Watershed Protection Plan For Highland Bayou, Highland Bayou Diversion Canal, Marchand Bayou, Moses Bayou, And Unnamed tributary of Moses Lake

---

Highland Bayou 2424A
Marchand Bayou 2424C
Highland Bayou Diversion Canal 2424G
Moses Bayou 2431A
Unnamed Tributary of Moses Lake 2431C

Funded By:

Texas Commission on Environmental Quality
TCEQ Grant Agreement 582-19-90214

Galveston Bay Estuary Program
17041 El Camino Real, Ste. 210
Houston, Texas 77058

Prepared By:

Texas Community Watershed Partners
Texas A&M University
1335 Regents Park Dr., Suite 260
Houston, Texas 77058

Draft Version Date: November 2019

The preparation of this report was financed through grants from the U.S. Environmental Protection Agency through the Texas Commission on Environmental Quality.

Acknowledgements

The Texas Coastal Watershed Program would like to thank and acknowledge the many individuals who have contributed to this Watershed Protection Plan. Their participation is the backbone of the plan. Entities include, in alphabetical order: Artist Boat, City of Bayou Vista, City of Hitchcock, City of La Marque, Galveston Bay Estuary Program, Galveston Bay Foundation, Galveston County, Galveston County Drainage District No. 2, Galveston County Engineering Department, Galveston County Health Department, Galveston County MUD 12, Galveston County Parks and Cultural Services Department, Galveston County Road and Bridge Department, Hitchcock Industrial Development Corporation, Texas A&M University, Galveston County AgriLife Extension Service, Texas Commission on Environmental Quality, Texas Parks and Wildlife Department, Texas Sea Grant, Texas State Soil and Water Conservation Board, U.S. Army Corps of Engineers Galveston District, University of Houston Coastal Center, and Water Control and Improvement District No. 19.

Highland Bayou WPP Project Team: Texas Community Watershed Partners
Steven Mikulencak, Celina Lowry, Amanda Solitro Ashcroft, Yu Wen Chou, Rebecca Davanon, Valeria Rodriguez Keese, Charriss York.

Executive Summary

Watershed Protection Plan For Highland Bayou, Highland Bayou Diversion Canal, Marchand Bayou, Moses Bayou, And Unnamed tributary of Moses Lake

Prepared by the Texas A&M University AgriLife Extension Service's Texas Community Watershed Partners
In Cooperation with the Galveston Bay Estuary Program
Grant No. 582-19-90214

Table of Contents

Table of Tables

Table of Figures

List of Acronyms

µg/L- micrograms per liter

ALU- Aquatic life uses

AU- Assessment Unit

AVMA- The American Veterinary Medical Association

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

CFU- Colony Forming Units

CHARM- Community Health and Resources Management

CN- curve number

CWA- Clean Water Act

DO- Dissolved Oxygen

DOI- U.S. Department of the Interior

DU- Dwelling Units

DUA- Dwelling Units per Acre

EMC- event mean concentration

EPA- U.S. Environmental Protection Agency

FOG- Fats, Oils, and Grease

GBAN- Galveston Bay Action Network

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
KAST-Kills and Spills Team
Lbs- pounds
LU- Land Use
LULC- Land use/Land Cover
mg/L- milligram per liter
MGD- million gallons per day
mL- milliliter
MOU- management/ maintenance agreement
MS4- Municipal Separate Storm Sewer Systems
MUD- Municipal Utility District
NA- Not Assessed
NOAA-National Oceanic and Atmospheric Agency
NPS- Non-Point Source
NRCS- Natural Resource Conservation Service
OSSF- Onsite Sewage Facility
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
TMDL- Total Maximum Daily Load
TPDES- Texas Pollutant Discharge Elimination System
TPWD- Texas Parks and Wildlife
TSS- Total Suspended Solids
TSSWCB- Texas State Soil and Water Conservation Board
TSWQS- Texas Surface Water Quality Sampling
TWDB- Texas Water Development Board
TX GLO- Texas General Land Office

UH- University of Houston

UHCC- University of Houston Coastal Center

UID- Unique ID Number

US HUD-US Department of Housing and Urban Development

USACE- U.S. Army Corps of Engineers

USDA- U.S. Department of Agriculture

USEPA- U.S. Environmental Protection Agency

USFWS- U.S Fish and Wildlife Service

USGS- U.S. Geological Survey

WCID- Water Control and Improvement District

WPP- Watershed Protection Plan

WQMP- Water Quality Management Plans

WWTP- Waste Water Treatment Plant

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 of activities that will have a positive impact on the area's water quality. An 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.

What is a Watershed?

A watershed is the 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 in to the bayou.

Project Area

The Highland Bayou, Highland Bayou Diversion Canal, Marchand Bayou, Moses Bayou, And Unnamed tributary of Moses Lake watersheds are located in Galveston County's southern mainland within the larger Highland Bayou Coastal Basin (Figure 1). The basin is bounded on the north by Dickinson Bayou, and on the west by Halls Bayou. Waterways within the basin drain eastery 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 1). The Highland and Marchand bayous watershed covers almost 23 square miles of land. Both bayous are listed by

TCEQ for water quality impairments from high bacteria levels and low dissolved oxygen (DO) levels.

The Highland Bayou Diversion Canal was constructed in the 1970's, 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. It is listed by TCEQ for water quality impairments from high bacteria levels.

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. It is listed by TCEQ for water quality impairments from high bacteria levels.

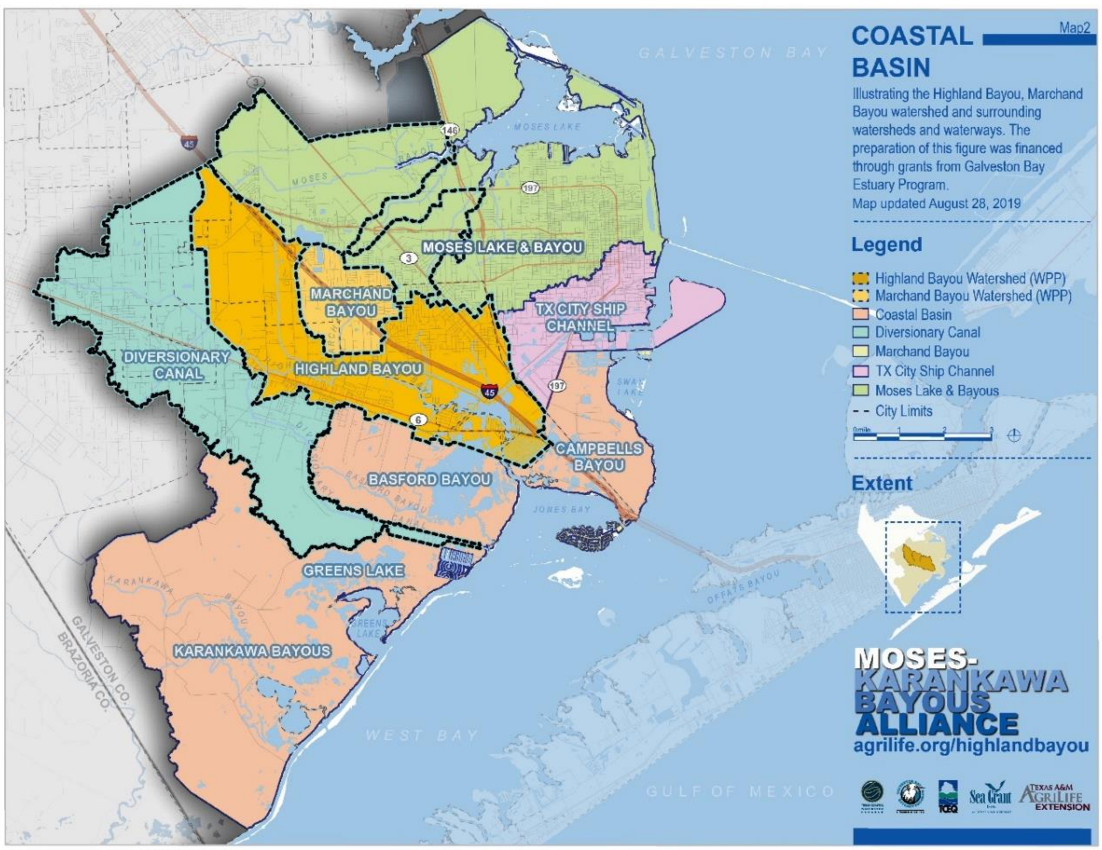


Figure 1. Map of the Highland Bayou coastal basin.

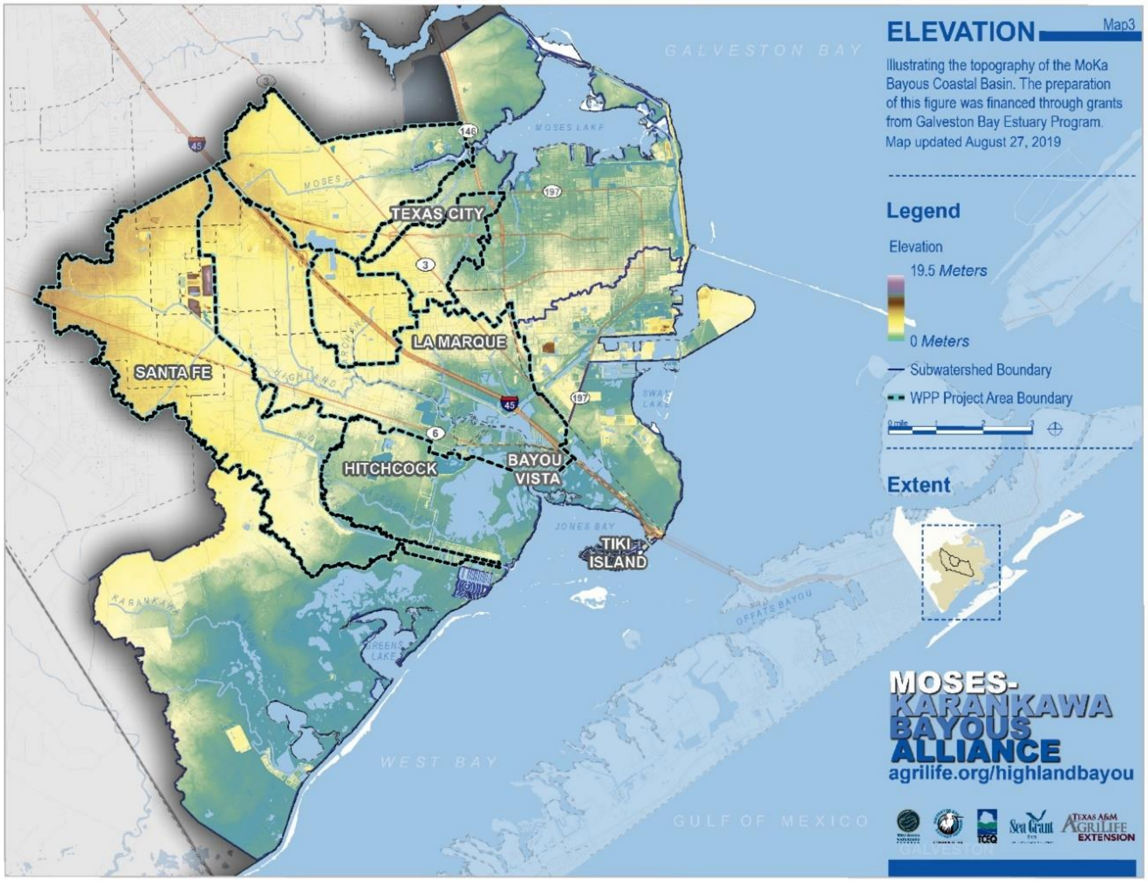


Figure 2. Elevation in the Highland Bayou Coastal Basin

Within the study area, the topography is flat (Figure 2) 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).

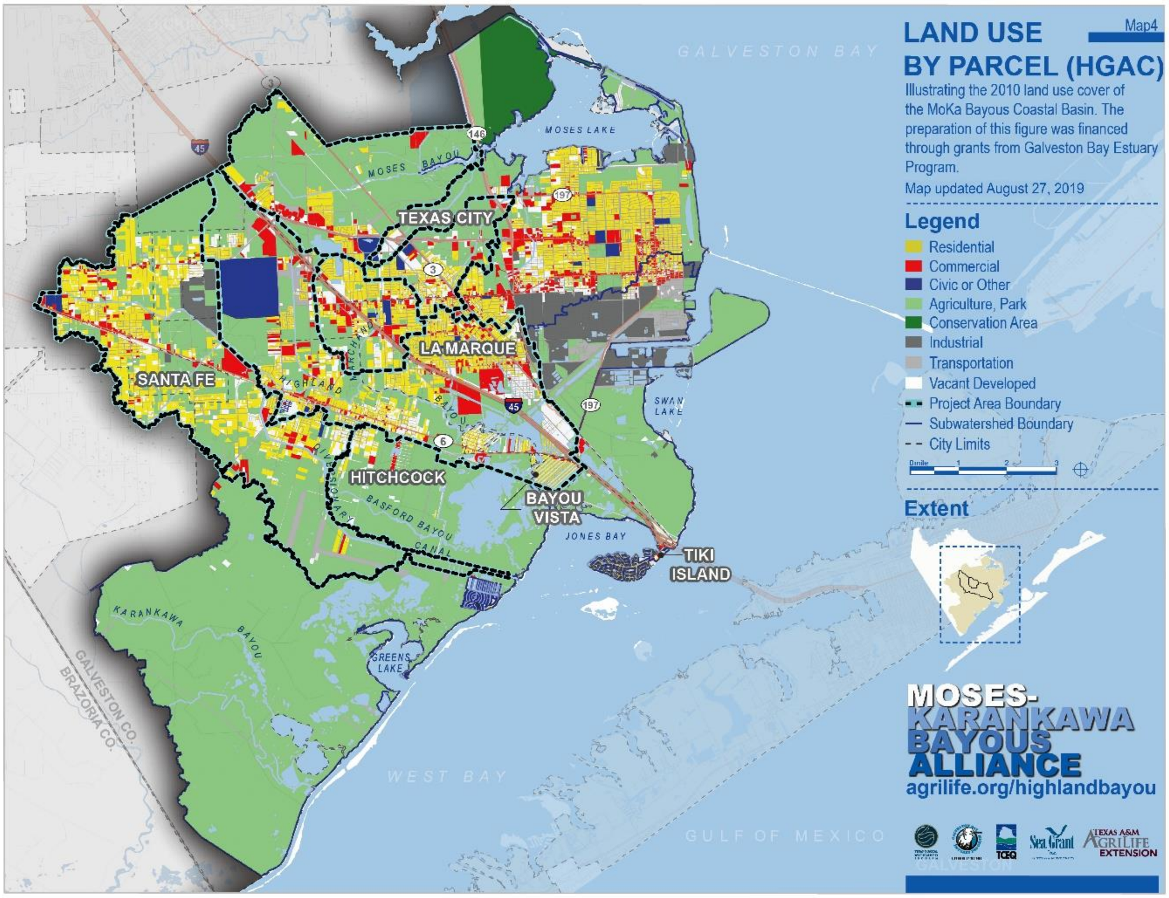


Figure 3. Parcel Land Use for the Highland Bayou Coastal Basin

In 2012, The Highland Bayou Watershed Characterization Report 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. The report is available online at agrilife.org/highlandbayou.

Elements of a Successful WPP

The US EPA identified nine elements as critical pieces of a watershed protection plan to achieve water quality improvements. A Watershed Protection Plan must address these elements before it can be approved by the US EPA and thus be eligible for Clean Water Act section 319-funded projects (Environmental Protection Agency, 2008), along with other funding sources.

Table 1. EPA Nine Elements of a Watershed Protection Plan

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 the 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 is reasonably expeditious. For this plan, a 10 year time horizon is used for load reduction estimates.
Element G**. Milestones**	Prepare interim measureable 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 being achieved over time and 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 included in Element E. This group identified and shared their concerns along with specific projects and project ideas that are the basis for this plan.

Regulatory Standards and Water Quality

All major waterbodies in Texas are classified by TCEQ into basins and segments. All waterbodies for this Plan are in Basin 24, 'Bays and Estuaries,' which includes all Texas bayous and inland surface waters that are tidally influenced through 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 further divided by TCEQ into assessment units (AUs), the smallest unit of analysis used by TCEQ to assess water quality. AUs for the project area are listed in Table 2. The catchment areas defined by these AUs are depicted in Figure 4.

Stream segments are assigned a designated use and an associated water quality standard. The primary use for waterways in the waterbodies in the Plan 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* (Texas Commission on Environmental Quality, 2010a). When an evaluation of water quality samples results in a set number of exceedances, the agency determines that the segment has failed particular water quality standards. Water quality assessments are based upon a rolling 7-year period, and it is updated every two years. The latest assessment was released in 2014. Water quality sampling events must be taken from at least two years, and no more than two-thirds of the samples can be assessed from any one year. A minimum of ten samples are needed to calculate a use attainment, although smaller sample sizes can be considered.

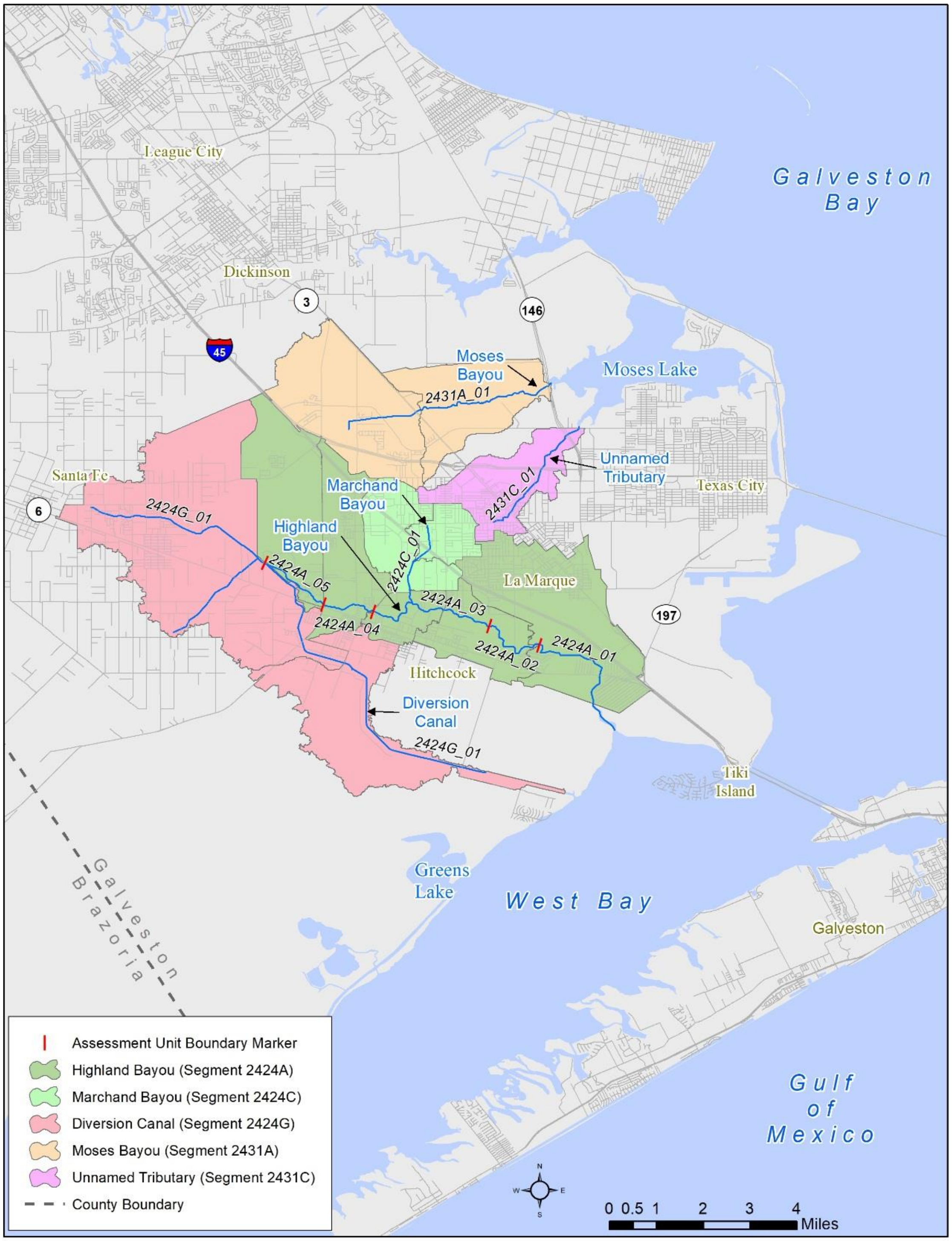


Figure 4. Project watersheds and TCEQ assessment units in the Highland Bayou Coastal Basin

303(d) Listing

The federal Clean Water Act (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. TCEQ publishes the Texas 303(d) list in the *2014 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). According to the 2014 Texas Integrated Report, Highland Bayou (2424A)—AUs 2-5—have been listed on the 303(d) list since 2002. Marchand Bayou (2424C_01) was also first listed in 2002. Highland Bayou segment 2424A_01 is listed as 'concerned' for low DO. The reason for the listing is depressed levels of DO and elevated levels of bacteria. The listed causes for the impairment are 'NPS' (EPA code 141) and 'Urban Runoff/Storm Sewers' (EPA code 177), and 'Source Unknown' (EPA code 140).

Table 2. Assessment Unit and assessment from the 2014 Integrated Report

Assessment Unit	Contact Recreation	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

Highland and Marchand Bayous 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 NPSs such as sewage collection systems, pet waste, urban runoff, and wildlife. These sources are described in 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 US (Environmental Protection Agency, 2000).

Many species of bacteria in contaminated water but not all can be measured or counted. Water quality analysts test 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 colony forming units (CFU) per 100 mL for *E. coli* in freshwater segments and 35 cfu per 100 mL for *Enterococcus* for saltwater segments (Texas Commission on Environmental Quality, 2010b)(Texas Administrative Code §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 ingesting some water.

Pollutants of Concern - Low Dissolved Oxygen and Nutrients

Low Dissolved Oxygen

Oxygen levels are a measure of the 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 of time, 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 Dissolved Oxygen Correlated to Nutrients and Other Phenomena

It is highly likely that NPS is a factor explaining observed levels of oxygen. Nutrients including nitrates and phosphorous 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 the growth of algae and other plant life in the water. In turn, the eventual decay of the algae starts a chemical process that consumes 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, phosphorous, and nitrogen. For example, algal blooms, which can be observed as a milky green coloration in the water, is indicated as 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 uses phosphate as a growth nutrient, phosphate levels decline during summertime algae blooms and rebound during the cool season. This indicates that algae is consuming phosphorous 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 phosphorous 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 phosphorous, 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 Phosphorous. Phosphorous 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 phosphorous. Total phosphate includes organic P, precipitates, colloidal phosphorous, and phosphorus adsorbed to suspended solids and sediment. Soluble forms of phosphorous 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 phosphorous to move through the environment, but phosphorous adsorption to the surfaces of suspended solids may account for a sizable portion of phosphorous 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 phosphorous promotes excessive plant growth. Sources of phosphorous 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 phosphorous. Excessive growth of algae can result in eutrophication and cause fish kills. High levels of chlorophyll can arise from anthropogenic sources of nitrogen and phosphorous.

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.

Element A: Identify Sources of Impairments and Loads

Stormwater Runoff is a fingerprint of the land

Water pollutants originate from both point and NPS 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 NPS 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 NPS is commonly understood to include fertilizers, insecticides, oils, sediment, and bacteria. Each NPS source might be small, but when considered together, they can exceed the pollution contribution from point sources. In fact, in many watersheds around the county, NPS 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 A-1). 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 pre-development runoff levels. As the amount of impervious surface cover increases in the watershed, the water quality of receiving water bodies degrades. Two neighboring properties, one developed and one undeveloped, both 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.

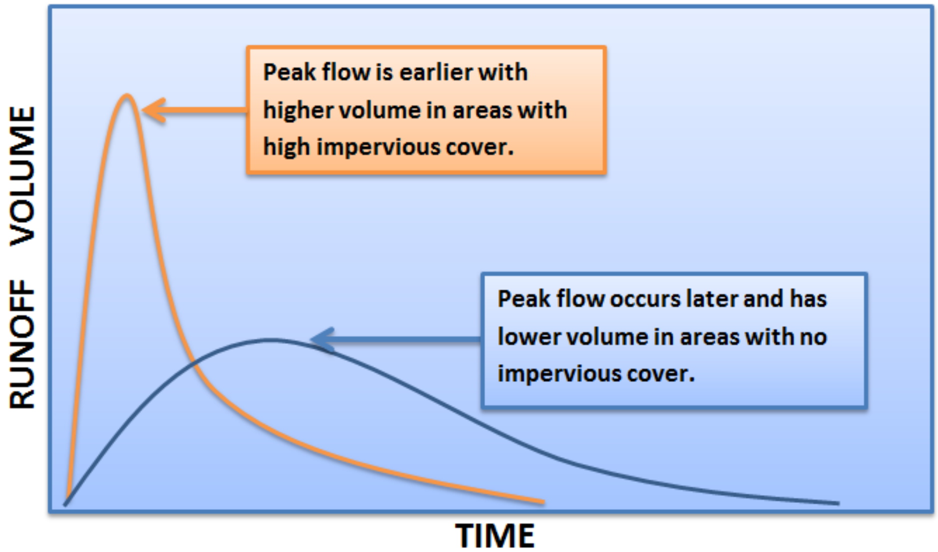


Figure 5. Generalized Hydrograph of Areas With and Without Impervious Surface Cover

The Origin Denotes the Rainfall Event

Stakeholder concerns about water quality were gathered and can be grouped into for categories: wastewater, flow & dredging, urbanization & development, Agriculture/wildlife/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 improved flow and flushing could have a positive impact on its water quality. The following table summarizes NPS sources that stakeholders discussed as likely contributors of NPS loads in the watershed.

Table 2. Pollutants by Source

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

There are four permitted wastewater treatment facilities in project area. (Map-11). 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 6 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 7-31-2012 and 7-31-2015. Effluent measurements in Table A-2 are reported for the 2014 calendar year to ensure a complete dataset (at the time of the request, November and December 2015 data was unavailable). The *Enterococci* daily maximum threshold was exceeded during only on month for both the City of Hitchcock and Galveston County MUD 12. Other effluent parameters remain within discharge limits: nitrogen (ammonia total, as nitrogen), biochemical oxygen demand, and flow.

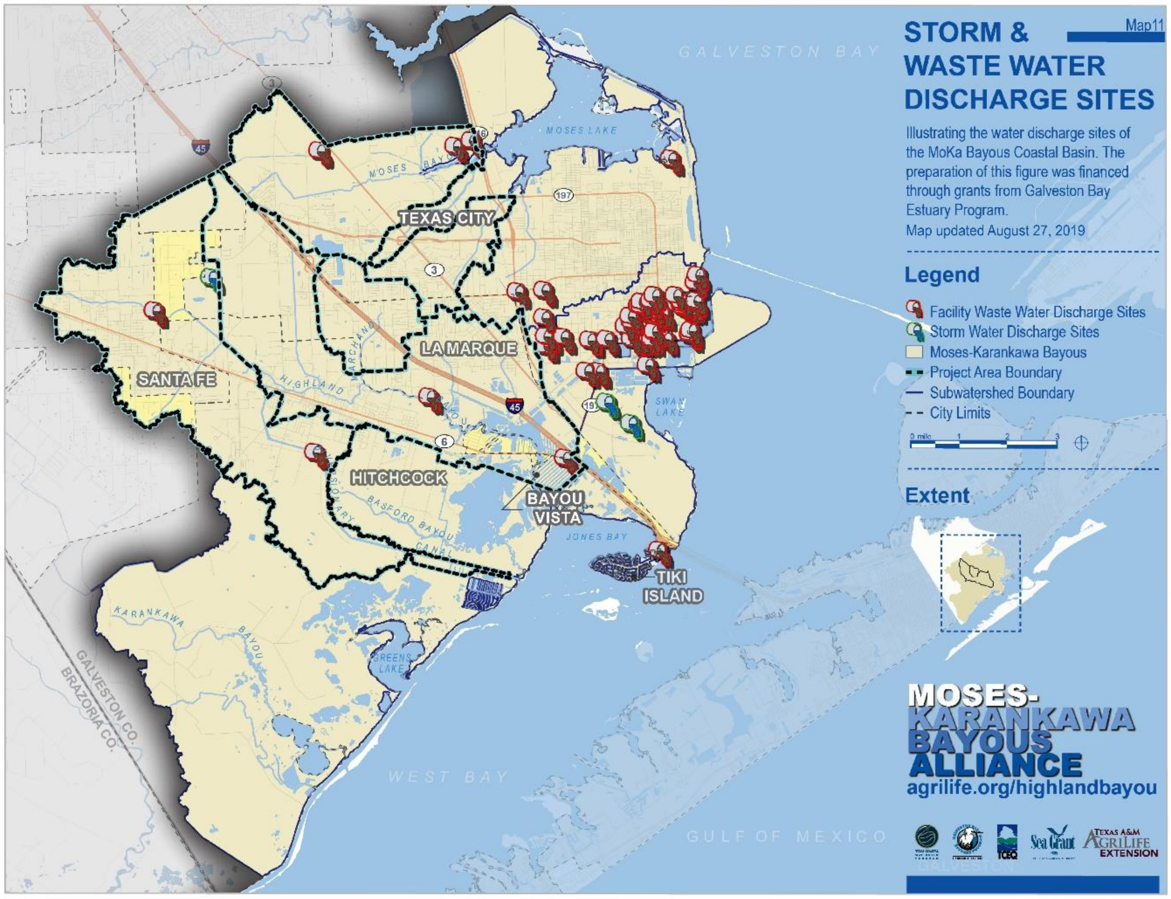


Figure 6. Storm and Wastewater Discharge Sites

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 recent as 2015. For the City of La Marque in FY2015, 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.

Sanitary Sewer Systems

Collection systems bring sewage from home and businesses to wastewater treatment facilities. 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 pro-rated share of population in each watershed AU.

Septic Systems

Onsite Sewage Facilities (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 draining into the Diversionary Canal. OSSFs are scattered throughout the rest of the project area in small numbers but not are 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 TX Highway 6 in the parts of unincorporated Galveston County, referred to as Freddiesville and Old Highland Bayou, just west of Bayou Vista. 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 non-performing. 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 1970's, 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 in. Most soils in this watershed have shallow water tables and low permeability (Map-13). 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.

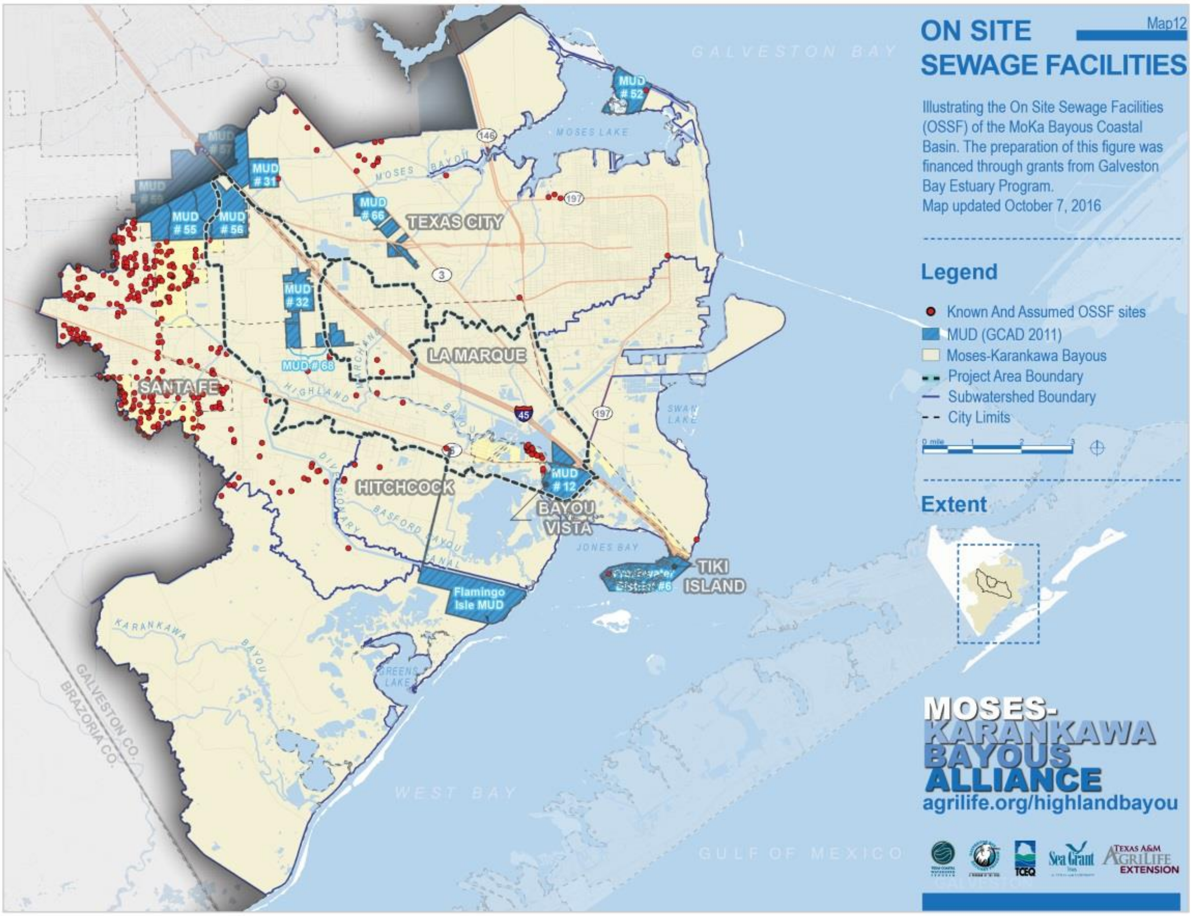


Figure 7. Onsite Sewage Facilities

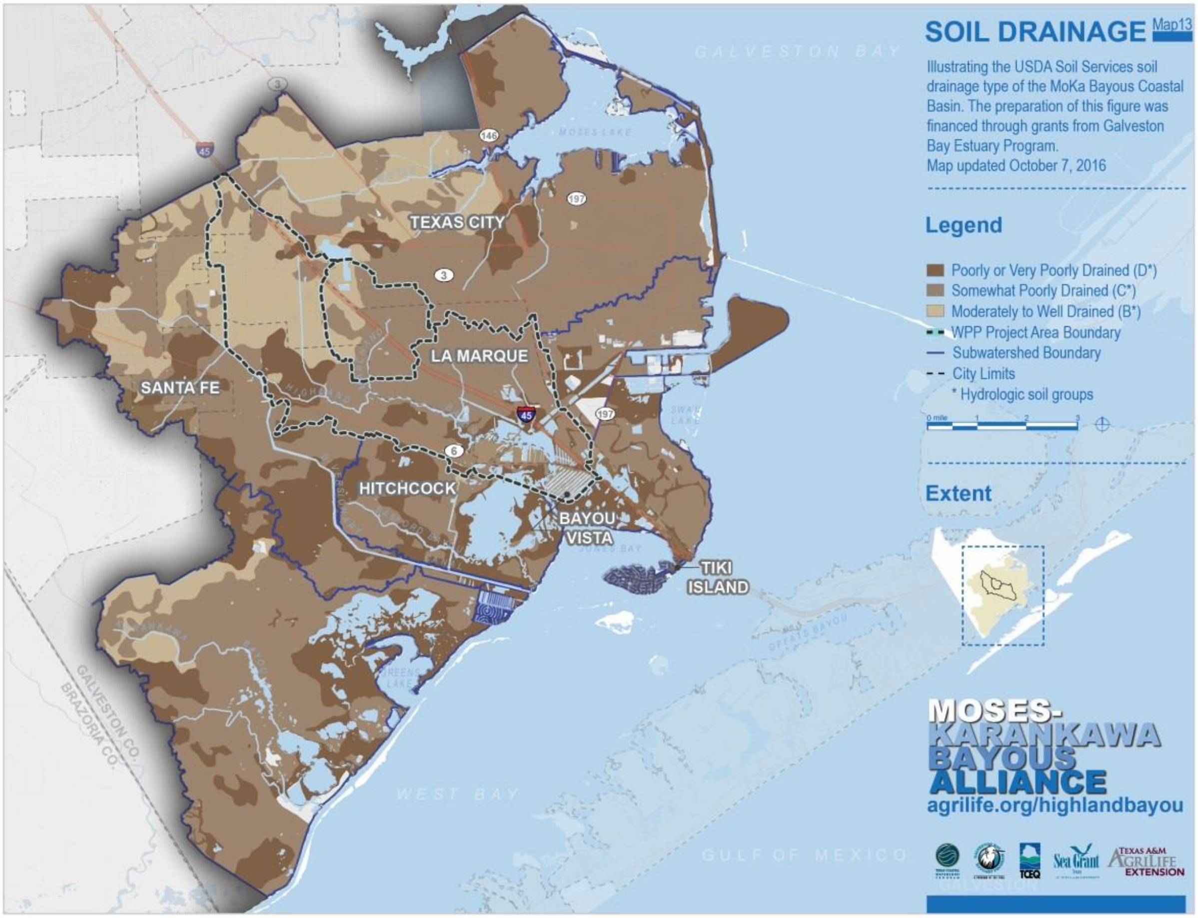


Figure 8. USDA Soil Services Soil Drainage Types

Table 4 includes the number of permits issued by year. (Source: Martin Entringer, Galveston County Health District in 2008.)

Table 3. 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 NPS a pollutant ‘source,’ however it may impact loading characteristics in Highland bayou. Changes in this watershed since the 1970’s 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 US Army Corps of Engineers in the early 1970’s. 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 headwaters 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 NPS 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, the impact of construction activities are still likely impacting 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. It has also been directly observed by the project team 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 I-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 are 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 and brings with it 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 10). Since the Highland and Marchand Bayou watershed includes 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.

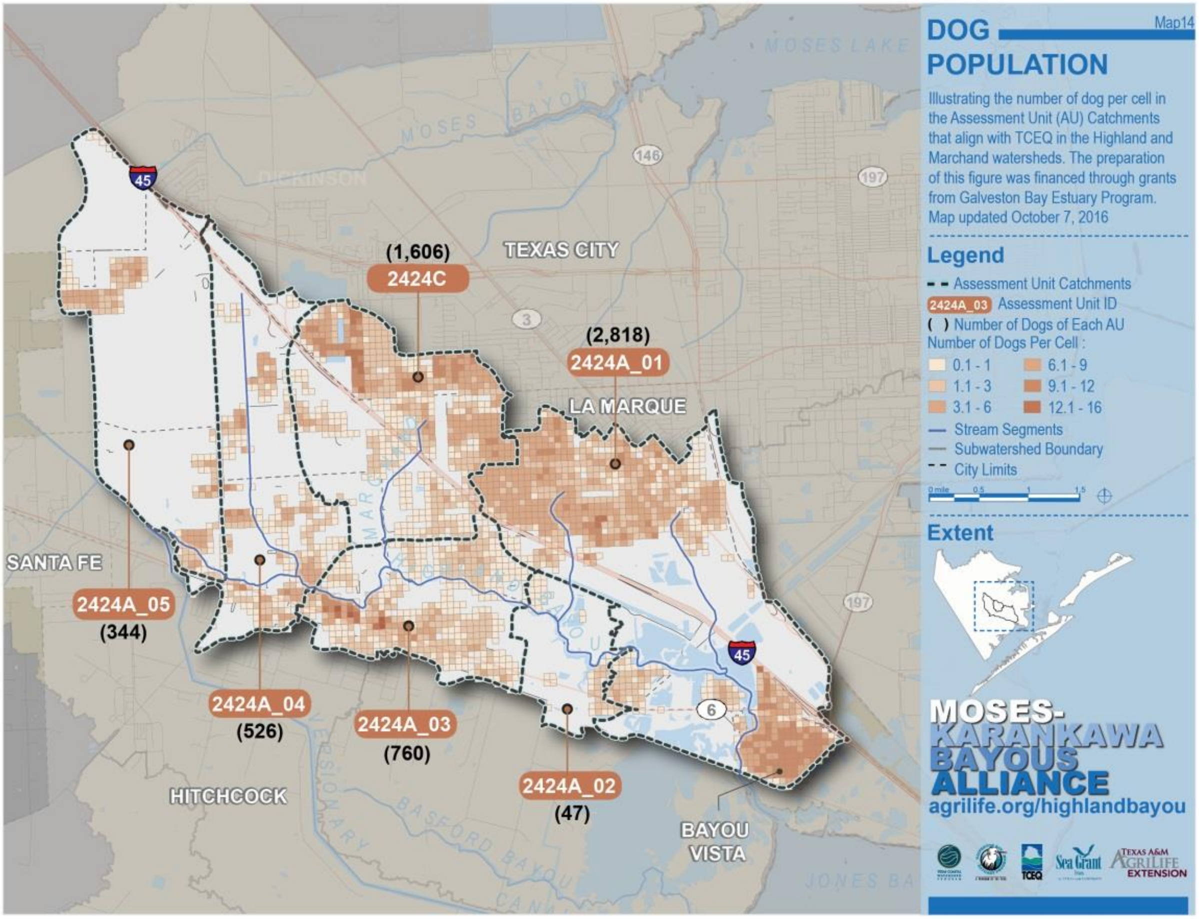


Figure 9. Dog Population in the MoKa Coastal Basin

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 NPS load in developed areas.

Urban Stormwater: MS4

MS4s Phase II regulations began in 1999 to regulate the management of NPS 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 A-4 below. MS4 permittees must address 6 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 4. 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 11 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 taxing purposes, but it can also inform an analysis for 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 NPS pollution is generated in each subbasin- this is the approach utilized for NPS 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.

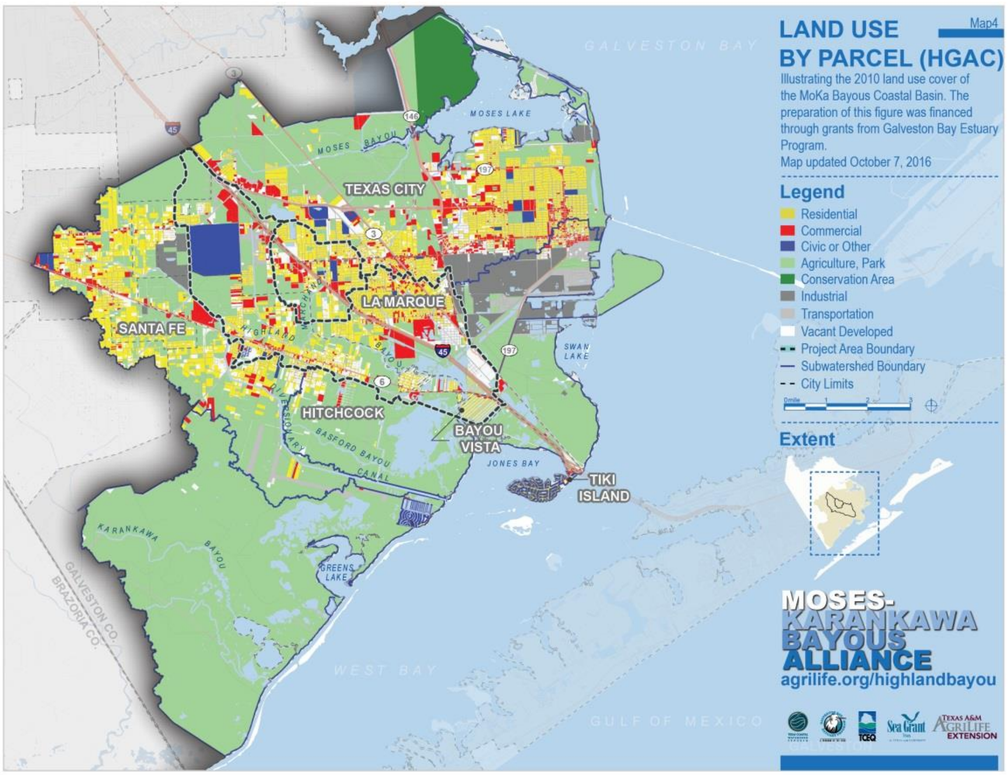


Figure 10. 2010 Land Use Cover of the MoKa Coastal Basin

Urban Stormwater: Land Cover & Impervious Surface

A land use-land cover change analysis was performed as part of this WPP effort, 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. Maps and full tables of the analyses are included in Appendix 2, LULC Analyses. Table 6 shows the increase in developed acreage in the Highland Bayou watershed over a 14-year period. Impervious surface cover is the most important factor concerning land use changes and water quality indicators.

Table 5. Increase in Developed Land, Highland and Marchand Bayous, 1996-2010

Watershed	Acres developed 1996	Acres developed 2010	Relative % increase	Increase as a % of the watershed
Highland Bayou	3,397	3,687	8.5	2.4
Marchand Bayou	1,046	1,138	8.8	3.7
Total	4,443	4,825	8.6	3.2

Land Cover and Impervious Surface in Highland Bayou. Highland saw a 14-year increase of 381 acres in developed land, including a 57 acre increase in high intensity development. Agricultural lands declined by 39 acres, undeveloped vegetated space declined by 247 acres, and wetlands of all types declined by 88 acres; this resulted in a net loss of 374 acres of undeveloped land. A loss of 90 acres of open water potentially corresponds with the 83 acres gained as beach or unconsolidated land. Although some of this may result from new sand mining operations in the basin. Approximately 7% of all developed land was high intensity development, 22% was medium intensity, 40% as low intensity, and 31% as open developed land. Approximately 44% of land in the basin is classified as developed, and it is estimated that 16% of the watershed is impervious surface cover. See Appendix 2 for detailed tables and maps.

Land Cover and Impervious Surface in Marchand Bayou. 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 35 acres respectively, and wetlands of all types decreased by 6 acres; this resulted in a net loss of 103 acres of undeveloped land. A loss of only 2 acres of total beach or unconsolidated land was lost, however total open water did not change. These values indicated that suburbanization is the primary land conversion in the basin. Approximately 8% of all developed land in the basin was high intensity development, 23% was medium, 38% was low, and 31% was open developed land. Developed land constitutes approximately 68 % of the basin, and it is estimated that 21% of the watershed is impervious surface cover. See Appendix 2 for detailed tables and maps.

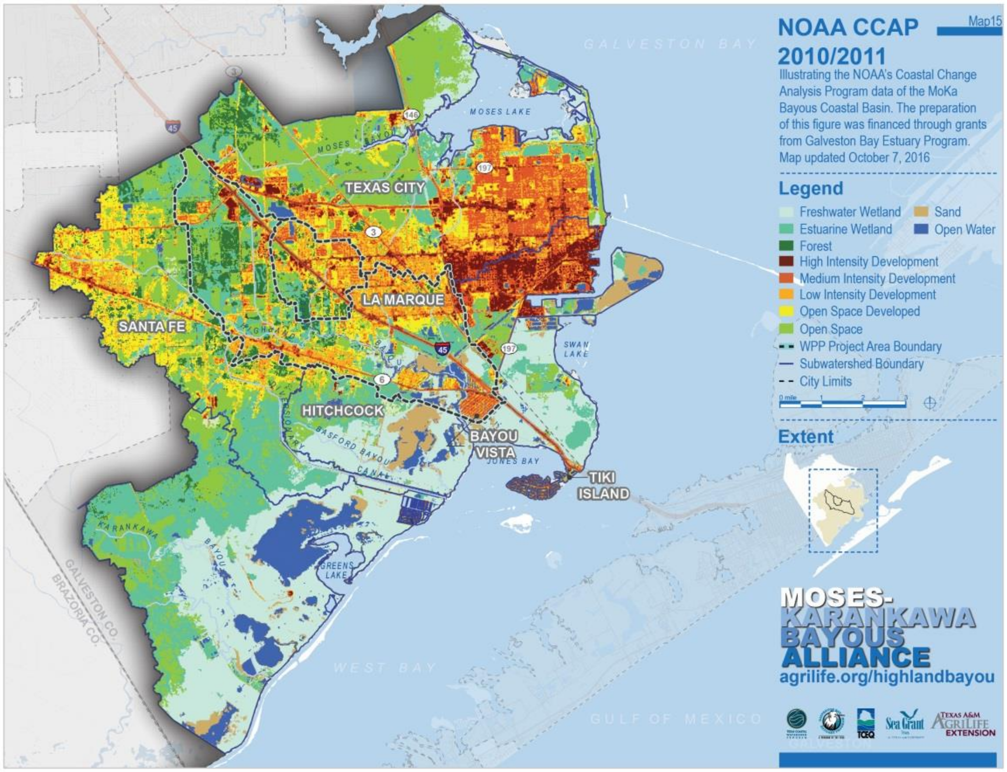


Figure 11. NOAA's C-CAP Data for the MoKa Bayous Coastal Basin

Agriculture/Wildlife/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 (Fig 16). 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.

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 includes 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 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 bottomlands along streams and marshes, and can be 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 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 in sections of Highland Bayou, creating stagnant pools of water in some areas. Trees and brush falling onto the banks is partly a natural process and it 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.

Open Space Preservation.

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. Fragmentation of land tracts resulting from the breakup of larger undeveloped lands and habitat loss from development are some of the threats wildlife populations

Bacteria Loading

Bacteria Load Duration Curves

The Load Duration Curve (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 non-regulatory 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 TMDL development as the equivalent of the “standard” FDC/LDC method used for bacteria WPP and TMDL development for non-tidal, 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 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 12 graphically illustrates this relationship for one station within the project area.

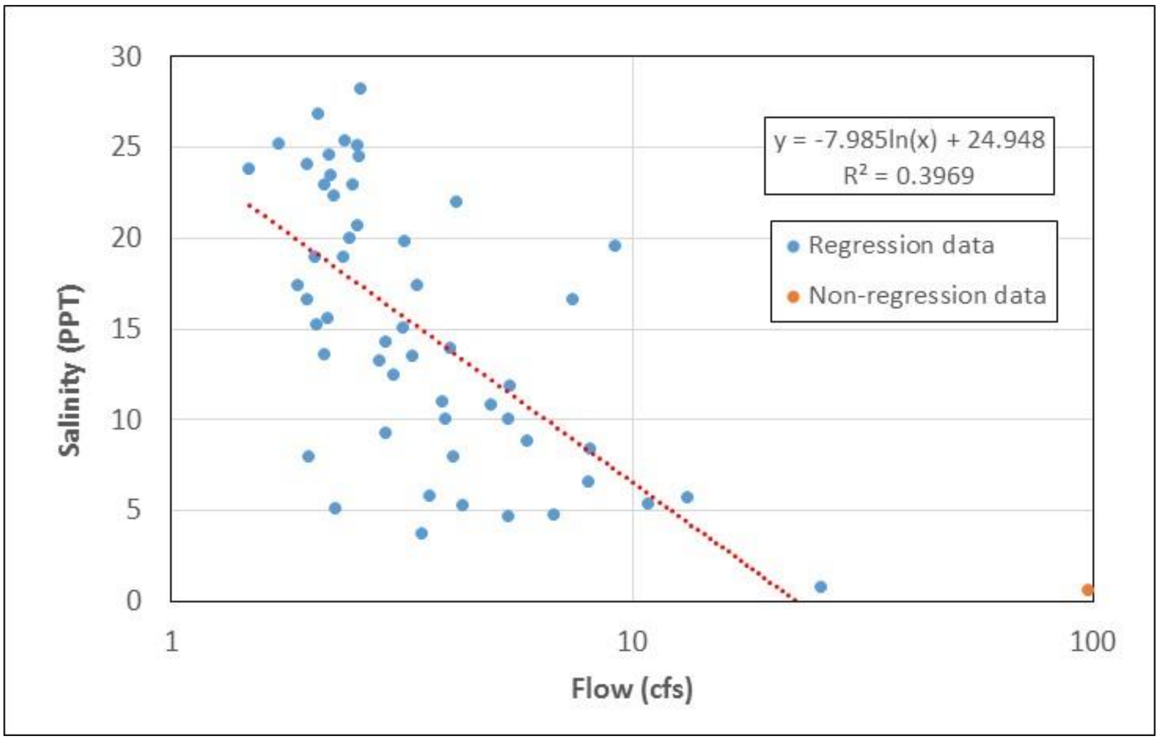


Figure 12 Scatter plot of salinity and estimated daily streamflow for station 18593, Highland Bayou Diversion Canal AU 2424G_01. This graphical depiction of the salinity to flow relationship is characteristic of those developed for all waterbodies in the project

The 20-year period of January 1, 1998 through December 31, 2017 was used in the development of the FDC for each station. The modified FDC is represented by the freshwater plus seawater (V_t) 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 V_t. The FDC for each station varies based on differences in baseflow and tidal influence. For example, station 16488 (Highland Bayou AUs 2424A_01, Figure 13) has more tidal include as well as a sustained baseflow from the upstream City of La Marque Westside WWTF discharge whereas station 11415 (Highland Bayou 2424_03, Figure 14) has less tidal include and no WWTF baseflow.

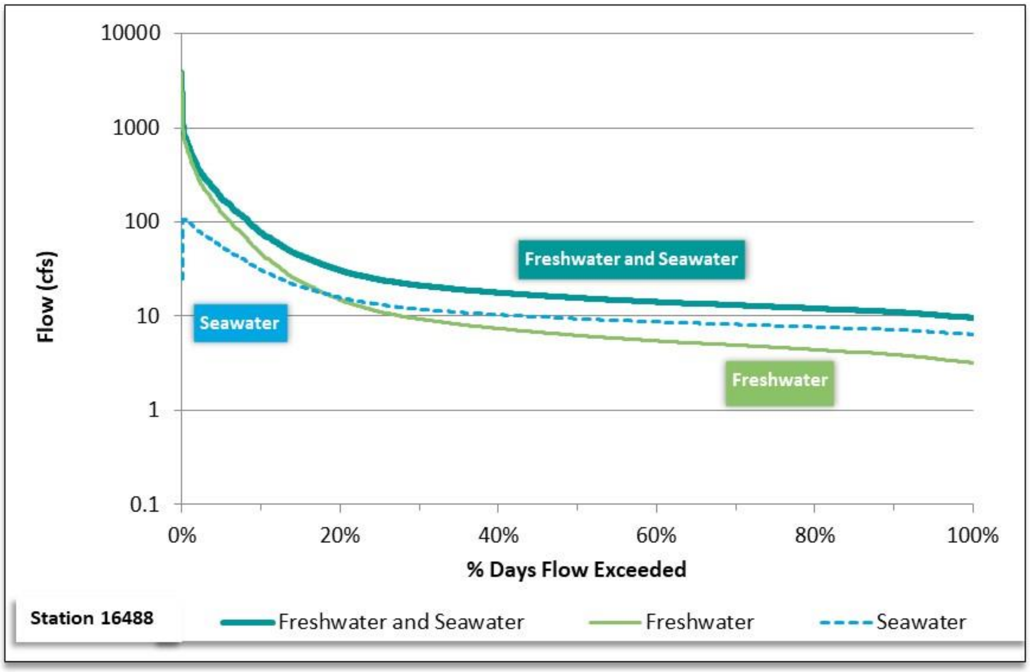


Figure 13. Modified FDC for station 16488, Highland Bayou AU 2424A_01.

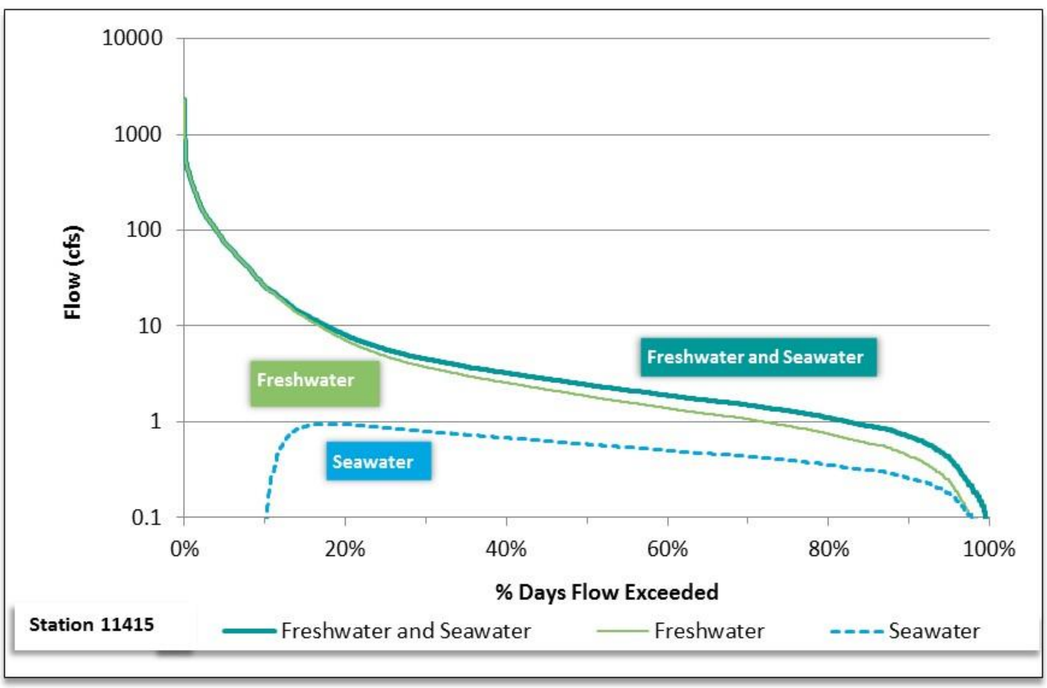


Figure 14. Modified FDC for station 11415, Highland Bayou AU 2424A_03.

Modified LDCs

LDCs provide the following information:

1. the allowable in-stream loading of Enterococci – blue line in the graphs below
2. an estimate of the existing loading (through data generated using the regression line of observed Enterococci data with estimated flow for the chosen SWQM station for each AU) - green line in the graphs below
3. 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).

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

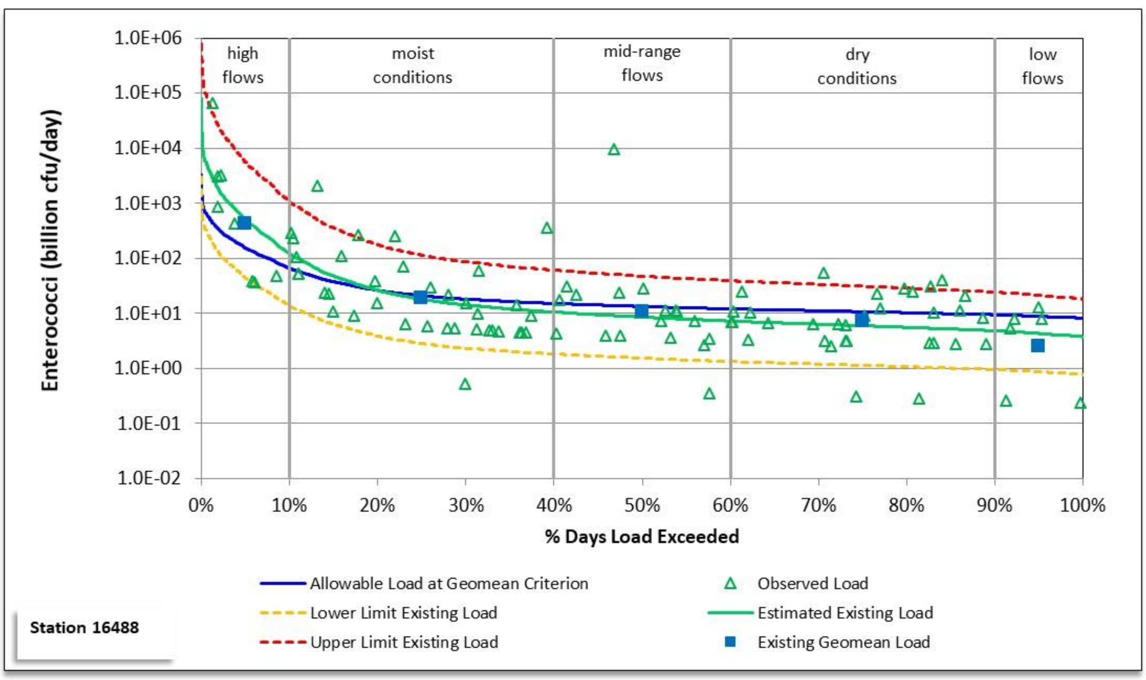


Figure 15. Modified LDC for station 16488, Highland Bayou AU 2424A_01, this station is nearist the mouth of Highland Bayou.

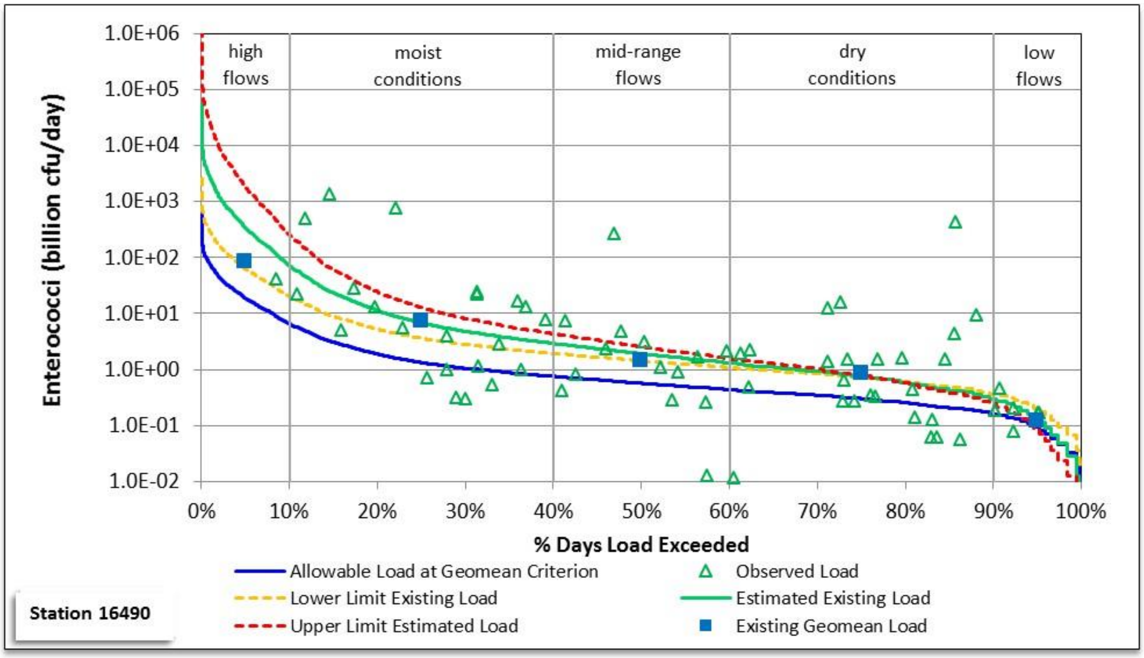


Figure 16. Modified LDC for station 16490, Marchand Bayou AU 2424C_01.

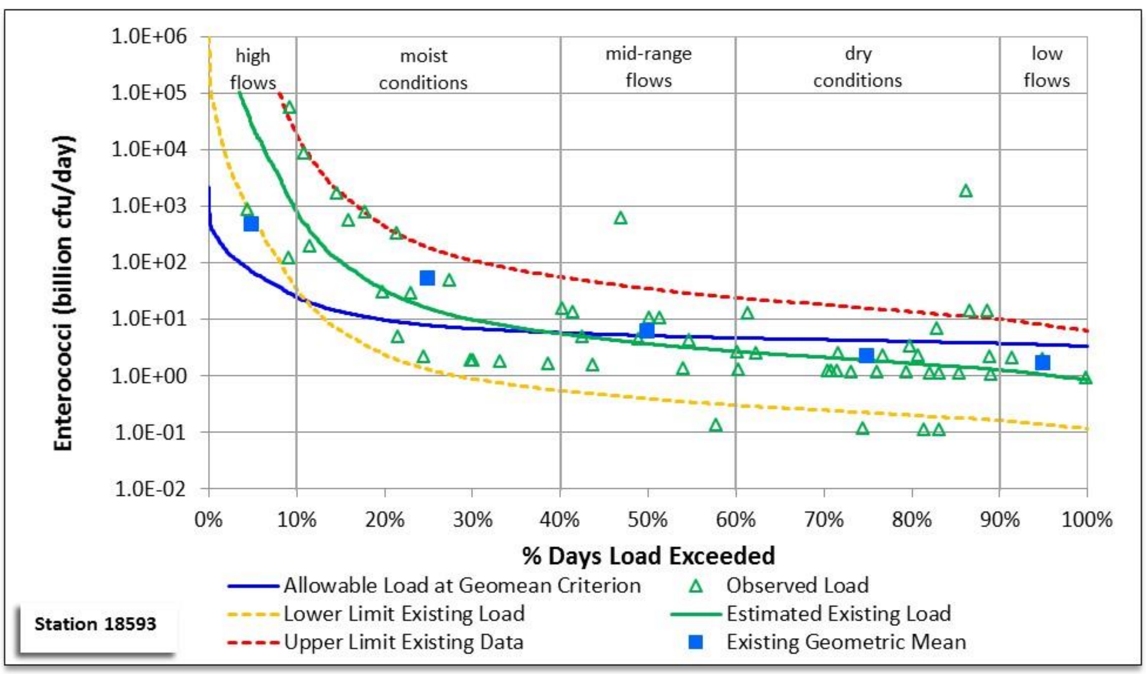


Figure 17. Modified LDC for station 18593, Highland Bayou Diversion Canal AU 2424G_01.

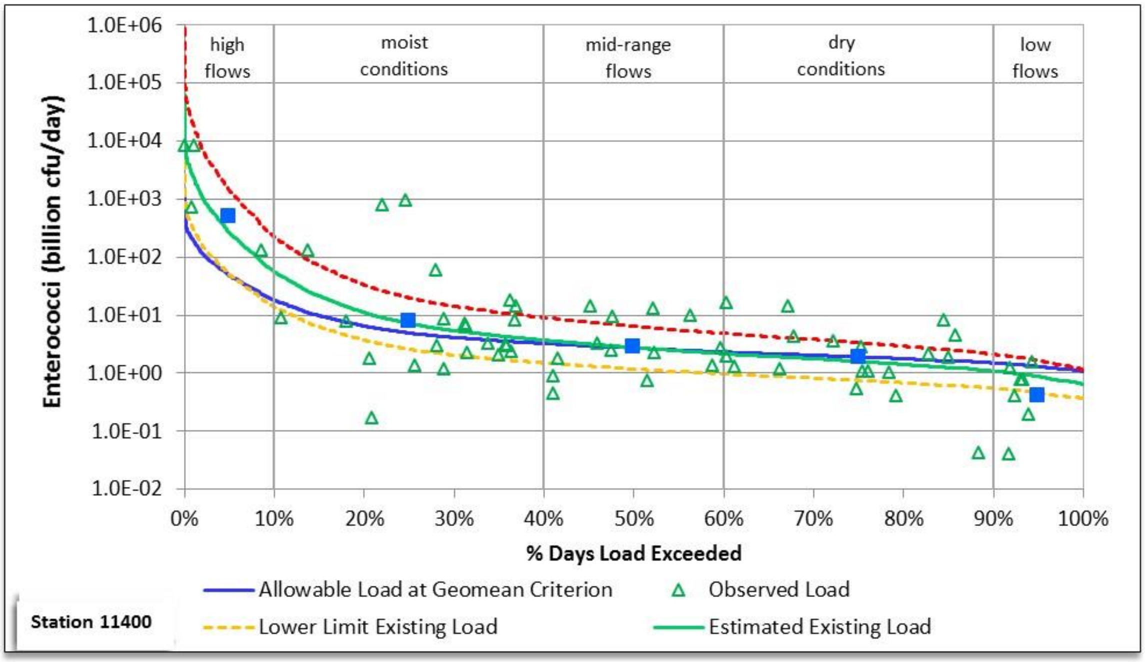


Figure 18. Modified LDC for station 11400, Moses Bayou AU 2431A_01

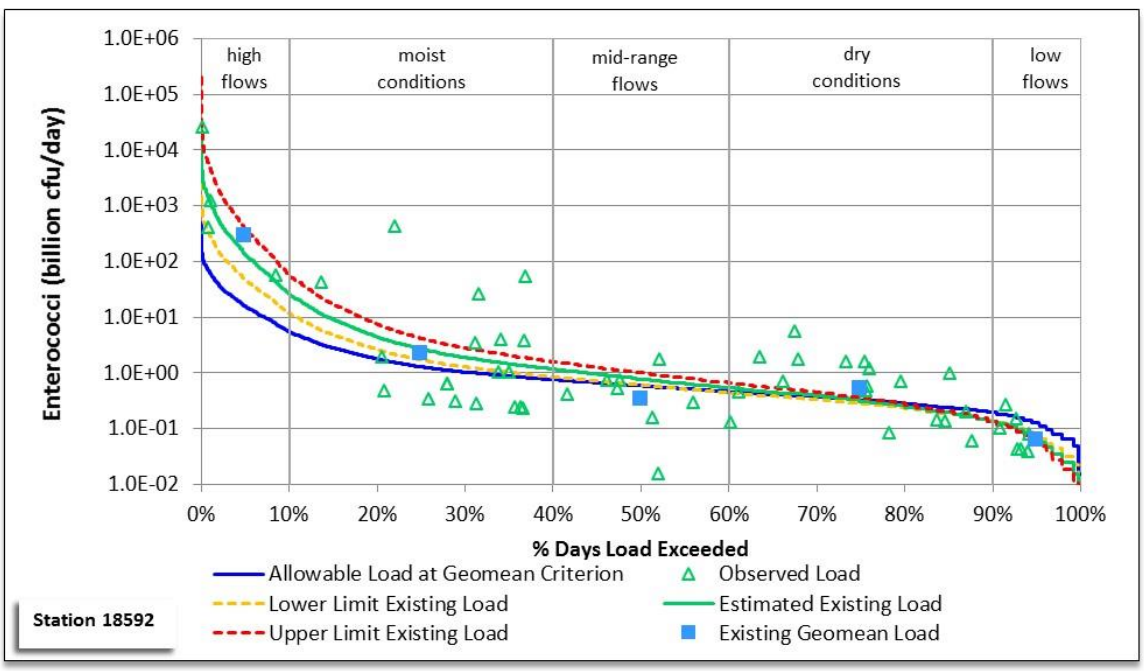


Figure 19. Modified LDC for station 18592, Unnamed Tributary of Moses Lake AU 2431C_01

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 is 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-flows 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 6. Estimated load reductions needed for each relevant AU of the Highland Bayou Coastal Basin.

NA – not applicable, no reduction required

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	472.869	6.150	466.719	98.7%	170,352	472.869
Most Conditions	10.680	3.650	7.030	65.8%	2,566	10.680
Mid-Range Flows	1.756	1.613	0.143	8.1%	52	1.756
Dry Conditions	2.101	2.224	-0.123	NA	-45	2.101
Low Flows	0.613	0.705	-0.092	NA	-34	0.613
Total	488.019	14.342	473.677	97.1%	172,892	488.019
Highland Bayou 2424A_03						
High Flows	2-10	52.203	4.967	90.5%	47.236	17,241
Most Conditions	10-40	8.498	2.063	75.7%	6.435	2,349
Mid-Range Flows	40-60	0.927	0.425	54.2%	0.502	183
Dry Conditions	60-90	0.553	0.333	39.8%	0.220	80
Low Flows	90-100	0.036	0.034	5.6%	0.002	1
Total	2-100	62.217	7.822	87.4%	54.395	19,854
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
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

Table 7. Summary of Enterococci assessment data for 2014 and draft 2016 Integrated Reports and percent reduction to meet primary contact recreation geometric mean criterion of 35 cfu/100 mL.

NA – not applicable, no reduction required; ND – no data

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%

Element B: Load Reductions

Load reductions are calculated for four priority management measures (Table 8). For each reduction, a brief narrative about reasoning, assumptions, and calculations is provided, followed by reduction tables for each practice. In short, under these assumptions, the watershed could observe a 42.1% load reduction in bacteria, a 10.5% reduction in nitrogen, and a 12.1% reduction in phosphorous at the end of a 10-year implementation horizon. There is reason to believe that greater reductions could be achieved through the implementation of related practices (i.e., WWTP improvements), or improved implementation or higher participation rates.

Table 8. Pollutant of concern by Management Measure

Projects	Bacteria	Nitrogen	Phosphorous
SSS Upgrades AA (09)	x	--	--
Pet Waste Pickup AA (18) & AA (19)	x	--	--
Green Infrastructure AA (24)	x	x	x
Stormwater Wetlands AA (24)	x	x	x

Load Reductions from Management Measure #1: SSS Upgrades and Improvements

For this load reduction, the focus is on 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 of 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 likely translates 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. Pro-rated 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 needs major repair, 9350 linear feet (lf) of broken or corroded line needs replacement, and approximately 20 lift stations need upkeep at a cost of $1.4 million dollars over 10 years and servicing approximately 15,000 residents (La Marque Meeting Minutes, Jan 2015). Assuming these repair characteristics hold for the entire watershed, these figures translate to the following watershed-wide repair figures (Table 9).

Table 9. Sanitary Sewer System Repairs

Activity	La Marque (pop. 15,141)	Watershed Wide (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 ten years. Combing a 80% repair effectiveness with a 15% failure rate over ten 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

1) Reductions assume a 10 year implementation horizon
2) Low *E. coli* concentration of 1.05 x 10^7 and a high value of 1.05 x 10^8 CFUs per 100mL
3) A bacteria conversion factor of 0.278 *Enterococcus* per *E. coli*.
4) Effective rate of volume reduction is 65% for ten years, or 6.5% per year.
5) Unreported SSOs from the collection system and from private lines are not factored, but are a known source.
6) Wastewater treatment plant SSO discharges are not factored, but are a known source.
7) All populations in incorporated areas are assumed to be serviced by a collection system and not on OSSF. GIS was used to allocate population by AU and incorporated areas; see load reduction table, Table B-3 below.

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 10).

Table 10. Bacteria load and reductions by assessment unit

	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 *Entero* 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 *Entero* 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 *Entero* from SSO (in Billion CFUs) (Low Concentration)	770.24	323.49	2.13	102.16	68.49	52.78	221.19
Annual Load *Entero* 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	65%	65%	65%	65%	65%	65%	65%

	Total	2424A_01	2424A_02	2424A_03	2424A_04	2424A_05	2424C_01
of Management Measure (xx) activities							
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 *Entero* 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%

Discussion of load reduction: SSS

The 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 an management measure in this load reduction section. Other management measures may address the impact of private lines.

Load Reductions from Management Measure (06) Fats, Oils, Grease and Wipes

For this load reduction, the focus is on educating homeowners on the impacts of fats, oils, grease, and wipes on their plumbing and the larger collection system for the community. I is assumed here 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). Pro rating 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 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 home owner 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 (18) and Management Measure (19) Pet Waste Pickup

For this load reduction, the focus 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 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 (see Map-14 and Table B-4 below). The AVMA (2012) estimates that 36.5 percent of households own dogs, and that of owning 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 percent of dog owners stated that they 'always' or 'sometimes' pick up their dog's waste. For this analysis, we assume 40% percent of owners pick up dog waste.

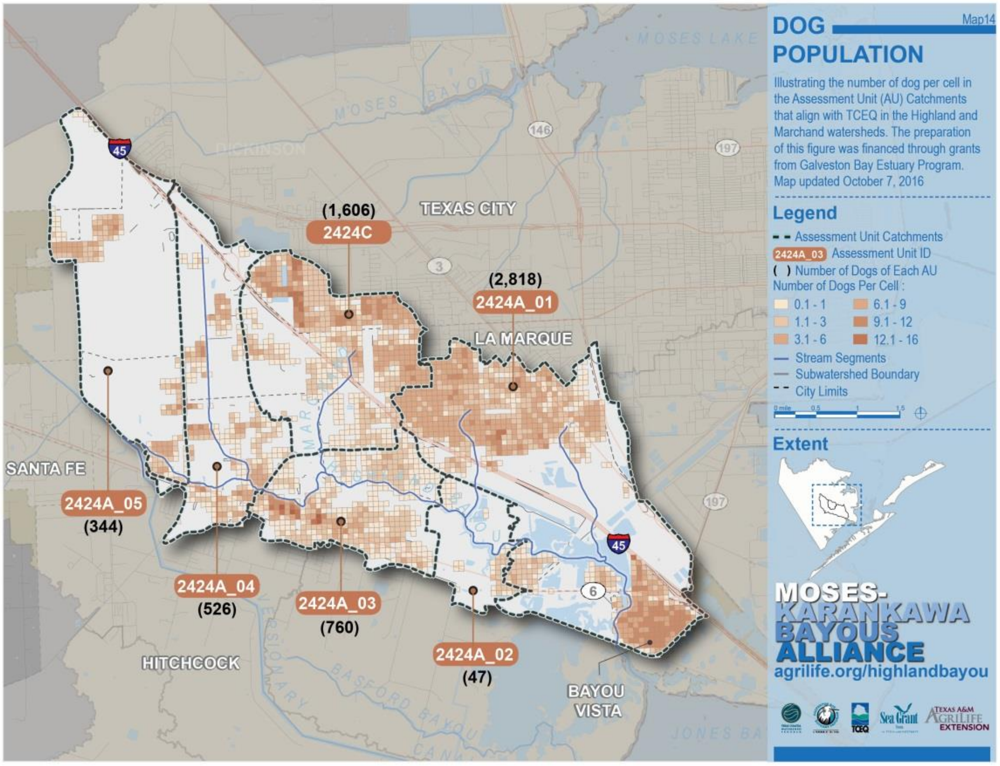


Figure 20 The number of dogs per Assessment unit.

Calculation Assumptions

1) Reductions assume a 10 year implementation horizon
2) The average dog produces 5.0x10^9 fecal coliform per day
3) A bacteria conversion factor of 0.278 *Enterococcus* per *E. coli*, and a bacteria conversion factor of 0.63 *E. coli* per fecal coliform.
4) Only 40% of dog waste is picked up; 60% is assumed left outdoors
5) A 20% increase in pick up rates over ten years, i.e., 48% pick up rate and 52% leave rate
6) 100% of 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 *Entero* / *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 11 allocates the dog population and load reduction by AU (from GIS analysis using DUs by AU) and shows the allocation of indicator bacteria load reduction and bacteria load reduction as percent of total indicator bacteria load in the watershed and by AU.

Table 11 Bacteria load and reductions by assessment unit

	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 *Entero* in Billions from all sources	422,534	175,635	5,396	44,646	54,349	41,936	100,573
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%

Discussion of Load Reduction: Pet Waste Pickup

The cost of education is comparatively low to other practices and the return on load reductions is potentially high. Several critical facts will determine whether or not 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). 23 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 (24) Green Infrastructure and Stormwater Wetlands

For this load reduction, activities focus 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 includes here 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. SWW are also referred to as 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 area draining into it.

Load reductions are estimated as two calculations, once for GI and once for SWW (Table 12; Table 13). 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 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 DUA). 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 phosphorous, and 54% for bacteria.

Table 12. Percent reduction for pollutants of concern by Green Infrastructure practice

Green Infrastructure 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 13. Percent reduction for pollutants of concern for Stormwater Wetlands

Green Infrastructure Practice	N	P	Bacteria
Stormwater Wetlands	35%	47%	72%

For sources and methods regarding these practices, please see Appendix D, Stormwater Best management Practices (BMP) Factsheets.

Calculation Assumptions

1) Reductions assume a 10 year implementation horizon
2) Management practices intercept 20% of existing runoff load
3) Loads and Load reductions do not factor in future growth
4) GI load reduction values
    a. 41% reduction for nitrogen
    b. 43% reduction for phosphorous
    c. 60% reduction for bacteria
5) Stormwater Wetland load reduction values
    a. 35% reduction assumed for nitrogen
    b. 47% reduction for phosphorous
    c. 72% reduction for bacteria
6) 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 14. Nitrogen load reductions from GI practices by assessment unit

Nitrogen Load Reduction from GI practices	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
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 15. Phosphorus load reductions from GI practices by assessment unit

Phosphorous 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 16. Enterococcus load reductions from GI practices by assessment unit.

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 17. Nitrogen load reductions from stormwater wetlands by assessment unit

Nitrogen 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	42,377	17,963	452	4,481	5,345	3,859	10,277
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 18. Phosphorus load reductions from stormwater wetlands by assessment unit

Phosphorous 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 19. Enterococcus load reductions from stormwater wetlands by assessment unit

Enterococcus Load Reductions from Stormwater Wetlands	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
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) for AU	422,535	175,635	5,396	44,646	54,349	41,936	100,573
Percent Reduction for AU	13.9%	14.2%	11.7%	13.9%	13.6%	12.8%	14.1%

Discussion of Load Reduction: GI and SWW

Load reduction and load reduction costs will vary by the specific practice utilized. An average value for all practices was utilized here.Effectiveness of the practices will depend on proper implementation, sizing, and siting. Implementation will be voluntary and undertaken by local public entities, private land owners, 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 a step 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 from All Practices

Bacteria

The following table shows estimated indicator bacteria load reductions from the implementation of all load reduction practices (Table 20). The high value bacteria concentration for SSO discharges are utilized in this table. It is possible that in ten years, through the adoption of the practices and repair programs, that the watershed could see a 42% reduction in bacteria from today's load values. Because of a lack of flow data, it is not possible to estimate if these load reductions would result in the bayou's removal from the 303(d) list.

Table 20. Estimated Enterococcus load reductions from four priority management measures by assessment unit

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%

Dissolved Oxygen

Table 21 shows estimated cumulative load reductions in nitrogen and phosphorous from the implementation of proposed GI practices and SWW. It is possible that in ten years, through the adoption of these practices, that that watershed could see a 10.5% reduction in nitrogen and a 12.1% reduction in phosphorous. 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 keep in mind that the 303(d) listing is for low DO and not for specific nutrients.

Table 21Cumulative load reductions in nitrogen and phosphorus from green infrastructure practices and stormwater wetlands

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%
Phosphorous (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
Phosphorous (lbs)	All AUs	2424A _01	2424A _02	2424A _03	2424A _04	2424A _05	2424C _01
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 BMPs for the voting exercise.

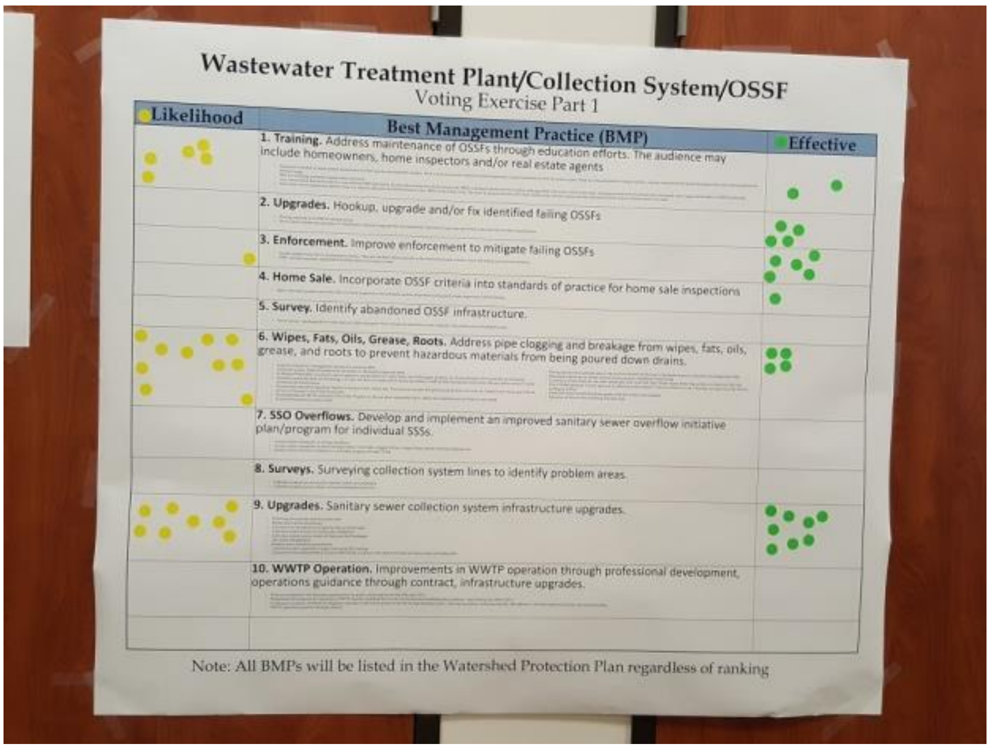


Figure 21. Wastewater Management Measures poster during the voting exercise

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: weighting 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 22). The fill list of 38 Management Measures is in Appendix 2.

Table 22. 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 & Stormwater Wetlands
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 twelve vote-getting Management Measures are the priority for implementation and water quality improvement. Stakeholders feel these are the best way 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 28 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 1.

For the 12 Management Measures, per the outline of EPA's 9 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 Table 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 the management measure, 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

Load Reduction Effectiveness – we use 'Low,' 'Medium,' and 'High,' 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 needed for successful implementation.

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

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 Sanitary Sewer Overflows (SSOs). SSOs associated with fats, oils, and grease (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 run 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 sanitary sewer system infrastructure.
Approach: Collection systems need routine maintenance to identify and eliminate SSOs 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 also 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	Likely Lead Entity
1. Adopt or update infrastructure management programs to plan and budget for proactive/preventative maintenance activities.	Wastewater service providers: City of Hitchcock, City of La Marque, MUD 12, City of Texas City
2. Identify areas in the collection system where I/I or aging infrastructure is a problem.	Wastewater service providers: City of Hitchcock, City of La Marque, MUD 12, City of Texas City
3. Rehabilitate collection system infrastructure to prevent SSOs and I/I.	Wastewater service providers: City of Hitchcock, City of La Marque, MUD 12, City of Texas City
4. Upgrade or repair private line connections to the wastewater collection system. Performed as necessary.	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: Fats, Oils, and Grease and Wipes in the Sanitary Sewer Collection System
Problem: The accumulation of FOG and wipes is a common problem resulting in sanitary sewer system overflows, malfunctions, and failures. As sewer lines clog and eventually break, raw sewage flows into local waterways or occur 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 along the all 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 hydrocarbons 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	Likely Lead Entity
1. Regulation and Policy for FOG in commercial settings: 1. Compile existing regulations within the watershed and share. 2. Examine, establish, and/or update regulations as necessary to address gaps. 3. Include enforcement measures 4. Perform outreach to promote participation and aid in compliance.	Wastewater treatment providers including City of Hitchcock, City of La Marque, City of Santa Fe and MUD 12; County agencies; County Commissioners

2. Utilize existing educational messaging related to cooking grease –Cease the Grease campaign materials: 1. Join the Cease the Grease workgroup. 2. Utilize available online social media materials and website content.	Wastewater treatment providers including City of Hitchcock, City of La Marque, City of Santa Fe and MUD 12; County agencies; County Commissioners; GBF
3. Pilot project - establish one Cease the Grease kitchen grease collection station at an apartment complex.	Wastewater treatment providers including City of Hitchcock, City of La Marque, City of Santa Fe and MUD 12; County agencies; County Commissioners; GBF
4. Utilize existing educational messaging related to wipes - Patty Potty campaign materials: 1. Bolster online presence using free Patty Potty materials on social media sites and webpages. 2. 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.	Wastewater treatment providers including City of Hitchcock, City of La Marque, City of Santa Fe and MUD 12; County agencies; County Commissioners
5. Utilize utility bills for distribution of educational material to homeowners: 1. Publicize costs for damages to sewer infrastructure to city	Wastewater treatment providers including City of Hitchcock, City of La Marque, City of Santa Fe and MUD 12; WCID 19.

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.	Wastewater treatment providers including City of Hitchcock, City of La Marque, City of Santa Fe and MUD 12; County agencies; County Commissioners; AgriLife
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 1970's 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 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 adjacent to unincorporated place, Freddiesville.

Implementation Objectives	Likely Lead Entity
1. Determine causes of flow reduction by requesting a study to identify contributing factors.	Galveston County Engineering with the USACE would perform the study. Other potential partners include the City of Hitchcock, City of La Marque, and MUD 12.
2. Conduct a sediment source study to find the cause of sediment entering the bayou.	Galveston County Engineering with the USACE would perform the study. Other potential partners include the City of Hitchcock, City of La Marque, and MUD 12.
3. Selectively remove sediment and clear vegetation from the channel as recommended during assessments performed by the USACE.	Galveston County Engineering as the permit applicant would coordinate dredging activities with the USACE. Other potential partners include City of Hitchcock, City of La Marque, MUD 12 and Resource Agencies.
4. Selectively remove accumulations of woody debris impeding flow within the channel in residential areas as recommended during assessments performed by the USACE.	Galveston County Engineering as the permit applicant would coordinate tree removal with the USACE. Other potential partners include City of Hitchcock, City of La Marque, and MUD 12.
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 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 with contributing waters through the dam and culvert. **Location:** Highland Bayou at the diversionary canal dam and culverts in Jack Brooks Park.

Implementation Objectives	Likely Lead Entity
1. Request information from the USACE about culverts to determine maintenance needs (potential removal of sediment and debris) to improve flow.	Galveston County Engineering; Municipalities; MUDs, AgriLife; USACE

2. Remove sediment and clear vegetation from culverts.	Galveston County Engineering; Municipalities; MUDs, AgriLife; USACE
3. Establish a management/maintenance agreement.	Galveston County Engineering; Municipalities; MUDs, AgriLife; 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 increased flow volumes and a concurrent a 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 amount of bacteria to surface waters. A single gram of dog feces can carry and 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 stay 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 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 AgriLife Extension, 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.

<table>
<tr><td colspan="2">Location: All project watersheds. 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.</td></tr>
<tr><th>Implementation Objectives</th><th>Likely Lead Entity</th></tr>
<tr><td>1. Distribute pet waste educational material 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.</td><td>City of Hitchcock; City of La Marque; City of Bayou Vista; MUD 12; WCID 19; HOAs; Galveston County; AgriLife</td></tr>
<tr><td>2. Install pet waste stations with bag dispensers in parks and other public spaces.</td><td>City of Hitchcock; City of La Marque; City of Bayou Vista; MUD 12; HOAs; Galveston County</td></tr>
<tr><td>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.</td><td>City of Hitchcock; City of La Marque; City of Bayou Vista; MUD 12; WCID 19; HOAs; Galveston County; AgriLife</td></tr>
<tr><th colspan="2">Estimated Bacteria and/or Nutrient Load Reduction</th></tr>
<tr><td colspan="2">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.</td></tr>
</table>

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: Green Infrastructure and Stormwater Treatment Wetlands
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 green infrastructure (GI) and stormwater wetlands (SWW)
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 is intended 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 then dry spells, requiring little to no additional water once plant populations are established. Rainwater harvesting systems also promote water conservation by providing an alternative water resource. 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 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". https://www.epa.gov/green-infrastructure/green-infrastructure-municipal-handbook.

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 Low Impact Development (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 (GIFT) Program. In 2015 they published the Ghirardi Family WaterSmart Park Stormwater BMP Assessment Report. Communities in the watershed can request rain barrel workshops (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	Likely Lead Entity
1. Update development codes to allow for GI projects during new development	City of Hitchcock; City of La Marque; City of Bayou Vista; City of

and stormwater retrofits; example ordinances are available for reference.	Santa Fe; MUD 12; County agencies; Developers; AgriLife
2. GI for public buildings and in public spaces: 1. Identify public entities interested in utilizing GI. 2. Design and implement GI projects including rain gardens, permeable pavement, bio-swales, vegetated curb extensions, rain water harvesting cisterns and WaterSmart landscaping.	City of Hitchcock; City of La Marque; City of Bayou Vista; City of Santa Fe; MUD 12; County agencies; Developers; AgriLife
3. Educate residents and public entities about GI: 1. Distribute educational materials about GI practices, how they can be used locally, and their impact on water quality. 2. Partner with AgriLife to host GI workshops, lectures and field trips to educate homeowners, businesses and municipal officials. 3. Partner with GBF to host rain barrel workshops for residents to promote water conservation.	AgriLife; GBF; GBEP
4. Encourage the use of constructed stormwater treatment wetlands: 1. Host constructed SWW workshops for public entities and developers. 2. Identify public entities interested in utilizing stormwater treatment wetlands and establish ordinances to consider these practices.	AgriLife; GBEP; GBF

3. Retrofit existing stormwater detention facilities into stormwater treatment wetlands where feasible. 4. 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 siting 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 anticipated 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) maintain drainage ditches north of Highland Bayou, and including 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 are 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 damages 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 sources of NPS pollution. 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 of the project area serviced by drainage infrastructure.

Implementation Objectives	Likely Lead Entity
1. Compile and review previous storm drainage system studies to determine the scope for an updated assessment.	Galveston County Storm Water Collaborative; Municipalities; Galveston County Engineering; GCDD2
2. Inventory stormwater infrastructure components: 1. Establish data objectives, requirements, and the data collection schedule. 2. Inventory and map public stormwater system. 3. Develop a plan to maintain and update inventory data.	Galveston County Storm Water Collaborative; Municipalities; Galveston County Engineering
3. Characterize stormwater system components in the inventory to prioritize improvement needs and pollution prevention measures.	Galveston County Storm Water Collaborative; Municipalities; Galveston County Engineering

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 a 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 wastes contribute nutrients, fertilizers, pesticides, and bacteria to our bayous. Storm drains, streets and other stormwater drainage infrastructure are not part of the sanitary sewer system 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 is included in Appendix XX. It is important; however, to communicate ordinance requirements to individuals and entities affected to encourage participation. **Location:** Entire project area.	
Implementation Objectives	**Likely Lead Entity**
1. Develop new or strengthen existing ordinances addressing lawn clipping and landscaping debris management. Example ordinances are widely available for reference.	City of La Marque, City of Hitchcock, City of Texas City, City of Bayou Vista, City of Santa Fe.

2. Communicate landscaping ordinance requirements or landscaping best practices to residents and landscaping contractors.	City of La Marque, City of Hitchcock, City of Texas City, City of Bayou Vista, City of Santa Fe.
3. Develop enforcement measures for the ordinance including penalties due following multiple offenses.	City of La Marque, City of Hitchcock, City of Texas City, City of Bayou Vista, City of Santa Fe.
4. Publicize contact information for reporting violations or poor disposal practices.	City of La Marque, City of Hitchcock, City of Texas City, City of Bayou Vista, City of Santa Fe.
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 amount 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 the technical and/or 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 the 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, non-federal 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	Likely Lead Entity
1. Identify existing conservation and habitat management plans within the watershed.	AgriLife; County agencies; NRCS; TSSWCB; TPWD; Resource agencies/organizations
2. Identify interested landowners to participate in conservation and habitat management plans. Facilitate communication between voluntary programs and potential participants. 1. Host landowner workshops addressing land management practices. 2. Distribute educational materials to landowners regarding land stewardship practices. 3. Develop and implement individual NRCS conservation	AgriLife; Landowners; County agencies; Resource agencies/organizations

plans, WQMPs, and 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 the maintenance for continued effectiveness must be considered. 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 #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 has been converted to developed uses and open lawns. Riparian zone restoration is covered in Appendix XX.

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 prairie, 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 maintains it 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 University of Houston (UH) Coastal Center (UHCC) manages about 300 acres of highly endangered coastal tallgrass prairie habitat. UHCC maintains areas of pristine prairie, and, when possible, restores areas invaded by exotic species or disturbed by human activity. UHCC provides access and equipment to support environmental research and supports outreach activities with public groups.

Back the Bay is an educational campaign through the 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 are able to 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 U.S. Army Corps of Engineers 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	**Likely Lead Entity**
1. Support acquisition and conservation of undeveloped natural lands: 1. Review area conservation plans and consult with resource and conservation organizations to identify protected lands within the watershed. 2. Identify and prioritize properties with the potential for conservation management. 3. Acquire undeveloped natural lands and encourage conservation easements.	Municipalities; MUDs; County agencies; AgriLife; Resource agencies/organizations; GBEP; GBF; Artist Boat; Houston Wilderness
2. Provide education for public entities and residents on loss of habitat for wildlife utilizing Back the Bay materials and other existing programs.	Municipalities; MUDs; County agencies; AgriLife; GBEP
3. Use regulatory techniques to preserve natural lands: 1. Require inquiry through the USACE for Section 404 mitigation needs during the building permit process. 2. Enact ordinances to protect certain trees from removal or discourage developers from cutting down all trees prior to construction.	Municipalities; MUDs; County agencies; AgriLife; Resource agencies/organizations
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: 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: On-Site Sewage Facility 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 offers OSSF workshops for homeowners, creates and distributes OSSF educational materials that outline maintenance needs (http://ossf.tamu.edu/), 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. The 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 home owners about proper OSSF operation and maintenance
Approach: GCHD continue and expand existing OSSF education programs and provide relevant local information on their website and social media platforms. AgriLife Galveston County Agents work with local entities and AgriLife specialists to hold homeowner trainings at least once each year. **Location:** Throughout the project area with extra attention to the Diversion Canal watershed.

Implementation Objectives	Likely Lead Entity
1. Galveston County will continue existing OSSF education programs.	GCHD
2. Identify households having OSSFs for a targeted outreach approach.	GCHD; AgriLife
3. Galveston County undertake new outreach methods such as mailouts notifying residents of septic online resources.	GCHD; AgriLife
4. AgriLife Extension host free homeowner workshops throughout the project areas	AgriLife; municipalities; GCHD; GBF.
Estimated Bacteria and/or Nutrient Load Reduction	
Reduction Effectiveness: Mid across the entire project area – Bacteria load reductions could be high in the Diversion Canal watershed where the largest number of OSSFs are fund, however effectiveness will be determined by rates of behavior change among OSSF owners. Likelihood of Success: 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. AgriLife workshops are a low-cost option for training, technical knowledge exists within the system and can be utilized with little to now cost for trainings.	

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 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 nuisance, non-native 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 hosta 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: AgriLife Extension 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:** Throughout the watershed	
Implementation Objectives	**Likely Lead Entity**
1. AgriLife Extension partner with Galveston County, Municipalities, GBF and interested groups to host at least one workshop per year for local landowners.	AgriLife
2. Distribute existing and/or create new outreach materials	AgriLife, Galveston County, Municipalities
Estimated Bacteria and/or Nutrient Load Reduction	
Reduction Effectiveness: Mid across the entire project area. Likelihood of Success: 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 23 below, an estimate of associated costs and potential funding source are listed for each Management Measure. Implementation of Management Measures are dependent upon funding and resources.

Potential Funding Sources

A comprehensive narrative of funding sources is provided in Appendix 6, Funding Sources. Funding sources are grouped by federal and state agencies, listed by program name and include eligibility, criteria, and funding limitations. Tables 23 and 24 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 have to 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, non-federal match, which can be a challenge. This is an additional layer to the application that requires match commitments in advance, either in dollars or non-cash 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 25). 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 23. Federal funding source for water quality activities; more information for each of the sources is provided in Appendix 5.

Federal Programs	Agency or Organization
Agricultural Water Enhancement Program	NRCS
Coastal and Estuarine Land Conservation Program	NOAA

Federal Programs	Agency or Organization
Community Development Block Grants (CDBG)	US HUD
Conservation Reserve Program	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 24. State funding sources for water quality activities; more information for each of the sources 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	Texas Water Development Board (TWDB)
Coastal Impact Assistance Program	TX GLO
Economically Distressed Areas Program	TWDB
Landowner Incentive Program	TPWD
Recreation Grant Program- Boating Access Grant	TPWD
Recreation Grant Program - Boat Sewage Pumpout Grant	TPWD
Reginal Water Supply and Wastewater Facilities Planning Program	TWDB

TCEQ 319 Grant	TSSWCB
Texas Clean River Programs	TCEQ
Texas Coastal Management Program	TX GLO
Texas Farm and Ranch Lands Conservation Program	TPWD

Technical and Financial Resources

Table 25 lists likely costs and technical assistance requirements for each management measure and its objectives. Required resources are organized by management measure and its objectives

Table 25. Technical and Financial Assistance

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
MM #1: **Infrastructure Upgrades to the Sanitary Sewer Collection System** Goal: To reduce the volume of raw sewage discharging from failing sanitary sewer system 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.	Variable	None
	Rehabilitate collection system infrastructure	$140,000 per year for approx. 2-3 lift stations, 900 linear feet of line replacement, and major line repairs	SSS infrastructure design and capacity standards; heavy/excavation equipment, professional planning and labor
	Upgrade or repair private line connections to the wastewater collection	To refurbish water and sewer lines for 130 houses and convert 2 old lift stations from gravity to forced main:	Heavy/excavation equipment, best practices for line maintenance and repairs.

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
	system. Performed as necessary	$500,000. Potential monetary help in the form of CDBG funds; IKE funding	
MM#2: **Wipes, Fats, Oils, and Grease and 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	Regulation and Policy for Fats, Oils, and Grease 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, AgriLife, 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, AgriLife, TCWP, GBF
	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, AgriLife, 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.

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
practices through education and outreach to residents and commercial entities on items that should not enter their drains.	Perform outreach to promote participation and aid in compliance.	$5,000-$10,000 per year for staff support, printing, and limited travel resources	No technical requirements
	Utilize existing educational messaging related to cooking grease –Cease the Grease campaign materials	$5,000-$10,000 one time cost to compile, ongoing staff time to follow through with campaign, assuming this ‘piggy backs with other efforts	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	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 ($)	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	$0.10/page	None

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
	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	None
	Host education and outreach workshops for residents and commercial entities	$5,000- $20,000 for staff time and coordination. First time costs likely to be high, as workshop becomes routine, costs expected to fall	Technical presentation at workshop
MM #3: **Stream flow within the Highland Bayou Channel** Goal: Improve flow conditions within the	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

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
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	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	Possibly USACE Section 14 program authority; Removal plan, equipment and disposal plan are required
MM #4: **Culvert Dam Maintenance in the Highland Bayou Channel** Goal: To improve flow within the Highland Bayou channel, via the	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

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
culvert and investigate maintenance needs for culverts within Jack Brooks Park.			County Parks; disposal site for sediment
	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	Distribute pet waste educational material to residents during public events	$200 per station + $32 per box of 800 replacement bags annually	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.	Waste collection agreement/maintenance schedule
	Distribute pet waste bag dispensers to residents during public events	$1,000 for materials biannually	None

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
and impact of pet waste on water quality.			
MM #6: **Green Infrastructure and Stormwater Treatment Wetlands** 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	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 siting 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-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
	Identify public entities interested in utilizing GI	None	None
	Design and implement GI projects including rain gardens, permeable	$2,000 - $100,000 per site, for design-construction. Projects range from minor	Heavy/Excavation equipment, vegetation, technical designs,

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
runoff using GI and SWW.	pavement, bio-swales, vegetated curb extensions, rain water harvesting cisterns and WaterSmart landscaping	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.	acquisition costs, volunteer management
	Educate residents as well as public entities about GI	$1,000 for materials biannually, Total of $2,000/year	Layout, design, & 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	None
	Partner with AgriLife to host GI workshops, lectures and field trips to educate homeowners, businesses and municipal officials	$20,000	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

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
	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
	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.	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	Heavy/Excavation equipment, design-construction plans, labor, property acquisition or easements, permitting

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
		costs for specific practices by unit	
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	No cost	Municipalities; MUDs; County agencies; Drainage districts; AgriLife; Resource agencies/organizations
	Inventory stormwater infrastructure components	$60,000	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
	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	Part of above cost, 30.2	Field survey and staff, knowledge of infrastructure and design standards

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
	pollution prevention measures		
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	None
	Develop enforcement measures for the ordinance including penalties due 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	None

Management Measure	Implementation Objective	Cost ($)	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	Technical presentation
	Distribute educational materials to landowners regarding land stewardship practices.	$1,000 for materials biannually, Total of $2,000/year	None

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
	Develop and implement individual NRCS conservation plans, WQMPs, and LIP participation	Variable	None
MM #10: **Preserve Existing Natural Areas** 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	Support acquisition of undeveloped natural lands for conservation	Cost varies, expected to be a 6-7 dollar figure acquisition, depending on size of property, assuming large properties with meaningful conservation value. Acquisition costs in addition to property costs	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 identify protected lands within the watershed	No cost	Technical knowledge of land management practices and their application
	Identify and prioritize properties with the potential for conservation management	No cost	Technical assistance with habitat and water quality merits of the property
	Acquire undeveloped natural lands and	Cost varies, expected to be a 6-7 dollar figure acquisition,	Legal assistance with title search, acquisition, use

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
education on habitat value for wildlife and water quality.	encourage conservation easements	depending on size of property, assuming large properties with meaningful conservation value. Acquisition costs in addition to property costs	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	Variable	None
	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

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
	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
MM# 11: On-Site Sewage Facility Training **Goal:** Improve maintenance of OSSFs by educating home owners 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 undertake new outreach methods such as mailouts notifying residents of septic online resources.	$5,000 for design, printing, and postage	GCHD has existing in house technical expertise
	AgriLife Extension host free homeowner workshops throughout the project areas	$500/workshop for instructor travel and venue costs	Technical knowledge for instructor
MM #12: Feral Hog Workshops	AgriLife Extension partner with Galveston County, Municipalities, GBF and interested groups to host at	$500/workshop for instructor travel and venue costs	Technical knowledge for instructor

Management Measure	Implementation Objective	Cost ($)	Technical Assistance
Goal: Host feral hog awareness and training workshops to promote the reduction of feral hog populations	least one workshop per year for local landowners.		
	Distribute existing and/or create new outreach materials	No cost for existing publications $2500 per *new* publication to develop, design, and print	None for existing publications Technical knowledge for authors of new publications

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 & 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

NPS 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 also 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 26. Contracted stakeholder goups

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

Organization	Title	First Name	Last Name
Galveston Bay Estuary Program	Technical Programs Coordinator	Michelle	Krause
Galveston Bay Estuary Program	Water and Sediment Quality/ Monitoring and Research Coordinator	Lisa	Marshall
Galveston Bay Estuary Program	Natural Resource Uses Coordinator	Lindsey	Lippert
Galveston Bay Foundation	Water Quality Volunteer Coordinator	Sarah	Gossett
Galveston Bay Foundation	Water Programs Manager	Nathan	Johnson
Galveston County	Galveston County Commissioner, Precinct 2	Joe	Giusti
Galveston County Drainage District #2	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/ TX Sea Grant	County Extension Agent	Julie	Massey
Galveston County Health District	Air and Water Pollution Services	Taylor	Sanford
Galveston County Health District	Consumer Health Manager	Martin	Entringer

Organization	Title	First Name	Last Name
Galveston County Health District	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 & 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
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 & Specialist - Soil	Jake	Mowrer

Organization	Title	First Name	Last Name
	Nutrient and Water Resource Management		
Texas A&M AgriLife Extension – Texas Coastal Watershed Program	Extension Program Specialist	Charriss	York
Texas Parks and Wildlife Department	Regional Biologist, Water Quality Program	Marty	Kelly
Texas Parks and Wildlife Department - KAST	KAST Region 3	Stephen	Mitchell
Texas State Soil & Water Conservation Board	Regional Watershed Coordinator	Brian	Koch
U.S. Army Corp of Engineers	Deputy Chief, Project Management Branch	Byron	Williams
U.S. Army Corps of Engineers	Hydraulic Engineer, H&H/Water Management Branch	Mario	Beddingfiel d
University of Houston 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 26).

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 stakeholders' role and activities that helped shape the management measures. Fifty six individuals were contacted and 40 one-on-one meetings were held.

Stakeholder working group meetings were held in 2015 & 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 E- 1. Mapping Exercise to compile list of best management practices and program activities

Selecting and Ranking Priority Management Measures

BMPs 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.

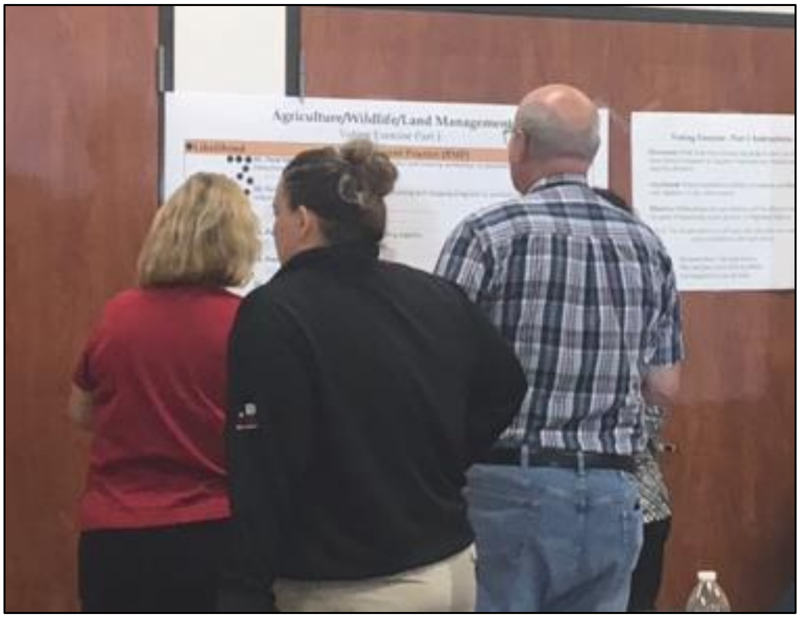


Figure E- 2. Voting exercise used to rank priority project ideas

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 County Coalition of Watersheds (GBCOW), a coalition of watershed groups in Galveston and Brazoria Counties was formed to manage the long-term implement 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 the resources of multiple organizations and programs to support the needs of outreach and environmental awareness for the WPP. Activities listed below are divided by WPP Management Measure.

General Outreach

Facebook. A Facebook page, the "Moses-Karankawa Bayous Alliance" was created for the project and planning process. This was 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 project website, http://agrilife.org/highlandbayou/, has been created for the project. It is 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 a number of approaches. Localities can take the initiative by creating their programs or they can partner with existing programs and customizing 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, Fats, Oils, Grease This activity area addresses homeowner awareness about the disposal of waste at home. The disposal of wipes and FOG in sinks and toils is a major cause of leakages and backups in the municipal sewage system result 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 compliment 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 hall, 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 waste is a known contributor to bacteria levels in waterways. The project team estimates that there are over 5000 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 and municipalities.

Management Measure #6: - Green Infrastructure & Stormwater Wetlands 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 such simple practices 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. 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 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 land owners having or are near large open spaces. Jack Brooks Park and the adjoining UH Prairie Center are known to have feral hog populations. Likely lead agencies are Galveston county parks and Texas A&M AgriLife.

Table 27. Education and Outreach resources available for Management Measure activities

Organization	Program
Artist Boat	Youth Eco-Art Workshop and Adventures
Galveston County/City of	County Tire Recycling Program
City of League City Police	National Drug Take Back Event
Don't Mess With Texas	Adopt A Highway
Don't Mess With Texas	Trash Off
Galveston Bay Estuary Program	Back the Bay Program
Galveston Bay Foundation	Cease the Grease
Galveston Bay Foundation	Dockwalkers
Galveston Bay Foundation	Galveston Bay Action Network

Organization	Program
Galveston Bay Foundation	Living Shorelines
Galveston Bay Foundation	Pump Don't Dump Campaign
Galveston Bay Foundation	Rain Barrel Workshops
Galveston Bay Foundation	Water Warriors
H-GAC	Disaster Debris Clearance and Removal Services
H-GAC	H-GAC Texas Stream Team
H-GAC	Illegal Dumping & Camera Sharing Program
H-GAC	Household Hazardous Waste Disposal
H-GAC	OSSF Visual Inspection Training
Houston-Galveston Subsidence	Water Detective WaterWise Kit
Keep Texas Beautiful	KTB Training
Keep Texas Beautiful	KTB Youth & Education Program
National Wild Turkey	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 & 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 the this WPP is divided into 3 parts: Near (1-2 years), Medium (3-5 years), and Long (6-15 years). Multi-year increments also take into account 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 13 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 22. Review of management measure voting exercise results

Table 28. Management Measure Implementation Schedule

Management Measure	Implementation Objective	Schedule of Implementation (years) 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 sanitary sewer system 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 B-2. 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

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
	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
MM #2: **Wipes, Fats, Oils, Grease 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	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 of existing local regulations, and assessment for 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

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
and outreach to residents and commercial entities on items that should not enter their drains.	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.
	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 1 Cease the Grease kitchen grease collection location within the watershed with 50 contacts per month utilize the kitchen grease collection station

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
	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 a	√			Join the Patty Potty Patrol

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
	"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 1 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 1 study to identify contributing factors to flow issues faced in the Highland Bayou Watershed; study agency USACE

Management Measure	Implementation Objective	Schedule of Implementation (years) 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.	Conduct a sediment source study to find the cause of sediment entering the bayou	√			Conduct 1 sediment source study; study agency USACE
	Selectively remove sediment and clear vegetation from the channel as recommended during assessments performed by the USACE		√	√	Remove sediment and vegetation selectively 1 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 5 trees per year in residential areas to improve flow and remove obstacles.
MM #4:	Request information from the USACE about culverts to determine maintenance needs (potential removal of	√			Submit 1 request for USACE to provide information about culverts

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
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.	sediment and debris) to improve flow				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	√			1 MOU established for culvert maintenance
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	Distribute pet waste educational material to residents during public events	√	√	√	Provide existing handouts and educational materials to 200 at events, workshops, meetings, etc. per year
	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

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
education and outreach to pet owners on proper pet waste management and impact of pet waste on water quality.	Distribute pet waste bag dispensers to residents during public events	√	√	√	100 pet waste bag dispensers given to residents per year
MM #6: **Green Infrastructure and Stormwater Treatment Wetlands**	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.
Goal: To reduce the amount of stormwater runoff entering local waterways by retaining rainfall on site or in neighborhood and regional detention	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 1 business interested in GI per month, or 12 per year

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
features and to treat stormwater runoff using GI and SWW.	Design and implement GI projects including rain gardens, permeable pavement, bio-swales, vegetated curb extensions, rain water harvesting cisterns and WaterSmart landscaping		√	√	1 GI demonstration project designed and built every two years
	Educate residents as well as public entities about GI	√	√	√	Host 1 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 6 handout/brochures about 6 GI practices
	Partner with AgriLife to host GI workshops, lectures and field trips to educate homeowners, businesses and municipal officials		√	√	1 GI workshop held per year for businesses, municipal officials, and homeowners

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
	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		√	√	1 constructed SWW workshop held per year
	Identify public entities interested in utilizing stormwater treatment wetlands and establish ordinances to consider these practices	√	√	√	Identify and contact 1 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,

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
					approx. 3% per year, for 6 years.
	Incorporate stormwater treatment wetlands during new development projects		√	√	Review and update local development codes to require or not prohibit the use of stormwater treatment 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	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	Schedule of Implementation (years) Near 1-2	 Medium 3-5	 Long 6-15	Milestones
where water quality practices could be implemented.	Inventory and map public stormwater system		√		Develop 1 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	Develop new or strengthen existing ordinances addressing lawn clipping and landscaping debris management. Example ordinances are widely available for reference		√		Work with all 5 municipalities in the basin to identify potential updates to local ordinances
	Ordinance requirements will be communicated to		√	√	Number of violations reported by year

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
debris and nutrients into stormwater.	residents and landscaping crews				
	Develop enforcement measures for the ordinance including penalties due following multiple offenses.		√	√	Work with all 5 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
MM #9: **Landowner Conservation Plans** Goal: To increase landowner participation in existing conservation and habitat management plans	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	√	√	√	Identification of 2 interested landowners in medium and long term periods

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
to decrease bacteria and nutrient loading and enhance water quality within the watershed.	programs with potential participants when appropriate				
	Host landowner workshops addressing land management practices	√	√		2 Workshops held per year, target attendance 10-20 land owners
	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 1 conservation plan, WQMP, or LIP participation
MM #10: **Preserve Existing Natural Areas** Goal: To preserve priority undeveloped	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

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
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.	Review area conservation plans and consult with resource and conservation organizations to identify protected lands within the watershed	√			Review complete, with recommendations for improvement of existing plans and to encourage adoption of new plans by currently non-participating land owners.
	Identify properties with the potential for conservation management	√	√	√	Identification of 5 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		√		Work with 3 city councils to identify appropriate ordinances for consideration and adoption.

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
	the Bay materials and other existing programs				
	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 developers from cutting down all trees prior to construction		√		Sparse tree removal ordinance for new construction established
MM# 11: On-Site Sewage Facility Training	Galveston County will continue existing OSSF education programs.	√	√	√	Number of webpage views
Goal: Improve maintenance of OSSFs by educating home owners about proper OSSF	Identify households having OSSFs for a targeted outreach approach.	√			Creation of map

Management Measure	Implementation Objective	Schedule of Implementation (years) Near 1-2	Medium 3-5	Long 6-15	Milestones
operation and maintenance	Galveston County undertake new outreach methods such as mailouts notifying residents of septic online resources.		√		Creation of new materials
	AgriLife Extension host free homeowner workshops throughout the project areas	√	√	√	1 workshop 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	AgriLife Extension partner with Galveston County, Municipalities, GBF and interested groups to host at least one workshop per year for local landowners.	√	√		1 workshop held each year, target attendance 30+
	Distribute existing and/or create new outreach materials	√	√		200 publication distributed each year

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 Plan. It is likely that some milestones will be accomplished sooner than anticipated while others will be completed slower than expected. Interim measureable 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 sub-watershed level. WPP implementation success will also be gauged by evaluating improvements in water quality. Table 14 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.

Table 29. 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 42.1%

Table H-2 below outlines environmental strategies and progress indicators that will determine if load reductions are being achieved. Water bodies not specified in the TSWQS for specific chlorophyll-a criteria are protected from excessive nutrient levels in order to support the general uses through the use of screening levels. The screening levels listed for nutrients and chlorophyll a are statistically derived from SWQ monitoring data and are to be used when site specific criteria have not been developed in the TSWQS (TCEQ, 2012).

Table H- 1. 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 3rd 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 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.	Reduce the number of measured exceedances in routine ambient water quality monitoring to fewer than 12 per year in the near term phase (5 years), and to fewer than 8 per year in the long term phase (beyond 5 years)	See ambient water quality monitoring program
Criteria NPS 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	See ambient water quality monitoring program

Strategies	Description of Activities	Progress Indicators	Monitoring Component
		sampling to zero on a rolling 7 year basis	
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 1 in 5 warm season sampling events	See ambient water quality monitoring program
Criteria for TCEQ Water Quality and Aesthetic Standard Goals			
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	Refers to water quality conditions that support levels of aquatic life activity. High	High measured diversity in macro- and	Monitoring activity is outside of

Strategies	Description of Activities	Progress Indicators	Monitoring Component
standards for High ALU	ALU waters have high diversity and the usual assemblage of species 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.	microbenthic biotic assemblages and trophic orders from primary producers to apex species.	specific recommendation in this WPP. Results will rely on 3rd party with monitoring and reporting duties
Meet TCEQ Aesthetic Standards: Water free of debris	Debris and litter removal improves the perceived quality by the public of the waterway.	Noticeable changes in amount of debris found near 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 3rd party with monitoring and reporting duties
Meet TCEQ Aesthetic	Suspended solids consists of fine particulates of organic	Fewer observed exceedances of	See ambient water quality

Strategies	Description of Activities	Progress Indicators	Monitoring Component
Standards: No suspended solids	and non-organic residue that stay suspended in the water column, either from NPS runoff or through effluent from wastewater treatment plants or other commercial and industrial activities.	screening limits for TSS	monitoring program; else, monitored by Texas Stream Team Volunteers or other 3rd 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 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 3rd party with monitoring and reporting duties

Element I: Monitoring Program & 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 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 co 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:

1. TCEQ's SWQM program
2. Texas Stream Team
3. Galveston County Health District
4. 2010-2011 Highland Bayou Sampling Program
5. 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 the Texas' 367 classified streams. Systematic monitoring is conducted for shorter time frames and in support of TMDL implementation 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 is 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 US EPA. Sampling is conducted by professional water quality specialists and under strict quality assurances using National Environmental Laboratory Accreditation Conference certified labs and methods. *At this time 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 the 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 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 non-existent, 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 short-term 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 NPS 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 6 stations within the Highland Bayou Watershed. Sampling began in November 2010 and concluded in July, 2011. All the major non-point 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 continuously data monitoring station was set up for field sampling where TX Route 6 crosses Highland Bayou.

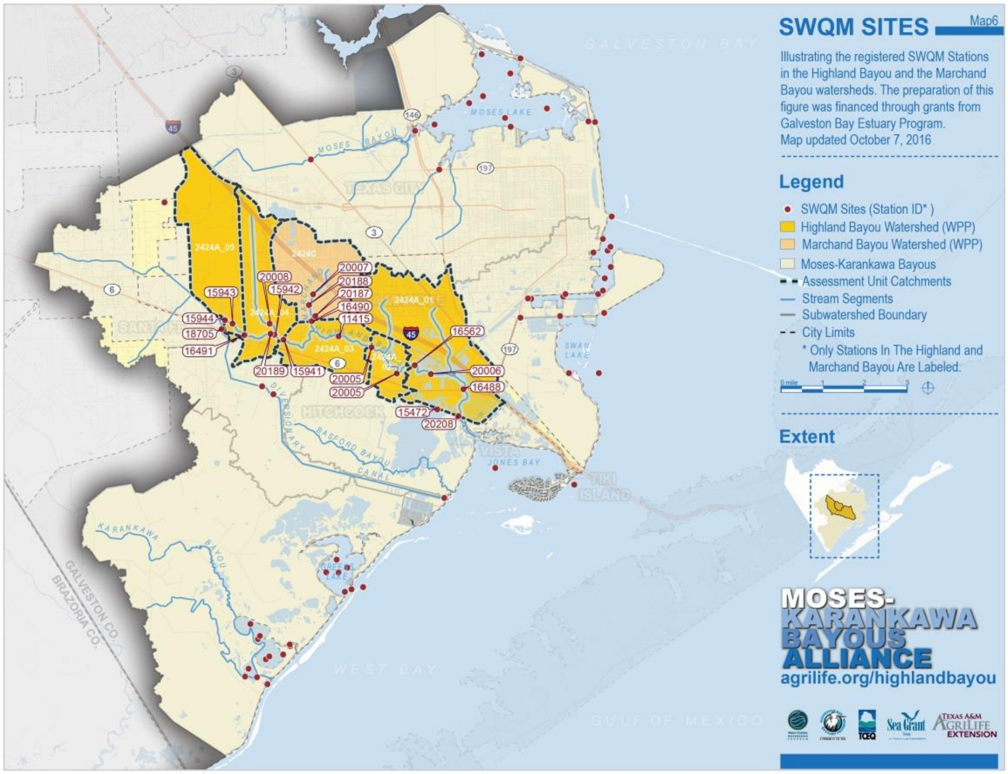
Proposed Monitoring

WPPS 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 being 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.

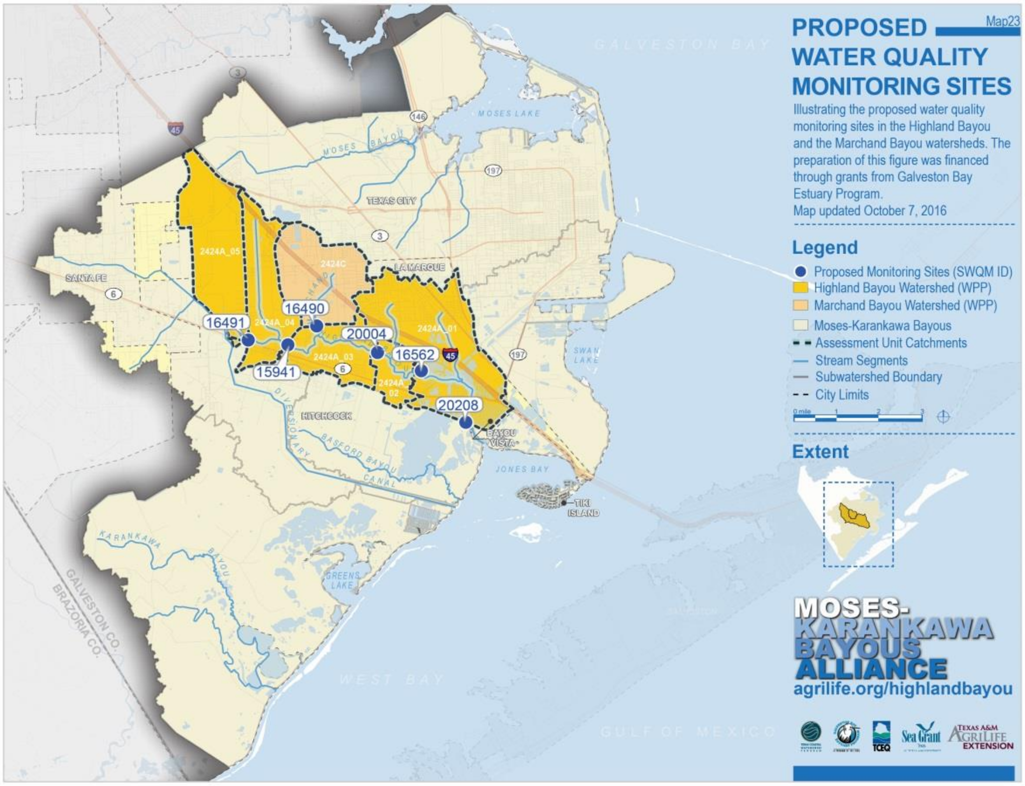
Table 15 below summarizes the SWQM stations that will be used for evaluating short term and long-term water quality conditions to guide the adaptive management approach. SWQM stations were selected for coincidence with the limits of listed segments, or alternatively AU ID catchments. Data collection will focus on collecting routine water quality samples from the 6 stations listed in Table I-1and shown on Map-23. These samples can be used for WPP implementation and in future waterbody assessments. Parameters monitored are listed in Table 1-2. Data from the last 7 years of bacteria and nutrient levels should be analyzed every 2 years and compared to interim target goals. Analyzing results every 2 years will also show spatial and historical trends that will assist with adjusting management strategies.

Table 30. 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_01	16562	Highland Bayou at end of Bayou Lane in Freddiesville	Galveston	Monthly
Highland Bayou	2424A_02	15941	Highland Bayou tidal at FM 519, 335 meters north of HWY 6 in City of Hitchcock	Galveston	Monthly
Marchand Bayou	2424C_01	16490	Marchand Bayou tidal at FM 519 in City of Hitchcock	Galveston	Monthly
Highland Bayou	2424A_03	16491	Highland Bayou at FM 2004 in City of Hitchcock	Galveston	Monthly
Highland Bayou	2424A_04	20004	Highland Bayou approximately 100 m downstream of City of La Marque. WWTP #WQ0010410001 is located 170 m upstream of Lake Road terminus	Galveston	Monthly
Highland Bayou	2424A_05	20208	Highland Bayou at railroad bridge 1.10 km downstream of HWY 6 near City of Texas City	Galveston	Monthly



Map- 6. Registered SWQM Stations



Map- 23. Proposed WQM Stations for Tracking Water Quality Improvements

Table I-2 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 31. Water Quality Parameters Used for Measuring Progress.

Field Data	
Dissolved oxygen (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 & C are tidally influenced)	
***E. coli* (#/100mL) freshwater only**	*Enterococci* (#/100mL) saltwater only
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 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. Bacterial Source Tracking is a relatively new approach that utilizes a bacteria DNA library, which is prepared using known sources from within the watershed. Water quality monitoring samples 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 Bacterial Source Tracking 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 & 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.