrastructure Upgrades to the Sanitary Sewer Collection System* Goal: To reduce the volume of raw sewage discharging from failing SSS infrastructure.	Adopt or update asset management programs to encourage proactive/preventative maintenance activities	√	√	√	5% of asset management programs adopting preventative maintenance techniques
	Identify areas in the collection system where I/I or aging infrastructure is a problem.		√	√	See Table 10. 6.5% SSO volume discharge reduction per year. 2–3 points with major repairs per year, approx. 900 linear feet of line replaced a year, and 1–3 lift stations repaired per year, for a 10-year implementation horizon
	Rehabilitate collection system infrastructure			√	10% of identified private line connections needing repair replaced for a 10-year implementation horizon
	Upgrade or repair private line connections to the wastewater collection system. Performed as necessary		√	√	10% of identified private line connections needing repair replaced for a 10-year implementation horizon

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
MM #2: Wipes, FOG and Roots in the Sanitary Sewer Collection System* Goal: To minimize the introduction of SSO raw sewage into local waterways. Reduce the deposition FOG and wipes from entering sewer lines. Encourage proper disposal practices through education and outreach to residents and commercial entities on items that should not enter their drains.	Draft and adopt ordinance and local policy for FOG in commercial settings	√	√		Draft and adopt updated ordinance and policies for grease maintenance at commercial entities
	Compile existing regulations within the watershed and share.	√			Final report on existing local regulations, and assessment of how to improve and update compliance and enforcement
	Examine, establish, and/or update regulations as necessary to address gaps.	√	√		Draft and adopt updated ordinance and policies for grease maintenance at commercial entities
	Include enforcement measures		√	√	Municipalities and municipal agencies have updated
	Perform outreach to promote participation and aid in compliance.	√	√	√	Educational materials handed out to 10 commercial entities per month
	Utilize existing educational materials related to cooking grease –Cease the Grease campaign	√	√		Provide existing handouts and educational materials to 100 contacts per year at events, workshops, meetings, etc.

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
	Join the Cease the Grease workgroup.	√			Join the Cease the Grease workgroup
	Utilize available online social media materials and website content.	√	√		1–3 social media posts per month utilizing materials from Cease the Grease
	Pilot project – establish one Cease the Grease kitchen grease collection station at an apartment complex		√	√	Establish one Cease the Grease kitchen grease collection location within the watershed with 50 contacts per month utilize the kitchen grease collection station
	Utilize existing educational messaging related to wipes – Patty Potty campaign materials	√	√	√	Provide existing handouts and educational materials to 100 contacts per year at events, workshops, meetings, etc.
	Bolster online presence using free Patty Potty materials on social media sites and webpages	√	√		1–3 social media posts per month utilizing materials from Patty Potty Patrol
	Join the Patty Potty Patrol for access to videos, inserts, and public service announcements. Save Water Texas Coalition members receive a discount. Project ideas include showing a Patty Potty video clip on the topic of flushable wipes in movie theatres (as the San Jacinto River Authority currently does); and setting up a standup cardboard cut-out of Patty Potty with	√			Join the Patty Potty Patrol

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
	a “don’t flush wipes” message in City Hall lobby				
	Publicize costs for damages to sewer infrastructure to city taxpayers. “Cleaning out wipes that go down the drain is costing tax dollars.” Include a list of annual repairs for pump stations with costs, photos, the dos and don’ts of flushing and drains.	√	√		Development of one municipal specific, public education handout or brochure per city
	Host education and outreach workshops for residents and commercial entities	√	√	√	Host 1–2 workshops per year
MM #3: Stream flow within the Highland Bayou Channel	Determine causes of flow reduction by requesting a study to identify contributing factors	√			Request one study to identify contributing factors to flow issues faced in the Highland Bayou Watershed: study agency USACE
	Conduct a sediment source study to find the cause of sediment entering the bayou	√			Conduct one sediment source study: study agency USACE

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
Goals: Improve flow conditions within the Highland Bayou channel by improving channel flow and by removing impediments to flow, such as fallen trees and sediment accumulation.	Selectively remove sediment and clear vegetation from the channel as recommended during assessments performed by the USACE		√	√	Remove sediment and vegetation selectively one time per year; Reuse sediment as feasible for ecological wetland restoration activities near Jones Bay.
	Selectively remove accumulations of woody debris impeding flow within the channel in residential areas as recommended during assessments performed by the USACE		√	√	Removal of five trees per year in residential areas to improve flow and remove obstacles.
MM #4: **Culvert Maintenance in the Highland Bayou Channel** Goal: To improve flow within the Highland Bayou channel via the culvert and investigate maintenance needs for culverts within Jack Brooks Park.	Request information from the USACE about culverts to determine maintenance needs (potential removal of sediment and debris) to improve flow	√			Submit one request for USACE to provide information about culverts so maintenance needs can be determined
	Remove sediment and clear vegetation from culverts		√	√	Responsible entities manage sediment and vegetation removal from culverts
	Establish a management/maintenance agreement	√			One memorandum of understanding (MOU) established for culvert maintenance
MM #5: **Pet Waste Education**	Distribute pet waste educational material to	√	√	√	Provide existing handouts and educational materials for 200 at events,

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
	residents during public events				workshops, meetings, etc. per year
Goal: To reduce bacteria loads from pet waste, encourage pet owners to pick up pet waste by providing pet waste stations in public areas, and provide education and outreach to pet owners on proper pet waste management and impact of pet waste on water quality.	Install pet waste stations with bag dispensers in parks and other public spaces		√	√	Installation of 10 pet waste stations at high visibility, pet friendly public locations or apartment complexes
	Distribute pet waste bag dispensers to residents during public events	√	√	√	100 pet waste bag dispensers given to residents per year
MM #6: **GI and SWW**	Update development codes to allow for GI projects during new development and stormwater retrofits; example ordinances are available for reference		√		Final report on existing local ordinances and recommended strategies for updating specific codes or site review procedures.
	GI for public buildings and in public spaces		√	√	Design and construction of demonstration project at municipal or public facility with high public visibility.
	Identify public entities interested in utilizing GI	√	√		Stormwater coordinator identifies and contacts one business interested in GI per month, or 12 per year
Goal: To reduce bacteria loads from pet waste, encourage pet owners to pick up pet waste by providing pet waste stations in	Design and implement GI projects including rain gardens, permeable pavement, bio-swales,		√	√	One GI demonstration project designed and built every two years

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
public areas, and provide education and outreach to pet owners on proper pet waste management and impact of pet waste on water quality.	vegetated curb extensions, rainwater harvesting cisterns and WaterSmart landscaping				
	Educate residents as well as public entities about GI	√	√	√	Host one GI workshop in watershed for homeowners per year
	Distribute educational materials about GI practices, how they can be used locally, and their impact on water quality	√	√	√	Development of six handouts or brochures about six GI practices
	Partner with Texas AgriLife Extension Service to host GI workshops, lectures and field trips to educate homeowners, businesses and municipal officials		√	√	One GI workshop is held per year for businesses, municipal officials, and homeowners
	Partner with GBF to host rain barrel workshops for residents to promote water conservation		√	√	20 rain barrels created or given away per workshop hosted per year in watershed
	Encourage the use of constructed stormwater treatment wetlands	√	√	√	10-acre stormwater treatment wetlands created within the Highland Bayou Watershed
	Host constructed SWW workshops for public entities and developers		√	√	One constructed SWW workshop is held per year

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
	Identify public entities interested in utilizing stormwater treatment wetlands and establish ordinances to consider these practices	√	√	√	Identify and contact one business interested in GI per month
	Retrofit existing stormwater detention facilities into stormwater treatment wetlands where feasible		√	√	Design and implement green infrastructure systems to intercept and treat existing load runoff, approx. 3% per year, for six years.
	Incorporate stormwater treatment wetlands during new development projects		√	√	Review and update local development codes to require or not prohibit the use of stormwater wetlands in new development
MM #7: Stormwater Infrastructure Assessment Surveys Goal: To assess stormwater drainage system infrastructure to improve system management and identify maintenance needs and opportunities for where water quality practices could be implemented.	Compile and review previous storm drainage system studies to determine the scope needed for an updated assessment	√	√		Previous storm drainage system study scopes compiled and reviewed
	Inventory stormwater infrastructure components		√		Development of inventory for stormwater infrastructure within the Highland Bayou Watershed
	Establish data objectives, requirements, and the data collection schedule		√		Development of data collection schedule, data objectives, and data requirements

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
	Inventory and map public stormwater system		√		Develop one map showing public stormwater systems
	Include a plant to maintain data and update inventory as required		√	√	Development of stormwater infrastructure inventory plan
	Characterize stormwater system components in the inventory to prioritize improvement needs and pollution prevention measures		√	√	Development of characterized stormwater system components in the inventory
MM #8: Landscaping and Landscaping Debris Ordinances Goal: To decrease and minimize the introduction of lawn debris and nutrients into stormwater.	Develop new or strengthen existing ordinances addressing lawn clipping and landscaping debris management. Example ordinances are widely available for reference		√		Work with all five municipalities in the basin to identify potential updates to local ordinances
	Ordinance requirements will be communicated to residents and landscaping crews		√	√	Number of violations reported by year
	Develop enforcement measures for the ordinance including penalties assessed following multiple offenses.		√	√	Work with all five municipalities in the basin to identify potential updates to enforcement measures and penalties
	Publicize contact information for reporting violations or poor disposal practices.	√			Distribute contact information to stakeholders at public events

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
MM #9: **Landowner Conservation Plans** Goal: To increase landowner participation in existing conservation and habitat management plans to decrease bacteria and nutrient loading and enhance water quality within the watershed.	Identify existing conservation and habitat management plans within the watershed	√			Review all existing conservation and habitat management plans found
	Identify interested landowners to participate in conservation and habitat management plans. Facilitate communication between organizations with existing voluntary programs with potential participants when appropriate	√	√	√	Identification of two interested landowners in medium- and long-term periods
	Host landowner workshops addressing land management practices	√	√		two Workshops held per year, target attendance 10-20 landowners
	Distribute educational materials to landowners regarding land stewardship practices.	√	√	√	50 contacts reached with educational materials per year
	Develop and implement individual NRCS conservation plans, WQMPs, and LIP participation		√	√	Development of one conservation plan, WQMP, or LIP participation
MM #10: **Preserve Existing Natural Areas** Goal: To preserve priority undeveloped lands in their	Support acquisition of undeveloped natural lands for conservation	√	√	√	10-40 acres at critical locations with high potential for realizing water quality improvement, per five-year period
	Review area conservation plans and consult with	√			Review complete, with recommendations for

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
natural state and protect the water quality benefits of undeveloped land and improve land management practices of undeveloped areas by providing education on habitat value for wildlife and water quality.	resource and conservation organizations to identify protected lands within the watershed				improvement of existing plans and to encourage adoption of new plans by currently nonparticipating landowners.
	Identify properties with the potential for conservation management	√	√	√	Identification of five properties with potential for conservation management within the watershed
	Acquire undeveloped natural lands and encourage conservation easements		√	√	10-40 acres at critical locations with high potential for water quality improvement, per five-year period
	Provide education for public entities and residents on loss of habitat for wildlife utilizing Back the Bay materials and other existing programs		√		Work with three city councils to identify appropriate ordinances for consideration and adoption.
	Use regulatory techniques to preserve natural lands		√	√	Preserve natural land using regulatory techniques
	Require inquiry through the USACE for Section 404 mitigation needs during the building permit process			√	Inquiry through the USACE for Section 404 mitigation needs during the building permit process required
	Enact ordinances to protect certain trees from removal or discourage		√		Sparse tree removal ordinance for new construction established

Management Measure	Implementation Objective	Near (1-2) *	Medium (3-5) *	Long (6-15) *	Milestones
	developers from cutting down all trees prior to construction				
MM #11: On-Site Sewage Facility Training Goal: Improve maintenance of OSSFs by educating homeowners about proper OSSF operation and maintenance	Galveston County will continue existing OSSF education programs.	√	√	√	Number of webpage views
	Identify households having OSSFs for a targeted outreach approach.	√			Creation of map
	Galveston County undertakes new outreach methods such as mailouts notifying residents of septic online resources.		√		Creation of new materials
	Texas AgriLife Extension Service host free homeowner workshops throughout the project areas	√	√	√	One workshop is held each year, target attendance 30+
MM #12: Feral Hog Workshops Goal: Host feral hog awareness and training workshops to promote the reduction of feral hog populations	Texas AgriLife Extension Service partner with Galveston County, Municipalities, GBF and interested groups to host at least one workshop per year for local landowners.	√	√		One workshop is held each year, target attendance 30+
	Distribute existing and/or create new outreach materials	√	√		200 publications distributed each year

*Schedule of Implementation (years)

Element H: Criteria for Reduction Achievements/Monitoring and Measuring Progress

This WPP identifies strategies for achieving both the measurable milestones of the project stakeholders as well as a closer approximation to the current state water quality standards for the watershed. Milestones (Element G) are used to evaluate progress in implementing specific management measures recommended in the WPP. It is likely that some milestones will be accomplished sooner than anticipated while others will be completed slower than expected. Interim measurable milestones are identified in the implementation schedule presented in Element G. As these management measures are implemented within the watershed, water quality benchmarks and environmental indicators will need to be assessed to measure nutrient and bacteria reductions at the subwatershed level. WPP implementation success will also be gauged by evaluating improvements in water quality. Table 33 below illustrates bacteria reduction goals from levels reported in the 2010 Texas Integrated Report (TCEQ, 2010a). Measuring progress is an important component of adaptive management, which will be used to guide decisions throughout the implementation of this WPP. If the WPP is not meeting interim targets or making progress towards attaining state water quality standards, the WPP will be revised to update management practices.

The first assessment of progress will occur in 2021 through a TGLO CMP funded project titled *Galveston Bay Coalition of Watersheds*. This assessment will use Clean Rivers Program data collected in 2020 and 2021 to determine the current state of water quality in four watersheds including Highland Bayou.

Table 33. Enterococcus reduction milestones.

Implementation Year	Reduction Goals in percent
Year 3 (2023)	Reduce by 5%
Year 5 (2025)	Reduce by 15%
Year 10 (2030)	Reduce by 42%

Table 34. Dissolved oxygen reduction milestones.

Implementation Year	Percent reduction in the number of measured DO exceedances
Year 3 (2023)	5%
Year 5 (2025)	10%
Year 10 (2030)	23%

Over a 10-year sampling period, 23% of events exceeded the DO criterion. The goal is for implemented management measures to reduce the number of exceedances to 18% of samples by 2023, to 13% by 2025, and to less than 1% of samples by 2030. (Table 34). Any nutrient runoff will likely be reduced by the same management measures used to improve dissolved oxygen and reduce bacteria.

Table 35 outlines environmental strategies and progress indicators that will determine if load reductions are being achieved. Water bodies not specified in the Texas Surface Water Quality System (TSWQS) for specific chlorophyll-a criteria are protected from excessive nutrient levels to support the general uses through the use of screening levels. The screening levels listed for nutrients and chlorophyll-a are statistically derived from monitoring data and are to be used when site specific criteria have not been developed in the TSWQS (TCEQ, 2012).

Table 35. Criteria for load reduction goals.

Strategies	Description of Activities	Progress Indicators	Monitoring Component
Criteria 303(d) Listing Pollutant Reduction Goals			
Reduce the number of dissolved oxygen minimum standards exceedances	Between 2001 and 2011 there were 18 exceedances for DO minimum standards over 77 sampling events.	Reduce the number of measured exceedances in routine ambient sampling to fewer than two events per year	Monitored by Texas Stream Team Volunteers or other third-party with monitoring and reporting duties
Reduce the number of bacteria (enterococcus) exceedances in routine ambient water quality monitoring	Between 2001 and 2011 there were 436 sampling events in the SWQM database and a total of 188 exceedances for the criteria of 89 CFUs/100mL. The rate of observed values	Reduce the number of measured exceedances in routine ambient water quality monitoring to fewer than 12 per year in the near-term phase (five years), and to fewer than eight per year in	See ambient water quality monitoring program

Strategies	Description of Activities	Progress Indicators	Monitoring Component
	exceeding these limits is 43% of all sampling events and a count of approximately 19 sampling events out of 43 events. The median value across all sampling stations in the basin is 79, while the average is 1,049, indicating the influence of extreme counts on values overall.	the long-term phase (beyond five years)	
Criteria Nonpoint Source Pollutants of Concern Related to 303(d) Criteria Goals			
Sustain Total Phosphate screening limits and exceedances	Between 2001 and 2011 there were 47 sampling events for Total Phosphate and no observed exceedances for the screening limit	Sustain the number of screening limit exceedances in routine ambient sampling to zero on a rolling 7-year basis	See ambient water quality monitoring program
Sustain Nitrate screening limits and exceedances	Between 2001 and 2011 there were 207 sampling events in the SWQM database for the study area. No exceedances were observed in measured values	Sustain the number of screening limit exceedance in routine ambient monitoring to zero on a rolling 7-year basis	See ambient water quality monitoring program
Sustain average Chlorophyll-a screening limits; Reduce exceedances occurring in warm season sampling	Chlorophyll-a can be an indicator of excessive nutrients. Between 2001 and 2011 there were 96 sampling events in the basin and 27 exceedances of screening limits (21 micrograms/L). 26 exceedances were measured in the warm season	Keep median and average values on a rolling 7-year basis to be below the screening limit. Reduce the number of measured exceedances to fewer than one in five warm season sampling events	See ambient water quality monitoring program
Criteria for TCEQ Water Quality and Aesthetic Standard Goals			

Strategies	Description of Activities	Progress Indicators	Monitoring Component
Meet TCEQ water quality standards for primary contact recreational uses	Refers to activities where there is a significant likelihood of ingestion of water. This includes activities such as wading, swimming, water skiing, diving, tubing, surfing, and whitewater paddling or rafting.	Bacteria levels under 35/89 for E*nterococcus* CFU's	See ambient water quality monitoring program
Meet TCEQ water quality standards for High ALU	Refers to water quality conditions that support levels of aquatic life activity. High ALU waters have high diversity, and the usual assemblage of species is expected for that waterbody. Also, species diversity and richness will be high, although not exceptional. The trophic structure or food chain may be slightly imbalanced.	High measured diversity in macro- and microbenthic biotic assemblages and trophic orders from primary producers to apex species.	Monitoring activity is outside of specific recommendation in this WPP. Results will rely on third-party monitoring and reporting duties
Meet TCEQ Aesthetic Standards: Water free of debris	Debris and litter removal improve the perceived quality by the public of the waterway.	Noticeable changes in the amount of debris found near the banks of the bayou or free floating within the Highland Bayou Watershed	
Meet TCEQ Aesthetic Standards: Water has no odor	Increased organic matter can cause reductions in DO, alter taste and create odors in drinking water, and it can cause destruction of fish and aquatic plant habitat.	Chlorophyll-*a* limits from 0.005 to 0.15 mg/L	
Meet TCEQ Aesthetic Standards: No foam, oil, or other residues on water surface	Boating activities and illicit dumping through storm drains or on land can result in sheens and residues on the waterway, fouling its use for recreational and other aquatic uses.	Fewer observed or reported oil or fuel sheens, whether from boating activities or the illegal disposal of materials in storm drains	Monitored by Texas Stream Team Volunteers or other third-party with monitoring and reporting duties

Strategies	Description of Activities	Progress Indicators	Monitoring Component
Meet TCEQ Aesthetic Standards: No suspended solids	Suspended solids consist of fine particulates of organic and nonorganic residue that stay suspended in the water column, either from nonpoint sources or through effluent from wastewater treatment plants or other commercial and industrial activities.	Fewer observed exceedances of screening limits for total suspended solids	See ambient water quality monitoring program; else, monitored by Texas Stream Team Volunteers or other third-party with monitoring and reporting duties
Criteria for General Goals			
Reduction in algal blooms per year	Algal blooms may occur when concentrations of nitrate are greater than 0.1 mg/L. Excessive nitrogen can promote plant growth that interferes with ambient levels of DO, clogs channels, and lowers the aesthetic quality of waterways.	Nitrate concentrations below 0.1 mg/L Reduction in nuisance algal blooms per year	See ambient water quality monitoring program
Reduction in fish kills per year	Algal blooms interfere with DO and can cause DO to drastically decrease. Algal blooms may occur when nitrate levels are over 0.1 mg/L.	Nitrate concentrations below 0.1 mg/L to avoid nuisance algal blooms leading to fish kills. Fewer than two reported fish kills per year for segments 2424A and 2424C_01, combined.	Monitoring activity is outside of specific recommendation in this WPP. Results will rely on third-party monitoring and reporting duties

Element I: Monitoring Program and Schedule

Highland, Marchand, Moses Bayous, the diversion canal, and the unnamed tributary of Moses Lake are on the TCEQ 303(d) list for elevated bacteria and low DO. Nutrients are also understood to be contributing to the impairment. The monitoring resources and strategies outlined here will be implemented to verify that bacteria and nutrient reductions are occurring in the project area, and that the water quality goals set in this WPP are being achieved. The monitoring strategy will rely on the use of water quality data collected through routine sampling to ultimately demonstrate success. As currently implemented, the existing monitoring network cannot achieve all the objectives recommended to measure actual environmental progress. Additionally, no sampling is currently being

conducted in support of this WPP. As of today, existing sampling programs are insufficient to assess progress towards attaining water quality standards. However, there are programmatic resources in the region that through cooperative agreements and program adjustments could provide support in resources and capacity for a successful monitoring program in the watershed.

Historical and Current Monitoring

Several programs have monitored or currently monitor water quality in the Highland Bayou Watershed:

- TCEQ's SWQM program
- Texas Stream Team
- Galveston County Health District
- 2010–2011 Highland Bayou Sampling Program
- Real Time Monitoring USGS stations

TCEQ's SWQM Program

TCEQ monitors water quality through its SWQM Program. The program consists of four monitoring categories: routine, special, permit-support, and systematic. The routine and systematic categories both support TCEQ's objective to evaluate aquatic systems in the state for attainment of use standards. Routine monitoring is generally long-term (longer than five years) and is conducted at most of Texas' 367 classified streams. Systematic monitoring is conducted for shorter time frames and in support of Watershed Based Plans and assessment of 303(d) segments. Permit support and special monitoring are localized project-specific sampling programs.

Sampling locations are coordinated through the Texas Clean Rivers Program and are funded through TCEQ, in partnership with regional and local organizations. The program is coordinated by Texas State University (San Marcos) and in partnership with TCEQ, H-GAC, and the EPA. Sampling is conducted by professional water quality specialists and under strict quality assurances using National Environmental Laboratory Accreditation Conference certified labs and methods. *Currently no sampling under this program is being conducted in support of this WPP.*

Texas Stream Team

In the Houston region, the Clean Rivers Program also supports the Texas Stream team program conducted by citizen volunteers. This too is administered in part by H-GAC and supports TCEQ's SWQM program. The Texas Stream Team program is structured into volunteer groups that are managed at the community level by organizations such as GBF and the Galveston Master Naturalists. This program is not covered by the same quality assurances whereas the main SWQM program is.

Rather, the results from the Stream Team are used to identify emerging water quality issues and trends, which may be used to justify a more rigorous and quality-assured sampling effort through TCEQ's SWQM programs. *Texas Stream Team conducts sampling in the study area, but no sampling is currently being conducted in support of this WPP.*

Galveston County Health District

The Air and Water Pollution Services Division of GCHD conducts a water quality sampling program supported by county funds, staff, and facilities. The sampling program is conducted in support of sewage treatment plant inspections, stormwater sampling, and investigation of citizen complaints. Its sampling program relies on standards and locations that differ from the SWQM program. This means that any monitoring supported by GCHD as part of this WPP will require coordination about these standards and locations. Funding for non-Health District sampling efforts is extremely limited or nonexistent, and any support from the county will have to be coupled with additional funding to cover the effort, either as grants or as county appropriations.

2010–2011 Highland Bayou Sampling Program

The Highland Bayou Sampling program was a shorter water quality study conducted in support of the characterization report and watershed protection planning. Sampling was funded by the American Recovery and Reinvestment Act and conducted in accordance with an existing amended Quality Assurance Project Plan. The effort was managed by the Texas Coastal Watershed Program and conducted by water quality specialists from the Environmental Institute of Houston, University of Houston Clear-Lake. The program was designed to assist with the characterization of the Highland Bayou watershed and to monitor the impacts of nonpoint source pollution on local waterways in the basin. Results of the program were submitted for entry in TCEQ's SWQM database and will be used in ongoing efforts by TCEQ to assess segments in the study area.

The sampling program consisted of six events at six stations within the Highland Bayou Watershed. Sampling began in November 2010 and concluded in July 2011. All the major nonpoint source water quality parameters were tested, including:

- Water Temperature
- Specific Conductance
- Salinity
- DO
- pH
- Instantaneous Flow
- Secchi Depth
- Chlorine
- Total Suspended Solids
- Chloride
- Chlorophyll-a
- Enterococci
- Total Nitrates
- Orthophosphate
- Total Phosphate
- Sulfate

USGS Real Time Monitoring

As of 2016, there is one operating USGS stream gauge in the project area. The USGS gauges monitor flow conditions and precipitation, but they do not monitor water quality parameters. The operating USGS station in the basin is located at the La Marque pump station in the Texas City Levee, station 08077740. The station is supported in part by Galveston County (USGS, 2016).

Two other stations were established within the Highland Bayou Watershed, but their use has been discontinued. Between 1997 and 2003, a USGS station (08077690) was operating at a point near the diversion point from Highland Bayou to the diversionary canal. For fourteen months, beginning in 2006, a continuous data monitoring station was set up for field sampling where Texas Route 6 crosses Highland Bayou.

Proposed Monitoring

WPP's assume certain levels of uncertainty when they are developed and implemented. As the management measures outlined in Element C are put into practice, it will be necessary to measure and test water quality for certain parameters over time and adjust the WPP as necessary if water quality goals are not achieved. This practice of adaptive management will allow results to guide future strategies and implementation efforts. The monitoring strategy outlined below will be implemented to check if bacteria and nutrient reductions are occurring, and that the goals set by this WPP are being achieved according to schedule. Ambient water quality data will be routinely monitored at downstream SWQM stations.

Table 36 summarizes the SWQM stations that will be used for evaluating short term and long-term water quality conditions to guide the adaptive management approach. SWQM stations were selected for coincidence with the limits of listed segments, or alternatively AU ID catchments. Data collection will focus on collecting routine water quality samples from the six stations listed in Table 35 and shown in Figure 34. These samples can be used for WPP implementation and in future waterbody assessments. Parameters monitored are listed in Table 37. Data from the last seven years of bacteria and nutrient levels should be analyzed every two- years and compared to interim target goals. Analyzing results every two years will also show spatial and historical trends that will assist with adjusting management strategies. Results at the three, five, and 10-year milestones will be compared to the goal reductions to determine progress and need for adapting BMP strategies.

Table 36. Priority monitoring stations selected for measuring progress.

Subwatershed	Segment ID	SWQM Station ID	SWQM Station Description	County	Monitoring Frequency Proposed in WPP
Highland Bayou	2424A_04	16491	Highland Bayou at FM 2004 in Hitchcock	Galveston	Monthly
Highland Bayou	2424A_04	15941	Highland Bayou tidal at FM 519, 335m north of SH6 in city of Hitchcock	Galveston	Monthly
Highland Bayou	2424A_03	11415	Highland Bayou at Fairwood Road in La Marque	Galveston	Monthly
Highland Bayou	2424A_01	16562	Highland Bayou at the end of Bayou Lane Freddiesville	Galveston	Monthly
Highland Bayou	2424A_01	16488	Highland Bayou 80m northeast of SH 6 bridge center point in Bayou Vista west of IH 45	Galveston	Monthly
Marchand Bayou	2424C_01	20007	Marchand Bayou at bridge on Carbide Park Road north of FM 519 and 590m downstream of IH 45 in La Marque	Galveston	Monthly
Marchand Bayou	2424C_01	20188	Unnamed tributary to Marchand Bayou 720m south of the intersection of Prairie and Walker streets in La Marque	Galveston	Monthly
Marchand Bayou	2424C_01	20187	Unnamed east tributary to Marchand Bayou 150m upstream of the confluence at Carbide Park in La Marque	Galveston	Monthly
Marchand Bayou	2424C_01	16490	Marchand Bayou tidal at FM 519 in Hitchcock	Galveston	Monthly
Diversion Canal	2424G_01	20873	Highland Bayou Diversion Canal at Jack Brooks Road approx. 850m north of Hwy 6 in Hitchcock	Galveston	Monthly
Diversion Canal	2424G_01	18593	Highland Bayou Diversion Canal mid channel at Second street bridge 467m upstream of Price Road WWTP	Galveston	Monthly

Subwatershed	Segment ID	SWQM Station ID	SWQM Station Description	County	Monitoring Frequency Proposed in WPP
Diversion Canal	2424G_01	20848	Unnamed tributary of Highland Bayou Diversion Canal 1.07km south and 566m east of the intersection	Galveston	Monthly
Moses Bayou	2431A_01	17910	Moses Bayou at SH 3 in Texas City	Galveston	Monthly
Moses Bayou	2431A_01	11400	Moses Bayou at northbound SH 146 bridge at mid-bridge north of La Marque	Galveston	Monthly
Unnamed Tributary	2431C_01	18592	Unnamed tributary of Moses Lake at State Loop 197/25th Ave. north 432m east of Northbound SH 146 in Texas City	Galveston	Monthly

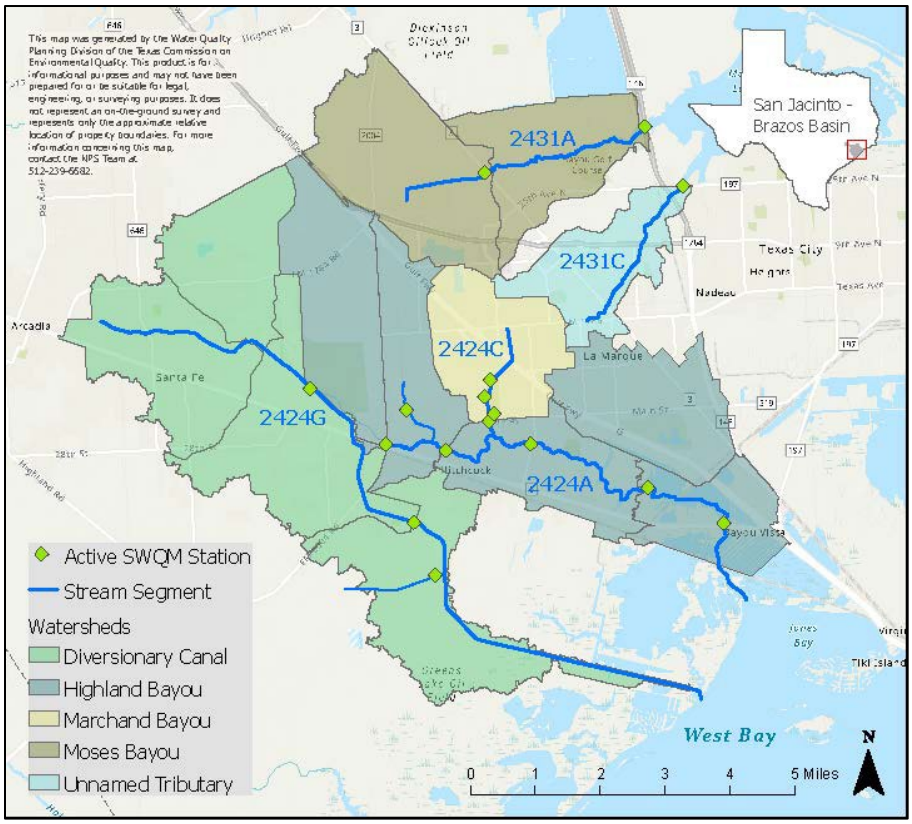


Figure 34. Active SWQM stations.

Table 37 provides a subset of key parameters collected through the routine monitoring program that will be utilized to demonstrate progress toward reducing bacteria and nutrient concentrations in subwatersheds over time.

Table 37. Water quality parameters used for measuring progress.

Field Data	
DO (mg/L)	Specific conductance
pH	Flow (collected at USGS gage station)
Days since last rainfall	Instantaneous Flow
Odor of water	Biological activity
Water temperature	Illegal dumping activity
Salinity	Animal activity
Total Suspended Solids	Secchi Depth
Bacteria Data (All Sections of 2424A and C are tidally influenced)	
E. coli (freshwater)	*Enterococci* (saltwater)
Nutrients Data	
Chlorine	Chloride
Total Nitrates	Chlorophyll-a
Total Phosphate	Sulfate
Orthophosphate	Total dissolved solids

Additional Monitoring

The stakeholder group expressed interest in employing Bacterial Source Tracking (BST) techniques as an additional management tool for the Highland Bayou Coastal Basin, even though it did not rise to the level of a top 12 management measure. The BST technique frequently used in Texas utilizes a local bacteria DNA library, which uses known sources from within the watershed. Water quality monitoring samples (the unknowns) are compared to the library to determine the most significant contributors of bacteria. This data could be used to confirm and/or adjust ongoing and planned implementation efforts. The need for targeted BST analysis within the Highland Bayou

Coastal Basin will be re-evaluated based on the results of a GBEP funded BST project for bayous in the lower Galveston Bayou watershed. Should stakeholders determine additional BST data is needed, appropriate funding will be pursued as a part of the implementation strategy.

Monitoring Objectives and Timeline

Continue Texas Stream Team and Clean Rivers Program Surface Water Quality Monitoring

- Establish an interest in Texas Stream Team with Universities and schools within the Highland Bayou Coastal Basin.
- Recruit more volunteers for Texas Stream Team water quality monitoring efforts within the Highland Bayou Coastal Basin.
- Train more volunteers for Texas Stream Team water quality monitoring efforts that can sample within the Highland Bayou Coastal Basin.
- Work with the Clean Rivers Program to include Priority Monitoring Sites in their monitoring program:
    - Timeline: Recruit volunteers in Year 1. Monthly sampling throughout the year beginning in Year 2 and ongoing thereafter.

Galveston County Health District Stormwater Sampling

- Identify locations in the Highland Bayou Coastal Basin ideal for stormwater sampling (areas with OSSFs, near sewage treatment plants, drainage ditches or water bodies that flow into State waters) and that align with the GCHD sampling program
- Compile and review stormwater monitoring results within MS4 Phase II annual reports from the city of Hitchcock, the city of La Marque and Galveston County
- Compile and review WWTP effluent reports, in particular the occurrence of bacteria exceedances in effluent and how that might relate to ambient water quality monitoring results
- Evaluate relationships between ambient water quality monitoring results and management activities of entities in the basin that discharge effluent, and collaborate to improve coordination:
    - Timeline: Contingent on discussions with GCHD.

TCEQ's SWQM Program

- Work with TCEQ to include priority monitoring sites in their SWQM program:
    - Timeline: Sampling event every 1-2 months throughout the year.

Sampling program timeline mentioned above will be contingent on available funding and resources.

Appendix A: Land Use/Land Cover Change Tables (1996-2010)

Measuring Land Cover

C-CAP is a remote sensing program designed to measure the type and extent of land coverage. The program provides standardized data for coastal communities to measure changes to land coverage and usage over time. High resolution data is provided for certain targeted coastal areas, including around Galveston Bay. C-CAP categorizes land cover date into over 20 categories, and which were used for the analysis in this report. Maps 26-29, in this appendix depicts data used from years 1996, 2001, 2006, 2010, respectively.

Changes in land coverage by type as measured over a 15-year period are summarized in Tables 37-41 in this section. Analyses indicate that some minor acreage was converted to land development in both watersheds. There is a similar decline in most other land use categories, such as agricultural lands and vegetated undeveloped lands. As a percentage of the total land over the 15-year period, about 2-3% of the land was converted to developed uses.

Using C-CAP data, estimates for impervious surface (IS) cover can be made for each subbasin. Ratios of IS cover are defined for each C-CAP land use classification.

Table 38 shows land cover change for each watershed in the project area.

Table 38. Highland Bayou watershed land use change.

Highland Bayou	1996		2001		2006		2010	15-year net change
	Acres	%Change	Acres	%Change	Acres	%Change	Acres	
Developed, High Intensity	356	1.4%	361	12.2%	405	2%	413	16%
Developed, Medium Intensity	1061	1.5%	1077	5.1%	1132	4.2%	1179	11.1%

Highland Bayou	1996		2001		2006		2010	15-year net change
Developed, Low Intensity	1982	1%	2001	2.5%	2052	2.3%	2099	5.9%
Developed, Open Space	1531	0.3%	1536	3.2%	1585	2.3%	1621	5.9%
Total Developed Lands	**4930**	**0.9%**	**4975**	**4%**	**5174**	**2.7%**	**5312**	**7.7%**
Cultivated Crops	6	0%	6	16.7%	7	0%	7	16.7%
Pasture/Hay	731	-0.8%	725	-5.4%	686	-1.2%	678	-7.3%
Grassland/Herbaceous	638	1.4%	647	4.6%	677	-3.5%	653	2.4%
Total Agricultural Lands	**1375**	**0.2%**	**1378**	**-0.6%**	**1370**	**-2.3%**	**1338**	**-2.7%**
Deciduous Forest	608	-1.2%	601	-6.3%	563	-4.1%	540	-11.2%
Evergreen Forest	581	-5.9%	547	-0.9%	542	-3.1%	525	-9.6%
Mixed Forest	215	-2.8%	209	-8.6%	191	-8.4%	175	-18.6%
Scrub/Shrub	551	1.3%	558	-11.3%	495	-5.5%	468	-15.1%
Total Vegetated Undeveloped Lands	**1955**	**-2%**	**1915**	**-6.5%**	**1791**	**-4.6%**	**1708**	**-12.6%**
Palustrine Forested Wetland	937	0.2%	939	-2.6%	915	-1.3%	903	-3.6%
Palustrine Scrub/Shrub Wetland	355	-0.3%	354	-4.5%	338	-3.3%	327	-7.9%
Palustrine Emergent Wetland	991	0.7%	998	-2.4%	974	0.3%	977	-1.4%
Total Palustrine Wetlands	**2283**	**0.4%**	**2291**	**-2.8%**	**2227**	**-0.9%**	**2207**	**-3.3%**
Estuarine Forested Wetland					0		0	
Estuarine Emergent Wetland	699	1.3%	708	-1.8%	695	-1.2%	687	-1.7%
Total Estuarine Wetlands	**699**	**1.3%**	**708**	**-1.8%**	**695**	**-1.2%**	**687**	**-1.7%**
Unconsolidated Shore	216	0%	216	50.5%	325	-0.3%	324	50%
Bare Land/Beach	30	-76.7%	7	-28.6%	5	0%	5	-83.3%
Total Beach/Bare Land	**246**	**-9.3%**	**223**	**48%**	**330**	**-0.3%**	**329**	**33.7%**
Open Water	599	0.2%	600	-16.2%	503	1.2%	509	-15%
Palustrine Aquatic Bed	6	0%	6	16.7%	7	0%	7	16.7%
Total Open Water	**605**	**0.2%**	**606**	**-15.8%**	**510**	**1.2%**	**516**	**-14.7%**

Table 39. Marchand Bayou watershed land use change.

Marchand Bayou	1996		2001		2006		2010	15-year net change
	Acres	%Change	Acres	%Change	Acres	%Change	Acres	
Developed, High Intensity	113	1.8%	115	14.8%	132	0.8%	133	17.7%
Developed,	338	0%	338	12.4%	380	0.3%	381	12.7%

Marchand Bayou	1996		2001		2006		2010	15-year net change
Medium Intensity								
Developed, Low Intensity	595	0.2%	596	4.4%	622	0.3%	624	4.9%
Developed, Open Space	503	0%	503	2.8%	517	0.6%	520	3.4%
Total Developed Lands	**1549**	**0.2%**	**1552**	**6.4%**	**1651**	**0.4%**	**1658**	**7%**
Cultivated Crops	0		0		0		0	
Pasture/Hay	182	0%	182	-28%	131	-0.8%	130	-28.6%
Grassland/Herbaceous	89	0%	89	-18%	73	2.7%	75	-15.7%
Total Agricultural Lands	**271**	**0%**	**271**	**-24.7%**	**204**	**0.5%**	**205**	**-24.4%**
Deciduous Forest	152	0%	152	-2%	149	0%	149	-2%
Evergreen Forest	122	0%	122	-3.3%	118	5.9%	125	2.5%
Mixed Forest	27	0%	27	-3.7%	26	0%	26	-3.7%
Scrub/Shrub	103	0%	103	-20.4%	82	-14.6%	70	-32%
Total Vegetated Undeveloped Lands	**404**	**0%**	**404**	**-7.2%**	**375**	**-1.3%**	**370**	**-8.4%**
Palustrine Forested Wetland	126	0%	126	-1.6%	124	10.5%	137	8.7%
Palustrine Scrub/Shrub Wetland	48	0%	48	-2.1%	47	-31.9%	32	-33.3%
Palustrine Emergent Wetland	16	0%	16	-6.2%	15	0%	15	-6.2%
Total Palustrine Wetlands	**190**	**0%**	**190**	**-2.1%**	**186**	**-1.1%**	**184**	**-3.2%**
Estuarine Forested Wetland					0		0	
Estuarine Emergent Wetland	0		0		0		0	
Total Estuarine Wetlands	**0**		**0**		**0**		**0**	
Unconsolidated Shore	6	0%	6	0%	6	0%	6	0%
Bare Land/Beach	2	-100%	0		0		0	-100%
Total Beach/Bare Land	**8**	**-25%**	**6**	**0%**	**6**	**0%**	**6**	**-25%**
Open Water	30	0%	30	0%	30	0%	30	0%
Palustrine Aquatic Bed	2	0%	2	0%	2	0%	2	0%
Total Open Water	**32**	**0%**	**32**	**0%**	**32**	**0%**	**32**	**0%**

Table 40. Diversion canal watershed land use change.

Diversionary Canal	1996		2001		2006		2010	15-year net change
	Acres	% Change	Acres	% Change	Acres	% Change	Acres	
Developed, High Intensity	91	2.2%	93	14%	106	8.5%	115	26.4%
Developed,	315	8.6%	342	8.8%	372	2.7%	382	21.3%

Medium Intensity								
Developed, Low Intensity	1225	3.3%	1266	-0.5%	1260	1%	1273	3.9%
Developed, Open Space	3417	1.3%	3460	-0.1%	3456	1.2%	3496	2.3%
Total Developed Lands	**5048**	**2.2%**	**5161**	**0.6%**	**5194**	**1.4%**	**5266**	**4.3%**
Cultivated Crops	63	1.6%	64	-31.2%	44	0%	44	-30.2%
Pasture/Hay	1737	-2.1%	1701	0.2%	1704	-0.6%	1693	-2.5%
Grassland/Herbaceous	703	0.3%	705	2.3%	721	2.4%	738	5%
Total Agricultural Lands	**2503**	**-1.3%**	**2470**	**0%**	**2469**	**0.2%**	**2475**	**-1.1%**
Deciduous Forest	569	-3.2%	551	-2.7%	536	-2.4%	523	-8.1%
Evergreen Forest	352	-8.5%	322	-4.3%	308	-2.6%	300	-14.8%
Mixed Forest	49	-8.2%	45	-8.9%	41	-2.4%	40	-18.4%
Scrub/Shrub	718	0%	718	-1.3%	709	-4.8%	675	-6%
Total Vegetated Undeveloped Lands	**1688**	**-3.1%**	**1636**	**-2.6**	**1594**	**-3.5**	**1538**	**-8.9**
Palustrine Forested Wetland	395	0%	395	2.8%	406	-0.5%	404	2.3%
Palustrine Scrub/Shrub Wetland	347	-4.6%	331	-0.3%	330	-4.2%	316	-8.9%
Palustrine Emergent Wetland	1743	-0.7%	1730	-0.7%	1718	-0.3%	1712	-1.8%
Total Palustrine Wetlands	**2485**	**-1.2%**	**2456**	**-0.1**	**2454**	**-0.9**	**2432**	**-2.1**
Estuarine Forested Wetland					3	0	3	
Estuarine Emergent Wetland	598	0.3%	600	-5.2	569	0	569	-4.8
Total Estuarine Wetlands	**598**	**0.3%**	**600**	**-4.7%**	**572**	**0%**	**572**	**-4.3%**
Unconsolidated Shore	104	0%	104	-2.9%	101	0%	101	-2.9%
Bare Land/Beach	20	-15%	17	229.4%	56	0%	56	180%
Total Beach/Bare Land	**124**	**-2.4%**	**121**	**29.8%**	**157**	**0%**	**157**	**26.6%**
Open Water	174	0.6%	175	2.3%	179	0%	179	2.9%
Palustrine Aquatic Bed	20	0%	20	0%	20	0%	20	0%
Total Open Water	**194**	**0.5%**	**195**	**2.1%**	**199**	**0%**	**199**	**2.6%**

Table 41. Moses Bayou watershed land use change.

Moses Bayou	**1996**		**2001**		**2006**		**2010**	**15-year net change**
	Acres	**%Change**	**Acres**	**%Change**	**Acres**	**%Change**	**Acres**	
Developed, High Intensity	210	3.3%	217	0.5%	218	1.4%	221	5.2%
Developed, Medium Intensity	313	4.2%	326	23.9%	404	3.5%	418	33.5%
Developed,	351	2.6%	360	16.7%	420	2.4%	430	22.5%

Moses Bayou	1996		2001		2006		2010	15-year net change
Low Intensity								
Developed, Open Space	608	0.7%	612	12.4%	688	0.6%	692	13.8%
Total Developed Lands	**1482**	**2.2%**	**1515**	**14.2%**	**1730**	**1.8%**	**1761**	**18.8**
Cultivated Crops	159	0%	159	0%	159	0%	159	0%
Pasture/Hay	1500	-1.1%	1484	-2.8%	1443	-0.6%	1434	-4.4%
Grassland/Herbaceous	526	0%	526	-3.8%	506	-0.2%	505	-4%
Total Agricultural Lands	**2185**	**-0.7%**	**2169**	**-2.8%**	**2108**	**-0.5%**	**2098**	**-4%**
Deciduous Forest	430	-0.5%	428	-8.2%	393	-0.8%	390	-9.3%
Evergreen Forest	137	0%	137	-3.6%	132	13.6%	150	9.5%
Mixed Forest	31	0%	31	-9.7%	28	0%	28	-9.7%
Scrub/Shrub	647	0%	647	-7%	602	-5.6%	568	-12.2%
Total Vegetated Undeveloped Lands	**1245**	**-0.2%**	**1243**	**-7.1%**	**1155**	**-1.6%**	**1136**	**-8.8%**
Palustrine Forested Wetland	480	0%	480	-14.8%	409	0.2%	410	-14.6%
Palustrine Scrub/Shrub Wetland	197	-1%	195	-3.1%	189	-0.5%	188	-4.6%
Palustrine Emergent Wetland	380	-1.8%	373	-4%	358	-0.6%	356	-6.3%
Total Palustrine Wetlands	**1057**	**-0.9%**	**1048**	**-8.8%**	**956**	**-0.2%**	**954**	**-9.7%**
Estuarine Forested Wetland					0		0	
Estuarine Emergent Wetland	116	0%	116	-5.2%	110	0%	110	-5.2%
Total Estuarine Wetlands	116	0%	116	-5.2%	110	0%	110	-5.2%
Unconsolidated Shore	51	0%	51	-2%	50	0%	50	-2%
Bare Land/Beach	6	-66.7%	2	0%	2	0%	2	-66.7%
Total Beach/Bare Land	**57**	**-7%**	**53**	**-1.9%**	**52**	**0%**	**52**	**-8.8%**
Open Water	150	0%	150	24%	186	0%	186	24%
Palustrine Aquatic Bed	22	0%	22	-18.2%	18	0%	18	-18.2%
Total Open Water	**172**	**0%**	**172**	**18.6%**	**204**	**0%**	**204**	**18.6%**

Table 42. Unnamed tributary watershed land use change.

Unnamed Tributary	1996		2001		2006		2010	15-year net change
	Acres	%Change	Acres	%Change	Acres	%Change	Acres	
Developed, High Intensity	65	0%	65	10.8%	72	1.4%	73	12.3%
Developed,	287	0.3%	288	1.7%	293	0.3%	294	2.4%

Medium Intensity								
Developed, Low Intensity	492	0.2%	493	2.2%	504	0%	504	2.4%
Developed, Open Space	308	0.3%	309	6.1%	328	0.3%	329	6.8%
Total Developed Lands	1152	0.3%	1155	3.6%	1197	0.3%	1200	4.2%
Cultivated Crops	37	0%	37	-13.5%	32	0%	32	-13.5%
Pasture/Hay	248	0.4%	249	-4%	239	0%	239	-3.6%
Grassland/Herbaceous	92	1.1%	93	-8.6%	85	3.5%	88	-4.3%
Total Agricultural Lands	377	0.5%	379	-6.1%	356	0.8%	359	-4.8%
Deciduous Forest	51	-2%	50	-2%	49	0%	49	-3.9%
Evergreen Forest	8	0%	8	0%	8	-12.5%	7	-12.5%
Mixed Forest	1	0%	1	0%	1	0%	1	0%
Scrub/Shrub	128	0%	128	-3.9%	123	-0.8%	122	-4.7%
Total Vegetated Undeveloped Lands	188	-0.5%	187	-3.2%	181	-1.1%	179	-4.8%
Palustrine Forested Wetland	128	0%	128	-2.3%	125	-0.8%	124	-3.1%
Palustrine Scrub/Shrub Wetland	101	0%	101	-1%	100	0%	100	-1%
Palustrine Emergent Wetland	53	-1.9%	52	-5.8%	49	0%	49	-7.5%
Total Palustrine Wetlands	282	-0.4%	281	-2.5%	274	-0.4%	273	-3.2%
Estuarine Forested Wetland					0		0	
Estuarine Emergent Wetland	39	0	39	-15.4	33	0	33	-15.4
Total Estuarine Wetlands	39	0%	39	-15.4%	33	0%	33	-15.4%
Unconsolidated Shore	19	0	19	-10.5	17	0	17	-10.5
Bare Land/Beach	4	-100	0		0		0	-100
Total Beach/Bare Land	23	-17.4%	19	-10.5%	17	0%	17	-26.1%
Open Water	0		0		0		0	
Palustrine Aquatic Bed	4	0	4	0	4	0	4	0
Total Open Water	4	0%	4	0%	4	0%	4	0%

Appendix B: Additional FDC/LDCs by Station

The following load duration and flow duration curves were produced by the Texas Institute of Applied Environmental Research at Tarleton State University as part of the report titled *Assessment of Bacteria Loads and Dissolved Oxygen Impairments for Highland Bayou, Marchand Bayou, and Moses Bayou Watersheds* by Dr. Larry Hauck and Narayanan Kannan.

Modified Flow Duration Curves by Station

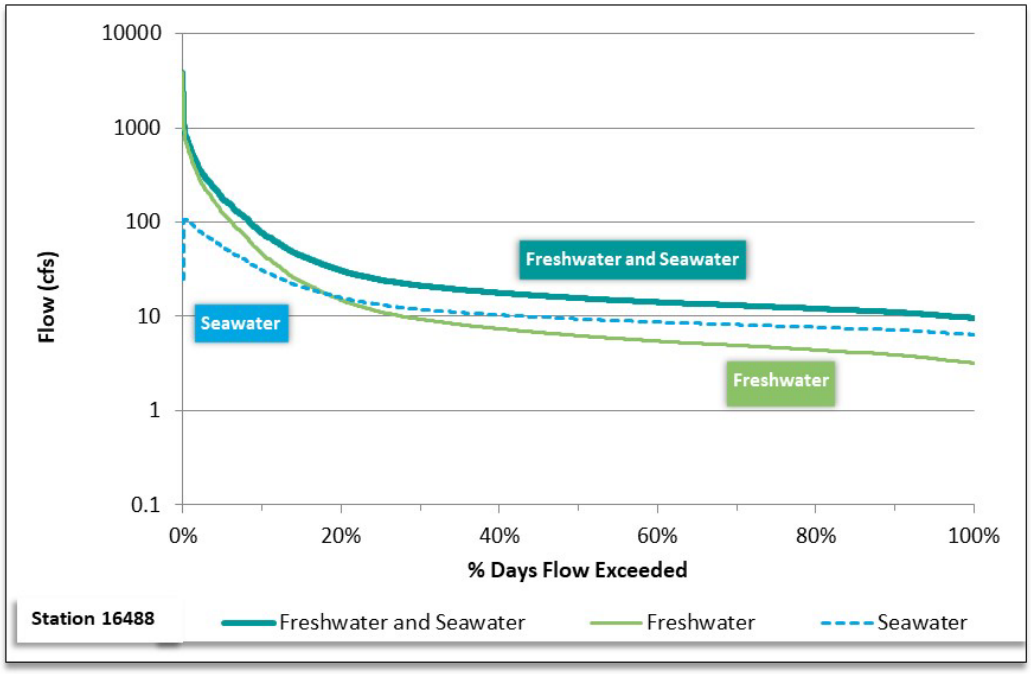


Figure 35. Modified FDC for station 16488, Highland Bayou AU 2424A_01.

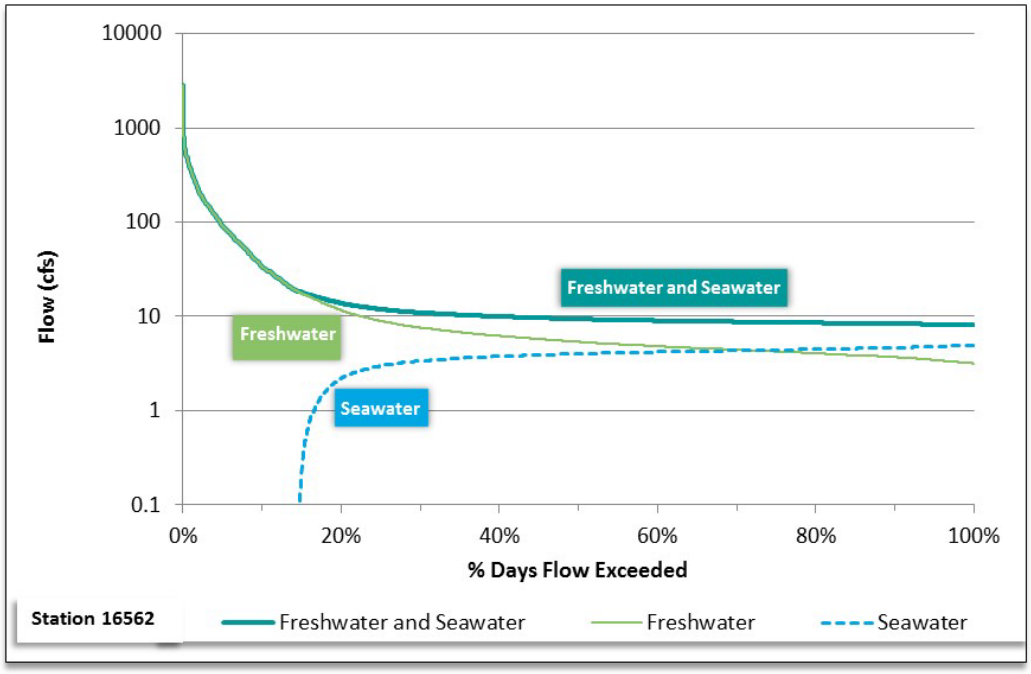


Figure 36. Modified FDC for station 16562, Highland Bayou AU 2424A_02.

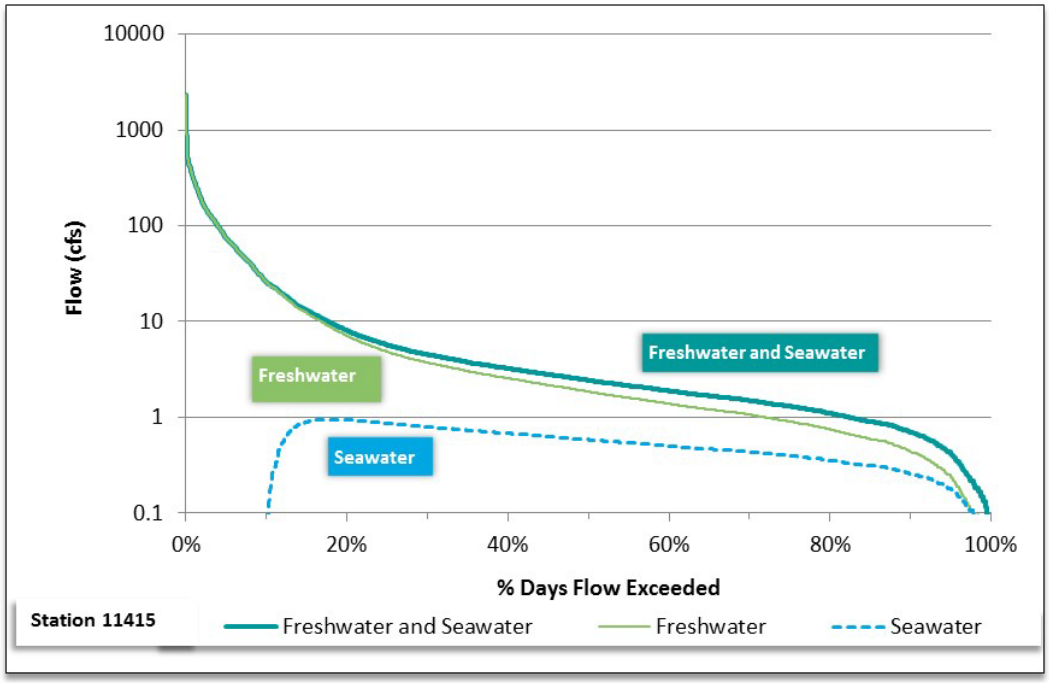


Figure 37. Modified FDC for station 11415, Highland Bayou AU 2424A_03.

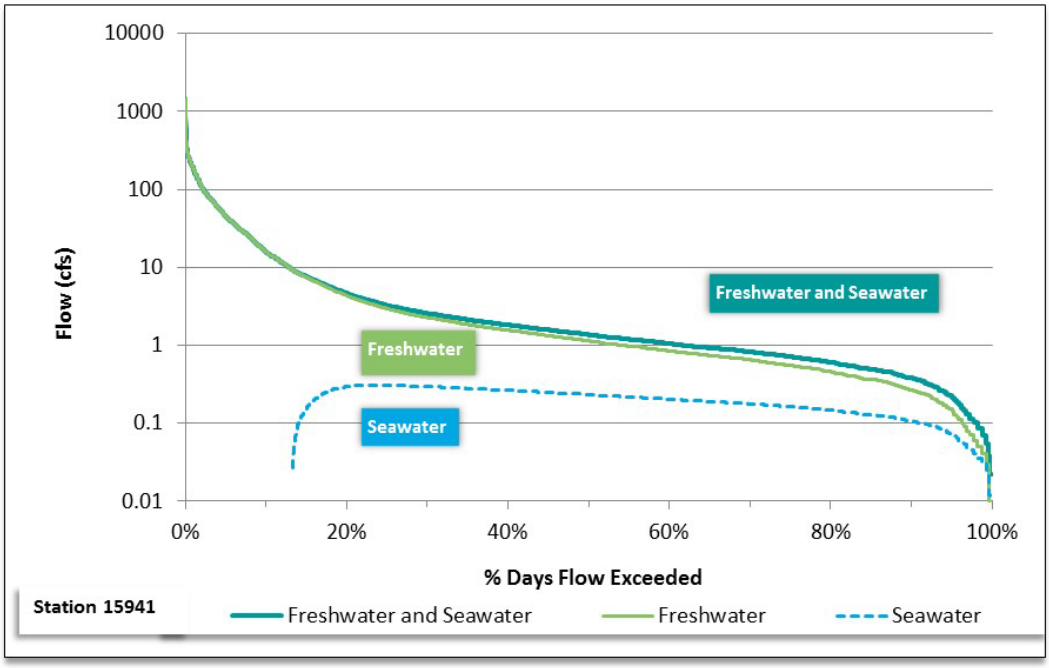


Figure 38. Modified FDC for station 15941, Highland Bayou AU 2424A_04.

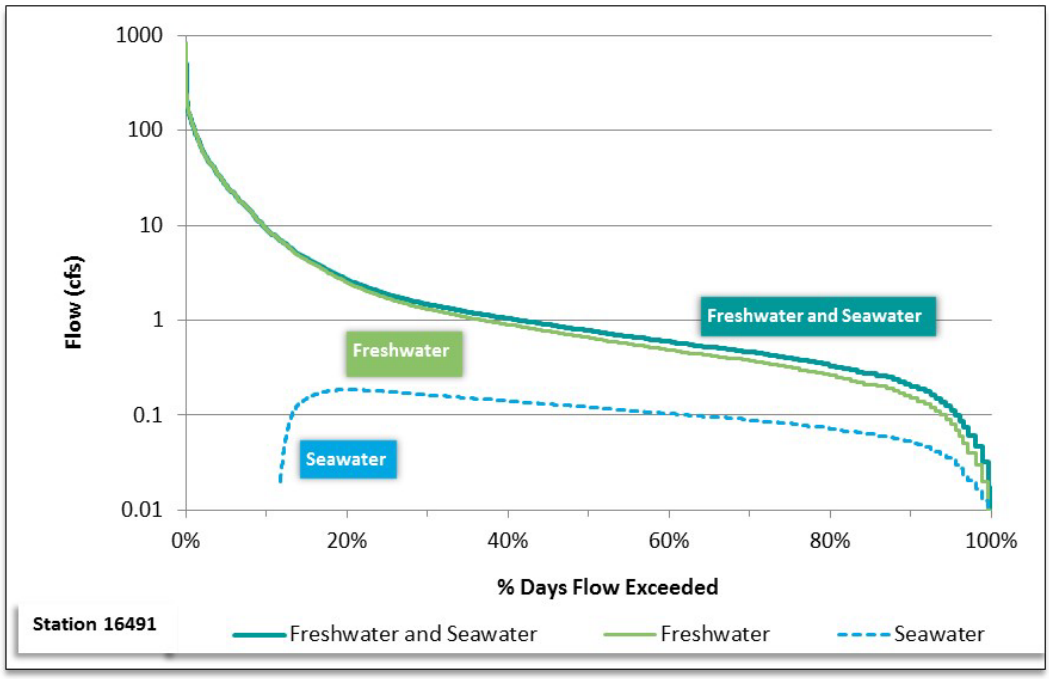


Figure 39. Modified FDC for station 16491, Highland Bayou AU 2424A_05.

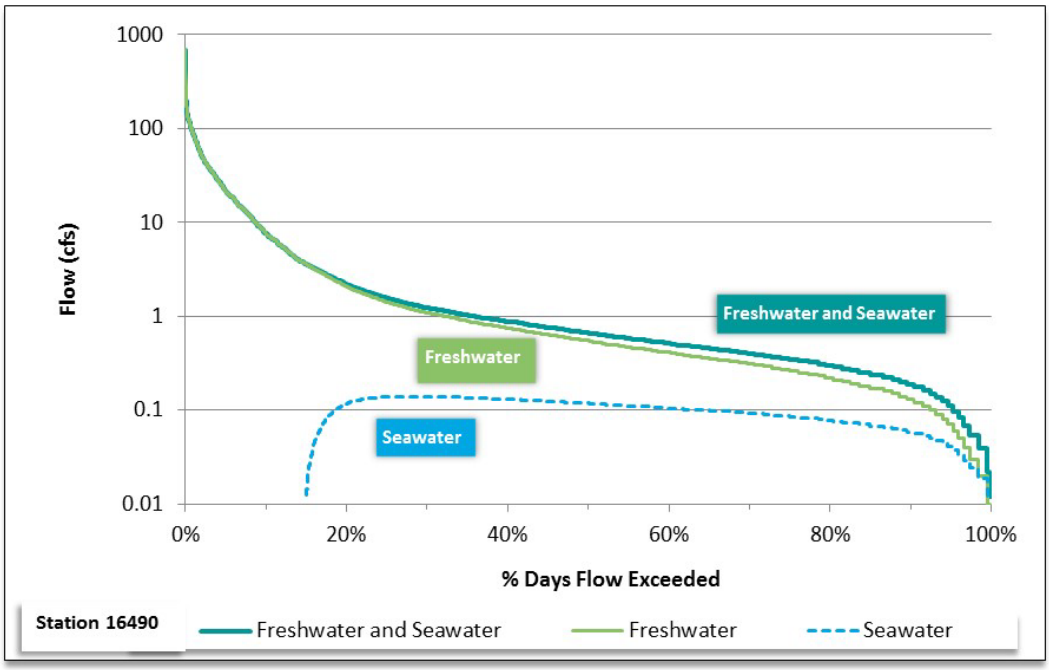


Figure 40. Modified FDC for station 16490, Marchand Bayou AU 2424C_01.

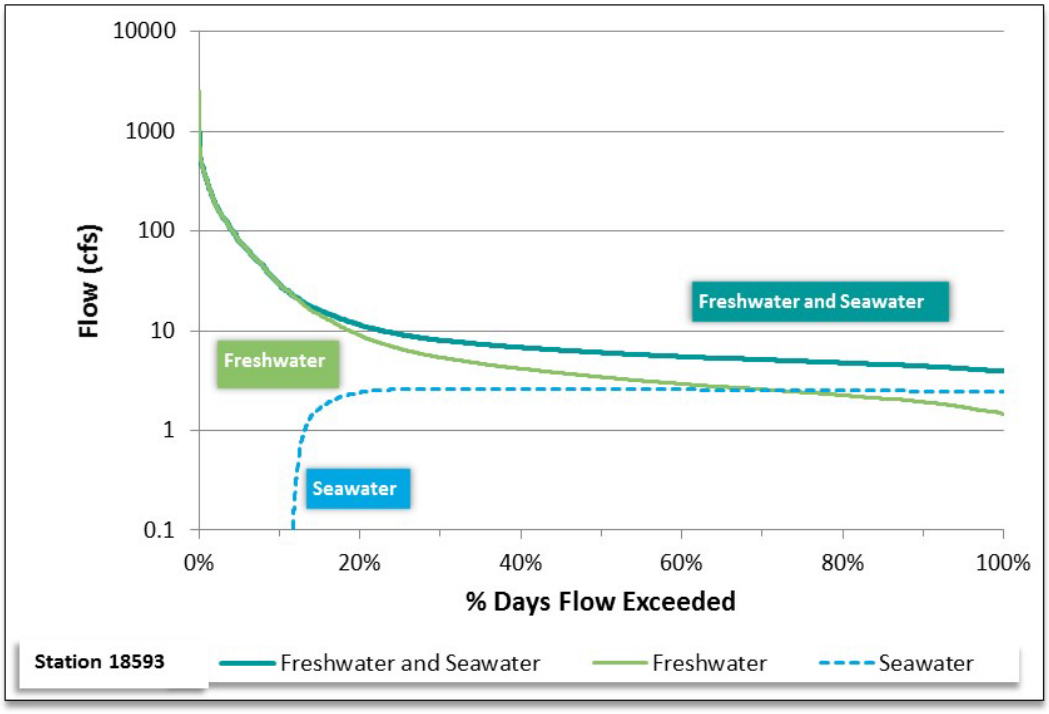


Figure 41. Modified FDC for station 18593, Highland Bayou Diversion Canal AU 2424G_01.

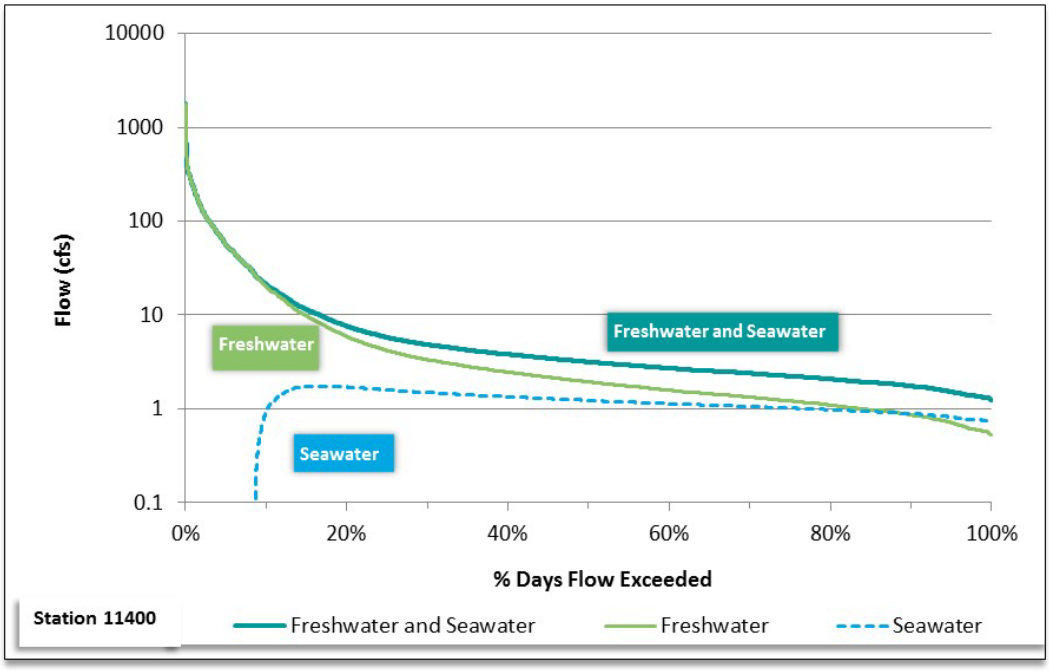


Figure 42. Modified FDC for station 11400, Moses Bayou AU 2431A_01

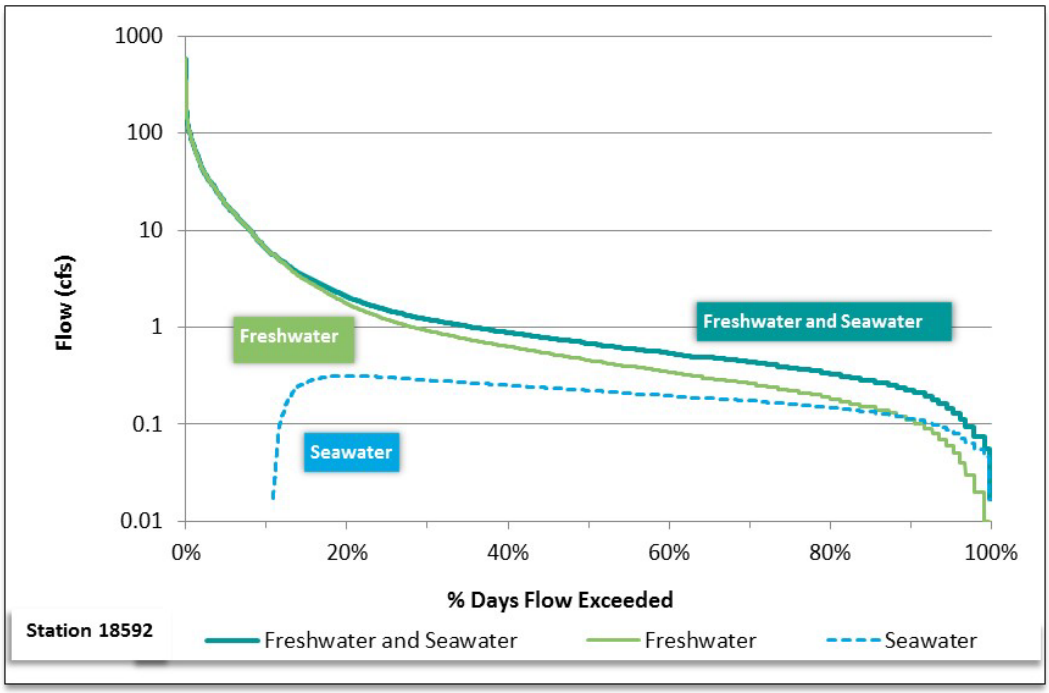


Figure 43. Modified FDC for station 18592, unnamed tributary of Moses Lake AU 2431C_01

Modified Load Duration Curves by Station

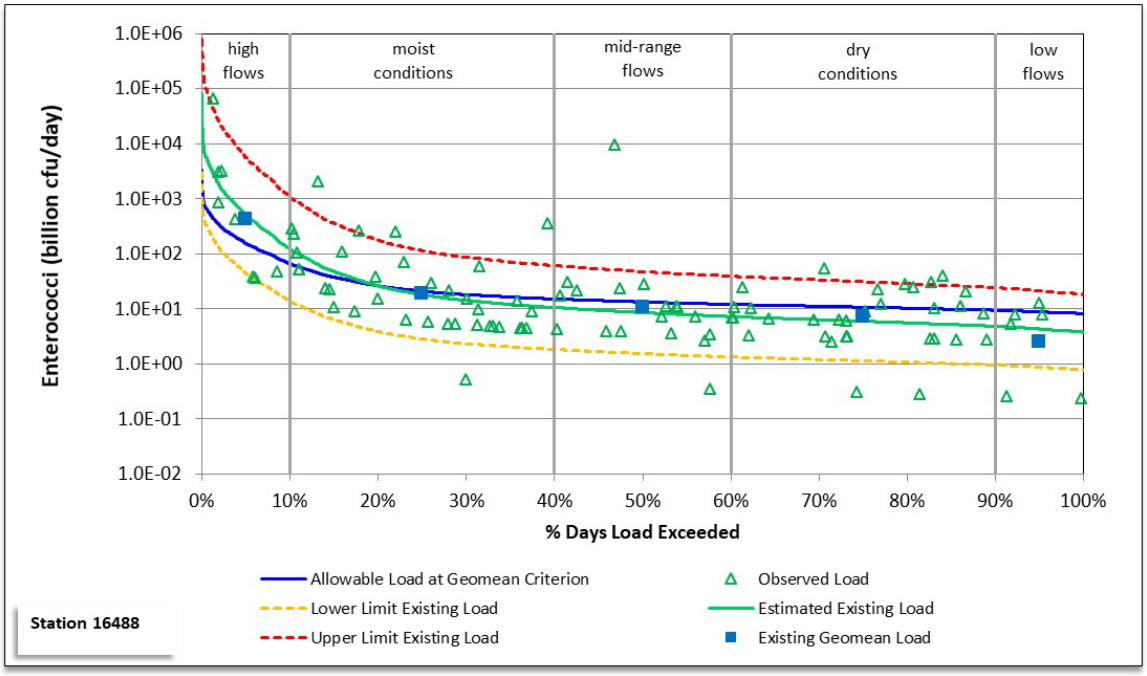


Figure 44. Modified LDC for station 16488, Highland Bayou AU 2424A_01.

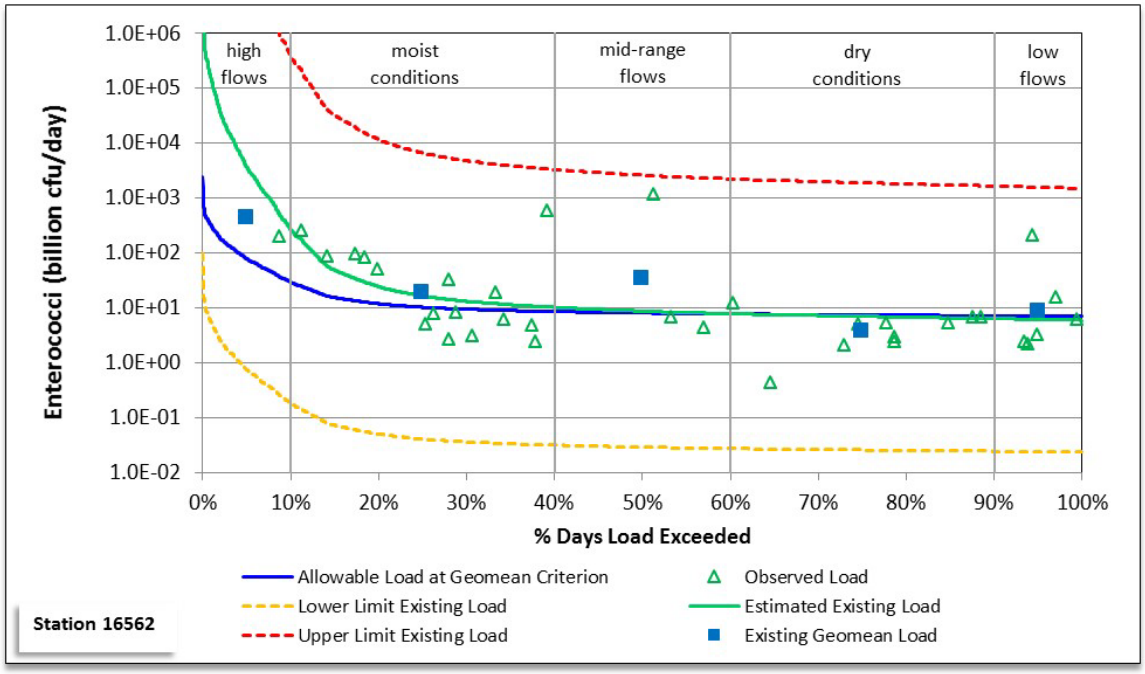


Figure 45. Modified LDC for station 16562, Highland Bayou AU 2424A_02.

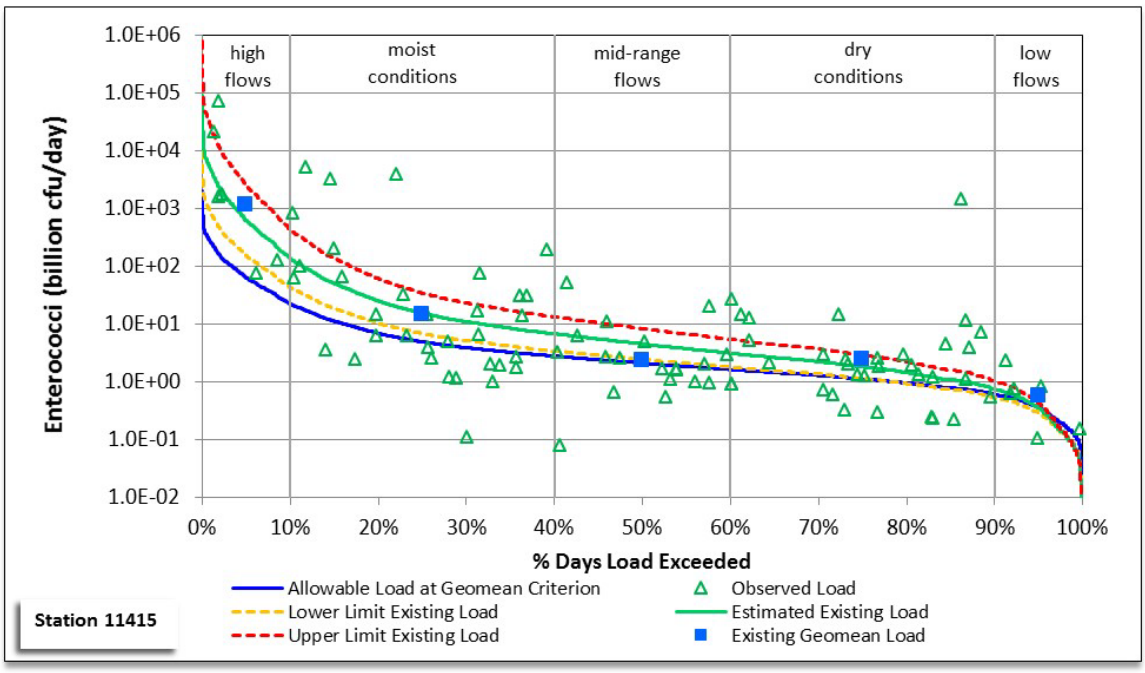


Figure 46. Modified LDC for station 11415, Highland Bayou AU 2424A_03.

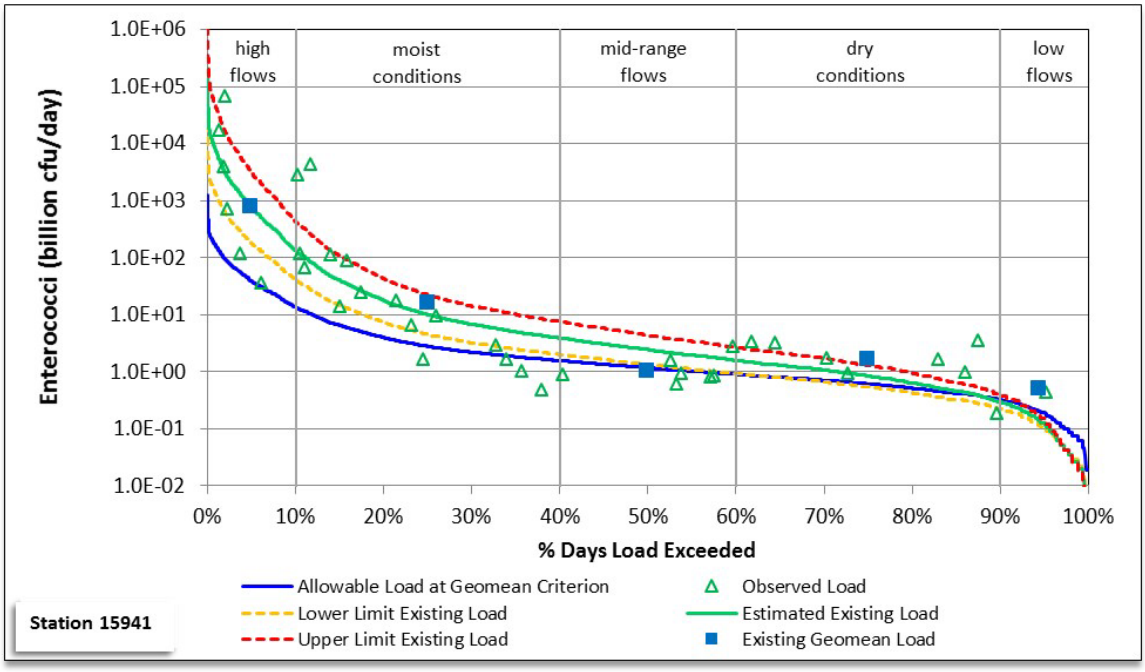


Figure 47. Modified LDC for station 15941, Highland Bayou AU 2424A_04.

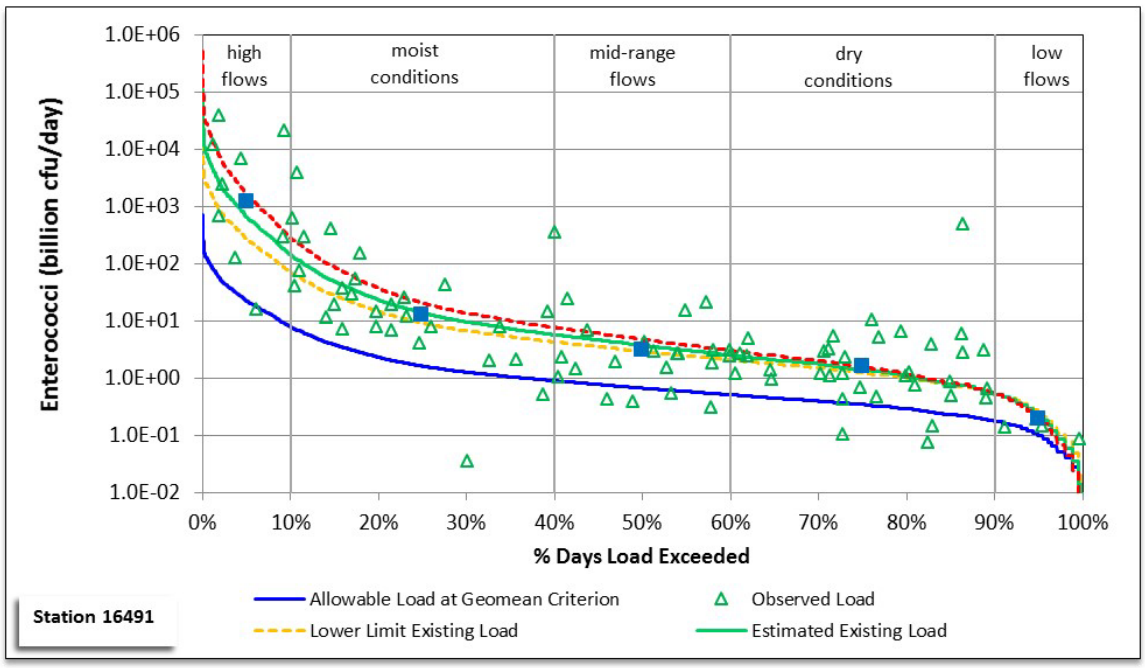


Figure 48. Modified LDC for station 16491, Highland Bayou AU 2424A_05.

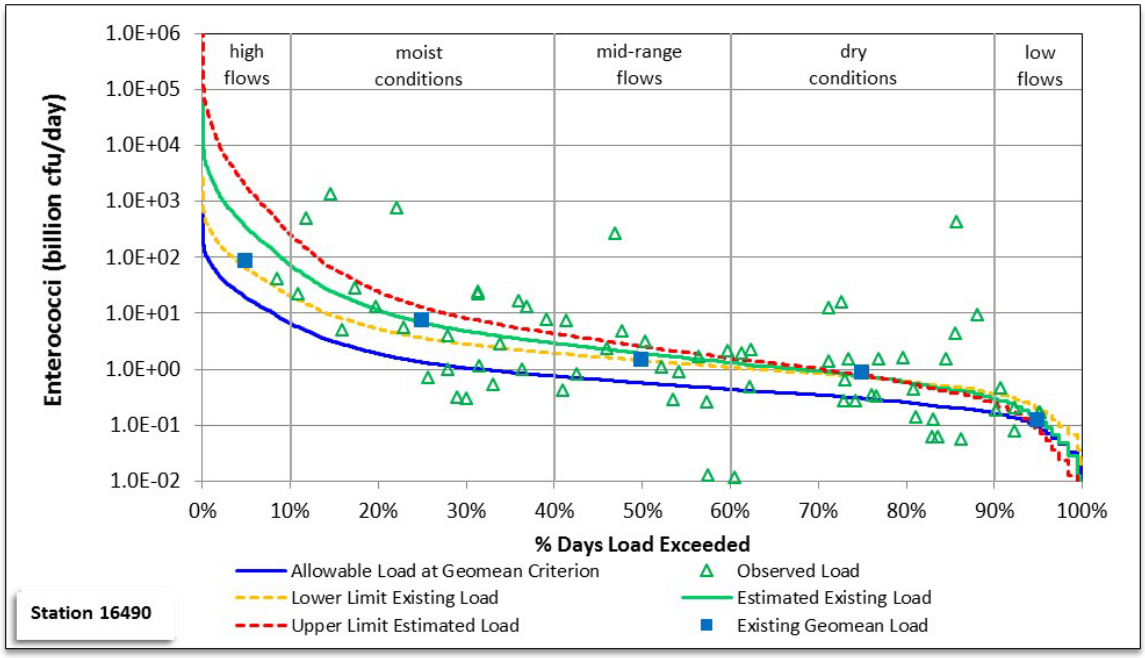


Figure 49. Modified LDC for station 16490, Marchand Bayou AU 2424C_01.

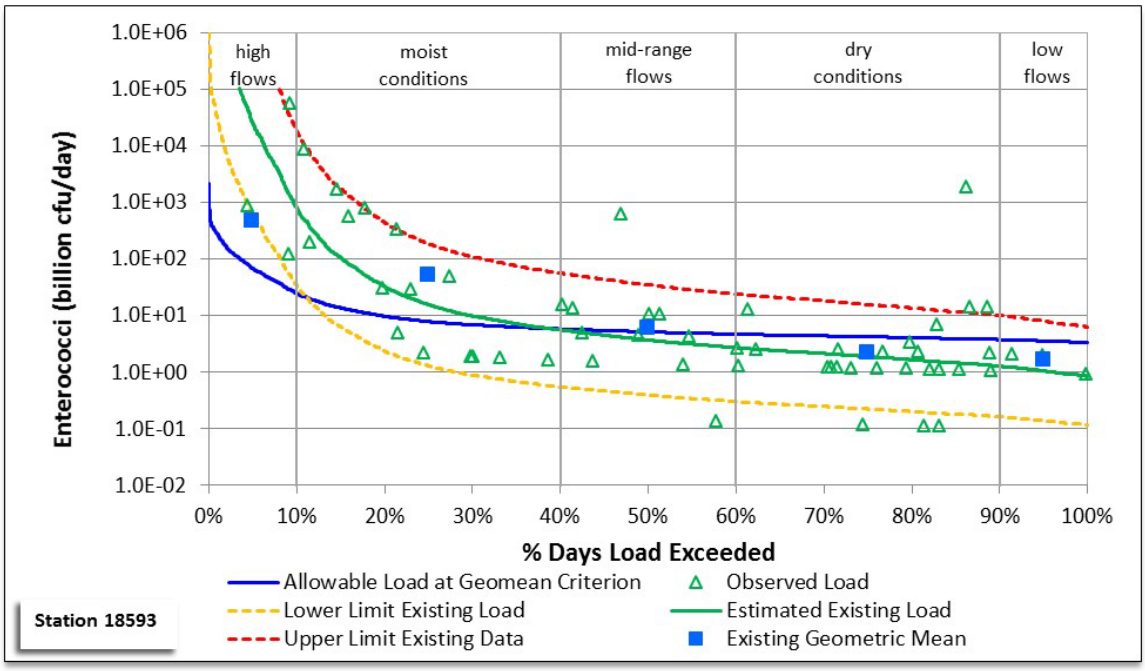


Figure 50. Modified LDC for station 18593, Highland Bayou Diversion Canal AU 2424G_01.

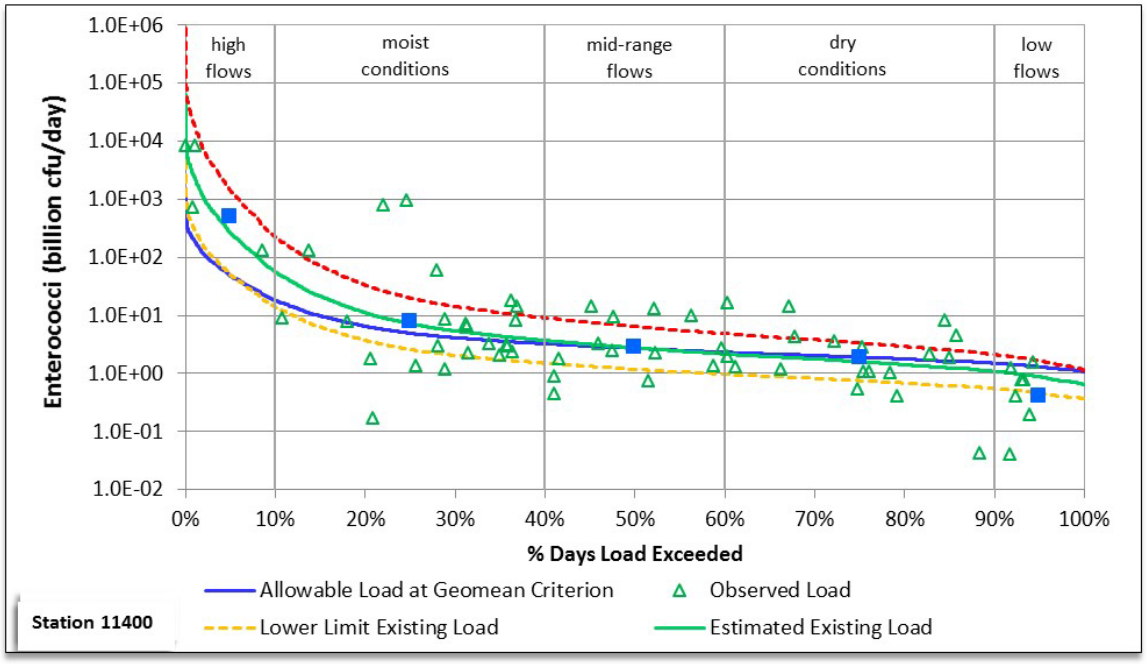


Figure 51. Modified LDC for station 11400, Moses Bayou AU 2431A_01

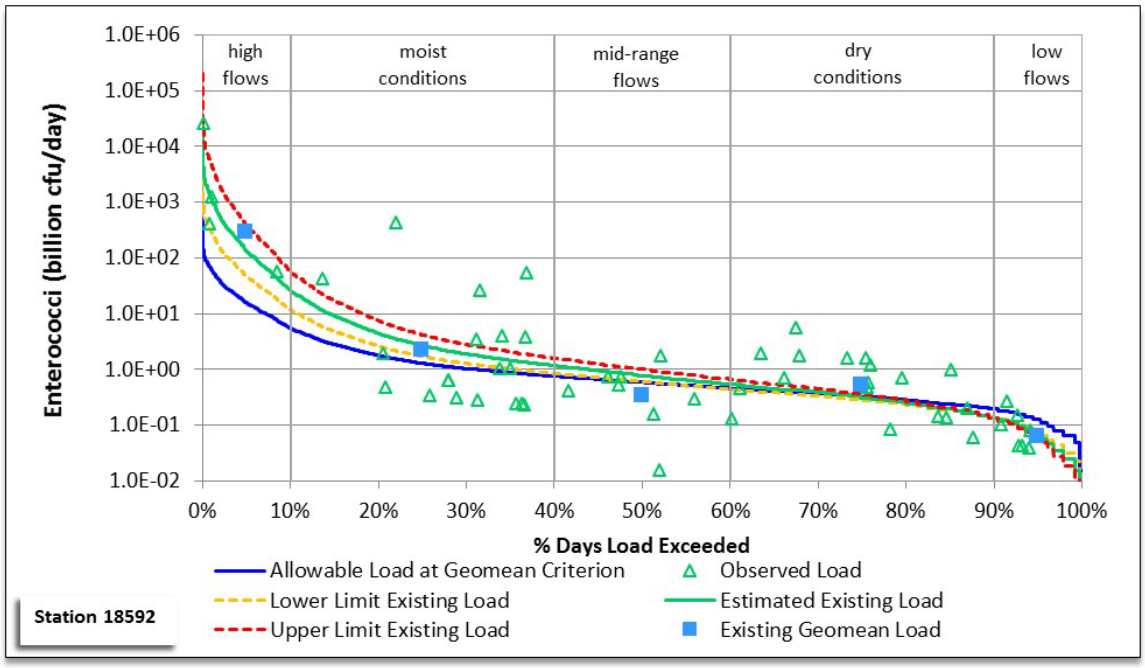


Figure 52. Modified LDC for station 18592, unnamed tributary of Moses Lake AU 2431C_01

Appendix C: Additional Future Projects

Twenty-six additional management measures were discussed by stakeholders but were not designated as Priority after the voting exercise. These Measures are still considered viable project areas for these watersheds and are included for consideration in future WPP updates as part of the iterative processes of watershed planning and management. A brief narrative including project directions and resources are provided for each. The Measures are categorized by nonpoint source pollution type for easy reference.

Wastewater

Connect to Central System or Upgrade Failing OSSFs

Where feasible, expanding service area boundaries shift wastewater management from private, onsite systems to a professionally managed, centralized treatment system. This option is available when municipalities are prepared to make capital investments to expand their service areas. Hitchcock recently completed such an expansion towards the Freddiesville area. Due to the limited use of septic systems in the project area, this activity is expected to have the most impact on load reductions in the diversion canal.

Improve Enforcement to Mitigate Failing OSSFs

After 1997, Galveston County stopped issuing permits for the construction of standard drain field OSSF systems in clay soils or in areas where the shallow groundwater surface was less than two feet deep. In these conditions common to the watershed, there were frequent instances of untreated septage flowing from drain fields. Older systems in the watershed have been “grandfathered” and homeowners have not been required to replace them with alternative systems. Funding levels limit the number of inspectors who can make inspections and identify failing systems. Currently, calls from neighbors or others to report a discharge are the typical cause for an OSSF inspection. An increased budget for better inspection and enforcement would result in better identification of malfunctioning OSSFs. This, in turn, would result in an increase in repairs or replacement of malfunctioning systems. GHCD currently funds and trains new inspectors. The Highland Bayou Watershed group will help solicit grant funding for the additional resources to support these activities. This activity is being pursued in other watersheds in the county, and partnerships with those watershed efforts could provide efficiencies of scale.

Incorporate OSSF Criteria Into Standards of Practice for Home Sale Inspections

Currently, home inspectors are not required to inspect OSSFs for homebuyers, nor is there an accepted standard procedure for inspections. Without a standard procedure, the methods to determine the operational status of OSSFs may vary with the inspector’s knowledge of OSSFs. Buyers may not be aware of an undersized, under-

maintained, or improperly functioning system. To ensure consistency and competence of OSSF inspections at the point of sale, rules specifying standardized procedures for OSSF inspections, at the sale of the home for all types of OSSF systems, must be developed and enforced. A thorough inspection will provide the home buyer with the information needed to determine if their lifestyle and water usage is within the capabilities of the OSSF associated with the home that is being sold.

Texas A&M AgriLife Extension Service is developing an inspection manual for conventional OSSFs. The manual provides step-by-step guidance for inspecting the septic tank and treatment area. A checklist is used to determine the operation status and identify inspection and maintenance frequencies. Texas A&M AgriLife Extension Service will recommend that inspectors in Galveston County follow the manual for conventional systems until such time that the rules required to standardize inspection of OSSFs are established (statewide or in Galveston County). The watershed group will work with the GCHD, GBF, TREC and other watershed groups to advance this action area.

The H-GAC hosts a course on OSSF visual inspection for home inspectors[5]. Participants learn how to identify failing OSSFs through visual inspection during this one-day course and will receive six continuing education hours from the Texas Real Estate Commission.

Target Areas for Intensive Water Quality Sampling Based on OSSF Pollution

Sampling efforts alone will not contribute directly to reduced bacteria counts; rather, the information obtained from sampling would be used to prioritize implementation efforts, and stakeholders expect to see decreases in bacteria counts as failing OSSFs are repaired or replaced. The recommended monitoring schedule included in Element I describes existing and recommended sampling programs to assess progress towards attaining water quality standards during the implementation activities within the project area. Before sampling locations can be selected for water quality monitoring, it is important to identify the location or likely location of all OSSFs (both permitted and non-permitted) to improve the monitoring strategy. H-GAC has an online mapping system for OSSFs in the region, as well as local knowledge on behalf of the staff of GCHD could be used to support the goals of this activity. Several ambient sampling locations could then be selected by the GCHD on project waterways. Stakeholder workgroup members plan to seek grant funding for sustained sampling and analysis.

[5] www.h-gac.com/on-site-sewage-facilities

Develop and Implement an Improved SSOI Plan/Program

The SSOI[6] is a voluntary program initiated in 2004 by the TCEQ, in an effort to address an increase in SSOs due to aging collection systems throughout the state and encourage corrective action before there is harm to human health and safety or the environment. Breaks, leaks, and overflows in these systems, collectively referred to as SSOs, create overflows of untreated sewage into the stormwater system and ultimately waterways.

Hitchcock and La Marque have both participated in TCEQ's SSOI program and are in different phases of assessment and implementation to reduce SSOs. Through the SSOI program, a plan for SSO reduction is submitted to TCEQ including a system inventory, sewer map update, inspections and testing, and system rehabilitation with multiple phases of construction. La Marque is in the process of issuing substantial capital improvement bonds for their SSO program. The city of Hitchcock completed their SSOI program agreement in 2013 and is continuing system rehabilitation construction activities for SSO reduction. While MUD 12 has not participated in TCEQ's SSOI program, they perform wastewater collection system surveys and also report information to TCEQ. Collection sytem improvements made by the city of Hitchcock, the city of La Marque and MUD 12 regarding SSO reduction is a continuous endevour that each of these wastewater service providers are committed to overcome. Stakeholder workgroup members proposed owners and operators of WWTPs in the Highland Bayou Watershed revisit their SSO reduction plan/program if completed and implement an SSOI plan/program if the entity has not participated in the SSOI through TCEQ, aiming for each WWTP in the watershed to have an implemented plan.

TCEQ is responsible for distributing educational materials about existing SSOI programs. SSS owners and operators are responsible for developing and implementing any SSOI plans. When appropriate, stakeholder workgroup members who are owners and operators should collaborate during the development or implementation of their respective SSOI plans. The stakeholder workgroup plans to seek funding for these activities from federal or state grant programs such as the CWA 319(h) grant program.

Surveying Collection System Lines to Identify Problem Areas

This measure specifically addresses the survey of collection system lines to identify problem areas. To address blockages effectively, a program expanded to entire SSS is ideal.

System rehabilitation projects (replacement of damaged or corroded lines, etc.) combined with improved monitoring technologies can bring an aging collection system into proper working order and reduce the number of SSO discharges. La Marque, as an SSOI participant, documents their progress within an annual progress report. For sewer

[6] www.tceq.texas.gov/compliance/investigation/ssoinitiative

pipes, lift stations, manholes, etc., the frequency of inspections is included as a required operations and maintenance activity. The The evaluation of I/I in the sanitary sewer is covered by the annual report through flow monitoring (wastewater treatment facility, lift stations, rainfall records, etc.), dye or smoke testing to identify leaks and illegal connections, and/or system and mapping updates.

Analog closed-circuit television (CCTV) technology is an industry standard for pipe inspection and are designed for small diameter (less than 60 inch diameter) pipelines to provide high resolution images of infrastrucure. Barriers for this technology are flow (the vehicle used to transport the CCTV cameras can only be used with low or no flows in the pipe), and high volumes of sediment or debris. Man-entry pipe inspection is typically done for larger pipes. These inspections would typically involved two inspectors to enter and document the pipe condition using photo and video as well as other general condition assessments. La Marque has used CCTV inspection robot cameras to inspect their lines.

Improvements in WWTP Operation

The objective of this action area is to improve treatment operations at facilities permitted by the TCEQ to treat domestic wastewater. In 2008, TCEQ instituted a state-wide requirement to include water quality-based bacteria effluent limitations and monitoring requirements for facilities permitted to treat domestic wastewater. All new permits issued after 2008 for these types of facilities will contain the new state-wide requirements. Facilities with existing permits to treat domestic sewage will be required to incorporate the new requirements when they seek permit renewals or amendments. All three permitted WWTPs in the watershed treat domestic wastewater and therefore have potential to contribute to the bacteria load and are operating under permits issued after the new permit requirements were initiated.

Workshops for plant operators, specifically addressing bacteria and troubleshooting methods, were recommended by stakeholders. There are various professional development opportunities for public works employees that offer free CEUs. Texas A&M Engineering Extension Service[7] offers a two-week training cycle for wastewater personnel interested in obtaining a TCEQ Class-C license exam. Sequentially delivered courses, offered at a reduced tuition, are taught over a two week period.

Stream Flow and Dredging Action Areas

Flow Within the Canal Communities. Dredging of Canals With Beneficial Uses for Dredge Material and Partnership for Volunteer Planting

This measure refers to improving the flowing water in the various canal communities along Highland Bayou. Over time, the flow of water throughout the watershed has

[7] teex.org/

noticeably decreased according to stakeholders, they believe attributed in part to sediment accumulation. Differences in depths between the canals (17') and the bayou (4') result in "trapped" water in the canals, resulting in stagnant flow and eutrophic conditions. Multiple fish kills have been observed in these communities. Bayou Vista, to improve water flow in its canals, has installed SolarBee water mixers, what have proven expensive and delivered mixed results. In addition to contributing to the ecological health of the watershed, leaders in local communities have expressed a need to dredge for the benefit of recreational boating. As such, this action area may fulfill multiple priorities.

A principal action identified for this activity involves the removal of sediment build-up. Improved flow and tidal exchange may result in lower bacteria levels. Reducing sediments in these areas can provide secondary benefits. For example, excavated dredge material can be used to create living shorelines, restore habitats, and enhance natural vegetation, all of which can further contribute water quality benefits. The U.S. Army Corps of Engineers and Galveston County have completed multiple projects in recent years using dredged material for beach nourishment and shoreline restoration.

Organizations such as GBF, TPWD, GBEP, the Galveston County Consolidated Drainage District, and the USACE can partner with communities to remove dredge material and use it for sustainable purposes (refer to Element D for further information). Further, these organizations can assist in water quality studies and sediment reduction studies. USACE should be contacted prior to conducting and dredging and habitat restoration projects.

Encourage Living Shorelines as an Alternative Form of Shoreline Protection When Possible

This action refers to stabilizing the shoreline using native vegetation alone or in combination with offshore sills. Living shorelines provide a natural alternative to "hard" shorelines like stone sills or bulkheads and provide benefits including nutrient pollution remediation, fish habitat provision, and buffering of land from waves and storms. Living Shorelines are composed of materials such as wetland plants, soil, stone, oyster reefs, dredge material, submerged aquatic vegetation and other organic resources. Due to the aquatic make-up of these shorelines, they help to improve water quality by removing nutrients such as nitrogen and phosphorus from the water and even trapping sediments during storm events.

For areas along all bayous in the project area, and even in the canal communities, living shorelines around bank edges help reduce erosion and stabilize the shoreline. The use of this alternative approach has proven to be successful along the diversion canal in Hitchcock. GBF, along with community partners, graded the shoreline back from the waterline to plant smooth cordgrass; due to the low wave energy in this area

no hard structure was necessary. The result yielded beautiful vegetation, and prevention of coastal erosion.

GBF and its partners aid in project design, material selection, permit application, construction, plant selection and installation, and may even be available help identify grant funding opportunities. On average the creation of such projects from concept to completion averages from 5-7 years.

Review of Bulkhead Standards to Include Maintenance Enforcement

The installation of bulkheads on Highland Bayou is regulated by multiple local entities within the region. Cities such as the city of La Marque have ordinances for the design and construction of bulkheads. An inspection is conducted to test the integrity of the bulkhead and ensure it follows local codes. The code may include language stating the owner must "maintain" the installation. Such language is subject to interpretation by each individual person. For these reasons, bulkheads decline over time and fail to prevent erosion of sediment into waterways. One solution may require inspections to be conducted biannually, every five years, or on a timeline the local entity deems appropriate. For guidance, local jurisdictions should gather model ordinances and assess suitability for local adoption. Communities should also review their ordinances over time to assess effectiveness, and improvement areas.

Shoreline Protection for the Railroad South of Bayou Vista to Maintain Boat Access and Reduce Erosion

A berm located south of Bayou Vista is experiencing severe erosion from wakes created by passing boats. This berm not only acts as a buffer against the wakes, but it also supports railroad tracks. To maintain canal access for boaters and minimize erosion of the berm, a variety of solutions were discussed by stakeholders. Areas that would benefit from coastal erosion protection have multiple solutions that both solve the problem of erosion and benefit the environment. Texas Parks and Wildlife Department administers a Boating Access Grant that can potentially dredge an area and use the dredge material to fill low lying areas that are prone to flooding. Dredge materials can also be used to create living shorelines, but the site would need to be evaluated for suitability, as living shorelines are not always possible. Another solution mentioned by the stakeholder group is to use rip-rap materials to control erosion and fill the areas subject to flooding. Collaboration between multiple entities would be necessary, including Bayou Vista, MUD 12, the U.S. Army Corps of Engineers, Burlington Norther and Santa Fe Railway (BNSF), and natural resource agencies. The property belongs to MUD 12 and the railroad is operated by BNSF.

Combine Detention Areas Into Multi-Use Areas (Regional Stormwater Detention Facilities) Where Possible

Stormwater detention is a requirement for new development throughout the project area, except in limited instances. New development must provide detention of sufficient runoff volume to minimize the impact of the development in terms of

flooding. The majority of the Highland-Marchand Bayou Watershed falls within GCDD2, with a small part in the extreme northwest3 falling in Galveston County Drainage District No 1. South of the Highland Bayou main stem there is no separate drainage district, and Galveston County drainage rules apply. GCDD2 defers to Galveston County drainage rules, such that the entire Highland Bayou watershed is governed by Galveston County rules.

Regional stormwater detention refers to consolidating smaller, individual detention projects into larger, more extensive projects. Concentrating detention regionally provides more opportunity for better maintenance and many more opportunities for multiple uses of detention basins, such as athletic fields, playgrounds, and picnic areas. Larger detention facilities also enable the incorporation of SWW into the detention basins. SWW are one of the very best practices for cleaning polluted stormwater runoff. The well-designed SWW also adds a measure of beauty and ecology.

There is local recognition of the value of larger detention facilities. For example, regional detention is referred to as a policy preference in the Galveston County Consolidated Drainage District drainage manual. There is currently no known activity to push for regional detention in the project area.

The water quality impact of SWW is significant (Jacob et al, 2012; International Stormwater BMP Database, 2014). Bacteria (*E. coli*) removal can easily be as high as 80-90%. Nitrate nitrogenremoval frequently exceeds 70% (International Stormwater BMP Database, 2014). These numbers put SWW in the highest performing group of GI practices. A very important example of a multi-use detention facility that incorporates the full gamut of cleansing wetlands, nature trails, and athletic facilities can be found in the Exploration Green Park[8], now under construction in Clear Lake.

Urbanization and Development Action Areas

Pet Waste Ordinances and Bylaws

Municipal ordinances and HOA bylaws can provide an incentive for residents to dispose of pet waste properly. Common areas and parks are good areas to publicize these rules. Model ordinances are available online and should be reviewed by localities for suitability and opportunities to improve applicability. Together with these rules is the need for enforcement and willingness to follow through on penalties for violations.

Reduce the Population of Stray Animals

Reducing stray pet populations can decrease the bacteria that enter our local waterbodies. Registration requirements include spaying and neutering pets in Bayou

[8] www.explorationgreen.org

Vista, Hitchcock, La Marque, and unincorporated Galveston County. Many spay/neuter programs, including some shelters, offer a reduced price for these services. Stakeholder workgroup members can partner with local shelters and veterinarians to provide education on the benefits of spaying and neutering.

Encourage Water Conservation Through Education

Through the installation of rain barrels and rain gardens, and using native plants, residents can learn about outdoor water conservation, and its impact on polluted runoff. Communities interested in water conservation education can contact GBF and Texas A&M AgriLife TCWP. The TCWP's WaterSmart program has a track record of successful demonstration projects around Galveston County.

GBF's rain barrel workshop[9] highlights the environmental benefits of collecting rainwater, and proper rain barrel installation instructions and tips. Registration is $35, which includes one 35-gallon barrel + one connector kit, and workshop registration. Workshop participants can purchase a maximum of 2 barrels + 2 kits. Attendees are encouraged to ask questions and take advantage of the resources offered, which help improve water quality in Galveston Bay.

Effective Landscaping Practices Though Education

Improper management of landscaping debris, fertilizers, and pesticides was a prominent concern of stakeholders. These materials, in excess, lead to increased BOD and can contribute to fish kills, and there is a need for public education about water quality impacts associated with landscaping practices. Homeowner education for spraying pesticides (e.g. *Cutter*® Backyard™ Bug Control Spray and similar products) was specifically recommended by stakeholders, including, how much to use, when to spray in relation to rain events, and for the homeowner to consider nearby waterbodies. Education for lawn contractors was also brought up by stakeholders as essential to reducing the amount of the above-mentioned materials entering surface waters.

Stakeholders in the watershed will work with programs like WaterSmart, Grow-Green, and Earth-Kind Landscaping to provide materials to homeowners about proper application rates for fertilizer and pesticides. Resources for sustainable landscape management are also available through AgriLife Extension's Master Gardener and Master Naturalist programs, and TCWP. Soil nutrient tests are offered through AgriLife Extension for homeowners and landscape managers to utilize soil nutrient analysis to ensure proper fertilizer application rates.

[9] www.galvbay.org/rainbarrel

Install Educational Watershed Signage

Many residents do not know what a watershed is, and many are not aware they live in a watershed. Recognizing the connection between runoff entering our storm drains and how it impacts Galveston Bay can help residents and visitors recognize bayous as a valuable natural resource, promoting awareness and stewardship. Installation of educational watershed signage within parks, along watershed boundaries, and on roads can help promote awareness and educate citizens. Stakeholder workgroup members mentioned that including a map of the watershed, or pictures on signs could be positive ways to attract attention. Initial funding for watershed signage is only the first step. Maintenance and replacement issues were brought up by stakeholders as a potential barrier for this action area. The likely lead agencies for this effort are the municipal public works departments, Galveston County Parks and Cultural Services Department, the Galveston County Road and Bridge Department, and GCHD.

Discourage Illegal Dumping Through Education and Programs

Illegal dumping refers to the unlawful disposal of used tires, construction debris, appliances, vehicles, boats, and household, commercial and industrial waste in places other than permitted facilities such as landfills and transfer stations. Illegal dumping impairs water quality through the inflow of debris, chemicals, oils, and fuels that are hazardous to aquatic life and recreational uses. While illegal dumping is not necessarily a direct source of bacteria or nutrients, stakeholders expressed concern for litter near waterways and throughout the surrounding communities. According to stakeholders, problem areas for illegal dumping include vacant properties, dead end streets, the ditches along I-45, and within Highland Bayou Park.

To deter illegal dumping, municipal entities could establish a hotline, websites, social media platforms, or apps for residents to report illegal dumping. For example, GBF's Galveston Bay Action Network (GBAN) allows residents to report sightings of illegal dumping online or through a smart phone app, which are then relayed to the appropriate enforcement agency. Other prevention actions include installing signs with phrases such as, "No dumping," "Violators will be prosecuted," "Illegal dumping is a crime," "Do Not Litter," etc. Lead organizations can also use resources from the "Don't Mess with Texas Campaign" (see Element E for more information). During this planning process, stakeholders reported that although the installation of signs works in some cases, it can have the counter-intuitive result of encouraging dumping in those areas. Another approach to illegal dumping may involve collaborating with nonprofit organizations, municipalities, and state and county agencies to provide locations to dispose of materials properly. The city of Dickinson offers monthly tire recycling for any Galveston resident.

Trash Bash[10] is an annual event where thousands of volunteers gather along Texas waterways to do their part in cleaning up the environment by participating in the largest single day waterway cleanup in the state of Texas. The Virginia Point Peninsula Preserve is the Highland Bayou Trash Bash site and is located at the mouth of Highland Bayou just south of Bayou Vista.

Discourage Residential Waste From Entering the Environment or SSS

Residential waste includes solutions and compounds commonly found in homes and garages. This may include fuel, oil, paint, solvents, cleaners, detergents, fertilizers, pesticides, and in particular pharmaceuticals. Residents are known to pour these into lawns or gutters where they flow into nearby waterways, or down kitchen and bathroom drains into the collection system; once in the system, these wastes may find their way into the environment through SSOs, leaks or WWTF discharges. WWTFs and OSSFs are not designed to treat many of the waste items described here. Once dispersed into the watershed, residential waste can impair water quality, harm aquatic life and make contact recreation and fishing problematic. One frequent misconception is that pouring kerosene or gasoline on fire ant mounds is an effective ant control practice, when in fact that is not true.

This action area seeks to educate residents and provide options for the proper disposal of these items. Activities that can address residential waste include household hazardous waste collection events, stormwater inlet marking with phrases such as “Only Rain Down the Drain” and “Drains to the Bay,” public awareness campaigns and signs. The “National Take Back Prescription Initiative” is one of many take back programs offered to help decrease the occurrence of accidental poisoning, overdose, and abuse posed by unwanted prescription medicines. Ensuring proper disposal also keeps prescriptions from being flushed down the toilet making it through the sewage treatment process and into our waterways. Local police departments can join this campaign to offer an alternative for residents looking to clean out their medicine cabinets. There are several tire recycling events in Galveston County. Galveston County residents may drop off up to 5 tires for recycling at the Dickinson Public Works building located at 3120 Deats Road from 7–10:30 a.m., the first Friday of every month. This free service is not available for commercial disposal and residents must be able to load and stack tires into the recycling trailer. The city of Dickinson’s Public Works Department can be contacted with questions. H-GAC’s Residential Recycling[11] webpage has a list of places that you can drop off hazardous household waste.

[10] www.trashbash.org/

[11] recycleinfo.org/recycling-galveston-county.html

Improve Erosion Control Practices During Construction and Development

Construction and development activities usually disturb acres of soil surface, which can remain exposed for months or more. Disturbed surfaces include the construction pad, roads, maintenance yards, and newly excavated detention ponds. If not managed properly, erosion at these sites can transport significant sediment into drainage conveyances and eventually waterways. Erosion adds turbidity to the water column, and the accumulation of eroded sediment in waterways removes flow capacity and can harm habitat for aquatic species. As development encroaches into the watershed, particularly in the Highland Bayou headwaters (AUs 2424A_4 and 2424A_5) and Moses Bayou (AU2431A) the potential for sediment erosion is high. Drainage District 2 has observed and characterized soils in the watershed as highly erodible, and the district frequently has to manage sediment removal from their conveyances.

Construction erosion BMPs range from hydraulic seed spreaders to silt fencing and traps. The objective in these situations is to stabilize the surface or collect sediment via traps. Developments or common plans of development larger than an acre within regulated MS4 are subject to local ordinances governing erosion and sediment control during the construction phase. There are very few areas in the watershed that are unincorporated and fall outside of a regulated MS4. MS4 municipalities in the watershed have used a “model ordinance” approach when they adopted their local ordinance, and which do not prescribe specific practices. This approach can allow for flexibility and innovation, but it can also result in minimal compliance. As with all BMPs, effective erosion control BMPs comes down to proper installation and maintenance during the construction phase. Figure 54 was taken north of the Highland Bayou watershed in 2016. The practice shown is not being maintained and sediment is flowing freely into the stormwater collection system. While communities may inspect sites using municipal inspectors, this duty is usually outsourced to third-party, consultant enforcement and reporting, which is the case for communities in the project area.

Figure 53. Example of a failing stormwater BMP; photo taken just north of the Highland Bayou watershed.

There are opportunities for communities to recommend higher standards for erosion control BMPs and to form cooperative agreements for inspection and enforcement. Multiple violations may result in penalties until the violations are remedied by the developer or its contractors. Similarly, the MS4 program requires the inclusion of language for educating the public about stormwater and could form the basis for a municipally led outreach program relating to this action area. Also, the GBF's GBAN program provides an online tool for collecting reports of pollution in the area, and this tool could be used to report failing erosion control BMPs or observations of excessive erosion.

Evaluate Existing Stormwater Strategies for Education Needs and Opportunities to Collaborate

In the past, the Galveston County "stormwater collaborative" of public sector professionals would meet monthly at county offices to share knowledge and ideas about stormwater management and the Phase II regulatory program. The group is organized by the GCHD and is aware of this WPP effort through GCHD participation.

EPAs Phase II Stormwater rules came into force in 1999 and require that municipalities be responsible for regulating unpermitted discharges into their stormwater conveyances, or MS4s. Phase II requires that municipalities adopt ordinances and programs to address six areas of activity (minimum control measures), which relate to stormwater and several nonpoint source pollutants of concern and stormwater. Most communities in the project area have taken the approach of adopting a "model ordinance" which is usually generic and not tailored to local conditions or the

priorities of the communities that adopt them. Municipalities in the basin should revisit their stormwater and construction site ordinances to assess opportunities to update known weak points as understood through previous enforcement actions. This may mean enhanced inspection frequencies or clearer standards about erosion abatement practices.

Cooperative agreements or MOUs could be utilized by municipalities in the watershed and nearby watersheds such as Dickinson Bayou to pool limited resources to address issues common to all communities, such as education or the creation of construction site standards. Street sweeping is one activity that sometimes falls under a community's Phase II program, but the equipment can be costly to purchase and maintain under any one community's annual budget. One minimum control measure within the Phase II program is a requirement to have an outreach program to educate the public on stormwater and stormwater pollution. No communities in the basin are formally integrating existing educational programs offered by a range of entities such Texas A&M AgriLife Extension Service, TCEQ, GBEP, or H-GAC into their Phase II outreach programs. Even short-term activities such as storm drain inlet stenciling can provide an educational benefit and enhance a community's compliance with Phase II rules.

Agricultural/Wildlife/Land Management Action Areas

Participate in Feral Hog Hunting and Trapping Programs

In addition to hosting feral hog awareness and training workshops, stakeholders identified a need to promote feral hog hunting and trapping programs. Stakeholders suggested that sterilization or extermination is necessary to be truly effective. During this planning process stakeholders suggested developing a feral hog bounty program, which could include tracking how many hogs are killed. While this program should be implemented across the project area, stakeholders identified areas near Jack Brooks Park as being a high priority. Organizations or groups which could take the lead on this project include the Texas Youth Hunting Program, through Texas Wildlife Association. The Houston Chapter of the National Wild Turkey Federation may also be willing to host a feral hog hunting event. Other possibilities include hiring a consultant trapper for public property and private homeowners responsible for trapping on private land. There are state regulations that govern the transport of non-native species across county lines, and there are Galveston County restrictions on hunting and trapping in the county. The specifics of these rules need to be better understood by the watershed group when designing a hunting and trapping program.

Discourage the Public From Feeding Pigeons and Other Birds

Stakeholders have reported pigeons in large numbers throughout the canal communities in the lower reach of the Highland Bayou watershed. Pigeons are seen at bayou access points and nesting under boat houses. For instance, stakeholders

reported seeing large numbers of pigeons at Louis Bait Camp. Such a high volume of birds will inevitably contribute to the bacteria and nutrient load of the waterway through bird droppings. The presence of wild birds is natural and desirable, and it is appropriate to consider bacterial loadings resulting from wildlife as part of natural or ambient conditions, this is included in the proposed monitoring program described in Element I. To reduce the attractiveness for wildlife, food sources can be kept to a minimum by prohibiting feeding by the public and removing trash (Environmental Protection Agency, 2001). Stakeholders suggested an education program be established to inform the public about the harmful effects caused by feeding waterfowl, both on the environment and the overall health of their population.

Restore and Repair Riparian Zones

A riparian zone is the strip of land along a river or stream. It is a transition zone from land to water and captures the surface runoff from higher ground, filtering out sediment and nutrients before it reaches the waterway. Vegetation traps sediment before it reaches rivers, and stabilizes the shoreline, reducing erosion. Likewise, soil microbes that thrive in this moist environment break down chemical pollutants like hydrocarbons, further protecting water quality. Their natural functions can counteract the effects of polluted runoff from pavement and buildings, protecting water quality and the river channel itself.

There are several projects that can be done to restore and repair these zones. Projects identified during this planning process include:

1. restoring native vegetation during projects within riparian areas,
2. utilizing native plants for bank stabilization or capturing pollutants in storm water runoff,
3. hosting a riparian and stream ecosystem workshop in the watershed, and
4. Identifying property owners and providing assistance in evaluating their property for restoration projects.

The Texas Riparian and Stream Ecosystem workshop[12] is a free, one-day workshop through the Texas Riparian Association where Texas A&M AgriLife Extension Service co-presents with local watershed protection groups to provide stakeholders with classroom presentations and field demonstrations highlighting the hydrology, natural healthy riparian function and possible causes of riparian degradation.

GBEP has worked to restore and repair riparian zones in the region. GBEP recently partnered with city of League City to enhance and restore riparian areas within Clear Creek Nature Park – located next to the tidally influenced reaches of Clear Creek, a

[12] texasriparian.org/

tributary of Galveston Bay. Other potential partners include the Texas Riparian Association, USDA, U.S. Fish and Wildlife Service, TPWD, and TSSWCB.

Encourage Use of the Bayou by the Public as a Natural Resource Through Education
Stakeholders expressed an interest in seeing more swimming or direct contact recreation in Highland Bayou as they had in years past. Residents and visitors recognize Highland Bayou as a valuable natural asset to the community.

A few stakeholders expressed the "education of youngsters as being the most critical part" because children are more likely to incorporate what they learn into their daily lives. In addition, they will typically remind adults of the environmental impacts of their actions. Artist Boat offers youth eco-art workshops and kayak adventures[13] to student groups on bayous leading into Galveston Bay. Students on these field trips learn how their everyday actions on land can have a long-reaching impact on water quality and the health of the environment. The EPA supports environmental education projects that promote environmental awareness and stewardship through the Environmental Education Grant proposal process.

TPWD describes involving residents in outdoor recreation as a "critical component of conservation," citing numerous studies that confirm the connection between outdoor recreation and caring for natural resources. The TPWD provides 50% matching funds to municipalities, counties, MUDs, and other local units of government with a population less than 500,000 to acquire and develop parkland or to renovate existing public recreation areas.

BST and Wildlife Surveys
BST analysis[14] on ambient surface water samples is used to identify the animal species sources of fecal bacteria contamination in water samples. BST is a relatively new approach that compares water quality monitoring samples to a bacteria DNA library, which is prepared using known sources from within the watershed. This enables watershed planning participants to determine the most significant contributors of bacteria. Utilizing BST results was recommended by stakeholders to adjust implementation efforts and facilitate adaptive management during watershed planning.

GBEP has funded a BST analysis for bayous flowing into Galveston Bay and while none of the project area waterways are being sampled, this baseline study will provide local data at no cost to this project. The information gleaned from this study can be used to prioritize efforts targeting specific sources of bacteria.

[13] www.artistboat.org/
[14] texasbst.tamu.edu/.

After the GBEP study is completed and the data reviewed, stakeholders may decide to pursue BST analysis within the project area watersheds. A report describing the results of the BST analysis at the subwatershed level for the Highland Bayou Watershed was proposed with a focus on evaluating human sources (WWTPs, sanitary sewer collection systems), domestic animals (both pets and livestock), and feral hogs.

While BST analysis alone will not reduce bacteria entering the bayous, the information obtained can be used to prioritize efforts targeting specific sources. The recommended monitoring schedule included in Element I includes BST analysis to supplement existing sampling programs to assess progress towards attaining water quality standards during the implementation activities within the Highland Bayou Watershed.

Appendix D: Funding Sources

Federal

Agricultural Water Enhancement Program (AWEP)
Entity: NRCS

This program provides financial and technical assistance to agricultural producers to implement agricultural water enhancement activities on agricultural land to conserve surface and ground water and improve water quality. Eligible entities or organizations form multi-year partnership agreements with NRCS to promote ground and surface water conservation.

Eligibility: Individual producers are not eligible. Eligible partners include federally recognized Indian Tribes, States, units of local government, agricultural or silvicultural associations or other groups of such producers and other nongovernmental organization with experience working with agricultural producers. Agricultural land must be in AWEP approved project areas.

Funding limitations: Financial assistance changes every fiscal year depending upon appropriations and agency priorities.

Coastal and Estuarine Land Conservation Program (CELCP)
Entity: NOAA

This program provides financial assistance to purchase significant coastal and estuarine lands, or conservation easements on such lands, from willing sellers. Lands or conservation easements acquired under this program are to be protected in perpetuity due to their importance for their ecological, conservation, recreational, historical or aesthetic values.

Eligibility: Participants must be in a state that has developed a CELCP plan for NOAA approval. The Texas CELCP plan was approved in 2010. An eligible public entity such as local governments, state or federal agencies, institutions of higher education, or other authorities such as park districts must submit the project proposal. Projects must complement working waterfront needs and advance the goals, objectives or implementation of local coastal management plans in addition to the state's CELCP plan.

Funding limitations: The program funds up to $3M per project, which is matched 1:1 with nonfederal funds from the public entity participant. The budget for projects under this program may vary annually contingent on the fiscal year budget. NOAA maintains a contingency list of projects in case a project falls through, or additional

funds become available. Projects unable to be funded for a particular fiscal year will remain on the list until they are superseded.

Community Development Block Grants

Entity: States and local jurisdictions

This program is intended to address one or more of the following: benefit low- and moderate-income persons, prevention or elimination of slums or blight, or address community development needs having a particular urgency because existing conditions pose a serious and immediate threat to the health or welfare of the community for which other funding is not available.

Eligibility: Business, Community/Watershed Group, Nonprofit Groups, Educational Institution, Private Landowner, Water and Wastewater Utilities, Local Government, State/Territorial Agency

Funding limitations: Program uses formula allocations to determine grant amount to the state and local jurisdiction which allocate funds to community projects. A match is not required for this program. Funding is based on appropriations for the fiscal year.

Conservation Reserve Program (CRP)

Entity: NRCS

This program provides financial assistance to agricultural landowners in establishing approved conservation practices. The goals of the CRP program are to reduce water runoff and sedimentation, protect groundwater and help improve conditions of lakes, rivers, ponds and streams.

Eligibility: Agricultural landowners

Funding limitations: Eligible participants can receive annual rental payments based on the agriculture rental value of the land and cost-share assistance for up to 50% of the participants' costs in establishing approved conservation practices.

Environmental Education (EE) Grants

Entity: EPA

Under the EE Grants Program, EPA seeks grant proposals from eligible applicants to support EE projects that promote environmental awareness and stewardship and help provide people with the skills to take responsible actions to protect the environment. This grant program provides financial support for projects that design, demonstrate, and/or disseminate EE practices, methods, or techniques.

Eligibility: Applicants must represent one of the following types of organizations to be eligible for an EE grant: local education agency, state education or environmental

agency, college or university, nonprofit organization as described in section 501(c)(3) of the Internal Revenue Code, noncommercial educational broadcasting entity, tribal education agency (which includes schools and community colleges controlled by an Indian tribe, band, or nation). Applicant organizations must be in the United States or territories and most of the educational activities must take place in the United States; or in the United States and Canada or Mexico; or in the U.S. Territories.

Funding limitations: EPA has distributed between $2 and $3.5 million in grant funding per year, supporting more than 3,600 grants.

Environmental Quality Incentive Program (EQIP)

Entity: NRCS

This program provides financial and technical assistance to help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and nonindustrial private forestland. Funds may also be used to help develop conservation plans which are required to obtain financial assistance. This program also aims to help producers meet Federal, State, Tribal and local environment regulations.

Eligibility: Owners of land in agricultural or forest production or people who are engaged in livestock, agricultural or forest production on eligible land and that have a natural resource concern on the land may participate in EQIP. Limited resource farmers/ranchers, beginning farmers/ranchers, and socially disadvantages producers and tribes may be eligible for higher practice payment rates for the implementation of conservation practices and conservations plans.

Funding limitations: Financial assistance payments are based on a portion of the average cost associated with practice implementation. Financial assistance is awarded through contracts up to a maximum term of ten years in length. Participants are limited to a $300,000 total payment for all contracts within any six-year period. Projects deemed to have special environmental significance by the NRCS may be eligible to receive a maximum of $450,000.

Targeted Watersheds Grant Program

Entity: EPA

This program is intended to provide financial and technical assistance for projects designed to strengthen the participant's organization. The program will provide local organizations, tribal and local governments with skills and techniques to protect their urban waterways and promote more vibrant, economically sustainable communities. The EPA's purpose is to encourage successful community-based approaches to protect and restore the nation's watersheds.

Eligibility: Funding will be provided for projects designed to strengthen an organization's capacity building and ability to carry out programs to protect human health and the environment.

Funding limitations: Funding will range from $30,000-70,000.

WaterSMART: Cooperative Watershed Management Program

Entity: The Bureau of Reclamation

This program invites States, Indian tribes, irrigation districts, water districts, local governmental entities, nonprofit organizations, existing watershed groups, and local and special districts (e.g., irrigation and water districts, county soil conservation districts) to submit proposals for Phase I activities to establish or further develop a watershed group. Funding may be used to develop a mission statement, project concepts, and a restoration plan.

Eligibility: Task A—Establishment of a Watershed Group: States, Indian tribes, local and special districts (e.g., irrigation and water districts, etc.), local governmental entities, interstate organizations, and nonprofit organizations. To be eligible, applicants must also meet all the requirements listed in Sec. III.A, Eligible Applicants. Task B—Further Development of an Existing Watershed Group: In order to be eligible to receive an award to fund activities under Task B, the applicant must be an eligible entity as described immediately above for Task A, and must be either be: (1) An existing "watershed group," (i.e., a grassroots, nonregulatory legal entity that otherwise meets the definition of a watershed group as described in Section I.B., Objective of Funding Opportunity Announcement; or (2) a participant in an existing watershed group. See also Sec. III.A, Eligible Applicants.

Funding limitations: Up to $100,000 in Federal funds may be awarded to an applicant per award, with no more than $50,000 awarded in each year of the project. The period of performance shall not exceed two years.

Water and Environmental Programs

Entity: USDA

This program provides financial assistance for drinking water, sanitary sewer, solid waste and storm drainage facilities in rural areas and cities and towns of 10,000 or less. Technical assistance and training are also available to assist rural communities with their water, wastewater, and solid waste problems.

Eligibility: Public bodies, nonprofit organizations and recognized Indian Tribes

Funding limitations: Financial assistance is provided in various ways including direct or guaranteed loans, grants, technical assistance, research and educational materials.

Different amounts of assistance exist depending on the project type and financial tool the participant is seeking.

Wetlands Reserve Program
Entity: NRCS

This program provides technical and financial support to landowners with their wetland restoration efforts. The program aims to offer landowners the opportunity to protect, restore, and enhance wetlands on their property.

Eligibility: Lands that are eligible under this program include: wetlands farmed under natural conditions, farmed wetlands; prior converted cropland; farmed wetland pasture; certain lands that have the potential to become a wetland as a result of flooding; rangeland, pasture, or forest production lands where the hydrology has been significantly degraded and can be restored; riparian areas which link protected wetlands; lands adjacent to protected wetlands that contribute significantly to wetland functions and values; and wetlands previously restored under a local, State, or Federal Program that need long-term protection.

Funding limitations: Depends on fiscal year appropriations and agreement terms with NRCS.

State

Beach Maintenance Reimbursement Fund Program
Entity: TX GLO

This program aims to share the responsibility of maintaining public beaches between the Land Office and local governments.

Eligibility: TX GLO provides support to cities or counties bordering the seaward shoreline of the Gulf of Mexico and are qualified local governments with state financial assistance for the purpose of cleaning and maintaining public beaches

Funding limitations: Funds are reimbursed based on actual expenses. Seventy-five percent of the funds are allocated based on a proportionate share of participant expenditure during the previous two fiscal years preceding application. Twenty-five percent is allocated based on the proportionate share of linear footage of gulf beach cleaned or maintained.

Boating Access Grants
Entity: TPWD

This program provides 75% matching fund grant assistance to construct new, or renovate existing, public boat ramps that provide public access to public waters for recreational boating.

Eligibility: Local government sponsors must make an application, provide the land, provide access to the proposed boat ramp, supply 25% of the development costs, and accept operation and maintenance responsibilities for a minimum 25-year period. The grant funds for dredging, stump removal, and aquatic weed control can be shown to clear lanes to make water bodies more accessible primarily for recreational motorboats as opposed to general navigation. Retaining walls to protect the integrity of boat ramps and associated parking lots (limited to 200 feet on either side of constructed facilities). Engineering (planning and design), and environmental clearance and permit costs

Funding limitations: This grant program provides 75% matching grant funds for the construction of public boat ramp facilities throughout Texas.

Clean Water State Revolving Fund (CWSRF)

Entity: State of Texas

This program provides low-interest loans that can be used for planning, design, and construction of wastewater treatment facilities, wastewater recycling and reuse facilities, collection systems, storm water pollution control, nonpoint source pollution control, and estuary management projects.

Eligibility: The program is open to a range of borrowers including municipalities, communities of all sizes, farmers, homeowners, small businesses, and nonprofit organizations. Project eligibility varies according to each state's program and priorities. Loans for wastewater treatment plant projects are only given to political subdivisions with the authority to own and operate a wastewater system.

Funding limitations: The program offers fixed and variable rate loans at subsidized interest rates. The maximum repayment period for a CWSRF loan is 30 years from the completion of project construction. Mainstream funds offer a net long-term fixed interest rate of 1.30% below market rate for equivalency loans (project adheres to federal requirements) and 0.95% for nonequivalency (project adheres to state requirements) loans. Disadvantaged community funds may be offered to eligible communities with principal forgiveness of 30%, 50%, or 70% based upon the adjusted annual median household income and the household cost factor.

Coastal Impact Assistance Program (CIAP)

Entity: Bureau of Ocean Energy Management, Regulation and Enforcement and TX GLO

This program helps fund eligible projects that target one of the following: conservation, protection or restoration of coastal areas, including wetlands, mitigation of damage to fish, wildlife, or natural resources, planning assistance and the

administrative costs of complying with this section, implementation of a federally approved marine, coastal, or comprehensive conservation management plan, and mitigation of the impact of development along the Outer Continental Shelf through funding of onshore infrastructure projects and public service needs.

Eligibility: State, federal agencies, along with universities (public or private), county and local governments, other state subdivisions and nonprofit organizations.

Funding limitations: Funds for this program may only be granted to the 18 Texas coastal counties of Orange, Jefferson, Chambers, Harris, Galveston, Brazoria Matagorda, Jackson, Calhoun, Refugio, San Patricio, Nueces, Kleberg, Willacy, and Cameron. After the review process and approval, the TX GLO will contract with vendors or sub-grantees to perform projects. Project expenses are reimbursed after they are incurred. Funding advancements may be allowed only under special conditions.

Economically Distressed Areas Program

Entity: TWDB

This program provides financial assistance for water and wastewater services in economically distressed areas where the present facilities are inadequate to meet residents' minimal needs. The program also includes measures to prevent future substandard development.

Eligibility: Projects must be in an area that was established as a residential subdivision as of June 1, 2005, have an inadequate water supply or sewer service to meet minimal residential needs, and a lack of financial resources to provide water supply or sewer services to satisfy those needs. All political subdivisions, including cities, counties, water districts, and nonprofit water supply corporations, are eligible to apply for funds. The applicant, or its designee, must be capable of maintaining and operating the completed system.

Funding limitations: Financial support is in the form of a grant or a combination of a grant and a loan. The program does not fund ongoing operation and maintenance expenses, nor does it fund new development.

LIP

Entity: TPWD

This program offers project cost-sharing for projects that positively impact the riparian areas and watersheds in Texas. Projects showing the greatest benefit to targeted watersheds will receive priority as do projects offering long-term protection, long-term monitoring and greater than the required minimum landowner contribution.

Eligibility: Eligible parties include private, nonfederal landowners wishing to enact good conservation practices on their lands in targeted ecoregions. Targeted ecoregions may change from year to year.

Funding limitations: Contracts will require a minimum of 25% landowner contribution (in-kind labor, materials, monetary, etc.).

Recreation Grant Program-Boating Access Grant
Entity: TPWD

This program provides financial assistance in the construction of public boat ramp facilities throughout Texas.

Eligibility: Local government sponsors must make an application, provide the land, provide access to the proposed boat ramp and accept operation and maintenance responsibilities for a minimum 25-year period.

Funding limitations: Local government sponsors must provide 25% of the development costs. The grant program provides 75% matching grant funds of the construction costs.

Recreation Grant Program-Boat Sewage Pump out Grant
Entity: TPWD

This program offers financial assistance for the construction and/or renovation, operation, and maintenance of pump out and portable toilet dump stations.

Eligibility: Private marinas and local governments are qualified for this grant.

Funding limitations: Funds for this program are distributed on a first-come, first-served basis and can constitute up to 75% of all approved project costs. Participants may charge a maximum fee of $5.00 to cover use and maintenance costs.

Regional Water Supply and Wastewater Facilities Planning Program
Entity: TWDB

This program provides funds for studies and analyses to evaluate and determine the most feasible alternatives to meet regional water supply and wastewater facility needs, estimate the costs associated with implementing feasible regional water supply and wastewater facility alternatives, and identify institutional arrangements to provide regional water supply and wastewater services for areas in Texas. All proposed solutions must be consistent with applicable regional or statewide plans and relevant laws and regulations. A water conservation plan must be included in the proposed plan.

Eligibility: Political subdivisions, such as cities, counties, districts or authorities created under the Texas Constitution with the legal authority to plan, develop, and operate regional facilities are eligible applicants. Additional applicants include any interstate compact commission to which the State is a party, and any nonprofit water supply corporation created and operating under Texas Civil Statutes Article 1434a.

Funding limitations: Funds are in the form of grants. Applicants must provide evidence of local matching funds on or before the date specified for negotiation and execution of a contract. Funds are generally limited to 50% of the total cost of the project, except that the board may supply up to 75% of the total cost to political subdivisions under certain conditions. Funds will be released only as reimbursement of costs actually incurred for approved activities. In-kind services may be substituted for any part of the local share if certain criteria are met.

TCEQ 319 Grant

Entity: TCEQ and TSSWCB

This program provides funds for activities that prevent or reduce nonpoint source pollution. Proposed projects should focus on agricultural and/or silvicultural nonpoint source pollution prevention and abatement activities within the boundaries of impaired or threatened watersheds. Specific activities that can be funded include development of nine-element watershed protection plans including the formation and facilitation of stakeholder groups, surface water quality monitoring, data analysis and modeling, implementation of nine-element watershed protection plans and the nonpoint source portion of total maximum daily load implementation plans, demonstration of innovative best management practices, technical assistance to landowners for conservation planning, public outreach/education, and monitoring activities to determine the effectiveness of specific pollution prevention methods.

Eligibility: All state agencies or political subdivisions of the State of Texas including cities, counties, school districts, state universities, nonprofit organizations, and special districts can apply for funding. Private organizations may participate in projects as partners or contractors but may not apply directly for funding.

Funding limitations: Grants are awarded annually and funds projects for up to three years.

Texas Clean Rivers Program

Entity: TCEQ

The program's main purpose is to develop partnerships to provide quality-assured data to TCEQ for use in decision-making, identification and evaluation of water quality issues, promote cooperative watershed planning, recommend management strategies, inform and engage stakeholders and adapt to changing priorities.

Eligibility: Partnerships range from river authorities, other agencies, regional entities, local government, industry and citizens. TCEQ provides most of the funding for conducting the monitoring, quality assurance, and data management functions of the program.

Funding limitations: Unknown

CMP
Entity: TX GLO

This program, funded by NOAA, is designed to ensure long-term environmental and economic health of the Texas Coast. The program has funded a wide variety of coastal management activities but has also developed the following categories for use of these funds: coastal natural hazards response, critical areas enhancement, Public Access, Waterfront Revitalization and Ecotourism Development, Permit Streamlining/Assistance, Governmental Coordination, Local Government Planning Assistance, and Water Sediment Quantity and Quality Improvements.

Eligibility: State and Local

Funding limitations: For on-the-ground habitat protection, restoration and land acquisition projects, eligible entities can expect up to $400,000 for individual large-scale projects and up to $100,000 for small-scale projects. Local Match must be 40% of the total project cost for this cycle. Match may be in the form of a “cash” match or an “in-kind” match or a combination of both.

Texas Farm and Ranch Lands Conservation Program (TFRLCP)
Entity: TPWD

TFRLCP was established by the Texas Legislature in 2005 with the purpose of conserving working lands with high values for water, fish and wildlife, and agricultural production, especially lands at risk of development. TFRLCP maintains and enhances the ecological and agricultural productivity of these lands through Agricultural Conservation Easements.
Eligibility: State and Local
Funding limitations: Unknown

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