BASIN CHARACTERIZATION REPORT FOR THE SAN JACINTO – BRAZOS COASTAL BASIN FOR INDICATOR BACTERIA

YEAR TWO

Segments: 1101, 1102, 1103, 1104, 1105, 1107, 1108, 1109, 1110, 1111, 1113, 2424, 2425, 2427, 2431, 2432, 2433, 2434, 2436, 2437, 2438, 2439

August 7, 2017

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Prepared for

Total Maximum Daily Load Program

Texas Commission on Environmental Quality

MC-203

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AU	Assessment Unit
BMP	Best Management Practice
C-CAP	Coastal Change Analysis Program
CMP	Coordinated Monitoring Program
CRP	Clean Rivers Program
E. coli	*Escherichia coli*
FDC	Flow Duration Curve
FIB	Fecal Indicator Bacteria
FOR	Friends of the River San Bernard
FROG	Fats, Roots, Oil and Grease
GIS	Geographic Information System
GIWW	Gulf Intracoastal Water Way
H-GAC	Houston-Galveston Area Council
I/I	Inflow and Infiltration
I-Plan	Implementation Plan
LDC	Load Duration Curve
LOESS	Locally-weighted Least Squares
LOQ	Limit of Quantitation
mi	Mile
mL	Milliliter
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System

NRCS	Natural Resources Conservation Service
OSSF	Onsite Sewage Facility
QAPP	Quality Assurance Project Plan
RUAA	Recreation Use Attainability Assessment
SAS	Statistical Analysis System
SSO	Sanitary Sewer Overflow
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TSSWCB	Texas State Soil and Water Conservation Board
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
WQMP	Water Quality Management Plan
WPP	Watershed Protection Plan
WWTF	Waste Water Treatment Facilities

1 INTRODUCTION

1.1 BACKGROUND AND OVERVIEW

Clean water is an important element to all living things. The Houston-Galveston Area Council (H-GAC) Clean Rivers Program (CRP) service area (Figure 1.1) contains 16,000 miles of streams and shoreline providing a network of valuable habitat and ecosystem services for the region, connecting freshwater streams to productive coastal estuaries and connecting us to nature and to each other. Clean water is a foundation for our regional economy, contributing $4 billion annually through ecotourism, oyster harvesting, and commercial fishing.

However, more than 80 percent of stream miles within the region fail to meet state water quality standards or screening criteria for one or more parameters. Rapid development and population growth, aging and poorly maintained infrastructure, and certain types of land management techniques strain the health of waterways if proper management practices are not in use or established. H-GAC was tasked by the Texas Commission on Environmental Quality (TCEQ) to apply a targeted basin approach to the San Jacinto – Brazos Coastal Basin (Basin 11), and portions of Basin 24 (referred to as Basin 11 for the remainder of this report). This approach characterized water quality problems, particularly bacteria; identified opportunities for public and stakeholder involvement; and recommended potential management approaches to begin to address bacteria impairments found in the Basin.

1.2 WATER QUALITY STANDARDS AND ASSESSMENT

The TCEQ conforms to the requirements of the federal Clean Water Act Sections 305 (b) and 303 (d) by producing the Texas Integrated Report of Surface Water Quality (Integrated Report) for Clean Water Act Sections 305 (b) and 303(d) every two years. The report assesses the state's waters to determine if they meet state water quality standards. Those water bodies, often referred to as segments, that do not meet water quality standards are included on the 303 (d) list as impaired.

The TCEQ established water quality standards to protect the public's health and use, and support aquatic life, while sustaining economic development. The standards set explicit goals for the quality of streams, lakes, rivers, and bays throughout the region.

Water quality standards identify appropriate uses for the state's surface waters, including aquatic life, recreation, and sources of public drinking water. Criteria are established to evaluate these uses, including: dissolved oxygen, temperature, pH, dissolved minerals, toxic substances, and bacteria.

These state standards are codified as state rules under Title 30, Chapter 307 of the Texas Administrative Code. The standards are written by the TCEQ under the authority of the Clean Water Act and the Texas Water Code. The US Environmental Protection Agency (EPA) approves the Texas Surface Water Quality Standards.

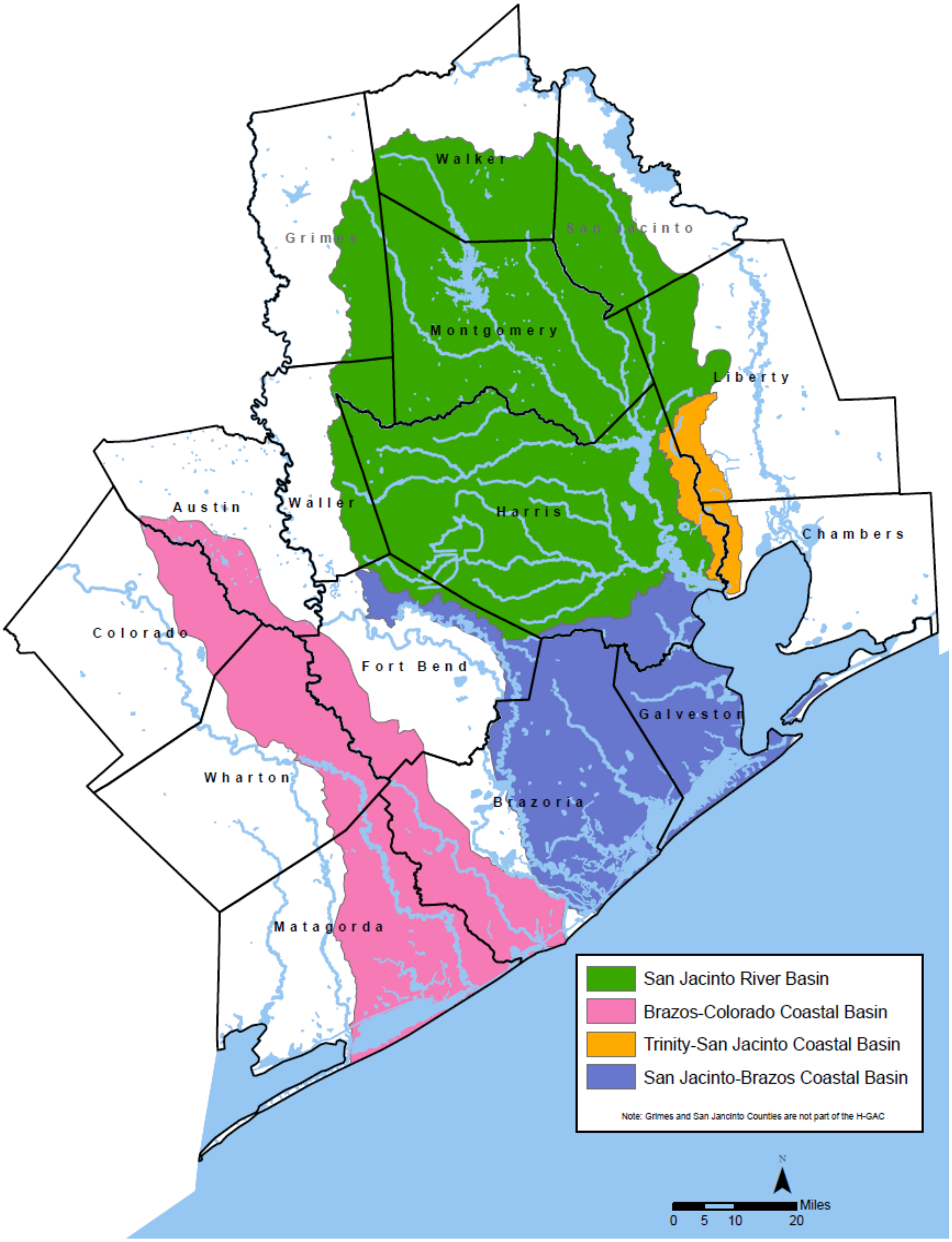


Figure 1.1. Four Texas river basins within the H-GAC Clean Rivers Program service boundary for southeast Texas.

The Texas Surface Water Quality Standards (TCEQ, 2010) are designed to

- Designate the uses, or purposes, for which the state's water bodies should be suitable;
- Establish numerical and narrative goals for water quality throughout the state; and
- Provide a basis on which TCEQ regulatory programs can establish reasonable methods to implement and attain the state's goals for water quality.

The TCEQ encourages public participation in development and revision of the water quality standards through participation on the Surface Water Quality Standards Advisory Work Group.

1.3 Contact Recreation and Bacteria

Water quality professionals are challenged to ensure the region's water bodies meet state water quality standards. Elevated bacteria concentrations represent the most common impairment in Texas.

Bacteria concentrations are used as indicators of the potential risk of illness during contact recreation (e.g. swimming and water skiing) from the ingestion of water. The state and the EPA use *E. coli* (fresh water) and enterococci (salt water) as fecal indicator bacteria (FIB) as they both are found in human and animal intestines and their feces. FIB is easily assessed and predictive of human health risk (Byappanahalli, 2012). The presence of FIB in waters suggests that human and animal wastes may be reaching the assessed waters because of such sources as inadequately treated wastewater, agriculture and animal sources (Bastropbayou.org, 2016).

On February 12, 2014, the TCEQ adopted revisions to the Texas Surface Water Quality Standards (TCEQ, 2010) and on September 23, 2014, the EPA approved the categorical levels of recreational use and their associated criteria. Recreational criteria are based on FIB rather than direct measurements of pathogens. Criteria are expressed as the number of bacteria per 100 milliliters (mL) of water (in terms of colony forming units, most probable number (MPN), or other applicable reporting measure.)

Recreational use consists of five categories for freshwater:

I. Primary Contact Recreation 1 – activities that pose a significant risk of ingestion of water (e.g., swimming, wading by children, water skiing, diving, tubing, surfing, and the following whitewater activities: kayaking, canoeing, and rafting). Classified segments are designated for Primary Contact Recreation 1 unless sufficient site-specific information demonstrates that (1) elevated concentrations of FIB frequently occur due to sources of pollution that cannot be reasonably controlled by existing regulations, (2) wildlife sources of bacteria are unavoidably high and there is limited aquatic recreational potential, or (3) secondary contact recreation is considered unsafe for other reasons, such as ship and barge traffic. The geometric mean for this criterion for *E. coli* of 126 most probable number (MPN) per 100 mL and an additional single sample criterion of 399 MPN per 100 mL in fresh water.
II. Primary Contact Recreation 2 – applies to water bodies where recreation activities that involve a significant risk of ingestion of water occur, but less frequently than for Primary Contact

Recreation 1 due to physical characteristics of the water body or limited public access. The geometric mean criterion for *E. coli* is 206 per 100 mL.

III. Secondary Contact Recreation 1 – activities that commonly occur but have limited body contact incidental to shoreline activity (e.g., wading by adults, fishing, canoeing, kayaking, rafting, and motor boating). These activities are presumed to pose a less significant risk of water ingestion than Primary Contact Recreation but more than the following category, Secondary Contact Recreation 2. The *E. coli* geometric mean criterion for fresh water is 630 MPN per 100 mL.

IV. Secondary Contact Recreation 2 – activities with limited body contact incidental to shoreline activity (e.g., fishing, canoeing, kayaking, rafting, and motor boating) that are presumed to pose a less significant risk of water ingestion than Secondary Contact Recreation 1. These activities occur less frequently than Secondary Contract Recreation 1 due to physical characteristics of the water body or limited public access. The geometric mean criterion for *E. coli* is 1,030 MPN per 100 mL.

V. Noncontact Recreation – activities that do not involve a significant risk of water ingestion, such as those with limited body contact incidental to shoreline activity, including birding, hiking, and biking. Noncontact recreation use may also be assigned where primary and secondary contact recreation activities should not occur because of unsafe conditions, such as ship and barge traffic. This category has a geometric mean criterion for *E. coli* of 2,060 MPN per 100 mL.

Figure 1.2 Creeks, bayous, rivers and bays are popular places for water activities. Water and children often equal contact recreation, Spring Creek, H-GAC CRP region.

Recreational use consists of three categories for saltwater:

I. Primary Contact Recreation 1 – the geometric mean criterion for enterococci is 35 MPN per 100 mL. The single sample criterion is 104 MPN per 100 mL.
II. Secondary Contact Recreation 1 – A secondary contact recreation 1 use for tidal streams and rivers can be established on a site-specific basis if justified by a use-attainability analysis and the water body is not a coastal recreation water as defined by the Beaches Environmental Assessment and Coastal Health Act of 2000 (Beach Act). The geometric mean criterion for enterococci is 175 MPN per 100 mL.
III. Noncontact recreation – a noncontact recreation use for tidal streams and rivers can be established on a site-specific basis if justified by the use-attainability analysis and the water body is not a coastal recreation water as defined by the Beach Act. The geometric mean criterion for enterococci is 350 MPN per 100 mL.

1.4 Total Maximum Daily Load Program

The development of an impaired water bodies list satisfies federal Clean Water Act requirements under Section 303 (d) by identifying waters that do not meet, or are not expected to meet, applicable water quality standards. States must develop a total maximum daily load (TMDL) for each pollutant that contributes to the impairment of a listed water body. The TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

A TMDL is like a budget – it determines the amount of a pollutant that a water body can receive and still meet its applicable water quality standards. TMDLs are the best possible estimates of assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. In addition to the TMDL an implementation plan (I-Plan) is developed. The I-Plan is a description of the regulatory and voluntary management measures necessary to improve water quality and restore full use of the water body.

The TMDL Program is a major component of Texas' overall process for managing the quality of its surface waters. The program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries in, or bordering on, the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses – such as drinking water supply, recreation, support of aquatic life, or fishing – of impaired or threatened water bodies.

1.5 Houston – Galveston Area Council

H-GAC, an established Council of Governments and regional planning agency for the Gulf Coast State Planning Region, has more than 35 years of regional environmental planning and public outreach experience. H-GAC continues to develop a comprehensive regional Geographic Information System (GIS) for valuable data analysis and modeling techniques. Many key agencies and individuals normally involved in regional water quality matters already work cooperatively under the umbrella of H-GAC's existing environmental committees and programs.

H-GAC is designated as the lead agency responsible for regional water quality assessment for the San Jacinto River Basin, Trinity-San Jacinto Coastal Basin, San Jacinto-Brazos Coastal Basin, Brazos-Colorado Coastal Basin, and Bays and Estuaries (Figure 1.1). H-GAC coordinates the CRP in these basins.

The Texas Clean Rivers Act requires river authorities to prepare written water quality assessment reports for their respective basins and present the reports to the Governor, TCEQ, Texas State Soil and Water Conservation Board, and Texas Parks and Wildlife Department. The data and information provided by the state's CRP partners form the backbone supporting the *Integrated Report*.

The Act also established the Texas Clean Rivers Program, funded by fees paid by wastewater discharge permittees and water rights holders. The CRP, under the direction of the TCEQ, requires continuous assessment of ambient water quality to identify key issues and develop management strategies statewide. Results from the CRP process help set the agenda for all other water quality management programs, including monitoring, standards development, permitting, enforcement, public outreach, and field investigation and research.

1.6 Report Purpose and Organization

The Basin project was initiated through a contract between the TCEQ and H-GAC. This report is the second report in a series of reports that record the actions, tasks and accomplishments of the TCEQ and H-GAC using the basin approach in Basin 11. This report is an update to The Basin Characterization Report for the San Jacinto-Brazos Coastal Basin for Indicator Bacteria (June 2016). The tasks for the second year of the project were to (1) build on public outreach and engagement; (2) acquire and update existing (historical) data and information to inform this report; (3) perform appropriate analyses to document the current state of water quality in the Basin and make water quality management recommendations with the concurrence of the TCEQ; (4) conduct special studies on identified segments and initiate water quality planning activities in accordance with TCEQ; and (4) initiate and coordinate Texas Stream Team activities within the Basin. This report contains:

- Information on historical data,
- Basin and watershed properties and characteristics,
- Summary of historical bacteria data that confirm the State of Texas 303 (d) listings of impairment due to the presence of FIB,
- Development of load duration curves,
- Segment special studies, and
- review of water quality management programs in the Basin.

2 Public Outreach and Stakeholder Involvement

2.1 Water Quality Planning Process

Throughout the water quality planning process, the TCEQ encourages the participation and input of residents and interest groups. Whether that contribution is providing comments on standards development, monitoring locations, and periodic assessments, or participating in recreation use attainability analyses (RUAAs), watershed protection plan (WPP) creation, and TMDL implementation plan (I-Plan) development, the public and interest groups are actively sought out and invited to play key roles in water quality planning.

The reasoning – local input is considered necessary for the success of water quality planning (Figure 2.1). Residents, business owners, industry representatives, local government staff, non-profit members, and other interested parties hold critical knowledge and technical expertise concerning watershed conditions and pollutant sources. These groups hold a stake in the quality of their water and, as stakeholders, are important in directing solutions to addressing pollutant concerns, identifying and recommending voluntary pollutant reduction measures, and becoming central to implementing those measures.

2.2 Project Outreach

To update the basin characterization report and continue building a foundation for future work in the basin, H-GAC engaged basin stakeholders by:

- maintaining contact with interested stakeholders and basin interest groups to share project information and provide notification of public meetings (Appendix A),
- updating as needed, the one-page information brochure (Appendix B),
- maintaining a Basin 11 website, and
- hosting public and one-on-one stakeholder meetings to share project information and feedback on topics concerning the basin.

In 2016, H-GAC identified a total of 372 potential stakeholders in Basin 11. H-GAC contacted each stakeholder through an email sent to the entire stakeholder group. The email “blast” was then followed up by prioritizing the list for further direct phone and email outreach. Each potential stakeholder was given the one-page project brochure. Stakeholders directly contracted were afforded greater project information, given an opportunity to fill out a project survey, and queried as to their interest in participating in future basin and watershed meetings. From the initial list of 372 potential stakeholders, 32 individuals and organizations voiced interest in participating in Basin 11. H-GAC followed up the initial 2016 outreach by hosting two public meetings and one-on-one meetings.

2.2.1 First Public Meeting

The first public meeting was held at the Brazoria County Public Library in Alvin, Texas on December 6, 2016. Seven stakeholders were present at the meeting. The attendees heard from H-GAC and Texas

State Soil and Water Conservation Board (TSSWCB) on water quality in the Basin, tools available to improve water quality and additional steps that will be taken under the basin approach.

2.2.2 One-on-One Meetings

Meeting with individuals and organizations directly is important for fostering interest, building support and trust with stakeholders. H-GAC initiated that process in year two with:

- Friendswood Economic Development Corporation
- City of Lake Jackson
- City of Texas City
- City of Manvel
- City of Alvin
- City of Dickinson

The one-on-one meetings focused on the characterized water quality information for the basin, discussing watershed interests, providing the project schedule, exchanging contact information and soliciting participation in future meetings. One-on-one meetings will continue in the third year of the basin approach.

2.2.3 Second Public Meeting

The second public meeting was held at the Brazoria County Public Library in Alvin, Texas on August 10, 2017. H-GAC contacted identified stakeholders directly through phone calls and personal email messages. Along with the meeting announcement, H-GAC offered to meet one-on-one with each organization and asked the organizations to assist with announcing the meeting. Outreach efforts resulted in eighteen stakeholders attending the meeting. The attendees were given a project update that included the latest information on Basin water quality, development of a draft Chocolate Bayou Technical Source Document, draft results of additional monitoring in Oyster Creek, and the next steps that will be taken under the basin approach.

2.3 Planning Outreach Tools

There are four watershed-based tools that were evaluated for use in Basin 11.

- Additional monitoring – segments and AUs in Basin 11 were reviewed for spatial and temporal environmental data gaps.
- Recreational Use Attainability Analysis (RUAA) – segments and AUs were reviewed for the appropriateness to conduct an RUAA.
- Watershed Protection Plan – segments and AUs were reviewed for the appropriateness to develop WPPs.
- TMDL studies – segments and AUs were reviewed for the appropriateness to conduct TMDL studies and develop implementation plans.

Determining when and where to engage the use of these tools will involve the input of local stakeholders and concerned residents. H-GAC, in analyzing available information for this basin, discusses the potential for utilizing one of these approaches as an initial starting point for the watershed planning process discussion. In certain cases, one or more of these tools has already begun or is in process. The segment analyses found in Appendix D notes if any of these tools has been used. Additionally, recommendations made in Section 6, Conclusions and Recommendations, will note if H-GAC suggests TCEQ consider implementing one of these tools in the future.

Figure 2.1 Bacteria Implementation Group stakeholder meeting, May 14, 2013.

2.4 Current and Future Basin 11 Involvement Opportunities

Implementing any of the tools listed in section 2.3 will actively involve residents and organizations. Outreach as the basin approach is implemented will use public notices, outreach materials, public meetings, and individual and organization surveys. Each tool generally hosts its own public engagement process. In addition to potential public and stakeholder engagement opportunities there are twelve existing projects that encourage involvement: CRP, Galveston Bay Estuary Program (GBEP), RUAAs (2 – Armand Bayou Above Tidal and Dickinson Bayou Above Tidal), WPP (3 - Bastrop Bayou WPP, Dickinson Bayou WPP, and Highland Bayou WPP), TMDLs (5 - Bacteria Implementation Group, Dickinson Bayou TMDL, Jarbo Bayou TMDL, Upper Texas Gulf Oyster Waters TMDL, and Upper Oyster Creek TMDL) and the Brazoria-Galveston Coalition of Watersheds.

2.4.1 Clean Rivers Program

H-GAC, as the CRP lead in the region, encourages resident and stakeholder involvement in its coordinated monitoring meetings and annual CRP Steering Committee meeting. H-GAC uses these outreach opportunities to assist the CRP program in addressing gaps in spatial and temporal monitoring, remove duplicative efforts due to proximity of monitoring stations, and to establish new monitoring stations to reflect a special study, e.g. TMDL, WPP, or special project (H-GAC, 2016).

2.4.2 Galveston Bay Estuary Program (GBEP)

GBEP is a regional watershed program that includes most of Basin 11 within its target watershed. The program is managed by the TCEQ and utilizes state and federal funding to implement the Galveston Bay Plan (*the Plan*). GBEP actively pursues stakeholder and public involvement in planning and implementing activities developed and administered in coordination with the program's management council, Galveston Bay Council, and five standing council subcommittees. Improving water quality is one of many activities described in *the Plan* (GBEP, 2016).

2.4.3 Recreation Use Attainability Analysis

RUAAs are scientific assessments conducted to evaluate and determine what category of recreational use is appropriate for a water body. These site-specific studies, carried out by the TCEQ, assess reasonable attainable recreational uses that can occur based on the physical and flow characteristics of a stream, e.g. water depth and persistence flow. Supporting information also includes outreach through surveying individuals and organizations with first-hand knowledge of the waterbody, to establish historical and existing patterns of recreational use (TCEQ, 2016). There are two RUAAs currently listed as in progress by the TCEQ for the basin: Armand Bayou Above Tidal – Segments 1113A and Dickinson Bayou Above Tidal – Segment 1104 (Figure 2.2). The Recreational Survey Reports have not been posted. The public will have an opportunity to review and comment on the reports and to any future TCEQ recreation use category recommendations.

2.4.4 Watershed Protection Planning

WPPs are watershed-based, stakeholder-led planning processes supported by the TCEQ and the Texas State Soil and Water Conservation Board (TSSWCB) to address non-point sources of pollution. The plans are developed by local stakeholders, usually with funding and technical assistance provided by the TCEQ and/or TSSWCB, along with the EPA (TCEQ, 2016). Public meetings, resident outreach, and public tours of the watershed are popular outreach tools used by WPP participants. There is currently one completed WPP and two WPPs in progress within Basin 11 (Figure 2.2), which present opportunities for public engagement.

- Bastrop Bayou Watershed Protection Plan. The WPP was approved in July 2016, capping off a ten-year stakeholder led process. Bacteria is a key water quality impairment. Sources of FIB were identified as coming from urban runoff and pet waste, in adequate wastewater management, and agriculture and animal production (Bastrop Bayou WPP, 2016). In addition to bacteria, stakeholders identified illegal dumping as an issue for the watershed.

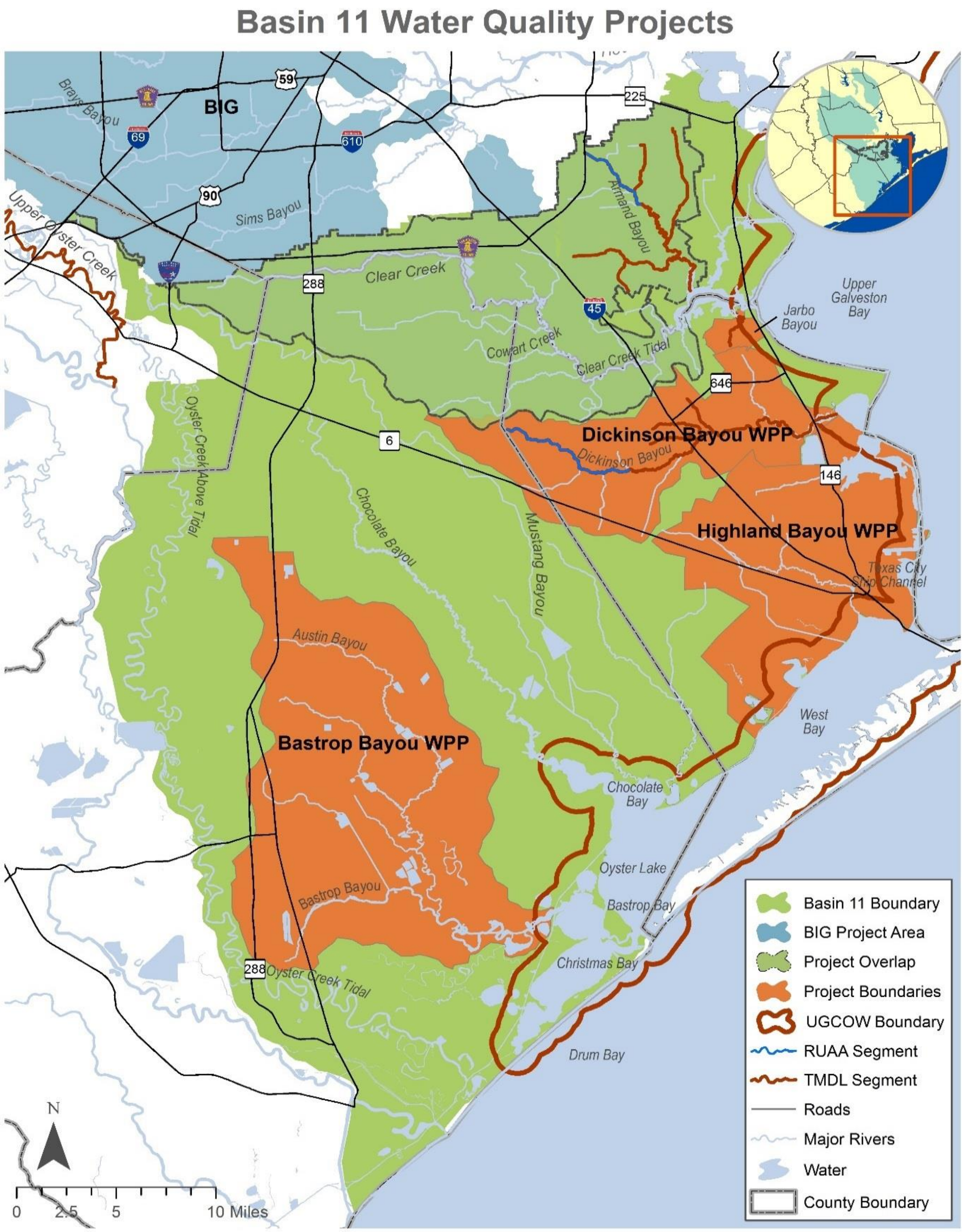


Figure 2.2. RUAAs, WPPs, and TMDL projects in Basin 11.

- Dickinson Bayou Watershed Protection Plan. The draft WPP was completed in February 2009. The Dickinson Bayou Watershed Partnership, an active group of watershed stakeholders, is currently drafting a document to bridge the gap between the WPP, the TMDL I-Plan and the nine elements of a watershed based plan to receive EPA approval. The WPP covers many topics from water quality impairments due to bacteria and low dissolved oxygen to land development, loss of habitat and flooding concerns (Dickinson Bayou Watershed Partnership, 2016).
- Highland Bayou Watershed Protection Plan. Stakeholders participating in the Moses-Karankawa Bayous Alliance are drafting the Highland Bayou WPP (Highland WPP, 2016). The WPP specifically address bacteria and dissolved oxygen impairments in Highland and Marchand Bayous but is also looking at watershed issues facing a region that includes Moses Bayou/Lake to Karankawa Bayou. This area includes the cities of Texas City, La Marque, Hitchcock, Bayou Vista and Tiki Island.

2.4.5 Total Maximum Daily Loads

TMDLs developed by the TCEQ, bring communities together to develop a plan to reduce pollutant loads to meet state standards. The TMDL is a scientifically derived target that describes the greatest amount of a substance that can be added to a waterway and the waterway remains healthy (TCEQ, 2016). A TMDL implementation plan (I-Plan) is then developed by local stakeholders to reduce the pollutant to meet the target. Public meetings are key to identifying local-specific measures adopted in the I-Plan and to encouraging the eventual use of those measures. There are five active TMDL projects in Basin 11 (Figure 2.2) that offer opportunities for public involvement.

- Bacteria Implementation Group. The Bacteria Implementation Group (BIG) oversees an implementation plan for 95 TMDLs approved and adopted since 2009. The I-Plan covers parts of nine counties (TCEQ, 2016): Brazoria, Galveston, Grimes, Harris, Fort Bend, Liberty, Montgomery, Walker, and Waller. A portion of the project area is in Basin 11 (shaded area on Figure 2.2). Sources of bacteria have been identified from inadequately treated waste water, illicit discharges, urban run-off, and feral hogs.
- Dickinson Bayou TMDL. The TCEQ adopted and the EPA approved eight TMDLs for the Dickinson Bayou watershed in June 2012. The Dickinson Bayou I-Plan was approved by the TCEQ on January 15, 2014 (TCEQ, 2016). The I-Plan address poorly treated waste water from waste water treatment facilities and on-site sewage facilities, illicit discharges due to sanitary sewer overflows, and urban run-off.
- Jarbo Bayou TMDL. The TMDL study is currently in progress. Stakeholders have met and have recommended to the TCEQ their interest in joining the BIG and implementing the BIG I-Plan. FIB sources were identified as urban run-off, sanitary sewer overflows and boater wastes.
- Upper Texas Gulf Coast Oyster Waters (UGCOWs) TMDL. Six TMDLs were adopted by the state (August 2008) and approved by the EPA (February 2009) for oyster producing waters in Galveston Bay. The I-Plan was approved by the TCEQ in August 2015 (TCEQ, 2016). While the I-Plan only cover a small portion of Basin 11, it is worth mentioning that improving fresh water sources from Basin 11 that enter the UGCOWs TMDL area can assist in implementing the plan. Additionally, many of the stakeholders that participate in the UGCOWs come from Basin 11. Boater wastes, deficient waste water treatment by waste water facilities or OSSFs, and wildlife are considered bacteria sources.

- Upper Oyster Creek TMDL. Upper Oyster Creek, due to hydrologic modifications, is part of the Brazos River Basin, Basin 12, and not Basin 11. Just like the UGCOWs TMDL, some of the stakeholders participating in the Upper Oyster Creek TMDL would likely participate in water quality planning in Basin 11. There are two TMDLs projects, dissolved oxygen and bacteria, for the Upper Oyster Creek. The dissolved oxygen project covers two TMDLs that were adopted by the TCEQ and approved by the EPA in July 2010 and September 2010, respectively. There is one TMDL for bacteria which was adopted by TCEQ, August 2007 and approve by the EPA, September 2007. The I-Plan, approved by the TCEQ in January 2014, addresses both the bacteria and dissolved oxygen impairments (TCEQ, 2016). The I-Plan recommended a set of voluntary measures to address bacteria and dissolved oxygen impairments caused by deficient human waste water treatment practices, agriculture and wildlife sources, and urban non-point sources.

2.4.6 Brazoria-Galveston Coalition of Watersheds

The Brazoria-Galveston Coalition of Watersheds is a watershed planning program started in 2017. The effort is seeking to build a collaboration among watershed protection planning initiatives and TMDL projects in Brazoria and Galveston Counties. The coalition will string together common water quality management elements and seek funding to jointly implement them across the combined project area. Texas AgriLife with support from the Galveston Bay Estuary Program has taken the lead on this program.

2.5 Texas Stream Team and Other Outreach Opportunities

H-GAC will coordinate outreach, workshops and volunteer training events in Basin 11. Several existing state and regional water quality programs can be brought to the basin to assist with education and offer early water quality best practices to reduce bacteria and other pollutants. Programs such as Texas Stream Team (Figure 2.2) offer hands-on volunteer opportunities for stakeholders and residents interested in water quality monitoring. Other programs, including those by the Texas A&M AgriLife Extension Service offer technical training to agriculture producers and owners of onsite sewage facilities (OSSFs) to offer implementable solutions to current practices with the goal of preventing or eliminating sources of bacteria.

2.5.1 Texas Stream Team

Texas Stream Team (TST) is a network of volunteer water quality monitors (Figure 2.3) that collect water quality information, expanding the monitoring capabilities of state and local partners, and making that information available to all Texans (H-GAC, 2016). At the state level, TST is administered by Texas State University, TCEQ and EPA. H-GAC is the lead regional TST agency. H-GAC provides certified water monitoring training to volunteer participants, using quality assured methods for gathering water quality information. There are currently 133 TST volunteers for 123 monitoring sites in the H-GAC CRP region and 66 TST volunteers at 66 sites in Basin 11.

2.5.1.1 Support for TST in Basin 11

During the second year of Basin 11 approach, H-GAC supported TST by hosing a TST training event on June 16, 2017. The event was held at the Brazoria County Public Library in Alvin, Texas. Eight new volunteers participated. H-GAC purchased supplies to build six TST monitoring kits for use in the basin.

2.5.2 Texas A&M AgriLife Extension Service

AgriLife Extension provides programs that center on water quality, including watershed education, land practices, and OSSFs (Agrilife Extension, 2016).

2.5.2.1 Texas Watershed Steward Program

AgriLife Extension's Texas Watershed Steward Program (TWS) is an educational program offering an online course and one-day workshop seeking to educate and inform local stakeholders about the watersheds where they live, water quality impairments and concerns, and steps that can be taken to help improve and protect their water resources. On July 11, 2017, Texas AgriLife hosted the program at the Brazoria County Fair Grounds in Angleton, Texas. Twenty-seven participants attended the event.

2.5.2.2 Lone Star Healthy Streams

AgriLife Extension's Texas Water Resources Institute (TWRI) manages the Lone Star Healthy Streams (LSHS) program which seeks to educate interested Texas farmers, ranchers, and landowners about proper grazing, feral hog management, and riparian area protection to reduce the levels of pollutant contamination to streams and rivers. TWRI hosts an informative LSHS website and conducts LSHS workshops around the state.

Figure 2.3 Texas Stream Team volunteer monitoring.

2.5.2.3 Onsite Wastewater Treatment Training Program

AgriLife Extension offers short courses and training centers to educate homeowners and improve the skills of installers, site evaluators and designers of onsite waste water treatment systems. The courses meet OSSF inspection credit hour requirements.

2.5.3 OSSF Real Estate Inspection Training Course and Homeowner Training

H-GAC offers a Texas Real Estate Commission (TREC) approved OSSF real estate training course and general OSSF information for homeowners. The real estate course is designed to help real estate agents and home inspectors identify OSSFs on properties and determine if failing through visual inspection. The course provides six TREC continuing education credit hours. H-GAC also offers training to homeowners interested in learning more about their OSSFs and basic inspection and repairs. On July 21, 2017, H-GAC offered its homeowner training at the Brazoria County Extension Office in Angleton, Texas. Nineteen residents were present at the workshop.

3 BASIN PROPERTIES

3.1 DESCRIPTION OF STUDY AREA

The San Jacinto-Brazos Coastal Basin (Basin 11), which is made up of segments contained within Basin 11 and for this report a portion of Basin 24 (Figure 3.1), lies in southeast Texas within the Houston-The Woodlands-Sugarland Metropolitan Statistical Area. The basin sits adjacent to Galveston Bay, west of Upper and Lower Galveston Bays and northwest of West Galveston Bay. The study area includes portions of four counties: Brazoria, Galveston, Harris, and Fort Bend. All or part of fifty-two cities, villages, and census-designated places can be found in the Basin. The basin's current population is 1 million, a 38% increase over the 2000 US Census (Table 3.1). H-GAC's forecast model projects the population to increase to 1.6 million by 2040. Pearland and League City are the largest cities based on population wholly contained within the Basin.

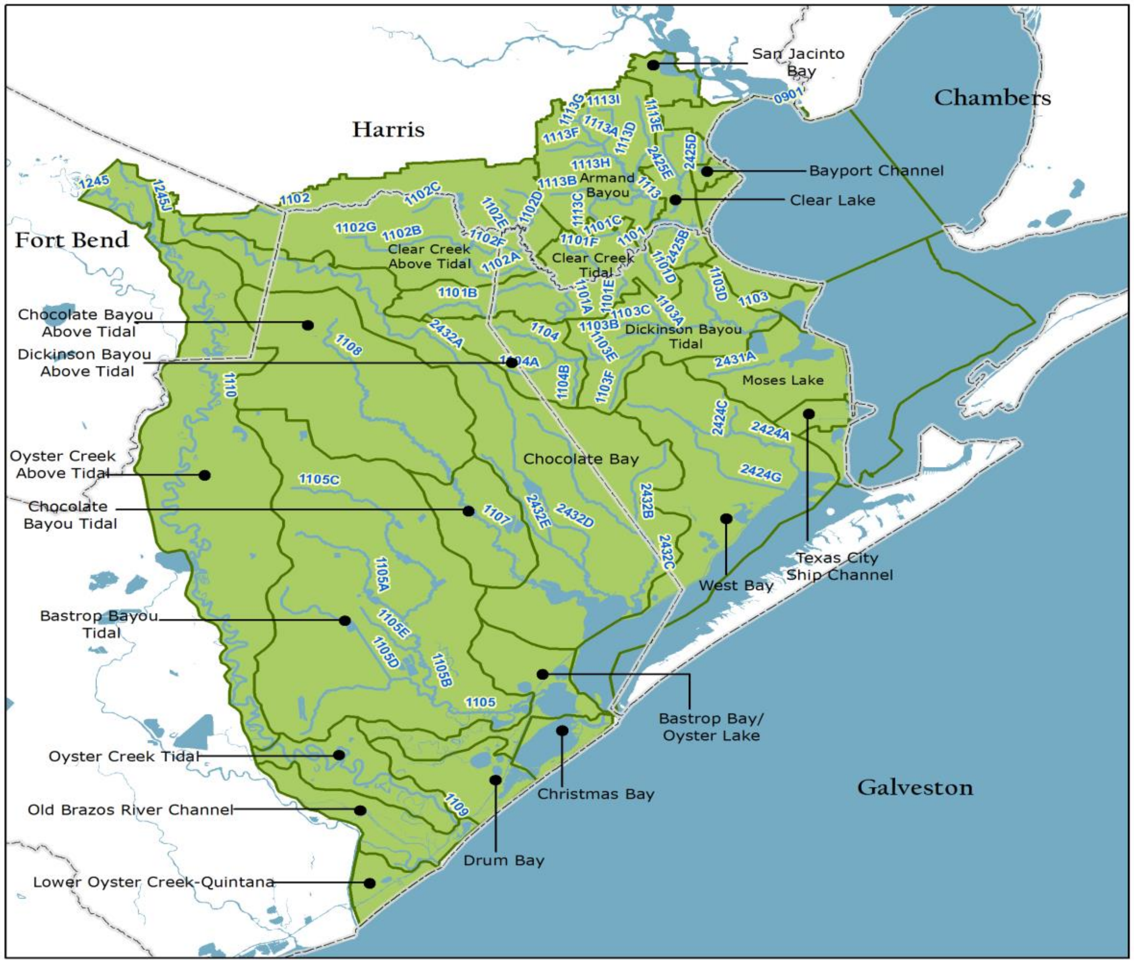
Basin 11: Population	
	Basin 11
2000 Population	725k
Current Population	1 mil.
Change 2000-Current	38%
2040 Population	1.6 mil.

Table 3.1: Basin 11 population growth since 2000 and projected growth to the year 2040.

The major tributaries to Galveston Bay generally flow from west to east or north to south. These major tributaries are divided into twenty-two segments (Figure 3.1). The 2014 *Integrated Report* (2015) provides the following segments found in the Basin for waterbodies considered in this document:

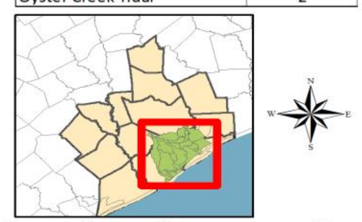
- Segments 1101 and 1102. Clear Creek originates in Fort Bend County and flows eastward forming the border between Harris and Brazoria counties before becoming the border between Harris and Galveston counties. Clear Creek empties into Clear Lake and Upper Galveston Bay.
- Segments 1103 and 1104. The headwaters to Dickinson Bayou can be found in Brazoria County where it travels eastward into Galveston County prior to entering Dickinson Bay and Lower Galveston Bay.
- Segment 1105. Bastrop Bayou and its major tributaries Austin and Flores Bayous, can be found wholly in Brazoria County flowing north to south prior to emptying into Bastrop Bay, a sub bay of Christmas Bay and West Bay.
- Segments 1107 and 1108. Chocolate Bayou begins it journey in Brazoria County and travels south to Chocolate Bay on West Galveston Bay.
- Segments 1109 and 1110. Lower Oyster Creek is a continuance of Oyster Creek (Segment 1245) that starts in Fort Bend County and flows south through Brazoria County prior to terminating at the Gulf Intracoastal Waterway (GIWW), a sheltered water conveyance for shipping and recreation along the Gulf Coast from Texas to Florida.

Basin 11 - Watershed



County Boundary
Major Rivers and Bayous
Watershed Boundary

Watershed	% of Basin 11
Bastrop Bay/Oyster Lake	2
Bayport Channel	>1
Chocolate Bay	11
Christmas Bay	1
Clear Lake	1.5
Dickinson Bayou Tidal	3
Drum Bay	1.5
Lower Galveston Bay	11
Moses Lake	2
San Jacinto Bay	1
Texas City Ship Channel	<1
Upper Galveston Bay	7.5
West Bay	11
Armand Bayou	3
Bastrop Bayou Tidal	12
Chocolate Bayou Above Tidal	6
Chocolate Bayou Tidal	2
Clear Creek Above Tidal	6
Clear Creek Tidal	3
Dickinson Bayou Above Tidal	2
Lower Oyster Creek-Quintana	1
Old Brazos River Channel	2
Oyster Creek Above Tidal	9
Oyster Creek Tidal	2



0 4.5 9 18 Miles

Source- Harris County Flood Control District (HCFCD), United States Geological Survey (USGS),10-HUC watershed boundary dataset and the H-GAC Clean Rivers Progrm (CRP) watersheds

Figure 3.1: Watershed Map of Basin, including Basin 11 and portions of Basin 24, for twenty-two segments.

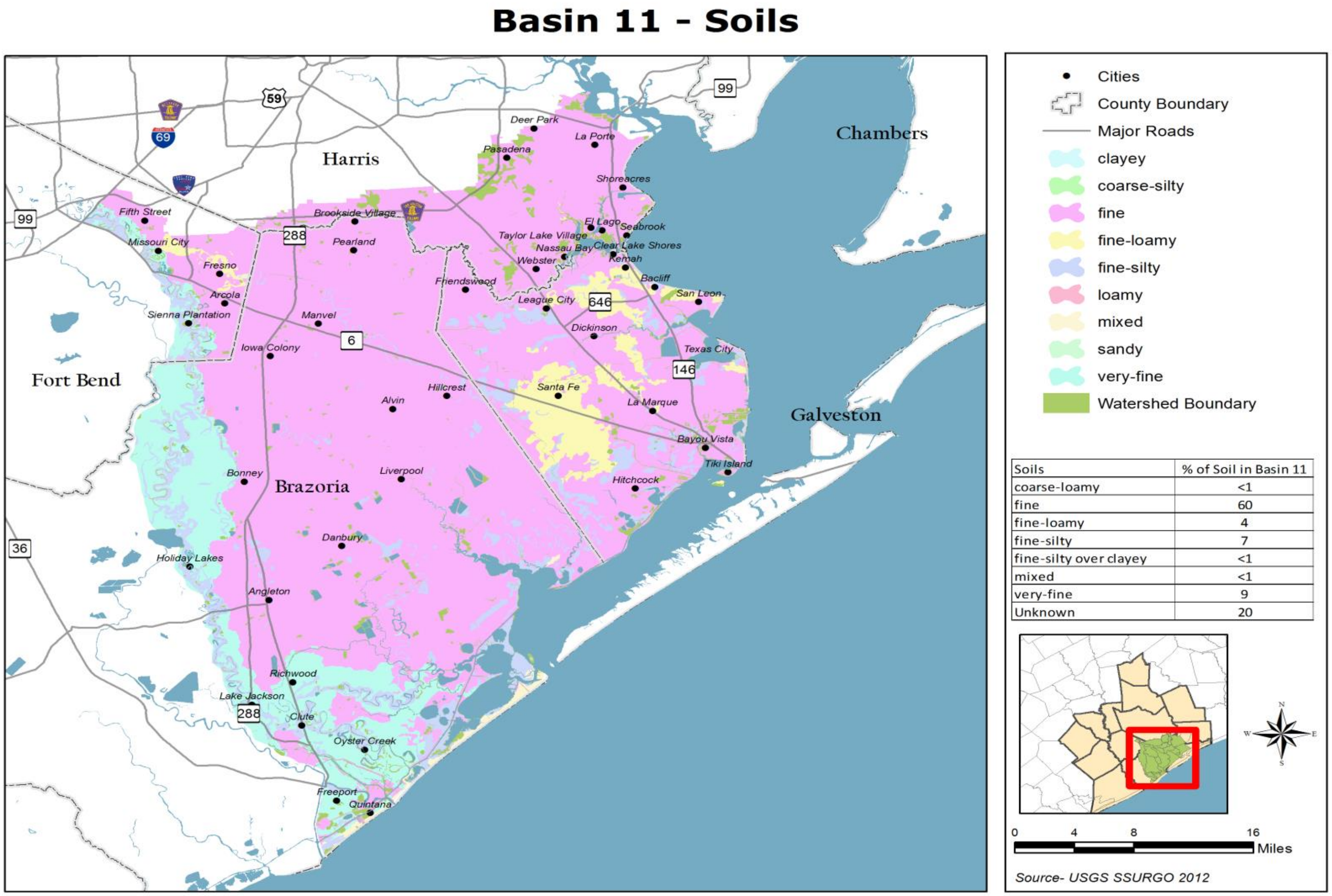
- Segment 1111. Old Brazos River Channel Tidal is a relict river channel that is found in Freeport, Brazoria County and terminates at the GIWW.
- Segment 1113. Armand Bayou is a major tributary to Clear Lake in Harris County.
- Segment 2424. West Bay including Highland and Marchand Bayous in southeast Galveston County travels north to south emptying into Jones Bay, a sub bay to West Galveston Bay.
- Segment 2425. Clear Lake, including tributaries Taylor and Jarbo Bayous, is the terminus for Clear Creek and Armand Bayou and empties into Upper Galveston Bay.
- Segment 2427. Segment covering land that drains to San Jacinto Bay on the San Jacinto River near Upper Galveston Bay.
- Segment 2431. Moses Lake, including its major tributary Moses Bayou, lies north of the cities of La Marque and Texas City and traverses eastward to Lower Galveston Bay.
- Segment 2432. Chocolate Bay, including major tributaries Mustang Bayou and Halls Bayou, begins its journey in Fort Bend County, the headwaters of Mustang Bayou. Chocolate Bay also receives water from Chocolate Bayou and terminates in West Galveston Bay.
- Segment 2433. Bastrop Bay/Oyster Lake is the receiving water for Bastrop Bayou and connects to Christmas Bay and the GIWW.
- Segment 2434. Christmas Bay is found in the southwestern portion of the project area connected to West Galveston Bay.
- Segment 2435. Drum Bay is found connected to Christmas Bay in the southwestern portion of the project area.
- Segment 2437. Texas City Ship Channel is the port for Texas City.
- Segment 2438. Bayport Channel is a port on Upper Galveston Bay south of San Jacinto Bay and north of Clear Lake.
- Segment 2439. Lower Galveston Bay an area adjacent to the Texas City Ship Channel and Moses Lake.

These segments are broken down further into assessment units (AUs). For the 22 segments, there are 91 AUs studied for this report (Appendix C). More detail on each of these segments and AUs can be found in Appendix D.

3.2 Geography

Typical soil types in the region include fine, poorly draining alluvial clays, silts, and loams with dispersed areas of sandy substrate resulting from subtropical climate and fluvial geologic characteristics (Figure 3.2). Average precipitation rates range from 40 to 50 inches per year (Table 3.2) with evaporation rates reaching up to 60 inches per year during drought conditions.

Topography ranges from just over 70 feet in Fort Bend County to near sea level at the shores of Galveston Bay. Surface water bodies include streams, rivers, bayous, lakes, reservoirs, bays and estuaries, and the open waters of Galveston Bay and the Gulf of Mexico. Freshwater inflows from streams and rivers into Galveston Bay are generally sluggish due to the gently sloping 0.04% relief (Snowden, 1989) found on the coastal plain (Figure 3.3).



Soils	% of Soil in Basin 11
coarse-loamy	<1
fine	60
fine-loamy	4
fine-silty	7
fine-silty over clayey	<1
mixed	<1
very-fine	9
Unknown	20

Figure 3.2 Basin 11 soil types and percentage of soil types within the basin.

Figure 3.3. Topographic relief in Basin 11 is small and consistent with the flat Texas Coastal Plain. The view from the Hoskins Mound Bridge (FM 227) at Bastrop Bayou looking south towards the community of Demi John Island and the USFWS Brazoria National Wildlife Refuge.

STATION	STATION_NAME	LATITUDE	LONGITUDE	Average Annual Rainfall (in)
GHCND:USC00413340	FREEPORT 2 NW TX US	28.9845	-95.3809	46.8
GHCND:USW00012923	GALVESTON SCHOLES FIELD TX US	29.2733	-94.8592	40.7
GHCND:USW00012975	HOUSTON CLOVER FIELD TX US	29.51889	-95.24167	49.8

Table 3.2. NOAA rain gauges located in or near Basin 11.

Many creeks and bayous in the region are intermittent water bodies that normally would not flow year-round without treated effluent discharges. Riparian vegetation is common along river floodplains. Primary mineral resources within the region include oil and gas fields, lime, sand, and gravel. Magnesium is also extracted from seawater (Handbook of Texas, 2016).

3.3 Land Cover and Ecosystems

All creeks and bayous within the Basin drain into Galveston Bay or the GIWW. The project area is primarily coastal prairies and marshes, broken up by ribbons of riparian hardwoods and pine forests that are continually influenced by the sea, wind, rain, and routine hurricanes. The flat nature of the coastal plain has seen the Brazos River meander across the basin. Over time, the elements and impacts from the Gulf of Mexico and the Brazos River have shaped the area by creating a network of streams, bayous, bays, estuaries, salt marshes, and tidal flats rich in wildlife. Native vegetation consists of tallgrass prairies, live oak woodlands, and a variety of halophilic (salt tolerant) plants. Extensive wetland and seagrass habitats provide food and shelter for numerous bird species and aquatic organisms.

The highly productive bays and estuaries bounded by marshes and built up reefs, support thriving recreational and commercial fishing and oyster economies. The open bays see recreational activity and commercial/industrial activity, with ships and barges transporting goods through the Galveston Bay area and along the GIWW. West Bay and southern bays are used predominantly for boating and fishing. Other popular recreational areas include Clear Lake, Dickinson Bayou, and Moses Lake where jet skiing, rowing, water skiing, and sailing are favorite pastimes.

The National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program (CCAP) data was used to assess land cover for the basin. Twenty-two land cover types were used to analyze the basin. Some of the land cover types were combined to form 10 land cover types, simplifying analysis (Figure 3.4). The basin covers over one million acres. The most predominant land cover type is Open Water (23%) (Table 3.3). Pasture/Hay and Natural Land Cover are the next two dominant land cover types at 16% and 13%, respectively. In addition to pasture land, cultivation is still a main source of agricultural production for the region making up nearly 8% of the land cover. NOAA's CCAP also delineates developed areas. The largest developed land cover type is Developed - Open Space (7%). Other developed categories, in order of size, are: Developed - Low Intensity (6%), developed - Medium Intensity (6%), and Developed - High Intensity (2%).

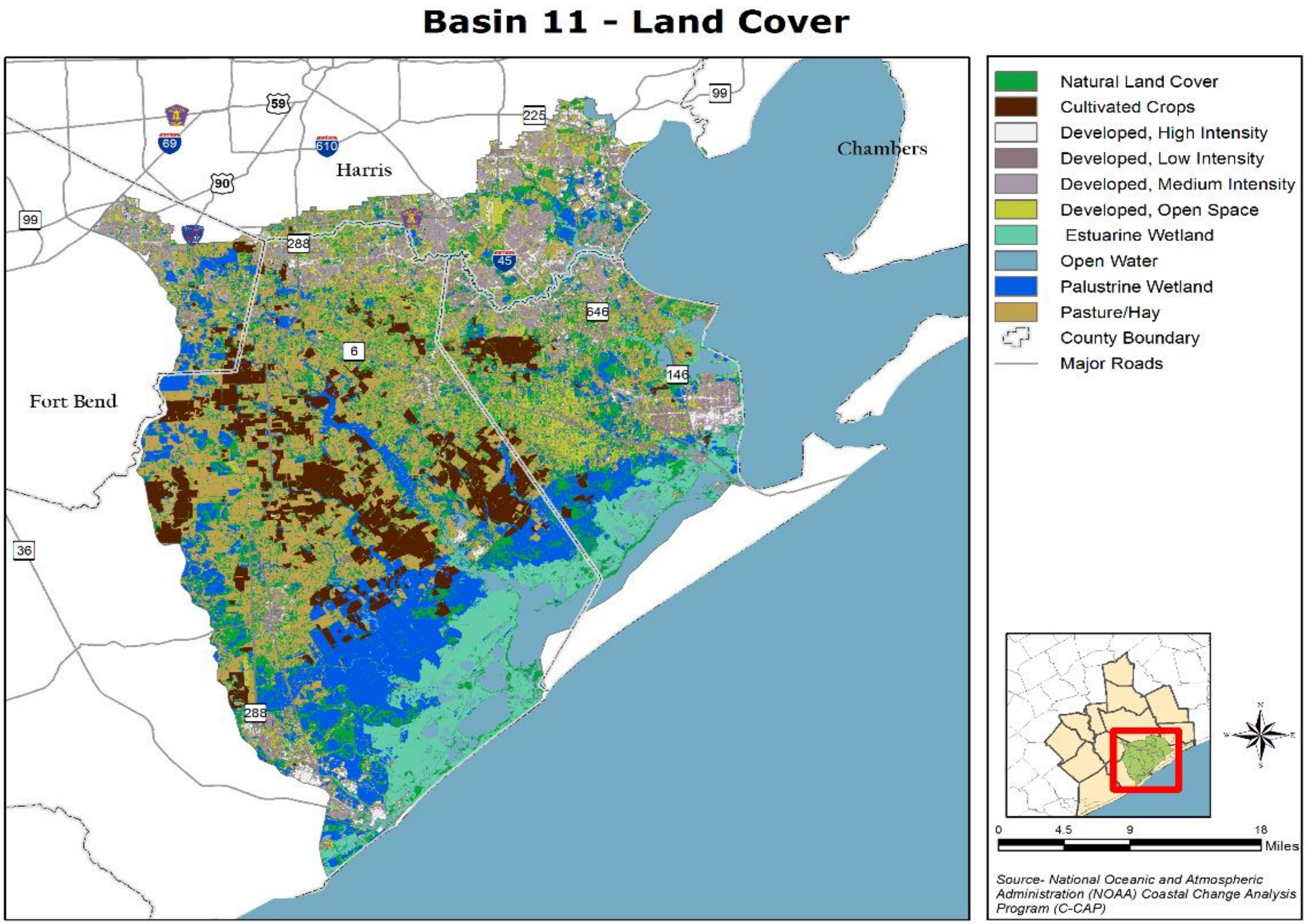


Figure 3.4: Land cover classification map for Basin 11.

Land uses in the region range from moderately dense urban developments to the north and east and less dense and more rural development to the south and west. The urban centers near the medium size cities of League City, Friendswood, and Pearland are found to be radially expanding residential and light commercial/industrial development. Among the growing albeit much smaller scattered cities to the south and west, large acreages of rural undeveloped land are still used for rice and hay production, cattle grazing, and mineral extraction. Heavy industrial development is found near the bays, e.g. ports of Texas City and Freeport.

Parcel data gathered from county appraisal districts for the basin were reviewed. The basin was found to contain 842,000 parceled acres of land (Figure 3.5). The largest single category was Vacant Developable Land (46%) with Residential and Undevelopable next, with 15% and 12%, respectively (Table 3.4). The next largest category was Park and Open Space (8%). Of note, Commercial and Industrial each made up nearly 2% of the reviewed parcel data.

TEN LAND COVER TYPES IN BASIN 11		
Land Cover Type	Area	Percentage of Basin
Cultivated Crops	88777.82	7.66
Developed High Intensity	23642.92	2.04
Developed Medium Intensity	64826.9	5.59
Developed Low Intensity	68414.28	5.9
Developed Open Space	79668.34	6.87
Estuarine Wetland	78113.79	6.74
Palustrine Wetland	153024.63	13.2
Natural Land Cover	153565.46	13.25
Open Water	264459.89	22.82
Pasture Hay	184575.96	15.92
Basin 11 Total	**1159069.99**	**99.99**

Table 3.3. Ten Land Cover Types found in Basin 11.

The largest protected undeveloped land in the Basin is the 44,413 acre Brazoria National Wildlife Refuge, which borders West Bay to the south, Chocolate Bay to the east and Bastrop Bayou to the west. Other protected lands are the 450 unequally distributed parks totaling 5,503 acres (Figure 3.6) and numerous conservation holdings held by non-profits, e.g. Houston Audubon and Galveston Bay Foundation.

Basin 11 - Land Use

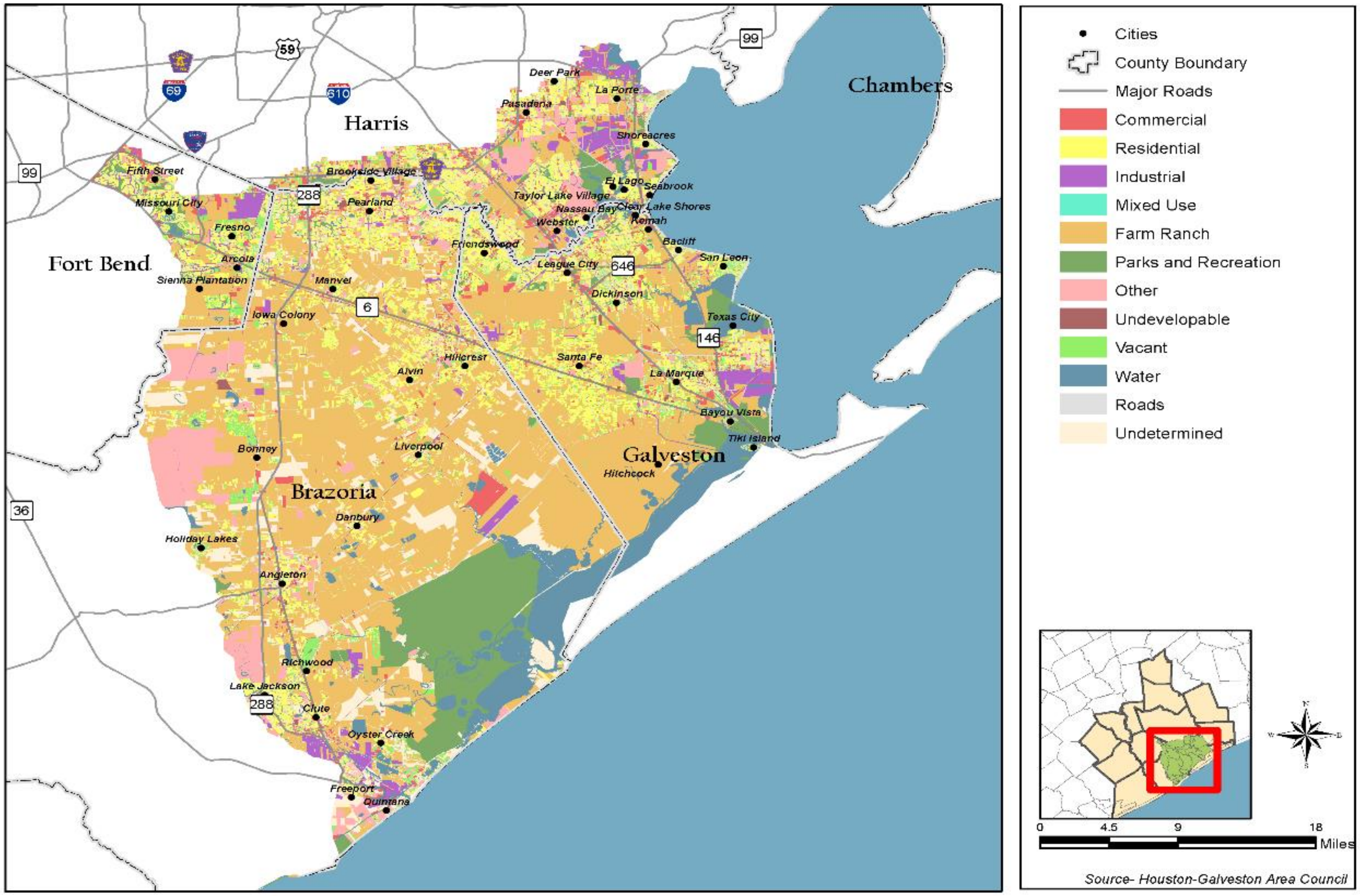


Figure 3.5. Eleven Land Use classification types found in Basin 11.

ELEVEN LAND USE CLASSIFICATIONS COVERING BASIN 11		
Category	Acres	% Basin
Commercial	14392.00	1.71
Public	46958.00	5.56
Industrial	15055.00	1.78
Multiple	44208.00	5.24
Other	1102.00	0.13
Park/Open Space	71309.00	8.45
Residential	124225.00	14.72
Undevelopable	100794.00	11.94
Unknown	532.00	0.06
Vacant Developable	387360.00	45.90
Open Water	35693.00	4.23
Total	**841628.00**	**99.72**

Table 3.4. Eleven Land Use classification types for Basin 11 broken out in acres and percent of basin for each type.

3.4 ECONOMIC DEVELOPMENT

3.4.1 Industry

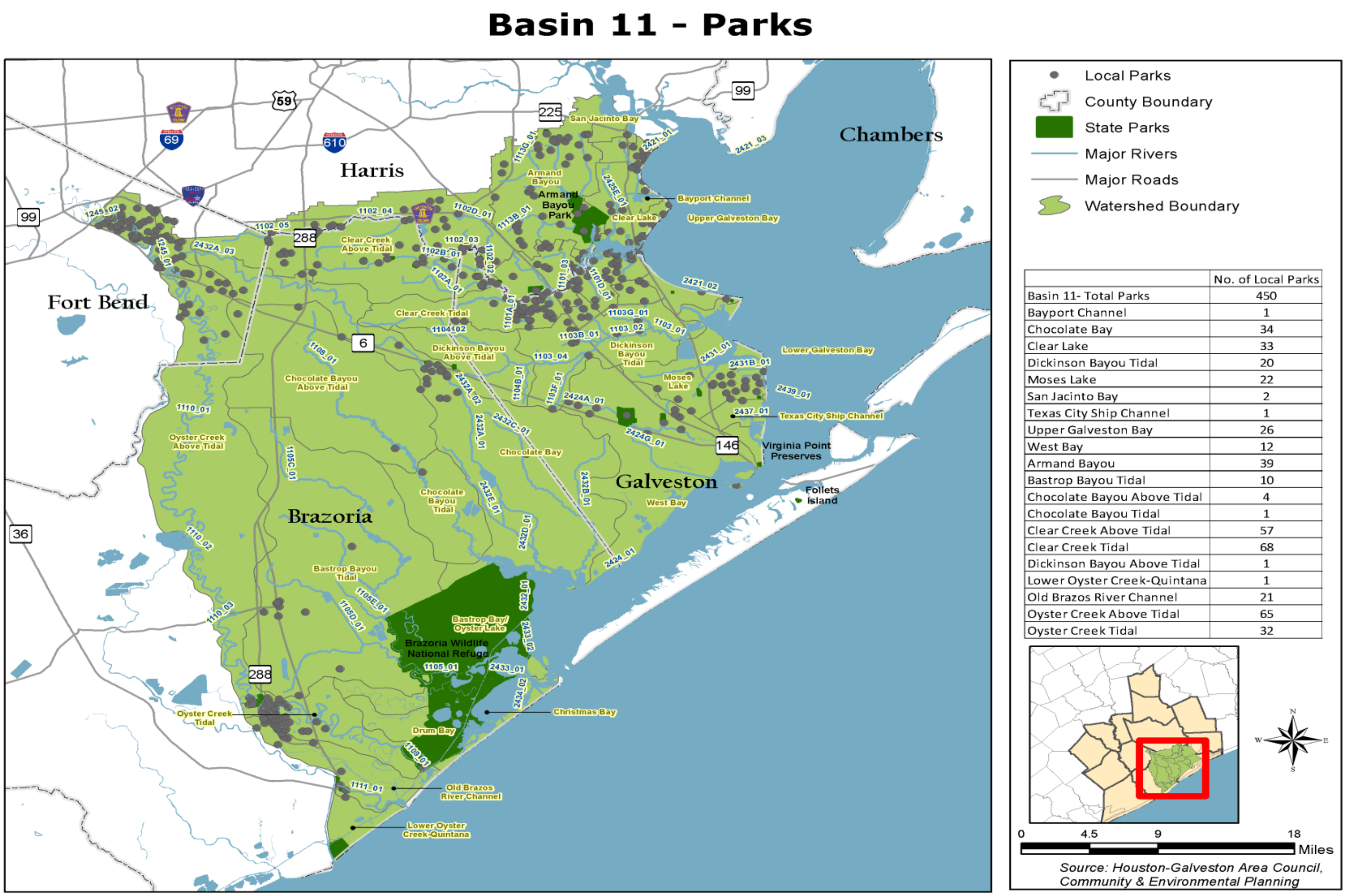
The ports, including the Port of Houston at Bayport Channel, Texas City, and Freeport are major economic hubs for the basin. Industrial parks are located throughout the San Jacinto-Brazos Coastal Basin, extending as far west as the Bastrop Bayou Tidal watershed near Freeport. The industrial parks grew out of the nexus of rail and port facilities, where the movement of products flows easily via truck, train, ship, and barge traffic.

3.4.2 Light Industry/Commercial

Beginning in the 1960s the basin's economy diversified from agriculture, mineral production, and port commerce. The aerospace industry began with the development of the National Aeronautics Space Administration's Johnson Space Center near Clear Lake. Establishment of the industry brought residential development and a future medical hub in the city of Webster. Once quiet bay shore communities began to cater to the new industry and the needs of the new residents. This transition and establishment of suburban commuter communities continues to the present.

3.4.3 Recreation and Ecotourism

Recreation and ecotourism expanded in the late 1980s and '90s. Commercial fishing and oyster harvesting, while still important to local economies has been supplanted by recreational fishing and businesses supporting bay recreation: boating, sailing, and water skiing. Numerous parks and open space and large natural areas encourage recreation and destination travel to participate in ecotourism, particularly birding.



	No. of Local Parks
Basin 11- Total Parks	450
Bayport Channel	1
Chocolate Bay	34
Clear Lake	33
Dickinson Bayou Tidal	20
Moses Lake	22
San Jacinto Bay	2
Texas City Ship Channel	1
Upper Galveston Bay	26
West Bay	12
Armand Bayou	39
Bastrop Bayou Tidal	10
Chocolate Bayou Above Tidal	4
Chocolate Bayou Tidal	1
Clear Creek Above Tidal	57
Clear Creek Tidal	68
Dickinson Bayou Above Tidal	1
Lower Oyster Creek-Quintana	1
Old Brazos River Channel	21
Oyster Creek Above Tidal	65
Oyster Creek Tidal	32

Figure 3.6. 450 parks found in Basin 11 and broken out for each segment.

3.4.4 Agriculture

With about 25 % of land use in the region classified as agricultural – crop production and cattle grazing, the basin participates as a major international agribusiness center, emphasizing the marketing, processing, packaging, and distribution of agricultural commodities including cotton, rice, sorghum, and other grains. Agricultural production values for the region in 2012 totaled more than $1.1 billion in revenues (Houston Metro Profile: KET Enterprises Inc.). Agricultural activity is focused in the southwestern watersheds of the San Jacinto-Brazos Coastal Basin.

3.5 Key Factors Influencing Water Quality

The combination of land uses within the basin has the potential to generate pollutants from numerous sources. Without proper best management practices, everything from industrial and agricultural processes to everyday activities, such as lawn care and auto maintenance, have the potential to introduce pollutants to area waterways. Ongoing urban development as predicted by expected population growth, will also increase impervious cover, which will ultimately generate nonpoint source pollution. Continued population growth within the region will also increase the volume of domestic wastewater effluent while initiating numerous construction projects that require Municipal Separate Storm Sewer System (MS4) discharge permits. With significant volumetric increases in wastewater discharges, including wastewater treatment facility (WWTF) effluents and MS4 discharges, the potential for point source pollutants will increase. Failing OSSFs, pet waste, illegal dumping, and illicit discharges are potential pollution sources within the region. Considering the broad range of land uses, looking at pollutants on a watershed scale allows for simultaneous analysis of potential pollution sources in multiple water bodies. Potential sources of FIB are discussed in Section 4, Historical Data Review.

3.6 Segment and AU Summaries (Appendix D)

Watershed Summaries include water quality information for each formally defined stream segment in the basin. Water quality impairments and concerns highlighted in the summaries were identified in the 2014 *Integrated Report*. The *Integrated Report* is a comprehensive evaluation of the condition of surface waters in Texas. It is based on historical monitoring data and provides resource managers with a tool for making informed decisions when directing agency programs. It identifies the water bodies that are not meeting contact recreation standards set for their use in the *Texas Surface Water Quality Standards*, published in Title 30, Chapter 307 of the Texas Administrative Code. The federal Clean Water Act requires the TCEQ to submit an updated *Integrated Report* to the EPA every two years.

Each watershed summary includes the following information:

- Segment Number
- Segment Name
- Segment Length
- Watershed Area
- Designated Uses
- Number of Active Monitoring Stations

- Texas Stream Team Monitors
- Permitted Outfalls
- Description
- Degree of Impairment (by percent of stream or water body impaired)
- FY 2014 Active Monitoring Stations
- Standards and Screening Criteria

The summary tables include an overview of bacteria impairments and concerns affecting the watershed, descriptions of the affected areas, possible causes and influences or concerns voiced by stakeholders, and possible solutions or actions to be taken. The summary tables are followed by narrative discussions of watershed characteristics, water quality issues, special studies and projects completed in the watershed, water quality trends, and recommendations.

Several watershed maps and statistical graphs accompany the discussions to illustrate spatial variations and critical bacteria trends. Typically, graphs are a plotted measure of bacteria values over time where the trend has been found to be statistically significant.

4 HISTORICAL DATA REVIEW

4.1 REVIEW OF ROUTINE MONITORING DATA FOR BASIN

4.1.1 Data Acquisition

Ambient *E. coli* and enterococci data were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS). The data represented the routine ambient bacteria and other water quality data collected for the project area by the TCEQ's CRP for the study area (CRP, 2016). General assessment criteria methodologies established by the TCEQ were used in data evaluations.

4.1.2 Analysis of Bacteria Data

Recent environmental monitoring within watersheds found in Basin 11 has occurred at numerous CRP monitoring stations (Figure 4.1). There are 133 monitoring sites being routinely visited by CRP partners. Of those 133 stations, the majority can be found in the Clear Creek, Armand Bayou, and Dickinson Bayou segments. Appendix C contains the table of all segments and assessment units (AUs) found in the study area. Appendix D provides greater detail on each AU and monitoring station.

Bacteria data retrieved from these stations through December 31, 2016, were reviewed, and trends were developed. The method for data selection, review, and trend analysis is discussed further in 4.2, Data Review Methodology. The Basin 11 bacteria trend for all data is an elevated bacteria geometric mean consistently two to two and half times the state standard for contact recreation (Figure 4.2).

Of the 91 AUs studied, there are 28 AUs currently listed as impaired for bacteria and given a category 5 listing (Table 4.1) in the 303 (d) List of Impaired Waters (2014 Integrated Report, 2015). These assessment units may be appropriate for development of future TMDLs. An additional 25 were listed in the category 4, a listing for AUs where the impairment is not suitable for a TMDL or for which a TMDL has already been approved. It should be noted that the 25 AUs are covered by an approved TMDL. A total of 3,521 bacteria samples were used in the 2014 Texas Integrated Report assessment for all 91 AUs assessed during the seven-year period from 2005 through 2012.

4.2 DATA REVIEW METHODOLOGY

4.2.1 Data Selection

Water quality data used for analyses in this report were extracted from a complete data set downloaded from SWQMIS on October 16, 2015. SWQMIS is a database that serves as the repository for TCEQ surface water quality data for the state of Texas. All data used for these analyses were collected under a TCEQ-approved Quality Assurance Project Plan (QAPP). Qualified data (data added to SWQMIS with qualifier codes that identify quality, sampling, or other problems that may render the data unsuitable) were excluded from the download. All data for all stations in Basin 11, collected from January 1, 2002, through December 31, 2016, were combined into a working data set. USGS flow data for gauging stations were downloaded from the U.S. Geological Survey (USGS) website on September 16, 2015.

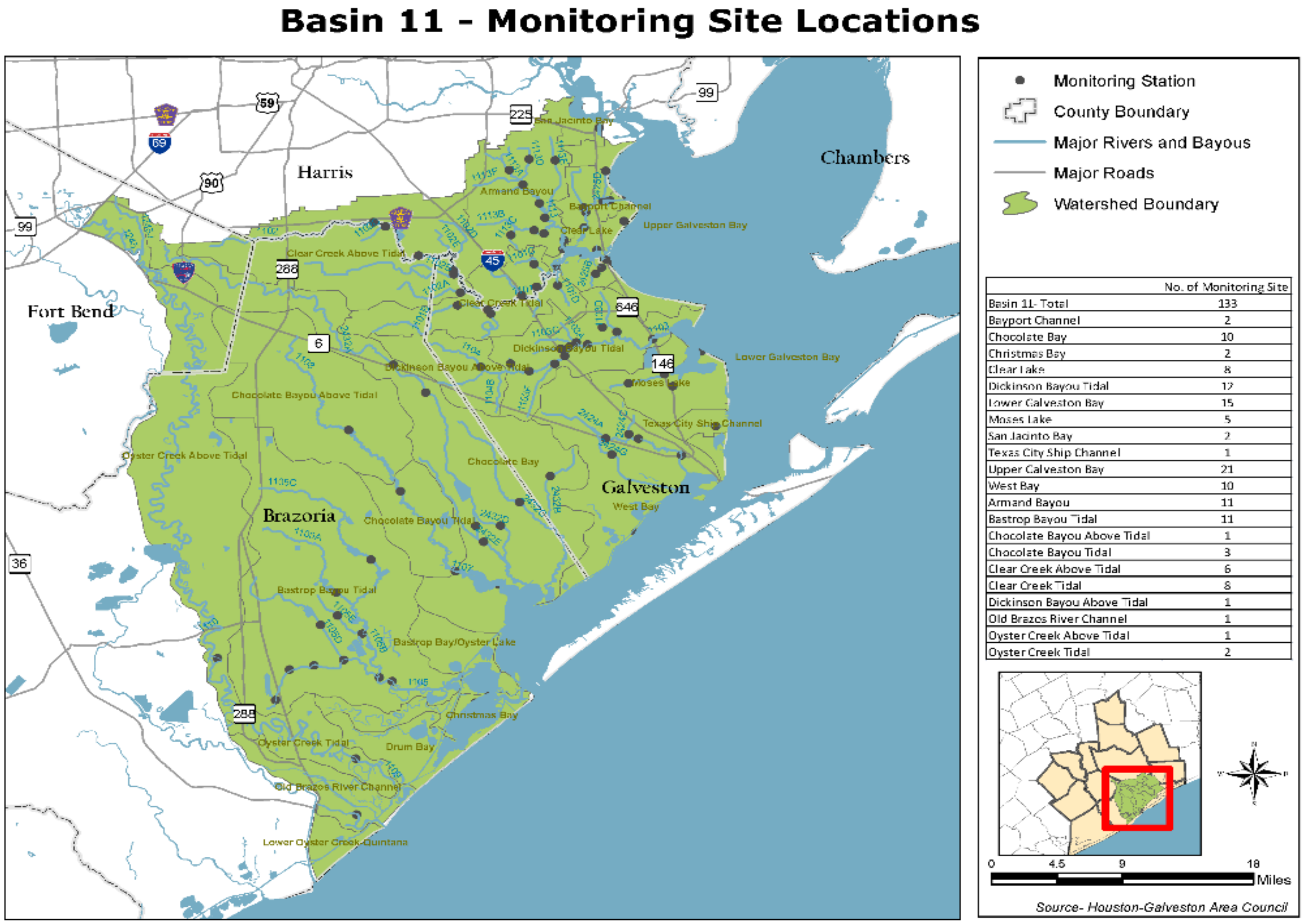


Figure 4.1. Texas Clean Rivers Program monitoring site locations contained in the study area.

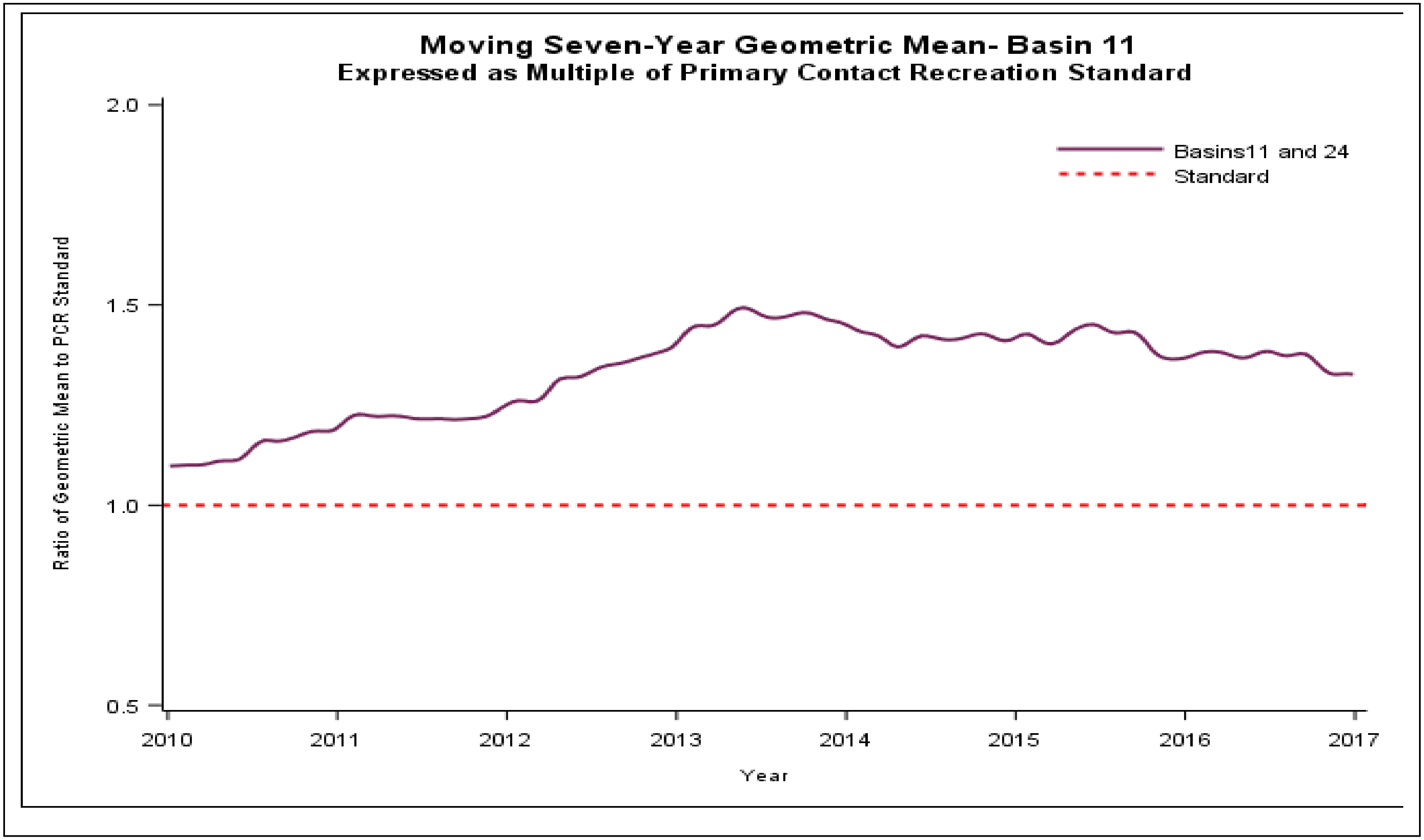


Figure 4.2. Moving relative bacteria geometric mean for all bacteria indicator data collected in Basin 11 for the period 2005 through 2016.

Variables in each data set were transformed as appropriate, and new variables were created to facilitate analysis and the graphical display of results. Censored data (data reported as “<[parameter limit of quantitation (LOQ)]>” were transformed to a value of one-half the parameter LOQ. In cases where some data reflected use of a lower LOQ than the current H-GAC CRP LOQ, the data were transformed to one-half of the current H-GAC CRP LOQ. In some cases, data from two or more STORET (method) codes were combined because the results obtained from each method can be considered equivalent. Any data that were not collected at a depth greater than 0.4 meters or that were not collected under a routine ambient monitoring program were deleted.

The following parameters were retained for analysis: *E. coli* (31699), Enterococci (31701).

4.2.2 Data Selection for Trend Analysis

A subset of data was compiled for segment-level trend analysis. The temporal range and number of available data, mean, median, and 95th percentile was calculated for each station and parameter and for all data in the segment. Station data were ranked by the number of data points, the length of the time series, and the proximity of data points to each other to develop parameter statistics for the segment. Stations with the longest time series and most data points were preferred in the cases where parameter statistics were similar. The station with the highest rankings on these measures in each segment was selected and mapped. If two stations were closely ranked, a station associated with a USGS gauging station was preferred. In almost all cases, the station selected based on numeric criteria was located near the downstream boundary of the segment. If that station was located far from the boundary, further evaluation was performed and another station was selected.

For each segment/parameter combination, one data point per month for each year was retained and data gaps were evaluated. If there were no data for a parameter in a segment during one year in the 15-year timeframe, additional data were added from the geographically closest station in the segment (for that year and parameter only). This process continued until a complete time series was produced. If any segment/parameter had either fewer than 30 data points or a time series range of less than seven years, it was deleted from the trend data subset and not included in the trend analysis. A separate dataset with these deleted data was saved for reference.

For station-level trend analysis, a data set containing all data for all stations in the 2015 CRP’s Coordinated Monitoring Schedule (CMS) was compiled. In addition, this station-level data set was transposed for analysis of inter-parameter relationships, correlations with flow, rain event reports, and other analyses, as deemed appropriate.

A table of descriptive statistics for FIB was produced for every monitoring station and segment (see Appendix D). In addition to basic summary statistics, water quality standard statistics were calculated.

All data management and statistical analysis was performed using Statistical Analysis System (SAS) version 9.3. Complete details of data selection, preparation, and analysis can be found in the SAS code used to select, format, and analyze data for this report can be made available for review by request.

BASIN 11 IMPAIRED ASSESSMENT UNITS						
Assessment Unit	**Name**	**Parameter**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
1103_01	Dickinson Bayou Tidal	*Enterococcus*	2005-2012	5a	32	72.75
1103E_01	Cedar Creek	*E. coli*	2005-2012	5a	30	126.62
1105_01	Bastrop Bayou Tidal	*Enterococcus*	2005-2012	5c	152	73.00
1105A_01	Flores Bayou	*E. coli*	2005-2012	5c	32	137.38
1105B_01	Austin Bayou Tidal	*Enterococcus*	2005-2012	5c	32	40.81
1105C_01	Austin Bayou Above Tidal	*E. coli*	2005-2012	5c	33	166.42
1105E_01	Brushy Bayou	*E. coli*	2005-2012	5c	16	565.54
1107_01	Chocolate Bayou Tidal	*Enterococcus*	2005-2012	5c	84	81.51
1108_01	Chocolate Bayou Above Tidal	*E. coli*	2005-2012	5c	24	159.03
1109_01	Oyster Creek Tidal	*Enterococcus*	2005-2012	5c	44	73.45
1110_01	Oyster Creek Above Tidal	*E. coli*	2005-2012	5c	27	201.33
1113_02	Armand Bayou Tidal	*Enterococcus*	2005-2012	5c	88	40.99
1113_03	Armand Bayou Tidal	*Enterococcus*	2005-2012	5c	24	47.59
1113A_01	Armand Bayou Above Tidal	*E. coli*	2005-2012	5c	130	354.06
1113B_01	Horsepen Bayou Tidal	*Enterococcus*	2005-2012	5c	95	66.89
1113C_01	Unnamed Tributary	*E. coli*	2005-2012	5c	66	186.85
1113D_01	Willow Springs Bayou	*E. coli*	2005-2012	5c	62	709.28
1113E_01	Big Island Slough	*E. coli*	2005-2012	5c	63	501.01
2424A_02	Highland Bayou	*Enterococcus*	2005-2012	5c	20	45.85
2424A_03	Highland Bayou	*Enterococcus*	2005-2012	5c	68	78.23
2424A_04	Highland Bayou	*Enterococcus*	2005-2012	5c	21	174.79
2424A_05	Highland Bayou	*Enterococcus*	2005-2012	5c	60	184.20
2424C_01	Marchand Bayou	*Enterococcus*	2005-2012	5a	44	139.17
2424G_01	Highland Bayou Diversion	*Enterococcus*	2005-2012	5c	30	37.60
2425B_01	Jarbo Bayou	*Enterococcus*	2005-2012	5a	32	98.96
2431A_01	Moses Bayou	*Enterococcus*	2005-2012	5c	38	43.53
2431C_01	Unnamed Tributary	*Enterococcus*	2005-2012	5c	32	49.96
2432C_01	Halls Bayou	*Enterococcus*	2005-2012	5c	44	94.56

Table 4.1. Impaired assessment units listed in the Texas 303 (d) list of impaired water bodies, Category 5 for Basin 11.

4.2.3 Trend Analysis Methodology

All data were screened with nonparametric correlation analysis (Kendall's tau-*b*) of the parameter value with the sample collection date to identify correlations that were significant at p <0.0545. These potential trends were then evaluated by simple linear regression of the natural log of the data on the time variable, LOESS (locally-weighted least squares) regression and correlation of flow-adjusted residuals, and seasonal Kendall/Sen Slope estimation/Theil regression. If more than 15 % of the data were censored at the analytical limit of quantitation, survival analysis (Tobit analysis in SAS PROC LIFEREG) was performed. The trends identified by Kendall correlation should be considered the most defensible, since nonparametric methods are insensitive to outliers in the time series. There were some cases where analysis of flow-adjusted concentrations suggested a significant trend that was not revealed by correlation analysis.

Plots of selected statistically significant trends are included as appropriate in the water quality reviews of each watershed in Appendix D. An inset was added to each plot of statistically significant trends to facilitate comparison. The trend suggested by each of the five analytical techniques appears in the inset, and are labeled as "Stable," "Increasing," or "Decreasing." If no (or insufficient) flow data were available, the flow-adjusted trend will appear as "Not Calculated" or "Insufficient Data." If the seasonal Kendall trend was not calculated due to gaps (missing seasons) in the time series, the trend will appear as "Not Calculated." If fewer than 15 percent of the data were censored, survival analysis was not performed, and the trend will show as "Not Applicable."

In addition, LOESS plots of the parameter value against time were made for every segment/parameter and station/parameter combination, whether a statistically significant trend was present or not. These graphs can be found in the appendix D of this report.

4.3 Bacteria Source Analysis

A common approach to analyze potential FIB sources is to review regulated and unregulated sources for the basin. Pollution sources that are regulated have permits under the Texas Pollutant Discharge Elimination System (TPDES) and the National Pollutant Discharge Elimination System (NPDES).

Unregulated sources, often consider nonpoint sources, are those where the pollutant originates from diffuse locations and is usually carried to surface waters by rainfall runoff. Nonpoint sources are not regulated by a permit. Examples of unregulated sources include: wildlife, OSSFs, and agriculture production.

4.3.1 Regulated Sources

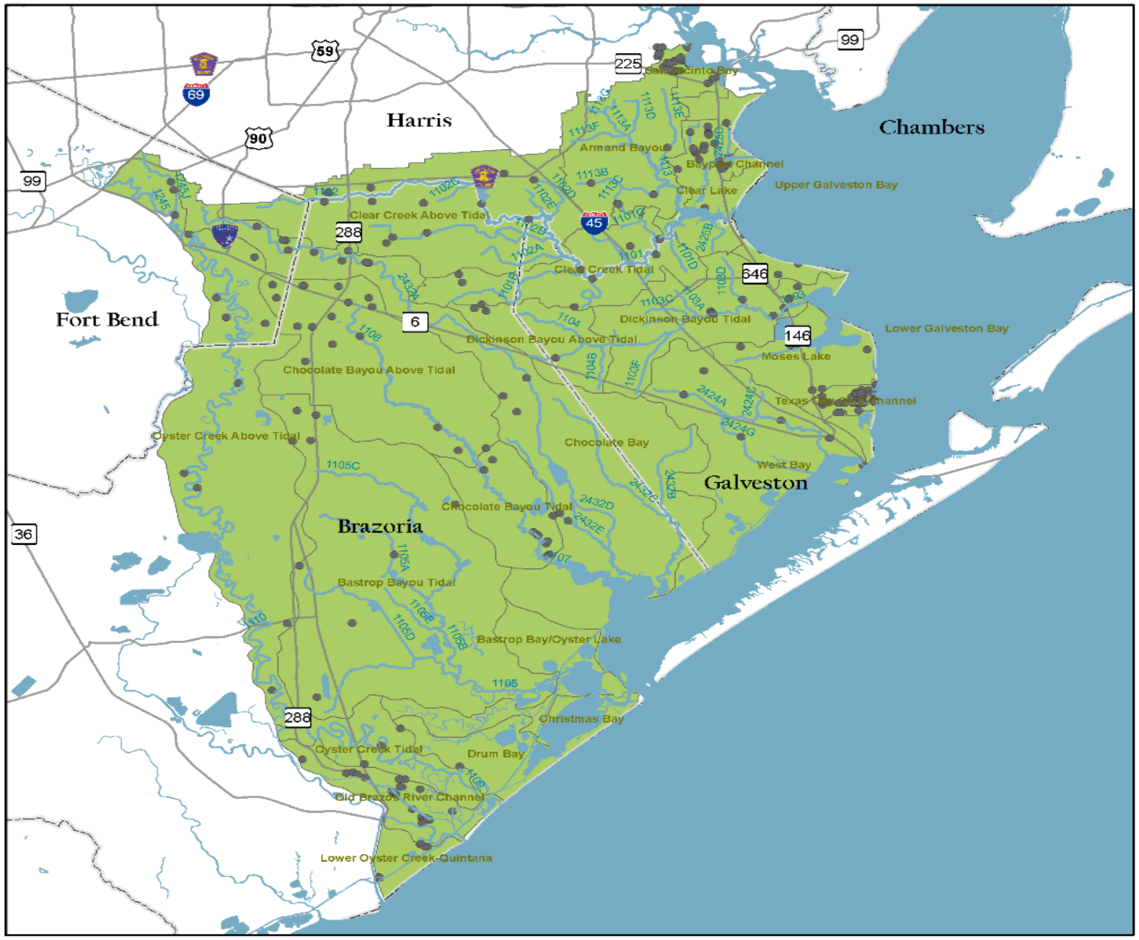
WWTFs and stormwater discharges from industries, construction, and MS4s of cities are regulated sources permitted under the TPDES and NPDES programs.

4.3.1.1 Domestic and Industrial Wastewater Treatment Facilities

There is a total of 280 regulated discharge facility outfalls located in Basin 11 (Figure 4.3). Those segments with high numbers of outfalls, e.g. San Jacinto, Texas City Ship Channel, and Old Brazos River

Channel, are the petroleum and chemical production hubs for the region. Most of these dischargers are industrial and would not be considered sources of bacteria.

Basin 11 - Waste Water Outfalls



Waste Water Outfalls
Major Rivers and Bayous
Major Roads
County Boundary
Watershed Boundary

	Waste Water Outfalls
Basin 11- Total	280
Bayport Channel	8
Chocolate Bay	19
Clear Lake	16
Dickinson Bayou Tidal	9
Drum Bay	1
Lower Galveston Bay	5
Moses Lake	6
San Jacinto Bay	37
Texas City Ship Channel	45
Upper Galveston Bay	8
West Bay	6
Armand Bayou	5
Bastrop Bayou Tidal	8
Chocolate Bayou Above Tidal	17
Chocolate Bayou Tidal	10
Clear Creek Above Tidal	13
Clear Creek Tidal	9
Dickinson Bayou Above Tidal	4
Lower Oyster Creek-Quintana	6
Old Brazos River Channel	30
Oyster Creek Above Tidal	15
Oyster Creek Tidal	3

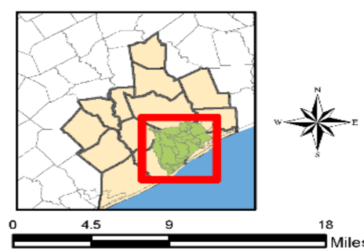


Figure 4.3 Wastewater treatment outfalls in Basin 11.

There are 155 industrial, municipal, and private WWTFs in the basin (Appendix E) of which 80 are permitted for bacteria in their effluent. Any future TMDL will require developing a waste load allocation for one or more of these facilities.

4.3.1.2 Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) are unauthorized discharges that must be addressed by the responsible party, either the TPDES permittee or the owner of the collections system that is connected to the permitted system. SSOs in dry weather most often result from blockages in the sewer collection pipes caused by tree roots, grease, and other debris. Inflow and Infiltration (I/I) are typical causes of SSOs under conditions of high flow in the WWTF system.

SSO data is reported by municipalities, and the TCEQ Region 12 Office maintains the database. SSO data reviewed for this basin covers the period of 2012 through 2015. Municipalities report the cause of the spill, an estimate of the size of the spill in gallons, and a general location of the spill.

Table 4.3 presents Basin 11 SSOs by the reported cause for the overflow, the number of events for each reported cause, and the approximate volume reported in 2016. Based on the municipality reports, combined blockages from fats, roots, oils, greases (FROG) and other, lift station failures, and I/I produce the largest number of SSOs in the basin, contributing over 80% of the unauthorized discharges.

Based on volume, I/I is the single largest SSO discharge in Basin 11. Infrastructure failures such as lift station collection system and WWTF operation failures collectively next to I/I, contribute the highest volume of untreated effluent to the basin. WWTF operational failures in 2016 disproportionately discharged the most untreated effluent while stemming from the second fewest events.

Year	Cause	Events	Total Volume (Thousand Gallons)
2016	Blockage in Collection System Due To Fats/Grease	12	5.371
2016	Blockage in Collection System-Other Cause	13	1.876
2016	Collection System Structural Failure	6	7.023
2016	Human Error	1	1.2
2016	Lift Station Failure	10	3.791
2016	Power Failure	1	12.32
2016	Rain / Inflow / Infiltration	25	440.295
2016	Unknown Cause	6	24.751
2016	WWTP Operation or Equipment Malfunction	3	18.6

Table 4.3. Basin 11 SSOs by reported cause, number of events and volume in 2016.

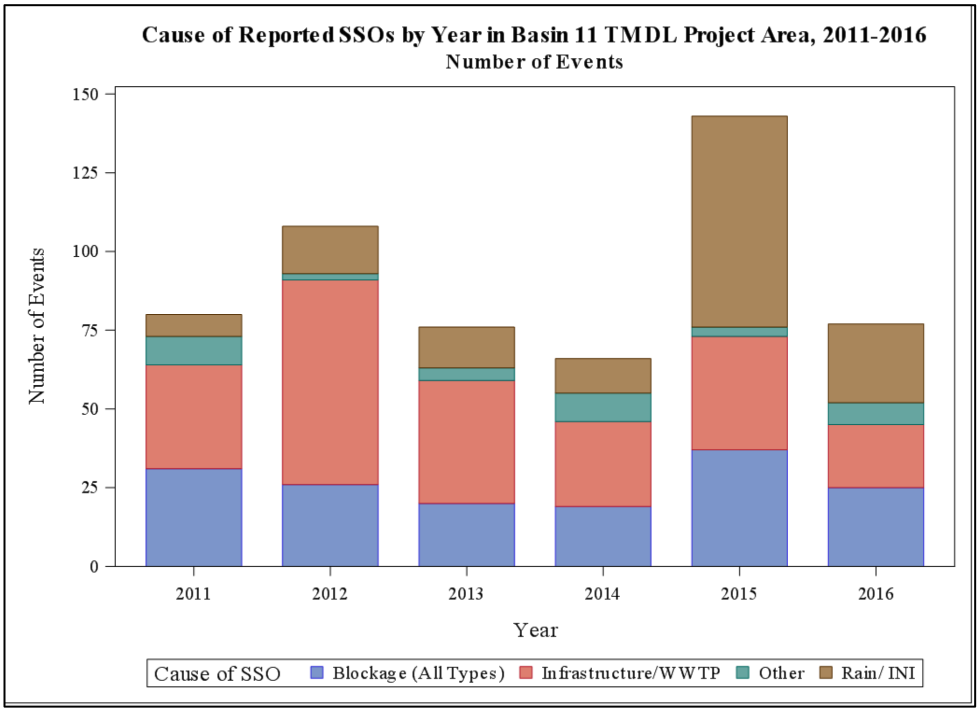


Figure 4.4. Bar graphs for Basin 11 reported SSOs during 2012-2016 by SSO type.

To observe SSO trends across the various causes, bar graphs were created for each cause (Figure 4.4). The five-year period is relatively short to identify trends, so these observations should be considered relatively weak. The number of events and estimated volume appear relatively constant for blockages. Infrastructure failures also appeared to be relatively stable collection system and WWTF operation failures appear to suggest possible improvement, with one particularly notable spike in volume found in 2012 in the collection system. Compared to other areas of the Houston Region, infrastructure failures in Basin 11 make up a higher proportion of reported SSOs. Blockage reported as other and I/I, suggest the influence in climate for the region that transitioned from drought to a higher precipitation, including several flooding events, during the period between 2012 and 2016.

4.3.1.3 TPDES Regulated Stormwater

Land based sources not attributed to WWTFs and their conveyance systems fall into two categories: regulated stormwater and unregulated. Regulated stormwater is permitted by the state under the TPDES and is considered a point source by the state. Stormwater from unregulated areas is consider a nonpoint source and will be discussed under unregulated sources below.

Municipalities are permitted under TPDES and the program is commonly referred to as the MS4 permit. There are two permits issued for regulated entities that fall under the TPDES permit: an individual and a general permit. Most MS4 permits issued for Basin 11 are general permits issued under MS4 Phase II guidance. Phase II permits are issued for municipalities with a population less than 100,000 and which fell into the EPA-defined urbanized area category. The Phase I individual permit currently covers municipalities with populations over 100,000. Only the cities of Houston and Pasadena, and Harris County fall under the Phase I permit in Basin 11.

While there are certain requirements that only a Phase I entity must comply with, the general purpose of the permitting program is for Phase I and Phase II permittees to reduce discharges of pollutants in stormwater to the "maximum extent practicable" by developing and implementing a Stormwater Management Program (SWMP). SWMP guidelines require the specification of best management practices (BMPs) that will assist in reducing pollutant sources in effluents contributing standards impairments in adjacent waterbodies.

The area of the basin that falls under the MS4 Phase I or Phase II is determined by the geographic extent of the area of the jurisdictional boundary of each regulated entity (Figure 4.5). Most permitted entities can generally be found in northern and eastern portions of the basin. There are 59 regulated entities in Basin 11 covering an area of 295,637 acres or approximately 26%. A listing of all permitted entities can be found in Appendix F.

4.3.1.4 Dry Weather Discharges/Illicit Discharges

In addition to stormwater, regulated entities under TPDES and NPDES permits must identify and correct dry weather discharges/illicit discharges that contribute effluent to the MS4 and have not been approved via permit or result from emergency firefighting activities. Examples of illicit discharges to the storm sewer, include: home sanitary pipes connected directly to the storm sewer, cross connections between municipal sanitary sewer and the storm sewer, leaking sanitary sewer leaching into storm sewer, and failing OSSFs leaking into the storm sewer.

4.3.1.5 Other Regulated Sources

Aquaculture production, concentrated animal feeding operations (CAFO), and livestock manure composting are a few activities that could potentially contribute to FIB in the basin. Reviewing the TCEQ's Central Registry for wastewater general permits did not produce active aquaculture production or livestock manure composting permits. There were however, three active CAFO permits in Segment 1110 Oyster Creek Above Tidal for three Texas Department of Criminal Justice prison units to produce egg-laying hens and swine.

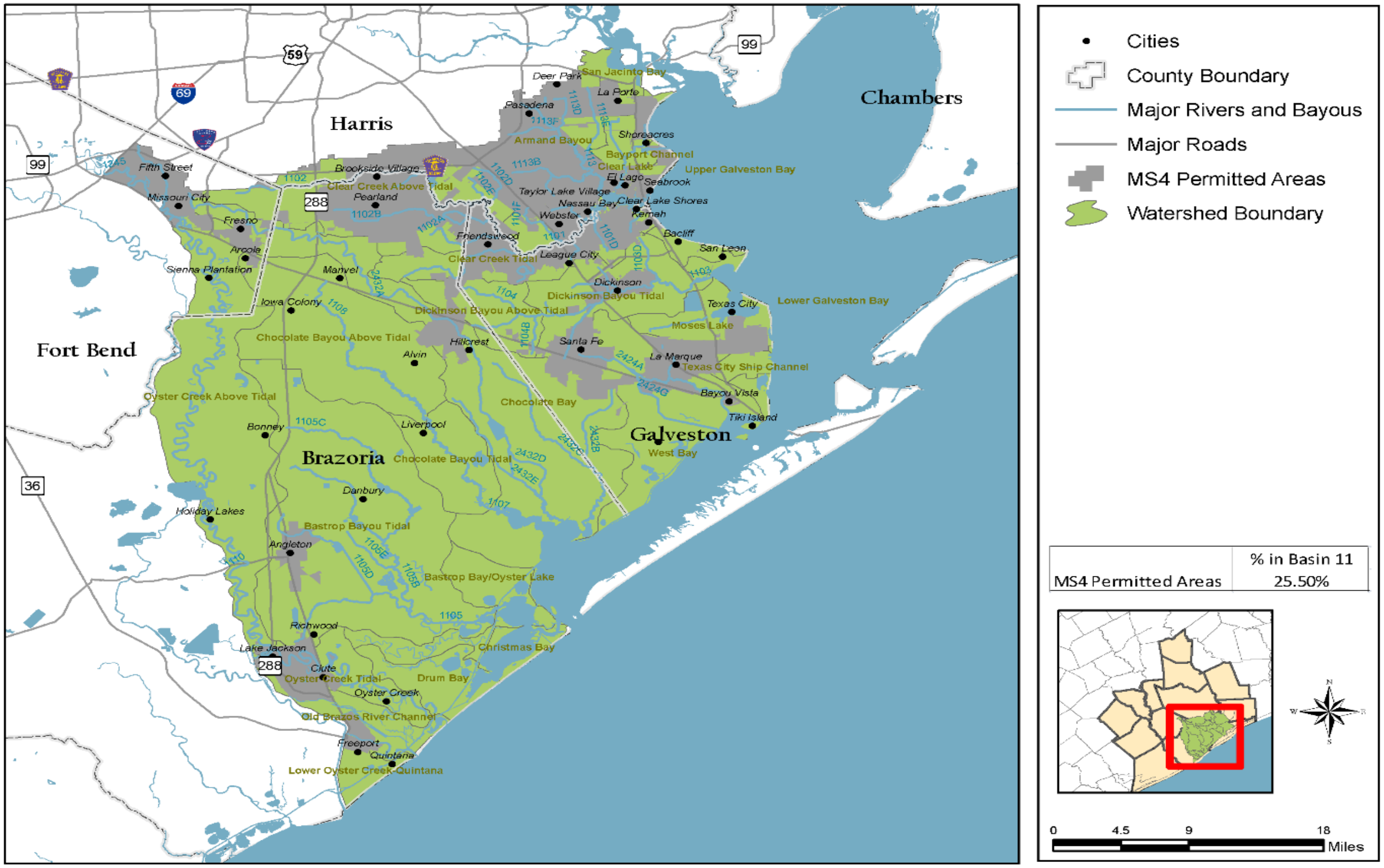
4.3.2 Unregulated Sources

Unregulated sources of FIB are often considered nonpoint sources in that they come from diffuse sources rather than a single source. Failing OSSFs, certain agricultural activities, land application fields, urban runoff not covered under a permit, and pet wastes are examples of unregulated sources.

4.3.2.1 Failing OSSFs

Away from municipal centers where more centralized public wastewater treatment is common, rural and suburban-rural residences and stand-alone commercial and industrial businesses, within the county or a city's extra territorial jurisdiction, are likely to use owner operated OSSFs, often referred to as septic systems. When functioning properly and sited correctly, much like WWTFs, OSSFs' contribution of FIB is little to none.

Basin 11 - MS4



	% in Basin 11
MS4 Permitted Areas	25.50%

Figure 4.5. MS4 permitted areas contained within Basin 11.

A few studies like Reed, Stowe & Yanke (2001) suggest a 12 % failure rate for OSSFs. That rate, derived from survey responses received from authorized agents (AA), falls in line with EPA's guidance on failure rates nationally of 10% to 20% (H-GAC, 2005). AAs are local authorities who have accepted responsibility from the TCEQ to permit OSSFs and enforce laws and rules governing OSSFs on behalf of the state.

H-GAC, in coordination with AAs, compiled the number of permitted and registered OSSFs in the H-GAC service region, including Basin 11. Additionally, H-GAC developed an OSSF geographic information database to identify potential unregistered and grandfathered OSSFs in H-GAC's service area using known OSSF locations, county parcel data and WWTF service boundaries (used to exclude addresses on centralized service). Permitted OSSFs are presented in Figure 4.6. There are 13,762 permitted OSSFs in the basin. Using H-GAC's estimate of unregistered and grandfathered OSSFs, there may be another 38,767 OSSFs in Basin 11. Appling the 12 % failure rate to 52,529, an estimated 6,300 systems are potentially failing in the basin.

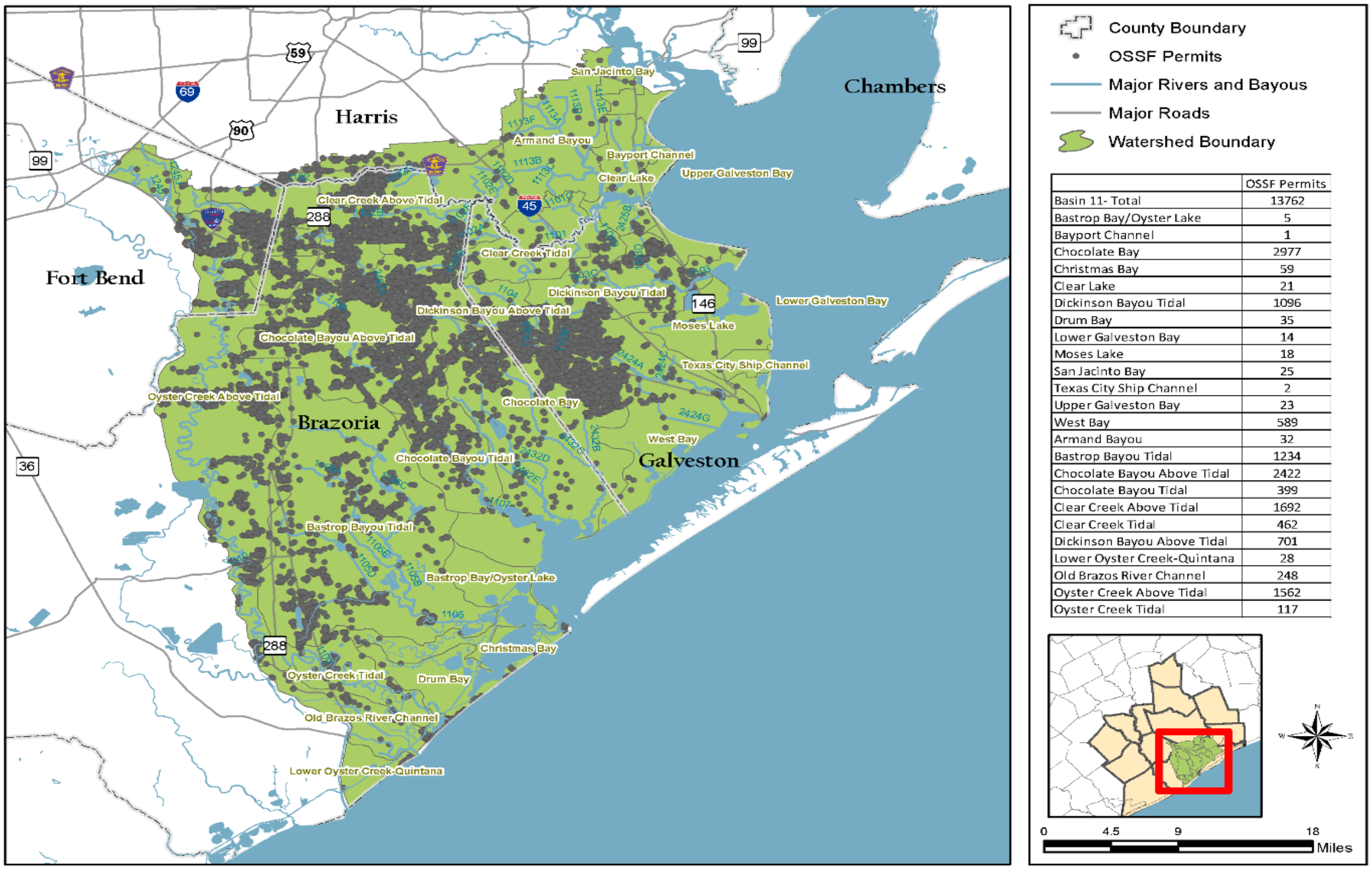
4.3.2.2 Agriculture

Agriculture production remains a large economic base for the counties in Basin 11. Figure 3.3 and Table 3.3 presented the current state of two agriculture-related land cover types, Cultivated Cropland and Pasture/Hay. Those two types make up 23 % of the basin. Agriculture is a non-permitted activity that potentially contributes FIB during production. FIB from agriculture can reach waterbodies from livestock grazing and land applications of manure as fertilizer during crop production. Table 4.4 contains county livestock figures for 2012 compiled by the United States Department of Agriculture Census of Agriculture (USDA, 2012).

USDA Livestock County-Level 2012					
County	**Cattle and Calves**	**Hogs and Pigs**	**Sheep and Lambs**	**Equine**	**Poultry**
Brazoria	78907	4218	1435	4572	6033
Ft. Bend	32731	693	255	2579	2938
Galveston	9772	343	283	1175	2886
Harris	35189	475	1238	5845	6374

Table 3.4. County-level livestock figures for counties found in Basin 11.

Basin 11 - OSSF Permits



	OSSF Permits
Basin 11- Total	13762
Bastrop Bay/Oyster Lake	5
Bayport Channel	1
Chocolate Bay	2977
Christmas Bay	59
Clear Lake	21
Dickinson Bayou Tidal	1096
Drum Bay	35
Lower Galveston Bay	14
Moses Lake	18
San Jacinto Bay	25
Texas City Ship Channel	2
Upper Galveston Bay	23
West Bay	589
Armand Bayou	32
Bastrop Bayou Tidal	1234
Chocolate Bayou Above Tidal	2422
Chocolate Bayou Tidal	399
Clear Creek Above Tidal	1692
Clear Creek Tidal	462
Dickinson Bayou Above Tidal	701
Lower Oyster Creek-Quintana	28
Old Brazos River Channel	248
Oyster Creek Above Tidal	1562
Oyster Creek Tidal	117

Figure 4.6. Permitted OSSFs in Basin 11.

State and federal voluntary programs work with agriculture producers to address nutrient, sediment, and bacteria impairments and concerns, including:

- Environmental Quality Incentives Program (EQIP) – The Natural Resources Conservation Service (NRCS) of the US Department of Agriculture (USDA) delivers “financial and technical assistance to agricultural producers to plan and implement conservation practices that improve soil, water, plant, animal, air, and related natural resources on agricultural land and non-industrial private forestland” (NRCS, 2016).
- Agricultural Conservation Easement Program (ACEP) – The NRCS provides financial and technical assistance to help conserve agricultural lands and wetlands and their related benefits, e.g. preserving working lands, wildlife habitat, open space, threatened and endangered species, and improving water quality (NRCS, 2016).
- Water Quality Management Program (WQMP) – The Texas State Soil and Water Conservation Board (TSSWCB) manages the program with the stated goal “to abate agricultural and/or silvicultural nonpoint source pollutant contributions to impaired or threatened waters…” (TSSWCB, 2016). There are 13 active WQMPs in the basin, 7 in the Oyster Creek watershed and 6 in West Galveston Bay watershed (TSSWCB personal communication, 2016).

4.3.2.3 Pets

Pets are another common unregulated source of FIB in urban and rural settings. Dense urban areas present a particularly unique setting for pet bacteria contributions. Dog parks, pet walks, and large feral populations of dogs and cats increase the likelihood that pet FIB is potentially significant. Connected impervious surfaces direct rainfall runoff to storm sewers with little treatment. Estimated rates of dog and cat ownership for each household have been developed and can be applied to generate an estimate for the number of dogs and cats found in Basin 11. Using the rates of 0.584 and 0.638 for dog and cat ownership for each household (AVMA, 2012) and a 2015 figure of 336,000 households in Basin 11 (American Community Survey, 2010-2014), yields an estimated population of 196,224 dogs and 214,368 cats in the basin.

4.3.2.4 Wildlife and Migratory Waterfowl

FIB can also come from wildlife and migratory waterfowl as bacteria are common in the intestines of all warm-blooded animals. All wildlife is attracted to the water, increasing the likelihood of direct depositing of bacteria and for FIB to be picked up off adjacent land during rainfall. Feral hogs have been identified as a large contributor to FIB, including direct fecal deposits, due to their desire to wallow in mud and spend time in and around water to escape the heat. While wildlife inhabits all parts of the basin, areas that remain undeveloped are key reservoirs for wildlife. Development only accounts for 14% of the land cover in the basin, which leaves large areas available for wildlife use (Figure 3.3, Table 3.3).

5 Bacteria Analysis Tools

Traditional water quality assessment begins with analyzing data using spatial and temporal trends. These basic analyses are often followed by more technical analysis seeking to correlate variables, better explain relationships, and/or understand cause and effect. For this project, H-GAC was asked to begin this more technical analysis by generating load duration curves (LDCs) and exploring bacteria loading related to variations in land cover. Once AUs are identified for further TMDL study, the next steps, not covered by this report, will be to start quantifying bacteria loadings and determine potential load reductions needed in each AU to meet the contact recreation standard.

5.1 Method

5.1.1 Station Selection

Monitoring data obtained from the SWQMIS database for each monitoring station located in above tidal segments in Basin 11 were examined to determine the data adequacy for Load Duration Curve (LDC) development. The stations containing adequate number of monitoring data were identified by examining the consistency of recorded flow and bacteria data. Stations with observed flow and bacteria data consistent for more than three years at regular intervals and currently in operation were selected for LDC development. If a station has consistent observations of bacteria data with inconsistent or no flow records, they were also considered in developing LDCs, but required additional measures to estimate representative flow.

To identify the most appropriate station to import the flow records for use in LDC development at those stations that are lacking flow data, two selection criteria were used:

1. total catchment area upstream to the station and land use
2. land cover characteristics of the upstream catchment.

If the upstream catchment area and land characteristics of two catchments are similar, then, the flow conditions from the two stations were considered as comparable and can be used in the other station. To identify the catchment area upstream to each selected station, catchment delineation analysis was conducted using elevation, stream network, and monitoring stations data in GIS environment.

5.1.1.1 Catchment Area Delineation

The datasets used for catchment delineation (Figure 5.1) were the USGS 10-meter Digital Elevation Model (DEM) released in 2013, the H-GAC CRP stream network, and CRP monitoring station locations geospatial data. The analysis was performed in ESRI's ArcGIS 10.2 Environment with Spatial Analyst extension.

First, the DEM was reconditioned using the CRP stream networks. The DEM reconditioning function modified the DEM by imposing the stream network features into it. Due to low slope in basin 11, burning of stream network into the DEM is essential to determine accurate drainage catchment areas. After that, the Fill tool in the Hydrology toolbox is used to remove any imperfections (sinks) in the digital elevation model. A sink is a cell that does not have an associated drainage value. Drainage values indicate the direction water will flow out of the cell, and are assigned during the process of creating a flow direction grid for the landscape. The flow direction was estimated using Flow Direction toolbox in Spatial Analyst. A flow direction grid assigns a value to each cell to indicate the direction of flow, the direction that water will flow from that cell based on the underlying topography of the landscape. The flow accumulation was then estimated. The flow accumulation calculates the flow into each cell by identifying the upstream cells that flow into each downslope cell. After the flow accumulation, catchment outlets (pour points) were placed. The catchment outlets in this delineation analysis are the selected monitoring stations. After snapping the catchment outlets, the catchments were delineated using the Watershed tool in Spatial Analyst. Finally, the delineated catchments were overlaid with existing CRP watersheds to merge with the boundaries in large CRP watersheds. This step was done to maintain consistency in common boundaries with CRP watersheds.

5.1.1.2 Land Use/Land Cover Analysis

Land use and cover directly influence hydrology and water quality of a catchment. In this analysis NOAA Coastal Change Program (C-CAP) 2006 and 2011 datasets with 22 land classes were combined for statistical analysis. The combinations, and variable names can be found in Table 5.1.

Class Name (original)	Combined Class	Variable Name
Bare Land	Natural Land Cover	Natural
Cultivated Crops	Cultivated Crops	Crops
Deciduous Forest	Natural Land Cover	Natural
Developed, High Intensity	Developed, High Intensity	Dev_High
Developed, Low Intensity	Developed, Low Intensity	Dev_Low
Developed, Medium Intensity	Developed, Medium Intensity	Dev_Med
Developed, Open Space	Developed, Open Space	Dev_Open
Estuarine Aquatic Bed	Estuarine Wetland	Wetland_est
Estuarine Emergent Wetland	Estuarine Wetland	Wetland_est
Estuarine Forested Wetland	Estuarine Wetland	Wetland_est
Estuarine Scrub/Shrub Wetland	Estuarine Wetland	Wetland_est
Evergreen Forest	Natural Land Cover	Natural
Grassland/Herbaceous	Natural Land Cover	Natural
Mixed Forest	Natural Land Cover	Natural
Open Water	Open Water	Water
Palustrine Aquatic Bed	Palustrine Wetland	Wetland_pal
Palustrine Emergent Wetland	Palustrine Wetland	Wetland_pal
Palustrine Forested Wetland	Palustrine Wetland	Wetland_pal

Class Name (original)	Combined Class	Variable Name
Palustrine Scrub/Shrub Wetland	Palustrine Wetland	Wetland_pal
Pasture/Hay	Pasture/Hay	Pasture
Scrub/Shrub	Natural Land Cover	Natural
Unconsolidated Shore	Natural Land Cover	Natural

Table 5.1. NOAA C-CAP 22 land cover types combined for analysis to 10 land cover types.

The land cover dataset contained a delineation of the acreage of each land cover type in the catchment associated with each monitoring station in the study area. The base 10 logarithms of acreage of each type was calculated and added to the dataset. The total area in the catchment (watershed) for each monitoring station was calculated, and the percentage of each land cover type in the catchment was calculated. The natural logarithm of the percentage of each land cover type was calculated and added to the dataset. Such information was also used in determining the catchments with similar characteristics that can be use flow data for LDC developments (Figure 5.1).

There were several stations with continuous observations of bacteria data, but that lacked flow data. Based on catchment area information and land characteristics we examined the adjacent catchments and stations as potential sources for comparable flow data for LDC development. Stations 17911 and 17913 are stations where this procedure was carried out.

Station 17911

Bacteria monitoring data for this station consists of measurements of both *E. coli* and enterococci. Continuous measurements of *E. coli* were observed from 2007 to 2011 and enterococci measurements were observed from 2012 to 2015. There were no flow records in this station. Station 11423, located 1.5 miles upstream from station 17911, contains consistent flow records from 2011 to 2015. Therefore, we decided to use the flow data from station 11423 to develop LDCs for station 17911. Since the flow is coming from the same catchment and the measurements were done 1.5 miles apart, flow values from station 11423 can be applied the station 17911. Per the available flow data period, only LDCs based on enterococci data could be developed for this station.

Station 17913

Like the station 17911, monitoring from this station also contains only bacteria data and no flow records. Bacteria data also follow the same monitoring schedule of quarterly monitoring of *E. coli* and enterococci. At about 2 miles upstream to this station location, the upstream main stream segment (Mustang Bayou) divides into two branches. One branch continues as Mustang bayou and the other one flows as Persimmon Bayou, which flows through this monitoring station. Station 11423 is located at the continuous section of Mustang Bayou and has flow monitored from 2011 to 2015. Therefore, we have decided to use the flow records from station 11423 for LDC development at station 17913, since it is the most adjacent station as well as it has the flow coming from same upstream catchment.

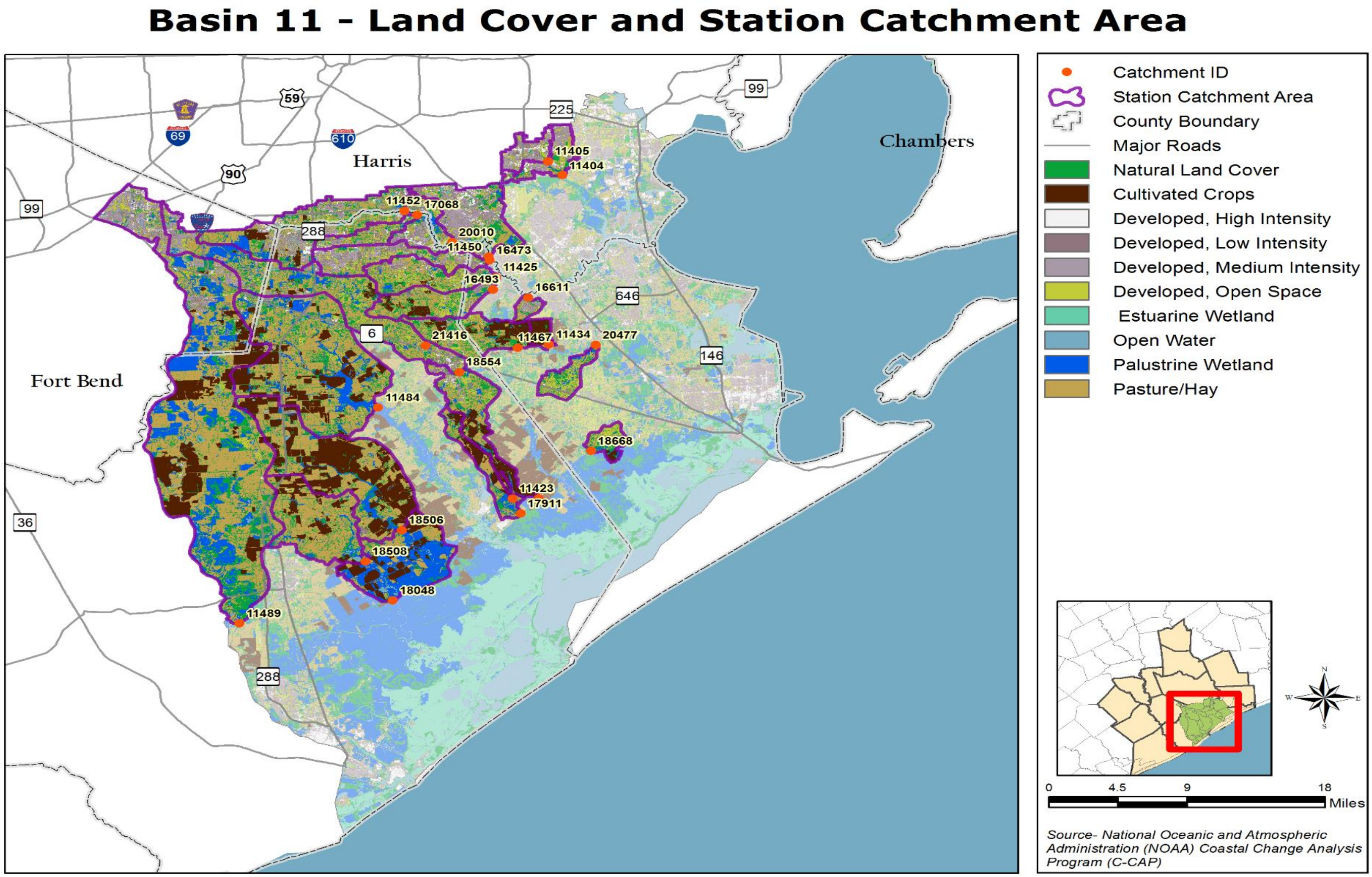


Figure 5.1. Basin 11 catchment area delineated with land cover analysis using 10 land cover types. Catchments developed for LDC development and correlation analysis.

5.1.1.3 Flow Duration Curve Development

The first step of developing a LDC is the development of flow duration curve (FDC) to identify the ranges of flow regimes. The observed flow records were arranged in descending order and ranked from 1 to N. Then the flow exceedance frequency (x-value of each point) was estimated by calculating the historical exceedance frequency of the measured flow, the percent of historical observations that equal or exceed the measured flow using the following formula:

$$F = 100 * \frac{R}{N+1}$$

where F is the frequency of occurrence (expressed as percent of time a flow value is equaled or exceeded), R is the rank, and N is the number of observations.

The sorted flow rate was plotted against the exceedance probability in a semi-log curve to generate the FDC. A common way to look at the duration curve is by dividing it into five zones based on percent exceedance, representing high flows (10% exceedance), moist condition (10% to 40% exceedance), mid-range flows (40% to 60% exceedance), dry condition (60% to 90% exceedance), and low flows (90% to 100% exceedance) (USEPA, 2007). In our LDC developments, we have adopted the EPA guide in determining the flow regimes in all LDCs of this study.

5.1.1.4 Load Duration Curve

The monitored bacteria concentrations were first paired with flow data in the FDC and then the daily loads of bacteria were estimated using the following formula:

*Daily Load (cfu/day) = Bacteria concentration (cfu/100mL) * flow (cfs) * conversion factor*

where the conversion factor is 24465715.2.

Calculated daily loads were then added to the FDC semi-log plot as a scatter plot diagram. Other than the monitored bacteria daily load points, there are two other curves generally added to a LDC. First, is the load regression (LR) curve. The LR curve shows the general trend of the monitored constituents based on a regression analysis. This curve helps to identify whether the constituent load is below or above the TMDL. It is useful in estimating the load reduction needed to maintain an unimpaired waterbody in each flow regime. The other important information in an LDC is the standard curve, which shows the allowable maximum daily limit of constituent loading to maintain the stream unimpaired.

5.1.1.5 *Load Regression Curve*

The LR curve developed in this study is based on EPA's LoadEst methodology. The LoadEst program is a FORTRAN-based, standalone program that generates the regression model for estimating the stream load of a specific constituents at a location. The calibration and estimation procedure in LoadEst are based on three statistical estimation methods. They are Adjusted Maximum Likelihood Estimation (AMLE), Maximum Likelihood Estimation (MLE), and Least Absolute Deviation (LAD). In this study, we used AMLE model to correct the first order bias and to estimate the instantaneous load of bacteria.

The AMLE equation is given as:
Ln(Load) = a0 + a1 LnQ

where:
Load = constituent load [kg/d]
LnQ = Ln(Q) - center of Ln(Q).

After the model was set up and the calibration, header, and estimation files were generated with appropriate information, the LoadEst program was run for both the constituents: *E. coli* and enterococci. Then the load regression curves were developed and added to the semi-log plots that include FDC and observed loading data.

5.1.1.6 *Water Quality Standard Curve:*

Generally, an LDC consists of one or two water quality standards or allowable maximum daily load curves. In this analysis, we have included two standard lines to represent geomean and single sample standards. The criterion for each standard line is given as:

E. coli:
Geomean: 126 MPN/100 mL
Single Sample: 399 MPN/100 mL

Enterococci:
Geomean: 35 MPN/100 mL
Single sample: 104 MPN/100 mL.

The daily load for standard lines were estimated based on following formula:
*TMDL (counts/day) = criterion * flow (cfs) * unit conversion factor.*

5.1.1.7 *Modified Load Duration Curve*

As part of the FY2017 project, H-GAC was asked to draft a Technical Support Document for Chocolate Bayou. To complete the TSD, LDCs would need to be developed for the tidal segment, 1107_01. A modified LDC approach is applied in tidal waterbodies. The difference between the modified LDC and the traditional approach is the application of salinity in the development of the FDC to account for tidal flux in the segment. In addition to salinity, the FIB is now enterococci, used to indicate the potential for pathogens in tidal waters. Segment 1107 contains two monitoring stations: 21178 near the town of Liverpool in the upper third of the watershed, and 11478 at FM 2004, near the point Chocolate Bayou transitions to Chocolate Bay.

To develop the modified LDCs, quarterly CRP enterococci and salinity measurements from 2004 to 2016 were acquired. Due to the tidal nature of the stream, there were no daily flow records to estimate the daily loads of bacteria. As a surrogate, USGS daily flow measurements at gauge station 08078000 from 2004-2015 were used. Daily flow records were generated and related to the salinity of the stream in the next step.

The daily, fresh water flow values at the tidal stations were calculated based on the flow values of upstream USGS station (ID 08078000) and drainage area ratio (DAR) method. To compute the Area Ratio, the area above the USGS gauge station is compared with the watershed contributing to the monitoring station downstream. In the case of station 11478, the contributing watershed includes the area between stations 11478 and 21178, in addition to the area contributing to 21178.

Once the DARs are known, freshwater flow values can be generated at each tidal station. The next step is to combine salinity observations (from CRP monitoring) taken at each station with adjusted daily fresh water flow values based on the date of the observation. The top and bottom 5% were considered outliers and eliminated from further calculations.

A linear regression curve and the curve-fitting equation were estimated to develop a daily freshwater flow-measured salinity relation. Using the linear regression equation in each station, daily salinity time series were generated with respect to the adjusted USGS flow values. The resulting equation developed for each station was then used to calculate the volume of seawater flowing through the station cross section over the period of a day.

The regression equations developed previously were then used to compute the total daily flow volume including both fresh and saline water. The modified FDC was then developed following similar procedures for creating an FDC in the above tidal segment. For more detail on developing modified LDCs, please review the Chocolate Bayou TSD.

5.1.1.8 Load Duration Curve Review

Figures 5.2 brings the LDC together with all the components, FDC, Geometric Mean and Single Grab Standard Curves, Observed Data, and the Load Regression Curve. LDCs were developed for 17 monitoring stations in Basin 11. Appendix D contains segment and AU summaries for the basin. Each summary contains LDCs created for the monitoring stations where sufficient bacteria and flow or reasonable accommodations for flow measures were found. Reviews concerning individual station LDCs are saved for the segment summaries in Appendix D.

The LDCs can be used to develop future load reductions during TMDL development. Using the flow regime 0% to 10% High Flows, 10% to 40% Moist Conditions, 40% to 60% Intermediate Conditions, 60% to 90% Dry Conditions and 90% to 100% Dry Conditions, the LDCs can be viewed as periods where the bacteria load meets the standard (i.e. the regression curve is below the geometric mean) and periods where it exceeds the standard (i.e. the regression curve is above the geometric mean). Additionally, individual observed data can be contrasted with the single grab standard curve to determine the relation of either above or below the single grab standard during a flow regime. This can be useful in calculating load reductions during TMDL development, but can also be useful in visually depicting reduction requirements to the public and conveying whether dry weather conditions or wet weather conditions present the biggest challenge in meeting the standard (e.g. dry weather inputs from WWTFs or wet weather sources, like stormwater).

Not all the LDCs from the 17 stations were used. Traditionally, LDCs are created for *E. coli* measures as flow can be measured easily for non-tidal waters. Stations in the lower reaches of Chocolate Bay presented the opportunity to consider LDCs from both *E. coli* and enterococci measurements. In each case, the LDC from enterococci exhibit load regression curves that remain mostly above the geometric mean and single sample standard curves. This was not found when the companion *E. coli* LDC was reviewed. Due to this, the LDCs created for enterococci were not used in the segment summaries. H-GAC has found reviewing stations in freshwater where *E. coli* and enterococci samples have been collected as a paired sample and analyzed that the relative geometric means for enterococci are typically higher and result in elevated bacteria trends when compared against the *E.coli* measurements.

5.1.2 Bacteria vs. Days Since Last Rain Plots

To assist with segment and AU bacteria analysis and to provide a surrogate when an LDC could not be developed (i.e. tidal waters or insufficient flow data) bacteria results were plotted against the number of days since the last significant rainfall (as determined by the collecting staff) reported in SWQMIS for the sample event. These plots provide an opportunity to look at the bacteria data in relationship to the standard and to potentially gauge the weather conditions, wet or dry, that the segment was in at the time the sample was taken. Figure 5.3 is an example of a plot developed for Clear Creek Tidal, Segment 1101, for bacteria data collected by CRP from 2002 to 2016. Each monitoring station in the segment has been given its own symbol. The data is plotted against the log base 10 of state's water quality standard as represented by the dashed red line.

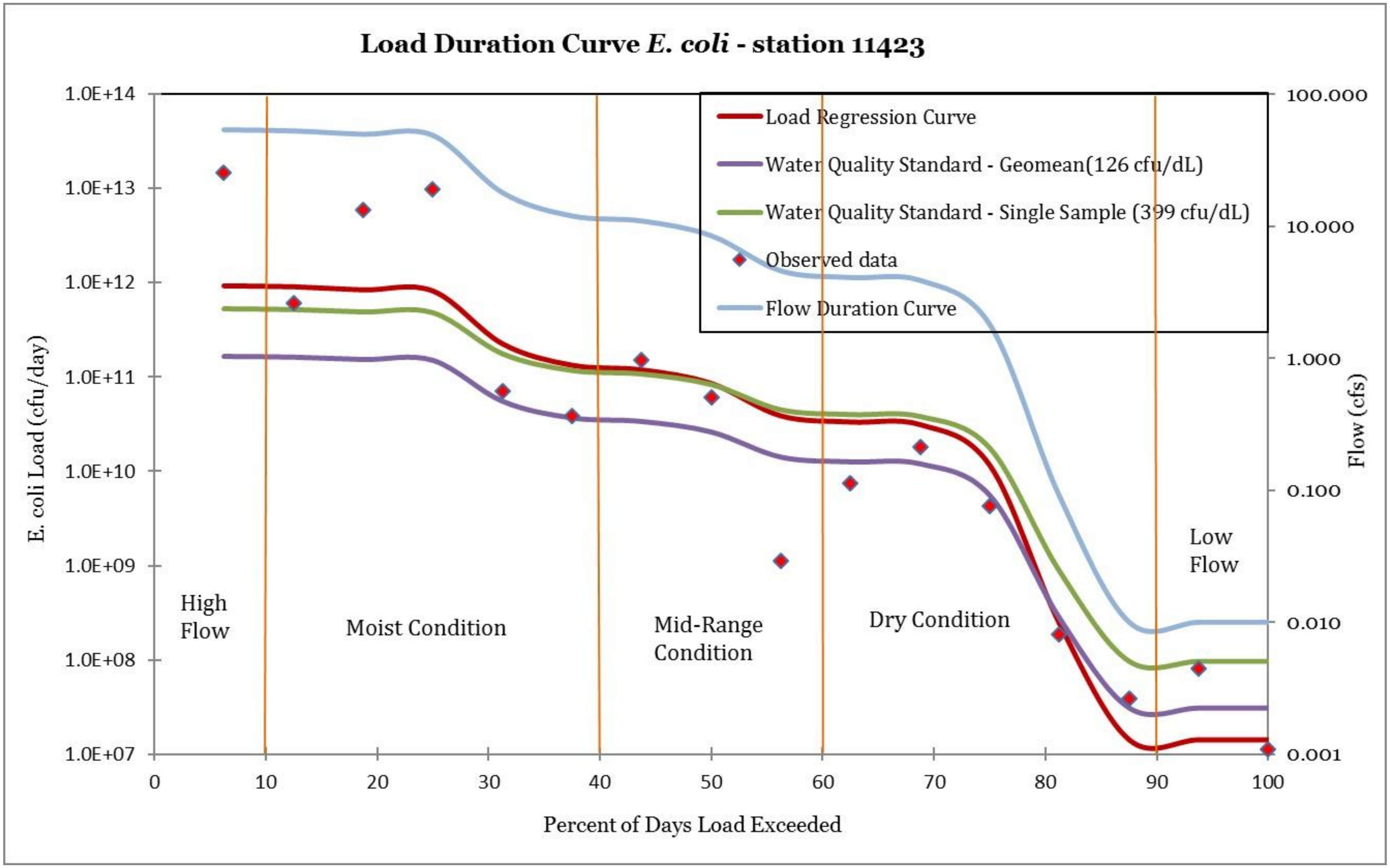


Figure 5.2. *E.coli* Load Duration Curve developed for station 11423 on Mustang Bayou in the Chocolate Bay segment.

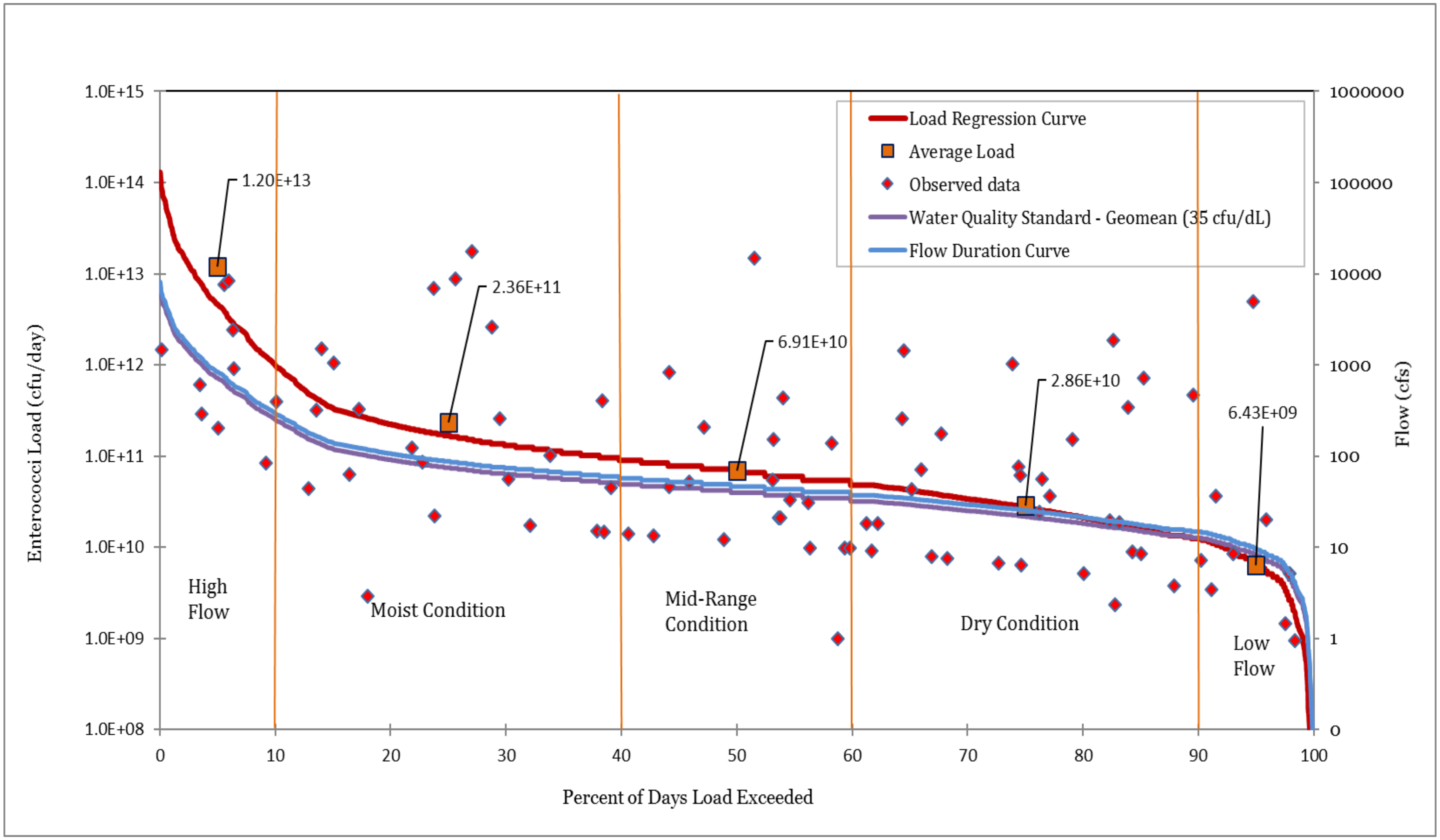


Figure 5.3 Enterococci Modified Load Duration Curve developed for station 11478 on Chocolate Bayou Tidal (1107_01).

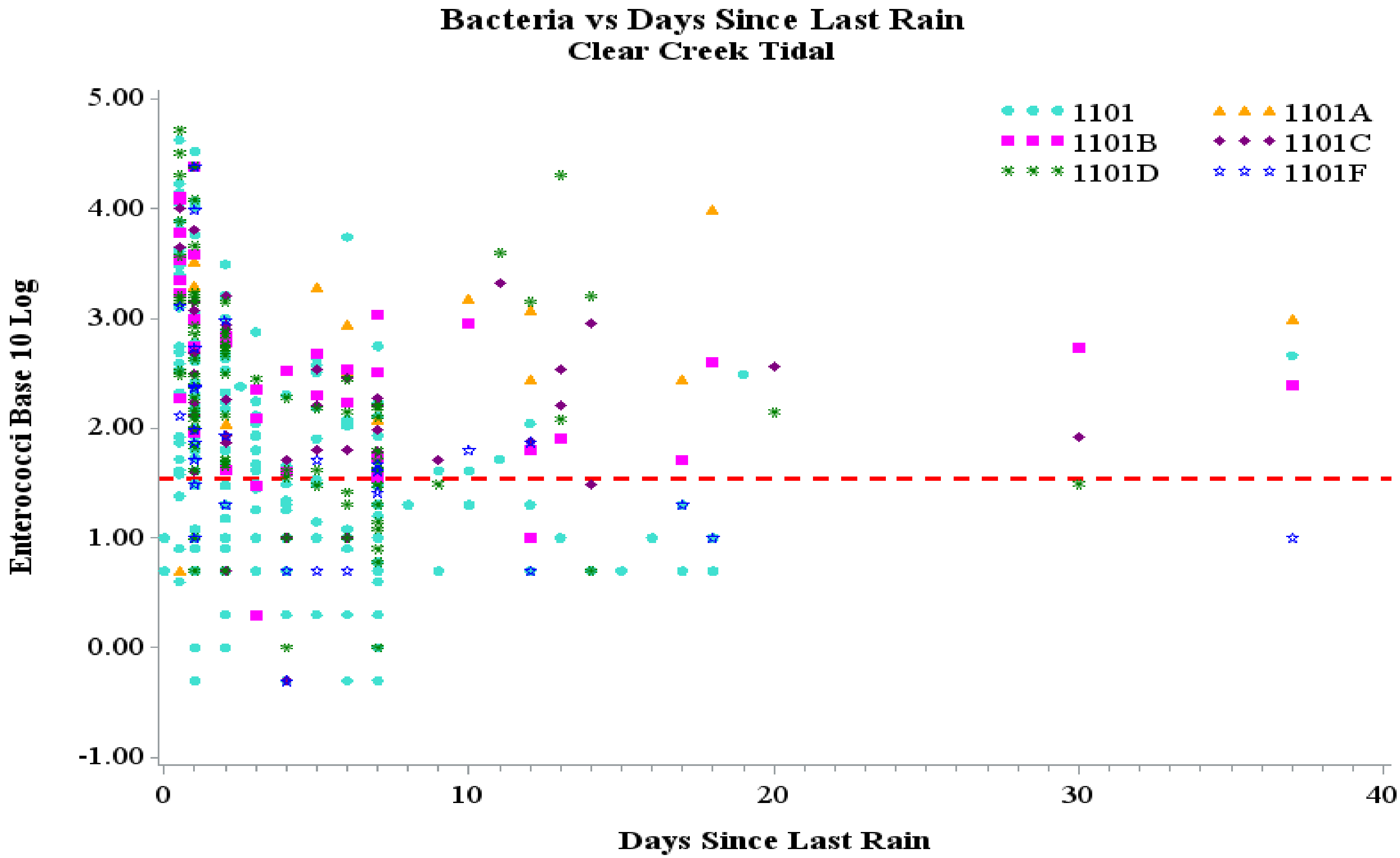


Figure 5.4. Bacteria vs. Days Since Last Rain for bacteria samples collected by CRP from the Clear Creek Tidal segment of Basin 11.

The weakness with using the Bacteria vs. Days Since Last Rain is that it is more difficult to discern the weather condition of the segment at the time the sample was taken. While streamflow is a good predictor of condition, a bacteria sample taken 10 or 20 days since last measurable rain could have been collected when the segment is still in a wet or even a high flow condition just as a sample collected one day since last rainfall could have been collected during dry or even a low flow condition. Interpretations must therefore be considered weak and conclusions limited in scope.

5.1.3 Statistical Analysis of Land Cover and Water Quality Load

5.1.3.1 Land Cover Data

The land cover data was processed following the method described in 5.1.1.2.

5.1.3.2 Precipitation Data

A list of NOAA weather stations in the study area was assembled, and the stations with data that spanned the period 2000-2016 were identified. Precipitation data from these stations were calculated (Table 3.2), and the station nearest to each monitoring station in the study area was determined using SAS PROC DISTANCE. NOAA data collected at the closest station was joined to the land cover data for each monitoring station and were downloaded on May 24, 2016. Total precipitation in inches on the previous day and the total for the previous three days were calculated and added to the record for each date.

5.1.3.3 Water Quality Data

Water quality data collected between June 1, 2000, and December 31, 2016, for all stations within the study area were extracted from a dataset of SWQMIS water quality data maintained by H-GAC. The data in the H-GAC dataset were downloaded from TCEQ on May 16, 2017.

Land cover data from 2006 and 2011 were added to the water quality dataset. Data collected before 2009 were added to the 2006 land cover dataset, and those collected 2009-2016 were added to the 2011 land cover data. The NOAA rainfall data were then added to the dataset.

A set of variables was selected for Basin 11 (Table 5.2). Two categorical variables were created: a “Wet / Dry” variable was created from the routine water quality parameter, and “Days Since Last Significant Rainfall.” These indicated whether there had been significant rainfall within three days (coded “Wet”) or not (“Dry”). A dominant land use variable was created to identify any land use that accounted for more than 40 percent of the catchment (coded “AGR,” “DEV,” or “UND”).

Variable Name	Comment	Source
Ammonia_N	mg/L	SWQMIS
Crops	Cropland, acres	NOAA (2006 and 2011 data)
Crops_pct	Cropland, percent of catchment area	NOAA (2006 and 2011 data)
Days_Since_Last_Rain		SWQMIS
Dev_High	High intensity development, acres	NOAA (2006 and 2011 data)
Dev_High_pct	Above, percent of catchment area	NOAA (calculated by H-GAC)
Dev_Low	Low intensity development, acres	NOAA (2006 and 2011 data)
Dev_Low_pct	Above, percent of catchment area	NOAA (calculated by H-GAC)
Dev_Med	Medium intensity development, acres	NOAA (2006 and 2011 data)
Dev_Med_pct	Above, percent of catchment area	NOAA (calculated by H-GAC)
Dev_Open	Open developed land, acres	NOAA (2006 and 2011 data)
Dev_Open_pct	Above, percent of catchment area	NOAA (calculated by H-GAC)
Dissolved_Oxygen	mg/L	SWQMIS
EC_log	Natural logarithm of *E. coli*	SWQMIS (calculation by H-GAC)
E__Coli	MPN/100 mL	SWQMIS
End_Date	Sample date	SWQMIS
Enterococci	MPN/100 mL	SWQMIS
GF_est	Unpermitted OSSFs (number in catchment, estimated)	H-GAC OSSF Database
NH3_log	Natural logarithm of NH3	SWQMIS (calculation by H-GAC)
Natural	All forest types, shrubs, grassland, bare land-acres	NOAA (2006 and 2011 data)
Natural_pct	Above, as percentage of catchment	NOAA (calculated by H-GAC)
PRCP	Precipitation on day of sampling (inches)	NOAA NCDC
Pasture	Pasture, acres	NOAA (2006 and 2011 data)
Pasture_pct	Above, percent of catchment area	NOAA (calculated by H-GAC)
Secchi_Transparency	meters	SWQMIS

Variable Name	Comment	Source
Specific_Conductance	Microseimens / cm	SWQMIS
TPhos_log	Natural logarithm of total phosphorus	SWQMIS (calculation by H-GAC)
TSS_log	Natural logarithm of total suspended solids	SWQMIS (calculation by H-GAC)
Temperature	Degrees C	SWQMIS
Total_Phosphorus	mg/L	SWQMIS
Total_Suspended_Solids	mg/L	SWQMIS
Water	Water, acres	NOAA (2006 and 2011 data)
Water_pct	Above, percent of catchment area	NOAA (calculated by H-GAC)
Wetland_est	Estuarine wetland, acres	NOAA (2006 and 2011 data)
Wetland_est_pct	Above, percent of catchment area	NOAA (calculated by H-GAC)
Wetland_pal	Palustrine wetlands, acres	NOAA (2006 and 2011 data)
Wetland_pal_pct	Above, percent of catchment area	NOAA (calculated by H-GAC)
ent_log	Natural logarithm of enterococci	SWQMIS (calculation by H-GAC)
flow_comp	Streamflow, CFS	SWQMIS or USGS
flow_log	Natural logarithm of streamflow	SWQMIS (calculation by H-GAC)
lcyr	Year land cover dataset was released (2006 or 2011)	NOAA
log10flow	Bas e10 logarithm of streamflow	SWQMIS or USGS – calculation by H-GAC
log_Crops	Base 10 logarithm of (acres + 1)	NOAA (calculated by H-GAC)
log_Dev_High	Base 10 logarithm of (acres + 1)	NOAA (calculated by H-GAC)
log_Dev_Low	Base 10 logarithm of (acres + 1)	NOAA (calculated by H-GAC)
log_Dev_Med	Base 10 logarithm of (acres + 1)	NOAA (calculated by H-GAC)
log_Dev_Open	Base 10 logarithm of (acres + 1)	NOAA (calculated by H-GAC)
log_Natural	Base 10 logarithm of (acres + 1)	NOAA (calculated by H-GAC)
log_Pasture	Base 10 logarithm of (acres + 1)	NOAA (calculated by H-GAC)
log_Water	Base 10 logarithm of (acres + 1)	NOAA (calculated by H-GAC)

Variable Name	Comment	Source
log_Wetland_est	Base 10 logarithm of (acres + 1)	NOAA (calculated by H-GAC)
log_Wetland_pal	Base 10 logarithm of (acres + 1)	NOAA (calculated by H-GAC)
logdate	Base 10 logarithm of collection data	SWQMIS (calculation by H-GAC)
logload		Surrogate for load (Calculation by H-GAC)
lu_dom	Dominant land use (type > 40 percent of catchment; AGR, NAT, DEV)	Calculation by H-GAC from NOAA data
ossf_n	Total OSSFs in catchment (permitted + estimated unpermitted)	H-GAC OSSF Database
pH		SWQMIS
pr_3day	Total precipitation in three days prior to sampling (inches)	NOAA NCDC (calculation by H-GAC)
pr_prevday	Total precipitation on the day prior to sampling (inches)	NOAA NCDC (calculation by H-GAC)
seg_type	Freshwater stream, tidal stream, or estuary	SWQMIS
spcon_log	Natural logarithm of specific conductance	SWQMIS (calculation by H-GAC)
station_id		SWQMIS
total_catch	Total area of catchment, acres	NOAA (calculated by H-GAC)
wet_dry	Wet = significant rain within 3 days; dry = > 3 days since significant rainfall (taken from field data in CRP database- 72053, days since significant rainfall	SWQMIS (calculation by H-GAC)
Dev_high	Sum of dev_high_pct and dev_med_pct	Calculated by H-GAC
Dev_low	Sum of dev_low_pct and dev_open_pct	Calculated by H-GAC
Nat2	Sum of natural_pct, wetland_pal_pct, wetland_est_pct	Calculated by H-GAC

Table 5.2. Variables identified in Basin 11 used to perform load correlation analyses.

5.1.3.4 Statistical Analysis

The focus of the statistical analysis is the relationship between *E. coli* load and land cover characteristics. Because the bacteria load is dependent upon flow, only sample events with an associated flow value were analyzed. To appropriately scale the variables, which is important for mixed model procedures, the actual load (expressed in MPN/day, for example) was not used. A surrogate variable that is proportional to the total load ("logload") was created by multiplying the natural log of *E. coli* density (expressed as MPN/100 mL prior to log transformation) by the base 10 logarithms of instantaneous flow.

Statistical analyses included the following:

- Nonparametric correlation analysis (Spearman analysis)
- SAS PROC MIXED
    - Mixed models are developed using generalized least squares/maximum likelihood estimation methods rather than ordinary least squares (OLS, used in regression and GLM/ANCOVA). Generalized least squares estimation relaxes the requirements of independent and normally distributed errors that must hold if inference and parameter estimation by OLS are to be valid. Mixed models can include random components that account for variance in data collected at different monitoring stations and/or serial correlation between repeated observations at the same station, and produce more "generalizable" parameter estimates.
    - Repeated measures or random coefficients mixed models were fit (if possible) to the data.
- SAS PROC GLM (general linear model, analysis of covariance)
    - After a model was fit using PROC MIXED, it was evaluated with PROC GLM to produce fit plots (Figure 5.6) and R^2 calculations.
- SAS PROC REG: Multiple Regression
    - Models that included land cover data and temporal trends were fit using multiple regression.
- The relationship between WWTF effluent discharge, SSO events and volume, and bacteria results at the segment level was examined using Spearman correlation.
    - Due to data limitations, the analysis was limited to data collected from 2011 through 2015.

- WWTF discharge data was taken from Discharge Monitoring Report data provided by TCEQ.
- SSO data was provided by TCEQ. The relative geometric mean (the geometric mean as a multiple of the standard for the segment-specific indicator bacterium) was calculated from routine water quality monitoring data obtained from SWQMIS.
    - All bacteria data (*E. coli* in non-tidal and enterococci in tidal segments) collected in the TMDL project area were used.

5.1.3.5 Summary of Statistical Analysis: E. coli load as a Function of Land Cover

The basin 11/24 dataset contained 343 observations from 17 monitoring stations, collected between November 2000 and May 2015. Each observation included instantaneous flow.

5.1.3.5.1 Correlation analysis

- *E. coli* loads were found to be positively correlated with the percentage of pasture in the Basin 11 watersheds.
- The loads are negatively correlated with developed open area.
- The significant correlations are fairly weak; the highest correlation was with pasture (0.163).

5.1.3.5.2 Regression analysis with land cover and rainfall/wet weather variables

- Correlation analysis may not provide information about how the distribution of other land cover types affects the relationship between a specific land cover type and the *E. coli* load. Multiple regression modeling can account for the influence of one type when all other types are held constant at their mean value.

- Regression of the *E. coli* load on all land cover types, including rainfall variables (precipitation total in the previous three days and wet/dry condition) and their interaction with land cover types suggests that there is a statistically significant relationship between the *E. coli* load and the percentage of land cover characterized as low intensity development, open developed area, and pasture.

- Low intensity development is associated with higher *E. coli* loads
- Pasture land is associated with higher loads during wet-weather conditions
- Open developed area is associated with lower loads.
- These variables explain less than 20 percent of the variation in *E. coli* loading in basin 11 (adjusted $R^2 = 0.173$).

- When the collection date is included in the model, the results suggest a trend of decreasing loads over time, but the trend does not appreciably increase the model R^2.

5.1.3.5.3 A repeated measures mixed model to predict the *E. coli* load was developed from a large suite of candidate variables (land cover data, several water quality parameters, derived categorical variables, precipitation data, and interactions between rain events and land cover).

- Eight variables were found to be significant predictors of *E. coli* loads (Table 5.3).
- The only land cover type that is a significant predictor is pasture land (associated with higher loads).
- The estimated number of unpermitted OSSFs is associated with higher loads.
- The model explains more than half of the variation in loads (adjusted $R^2 = 0.529$).

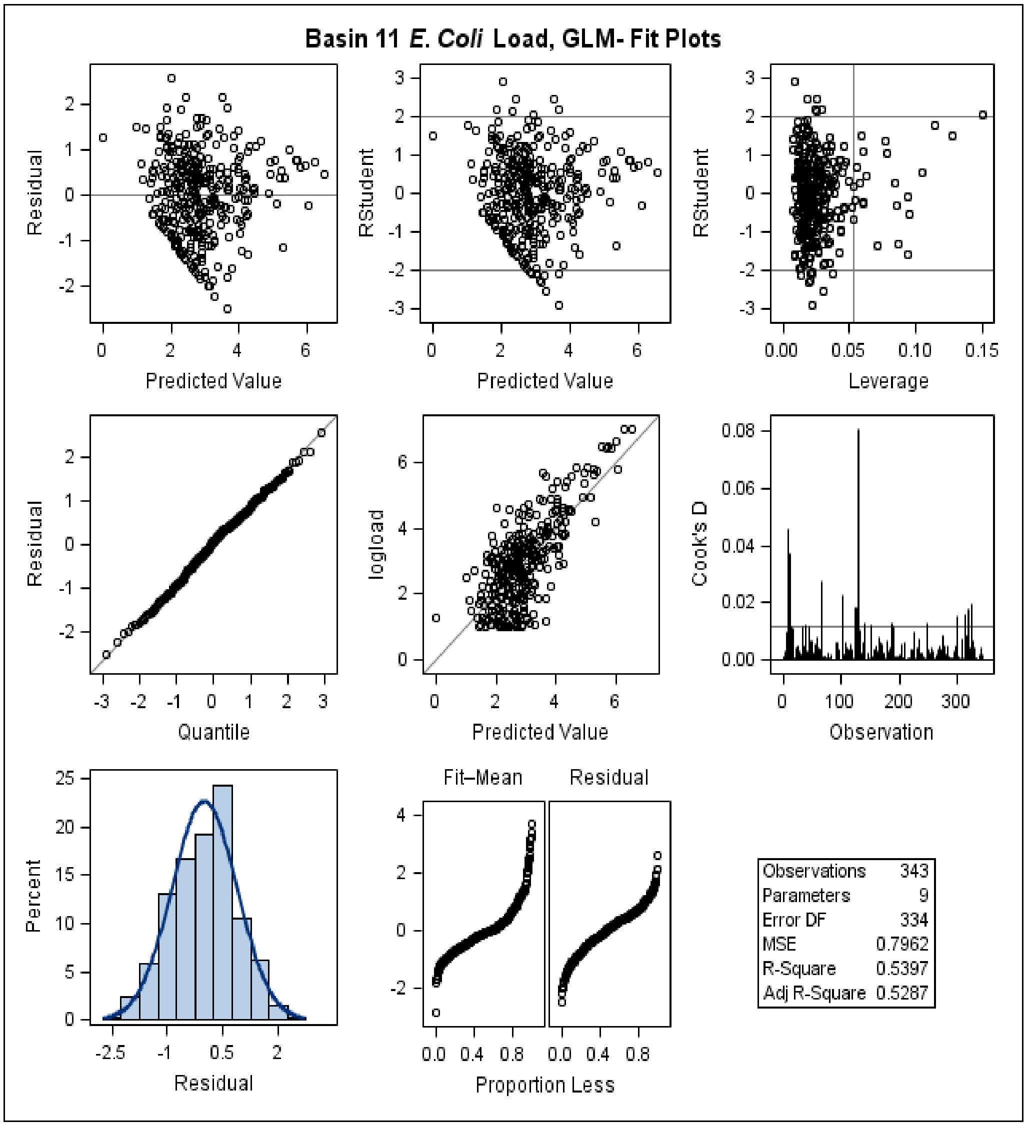


Figure 5.5 Basin 11 *E. Coli* load, GLM Fit Plots.

Summary Analysis				
Parameter	**Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	6.873389602	1.66331346	4.13	<.0001
Wet/Dry Variable: Dry	-0.348565967	0.11060073	-3.15	0.0018
Wet/Dry Variable: Wet	0.000000000	.	.	.
Time (trend)	0.970698864	0.26359405	3.68	0.0003
Total suspended solids (natural log)	0.354650987	0.05043823	7.03	<.0001
Temperature	-0.028771089	0.00738675	-3.89	0.0001
pH	-0.416227891	0.16548994	-2.52	0.0124
Specific conductance (natural log)	-1.724921319	0.24555681	-7.02	<.0001
Unpermitted OSSFs (estimated n)	0.004436892	0.00065128	6.81	<.0001
Undeveloped (percent) / 3-day rain total interaction	0.014973209	0.00354509	4.22	<.0001

Table 5.3. Summary Analysis using repeated measure mixed model statistical method.

- No correlation was found between annual mean loads calculated from DMR data and annual geometric means was found in basin 11 segments.
- Total annual SSO events and volume discharged were found to be negatively correlated with the annual geometric mean.

6 SEGMENT SPECIAL STUDIES

In year one, H-GAC recommended additional water quality management planning for six segments and 14 AUs in Basin 11 (Table 5.2). For 10 AUs H-GAC recommended potential TMDL studies: One study for the Dickinson Bayou watershed, 1103, two studies in the Chocolate Bayou watershed, 1107 and 1108, and seven studies for the Chocolate Bay watershed, 2432. For the remaining two segments and four AUs covering Oyster Creek, 1109_01 1110_01, 1110_02, and 1110_03, H-GAC is recommended the continued collection of bacteria data and collecting additional bacteria and continuous flow data. In year two, H-GAC with approval of the TCEQ, initiated a TMDL study for Chocolate Bayou Tidal and Above Tidal and augmented bacteria and flow data in Oyster Creek.

6.1 CHOCOLATE BAYOU

In 2017, H-GAC with TCEQ initiated a TMDL study for Chocolate Bayou Tidal (1107) and Chocolate Bayou Above Tidal (1108). H-GAC set out to address the first part of the TMDL process, determining the TMDL allocation, by completing the Technical Support Document (TSD). The second part of the process is to work with stakeholders within the watershed to develop a watershed planning document to describe the steps and measures needed to reduce bacteria concentration to the point it meets the TMDL allocation and ultimately the water quality standard. The second part is typically approached through a TMDL implementation plan (I-Plan) but can be addressed through other planning tools based on stakeholder desires. H-GAC will approach stakeholders in future meetings to determine the best approach.

6.1.1 Chocolate Bayou TSD

H-GAC completed the first draft of the TSD and submitted the document to the TCEQ. The document will be provided to stakeholders for reading and public comment in the future. A summary of the steps taken to develop the TSD and the final calculation are presented. The result of the TSD is the expression of the Total Maximum Daily Load allocation for each Chocolate Bayou segment. A TMDL is like a budget– it determines the amount of a pollutant that a water body can receive and still meet its applicable water quality standards. TMDLs are the best possible estimates of assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per unit of time, but may be expressed in other ways. The TMDL is expressed by the equation:

$$TMDL = WLA + LA + FG + MOS \qquad \text{Equation 1}$$

Where:

TMDL = total maximum daily load
WLA = waste load allocation, a term that includes all permitted sources
LA = load allocation, a term that expresses all non-regulated sources
FG = future growth, potential for future growth of permitted sources
MOS = margin of safety

To determine the TMDL there are several steps to follow.

6.1.1.1 Data Acquisition and Analysis

H-GAC gathered historical water quality and hydrology data for 1107 and 1108. Additional watershed data, including watershed population, wastewater and stormwater permits, were also collected and analyzed.

The 2014 Texas IR lists the assessment unit 1107_01 as impaired for contact recreational use due to high levels of enterococci bacteria. The assessment unit has been listed since 2010. The TCEQ assessment found the geomean for enterococci within this AU to be 82 MPN/100mL, more than twice the standard of 35 MPN/100mL (Table 3).

The 2014 Integrated Report designated assessment unit 1108_01 for the first time as impaired for contact recreation due to elevated levels of *E. coli* bacteria. The TCEQ assessment found the geomean for *E. coli* within this assessment unit to be 159.03 MPN/100mL, which is slightly above the standard of 126 MPN/100mL.

Water Body	Segment Number	Assessment Unit	Parameter	Station	No. of Samples	Data Date Range	Station Geometric Mean (MPN/100 mL)
Chocolate Bayou Tidal	1107	1107_01	Enterococcus	21178/11478	84	2005-2012	81.51
Chocolate Bayou Above Tidal	1108	1108_01	*E. coli*	11484	24	2005-2012	159.03

Table 6.1 2014 Integrated Report Summary for the Chocolate Bayou watershed. Source: TCEQ (2015).

Recent bacteria monitoring data was retrieved from TCEQ SWQIMS through February 28, 2017. The data were reviewed and trends were developed. Data collected between 2010 and 2017 continues to support the impairment finding in 1107_01 (Figure 6.1). Enterococci concentrations continue to increase in the segment.

The bacteria trend for 1108_01 sees the bacteria level skirting around the standard and above the standard at several points. The geometric mean for E. coli concentrations in segment 1108 is above the 126 MPN/100 mL standard for contact recreation. Table 4 presents the calculated bacteria geometric mean for SWQM bacteria data collected between 2010 and 2017.

Assessment Unit	**Parameter**	**Station**	**No. of Samples**	**Data Date Range**	**Geometric Mean (MPN/100 mL)**
1107_01	Enterococcus	21178/11478	79	2010-2016	115.0
1108_01	*E. coli*	11484	24	2010-2017	154.6

Table 6.2 Seven year bacteria geomean for both AUs for SWQM bacteria data collected between 2010-2017.

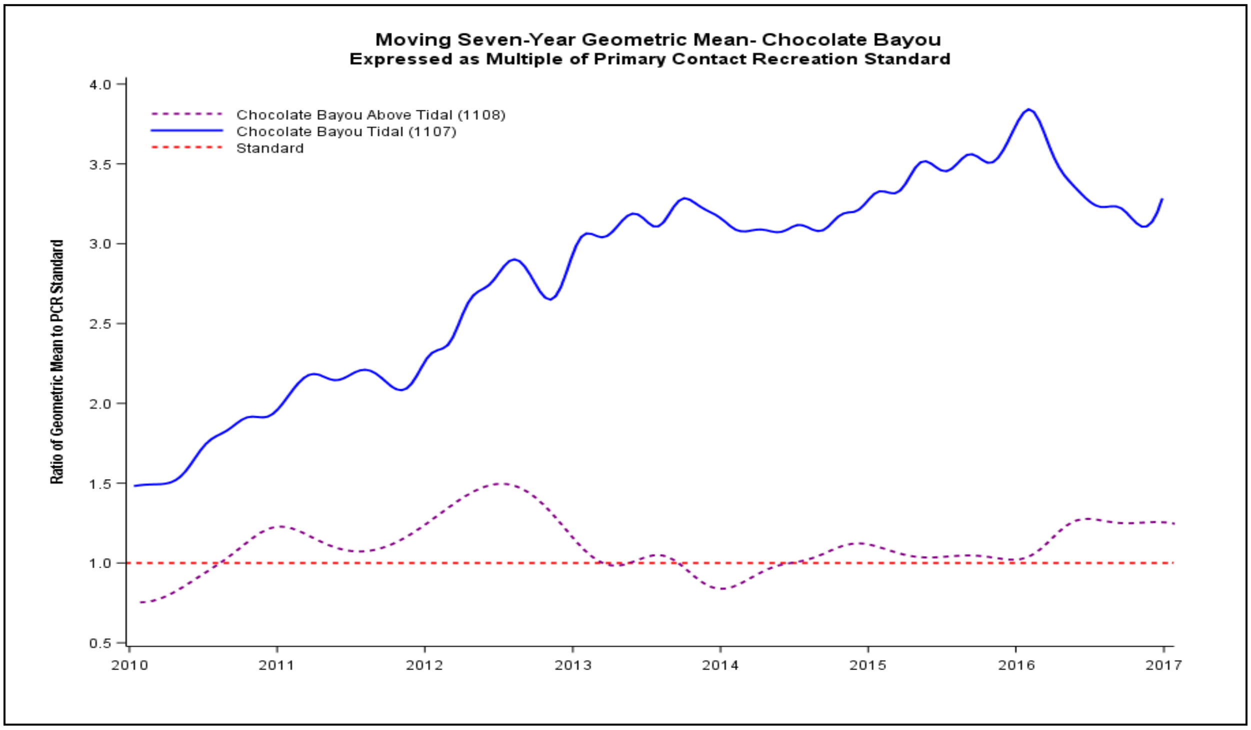


Figure 6.1 Bacteria geometric mean trends in 1107_01 and 1108_01 vs. the standard.

6.1.1.2 TMDL Load

The next step is to determine an assimilative loading value, i.e. FIB concentration, for a waterbody such that the value does not exceed the standards criteria developed for that pollutant. To perform this step, H-GAC used the LDC method described in Section 6. LDC method allows for the estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data. Segment 1107 presented the challenge of tidal fluctuations that alters flow, which is the bases for the LDC. A modified version of the LDC has been successfully used in tidal waters and was applied here.

The LDCs were developed for the three routine monitoring stations found in Chocolate Bayou, 11848 (1108) and 11478 and 21178 both in 1107 (Figure 6.2). Flow data was from USGS gauge 08078000 (Figure 6.2). Figures 6.3 and 6.4 are provided as an example of the LDCs developed for the TSD. It contains all elements: FDC, Water Quality Standard Curve, Load Regression Curve, Observed Data and Average Load of the observed data found in each flow regime (e.g. 0-10%, 10-40%). A modified LDC approach was needed for AU 1107_01 due to tidal influences at station 11478. This process was discussed in section 5 and more thoroughly in the TSD.

Chocolate Bayou - Monitoring Site Locations

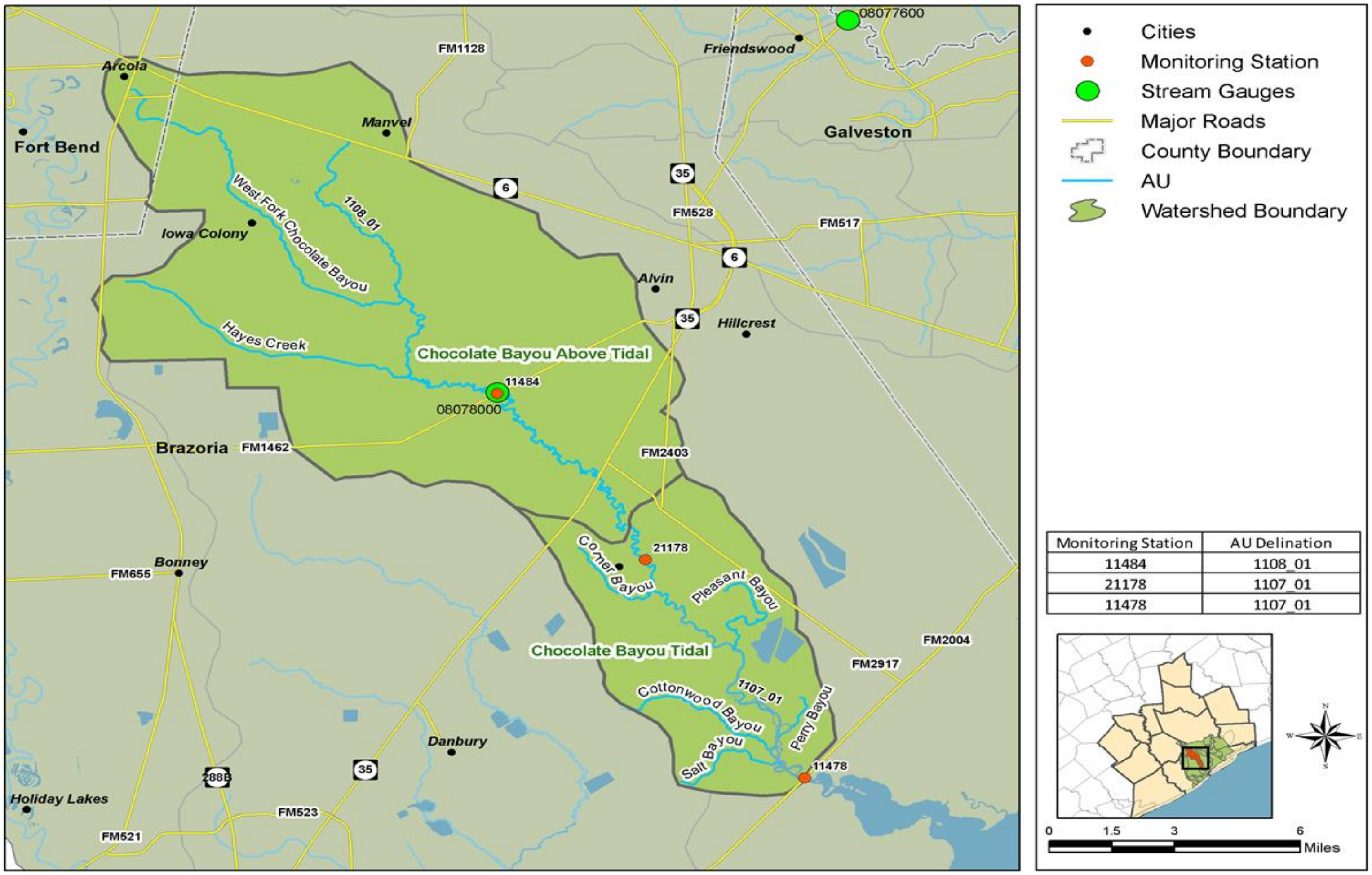


Figure 6.2 SWQM stations and USGS flow gauge locations in 1108_01 and 1107_01.

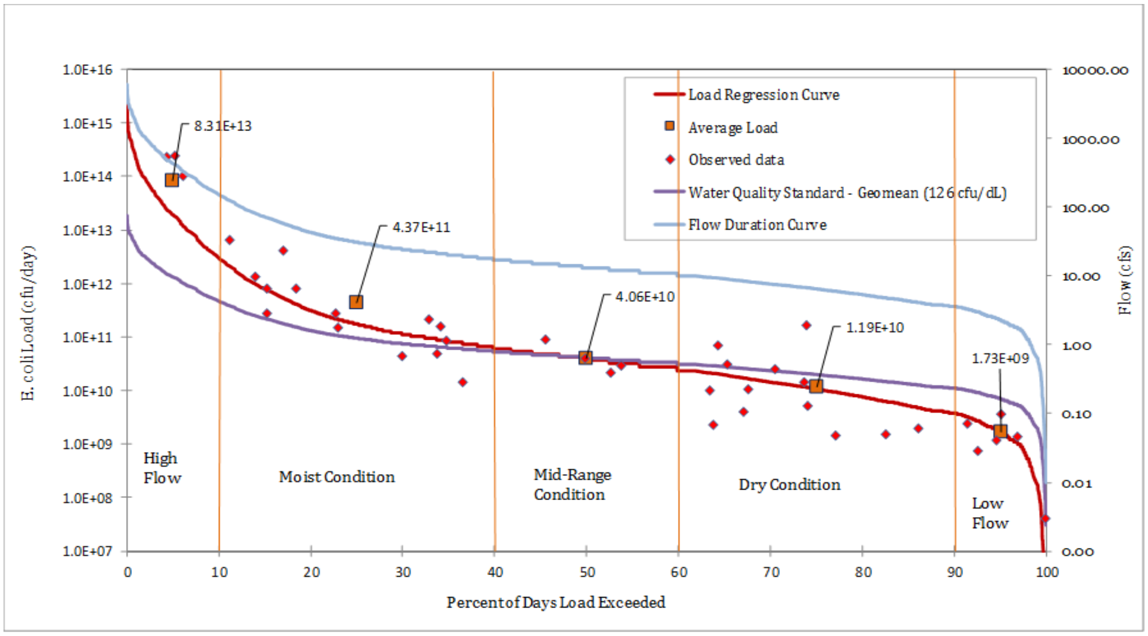


Figure 6.3 LDC for station 11484 in 1108.

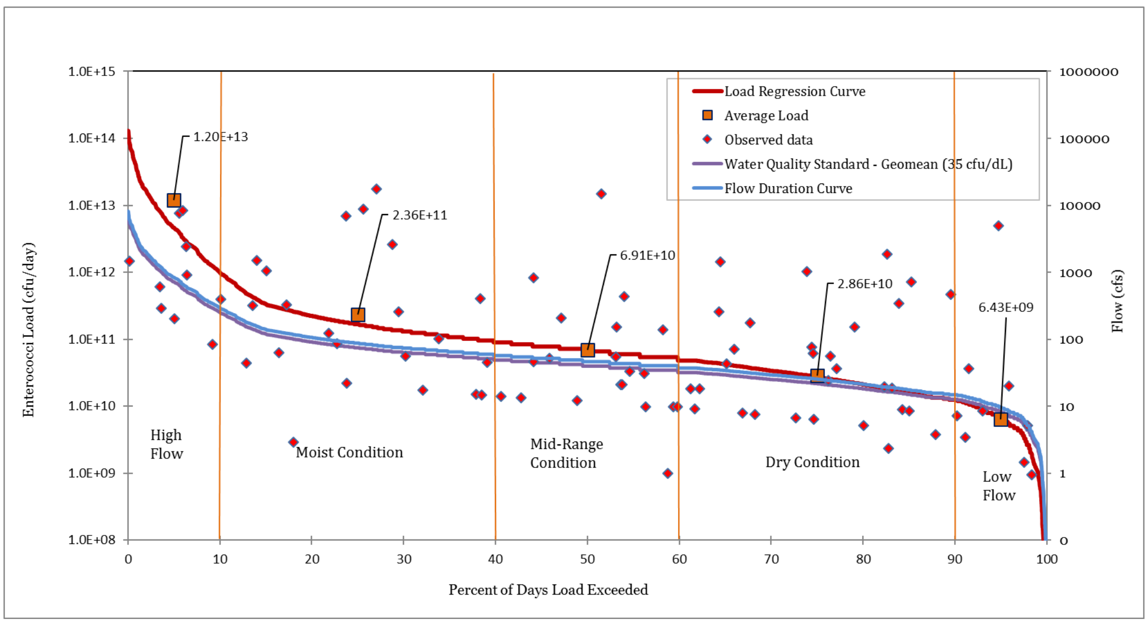


Figure 6.4 Modified LDC for station 11478 in 1107.

6.1.1.3 TMDL Load Allocation

In the prior steps, data was gathered and analyzed and LDC were developed. The LDC determines the TMDL load. Traditional approaches use the 5% days load exceeded point. The place on the Standard Curve where the curve meets 5% is the TMDL load. TMDLs were determined for the furthest downstream monitoring stations, 11484 and 11478 in 1108 and 1107 respectively. The TMDL loads is presented in Table 6.3.

Watershed	Segment	5% Exceedance Flow	5% Exceedance Load	LA_{trib} (Billion MPN/day)	TMDL (Billion MPN/day)
Chocolate Bayou Tidal	1007	838.50	7.18E+11	296.51	718.01
Chocolate Bayou Above Tidal	1008	433.00	1.33E+12	_	1,334.80

Table 6.3 TMDL calculation at the 5% exceedance flow in the High Flow condition.

Now that the TMDL is known, the rest of the variables for equation 1 must be solved. MOS is explicitly applied as a 5% reduction of the TMDL target criterion. For the tidal AU, that results in the standard being lowered from 35 MPN/100mL to 33.3 MPN/100mL. In the above tidal AU, the standard is lowered from 126 MPN/100mL to 119.7 MPN/100mL. Applying this to the TMDL values presented in Table 6.3 yields a MOS for the two segments. The MOS is presented in Table 6.4.

Watershed	Segment	TMDL (Billion MPN/day)	MOS (Billion MPN/day)
Chocolate Bayou Tidal	1007	718.01	21.08
Chocolate Bayou Above Tidal	1008	1,334.80	66.74

Table 6.4 MOS calculation based on TMDL calculated at the 5% exceedance flow.

The WLA is next calculated. Wastewater and stormwater permit information is used to calculate this variable. WWTF were identified for each segment. The full permitted flow for each WWTF was used to calculate a daily load by multiplying it with the standard criterion and summing up the results. It must be noted that there is a conversion factor used in each calculation to arrive at daily loading numbers. Please review the TSD for information on the conversion factor.

The WLA assigned to stormwater is a little more difficult. The method used for the Chocolate Bayou TSD was to estimate the percentage of the area of the permitted facility and calculate the difference between the watershed area and the portion under stormwater permit. Additionally, a future growth (FG) component must be calculated. FG is calculated using the WWTF permitted maximum daily flow with the estimated population growth, generally over the next 20-30 years.

Once the wastewater and stormwater allocations are made, summing the two provides the WLA. Table 6.5 presents the WLA.

Watershed	Segment	WLA_{wwtf} (Billion MPN/day)	WLA_{sw} (Billion MPN/day)	WLA (Billion MPN/day)
Chocolate Bayou Tidal	1107	18.37*	18.46	36.83
Chocolate Bayou Above Tidal	1108	47.78	57.96	105.74

Table 6.5 WLA calculation.

The TMDL, MOS, WLA, and FG components are now known. The last variable is then calculated by subtracting MOS, WLA and FG from the TMDL. The results are presented in the final TMDL load allocation table, Table 6.6.

Watershed	Segment	TMDL (Billion MPN/day)	MOS (Billion MPN/day)	WLA_{wwtf} (Billion MPN/day)	WLA_{sw} (Billion MPN/day)	LA (Billion MPN/day)	FG (Billion MPN/day)
Chocolate Bayou Tidal	1107	718.01	21.08	18.37	18.46	633.75	26.35
Chocolate Bayou Above Tidal	1108	1,334.80	66.74	47.78	57.96	1,067.47	94.85

Table 6.6 TMDL load allocation for AU 1107_01 and 1108_01 with FG included in WLAwwtf.

6.2 Oyster Creek

Oyster Creek is composed of two segments, Tidal Segment 1109 and Above Tidal Segment 1110. Oyster Creek Tidal is primarily characterized by natural, undeveloped land uses including forests and grasslands. There are many oxbow lakes and extensive coastal wetlands in the southern and northeastern portions of the watershed. Urban centers in this watershed include Richwood, Clute, and Lake Jackson in the northwestern portions of the watershed. There are also a few pockets of development at Oyster Creek and along CR226 to the east of Clute. Small plots of agricultural lands are also present in the northern reaches of the watershed. Oyster Creek Above Tidal is not developed and is used for agricultural purposes. Much of the area is bottomland forest, grassland, and wetland habitat with numerous oxbow lakes. There are a few pockets of development associated with Arcola, Sienna Plantation, Fresno, Bailey's Prairie, Bonney Village, Angleton, Holiday Lakes, and Lake Jackson. The very top of the watershed is highly developed and is part of Sugar Land and Missouri City.

6.2.1 Water Quality Issues

In 2016, H-GAC reviewed the 2014 IR and data collected since 2012. Results of that review can be found in Appendix D. A summary is provided below. While there was sufficient data to determine impairments in 1109_01 and 1110_01 there was insufficient flow data to perform an LDC analysis. The Oyster Creek watershed was found to be highly modified and its length and width far different from Chocolate Bayou, where there is a continuous USGS flow gauge. H-GAC determined that continuous flow data from Oyster Creek was needed to better characterize the impairment and to base watershed management actions. Also, for two AUs in Oyster Creek, 1110_01 and 1110_02, additional bacteria monitoring was needed.

6.2.1.1 Tidal Segment

The 2014 Texas Integrated Report (IR) lists the assessment unit 1109_01 as impaired for contact recreation due to elevated levels of enterococci bacteria. Per the TCEQ assessment, the geomean for this assessment unit is 73 MPN/100ml, which is more than twice the geomean standard of 35 MPN/100ml for enterococci. Due to the bacteria impairment, this segment does not fully meet the primary contact recreation designation; however, it does fully support high aquatic life use.

The moving geometric means for enterococci show significant increases in bacteria levels with mean concentrations consistently exceeding the 35 MPN/100 mL standard since 2010. Enterococci concentrations plotted over time show approximately half of the samples collected since 2000 out of compliance with state bacteria standards and half of the samples in compliance (Figure 6.4).

6.2.1.2 Above Tidal Segment

The IR lists the assessment unit 1110_01 as impaired for contact recreational use due to elevated levels of E. coli bacteria. The TCEQ assessment data and H-GAC analyses are summarized in Table 6.7: H-GAC 2008-2015 seven-year geometric mean assessment supports the results of the 2014 IR. the This segment does not fully support its contact recreation.

	TCEQ Assessment (2005-2012)	HGAC Analysis 2001-2008	HGAC Analysis 2008-2015
Assessment Unit	Geomean (MPN/100 mL) / % Grab Exceedance	Geomean (MPN/100 mL) / % Grab Exceedance	Geomean (MPN/100 mL) / % Grab Exceedance
1110_01	201 / NA	209 / 12.0	200 / 18.5

Table 6.7 Three bacteria geometric mean and percent single grab sample exceedance assessments for assessment unit 1110_01.

Moving seven-year geometric mean plots for *E. coli* show fluctuations over time with mean bacteria levels hovering around twice the state limit of 126 MPN/100 mL (Figure 6.5).

6.2.1.3 Additional Monitoring and Continuous Flow

Additional water quality monitoring was conducted in these AUs to minimize data gaps and better evaluate bacteria loadings throughout the entire segment. Figure 6.6 shows the location of current CRP and TCEQ monitoring locations and highlights the two stations, one new (11491) and one established (11489) that is being augmented with additional bacteria data. A flow gage was installed at the monitoring station located on Oyster Creek at Sims Road (station ID 11491). The selected Basin 11 monitoring locations have been reviewed by TCEQ and by the region's CRP coordinated monitoring program to ensure geographic coverage and that established AUs are being assessed.

Additional bacteria monitoring at station 11489 was collected five times during the project in addition to the routine quarterly CRP samples being collected by the TCEQ. This augmented bacteria data only included the collection of basic field parameters and total suspended solids (TSS).

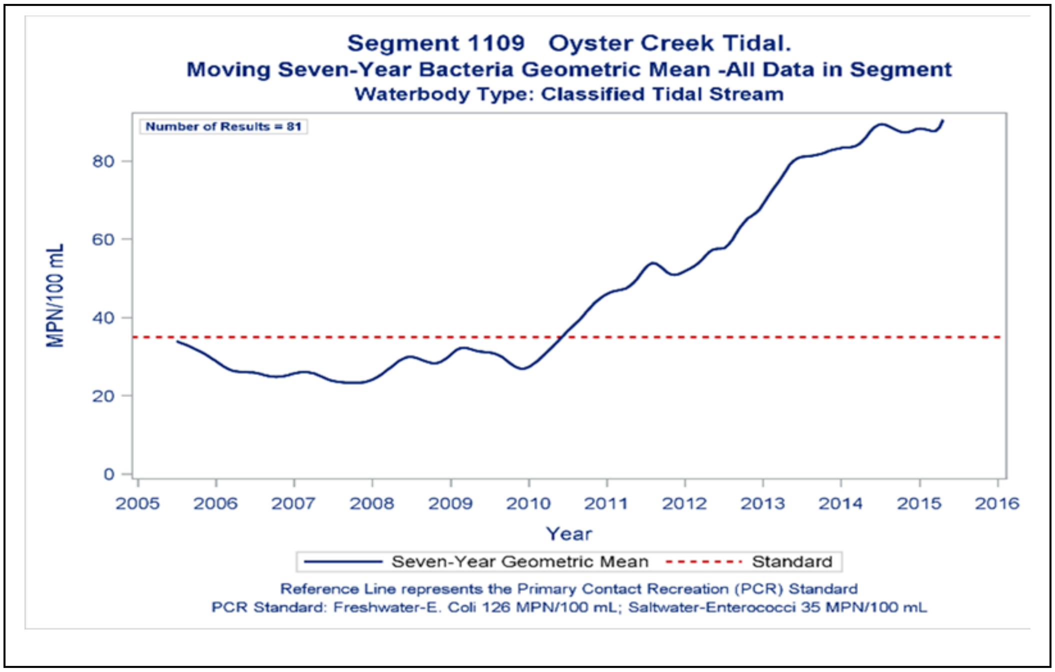


Figure 6.5 Seven-year geometric mean for Oyster Creek Tidal.

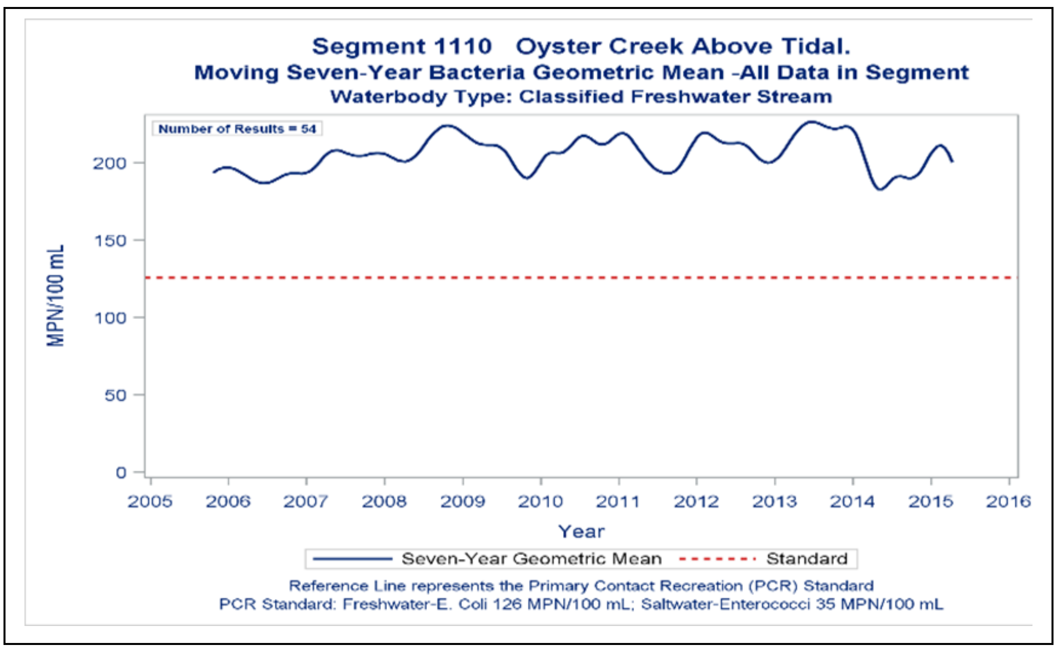


Figure 6.6 Seven-year geometric mean for Oyster Creek Above Tidal.

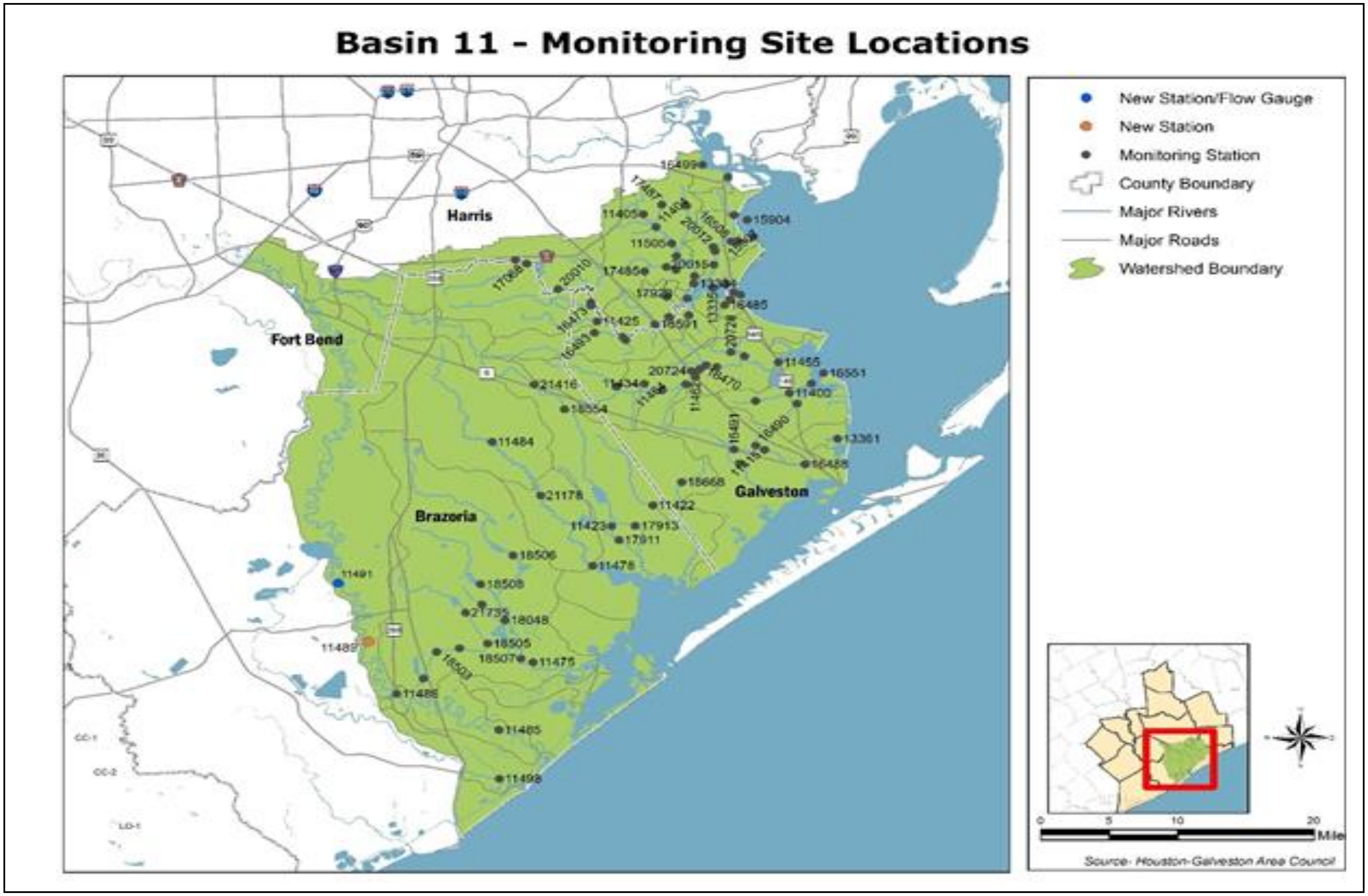


Figure 6.7 CRP and TCEQ Monitoring locations in Basin 11, including 11491, 11489 and 11486 in Oyster Creek.

Data collected at station 11491 included three routine CRP monitoring events and five additional bacteria monitoring events, for a total of eight monitoring events during the project period. Routine monitoring events were collected on a quarterly basis and include the collection of basic field parameters using a calibrated datasonde, as well as the collection of bacteria, conventional chemical parameters, and instantaneous flow.

The Amazon Bubbler water level gage was installed at station 11491, Oyster Creek at Sims Road, to monitor continuous instream flow in lieu of instantaneous flow measurements. Once the gage was installed, initial instantaneous flow data at varying stream stages, along with other detailed physical parameters, was collected to create a stage-discharge rating curve. The rating curve information was used to estimate continuous instream flow at this location based on the gage's water level measurements taken every 15 minutes. This data will then be used to develop hydrographs that provide the information necessary to conduct Load Duration Curve (LDC) analysis for this portion of Oyster Creek.

6.2.1.4 Additional Monitoring Data Analysis

The eight sample collection events at 11491 and five augmented sample collection events at 11489 were completed during Year Two. Analysis will follow in Year Three. The water level gauge was installed in February and began transmitting real-time data using a HDR GOES satellite transmitter with internal GPS. Gauge level in feet was measured on the quarter hour and transmitted via satellite to a data housing site at: https://stormcentral.waterlog.com/public/EIH. In Year Three, the gauge height and ambient flow monitoring will be used to generate the stage discharge rating curve and estimate continuous instream flow.

7 CONCLUSIONS AND RECOMMENDATIONS

Basin 11 land use was still consistent with a rural and agriculture dominant land cover with large areas of natural and wetland cover. Development still makes up less than 20 % of the basin, though the area's population, particularly in the north and eastern areas is expected to grow over the coming years. During the characterization of Basin 11, including portions of Basin 24, 22 segments and 91 AU were reviewed. Basin 11 data covering GIS and bacteria data were assessed and presented in previous sections. Additionally, H-GAC was asked to develop LDCs for AUs that sufficient bacteria and flow data were available. The results of that effort were reviewed in section 5 and are provided in Appendix D.

The main goal of this project was to distill this information down to provide the TCEQ, local decision-makers, and the public with a greater understanding of how bacteria is affecting water bodies in this basin, as well as suggest possible management planning measures to address impairments and data gaps over the coming years.

7.1 CONCLUSIONS

Results of the data reviewed, GIS analysis and generated LDCs for this Characterization Report suggests water quality for the basin is influenced by high concentrations of bacteria which could affect public health of those involved in contact recreation. The following general observation were found:

1. Active water quality planning in the basin covers almost the entire basin (Figure 2.2, page 10). Three watershed protection planning efforts, five TMDL projects, one estuary program, and development of a watershed coalition provide opportunities to address impaired waters in the basin if sufficient resources and willing local organizations earnestly support these planning endeavors. Results from the Bacteria Implementation Group suggest that applying resources judiciously can result in water quality improvements over time (2016 Annual Report, 2017).
2. Water quality planning recommendations to voluntarily address bacteria impairments commonly focus on improvement to human waste water treatment, waste water conveyance, agriculture, and urban non-point source practices.
3. While the northern and eastern portions of the basin are well developed, bacteria impairments and concerns are also found in the less developed southern and western parts of the basin. Potential sources of bacteria in these less developed areas include malfunctioning onsite waste water treatment facilities (OSSFs)and agriculture production.
4. Regression analysis and a repeated mixed measures model seeking to correlate *E. coli* source loads in the Basin with bacteria monitoring (Section 5, page 55) support the finding from point 3 above that low intensity development, those developments likely using OSSFs, and pastureland were associated with higher bacteria loads.

7.2 ACTIONS AND RECOMMENDATIONS

Based on the 2014 *Integrated Report*, approximately 18 % of the basin is fully supporting the contact recreation standard, while nearly 60 % of the basin does not meet the contact recreation standard. The remaining 22 % of the basin was either not assessed or was listed as a concern for bacteria. During the process to develop LDCs, H-GAC reviewed bacteria data and flow data through 2015 to determine if the data were sufficient. Table 7.1 applies this review along with updated water quality planning efforts to the 2014 *Integrated Report* for 50 of the AUs in Basin 11.

To determine the 50 AUs, the 91 AUs from the 2014 *Integrated Report* (Appendix C) were sorted by those that were fully supporting (FS) under the column 'Level of Support'. Those fully supporting were removed from the table. AUs listed under Category 4, while still considered not supporting (NS) the standard, have undergone some water quality management action, e.g. TMDL project. Those AUs given a Category 4 listing were removed. This process left 50 AUs. Additionally, the 2014 *Integrated Report* provides a column with data qualifiers such as 'Adequate Data (AD)', 'Limited Data (LD)', and 'Inadequate Data (ID)' for the seven-year period of data reviewed. This column was added to Table 5.1.

H-GAC then added a column of suggested recommendations for each of the 50 AUs. Several AUs will be moved from a Category 5 listing to a Category 4 listing when the 2016 Integrated Report becomes available. Armand Bayou, 1113, is an example of a segment where a TMDL project was recently completed. Some of the AUs given an LD or ID qualifier are expected to change as more data is collected for monitoring stations contained in the AUs.

Based on the information gathered by H-GAC and a review of the 2014 *Integrated Report*, H-GAC recommended in 2016, additional water quality management planning for six segments and 14 AUs in Basin 11 (Table 7.2). For 10 AUs H-GAC recommended potential TMDL studies: One study for the Dickinson Bayou watershed, 1103, two studies in the Chocolate Bayou watershed, 1107 and 1108, and seven studies for the Chocolate Bay watershed, 2432. For the remaining two segments and four AUs covering Oyster Creek, 1109_01 1110_01, 1110_02, and 1110_03, H-GAC recommended the continued collection of bacteria data and additional continuous flow data.

In 2017, actions were taken to begin to address the recommendations made in 2016. A TSD was drafted for Chocolate Bayou and a TMDL study is underway. Additional monitoring and collection of flow data was started in Oyster Creek. Once the data is evaluated, next steps will include development of a TSD. There is also interest in evaluating the Chocolate Bay watershed 2432, particularly 2432C_01, which has consistently shown impairment during previous IRs.

	BASIN 11 2014 INTEGRATED REPORT AND H-GAC DATA REVIEW									
Seg.	**AU**	**Name**	**Category**	**Parameter**	**No. Samples Assessed**	**Geometric Mean**	**Data Set Qualifier**	**Level of Support**	**H-GAC Data Review**	**H-GAC Recommendation**
1101	1101_01	Clear Creek Tidal		Enterococcus	12	1325.34	TR	NA	Part of BIG I-Plan	Continue to monitor, track BIG I-Plan implementation
	1101B_02	Chigger Creek		*E. coli*	13	157.4	TR	NA	Good data set after 2012	Continue to monitor, track BIG I-Plan implementation
	1101E_01	Unnamed Tributary		Enterococcus	14	5818.01	TR	NA	Part of BIG I-Plan	Continue to monitor, track BIG I-Plan implementation
1102	1102_01	Clear Creek Above Tidal		*E. coli*	3	71.6	ID	NA	Part of BIG I-Plan	Continue to monitor, track BIG I-Plan implementation
	1102_05	Clear Creek Above Tidal		*E. coli*	9	102.93	TR	NA	Part of BIG I-Plan	Continue to monitor, track BIG I-Plan implementation
	1102E_01	Mud Gully		*E. coli*					Part of BIG I-Plan	Continue to monitor, track BIG I-Plan implementation
1103	1103_01	Dickinson Bayou Tidal	5a	Enterococcus	32	72.75	AD	NS	Good data set. Lack Instream Flow Data.	Continue to monitor, track Dickinson I-Plan implementation and stakeholder efforts to develop WPP
	1103E_01	Cedar Creek	5a	*E. coli*	30	126.62	AD	NS	Good data set. Lack Instream Flow Data. Generated LDC.	Possible TMDL, track Dickinson I-Plan implementation and stakeholder efforts to develop WPP
	1103F_01	Unnamed Tributary		Enterococcus	7	1454.26	TR	NA	Inconsistent bacteria data. Lack Instream Flow Data.	Continue to monitor, track Dickinson I-Plan implementation and stakeholder

BASIN 11 2014 INTEGRATED REPORT AND H-GAC DATA REVIEW										
Seg.	**AU**	**Name**	**Category**	**Parameter**	**No. Samples Assessed**	**Geometric Mean**	**Data Set Qualifier**	**Level of Support**	**H-GAC Data Review**	**H-GAC Recommendation**
										efforts to develop WPP
	1103G_01	Unnamed Tributary		Enterococcus	7	693.52	LD	CN	Consistent but limited bacteria data. Lack Instream Flow Data.	Continue to monitor, track Dickinson I-Plan implementation and stakeholder efforts to develop WPP
1104	1104_01	Dickinson Bayou Above Tidal		*E. coli*	7	4699.07	TR	NA	Consistent recent bacteria data. Lack instream flow data.	Continue to monitor, track Dickinson I-Plan implementation and stakeholder efforts to develop WPP
	1104A_01	Unnamed Tributary		*E. coli*	8	176.54	TR	NA	Not reviewed.	Continue to monitor, track Dickinson I-Plan implementation and stakeholder efforts to develop WPP
1105	1105_01	Bastrop Bayou Tidal	5c	Enterococcus	152	73	AD	NS	Consistent Data. No Flow.	**WPP was approved in 2016 Track Implementation.**
	1105A_01	Flores Bayou	5c	*E. coli*	32	137.38	AD	NS	Consistent Data. No Flow. LDC Made.	**WPP was approved in 2016 Track Implementation.**
	1105B_01	Austin Bayou Tidal	5c	Enterococcus	32	40.81	AD	NS	Consistent Data. No Flow.	**WPP was approved in 2016 Track Implementation.**
	1105C_01	Austin Bayou Above Tidal	5c	*E. coli*	33	166.42	AD	NS	Consistent Data. No Flow. LDC Made.	**WPP was approved in 2016 Track Implementation.**

BASIN 11 2014 INTEGRATED REPORT AND H-GAC DATA REVIEW										
Seg.	**AU**	**Name**	**Category**	**Parameter**	**No. Samples Assessed**	**Geometric Mean**	**Data Set Qualifier**	**Level of Support**	**H-GAC Data Review**	**H-GAC Recommendation**
	1105D_01	Unnamed Tributary		*E. coli*	15	236.28	LD	CN	Little Data. No Flow.	**WPP was approved in 2016 Track Implementation.**
	1105E_01	Brushy Bayou	5c	*E. coli*	16	565.54	LD	NS	Little Data. No Flow.	**WPP was approved in 2016 Track Implementation.**
1107	1107_01	Chocolate Bayou Tidal	5c	Enterococcus	84	81.51	AD	NS	Consistent Data. No Flow.	**TMDL Study in Progress 2017.**
1108	1108_01	Chocolate Bayou Above Tidal	5c	*E. coli*	24	159.03	AD	NS	Consistent Data. Flow Data. LDC Made.	**TMDL Study in Progress 2017.**
1109	1109_01	Oyster Creek Tidal	5c	Enterococcus	44	73.45	AD	NS	Consistent Data. No Flow.	**Added flow gauge in 1110_02.**
1110	1110_01	Oyster Creek Above Tidal	5c	*E. coli*	27	201.33	AD	NS	Consistent Data. No Flow.	**Added flow gauge in 1110_02. Collecting additional bacteria data in 2017.**
	1110_02	Oyster Creek Above Tidal		*E. coli*					Lacks bacteria data, no flow.	**Added flow gauge in 1110_02. Collecting additional bacteria data at new station in 2017.**
	1110_03	Oyster Creek Above Tidal		*E. coli*					Lacks bacteria data, no flow.	**Added flow gauge in 1110_02. Recommend collecting bacteria data.**
1113	1113_02	Armand Bayou Tidal	5c	Enterococcus	88	40.99	AD	NS	Consistent Data. No Flow.	TMLD approved since 2014 IR. Track.
	1113_03	Armand Bayou Tidal	5c	Enterococcus	24	47.59	AD	NS	Consistent Data. No Flow.	TMLD approved since 2014 IR. Track.

BASIN 11 2014 INTEGRATED REPORT AND H-GAC DATA REVIEW										
Seg.	**AU**	**Name**	**Category**	**Parameter**	**No. Samples Assessed**	**Geometric Mean**	**Data Set Qualifier**	**Level of Support**	**H-GAC Data Review**	**H-GAC Recommendation**
	1113A_01	Armand Bayou Above Tidal	5c	*E. coli*	130	354.06	AD	NS	Consistent Data. No Flow.	TMLD approved since 2014 IR. Track.
	1113B_01	Horsepen Bayou Tidal	5c	Enterococcus	95	66.89	AD	NS	Consistent Data. No Flow.	TMLD approved since 2014 IR. Track.
	1113C_01	Unnamed Tributary	5c	*E. coli*	66	186.85	AD	NS	Consistent Data. No Flow.	TMLD approved since 2014 IR. Track.
	1113D_01	Willow Springs Bayou	5c	*E. coli*	62	709.28	AD	NS	Consistent Data. No Flow.	TMLD approved since 2014 IR. Track.
	1113E_01	Big Island Slough	5c	*E. coli*	63	501.01	AD	NS	Consistent Data. No Flow.	TMLD approved since 2014 IR. Track.
2424	2424A_02	Highland Bayou	5c	Enterococcus	20	45.85	AD	NS	Consistent Data. No Flow.	WPP in development. Need Flow.
	2424A_03	Highland Bayou	5c	Enterococcus	68	78.23	AD	NS	Consistent Data. No Flow.	WPP in development. Need Flow.
	2424A_04	Highland Bayou	5c	Enterococcus	21	174.79	AD	NS	Consistent Data. No Flow.	WPP in development. Need Flow.
	2424A_05	Highland Bayou	5c	Enterococcus	60	184.2	AD	NS	Consistent Data. No Flow.	WPP in development. Need Flow.
	2424C_01	Marchand Bayou	5a	Enterococcus	44	139.17	AD	NS	Consistent Data. No Flow.	WPP in development. Need Flow.
	2424G_01	Highland Bayou Diversion	5c	Enterococcus	30	37.6	AD	NS	Consistent Data. No Flow.	WPP in development. Need Flow.
2425	2425B_01	Jarbo Bayou	5a	Enterococcus	32	98.96	AD	NS	Consistent Data. No Flow.	TMDL study in progress. BIG I-Plan

	BASIN 11 2014 INTEGRATED REPORT AND H-GAC DATA REVIEW									
Seg.	**AU**	**Name**	**Category**	**Parameter**	**No. Samples Assessed**	**Geometric Mean**	**Data Set Qualifier**	**Level of Support**	**H-GAC Data Review**	**H-GAC Recommendation**
	2425B_02	Jarbo Bayou		Enterococcus			ID	NA	New station	TMDL study in progress. BIG I-Plan. Collecting Data.
2431	2431A_01	Moses Bayou	5c	Enterococcus	38	43.53	AD	NS	Consistent Data. No Flow.	Part of Highland WPP area - WPP in development. Need Flow.
	2431C_01	Unnamed Tributary	5c	Enterococcus	32	49.96	AD	NS	Consistent Data. No Flow.	Part of Highland WPP area - WPP in development. Need Flow.
	2431D_01	Unnamed Tributary		Enterococcus	6	141.11	LD	CN	Limited data set. No Flow.	Part of Highland WPP area - WPP in development. Need Flow.
2432	2432A_01	Mustang Bayou		*E. coli*	5	280.89	TR	NA	Good Dataset 2015, LDC created.	Potential for TMDL Study.
	2432A_02	Mustang Bayou		*E. coli*	5	6041.92	TR	NA	Good Dataset 2015, LDC created.	Potential for TMDL Study.
	2432A_03	Mustang Bayou		*E. coli*	5	441.3	TR	NA	Not reviewed.	Potential for TMDL Study.
	2432B_01	Willow Bayou		*E. coli*	19	254.19	LD	CN	Good Dataset 2015, LDC created.	Potential for TMDL Study.
	2432C_01	Halls Bayou	5c	Enterococcus	44	94.56	AD	NS	Good Dataset 2015, LDC created.	Potential for TMDL Study.
	2432D_01	Persimmon Bayou		Enterococcus	15	180.96	LD	CN	Good Dataset 2015, LDC created.	Potential for TMDL Study.
	2432E_01	New Bayou		Enterococcus	15	182.96	LD	CN	Good Dataset 2015, LDC created.	Potential for TMDL Study.

BASIN 11 2014 INTEGRATED REPORT AND H-GAC DATA REVIEW										
Seg.	**AU**	**Name**	**Category**	**Parameter**	**No. Samples Assessed**	**Geometric Mean**	**Data Set Qualifier**	**Level of Support**	**H-GAC Data Review**	**H-GAC Recommendation**
2433	2433_01	Bastrop Bay _ Oyster Lake		Enterococcus					Not reviewed.	2014 IR did not assess for contact recreation.

Table 7.1. Fifty AUs taken from the 2014 IR and compared with H-GAC data review. AD=Adequate Data, TR=Temporally Restricted, LD=Limited Data, ID=Inadequate Data, NA=Not Assessed, NS=Not Supporting, CN=Concern.

RECOMMENDED WATER QUALITY MANAGEMENT ACTIONS				
Seg.	**AU**	**Name**	**Category**	**H-GAC Recommendations**
1103	1103E_01	Cedar Creek	5a	Potential for TMDL Study.
1107	1107_01	Chocolate Bayou Tidal	5c	TMDL Study Initiated.
1108	1108_01	Chocolate Bayou Above Tidal	5c	Potential for TMDL Study.
1109	1109_01	Oyster Creek Tidal	5c	Segment lacks flow data.
1110	1110_01	Oyster Creek Above Tidal	5c	Continuous flow monitoring station established. Collected additional bacteria data.
	1110_02	Oyster Creek Above Tidal		Continuous flow monitoring station established. Collected additional bacteria data.
	1110_03	Oyster Creek Above Tidal		Recommend continuous flow station. Collect bacteria data.
2432	2432A_01	Mustang Bayou		Potential for TMDL Study.
	2432A_02	Mustang Bayou		Potential for TMDL Study.
	2432A_03	Mustang Bayou		Potential for TMDL Study.
	2432B_01	Willow Bayou		Potential for TMDL Study.
	2432C_01	Halls Bayou	5c	Potential for TMDL Study.
	2432D_01	Persimmon Bayou		Potential for TMDL Study.
	2432E_01	New Bayou		Potential for TMDL Study.

Table 7.2. H-GAC Recommended Water Quality Management Actions for Basin 11.

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APPENDIX A

BASIN 11 STAKEHOLDER OUTREACH APPROACH

Stakeholders	Outreach Approach
Coordinate with Existing WPPs • Dickinson Bayou • Highland-Marchand • Bastrop Bayou	Phone calls to the Project Managers for each WPP to: • Inform them of the project • Share the 1-page brochure for dissemination to their stakeholders • Provide opportunity for input / identify any potential opportunities or issues in the project area
Coordinate with Existing TMDLs • Armand Bayou • Jarbo Bayou • Upper Oyster Creek	Phone calls to the Project Managers for each TMDL to: • Inform them of the project • Share the 1-page brochure for dissemination to their stakeholders • Provide opportunity for input / identify any potential opportunities or issues in the project area
Bacteria Implementation Group	Project Manager will brief BIG Committee via e-mail of this project and ask for input, as appropriate.
Galveston Bay Foundation *Nate Johnson*	Phone call with GBF to: • Inform them of the project • Provide opportunity for input / identify any potential opportunities or issues in the project area
Galveston Bay Estuary Program *Sarah Berndhardt*	Phone call with GBEP to: • Inform them of the project • Provide opportunity for input / identify any potential opportunities or issues in the project area
Chambers of Commerce • Hitchcock COC • Texas City/La Marque COC • La Porte-Bayshore COC • Alvin-Manvel Area COC • Pasadena COC	Emails to COCs to: • Inform them of the project • Share the 1-page brochure for dissemination to their stakeholders • Provide opportunity for input / identify any potential opportunities or issues in the project area
Utility Districts	Emails to Utility Districts to: • Inform them of the project • Share the 1-page brochure for dissemination to their stakeholders • Provide opportunity for input / identify any potential opportunities or issues in the project area
Drainage Districts	Emails to Drainage Districts to: • Inform them of the project • Share the 1-page brochure for dissemination to their stakeholders • Provide opportunity for input / identify any potential opportunities or issues in the project area
Cities (50+ in project area)	Letters to cities in project area to:

• *Mayor* • *City Secretary* • *City Manager*	• Inform them of the project / Share the 1-page brochure • Offer in-person meeting or phone call to those interested in becoming more specifically involved In-person meetings to follow, depending on the interest shown by the counties
Counties • Brazoria • Fort Bend • Galveston • Harris	Letters to the counties (precincts in geography and all Judges) in project area to: • Inform them of the project / Share the 1-page brochure • Offer in-person meeting or phone call to those interested in becoming more specifically involved In-person meetings to follow, depending on the interest shown by the cities
County Extension Agents *(TxAgrilife)*	Emails to each county's contact to: • Inform them of the project • Share the 1-page brochure for dissemination to their stakeholders • Provide opportunity for input / identify any potential opportunities or issues in the project area
Texas State Soil & Water Conservation Board	Email to TSSWCB to: • Inform them of the project • Share the 1-page brochure for dissemination to their stakeholders • Provide opportunity for input / identify any potential opportunities or issues in the project area
Port of Freeport	Phone call with Port to: • Inform them of the project • Provide opportunity for input / identify any potential opportunities or issues in the project area
Port of Houston Authority	Phone call with Port to: • Inform them of the project • Provide opportunity for input / identify any potential opportunities or issues in the project area
University of Houston – Clear Lake and Environmental Institute of Houston	Email UHCL and EIH to: • Inform them of the project • Share the 1-page brochure for dissemination to their stakeholders • Provide opportunity for input / identify any potential opportunities or issues in the project area

APPENDIX B

BASIN 11 OUTREACH BROCHURE

San Jacinto-Brazos Coastal Basin

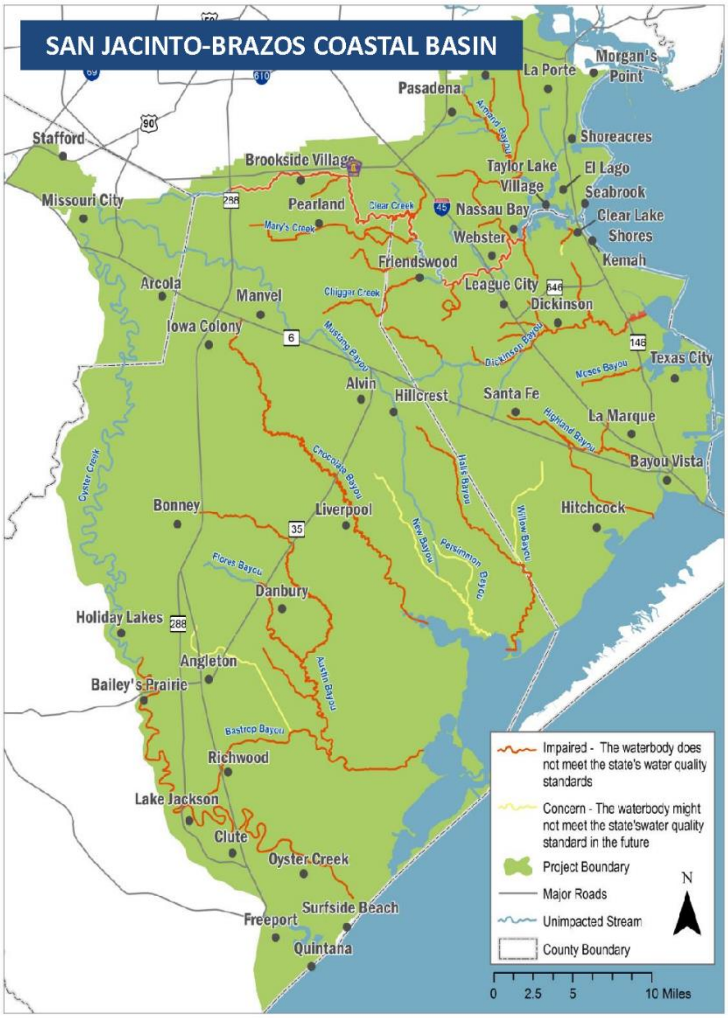
The Houston-Galveston Area Council (H-GAC) is working with local partners to reduce elevated bacteria levels in the basin.

What is a Basin?

A basin is an area of land, often associated with a river, where rainfall collects, then flows to a bay or ocean. Rainwater collected in the San Jacinto-Brazos Coastal Basin travels to Galveston Bay and the Gulf of Mexico.

How's the Water?

Many of the bayous and streams within this basin have high bacteria levels. According to standards set by the Texas Commission on Environmental Quality (TCEQ) these waterways may not be suitable for recreational activities, such as swimming.



APPENDIX C

2014 IR BASIN 11 SEGMENT AND ASSESSMENT UNITS

APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
1101	1101_01	Clear Creek Tidal	Upper segment boundary to Chigger Creek confluence	Enterococcus	35	2005-2012		12	1325.34
	1101_02	Clear Creek Tidal	Chigger Creek confluence to IH-45	Enterococcus	35	2005-2012	4a	41	188.47
	1101_03	Clear Creek Tidal	IH-45 to Cow Bayou	Enterococcus	35	2005-2012	4a	46	72.82
	1101_04	Clear Creek Tidal	Cow Bayou to confluence with Clear Lake	Enterococcus	35	2005-2012	4a	63	45.08
	1101A_01	Magnolia Creek	From Clear Creek Tidal confluence upstream 7.7 km (4.8 mi)	*E. coli*	*126*	2005-2012	4a	31	447.90
	1101B_01	Chigger Creek	From the headwaters to FM 528	*E. coli*	*126*	2005-2012	4a	71	226.60
	1101B_02	Chigger Creek	FM 528 to confluence with Clear Creek	*E. coli*	*126*	2005-2012		13	157.40
	1101C_01	Cow Bayou	From the Clear Creek Tidal confluence to SH3	*Enterococcus*	*35*	2005-2012	4a	21	178.30
	1101D_01	Robinson Bayou	From the Clear Creek Tidal confluence to 0.05 km (0.03 mi) upstream of Hewitt Street	*Enterococcus*	*35*	2005-2012	4a	52	638.34
	1101E_01	Unnamed Tributary	From Clear Creek Tidal confluence to a point upstream 3.0 km (1.9 mi) upstream	*Enterococcus*	*35*	2005-2012		14	5818.01

APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
	1101F_01	Unnamed Tributary	From the Clear Creek Tidal confluence to a point 7.9 km (4.9 mi) upstream	*E. coli*	*126*	2005-2012		23	81.09
1102	1102_01	Clear Creek Above Tidal	Upper segment boundary (Rouen Road) to SH 288	*E. coli*	*126*	2005-2012		3	71.60
	1102_02	Clear Creek Above Tidal	SH 288 to Hickory Slough confluence	*E. coli*	*126*	2005-2012	4a	108	182.37
	1102_03	Clear Creek Above Tidal	Hickory Slough confluence to Turkey Creek confluence	*E. coli*	*126*	2005-2012	4a	55	173.26
	1102_04	Clear Creek Above Tidal	Turkey Creek confluence to Mary's Creek confluence	*E. coli*	*126*	2005-2012	4a	40	348.30
	1102_05	Clear Creek Above Tidal	Mary's Creek confluence to lower segment boundary	*E. coli*	*126*	2005-2012		9	102.93
	1102A_01	Cowart Creek	Sunset Drive to SH35	*E. coli*	*126*	2005-2012	4a	26	273.97
	1102A_02	Cowart Creek	Confluence with Clear Creek to Sunset Dr.	*E. coli*	*126*	2005-2012	4a	46	359.97
	1102B_01	Mary's Creek	From the Clear Creek Above Tidal confluence upstream to the N. and S. Fork Mary's Creek near FM 518	*E. coli*	*126*	2005-2012	4a	152	206.11
	1102C_01	Hickory Slough	From the Clear Creek Above Tidal confluence upstream to a point 0.69 km (0.43 mi) upstream of Mykawa Road	*E. coli*	*126*	2005-2012	4a	37	392.35

APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
	1102D_01	Turkey Creek	From the Clear Creek Above Tidal confluence to a point 0.98 km (0.61 mi) upstream of Scarsdale Blvd.	*E. coli*	*126*	2005-2012	4a	1	4400.00
	1102E_01	Mud Gully	From the Clear Creek Above Tidal confluence to a point 0.80 km (0.49 mi) downstream of Hughes Road	*E. coli*	*126*	2005-2012			
	1102F_01	Mary's Creek Bypass	From the Mary's Creek confluence NE of FM 518 to a point 0.96 km (0.6 mi) upstream to the Mary's Creek confluence (NW of County Rd. 126)	*E. coli*	*126*	2005-2012	4a	20	159.39
	1102G_01	Unnamed Tributary	From the Mary's Creek confluence 1.3 km (0.84 mi) west of FM 1128 to a point 1.2 km (0.75 mi) upstream to the confluence of an unnamed tributary	*E. coli*	*126*	2005-2012	4a	10	430.41
1103	1103_01	Dickinson Bayou Tidal	From the Dickinson Bay confluence (downstream of State Hwy 146) upstream to the Gum Bayou confluence	*Enterococcus*	*35*	2005-2012	5a	32	72.75

APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
	1103_02	Dickinson Bayou Tidal	From Gum Bayou confluence upstream to the Benson Bayou confluence	*Enterococcus*	*35*	2005-2012	4a	46	51.77
	1103_03	Dickinson Bayou Tidal	From the Benson Bayou confluence to the Bordens Gully confluence	*Enterococcus*	*35*	2005-2012	4a		
	1103_04	Dickinson Bayou Tidal	From the Bordens Gully confluence upstream to a point 4.0 km (2.5 mi) downstream of FM 517	*Enterococcus*	*35*	2005-2012	4a	72	137.45
	1103A_01	Benson Bayou	From the Dickinson Bayou Tidal confluence to a point 0.6 km (0.37 mi) upstream of FM 646	*Enterococcus*	*35*	2005-2012	4a	45	271.14
	1103B_01	Bordens Gully	From the Dickinson Bayou Tidal confluence to a point 1.4 km (0.87 mi) upstream of FM 646	*Enterococcus*	*35*	2005-2012	4a	40	400.36
	1103C_01	Geisler Bayou	From the Dickinson Bayou Tidal confluence to a point 1.37 km (0.85 mi) upstream of FM 646	*Enterococcus*	*35*	2005-2012	4a	44	388.61
	1103D_01	Gum Bayou	From Dickinson Bayou Tidal confluence to State Hwy 96	*Enterococcus*	*35*	2005-2012	4a	32	112.42

APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
	1103E_01	Cedar Creek	From the Dickinson Bayou Tidal confluence to a point 0.63 km (0.39 mi) upstream of FM 517	*E. coli*	*126*	2005-2012	5a	30	126.62
	1103F_01	Unnamed Tributary	From the Dickinson Bayou Tidal confluence to a point 0.36 km (0.22 mi) upstream of State Hwy. 6	*Enterococcus*	*35*	2005-2012		7	1454.26
	1103G_01	Unnamed Tributary	From the confluence with Gum Bayou to a point 0.39 miles south of the FM 646/FM 1266 intersection between League City and Dickinson	*Enterococcus*	*35*	2005-2012		7	693.52
1104	1104_01	Dickinson Bayou Above Tidal	From the lower segment boundary (a point 4.0 km [2.5 mi] downstream of FM 517) to FM 517	*E. coli*	*126*	2005-2012		7	4699.07
	1104_02	Dickinson Bayou Above Tidal	From FM 517 upstream to FM 528	*E. coli*	*126*	2005-2012	4a	53	324.66
	1104A_01	Unnamed Tributary	From the Dickinson Bayou Above Tidal confluence to State Hwy 6	*E. coli*	*126*	2005-2012		8	176.54

APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
1105	1105_01	Bastrop Bayou Tidal	From the confluence with Bastrop Bay 1.1 km (0.7 mi) downstream of the Intracoastal Waterway in Brazoria County to a point 8.6 km (5.3 mi) upstream of Business 288 at Lake Jackson in Brazoria County	*Enterococcus*	*35*	2005-2012	5c	152	73.00
	1105A_01	Flores Bayou	From a point 2.6 km (1.6 mi) downstream of County Road 171 upstream to SH 35	*E. coli*	*126*	2005-2012	5c	32	137.38
	1105B_01	Austin Bayou Tidal	From the Bastrop Bayou Tidal confluence to the FM 2004 bridge crossing	*Enterococcus*	*35*	2005-2012	5c	32	40.81
	1105C_01	Austin Bayou Above Tidal	From FM 2004 upstream to 0.3 km (0.19 mi) upstream of SH 288	*E. coli*	*126*	2005-2012	5c	33	166.42
	1105D_01	Unnamed Tributary	From the Bastrop Bayou Tidal confluence to 0.57 km (0.35 mi) upstream of SH 288 Business	*E. coli*	*126*	2005-2012		15	236.28
	1105E_01	Brushy Bayou	Entire water body	*E. coli*	*126*	2005-2012	5c	16	565.54

APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
1107	1107_01	Chocolate Bayou Tidal	From the Chocolate Bay confluence 1.4 km (0.9 mi) downstream of FM 2004 to a point 4.2 km (2.6 mi) downstream of SH 35	*Enterococcus*	*35*	2005-2012	5c	84	81.51
1108	1108_01	Chocolate Bayou Above Tidal	From a point 4.2 km (2.6 mi) downstream of SH 35 to SH 6	*E. coli*	*126*	2005-2012	5c	24	159.03
1109	1109_01	Oyster Creek Tidal	From the Intracoastal Waterway confluence to a point 100 m (110 yds) upstream of FM 2004	*Enterococcus*	*35*	2005-2012	5c	44	73.45
1110	1110_01	Oyster Creek Above Tidal	From the lower segment boundary immediately upstream of FM 2004 to the Styles Bayou confluence	*E. coli*	*126*	2005-2012	5c	27	201.33
	1110_02	Oyster Creek Above Tidal	From Styles Bayou upstream to an unnamed tributary 2.9 km (1.8 mi) downstream of FM 1462	*E. coli*	*126*	2005-2012			
	1110_03	Oyster Creek Above Tidal	From an unnamed trbutary [2.9 km (1.8 mi) downstream of FM 1462] upstream to the Brazos River Diversion Dam	*E. coli*	*126*	2005-2012			

APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
1111	1111_01	Old Brazos River Channel Tidal	From the Intracoastal Waterway confluence to State Hwy 288	*Enterococcus*	*35*	2005-2012		23	14.57
1113	1113_01	Armand Bayou Tidal	From the Clear Lake confluence at Nasa Rd. 1 to the Horsepen Bayou confluence	*Enterococcus*	*35*	2005-2012		50	27.19
	1113_02	Armand Bayou Tidal	From the Horsepen Bayou confluence to the BIG Island Slough confluence	*Enterococcus*	*35*	2005-2012	5c	88	40.99
	1113_03	Armand Bayou Tidal	From the Big Island Slough confluence upstream to a point 0.8 km (0.5 mi) downstream of Genoa-Red Bluff Rd.	*Enterococcus*	*35*	2005-2012	5c	24	47.59
	1113A_01	Armand Bayou Above Tidal	From the upper segment boundary of Armand Bayou Tidal upstream to Beltway 8	*E. coli*	*126*	2005-2012	5c	130	354.06
	1113B_01	Horsepen Bayou Tidal	From the Armand Bayou confluence to State Hwy 3	*Enterococcus*	*35*	2005-2012	5c	95	66.89
	1113C_01	Unnamed Tributary	From Horsepen Bayou confluence to Reseda Driver	*E. coli*	*126*	2005-2012	5c	66	186.85
	1113D_01	Willow Springs Bayou	From the Armand Bayou confluence to a point 2.8 km (1.8 mi) upstream to an unnamed tributary	*E. coli*	*126*	2005-2012	5c	62	709.28

APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
	1113E_01	Big Island Slough	From the Armand Bayou confluence upstream to a point 2.4 km (1.5 mi) north of Spencer Hwy	*E. coli*	*126*	2005-2012	5c	63	501.01
2424	2424A_01	Highland Bayou	From the Jones Bay confluence upstream to Bayou Lane	*Enterococcus*	*35*	2005-2012		69	30.44
	2424A_02	Highland Bayou	From Bayou Lane upstream to Lake Road	*Enterococcus*	*35*	2005-2012	5c	20	45.85
	2424A_03	Highland Bayou	From Lake Road upstream to FM 519	*Enterococcus*	*35*	2005-2012	5c	68	78.23
	2424A_04	Highland Bayou	From FM 519 upstream to FM 2004	*Enterococcus*	*35*	2005-2012	5c	21	174.79
	2424A_05	Highland Bayou	From FM 2004 upstream to the headwaters just west of FM 1764	*Enterococcus*	*35*	2005-2012	5c	60	184.20
	2424C_01	Marchand Bayou	From Highland Bayou confluence to 0.72 km (0.45 mi) north of IH-45	*Enterococcus*	*35*	2005-2012	5a	44	139.17
	2424G_01	Highland Bayou Diversion	From confluence with an unnamed tributary adjacent to Jones Bay upstream to Highland Bayou confluence	*Enterococcus*	*35*	2005-2012	5c	30	37.60
2425	2425_01	Clear Lake	Entire segment	*Enterococcus*	*35*	2005-2012		103	16.13
	2425A_01	Taylor Lake	From the Clear Lake confluence to the Taylor Bayou	*Enterococcus*	*35*	2005-2012		25	15.66

APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
			confluence near Red Bluff Rd.						
	2425B_01	Jarbo Bayou	From the Clear Lake confluence upstream to Lawrence Rd.	*Enterococcus*	*35*	2005-2012	5a	32	98.96
	2425B_02	Jarbo Bayou	From Lawrence Rd. to headwaters 1.1 km (0.67 mi) upstream of FM 518	*Enterococcus*	*35*	2005-2012			
	2425D_01	Taylor Bayou	From the Taylor Lake confluence to a point 4.6 km (2.8 mi) upstram of State Hwy 146	*Enterococcus*	*35*	2005-2012		25	15.94
	2425E_01	HCFCD Ditch A	From the Taylor Lake confluence to a point 0.28 km (0.17 mi) downstream of Fairmont Parkway	*Enterococcus*	*35*	2005-2012		25	30.73
2427	2427_01	San Jacinto Bay	Entire segment	*Enterococcus*	*35*	2005-2012		124	18.72
2431	2431_01	Moses Lake	Entire segment	*Enterococcus*	*35*	2005-2012		55	19.62
	2431A_01	Moses Bayou	From Moses Lake confluence to 2.2 km (1.4 mi) upstream of State Hwy 3	*Enterococcus*	*35*	2005-2012	5c	38	43.53
	2431C_01	Unnamed Tributary	From confluence with the southern arm (west) of Moses Lake to a point 0.45 miles upstream of State	*Enterococcus*	*35*	2005-2012	5c	32	49.96

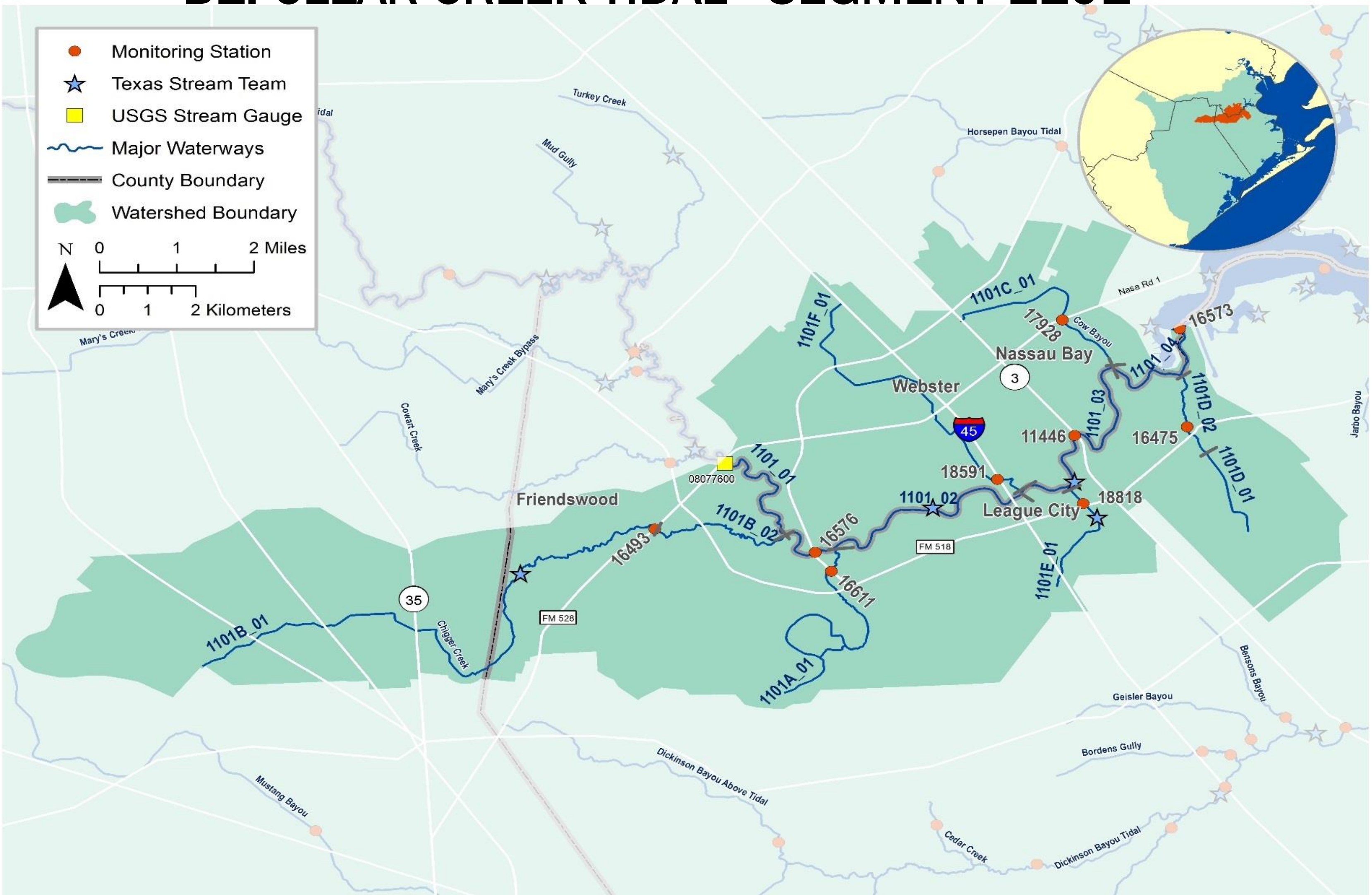
APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
			Hwy 3 near La Marque						
	2431D_01	Unnamed Tributary	From the confluence with the southern arm (east) of Moses Lake to a point 0.6 mi upstream of State Hwy 146 in Texas City	*Enterococcus*	*35*	2005-2012		6	141.11
2432	2432_01	Chocolate Bay	Entire segment	*Enterococcus*	*35*	2005-2012		70	12.22
	2432A_01	Mustang Bayou	From the New Bayou confluence upstream to County Rd. 166	*E. coli*	*126*	2005-2012		5	280.89
	2432A_02	Mustang Bayou	From County Rd. 166 upstream to an unnamed tributary 0.3 km upstream of SH 35	*E. coli*	*126*	2005-2012		5	6041.92
	2432A_03	Mustang Bayou	From an unnamed tributary 0.3 km upstream of SH 35 upstream to an unnamed tributary downstream of Cartwright Rd.	*E. coli*	*126*	2005-2012		5	441.30
	2432B_01	Willow Bayou	From the Halls Bayou confluence to a point 9.7 km (6 mi) upstream	*E. coli*	*126*	2005-2012		19	254.19

APPENDIX C: 2014 Texas Integrated Report (TCEQ, 2015) Segment and Assessment Units for Basin 11									
Segment	**Assessment Unit**	**Name**	**Assessment Unit Description**	**Parameter**	**Standards Criteria (MPN/100 mL)**	**Data Date Range**	**Category**	**No. of Samples in AU**	**AU Geometric Mean (MPN/100 mL)**
	2432C_01	Halls Bayou	From the Chocolate Bay confluence upstream to a point 31.5 km (19.6 mi) upstream	*Enterococcus*	*35*	2005-2012	5c	44	94.56
	2432D_01	Persimmon Bayou	From the New Bayou confluence upstream to the confluence with Mustang Bayou	*Enterococcus*	*35*	2005-2012		15	180.96
	2432E_01	New Bayou	From the Chocolate Bay confluence upstream 25.4 km (15.8 mi) to an unnamed tributary	*Enterococcus*	*35*	2005-2012		15	182.96
2433	2433_01	Bastrop Bay _ Oyster Lake	Entire segment	*Enterococcus*	*35*	2005-2012			
2434	2434_02	Christmas Bay	Remainder of Segment	*Enterococcus*	*35*	2005-2012		30	11.01
2436	2436_01	Barbours Cut	Entire segment	*Enterococcus*	*35*	2005-2012		59	17.77
2437	2437_01	Texas City Ship Channel	Entire segment	*Enterococcus*	*35*	2005-2012		27	11.52
2438	2438_01	Bayport Channel	Entire segment	*Enterococcus*	*35*	2005-2012		29	13.36
2439	2439_01	Lower Galveston Bay	Area adjacent to the Texas City Ship Channel and Moses Lake	*Enterococcus*	*35*	2005-2012		44	10.42

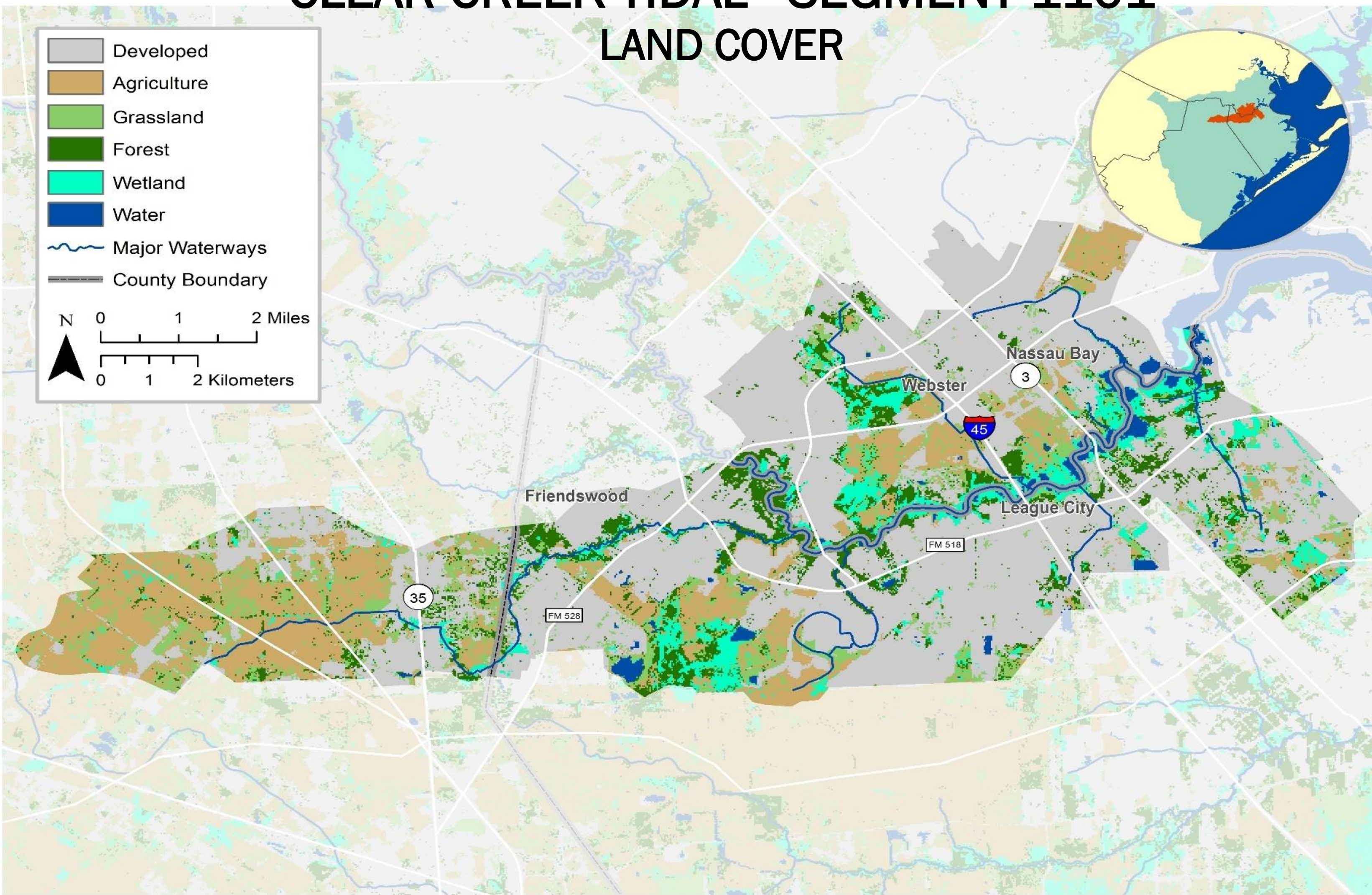
APPENDIX D

SEGMENT AND AU SUMMARIES

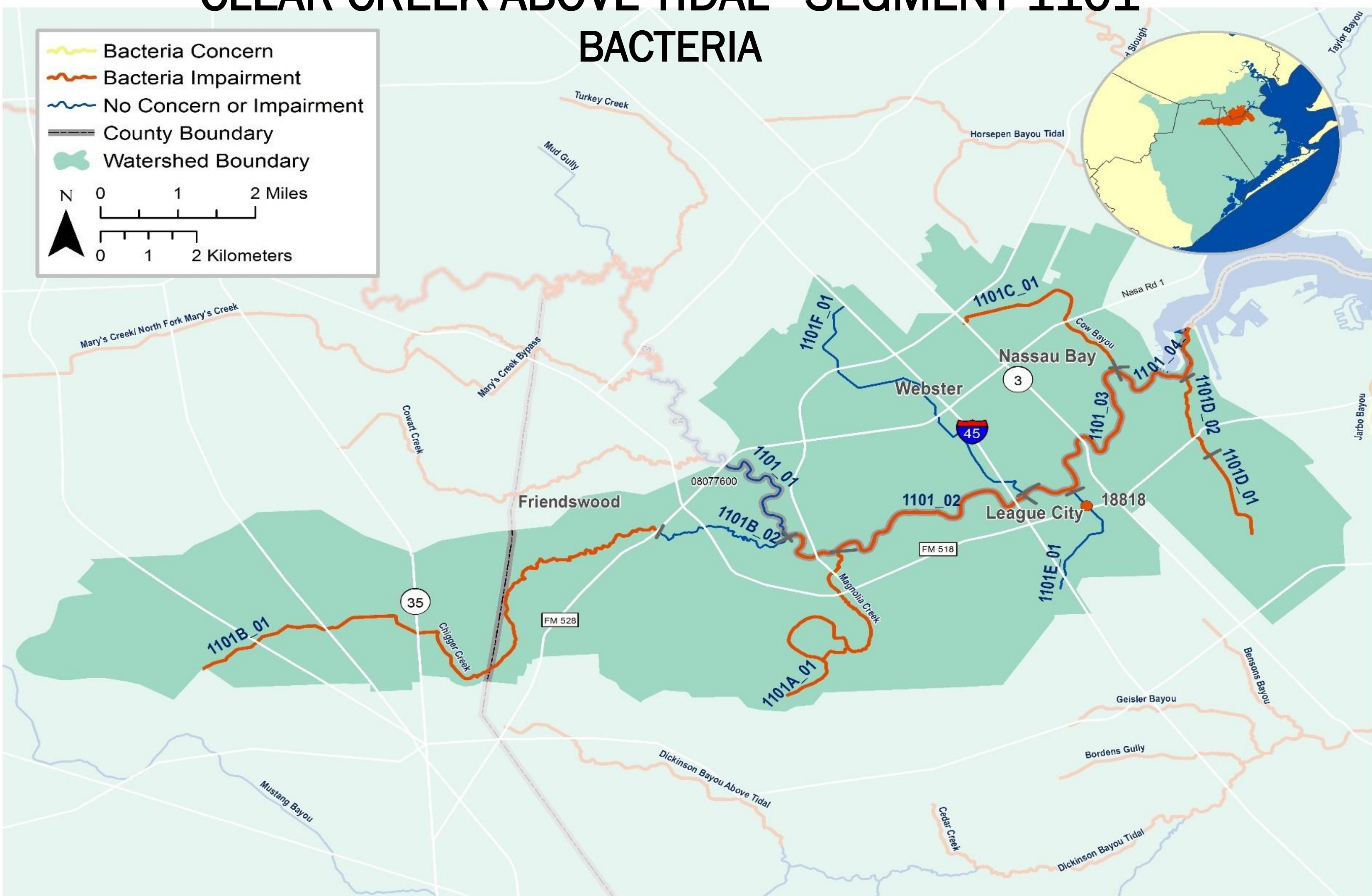
B1. CLEAR CREEK TIDAL - SEGMENT 1101



CLEAR CREEK TIDAL - SEGMENT 1101
LAND COVER

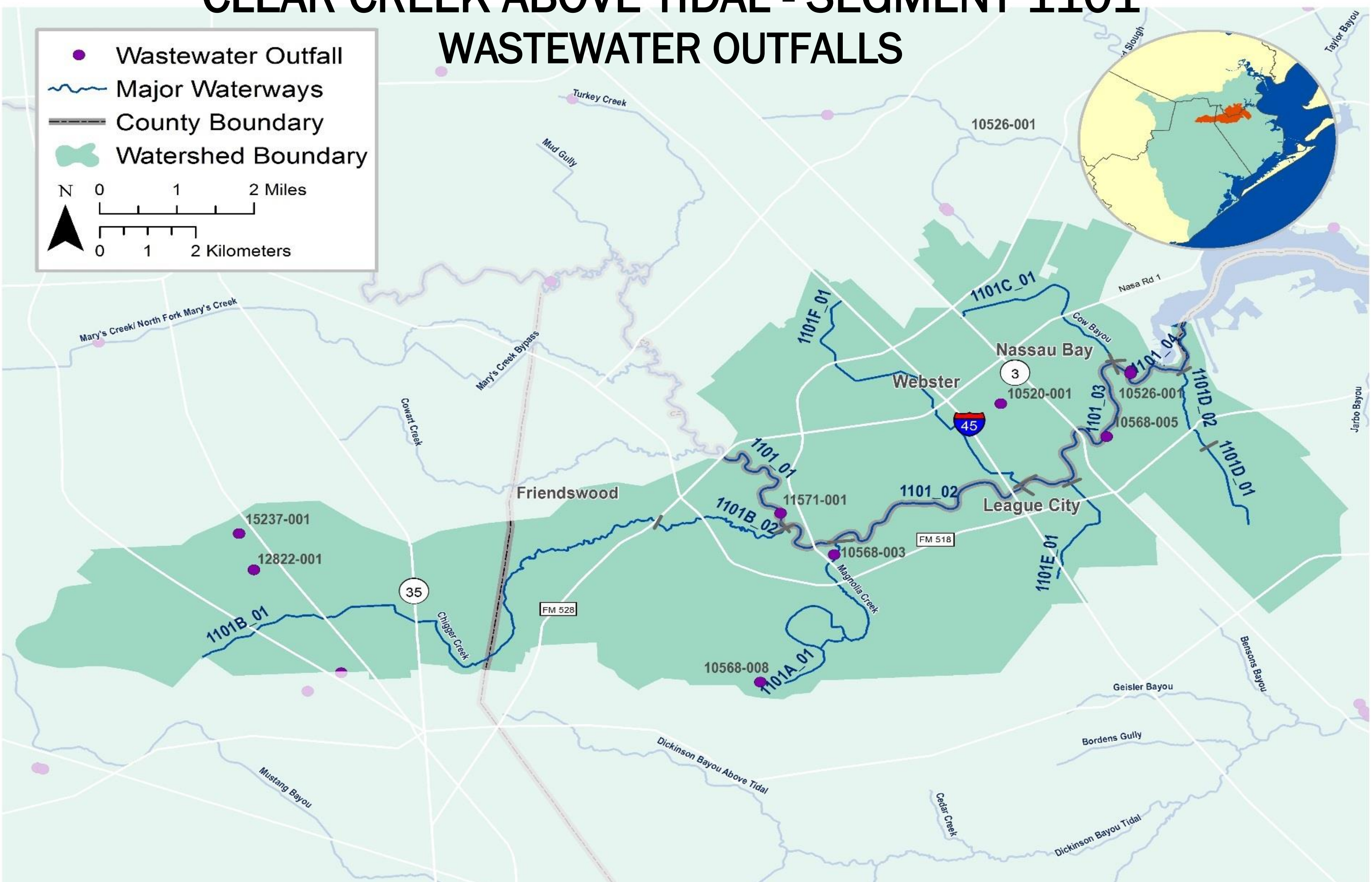


CLEAR CREEK ABOVE TIDAL - SEGMENT 1101
BACTERIA



CLEAR CREEK ABOVE TIDAL - SEGMENT 1101

WASTEWATER OUTFALLS



Percent of Stream Impaired or of Concern

Segment ID	Bacteria
1101	81
1101A	100
1101B	83
1101C	100
1101D	-
1101F	-

Segment 1101

Standards	Tidal Stream	Perennial Stream	Screening Levels	Tidal Stream	Perennial Stream
Temperature (°C/°F):	35 / 95	35 / 95	Ammonia-N (mg/L):	0.46	0.33
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0 / 3.0	5.0	Nitrate-N (mg/L):	1.10	1.95
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0 / 2.0	3.0	Orthophosphate Phosphorus (mg/L):	0.46	0.37
pH (standard units):	6.5-9.0	6.5-9.0	Total Phosphorus-P (mg/L):	0.66	0.69
Enterococci (MPN/100mL) (grab):	104		Chlorophyll *a* (µg/L):	21	14.1
Enterococci (MPN/100mL) (geometric mean):	35				
E. coli (MPN/100 mL) (grab):		399			
E. coli (MPN/100 mL) (geometric mean):		126			

FY 2016 Active Monitoring Stations

Site ID	Site Description	Frequency	Monitoring Entity	Parameter Groups

11446	Clear Creek Tidal at SH 3	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16475	Robinson Bayou at FM 270	Quarterly	EIH	Field, Conventional, Bacteria
16493	Chigger Creek at FM 528 Bridge	Quarterly	EIH	Field, Conventional, Bacteria
16573	Clear Creek Tidal at the confluence with Clear Lake	Monthly	HCPHES	Field, Conventional, Bacteria
16576	Clear Creek Tidal at Brookdale	Quarterly	EIH	Field, Conventional, Bacteria
16611	Magnolia Creek upstream of FM 518	Quarterly	EIH	Field, Conventional, Bacteria
16611	Magnolia Creek upstream of FM 518	Three / Year	H-GAC	Flow, 24-hr DO
17928	Cow Bayou at NASA Rd 1	Quarterly	EIH	Field, Conventional, Bacteria
18591	Trib of Clear Creek (Cemetery Ditch) at I-45	Quarterly	EIH	Field, Conventional, Bacteria
18818	Unnamed Trib of Clear Creek Tidal at FM 518 (Newport Ditch)	Three / Year	H-GAC	Flow, 24-hr DO

Water Quality Issues Summary

Issue	2014 Assessment *I – Impaired* *C – Of Concern*	Possible Causes / Influences / Concerns Voiced by Stakeholders	Possible Solutions / Actions To Be Taken
Elevated Levels of Indicator Bacteria	1101 I 1101A I 1101B I 1101C I 1101 D I	▪ Rapid urbanization and increased impervious cover ▪ Constructed stormwater controls failing ▪ Animal waste from agricultural production and domestic animal facilities ▪ WWTF non-compliance, overflows, and collection system by-passes ▪ Direct and dry weather discharges ▪ Poorly operated or undersized WWTFs	▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems ▪ Increase monitoring requirements for self-reporting

		▪ Waste haulers illegal discharges/improper disposal ▪ Improper or no pet waste disposal ▪ Developments with malfunctioning OSSFs	▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ More public education on pet waste disposal ▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs

Segment Discussion:

Watershed Characteristics: The Clear Creek Tidal watershed has experienced rapid growth of residential and commercial development over the past decade. Areas of grasslands and forestlands have been developed, but there are still a few plots of undeveloped grassland and cultivated fields present, particularly in the western and southern parts of the watershed. Most of the higher intensity development is centered along the I-45 corridor in the eastern side of the watershed in the cities of Nassau Bay, Webster, Friendswood, and League City. The Johnson Space Center and the Baybrook Mall are located within this watershed. The majority of the high intensity development is served by WWTFs, but some of the surrounding lower intensity development in the unincorporated areas relies upon OSSFs.

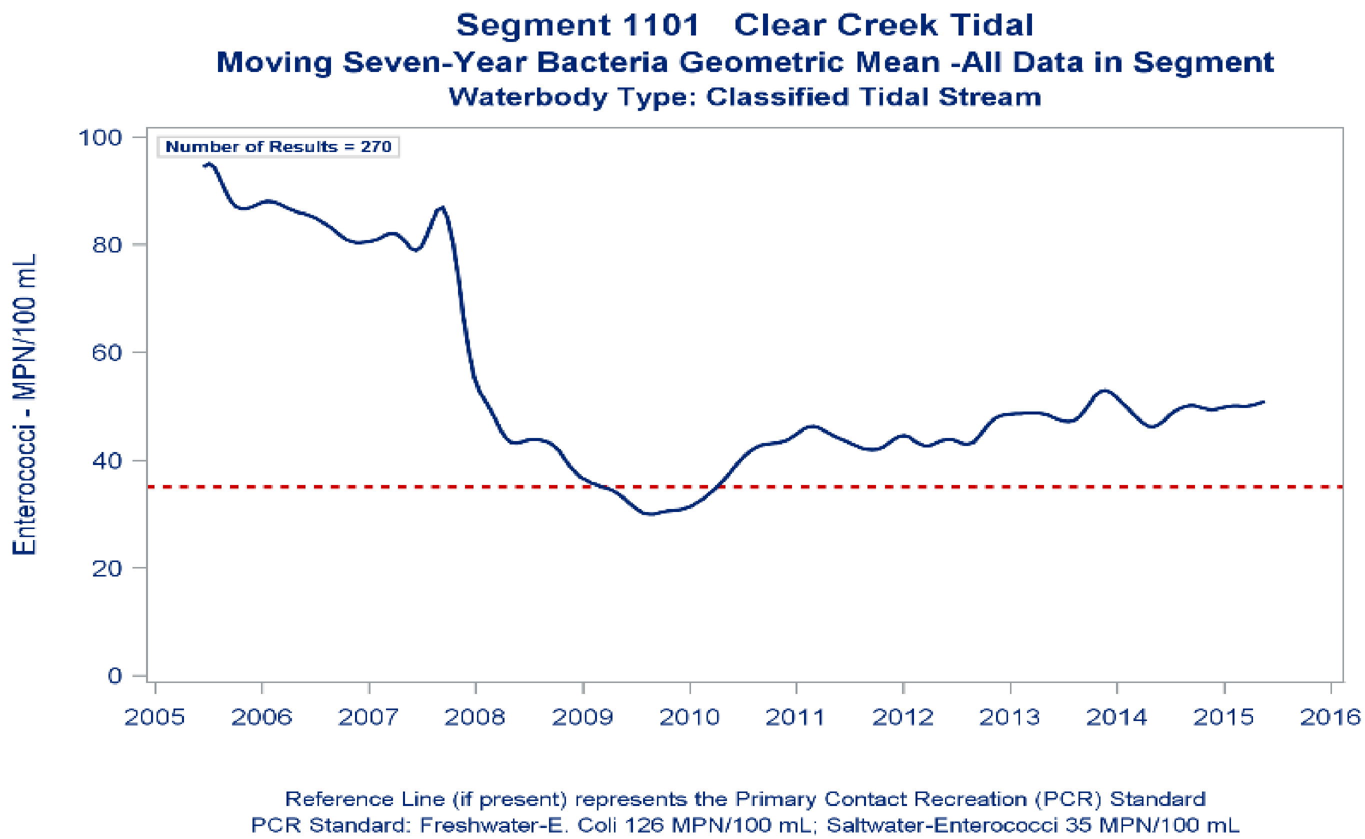
Water Quality Issues: Most assessment units (AUs) in segment 1101 (Clear Creek Tidal) are not supporting their contact recreation use designations. Segments 1101A, 1101B, 1101C, 1101D, and the main segment of Clear Creek Tidal are listed as being impaired for bacteria in the 2014 Texas Integrated Report. Refer to the table below for a breakdown of enterococci geomeans and percent exceedances.

Assessment Unit	HGAC Analysis 2001-2008 Geomean (MPN/100 mL) / % Grab Exceedance	HGAC Analysis 2008-2015 Geomean (MPN/100 mL) / % Grab Exceedance
1101A	Insufficient Data	563 / 92.9
1101B	Insufficient Data	410 / 93.3
1101C	93 / 80.9	347 / 90.5
1101D	106 / 74.1	580 / 85.7
1101F	68 / 64.3	60 / 57.1

Special Studies/Projects: Assessment unit falls within the Bacteria Implementation Group's (BIG) Implementation Plan because of the Clear Creek TMDL. H-GAC facilitates the BIG and participates in implementation projects to improve water quality. Overall the BIG project area has seen improvements in bacteria geomeans that has been traced to effort of the City of Houston and Harris County implementing bacteria reduction efforts. Bacteria reduction efforts have included addressing sanitary sewer overflow by repairing or replacing infrastructure, addressing failing onsite sewage system facilities, comprehensive stormwater basins, and education. This assessment unit will require future tracking to determine if improvements begin to include Clear Creek.

Trends: Regression analysis identified significant water quality trends for the majority of classified and unclassified segments in the Clear Creek Tidal watershed. Segment 1101B had a significant trend in decreasing *E. coli*.

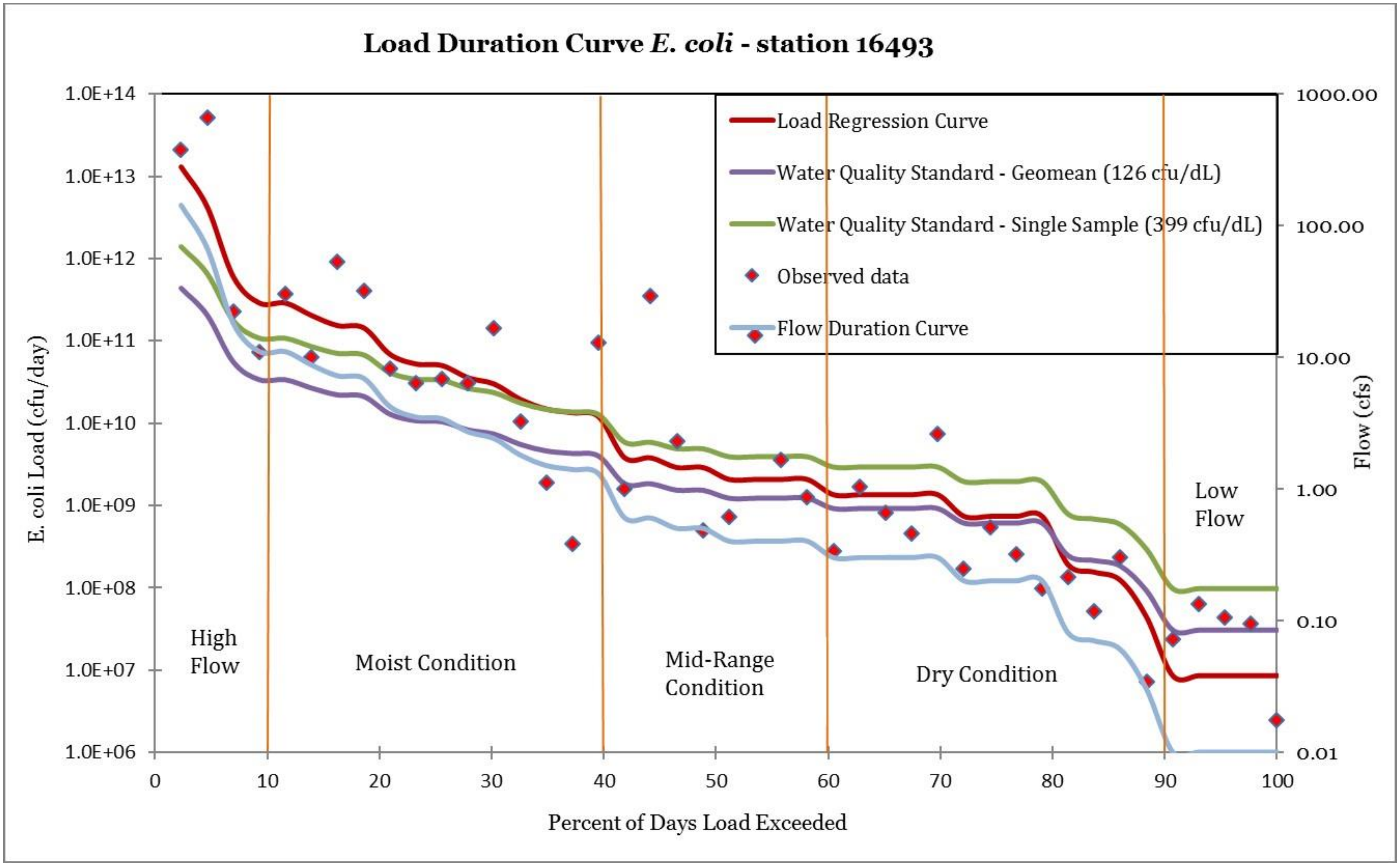
A bacteria impairment is present for segments 1101, 1101A, 1101B, 1101C, and 1101D. Data collection for stations located on segments 1101A and 1101B began in 2011. Although the available data is relatively short term, bacteria geomeans for these segments have remained above the state water quality standard since data collection began in 2011. Other than a temporary bacteria reduction between 2008 to 2010, the main segment of Clear Creek Tidal has also maintained enterococci geomeans exceeding the 35 MPN/100 mL standard since 2005. Moving bacteria geomeans for segments 1101C and 1101D show a significant increase in *E. coli* geomeans since around 2013 and 2011, respectively.

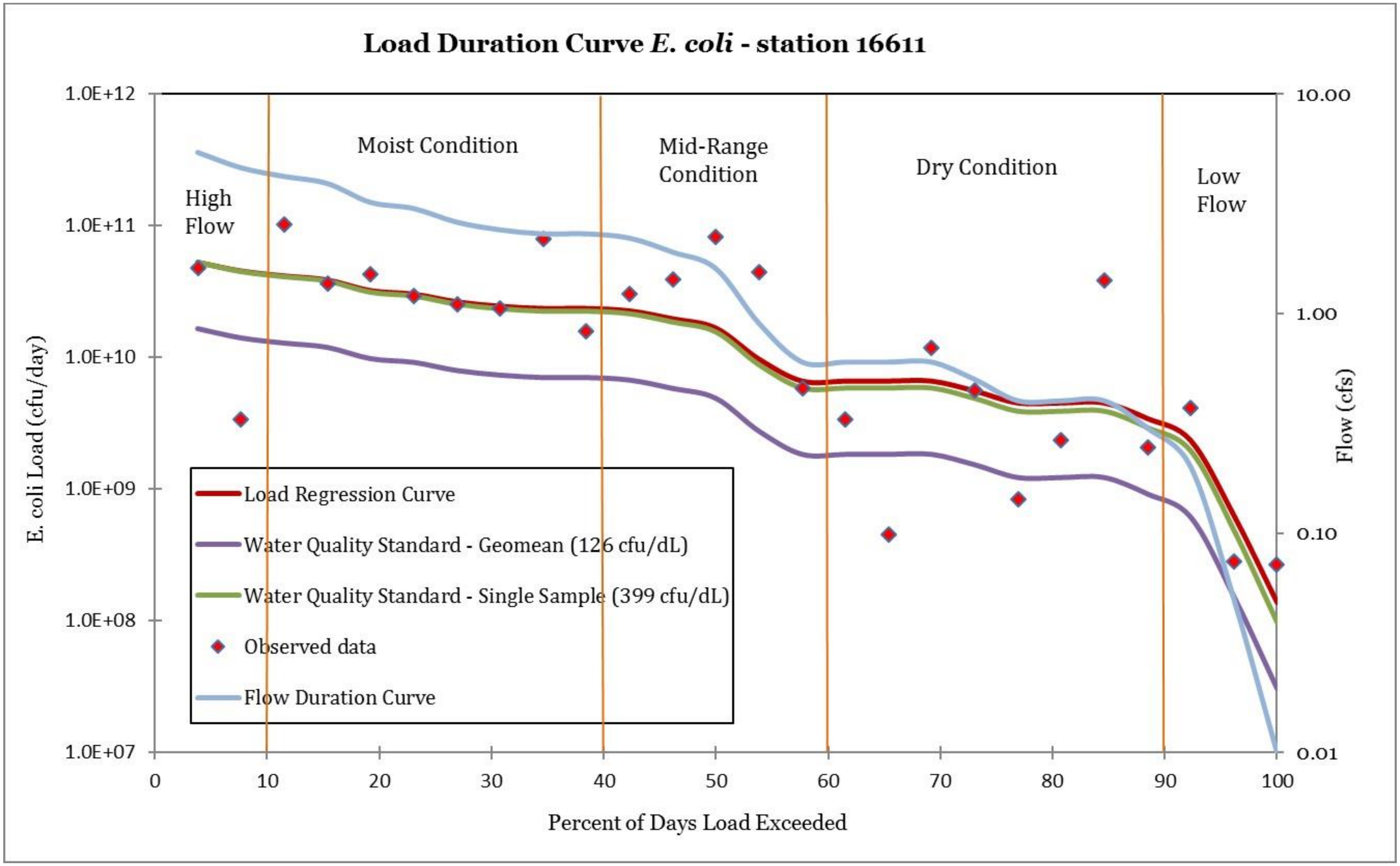


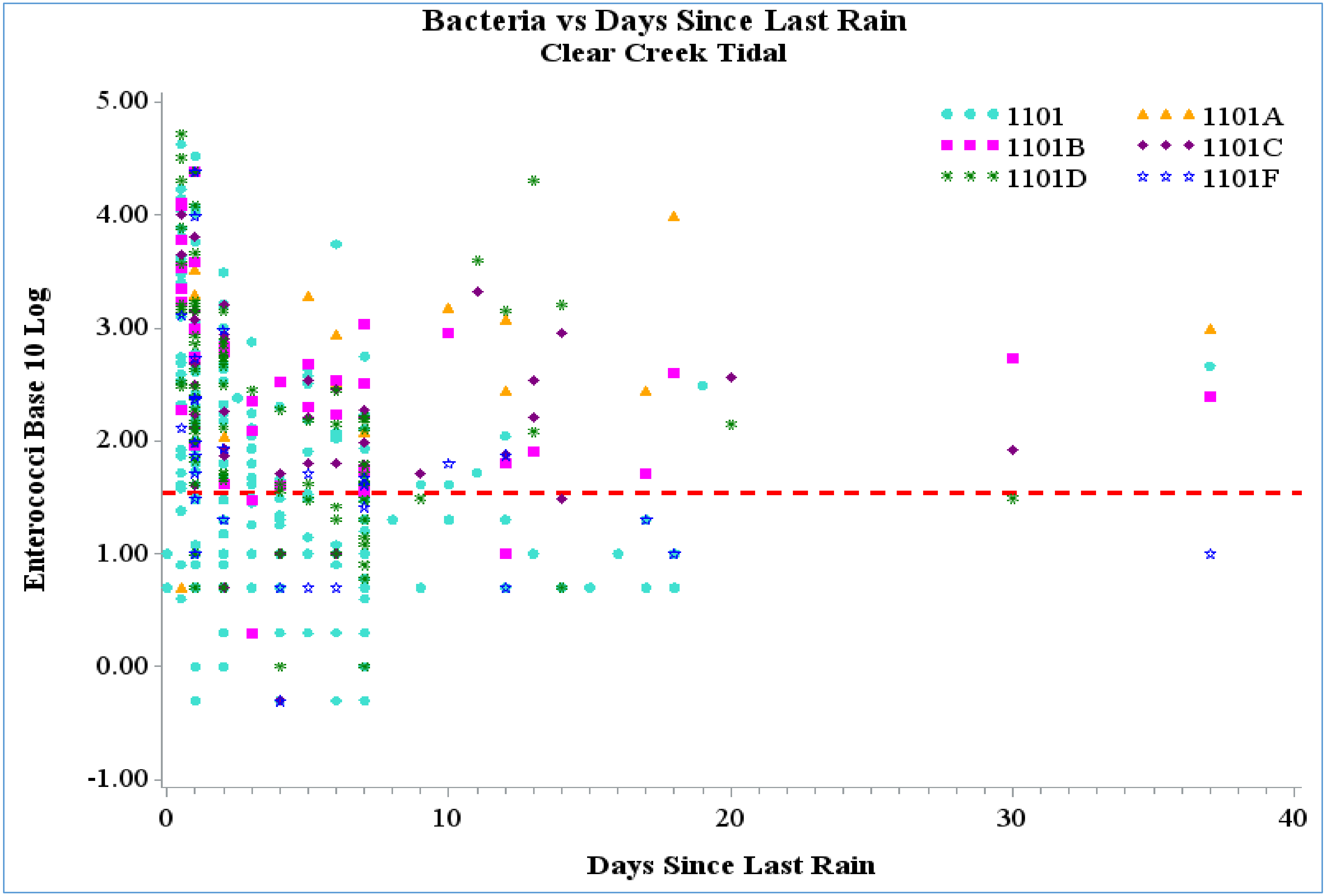
Segment 1101 Clear Creek Tidal
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Classified Tidal Stream
Number of Results = 270
Enterococci - MPN/100 mL
100
80
60
40
20
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Reference Line (if present) represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

Load Durration Curves:

Available flow data and bacteria date were sufficient to complete an LDC for the two freshwater stations in this tidal segment, 16493 and 16611, Chigger Creek and Magnolia Creek respectively. Using the results of the LDC and the Days Since Last Rain, factors affecting bacteria levels in this segment do appear to correlate with potential waste loads from WWTFs and OSSFs, particularly for station 16611 on Magnolia Creek (1101A). Reading the LDC, the Load Regression Curve (LRC) for bacteria data plotted for station 16493, exceeds the geomean standard and single grab standard approximately 40 percent of the time during wet to medium conditions. The bacteria regression curve falls below the Single Standard curve at 40 percent and falls below the Geomean Standard curve during drying conditions at 80% of days load exceeded. Looking at the LDC created for station 16611, the LRC stays at or above the single grab standard 100% of the time. We expect wastewater treatment and OSSF to be contributing to bacteria exceedances when the LDC load regression curve is found above the standard during dry weather conditions, when nonpoint sources are little to non-existent. The Days Since Last Rain plot support this as the observed data at even forty days out since last recorded rainfall appears to exceed the standard. Again the segment 1101A containing the station 16611 is the standout here with the majority of samples collected contained *E. coli* above the standard, shown here with the dashed red line.

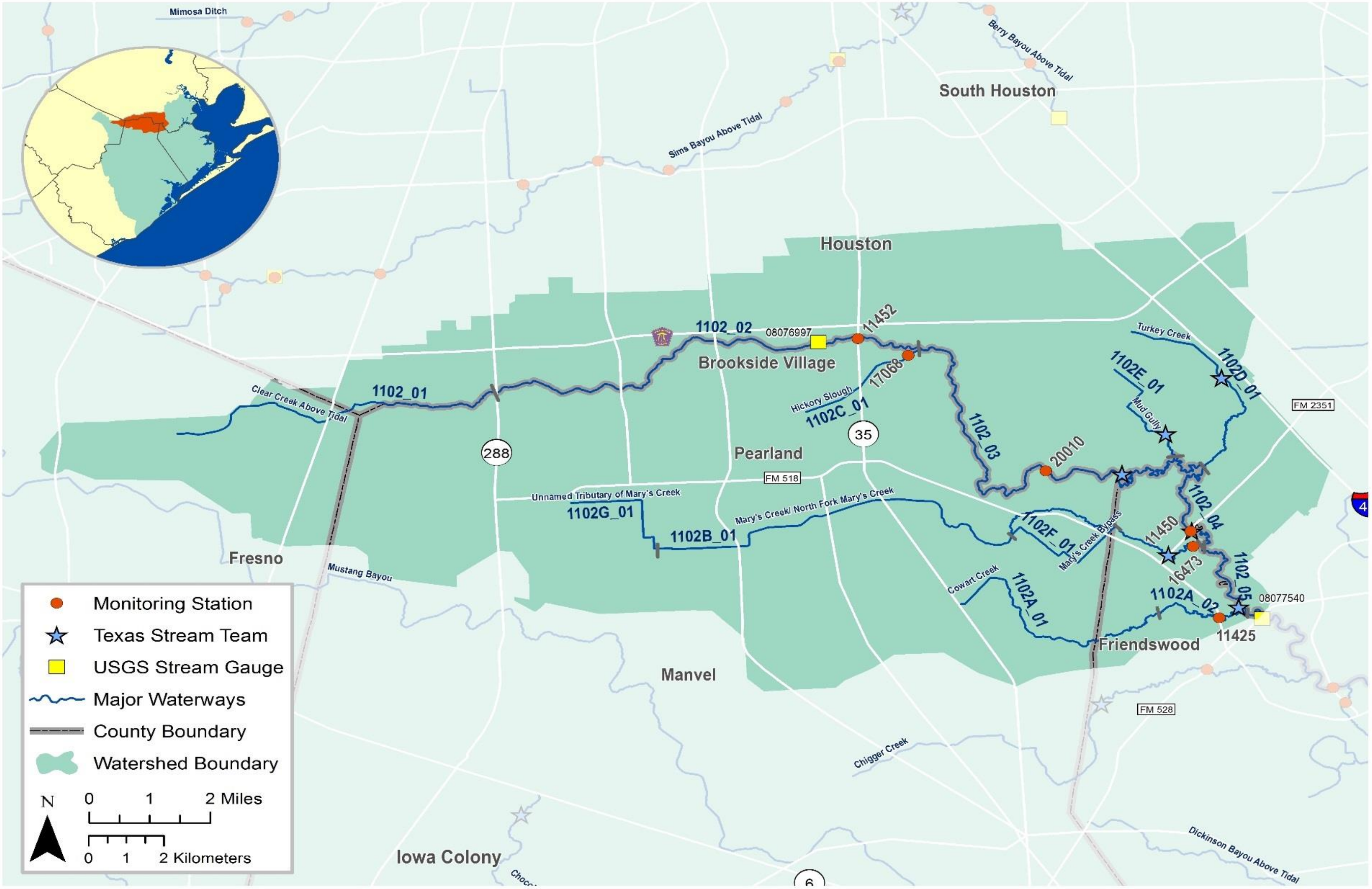

Load Duration Curve E. coli - station 16493
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
E. coli Load (cfu/day)
1000.00
100.00
10.00
1.00
0.10
0.01
Flow (cfs)
0
10
20
30
40
50
60
70
80
90
100
Percent of Days Load Exceeded
Load Regression Curve
Water Quality Standard - Geomean (126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow


Load Duration Curve *E. coli* - station 16611
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
E. coli Load (cfu/day)
10.00
1.00
0.10
0.01
Flow (cfs)
0
10
20
30
40
50
60
70
80
90
100
Percent of Days Load Exceeded
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow
Load Regression Curve
Water Quality Standard - Geomean (126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve

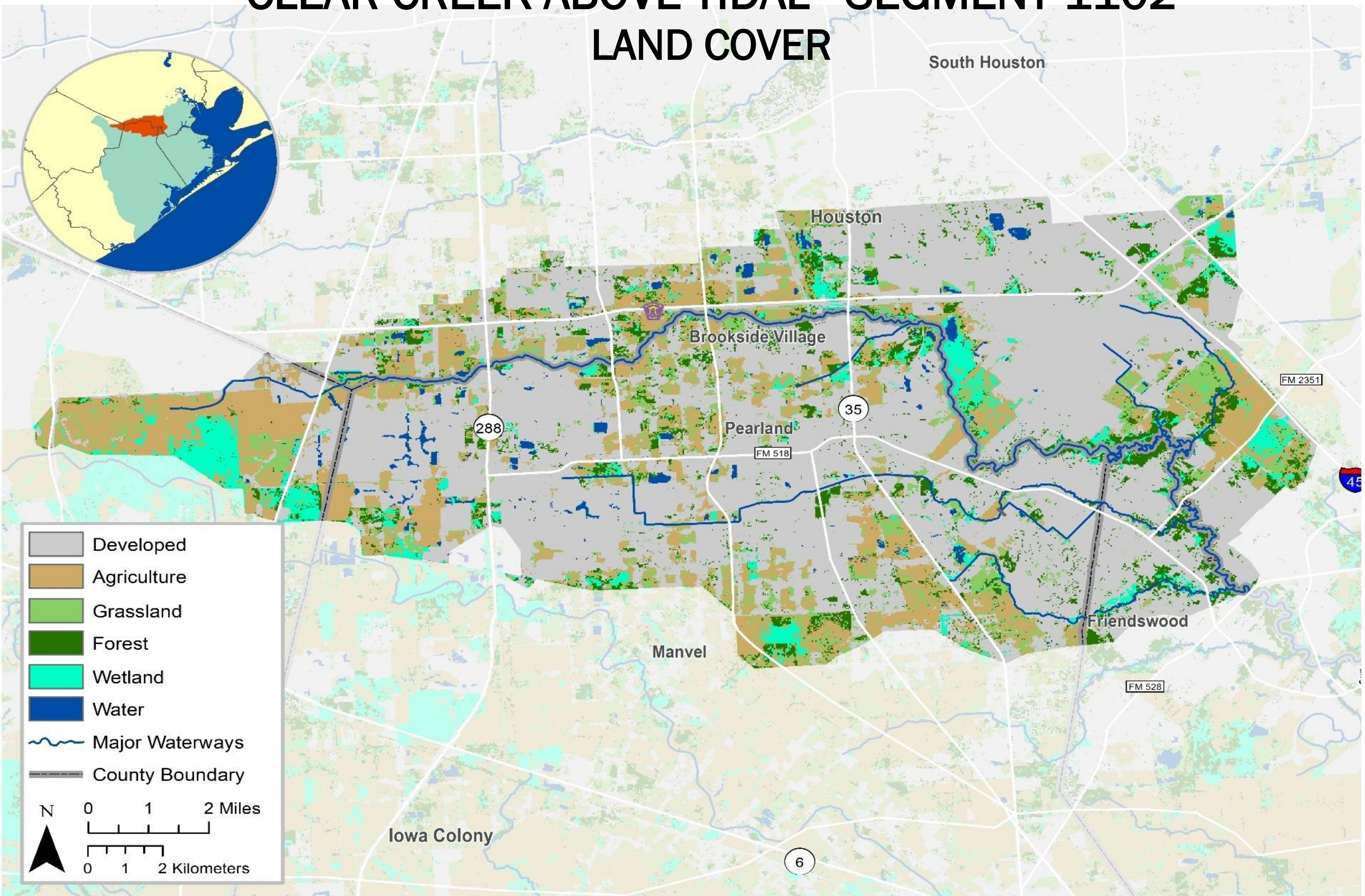

Bacteria vs Days Since Last Rain
Clear Creek Tidal
Enterococci Base 10 Log
Days Since Last Rain
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
0
10
20
30
40
1101
1101A
1101B
1101C
1101D
1101F

Recommendations
Address concerns found in this segment summary through stakeholder participation.
Continue collecting water quality data to support actions associated with any future watershed protection plan development and possible modeling.
Continue to work with the BIG to implement and track the I-Plan recommendations to reduce bacteria.

B2. CLEAR CREEK ABOVE TIDAL – SEGMENT 1102

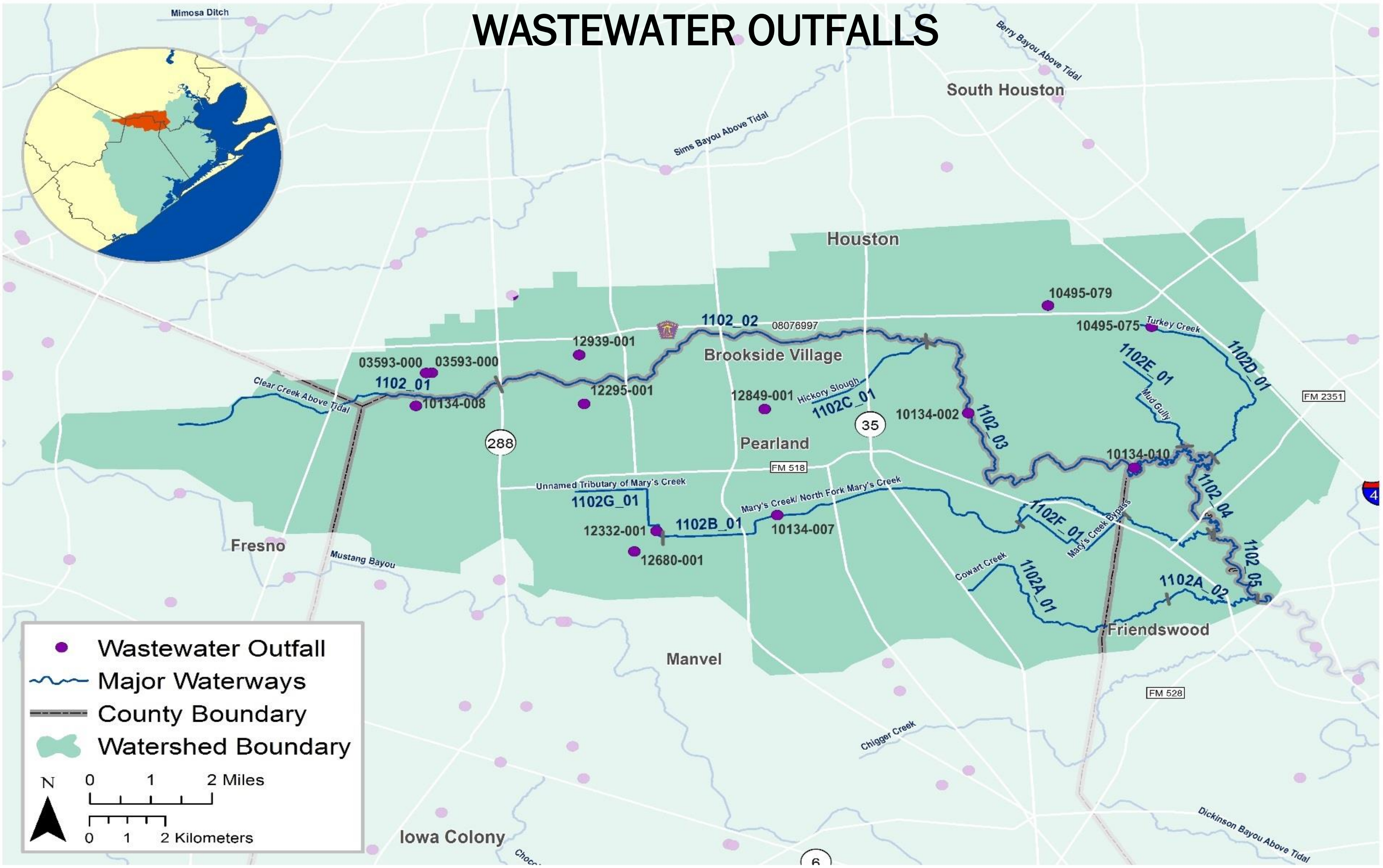


CLEAR CREEK ABOVE TIDAL - SEGMENT 1102
LAND COVER



CLEAR CREEK ABOVE TIDAL - SEGMENT 1102
BACTERIA

CLEAR CREEK ABOVE TIDAL - SEGMENT 1102
WASTEWATER OUTFALLS



Segment Number:	1102	Name:	Clear Creek Above Tidal		
Length:	31 miles	Watershed Area:	115 square miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life
Number of Active Monitoring Stations:	6	Texas Stream Team Monitors:	6	Permitted Outfalls:	13
Description:	Segment 1102 (Perennial Stream w/ high ALU): From a point 100 meters (110 yards) upstream of FM 528 in Galveston/Harris County to Rouen Road in Fort Bend County Segment 1102A (Intermittent Stream with Pools w/ limited ALU): Cowart Creek (unclassified water body) – From the Clear Creek Above Tidal confluence in Galveston County to SH 35 in Brazoria County Segment 1102B (Perennial Stream w/ intermediate ALU): Mary's Creek/North Fork Mary's Creek (unclassified water body) – Perennial stream from the confluence with Clear Creek to confluence with North and South Fork Mary's Creek near FM 1128, approximately 5 km (3.1 mi) SW of Pearland. Includes perennial portion of North Fork Mary's Creek to confluence with unnamed tributary Segment 1102C (Perennial Stream w/ high ALU): Hickory Slough (unclassified water body) – From the Clear Creek Above Tidal confluence to a point 0.69 km (0.43 mi) upstream of Mykawa Road Segment 1102D (Perennial Stream w/ high ALU): Turkey Creek (unclassified water body) – From the Clear Creek Above Tidal confluence to a point 0.98 km (0.61 mi) upstream of Scarsdale Blvd Segment 1102E (Perennial Stream w/ high ALU): Mud Gully (unclassified water body) – From the Clear creek Above Tidal confluence to a				

	point 0.80 km (0.49 mi) downstream of Hughes Road Segment 1102F (Perennial Stream w/ high ALU): Mary's Creek Bypass (unclassified water body) – From the Mary's Creek confluence NE of FM 518 to a point 0.96 km (0.60 mi) upstream to the Mary's Creek confluence (NW of County Road 126) Sub-Segment 1102G (Perennial Stream w/ high ALU): Unnamed Tributary of Mary's Creek (unclassified water body)—From the Mary's Creek confluence 1.3 km (0.84 mi) west of FM 1128 to a point 1.2 km (0.75 mi) upstream to the confluence of an unnamed tributary

Percent of Stream Impaired or of Concern	
Segment ID	**Bacteria**
1102	72
1102A	100
1102B	100
1102C	100
1102D	100
1102E	
1102F	100
1102G	100

Segment 1102			
Standards	**Perennial Stream**	**Screening Levels**	**Perennial Stream**
Temperature (°C/°F):	35 / 95	Ammonia (mg/L):	0.33
Dissolved Oxygen *(24-Hr Average)* (mg/L):	5.0 / 4.0	Nitrate-N (mg/L):	1.95
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0 / 3.0	Orthophosphate Phosphorus (mg/L):	0.37

pH (standard units):	6.5-9.0	Total Phosphorus (mg/L):	0.69
E. coli (MPN/100 mL) (grab):	399	Chlorophyll *a* (µg/L):	14.1
E. coli (MPN/100 mL) (geometric mean):	126		
Chloride (mg/L as Cl):	200		
Sulfate (mg/L as SO_4):	100		
Total Dissolved Solids (mg/L):	600		

FY 2016 Active Monitoring Stations

Site ID	Site Description	Frequency	Monitoring Entity	Parameter Groups
11425	Cowart Creek at FM 518	Quarterly	EIH	Field, Conventional, Bacteria
11450	Clear Creek at FM 2351	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
11452	Clear Creek at Telephone Rd	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*, Flow
16473	Mary's Creek at Mary's Crossing	Quarterly	EIH	Field, Conventional, Bacteria
17068	Hickory Slough at Robinson Drive	Quarterly	EIH	Field, Conventional, Bacteria
20010	Clear Creek at end of Yost Rd in Pearland	Quarterly	EIH	Field, Conventional, Bacteria

Water Quality Issues Summary

Issue	2014 Assessment *I – Impaired* *C – Of Concern*	Possible Causes / Influences / Concerns Voiced by Stakeholders	Possible Solutions / Actions To Be Taken
Elevated Levels of Indicator Bacteria	1102 I 1102A I 1102B I 1102C I 1102D I 1102F I 1102G I	▪ Rapid urbanization and increased impervious cover ▪ Animal waste from agricultural production and domestic animal facilities ▪ Constructed stormwater controls failing ▪ Poorly operated or undersized WWTFs	▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems

		▪ WWTF non-compliance, overflows, and collection system by-passes ▪ Direct and dry weather discharges ▪ Waste haulers illegal discharges/improper disposal ▪ Improper or no pet waste disposal ▪ Developments with malfunctioning OSSFs	▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Create and implement Water Quality Management Plans for individual agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ Impose new or stricter bacteria limits than currently designated by TCEQ ▪ Regionalize chronically non-compliant WWTFs ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ More public education on pet waste disposal ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education regarding OSSF operation and maintenance

Segment Discussion:

Watershed Characteristics: Rapid population growth in the Clear Creek Above Tidal watershed has sparked the expansion of residential and commercial development primarily along FM518 though Friendswood and Pearland. Scattered areas of open space are still present throughout the watershed that will likely be developed as growth continues in the area. There are also some agricultural land uses in the southern and western portions of the watershed. The majority of development is served by WWTFs, but there are still several areas that use OSSFs as their primary means of wastewater treatment.

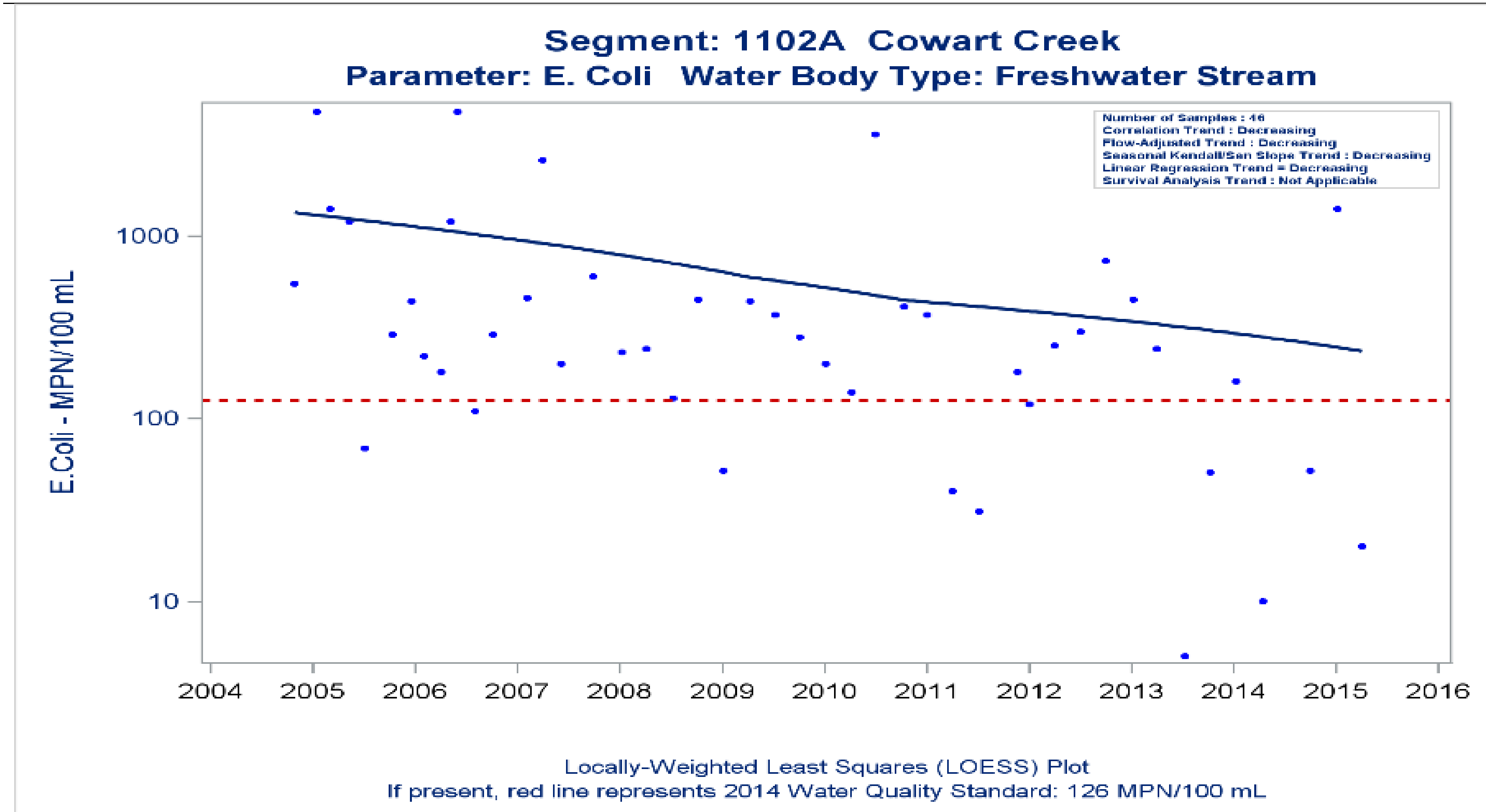
Water Quality Issues: There are 13 assessment units (AUs) in this watershed. The 2014 Texas Integrated Report lists the AU 1102_02, 1102_03, and 1102_04 of the main channel of Clear Creek Above Tidal and 6 unclassified segments as impaired for recreational use due to elevated levels of indicator bacteria.

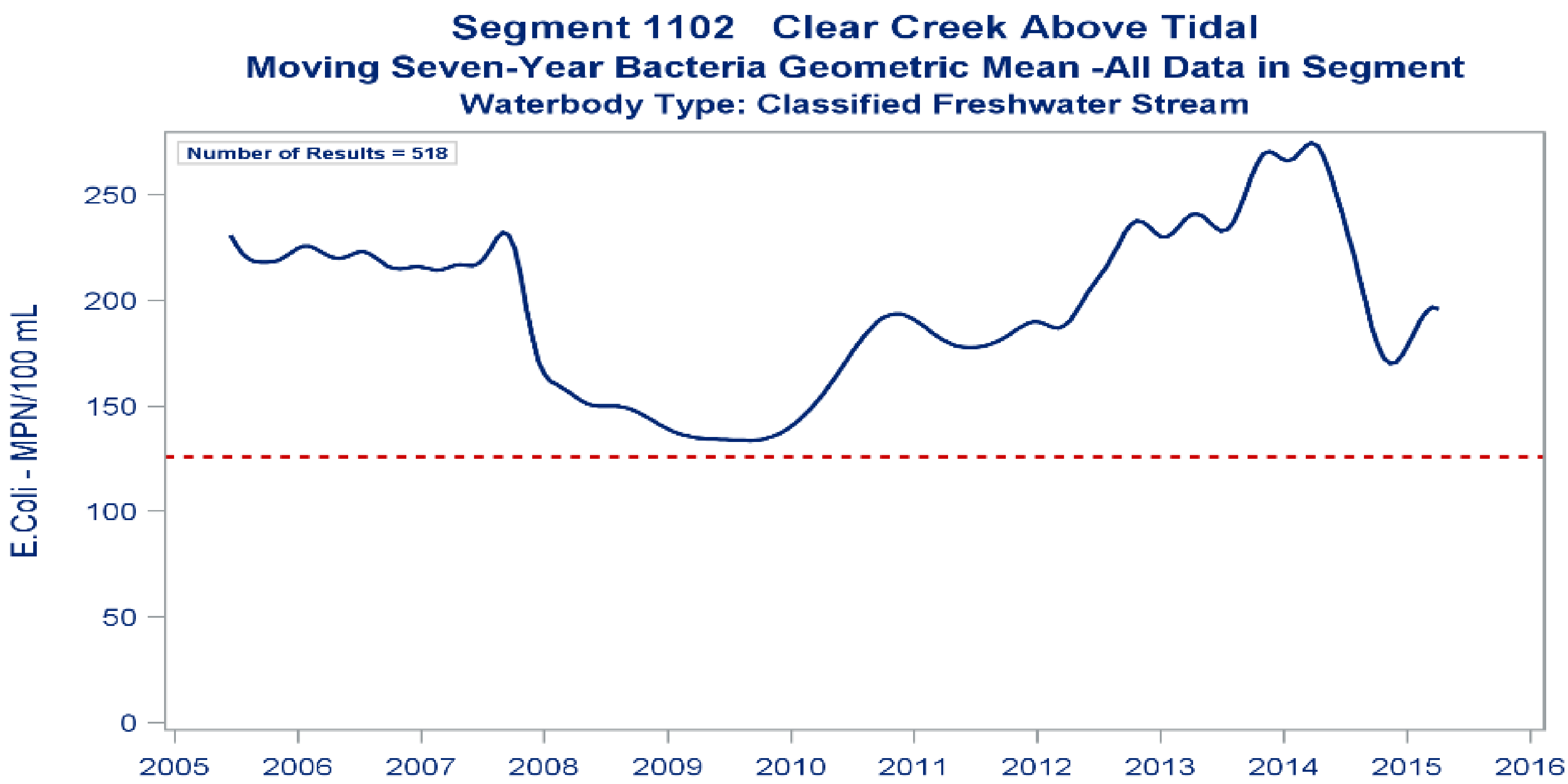
Assessment Unit	TCEQ Assessment (2005-2012) Geomean (MPN/100 mL) / % Grab Exceedance	HGAC Analysis 2001-2008 Geomean (MPN/100 mL) / % Grab Exceedance	HGAC Analysis 2008-2015 Geomean (MPN/100 mL) / % Grab Exceedance
1102_02	182 / NA	248 / 38.8	124 / 20.8
1102_03	173 / NA	68 / 0.0	181 / 21.4
1102_04	348 / NA	260 / 31.8	171 / 12.5
1102A_02	360 / NA	504 / 52.6	157 / 25.9
1102B_01	206 / NA	231 / 25.0	328 / 33.3
1102C_01	392 / NA	93 / 18.9	120 / 28.6

Although a TMDL has been completed for this segment, most of the assessment units remain impaired for contact recreation.

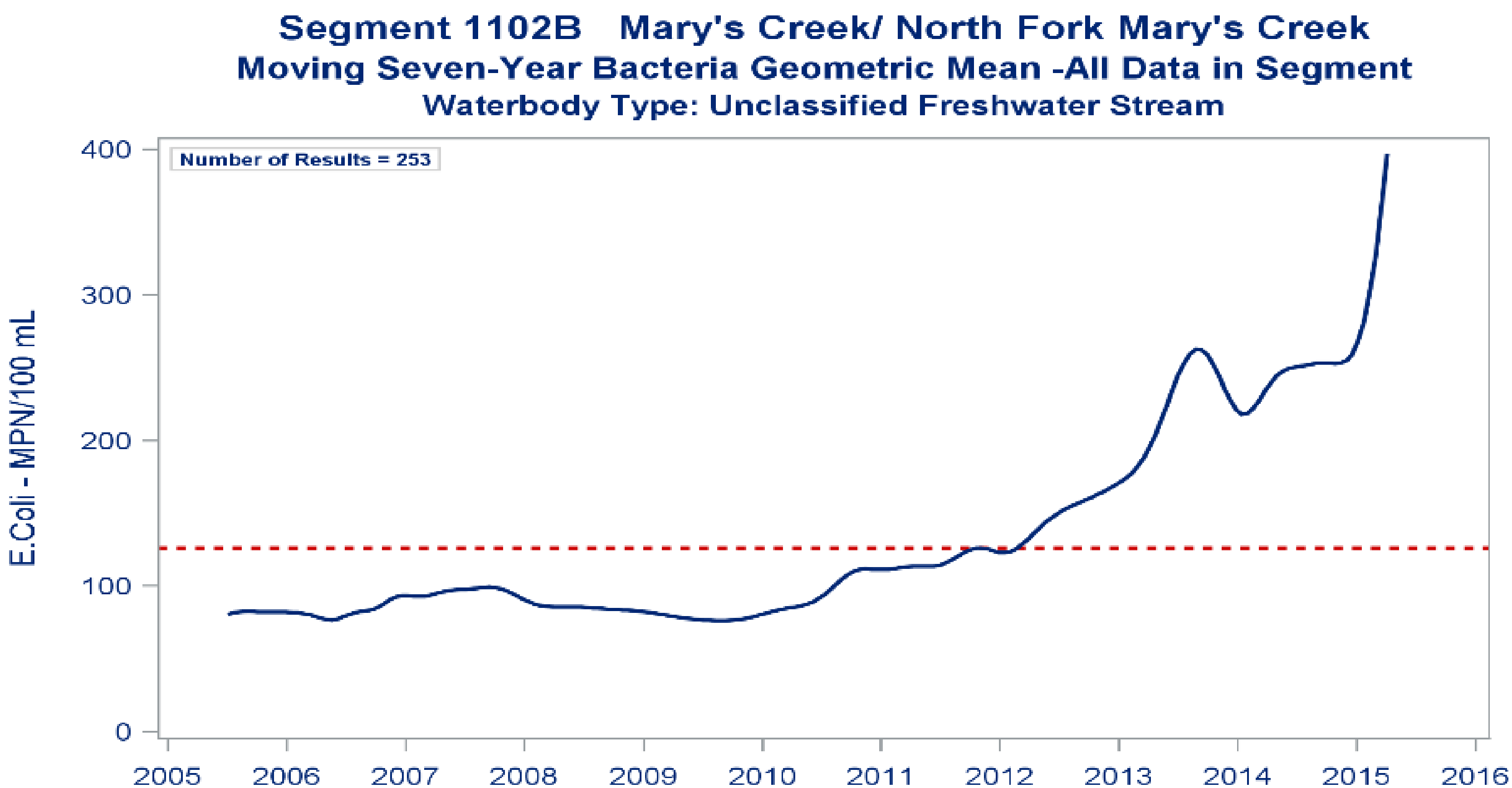
Special Studies/Projects: Assessment unit falls within the Bacteria Implementation Group's (BIG) Implementation Plan because of the Clear Creek TMDL. The I-Plan was completed and approved by the TCEQ in January 2013. H-GAC facilitates the BIG and participates in implementation projects to improve water quality. Overall the BIG project area has seen improvements in bacteria geomeans that has been traced to effort of the City of Houston and Harris County implementing bacteria reduction efforts. Bacteria reduction efforts have included addressing sanitary sewer overflow by repairing or replacing infrastructure, addressing failing onsite sewage system facilities, comprehensive stormwater basins, and education. This assessment unit will require future tracking to determine if improvements begin to include Clear Creek.

Trends: Most the Clear Creek Above Tidal watershed is impaired for bacteria. Regression analysis detected a slight decrease in *E. coli* concentrations over time at Cowart Creek; however, bacteria exceedances are still common. Moving seven-year bacteria geometric mean plots for the main segment show several fluctuations in bacteria levels during the period of record with *E. coli* geomeans consistently higher than the 126 MPN/100 mL standard since 2005.Geometric means for bacteria at Mary's Creek reveal a significant increase in bacteria since around 2012. Reasons for fluctuations in geomean bacteria levels during the period of record are likely related to rain events when collection systems overflow, WWTFs and OSSFs malfunction, and pet waste, livestock fields, and enclosures lead to higher bacteria levels in stormwater.


Segment: 1102A Cowart Creek
Parameter: E. Coli Water Body Type: Freshwater Stream
Number of Samples : 46
Correlation Trend : Decreasing
Flow-Adjusted Trend : Decreasing
Seasonal Kendall/Sen Slope Trend : Decreasing
Linear Regression Trend = Decreasing
Survival Analysis Trend : Not Applicable
E.Coli - MPN/100 mL
1000
100
10
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Locally-Weighted Least Squares (LOESS) Plot
If present, red line represents 2014 Water Quality Standard: 126 MPN/100 mL



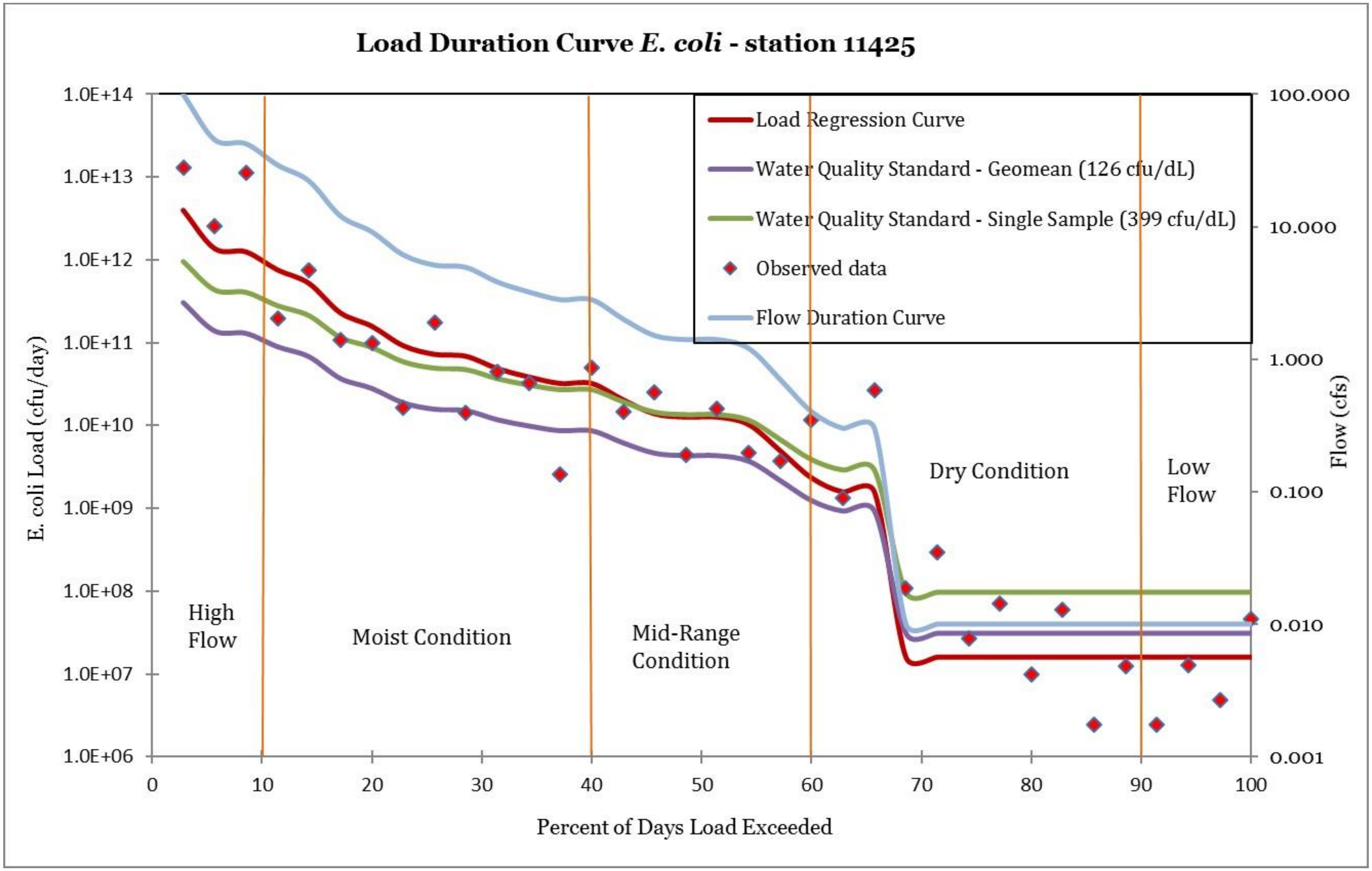
Reference Line (if present) represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

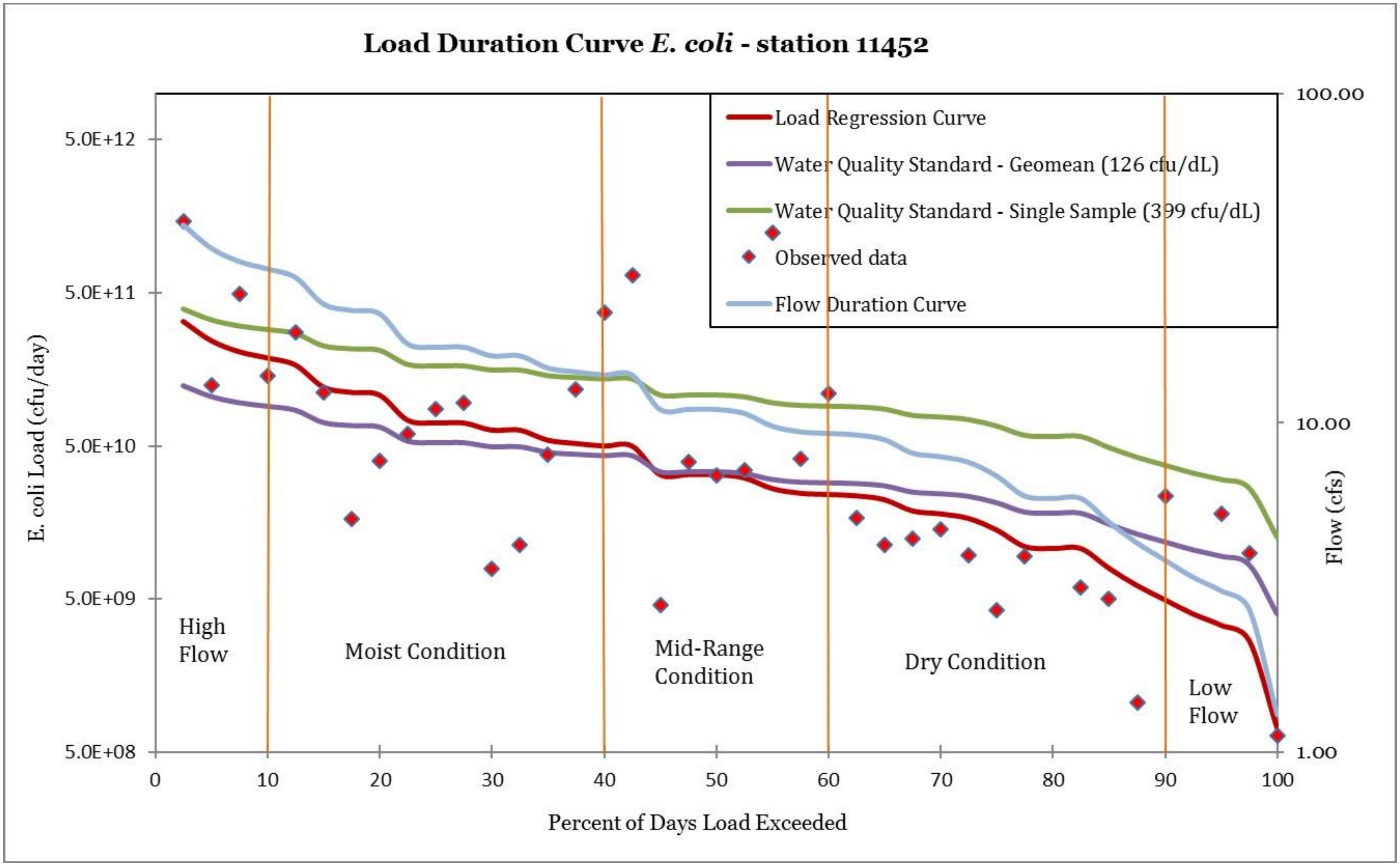


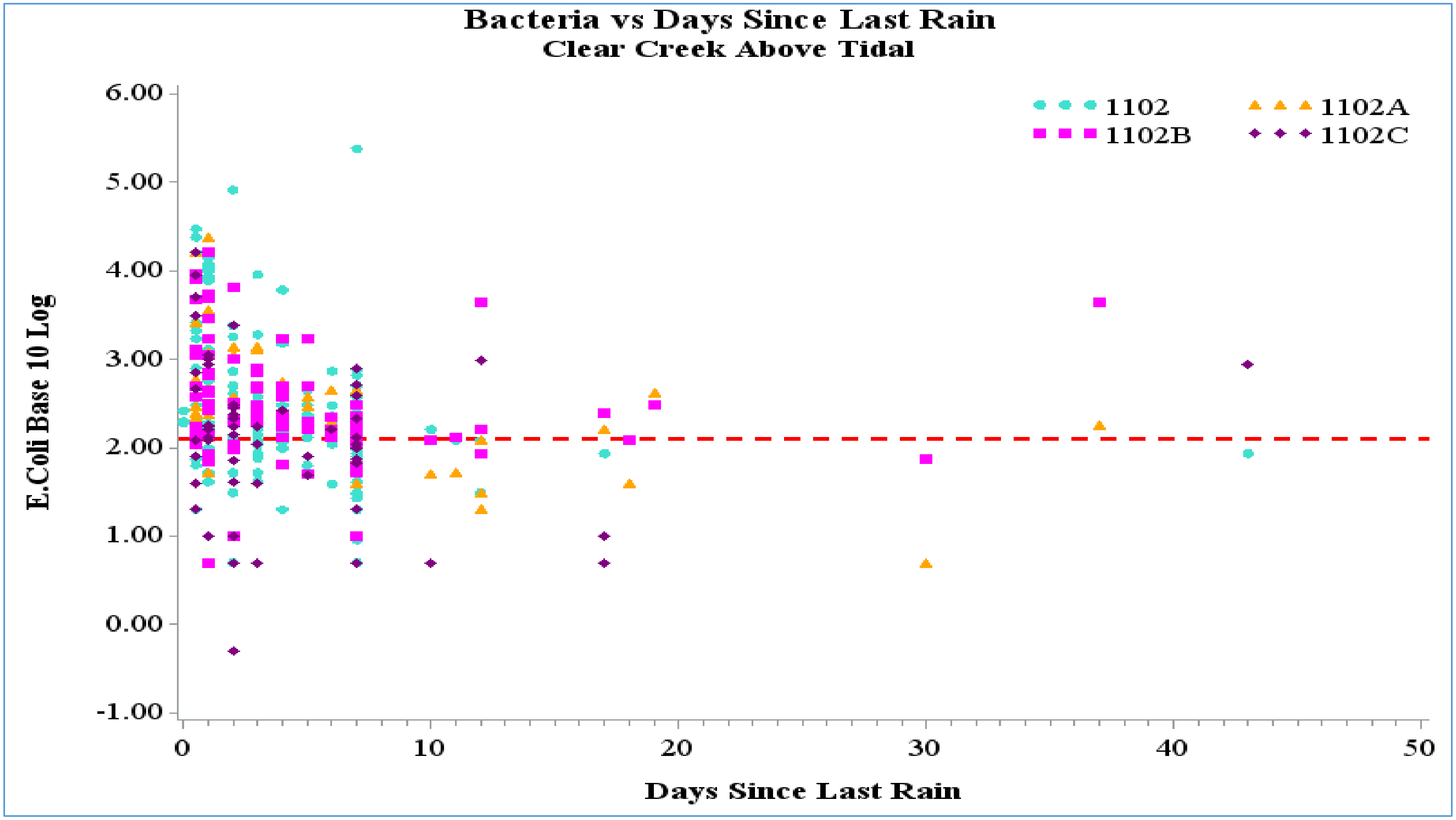
Reference Line (if present) represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

Load Duration Curves

Available flow data and bacteria date were sufficient to complete an LDC for the two stations in this segment, 11425 and 11452, Cowart Creek and Clear Creek at Telephone Road respectively. Using the results of the LDC and the Days Since Last rain, factors affecting bacteria levels in this segment do not appear to strongly correlate with potential waste loads from WWTFs and OSSFs. Reading the LDC, the Load Regression Curve for bacteria data plotted for station 11425, exceeds the geomean standard and single grab standard approximately 40 percent of the time during wet to medium conditions. The bacteria regression curve falls below the Single Standard curve at 40 percent and falls below the Geomean Standard curve during drying conditions between 70 and 80% of days load exceeded. The LDC for station 11452 remains below the Single Standard and falls below the Geomean Standard curve at 50% of Days Load Exceeded. We expect wastewater treatment and OSSF to be contributing to bacteria exceedances when the LDC load regression curve is found above the standard during dry weather conditions, when nonpoint sources are little to non-existent. The Days Since Last Rain support this as the observed bacteria data straddles the standard evenly past 10 days since last rainfall.

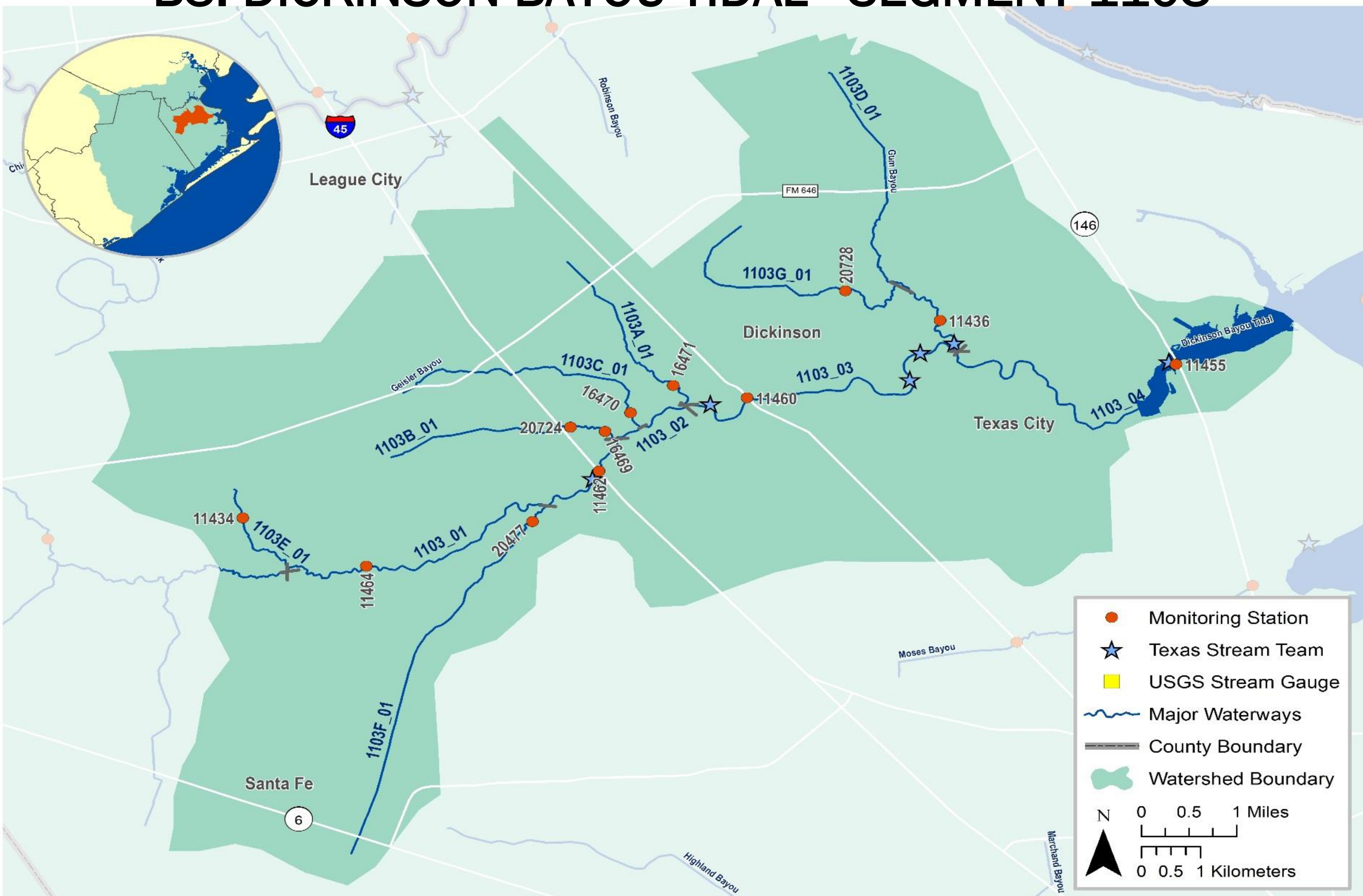

Load Duration Curve E. coli - station 11425
E. coli Load (cfu/day)
Flow (cfs)
Percent of Days Load Exceeded
Load Regression Curve
Water Quality Standard - Geomean (126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
100.000
10.000
1.000
0.100
0.010
0.001
0 10 20 30 40 50 60 70 80 90 100


Load Duration Curve E. coli - station 11452
Load Regression Curve
Water Quality Standard - Geomean (126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve
5.0E+12
5.0E+11
5.0E+10
5.0E+09
5.0E+08
E. coli Load (cfu/day)
100.00
10.00
1.00
Flow (cfs)
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow
0
10
20
30
40
50
60
70
80
90
100
Percent of Days Load Exceeded

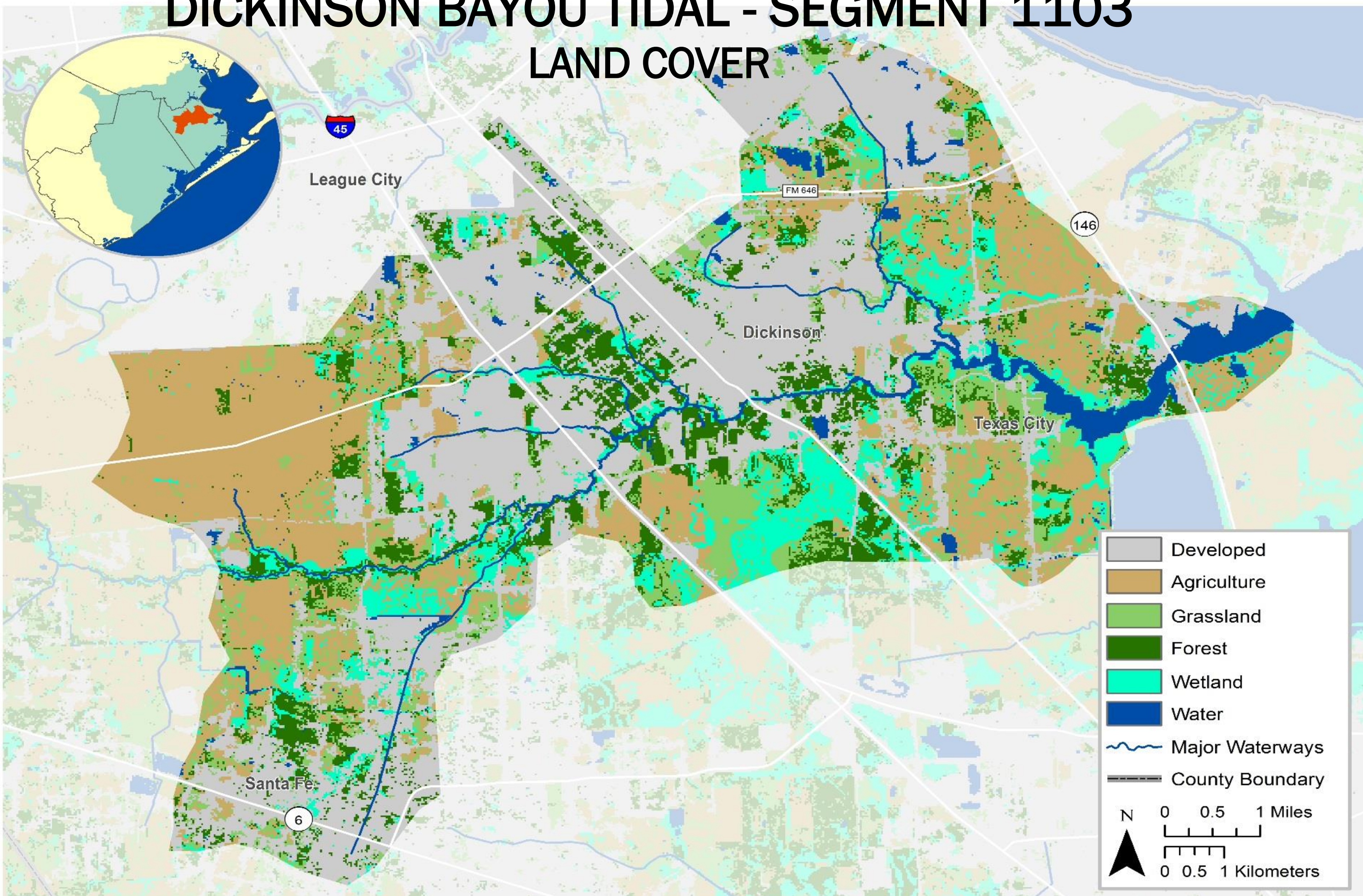

Bacteria vs Days Since Last Rain
Clear Creek Above Tidal
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
E.Coli Base 10 Log
0
10
20
30
40
50
Days Since Last Rain
1102
1102A
1102B
1102C

Recommendations
Address concerns found in this segment summary through stakeholder participation.
Continue collecting water quality data to support actions associated with the current I-Plan, with any future watershed protection plan development and possible modeling.
Continue to work with the BIG to implement the I-Plan recommendations for bacteria reduction.

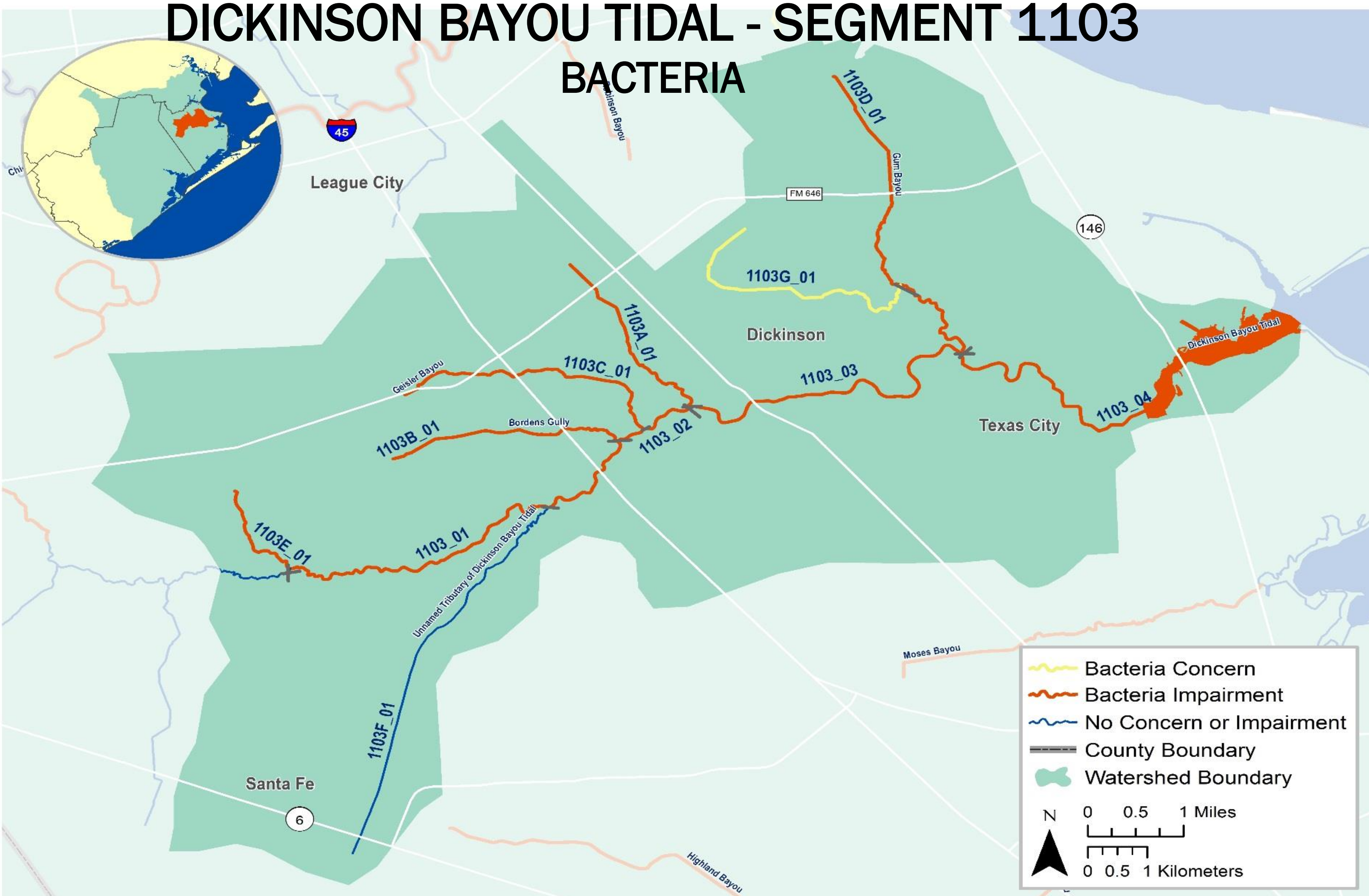
B3. DICKINSON BAYOU TIDAL - SEGMENT 1103



DICKINSON BAYOU TIDAL - SEGMENT 1103
LAND COVER



DICKINSON BAYOU TIDAL - SEGMENT 1103
BACTERIA



DICKINSON BAYOU TIDAL - SEGMENT 1103
WASTEWATER OUTFALLS

Segment Number:	1103	Name:	Dickinson Bayou Tidal		
Length:	15 miles	Watershed Area:	60 square miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life
Number of Active Monitoring Stations:	12	Texas Stream Team Monitors:	6	Permitted Outfalls:	14

Description:	Segment 1103 (Tidal Stream w/ high ALU): From the Dickinson Bay confluence 2.1 km (1.3 mi) downstream of SH 146 in Galveston County to a point 4.0 km (2.5 mi) downstream of FM 517 in Galveston County Segment 1103A (Tidal Stream w/ high ALU): Bensons Bayou (unclassified water body) — From the Dickinson Bayou confluence to point 0.6 km (0.37 mi) upstream of FM 646 in Galveston County Segment 1103B (Tidal Stream w/ high ALU): Bordens Gully (unclassified water body) — From the Dickinson Bayou Tidal confluence to a point 1.4 km (0.87 mi) upstream of FM 646 in Galveston County Segment 1103C (Tidal Stream w/ high ALU): Geisler Bayou (unclassified water body) — From the Dickinson Bayou Tidal confluence to a point 1.37 km (0.85 mi) upstream of FM 646 in Galveston County Segment 1003D (Tidal Stream w/ high ALU): Gum Bayou (unclassified water body) — From the Dickinson Bayou Tidal confluence to State Hwy 96 in Galveston County Segment 1003E (Perennial Stream w/ high ALU): Cedar Creek (unclassified water body) — From the Dickinson Bayou Tidal confluence to a point 0.63 km (0.39 mi) upstream FM 517 in Galveston County Segment 1003F (Tidal Stream w/ high ALU): Unnamed tributary of Dickinson Bayou Tidal (unclassified water body) – From the Dickinson Bayou Tidal confluence to a point 0.36 km (0.22 mi) upstream of State Hwy 6 Segment 1103G (Tidal Stream w/ high ALU): Unnamed Tributary of Gum Bayou (unclassified water body) – From the confluence with Gum Bayou to a point 0.39 miles south of the FM646/FM1266 intersection between League City and Dickinson

Percent of Stream Impaired or of Concern	
Segment ID	**Bacteria**
1103	100
1103A	100
1103B	100
1103C	100
1103D	100
1103E	100

Segment 1103					
Standards	Tidal Stream	Perennial Stream	**Screening Levels**	Tidal Stream	Perennial Stream
Temperature (°C/°F):	35 / 95	35 / 95	Ammonia-N (mg/L):	0.46	0.33
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	5.0	Nitrate-N (mg/L):	1.10	1.95
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	3.0	Orthophosphate Phosphorus (mg/L):	0.46	0.37
pH (standard units):	6.5-9.0	6.5-9.0	Total Phosphorus-P (mg/L):	0.66	0.69
Enterococci (MPN/100mL) (grab):	104		Chlorophyll-*a* (µg/L):	21	14.1
Enterococci (MPN/100mL) (geometric mean):	35				
E. coli (MPN/100 mL) (grab):		399			
E. coli (MPN/100 mL) (geometric mean):		126			

FY 2016 Active Monitoring Stations				
Site ID	**Site Description**	**Frequency**	**Monitoring Entity**	**Parameter Groups**
11434	Cedar Creek at FM 517	Quarterly	EIH	Field, Conventional, Bacteria
11436	Gum Bayou at FM 517	Quarterly	EIH	Field, Conventional, Bacteria
11455	Dickinson Bayou Tidal at SH 146	Quarterly	EIH	Field, Conventional, Bacteria
11460	Dickinson Bayou at SH 3	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
11462	Dickinson Bayou Tidal At IH-45	Quarterly	EIH	Field, Conventional, Bacteria
11464	Dickinson Bayou Tidal N of Arcadia	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16469	Borden's Gulley at FM 517	Quarterly	EIH	Field, Conventional, Bacteria
16470	Geisler Bayou at FM 517 Bridge	Quarterly	EIH	Field, Conventional, Bacteria
16471	Benson's Bayou on Wagon Rd	Quarterly	EIH	Field, Conventional, Bacteria
20477	Unnamed Trib of Dickinson Bayou at Ave L SW of Dickinson	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
20724	Borden's Gully at Spruce Drive	Quarterly	EIH	Field, Conventional, Bacteria, Flow
20728	Trib of Gum Bayou at Owens Drive	Quarterly	EIH	Field, Conventional, Bacteria, Flow

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Levels of Indicator Bacteria	1103 I 1103A I 1103B I 1103C I 1103D I 1103E I	▪ Rapid urbanization and increased impervious cover ▪ Constructed stormwater controls failing ▪ Animal waste from agricultural production and domestic animal facilities ▪ WWTF non-compliance, overflows, and collection system by-passes ▪ Poorly operated or undersized WWTFs ▪ Direct and dry weather discharges ▪ Waste haulers illegal discharges/improper disposal ▪ Improper or no pet waste disposal ▪ Developments with malfunctioning OSSFs	▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems ▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Create and implement Water Quality Management Plans for individual agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ Impose new or stricter bacteria limits than currently designated by TCEQ ▪ Increase monitoring requirements for self-reporting ▪ Regionalize chronically non-compliant WWTFs ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ More public education on pet waste disposal ▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs

Segment Discussion:

Watershed Characteristics: The Dickinson Bayou Tidal Watershed is heavily developed in the areas surrounding I-45 and FM517 around the City of Dickinson. This watershed also includes parts of Santa Fe and Texas City. Large tracts of the watershed are still undeveloped or are used for agriculture particularly at the west end of FM517 and south of the City of Dickinson. There are a number of small acreage farms is these areas that are used for grazing by cattle and horses. Most of the developed areas within the City of Dickinson are served by WWTFs but the rest of the rural area uses OSSFs.

Water Quality Issues: The 2014 Texas Integrated Report lists all four assessment units of segment 1103 as well as five tributaries (1103A, 1103B, 1103C, 1103D, and 1103E) as impaired for contact recreation due to high levels of indicator bacteria. Unclassified segment 1103G is listed as a concern for near nonattainment. Unclassified segment 1103F was not assessed for the 2014 IR; however, data suggests that this segment is highly impaired for contact recreation. A table of the TCEQ assessment as well as H-GAC 7 year analyses is located below:

Assessment Unit	TCEQ Assessment (2005-2012) Geomean (MPN/100 mL) / % Grab Exceedance	HGAC Analysis 2001-2008 Geomean (MPN/100 mL) / % Grab Exceedance	HGAC Analysis 2008-2015 Geomean (MPN/100 mL) / % Grab Exceedance
1103_01	73 / NA	31 / 25.0	91 / 32.1
1103_02	52 / NA	22 / 19.5	55 / 34.4
1103_04	137 / NA	65 / 39.6	155 / 59.3
1103A_01	271 / NA	91 / 43.5	271 / 67.9
1103B_01	400 / NA	213 / 81.0	489 / 82.6
1103C_01	388 / NA	143 / 61.9	310 / 82.1
1103D_01	112 / NA	41 / 17.4	141 / 44.4
1103E_01	127 / NA	131 / 18.2	114 / 3.8
1103F_01	1454 / NA	NA / NA	598 / 78.6
1103G_01	694 / NA	NA / NA	669 / 76.5

Special Studies/Projects: This segment has been included in two TMDL projects and a watershed protection plan (WPP). The bacteria TMDL and I-Plan was completed for this segment and the above tidal segment in 2014. The WPP is being revised to address comments made by the

EPA. Texas A&M AgriLife facilitated both the TMDL and the WPP projects. Texas AgriLife is currently working with the Texas Institute for Applied Environmental Research at Tarleton State University and stakeholders to complete a crosswalk document between the completed TMDL and the draft WPP. The completed crosswalk will assist the WPP approval process. Dickinson Bayou Tidal is also part of the Galveston Bay System Survey for Dioxin and PCBs. Texas AgriLife is facilitating the Galveston – Brazoria County Coalition of Watersheds to bring stakeholders involved in TMDL I-Plan and WPP implementation, including this watershed, together to build cooperation on common bacteria issues and BMPs. The goal is a regional watershed planning group that will elevate issues and attract funding.

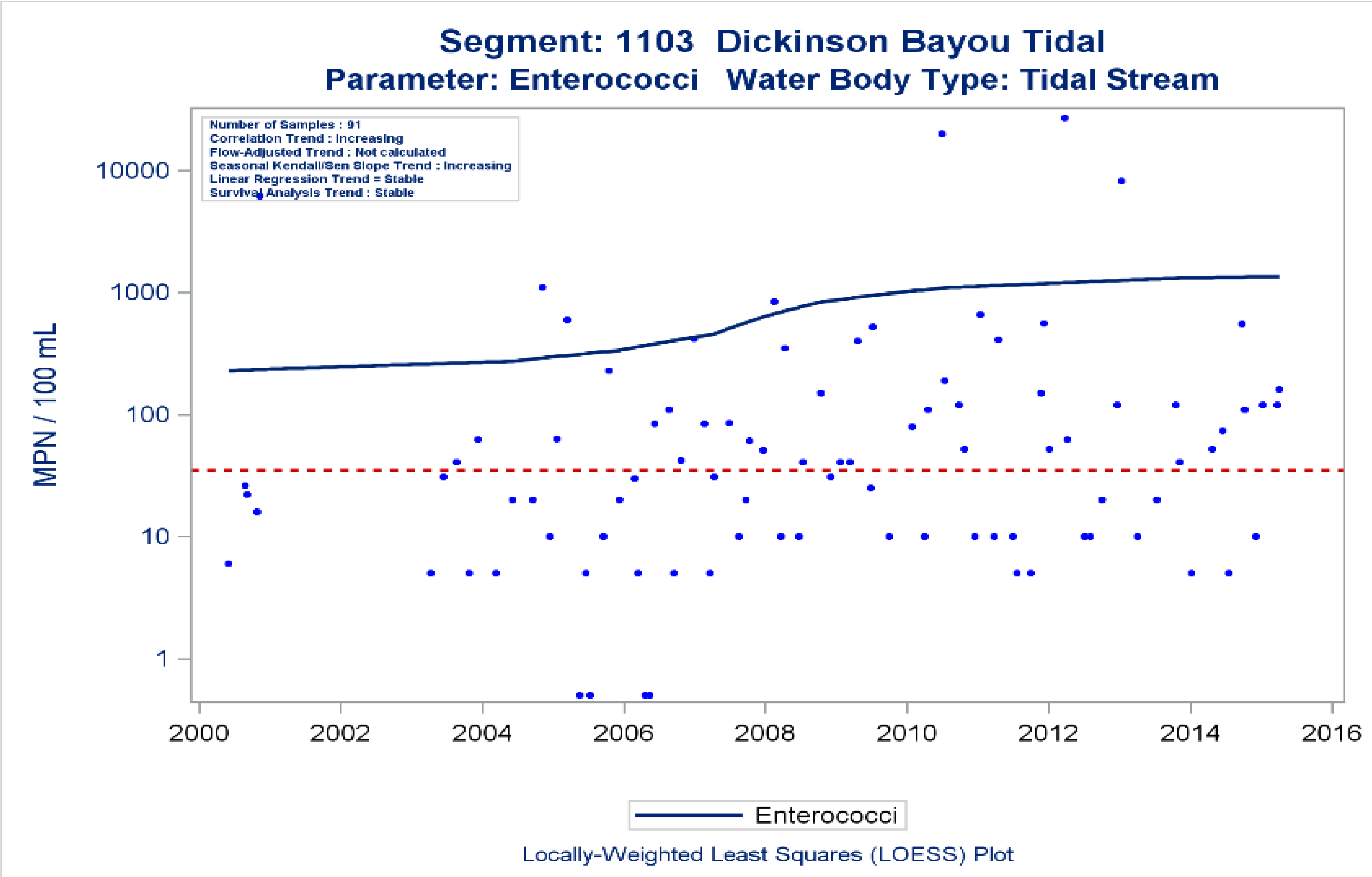
The Galveston Bay Foundation with TCEQ completed the Upper Texas Gulf Coast Oyster Waters TMDL I-Plan in 2015, which includes Dickinson Bay.

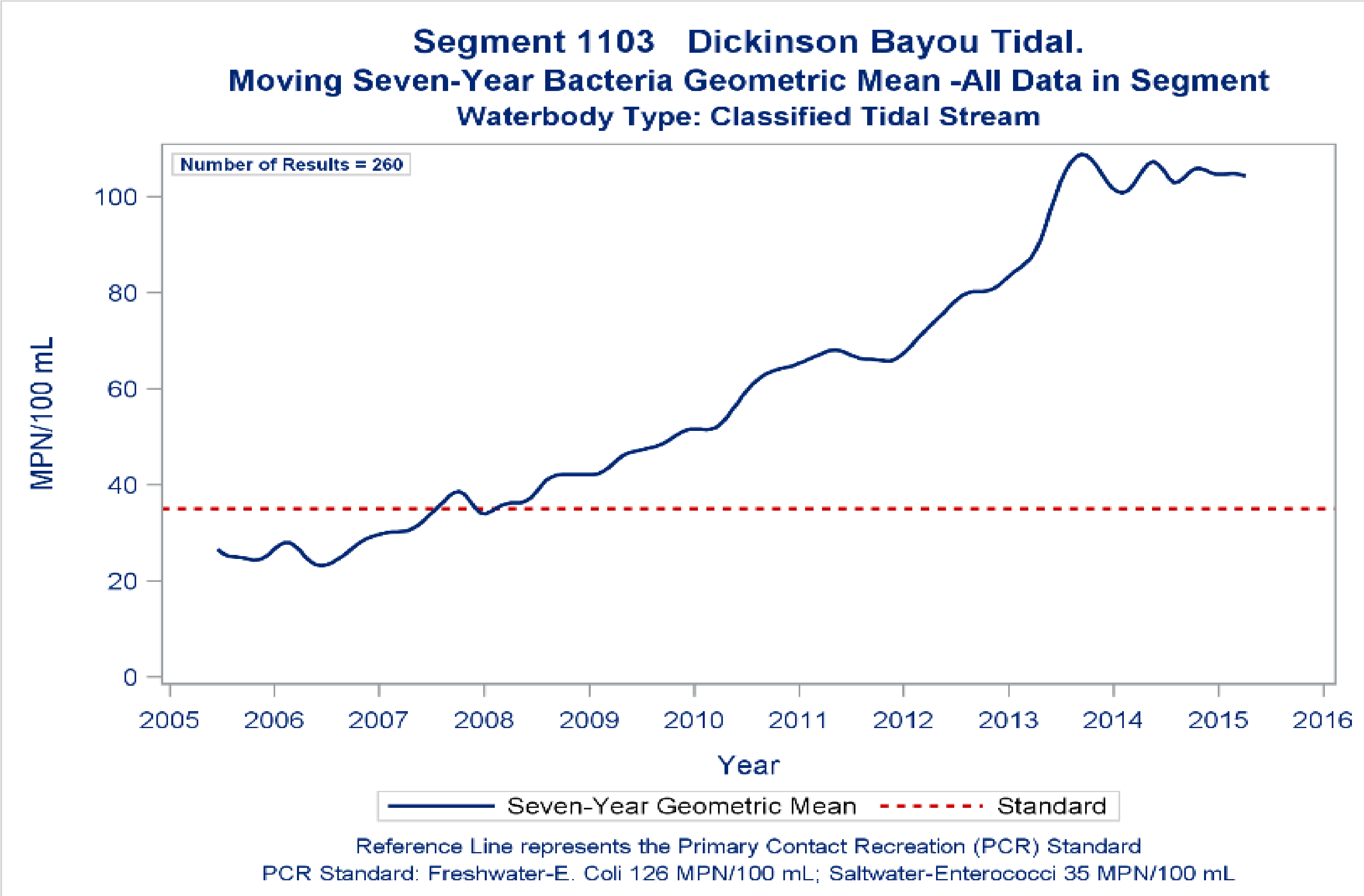
Implementation measures are currently underway. There are seven specific implementation measures for Dickinson Bayou WPP:

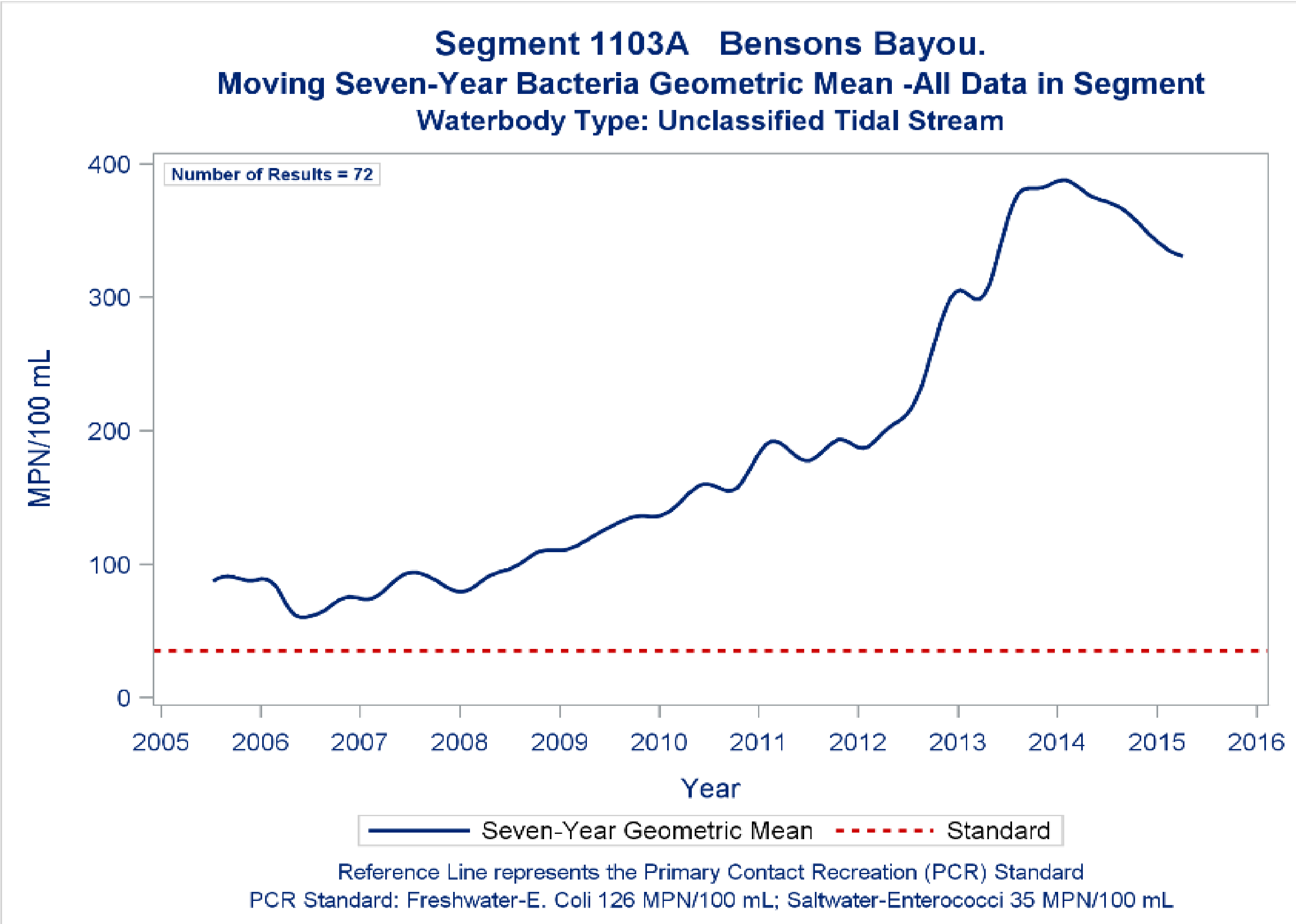
1. Manage OSSFs
2. Address WWTFs & collection systems
3. Address animal waste
4. Restore and repair riparian zones
5. Preserve and restore natural wetlands
6. Construct stormwater treatment wetlands
7. Implement stormwater Best Management Practices (BMP)

Trends: Regression analysis of water quality data revealed 1 statistically significant bacteria trend for all segments in the Dickinson Bayou Tidal watershed. An increase in enterococci was detected for segment 1103D, Gum Bayou.

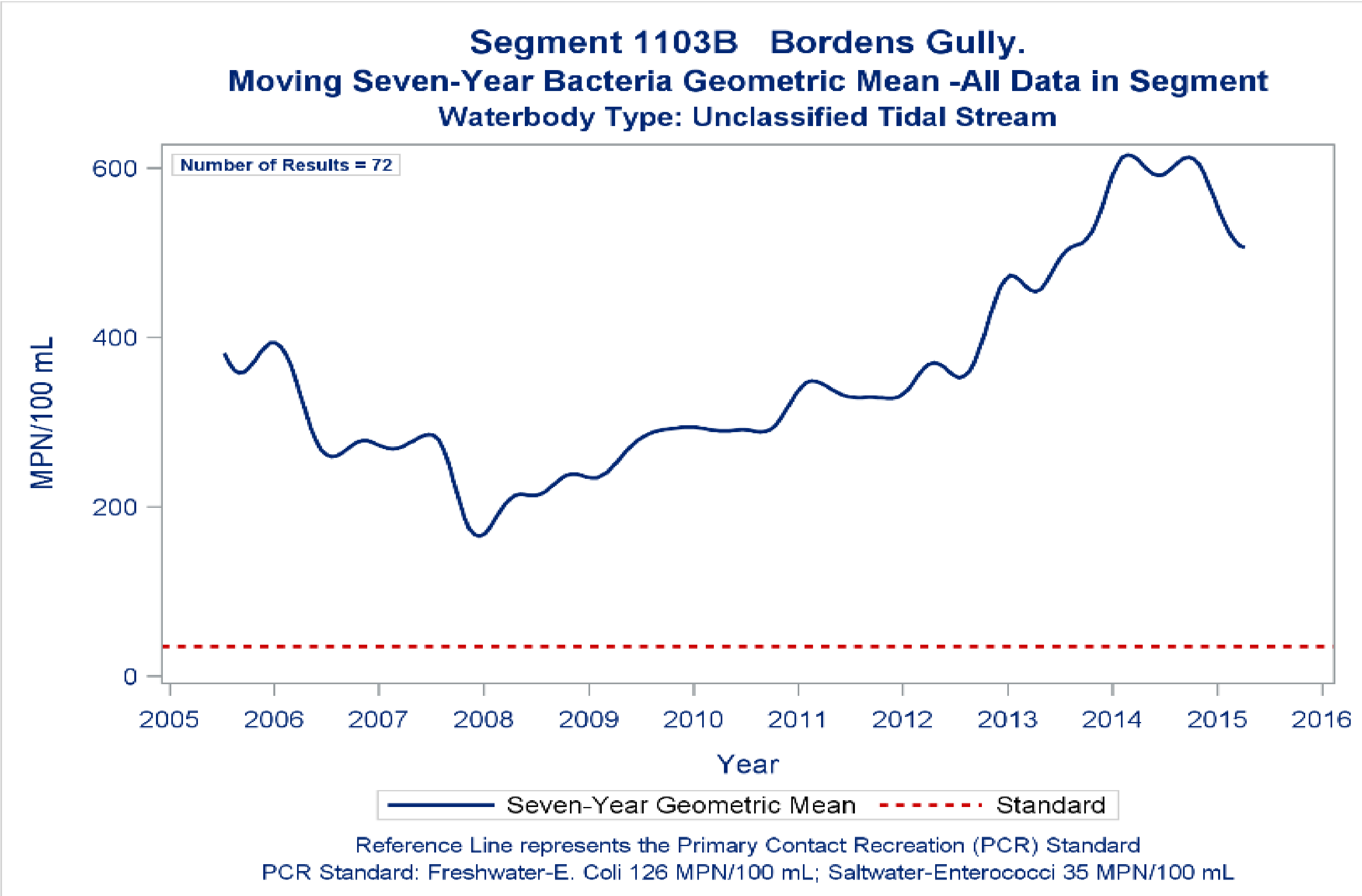
The entire Dickinson Bayou Tidal watershed is designated as impaired for bacteria. Current trends and moving geometric means for enterococci show that bacteria levels are still a major concern in this watershed. Regression analysis of bacteria data for the main segment revealed a gradual increase in enterococci over time with concentrations reaching levels greater than 10,000 MPN/100 mL during the period of record. Moving seven-year bacteria geometric means for each segment in this watershed show mean enterococci gradually increasing at levels significantly higher than the 35 MPN/100 mL water quality standard.


Segment: 1103 Dickinson Bayou Tidal
Parameter: Enterococci Water Body Type: Tidal Stream
Number of Samples : 91
Correlation Trend : Increasing
Flow-Adjusted Trend : Not calculated
Seasonal Kendall/Sen Slope Trend : Increasing
Linear Regression Trend = Stable
Survival Analysis Trend : Stable
MPN / 100 mL
10000
1000
100
10
1
2000
2002
2004
2006
2008
2010
2012
2014
2016
Enterococci
Locally-Weighted Least Squares (LOESS) Plot

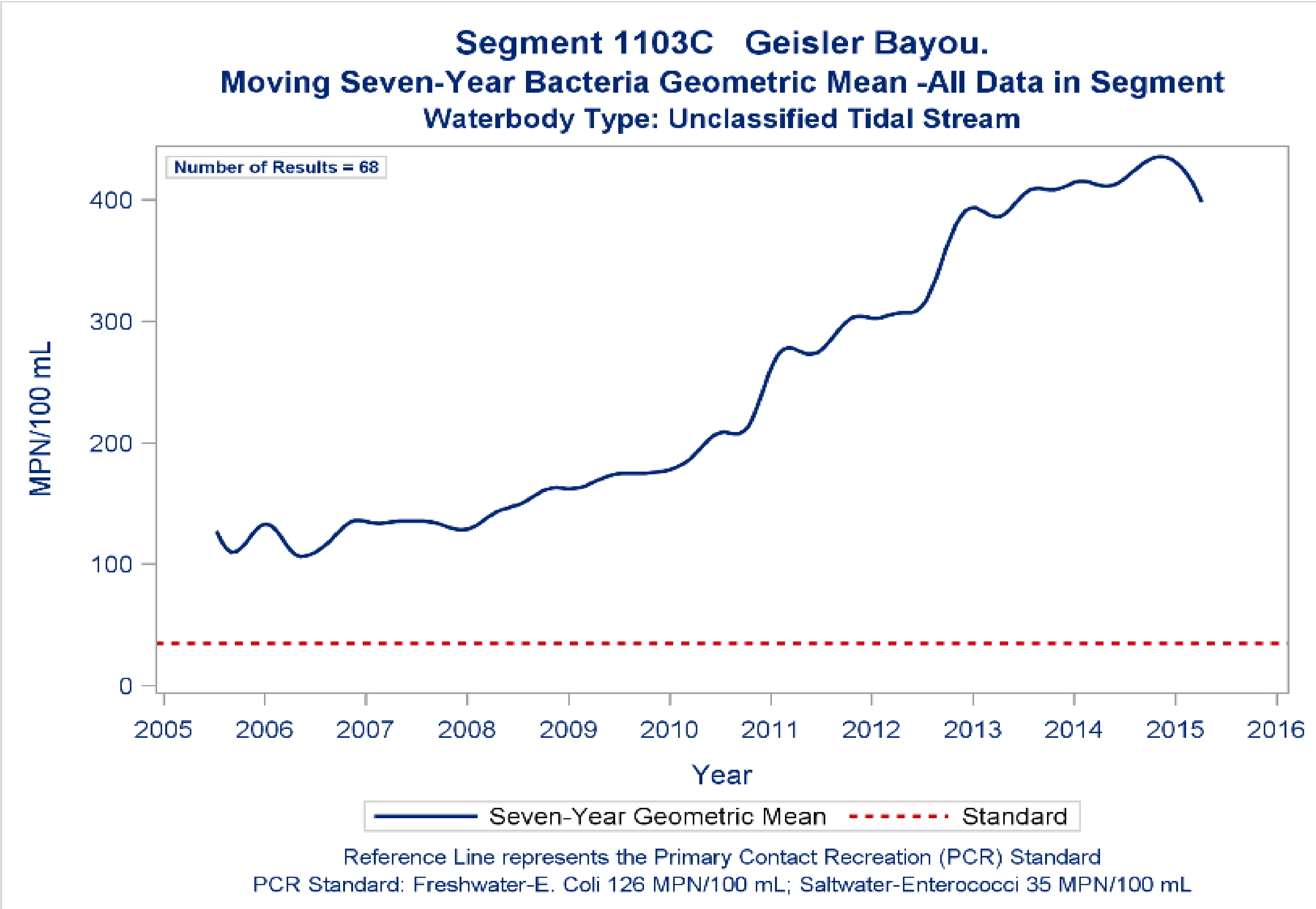

Segment 1103 Dickinson Bayou Tidal.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Classified Tidal Stream
Number of Results = 260
MPN/100 mL
100
80
60
40
20
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

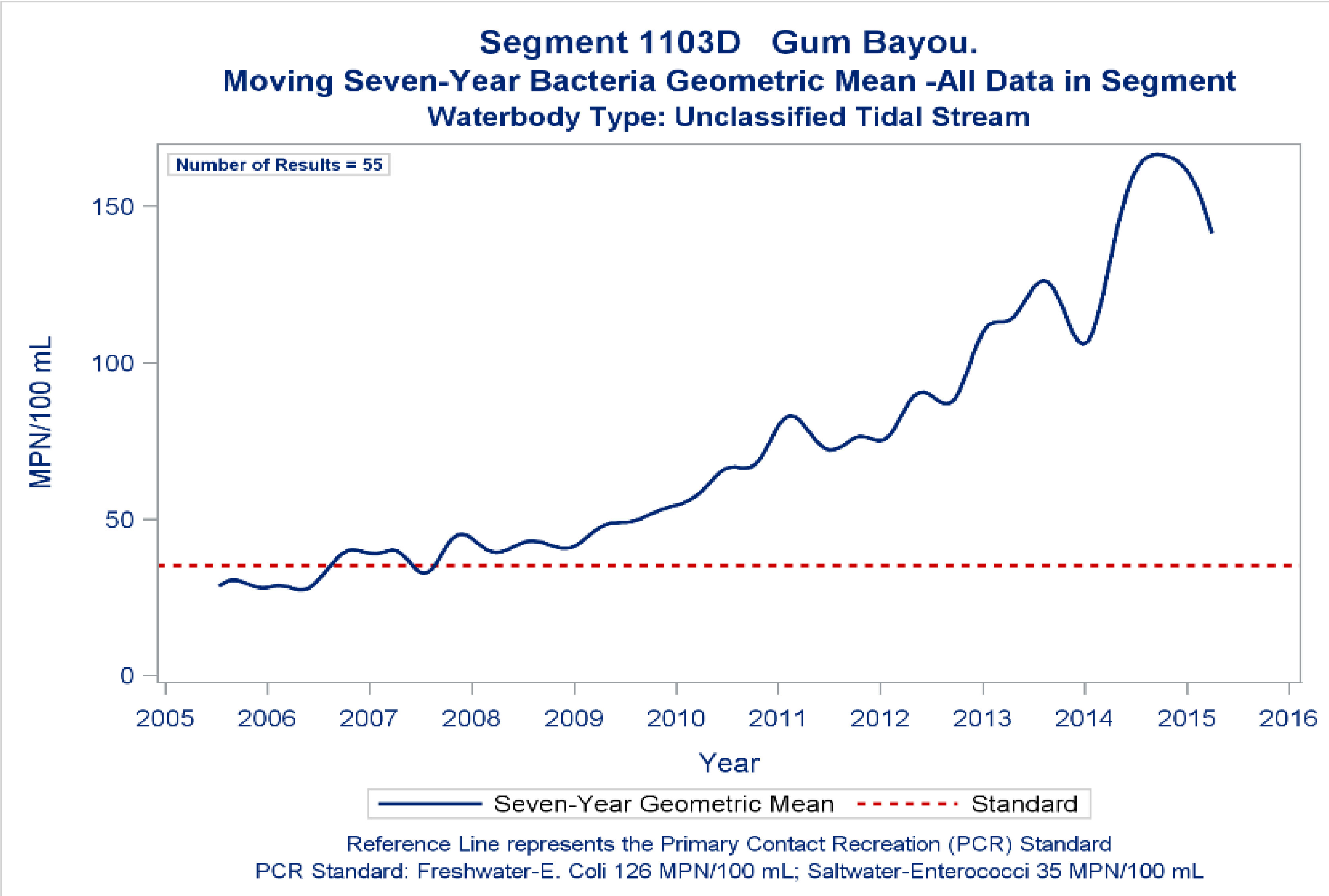


Segment 1103A Bensons Bayou.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 72
400
300
200
100
0
MPN/100 mL
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL



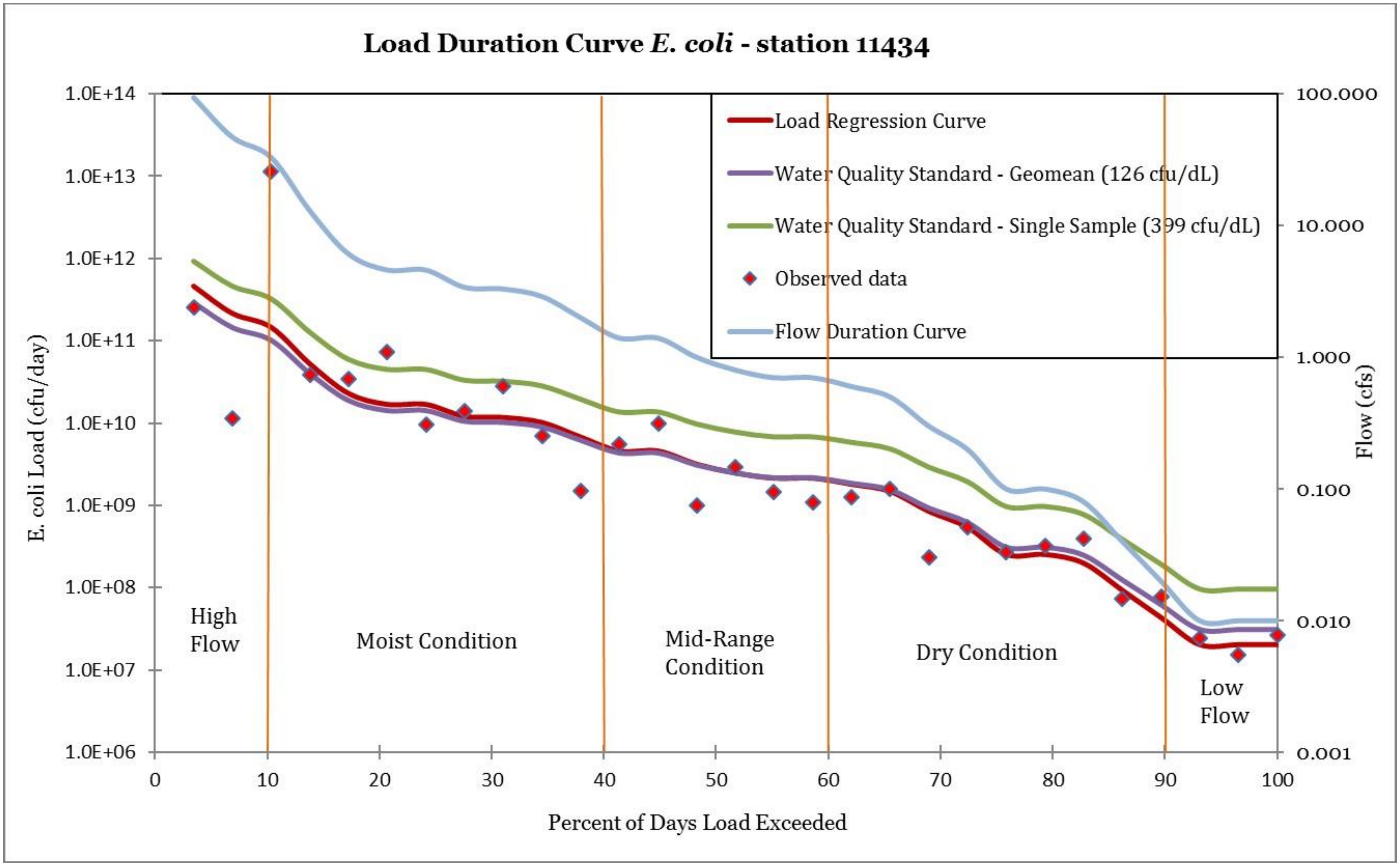
Segment 1103B Bordens Gully.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 72
600
400
200
0
MPN/100 mL
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL


Segment 1103C Geisler Bayou.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 68
MPN/100 mL
0
100
200
300
400
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

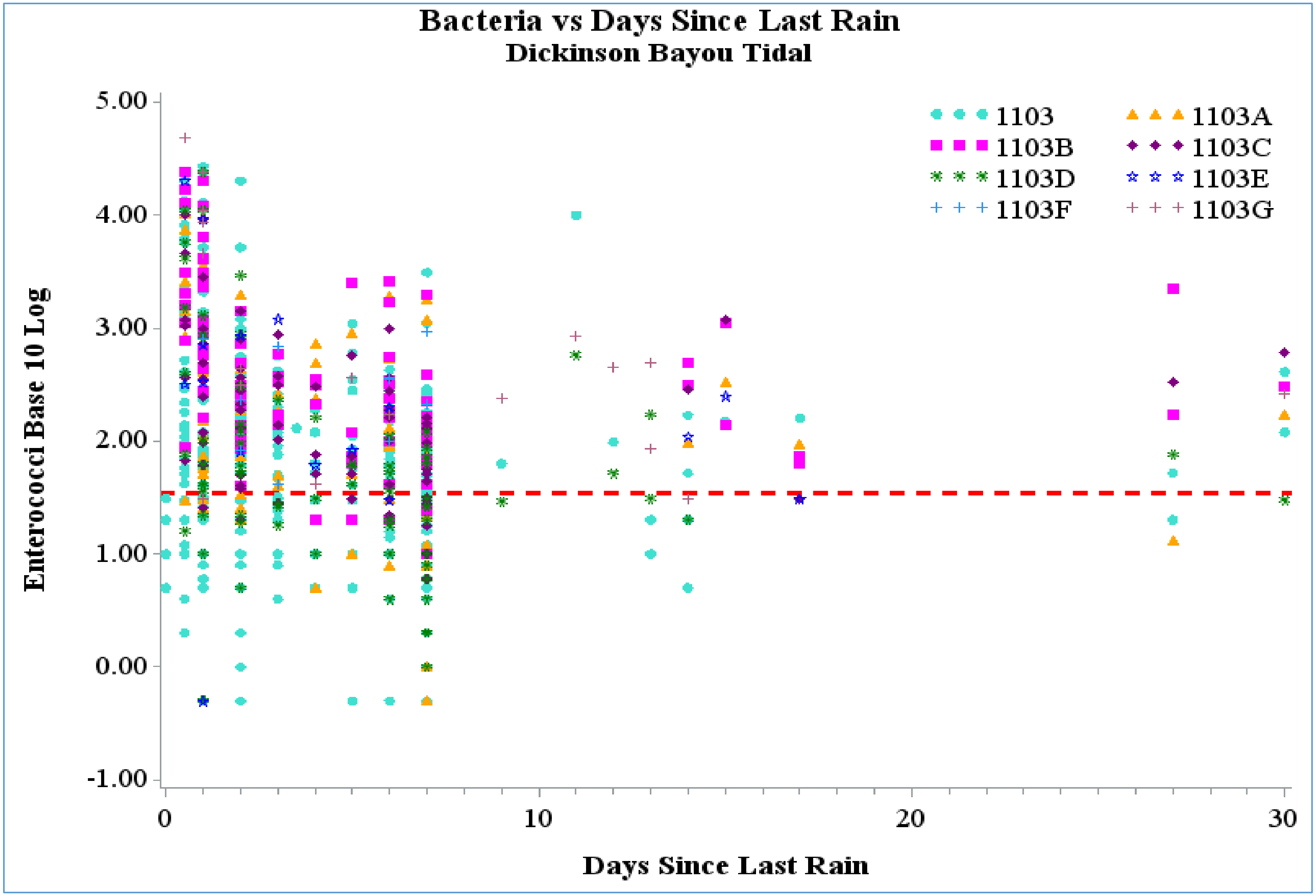

Segment 1103D Gum Bayou.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 55
150
100
50
0
MPN/100 mL
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

Load Duration Curves

Available flow data and bacteria date were sufficient to complete an LDC for one station in this tidal segment, 11434 Cedar Creek. Using the results of the LDC and the Days Since Last Rain, factors affecting bacteria levels in this segment do not appear to strongly correlate with potential waste loads from WWTFs and OSSFs during dry conditions. Reading the LDC, the Load Regression Curve for bacteria data plotted remains below the single grab standard and parallels the geomean standard curve through all conditions. We would expect wastewater treatment and OSSF to be contributing to bacteria exceedances when the LDC load regression curve is found above the standard during dry weather conditions, when nonpoint sources are little to nonexistent. The Days Since Last Rain last rainfall supports this conclusion as 11434 station on Cedar Creek (1103E) tracks slightly above the standard but remain close to the standard (Dashed red Line). LDCs for other assessment units for this tidal segment were not developed as flow is difficult to calculate in tidal conditions. Looking at the Days Since Last Rain for these assessment units excluding 1103F and the above mentioned 1103E, there does appear that waste

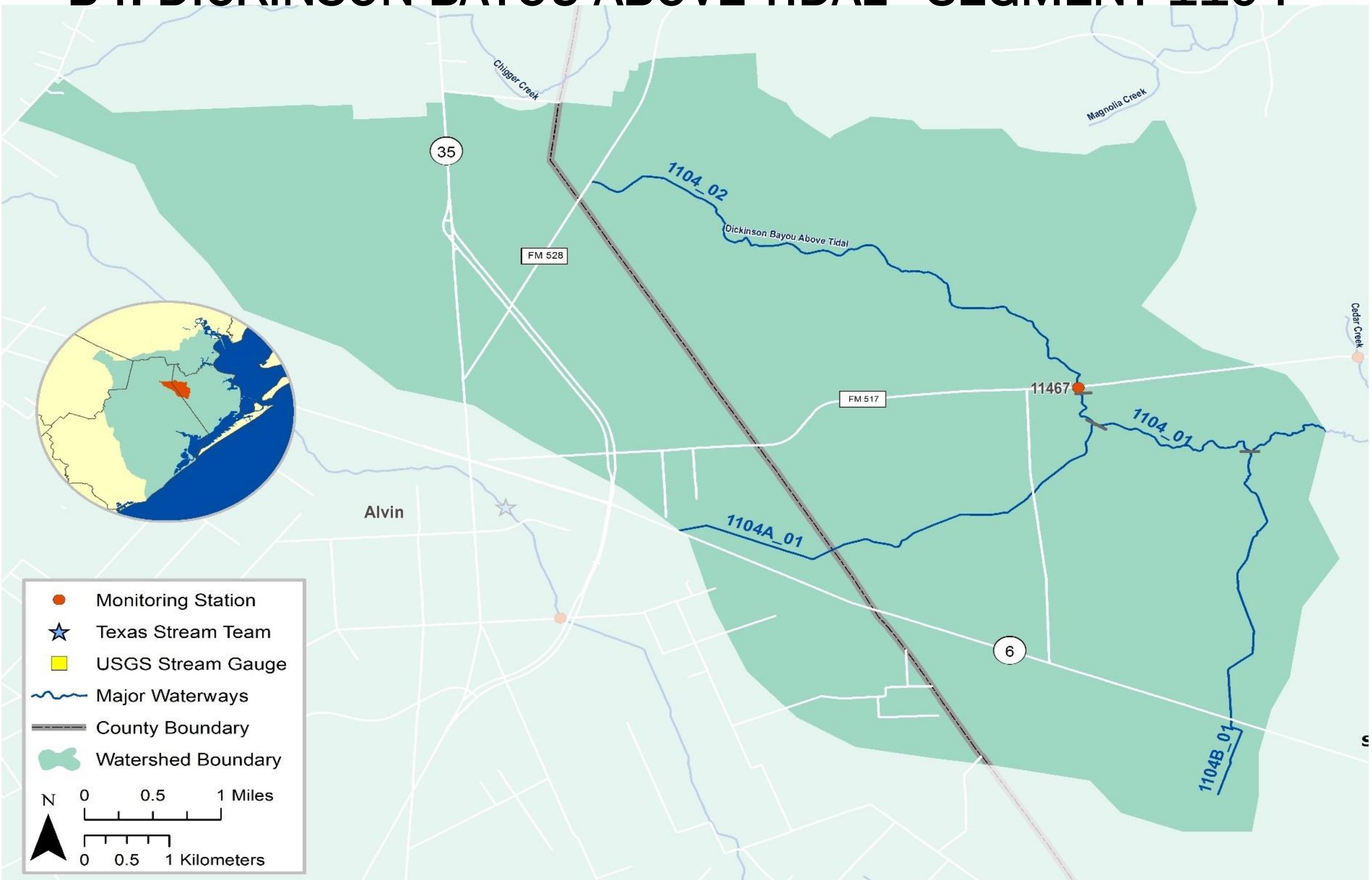


Load Duration Curve E. coli - station 11434
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
E. coli Load (cfu/day)
100.000
10.000
1.000
0.100
0.010
0.001
Flow (cfs)
Load Regression Curve
Water Quality Standard - Geomean (126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow
0
10
20
30
40
50
60
70
80
90
100
Percent of Days Load Exceeded

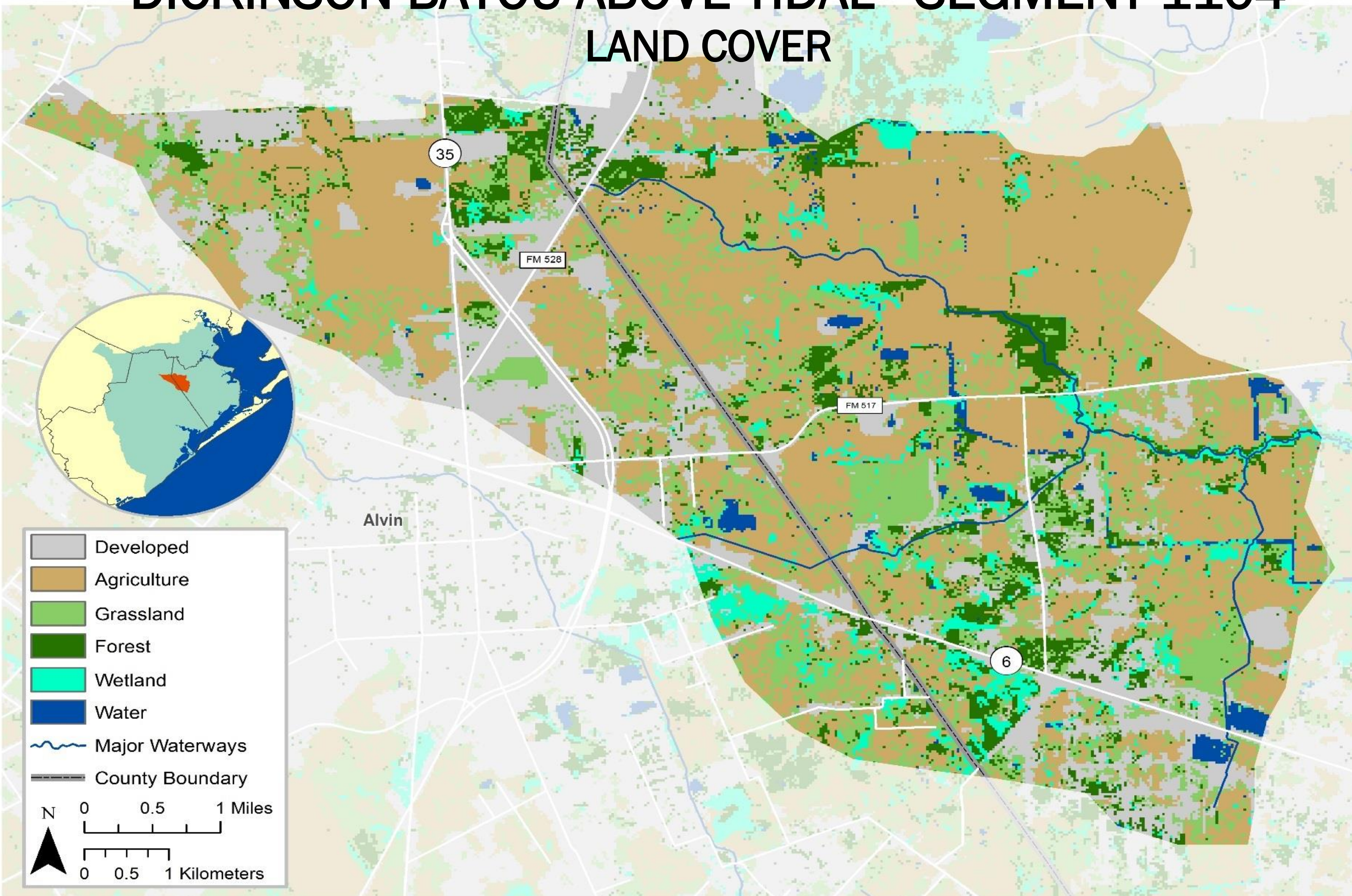

Bacteria vs Days Since Last Rain
Dickinson Bayou Tidal
Enterococci Base 10 Log
Days Since Last Rain
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
0
10
20
30
1103
1103A
1103B
1103C
1103D
1103E
1103F
1103G

Recommendations
Address concerns found in this segment summary through stakeholder participation.
Continue collecting water quality data to support actions associated with the TMDL I-Plan and any future watershed protection plan.
Continue working with Texas AgriLife to implement the WPP.
Support and track the implementation of best practices to reduce bacteria under elements of the Dickinson and Upper Gulf Coast Oyster Waters TMDL I-Plans.

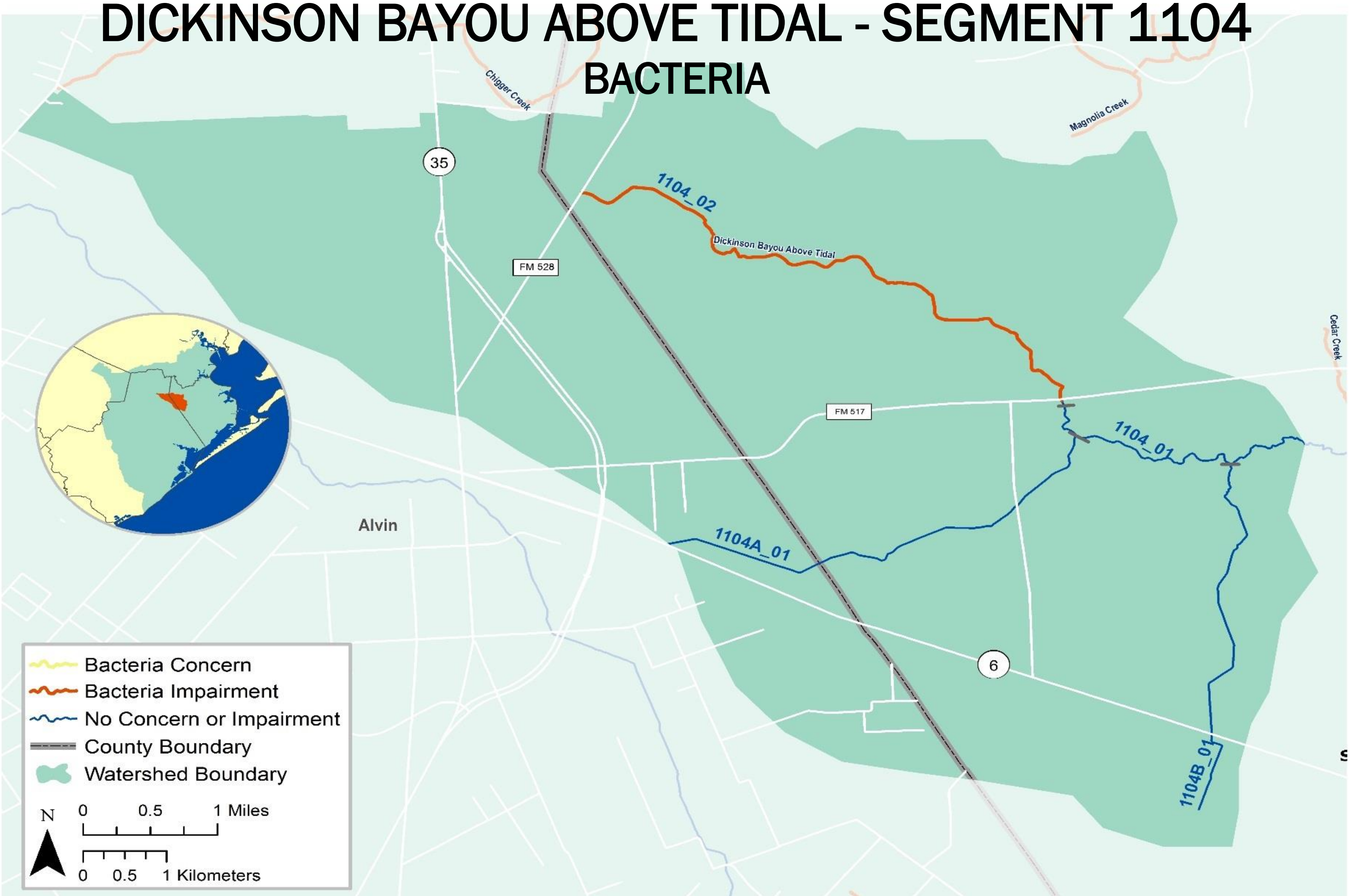
B4. DICKINSON BAYOU ABOVE TIDAL - SEGMENT 1104

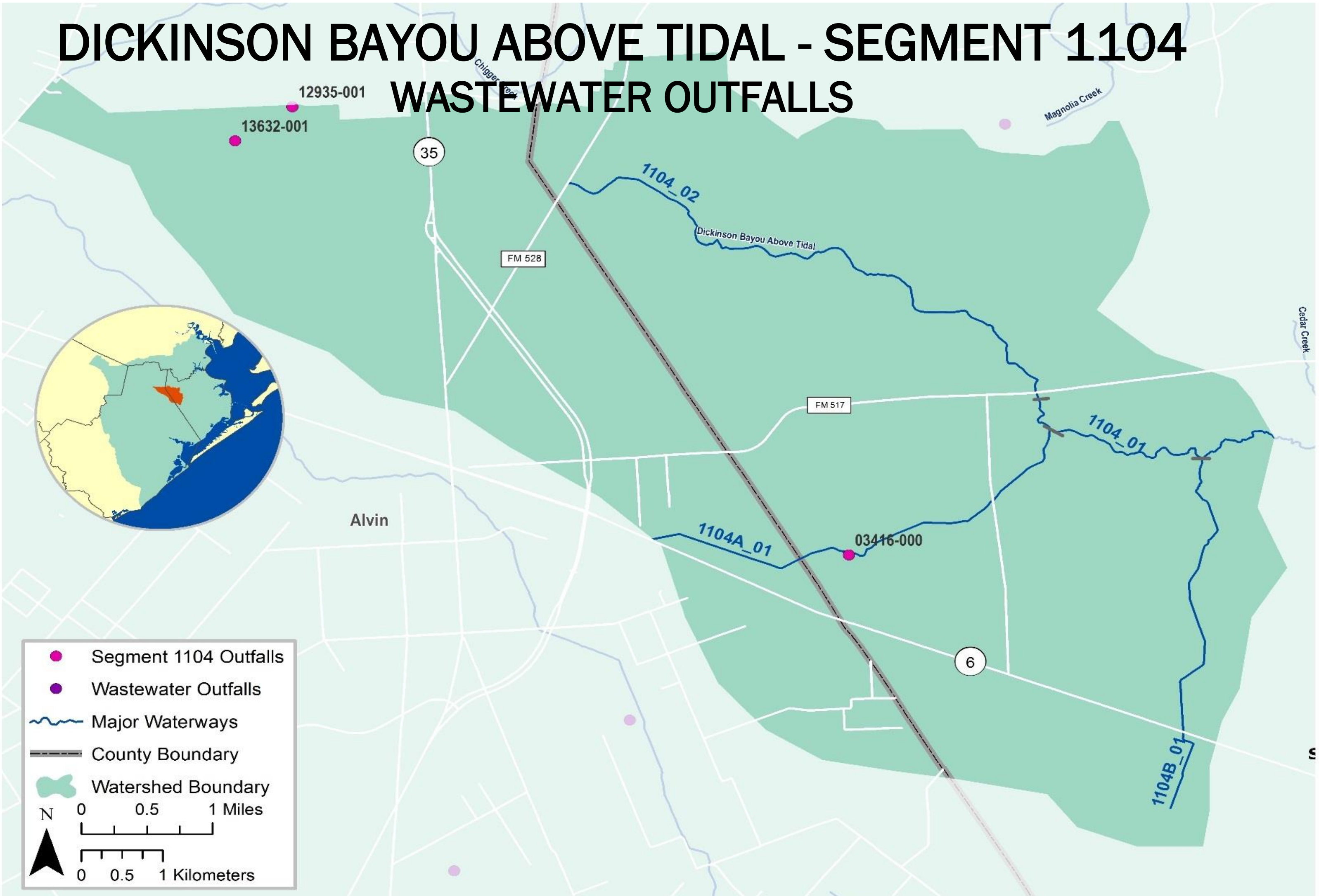


DICKINSON BAYOU ABOVE TIDAL - SEGMENT 1104
LAND COVER



DICKINSON BAYOU ABOVE TIDAL - SEGMENT 1104
BACTERIA





DICKINSON BAYOU ABOVE TIDAL - SEGMENT 1104
WASTEWATER OUTFALLS
12935-001
13632-001
35
FM 528
1104_02
Dickinson Bayou Above Tidal
Magnolia Creek
Cedar Creek
FM 517
1104_01
1104A_01
03416-000
Alvin
6
1104B_01
Segment 1104 Outfalls
Wastewater Outfalls
Major Waterways
County Boundary
Watershed Boundary
N
0 0.5 1 Miles
0 0.5 1 Kilometers

Segment Number:	1104	Name:	Dickinson Bayou Above Tidal		
Length:	8 miles	Watershed Area:	32 square miles	Designated Uses:	Primary Contact Recreation 1; Intermediate Aquatic Life
Number of Active Monitoring Stations:	1	Texas Stream Team Monitors:	0	Permitted Outfalls:	3
Description:	Segment 1104 (Perennial Stream w/ intermediate ALU): From a point 4.0 km (2.5 mi) downstream of FM517 in Galveston County to FM 528 in Galveston County Segment 1104A (Perennial Stream w/ high ALU): Unnamed Tributary of Dickinson Bayou Above Tidal (unclassified water body) – From the Dickinson Bayou Above Tidal confluence to State Hwy 6 Segment 1104B (Perennial Stream w/ high ALU): Unnamed Tributary of Dickinson Bayou Above Tidal (unclassified water body) – From the Dickinson Bayou Above Tidal confluence to a point 0.46 km (0.73 mi) upstream of State Hwy 6				

Percent of Stream Impaired or of Concern	
Segment ID	Bacteria
1104	72

Segment 1104

Standards	Perennial Stream	Screening Levels	Perennial Stream
Temperature (°C/°F):	32 / 90	Ammonia (mg/L):	0.33
Dissolved Oxygen *(24-Hr Average)* (mg/L):	5.0 / 4.0	Nitrate-N (mg/L):	1.95
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0 / 3.0	Orthophosphate Phosphorus (mg/L):	0.37
pH (standard units):	6.5-9.0	Total Phosphorus (mg/L):	0.69
E. coli (MPN/100 mL) (grab):	399	Chlorophyll *a* (µg/L):	14.1
E. coli (MPN/100 mL) (geometric mean):	126		
Chloride (mg/L as Cl):	200		
Sulfate (mg/L as SO_4):	100		
Total Dissolved Solids (mg/L):	600		

FY 2016 Active Monitoring Stations

Site ID	Site Description	Frequency	Monitoring Entity	Parameter Groups
11467	Dickinson Bayou at FM 517	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*, Flow

Water Quality Issues Summary			
Issue	2014 Assessment *I – Impaired* *C – Of Concern*	Possible Causes / Influences / Concerns Voiced by Stakeholders	Possible Solutions / Actions To Be Taken
Elevated Levels of Indicator Bacteria	1104 I	▪ Animal waste from agricultural production, wildlife ranch, and domestic animal facilities ▪ Constructed stormwater controls failing ▪ Rapid urbanization and increased impervious cover ▪ Developments with malfunctioning OSSFs ▪ Improper or no pet waste disposal ▪ Poorly operated or undersized WWTFs ▪ Waste haulers illegal discharges/improper disposal ▪ Direct and dry weather discharges ▪ WWTF non-compliance, overflows, and collection system by-passes	▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Create and implement Water Quality Management Plans for individual agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems ▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education on pet waste disposal ▪ Regionalize chronically non-compliant WWTFs ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Impose new or stricter bacteria limits than currently designated by TCEQ ▪ Increase monitoring requirements for self-reporting

Segment Discussion:

Watershed Characteristics: The Dickinson Bayou Above Tidal watershed is not as developed as many of the surrounding watersheds. It includes portions of the cities of Santa Fe, League City, Friendswood, and Alvin. Residential and commercial development has been occurring throughout the watershed along major thoroughfares such as FM528 and Texas Highway 6. The predominant land use in the watershed is agriculture and grassland. The majority of the watershed is on OSSFs. There is a large wildlife ranch located immediately downstream of FM517 on the western and southern shoreline of the bayou.

Water Quality Issues: The 2014 Texas Integrated Report (IR) lists the assessment unit 1104_02 as impaired for contact recreation due to elevated levels of *E. coli*. A graph of the moving seven year bacteria geomean is located to the right.

Special Studies/Projects: This segment has been included in a bacteria TMDL project and a watershed protection plan (WPP), both of which are facilitated by Texas AgriLife. The TMDL and I-Plan has been completed and approved by the TCEQ and EPA. The WPP has been completed but is still waiting for EPA approval. Texas AgriLife is currently working with the Texas Institute for Applied Environmental Research at Tarleton State University and stakeholders to complete a crosswalk document between the completed TMDL and the draft WPP. The completed crosswalk will assist the WPP approval process. Texas AgriLife is facilitating the Galveston – Brazoria County Coalition of Watersheds to bring stakeholders involved in TMDL I-Plan and WPP implementation, including this watershed, together to build cooperation on common bacteria issues and BMPs. The goal is a regional watershed planning group that will elevate issues and attract funding.

The Galveston Bay Foundation with the TCEQ completed an I-Plan for the Upper Texas Gulf Coast Oyster Waters TMDL in 2015. An RUAA survey was completed for this AU and is currently under review by the TCEQ. Should the RUAA proceed, next steps would include approving the survey and developing recommendations.

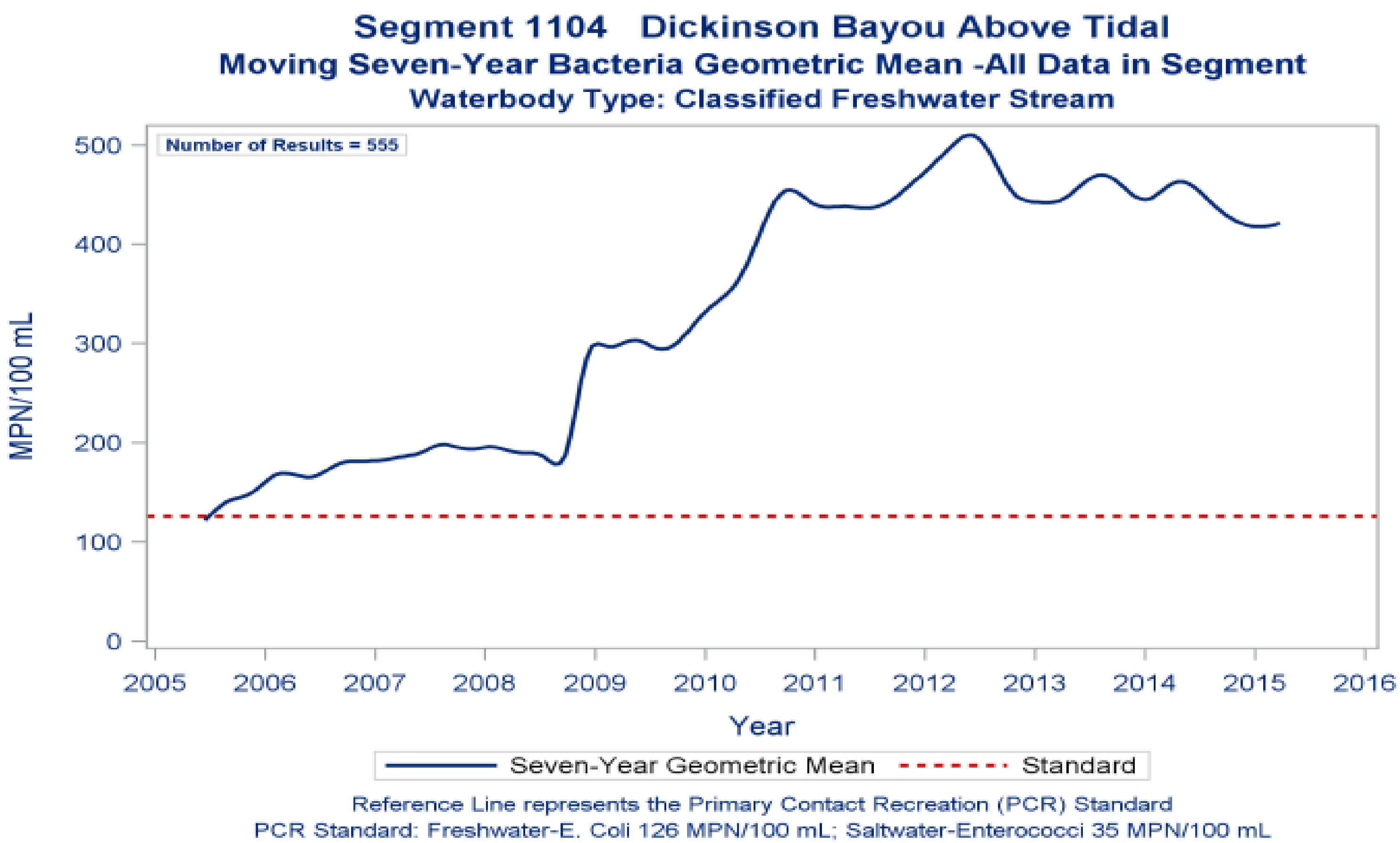
Implementation measures are currently underway. There are seven specific implementation measures for Dickinson Bayou WPP:

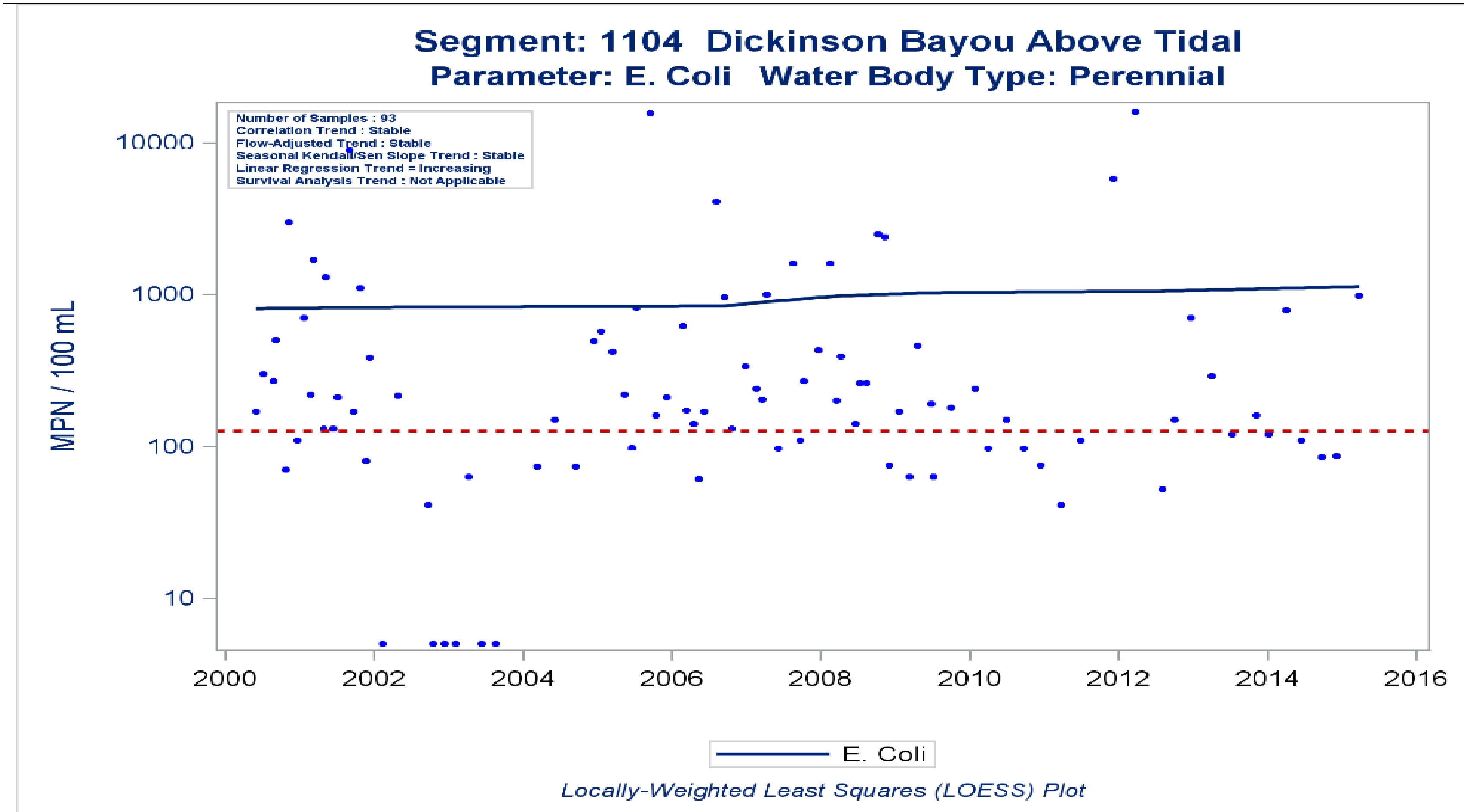
1. Manage OSSFs
2. Address WWTFs & collection systems
3. Address animal waste

4. Restore and repair riparian zones
5. Preserve and restore natural wetlands
6. Construct stormwater treatment wetlands
7. Implement stormwater Best Management Practices (BMP)

Trends: This segment is currently impaired for bacteria.

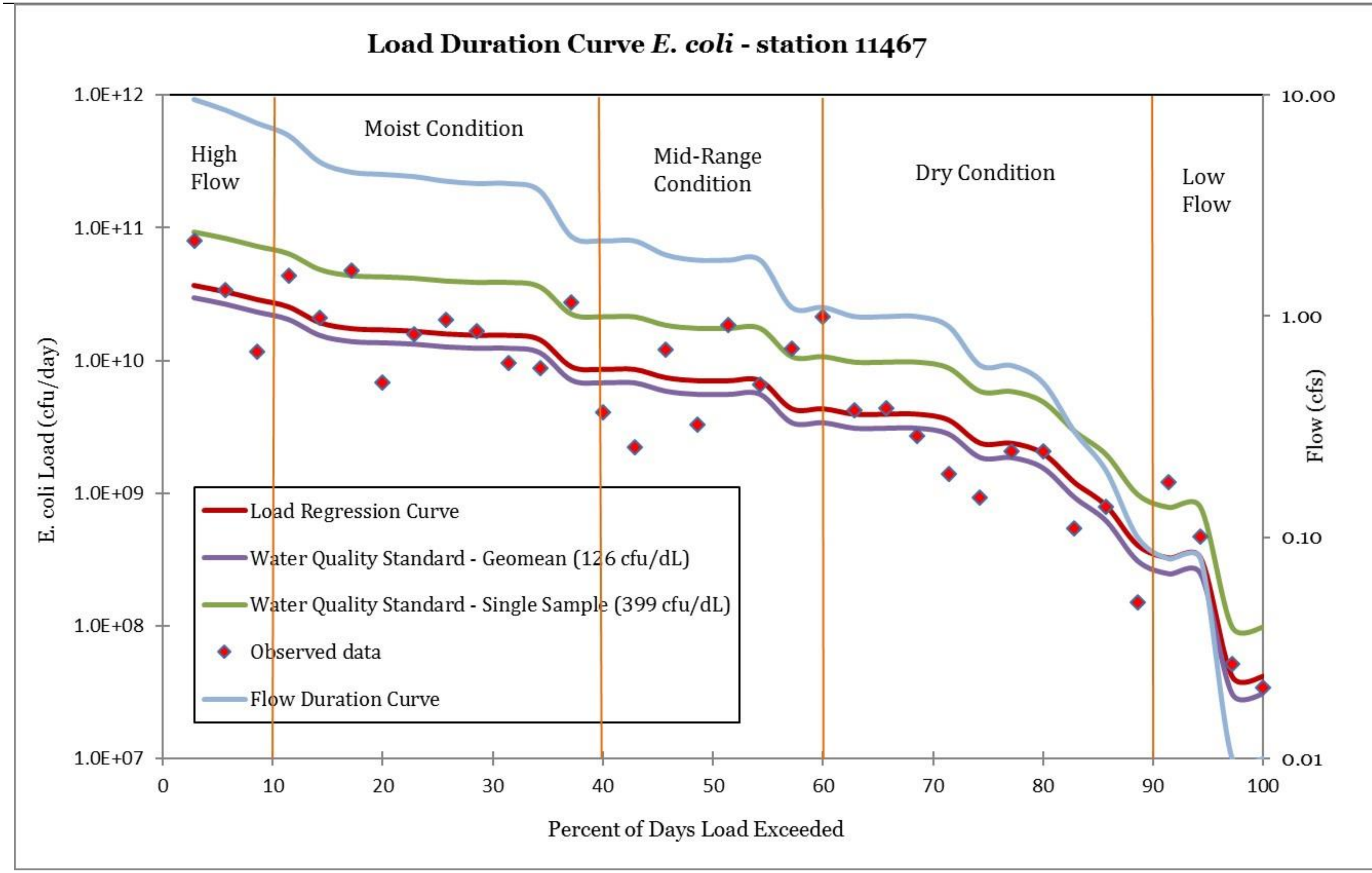
No significant changes over time were detected for *E. coli* during the period of record, although the majority of samples collected exceed the state water quality standard of 126 MPN/100 mL. Moving seven-year bacteria geometric means support this observation with mean *E.coli* levels consistently fluctuating above the standard since 2005. Mean bacteria levels reached their peak in 2012 and appear to be making a slow decline since then, but there is still a long way to go before concentrations fall within compliance.


Segment 1104 Dickinson Bayou Above Tidal
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Classified Freshwater Stream
Number of Results = 555
500
400
300
200
100
0
MPN/100 mL
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

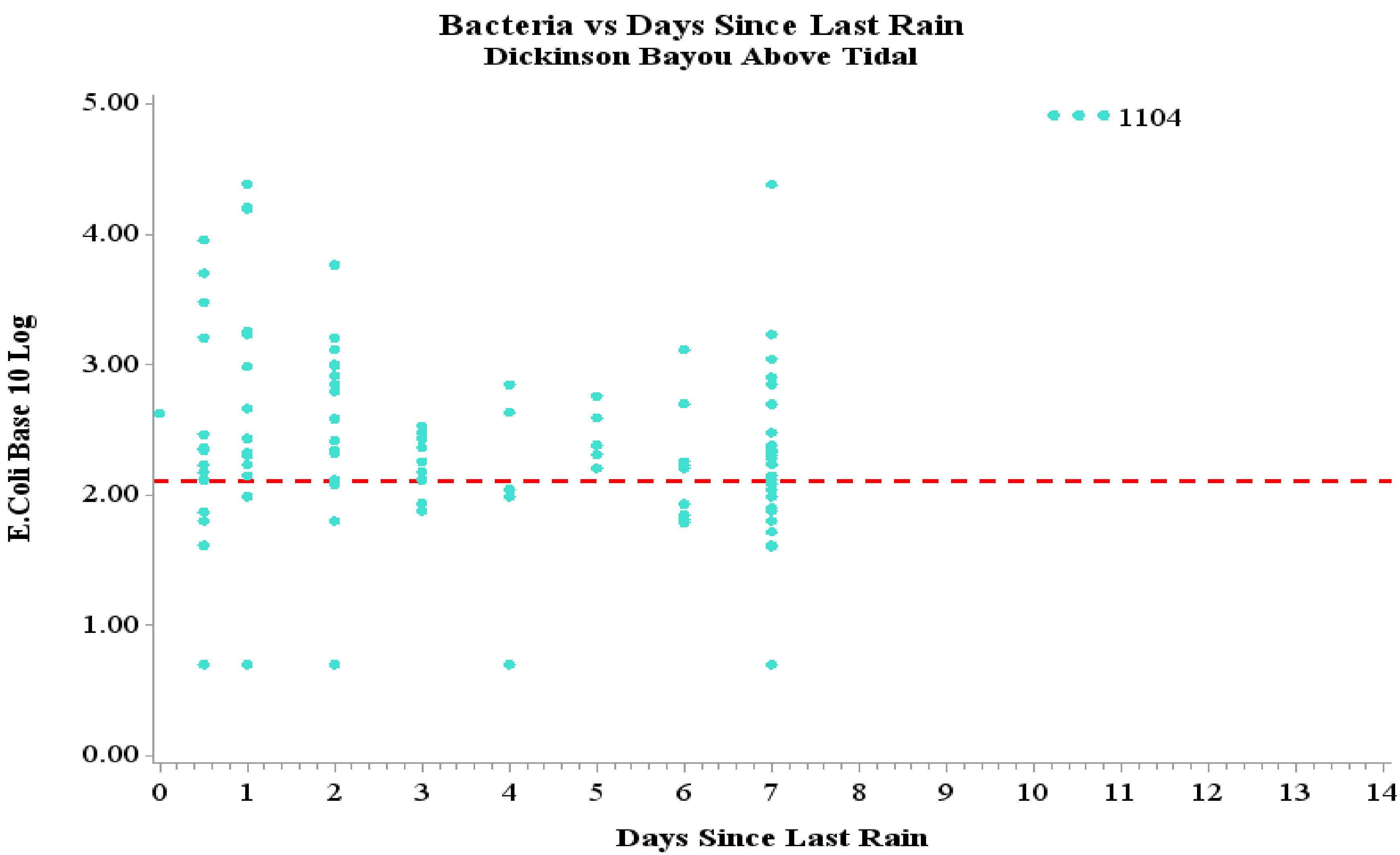

Segment: 1104 Dickinson Bayou Above Tidal
Parameter: E. Coli Water Body Type: Perennial
Number of Samples : 93
Correlation Trend : Stable
Flow-Adjusted Trend : Stable
Seasonal Kendall/Sen Slope Trend : Stable
Linear Regression Trend = Increasing
Survival Analysis Trend : Not Applicable
MPN / 100 mL
10000
1000
100
10
2000
2002
2004
2006
2008
2010
2012
2014
2016
E. Coli
Locally-Weighted Least Squares (LOESS) Plot

Load Duration Curve

Available flow data and bacteria data were sufficient to complete an LDC for one station in this above tidal segment, 11467. The size of the catchment area for this station is 16 acres and 883 ac. ft. of catchment volume. Land use is mixed with residential, industrial and agriculture. Continuous flow is not available for this station, however, surrogate flow data was taken from an adjacent catchment, segment 1101, station 16493, that contains similar characteristics (16 acres, 706 ac-ft. volume and common land uses). Using the results of the LDC and the Days Since Last Rain, factors affecting bacteria levels in this segment do appear to correlate with potential waste loads from WWTFs and OSSFs. Reading the LDC, the Load Regression Curve for bacteria data plotted exceeds the geomean standard while below the single grab standard for 100 percent of the Percent of Days Exceeded covering all conditions from extremely wet to extremely dry. We expect wastewater treatment and OSSFs as likely contributing to bacteria exceedances when the LDC load regression curve is found above the standard during dry weather conditions, when nonpoint sources are little to non-existent. The Days Since Last Rain support this as a majority of the observed bacteria data taken for all time frames since the last recorded rainfall appear to exceed the standard (dashed red line).

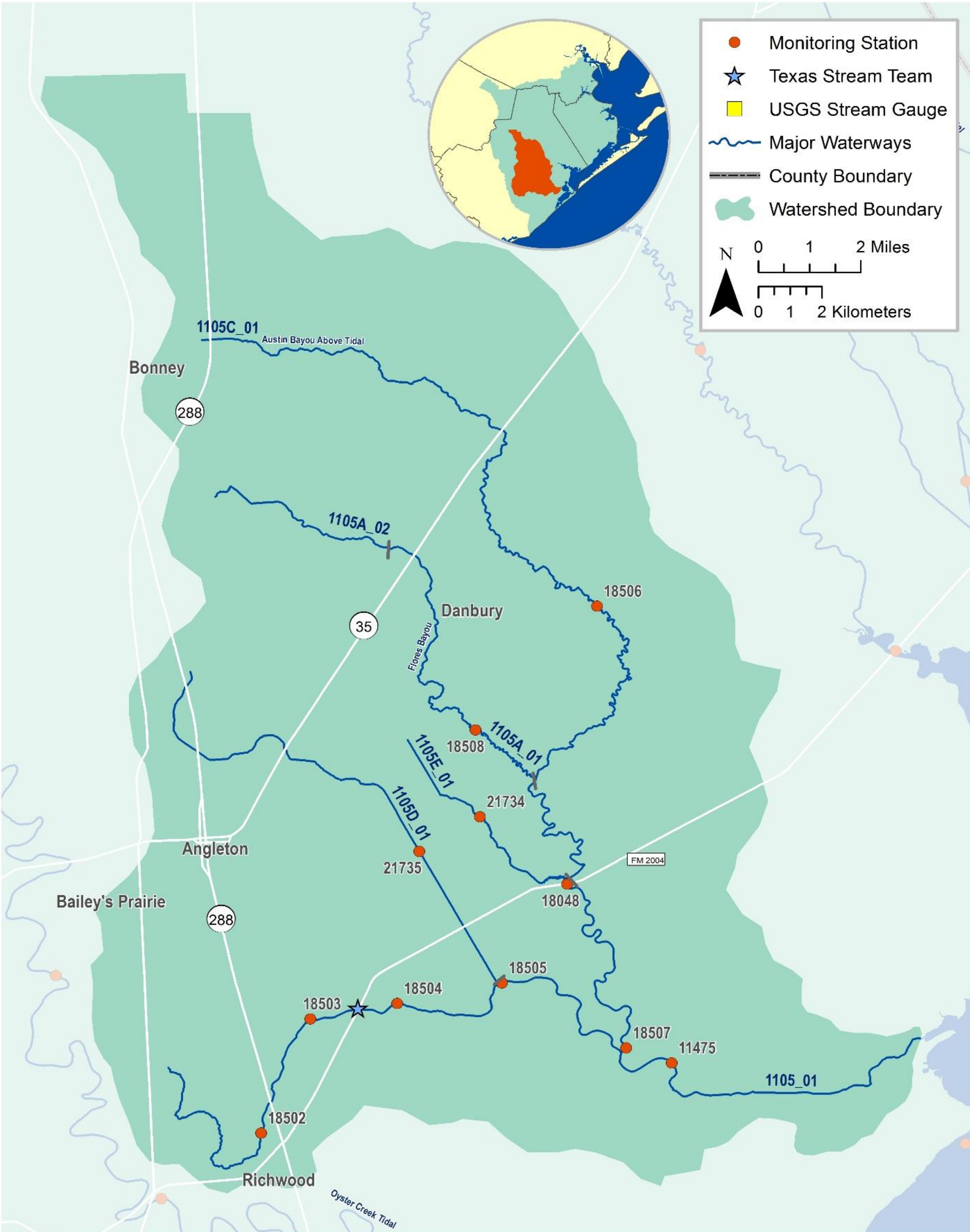


Load Duration Curve E. coli - station 11467
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow
E. coli Load (cfu/day)
Flow (cfs)
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
10.00
1.00
0.10
0.01
0 10 20 30 40 50 60 70 80 90 100
Percent of Days Load Exceeded
Load Regression Curve
Water Quality Standard - Geomean (126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve


Bacteria vs Days Since Last Rain
Dickinson Bayou Above Tidal
1104
E.Coli Base 10 Log
Days Since Last Rain
5.00
4.00
3.00
2.00
1.00
0.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14

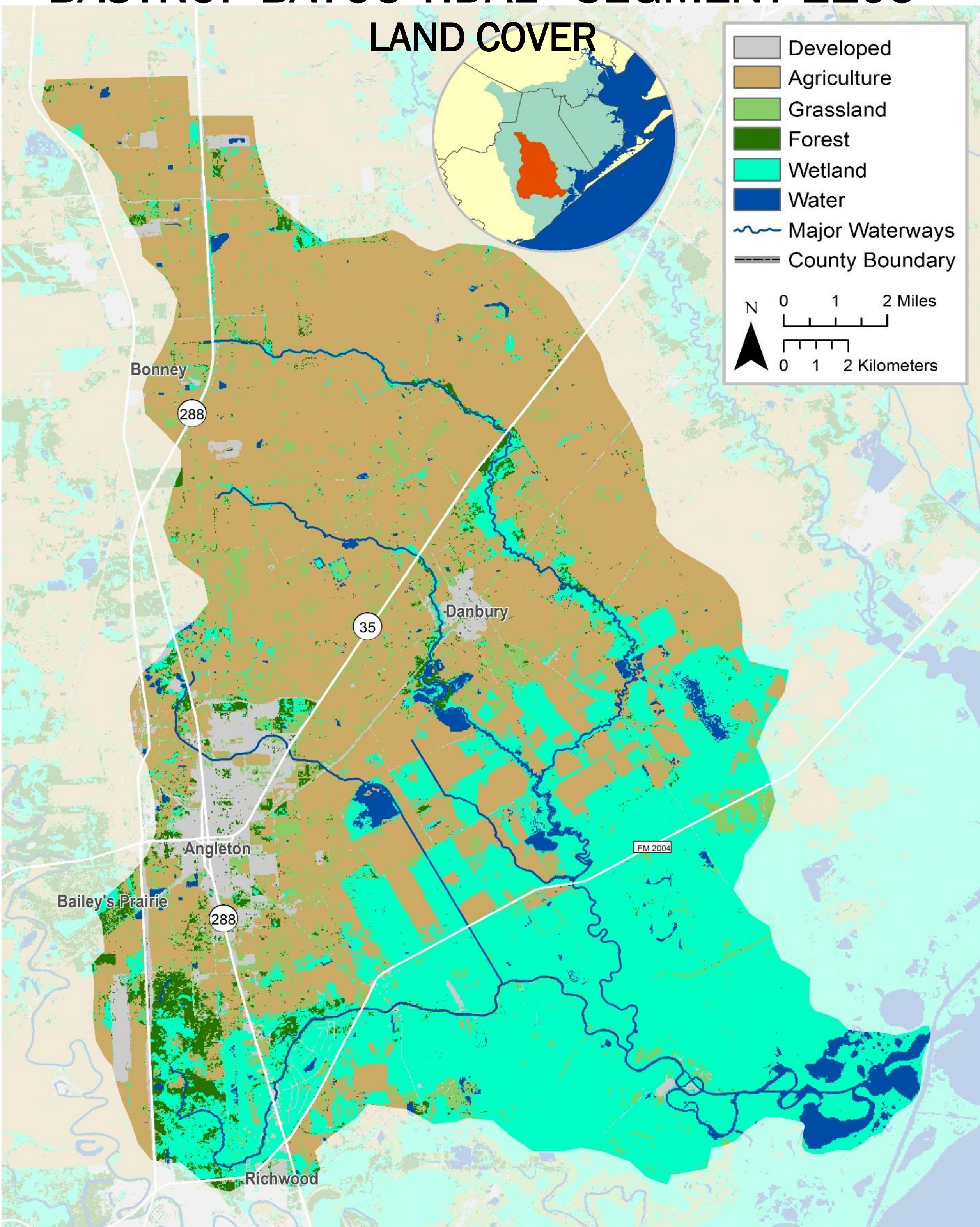
Recommendations
Address concerns found in this segment summary through stakeholder participation.
Continue collecting water quality data to support actions associated with any future watershed protection plan development and possible modeling.
Continue working with Texas AgriLife to help implement the bacteria TMDL and the WPP.

B5. BASTROP BAYOU TIDAL - SEGMENT 1105



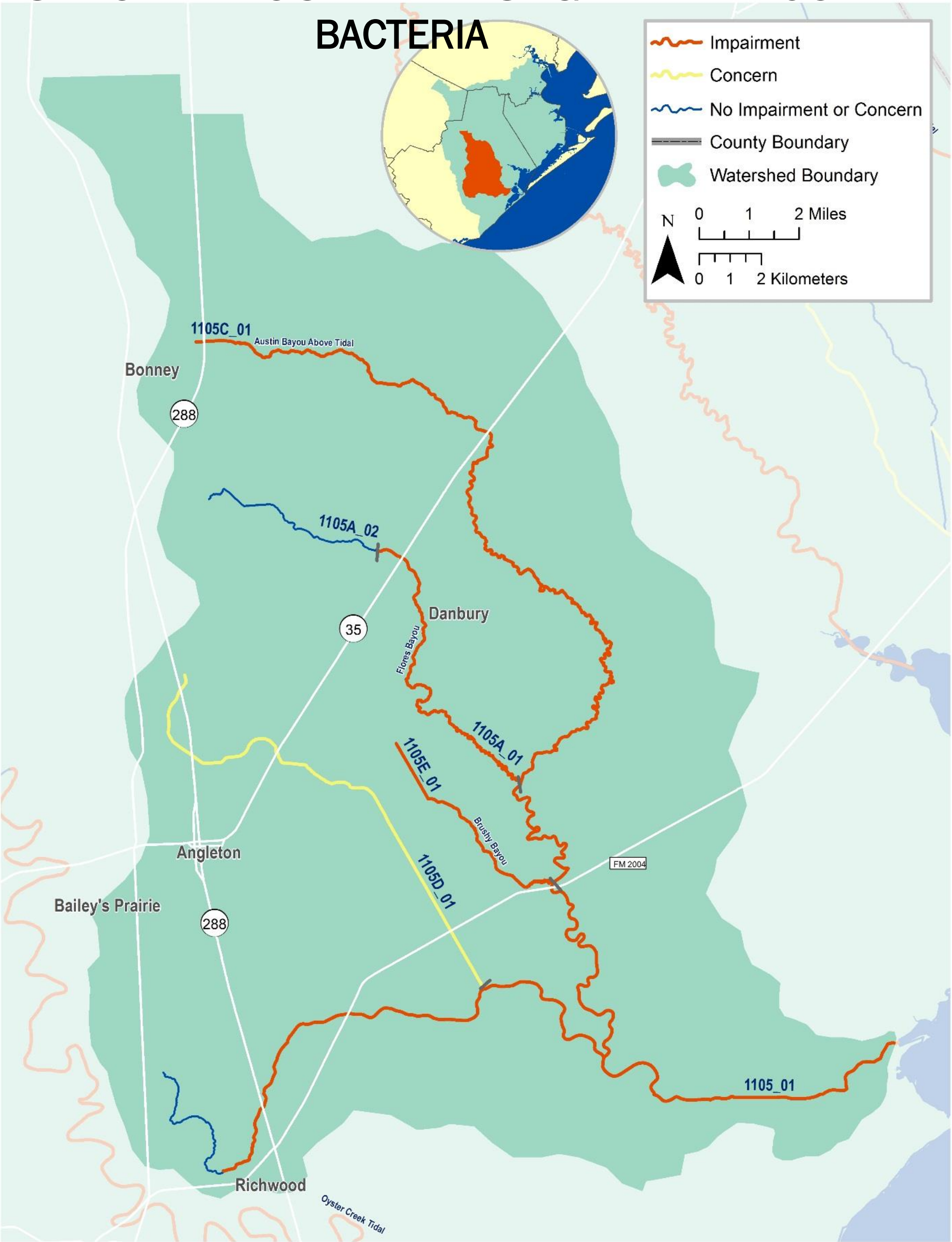
BASTROP BAYOU TIDAL - SEGMENT 1105

LAND COVER



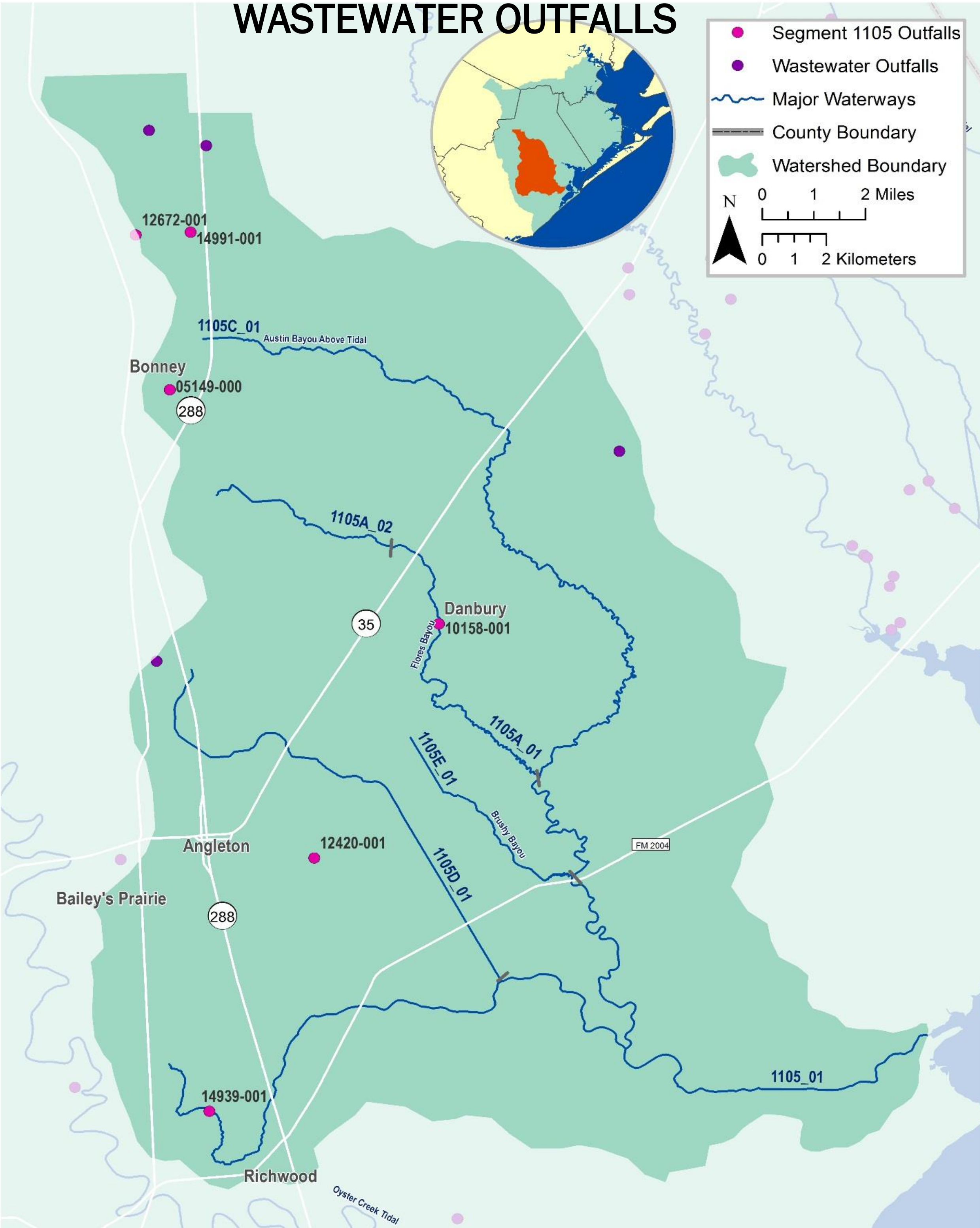
BASTROP BAYOU TIDAL - SEGMENT 1105

BACTERIA



BASTROP BAYOU TIDAL - SEGMENT 1105

WASTEWATER OUTFALLS



Segment Number:	1105	Name:	Bastrop Bayou Tidal		
Length:	19 miles	Watershed Area:	217 square miles	Designated Uses:	Primary Contact Recreation 1, High Aquatic Life
Number of Active Monitoring Stations:	10	Texas Stream Team Monitors:	1	Permitted Outfalls:	9
Description:	Segment 1105 (Tidal Stream w/ high ALU): From the confluence with Bastrop Bay 1.1 km (0.7 miles) downstream of the Intracoastal Waterway in Brazoria County to a point 8.6 km (5.3 mi) upstream of Business 288 at Lake Jackson in Brazoria County. Segment 1105 A (Perennial Stream w/ intermediate ALU): Flores Bayou (unclassified water body) – From a point 2.6 km (1.6 mi) downstream of County Road 171 upstream to SH35 in Brazoria County Segment 1105B (Tidal Stream w/ high ALU): Austin Bayou Tidal (unclassified water body) – From the Bastrop Bayou Tidal confluence to the FM 2004 bridge crossing in Brazoria County Segment 1105C (Perennial Stream w/ high ALU): Austin Bayou Above Tidal (unclassified water body) – From FM 2004 upstream (Austin Bayou Tidal upper boundary) to 1.73 mi upstream from where the water body crosses County Road 51 Segment 1105D (Perennial Stream w/ high ALU): Unnamed Tributary of Bastrop Creek (unclassified water body)—From the Bastrop Bayou Tidal confluence to 0.57 km (0.35 mi) upstream of SH 288 Bus in Brazoria County Segment 1105E (Perennial Stream w/ high ALU): Brushy Bayou (unclassified water body) – From the confluence with Austin Bayou Above Tidal (1105C) upstream to end of canal approximately 0.4 mi upstream of FM210 crossing east of the City of Angleton in Brazoria County				

Percent of Stream Impaired or of Concern

Segment ID	Bacteria
1105	100
1105A	62
1105B	100
1105C	100
1105D	100
1105E	100

Segment 1107

Standards	Tidal Stream	Perennial Stream	Screening Levels	Tidal Stream	Perennial Stream
Temperature (°C/°F):	35 / 95	35 / 95	Ammonia-N (mg/L):	0.46	0.33
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	5.0 / 4.0	Nitrate-N (mg/L):	1.10	1.95
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	3.0 / 3.0	Orthophosphate Phosphorus (mg/L):	0.46	0.37
pH (standard units):	6.5-9.0	6.5-9.0	Total Phosphorus-P (mg/L):	0.66	0.69
Enterococci (MPN/100mL) (grab):	89		Chlorophyll-*a* (µg/L):	21	14.1
Enterococci (MPN/100mL) (geometric mean):	35				
E. coli (MPN/100 mL) (grab):		399			
E. coli (MPN/100 mL) (geometric mean):		126			

FY 2016 Active Monitoring Stations				
Site ID	Site Description	Frequency	Monitoring Entity	Parameter Groups
11475	Bastrop Bayou at CR 227	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
18048	Austin Bayou at FM 2004	Quarterly	EIH	Field, Conventional, Bacteria
18502	Bastrop Bayou near CR 201	Quarterly	EIH	Field, Conventional, Bacteria
18503	Bastrop Bayou Upstream FM 2004	Quarterly	EIH	Field, Conventional, Bacteria
18504	Bastrop Bayou Bastrop Beach Rd	Quarterly	EIH	Field, Conventional, Bacteria
18505	Bastrop Bayou Brazoria CR 504	Quarterly	EIH	Field, Conventional, Bacteria
18506	Austin Bayou At Brazoria CR 210	Quarterly	EIH	Field, Conventional, Bacteria
18507	Austin Bayou N of Bastrop Bayou Confluence	Quarterly	EIH	Field, Conventional, Bacteria
18508	Flores Bayou at Brazoria CR 210	Quarterly	EIH	Field, Conventional, Bacteria
18509	Tributary of Bastrop Bayou Tidal upstream of CR 210	Quarterly	EIH	Field, Conventional, Bacteria
21734	Brushy Bayou at CR 213	Quarterly	EIH	Field, Conventional, Bacteria
21735	Tributary of Bastrop Bayou Tidal at CR 213	Quarterly	EIH	Field, Conventional, Bacteria

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Course*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Levels of Indicator Bacteria	1105 I 1105A I 1105B I 1105C I 1105D C 1105E I	▪ Animal waste from agricultural production and domestic animal facilities ▪ Constructed stormwater controls failing ▪ Developments with malfunctioning OSSFs ▪ Improper or no pet waste disposal ▪ Poorly operated or undersized WWTFs ▪ WWTF non-compliance, overflows, and collection system by-passes ▪ Direct and dry weather discharges ▪ Waste haulers illegal discharges/improper disposal	▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Create and implement Water Quality Management Plans for individual agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems ▪ More public education regarding OSSF operations and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education on pet waste disposal ▪ Regionalize chronically non-compliant WWTFs ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Increase monitoring requirements for self-reporting ▪ Impose new or stricter bacteria limits than currently designated by TCEQ

Segment Discussion:

Watershed Characteristics: The Bastrop Bayou Watershed is predominantly rural in nature with two urban centers of Danbury and the City of Angleton located in the center and western portions of the watershed, respectively. The area adjacent to and downstream of FM 2004 is primarily undeveloped wetlands, a portion of which is part of the Texas Coastal Preserve. This area is home to extensive habitat, endangered and threatened shorebirds, waterfowl, grassland species, and birds of prey. The primary means of wastewater management in this watershed is OSSFs. The northern reaches of the watershed is dominated by agricultural land uses.

Water Quality Issues: The 2014 Texas Integrated Report (IR) lists the assessment unit 1105_01 and the tributary 1105B_01 as impaired for contact recreation due to elevated levels of enterococci bacteria. The 2014 IR also lists the tributaries 1105A_01, 1105C_01, and 1105E_01 as impaired for contact recreation due to high levels of *E. coli*. The TCEQ assessment as well as the H-GAC in house analyses are described below:

Assessment Unit	TCEQ Assessment (2005-2012)	HGAC Analysis 2001-2008	HGAC Analysis 2008-2015
	Geomean (MPN/100 mL) / % Grab Exceedance	Geomean (MPN/100 mL) / % Grab Exceedance	Geomean (MPN/100 mL) / % Grab Exceedance
1105_01	73 / NA	31 / 27.8	84 / 40.4
1105A_01	137 / NA	183 / 25.0	195 / 29.6
1105B_01	41 / NA	17 / 21.4	60 / 37.0
1105C_01	166 / Na	127 / 13.6	368 / 40.7

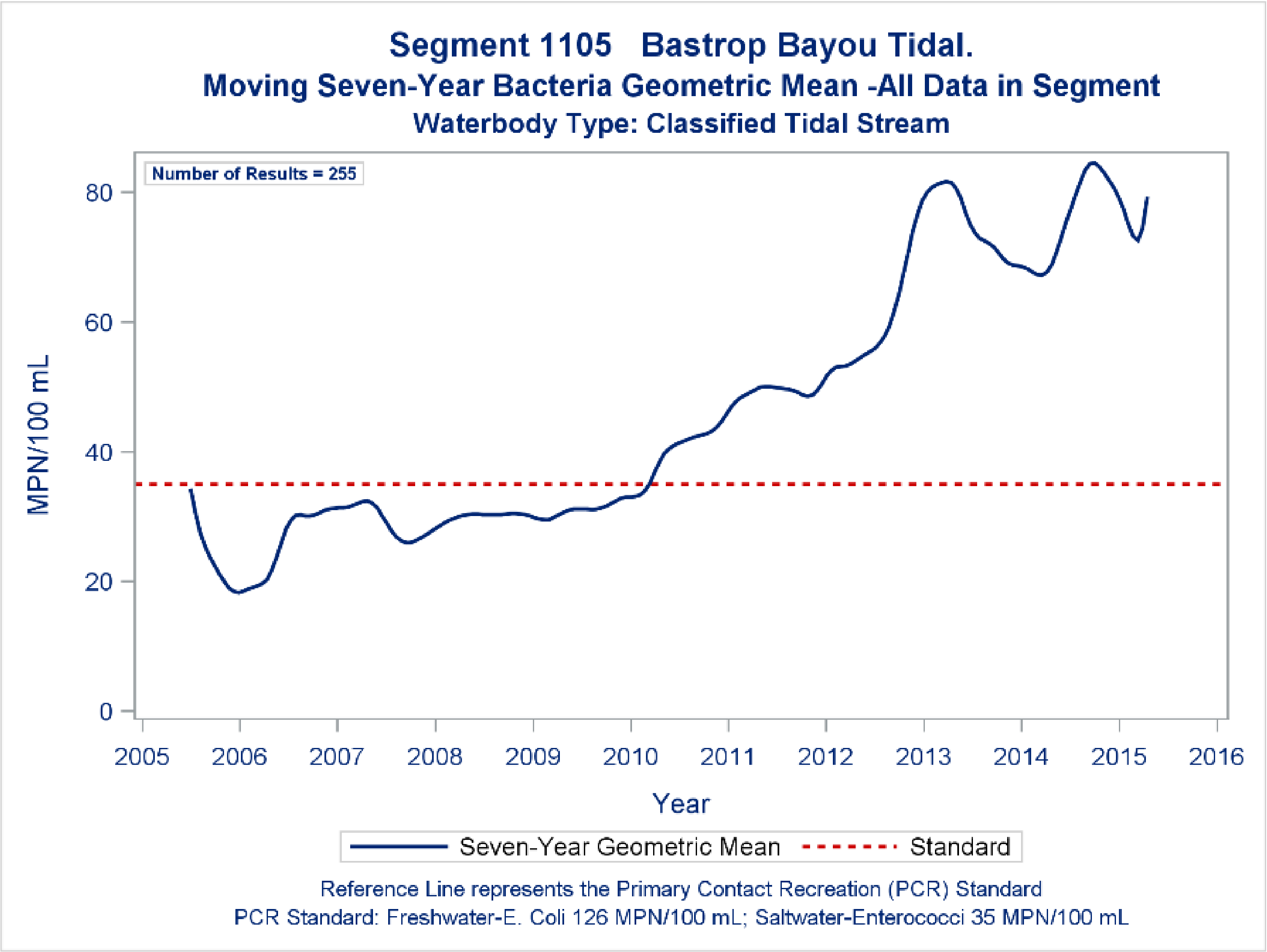
The segments 1105B and 1105C are new additions to the 2014 303(D) list for bacteria.

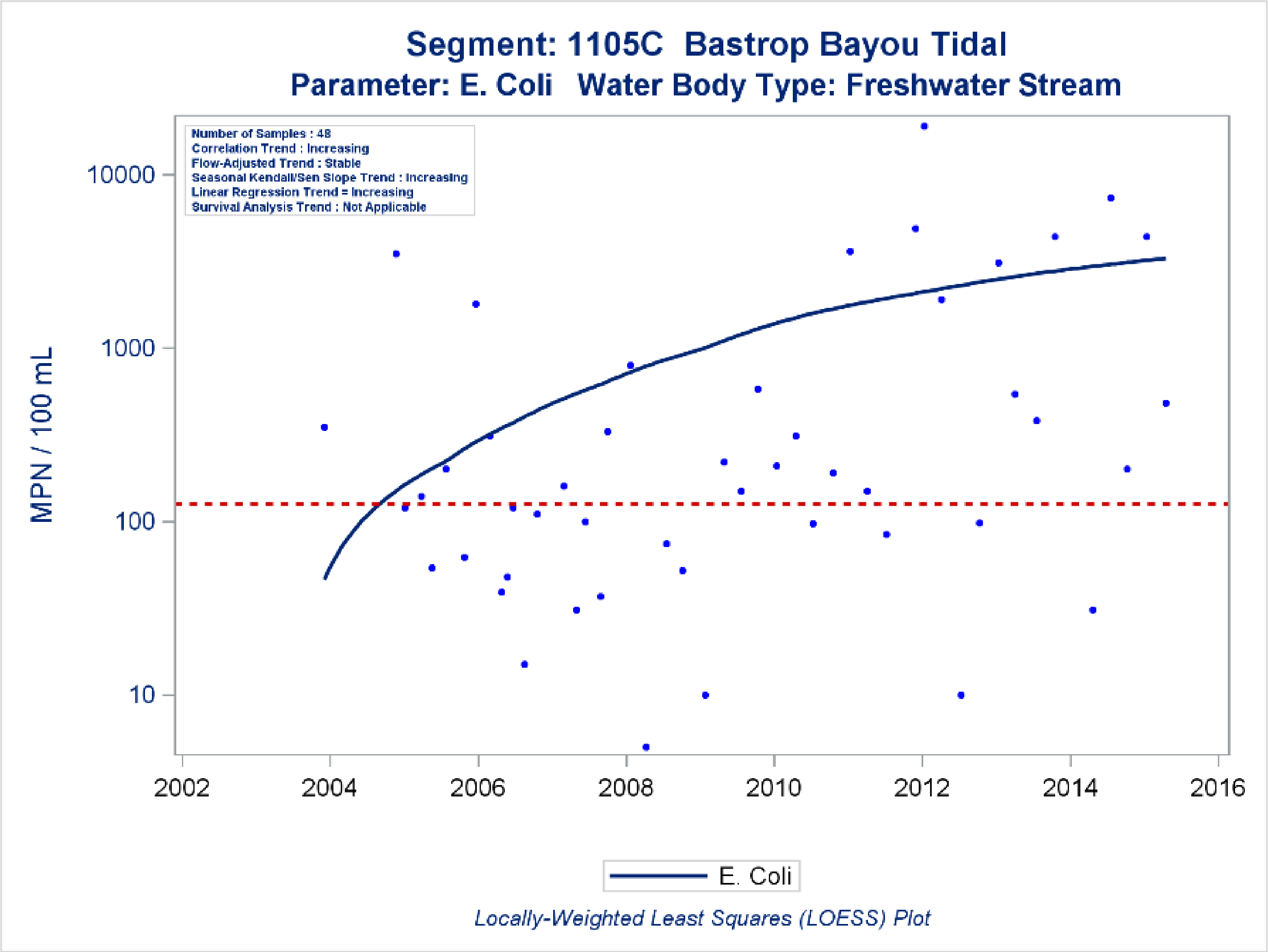
Special Studies/Projects: Since 2006, H-GAC, TCEQ, and local partners have been working to develop and implement a Watershed Protection Plan (WPP) for this watershed. The EPA approved the WPP in July 2016. H-GAC is currently partnering with TCEQ on an effort to implement select portions of the WPP. Texas AgriLife is facilitating the Galveston – Brazoria County Coalition of Watersheds to bring stakeholders involved in TMDL I-Plan and WPP implementation, including this watershed, together to build cooperation on common bacteria issues and BMPs. The goal is a regional watershed planning group that will elevate issues and attract funding.

Implementation efforts have already begun in the watershed, including installation of educational signage, transition to sanitary sewer service or remediation of failing OSSFs, and creation of a new dog park for the City of Angleton.

Trends: The only significant bacteria trend detected during the period of record was for the Austin Bayou Above Tidal segment. *E. coli* concentrations show a gradual increase over time for this segment with the majority of samples exceeding the 126 MPN/100 mL standard. Although regression analysis did not detect any other changes in bacteria levels over time, moving seven-year bacteria geometric means revealed a steady rise in mean enterococci concentrations on the main segment since 2005.

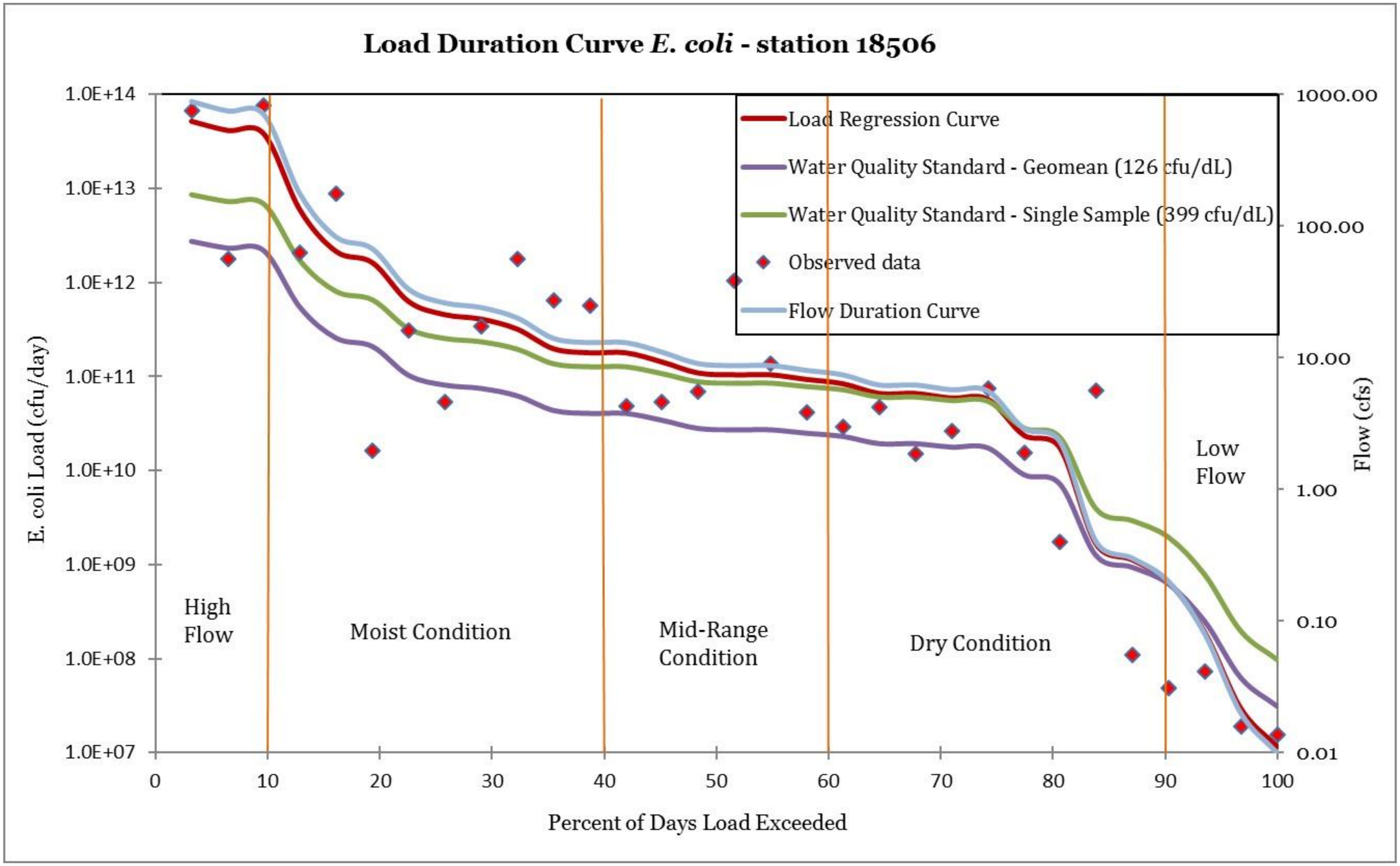
It should be noted that less than 50 samples were collected during the period of record in the unclassified segments of this watershed (1105A to 1105E). Due to the relatively small sample size for these segments, identified trends seen should be evaluated with caution. Additional long term data is required to better assess variations in water quality over time.

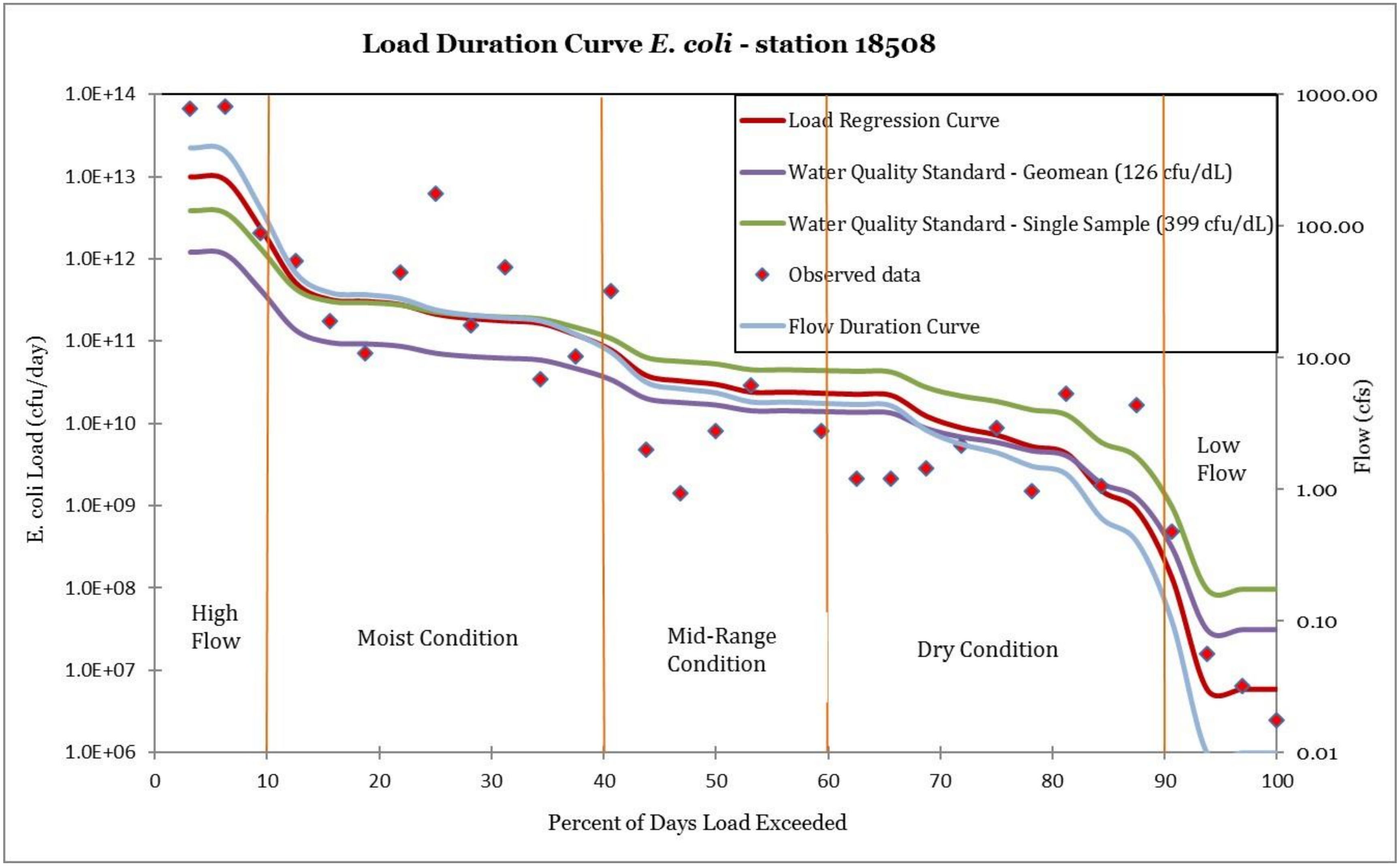

Segment 1105 Bastrop Bayou Tidal.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Classified Tidal Stream
Number of Results = 255
MPN/100 mL
0
20
40
60
80
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

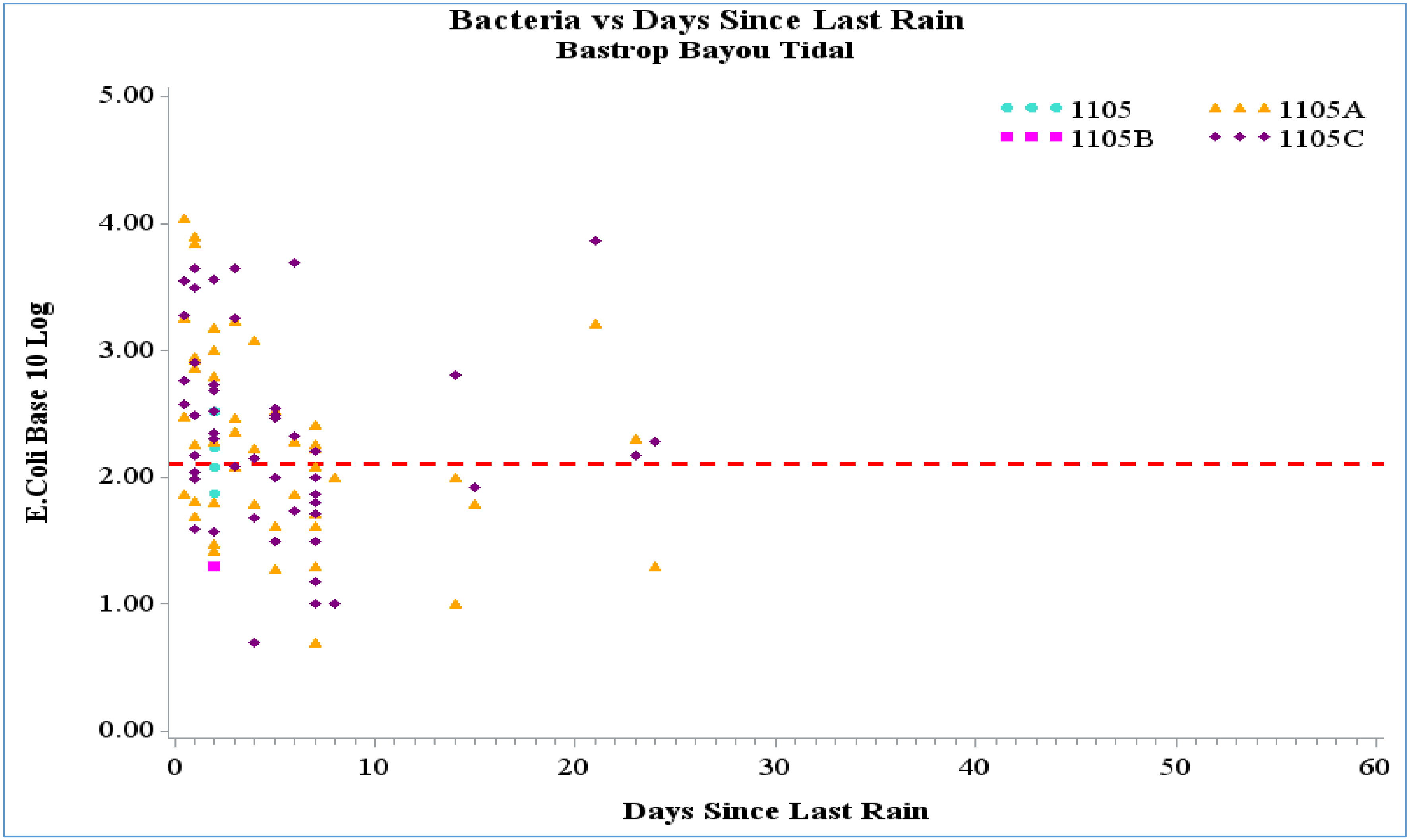

Segment: 1105C Bastrop Bayou Tidal
Parameter: E. Coli Water Body Type: Freshwater Stream
Number of Samples : 48
Correlation Trend : Increasing
Flow-Adjusted Trend : Stable
Seasonal Kendall/Sen Slope Trend : Increasing
Linear Regression Trend = Increasing
Survival Analysis Trend : Not Applicable
MPN / 100 mL
10000
1000
100
10
2002
2004
2006
2008
2010
2012
2014
2016
E. Coli
Locally-Weighted Least Squares (LOESS) Plot

Load Duration Curves

Available flow data and bacteria date were sufficient to complete an LDC for the two freshwater stations in this tidal segment, 18506 and 18508, Austin Bayou and Flores Bayou respectively. Using the results of the LDC and the Days Since Last Rain, factors affecting bacteria levels in this segment do appear to correlate with potential waste loads from WWTFs and OSSFs, particularly for station 18506. It should be noted that this result is from very few bacteria observations. Reading the LDC, the Load Regression Curve for bacteria data plotted exceeds the geomean standard and single grab standard for station 18506 approximately 100 percent of the time during very wet to very dry conditions. The bacteria regression curve for station 18508 falls below the Single Standard curve between 10 and 20 percent and falls below the Geomean Standard curve during drying conditions at 80% of days load exceeded. We expect wastewater treatment and OSSF as likely contributors to bacteria exceedances when the LDC load regression curve is found above the standard during dry and very dry weather conditions, when nonpoint sources are little to non-existent. The Days Since Last Rain support this as the observed bacteria data seven days out is slightly below the standard since last recorded rainfall though limited data past ten days appears in a few cases to exceed the standard (dashed red line).


Load Duration Curve *E. coli* - station 18506
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
E. coli Load (cfu/day)
1000.00
100.00
10.00
1.00
0.10
0.01
Flow (cfs)
0
10
20
30
40
50
60
70
80
90
100
Percent of Days Load Exceeded
Load Regression Curve
Water Quality Standard - Geomean (126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow

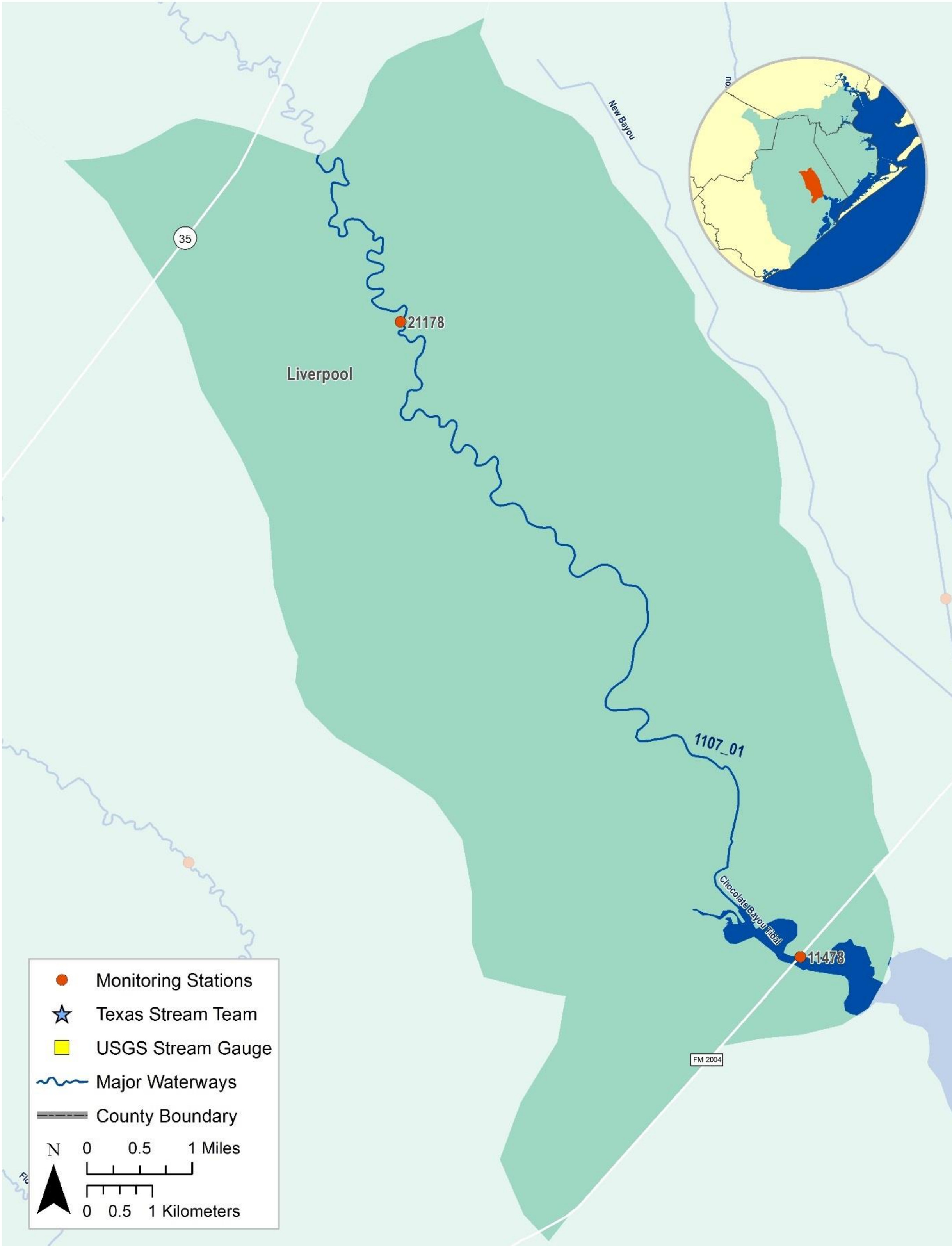

Load Duration Curve E. coli - station 18508
Load Regression Curve
Water Quality Standard - Geomean (126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve
E. coli Load (cfu/day)
Flow (cfs)
Percent of Days Load Exceeded
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
1000.00
100.00
10.00
1.00
0.10
0.01
0
10
20
30
40
50
60
70
80
90
100



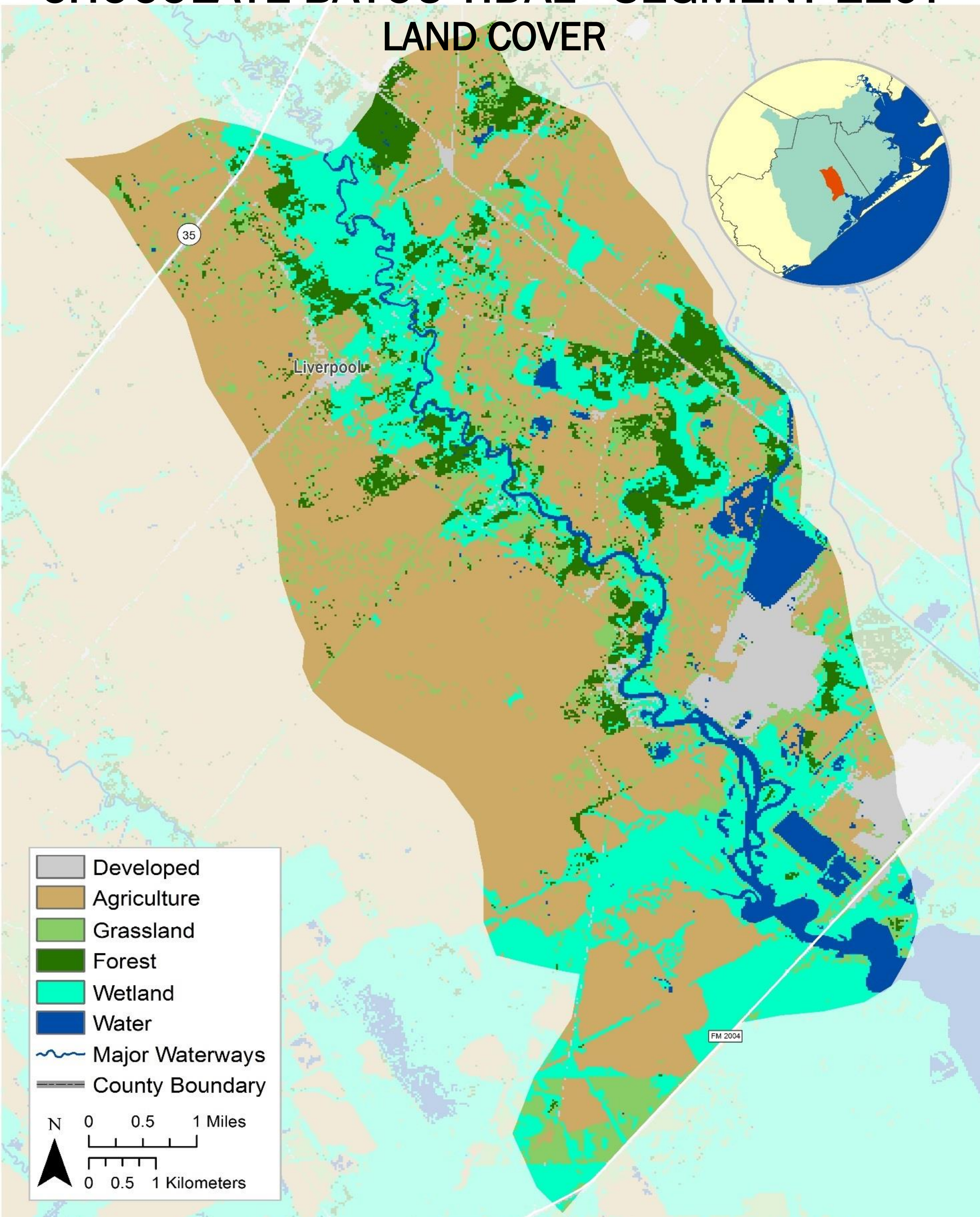
Bacteria vs Days Since Last Rain
Bastrop Bayou Tidal
1105
1105A
1105B
1105C
E.Coli Base 10 Log
5.00
4.00
3.00
2.00
1.00
0.00
0
10
20
30
40
50
60
Days Since Last Rain

Recommendations
Address concerns found in this segment summary through stakeholder participation and the completed WPP.
Continue collecting water quality data to support actions associated with WPP implementation.
Pursue a new local partner to Clean Rivers Program to collect additional data that would help better isolate problem areas.
Support best practice implementation efforts and track bacteria reduction

B6. CHOCOLATE BAYOU TIDAL - SEGMENT 1107

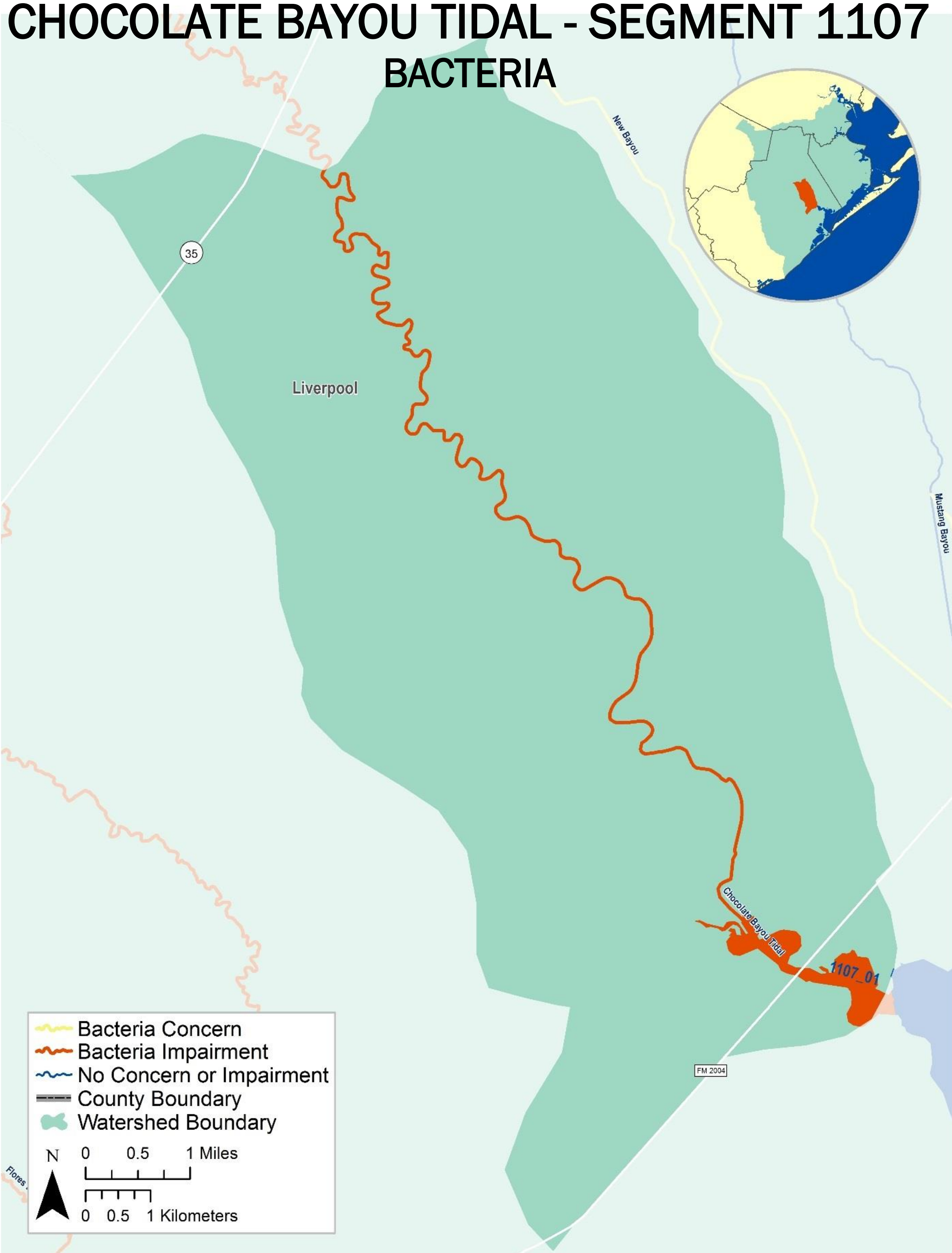


CHOCOLATE BAYOU TIDAL - SEGMENT 1107
LAND COVER

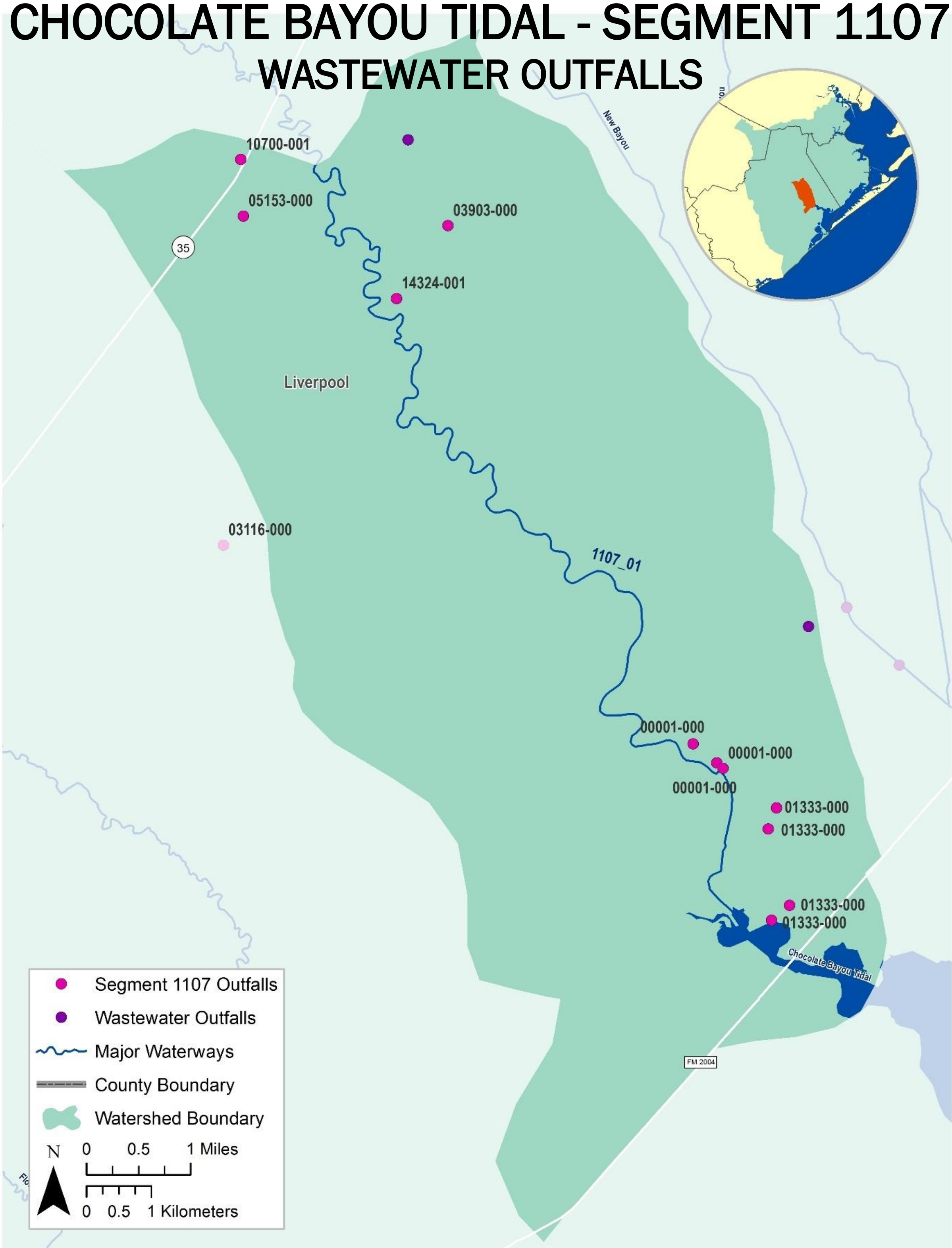


CHOCOLATE BAYOU TIDAL - SEGMENT 1107

BACTERIA



CHOCOLATE BAYOU TIDAL - SEGMENT 1107
WASTEWATER OUTFALLS



Segment Number:	1107	Name:	Chocolate Bayou Tidal		
Length:	16 miles	Watershed Area:	37 square miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life
Number of Active Monitoring Stations:	2	Texas Stream Team Monitors:	0	Permitted Outfalls:	10
Description:	From the Chocolate Bay confluence 1.4 km (0.9 mi) downstream of FM 2004 to a point 4.2 km (2.6 mi) downstream of SH 35 in Brazoria County				

Percent of Stream Impaired or of Concern	
Segment ID	Bacteria
1107	100

Segment 1007			
Standards	Tidal Stream	Screening Levels	Tidal Stream
Temperature (°C/°F):	35 / 95	Ammonia-N (mg/L):	0.46
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	Nitrate-N (mg/L):	1.10
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.46
pH (standard units):	6.5-9.0	Total Phosphorus-P (mg/L):	0.66
Enterococci (MPN/100mL) (grab):	104	Chlorophyll-*a* (µg/L):	21
Enterococci (MPN/100mL) (geometric mean):	35		

FY 2016 Active Monitoring Stations				
Site ID	**Site Description**	**Frequency**	**Monitoring Entity**	**Parameter Groups**
11478	Chocolate Bayou at FM 2004	Quarterly	EIH	Field, Conventional, Bacteria, Chlorophyll *a*
11478	Chocolate Bayou at FM 2004	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
21178	Chocolate Bayou at Brazoria CR 171/Mustang Chocolate Bayou Rd in Liverpool	Quarterly	EIH	Field, Conventional, Bacteria

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Levels of Indicator Bacteria	1107 I	▪ Animal waste from agricultural production, hobby farms, and riding stables ▪ Rapid urbanization and increased impervious cover ▪ Constructed stormwater controls failing ▪ Developments with malfunctioning OSSFs ▪ Improper or no pet waste disposal ▪ Direct and dry weather discharges ▪ Poorly operated or undersized WWTFs ▪ Waste haulers illegal discharges/improper disposal ▪ WWTF non-compliance, overflows, and collection system by-passes	▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Create and implement Water Quality Management Plans for individual agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Add water quality features to stormwater systems ▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education on pet waste disposal

			▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Impose new or stricter bacteria limits than currently designated by TCEQ ▪ Increase monitoring requirements for self-reporting

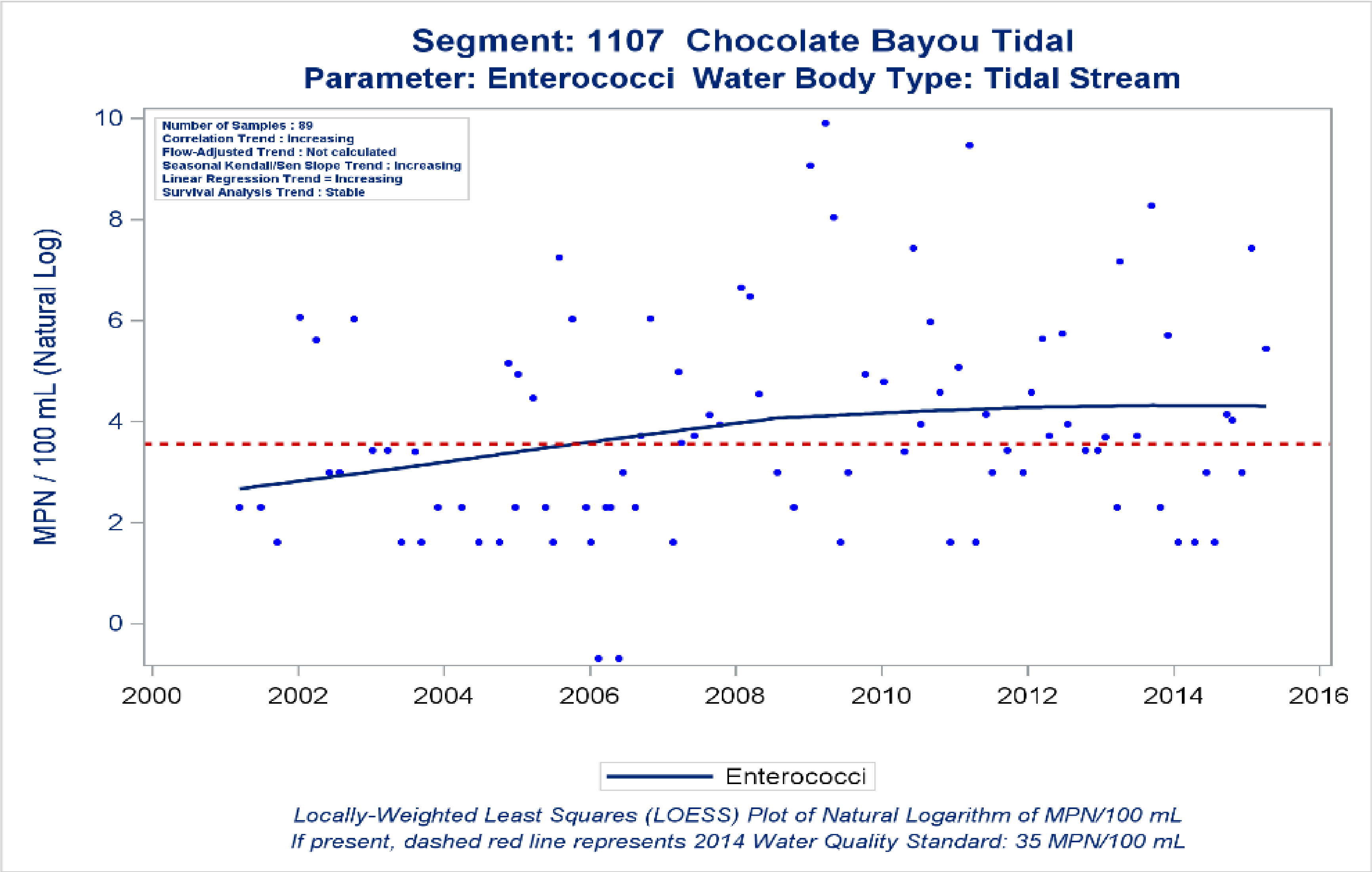
Segment Discussion:

Watershed Characteristics: The Chocolate Bayou Tidal watershed is predominantly rural with pockets of urban and industrial development scattered throughout. The community of Liverpool is located in the northwest and a large industrial complex is located in the southeast portion of the watershed. Duck Lake and Monsanto Reservoir are impoundments used primarily for industrial purposes. The rest of the watershed is used for agriculture and contains a number of irrigation canals.

Water Quality Issues: The 2014 Texas Integrated Report lists the assessment unit 1107_01 as impaired for contact recreational use due to high levels of enterococci bacteria. The TCEQ assessment found the geomean for enterococci within this AU to be 82 MPN/100ml, which is more than twice the standard of 35 MPN/100ml.

Special Studies/Projects: H-GAC is working with the TCEQ TMDL Program and local stakeholders to draft a Chocolate Bayou TMDL and I-Plan for 1107 and 1108. The draft Technical Support Document (TSD) has been completed and submitted to the TCEQ. The next steps will include the completion of the TMDL using the TSD and drafting the I-Plan with stakeholder participation. Texas AgriLife is facilitating the Galveston – Brazoria County Coalition of Watersheds to bring stakeholders involved in TMDL I-Plan and WPP implementation, including this watershed, together to build cooperation on common bacteria issues and BMPs. The goal is a regional watershed planning group that will elevate issues and attract funding.

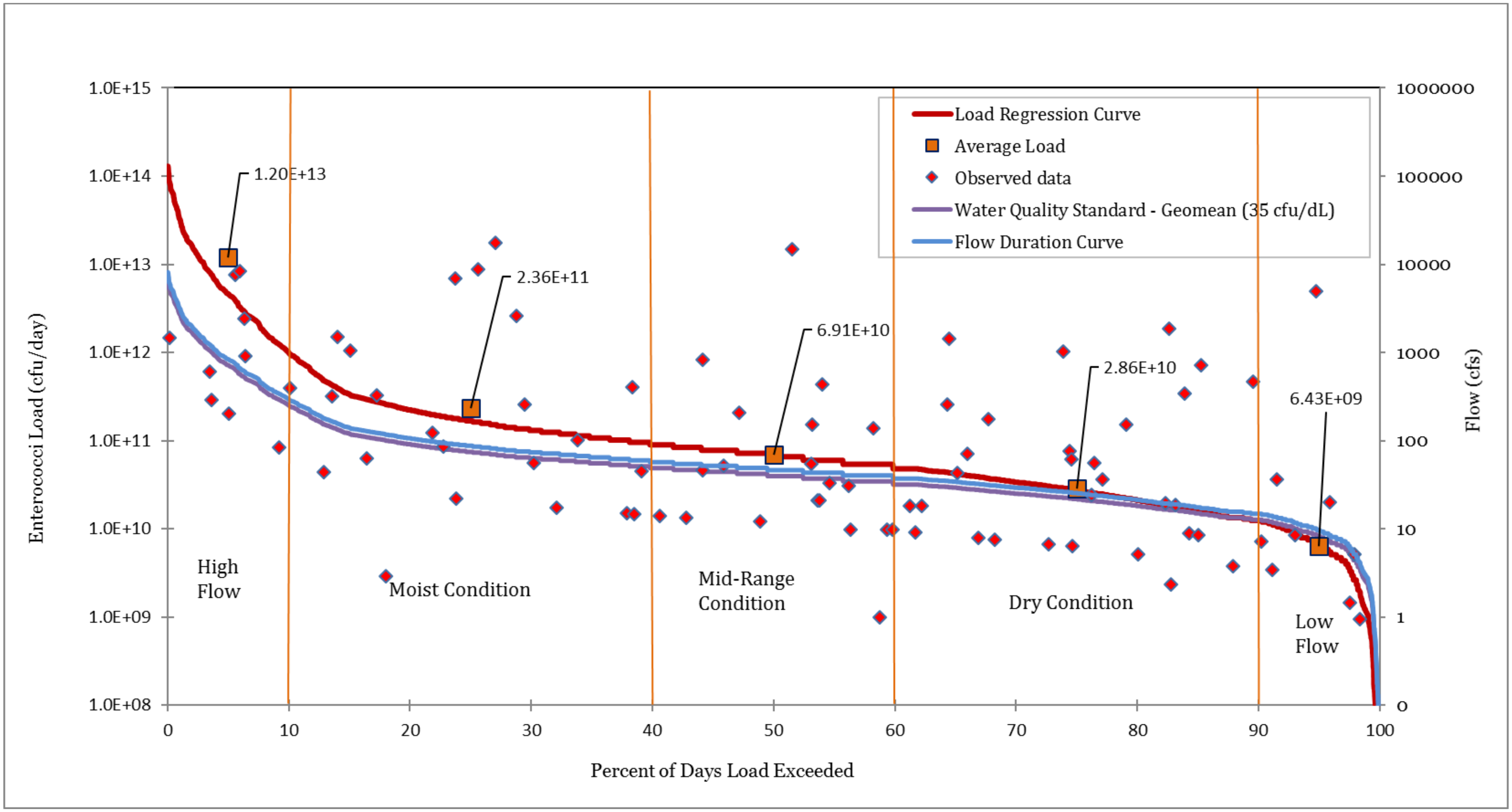
Trends: Enterococci concentrations continue to increase throughout the watershed, with nearly half the samples collected since 2000 exceeding the geometric mean standard of 35 MPN/100 mL. Runoff from agricultural areas, WWTF effluent, and malfunctioning OSSFs may be reasons for bacteria loadings in the waterway.


Segment: 1107 Chocolate Bayou Tidal
Parameter: Enterococci Water Body Type: Tidal Stream
Number of Samples : 89
Correlation Trend : Increasing
Flow-Adjusted Trend : Not calculated
Seasonal Kendall/Sen Slope Trend : Increasing
Linear Regression Trend = Increasing
Survival Analysis Trend : Stable
MPN / 100 mL (Natural Log)
10
8
6
4
2
0
2000
2002
2004
2006
2008
2010
2012
2014
2016
Enterococci
Locally-Weighted Least Squares (LOESS) Plot of Natural Logarithm of MPN/100 mL
If present, dashed red line represents 2014 Water Quality Standard: 35 MPN/100 mL

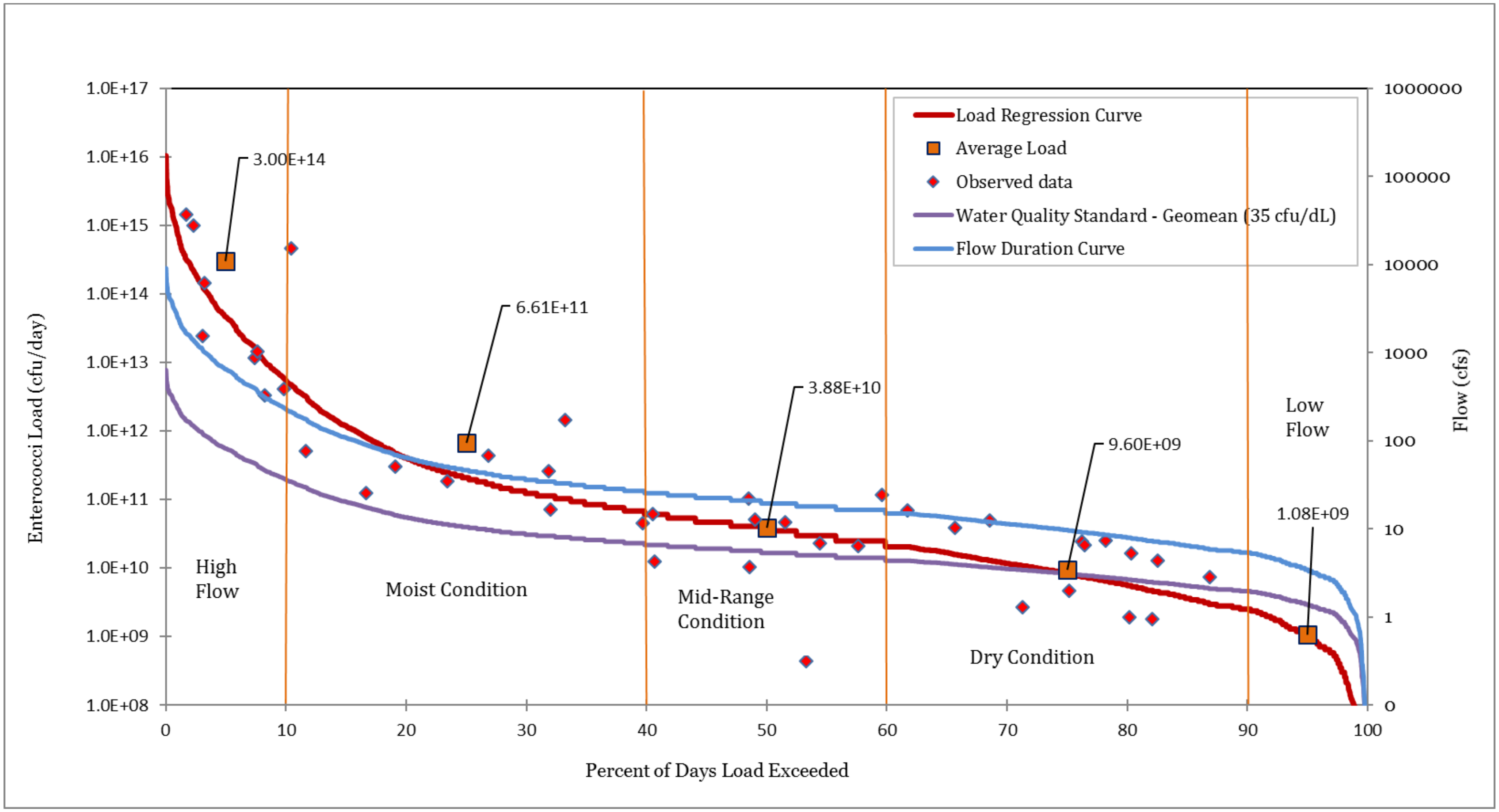
Load Duration Curves

In FY2017 the modified LDC approach was applied to segment 1107 due to the tidal nature of the segment. Please refer to the Chocolate Bayou TSD for more on the modified LDC approach. A review of the completed LDCs suggest a strong influence of stormwater on bacteria loads. This influence is seen at both the upstream monitoring station 21178 and the downstream station 11478. During High Flow and Moist Conditions, the Load Regression Curve for the sampled bacteria data maintain a geometric mean above the standard. In the transition zone between Moist and Dry Conditions, the bacteria geometric mean during the Mid-Range condition begins to approach the standard. The regression curve crosses over the standard in the Dry Conditions. This suggest that while there is a strong stormwater contribution to bacteria, sources more associated with dry conditions like illicit discharges and wastewater treatment effluent are potential contributors to the base bacteria load.

Modified Load Duration Curve at station 11478



Modified Load Duration Curve at station 21178



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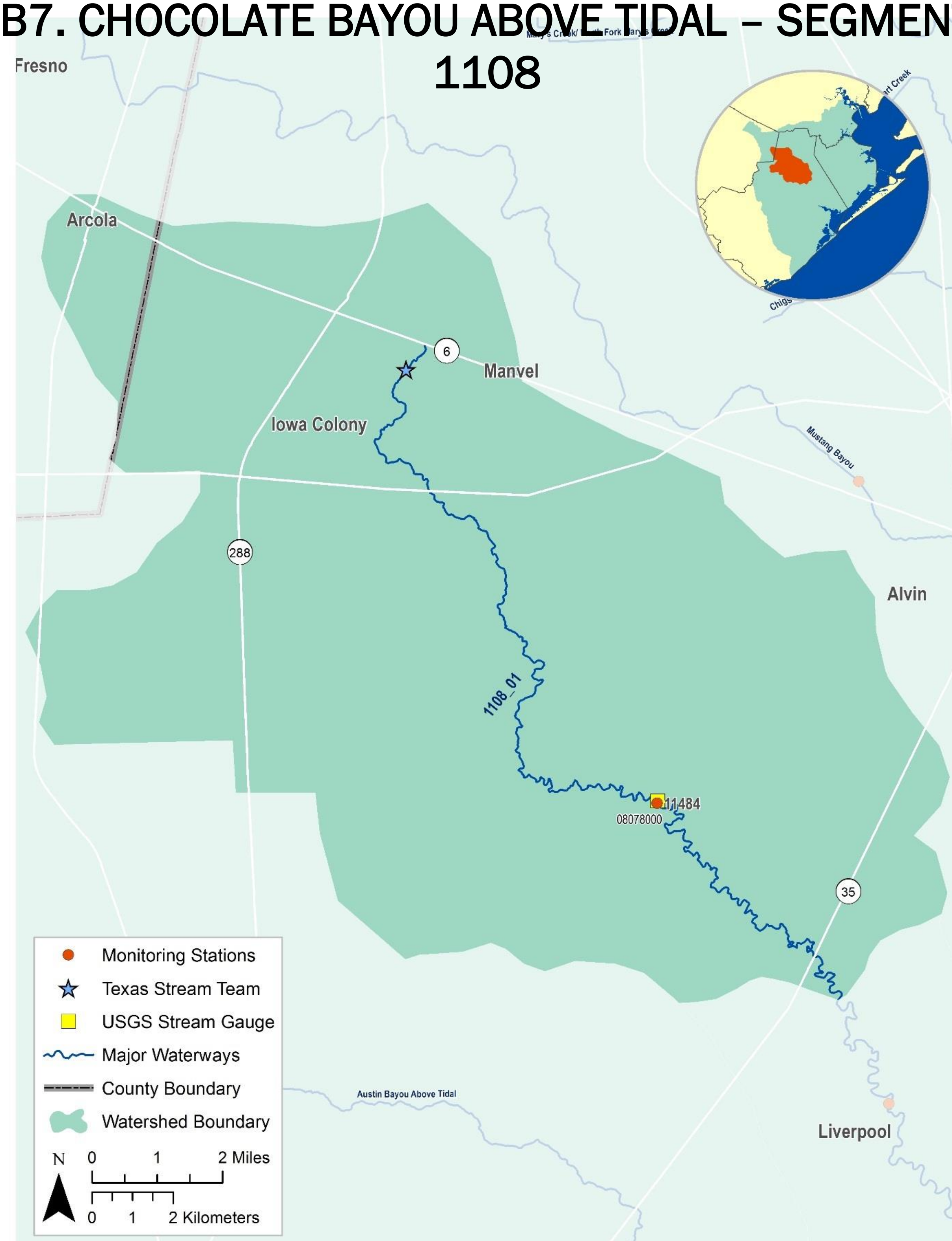
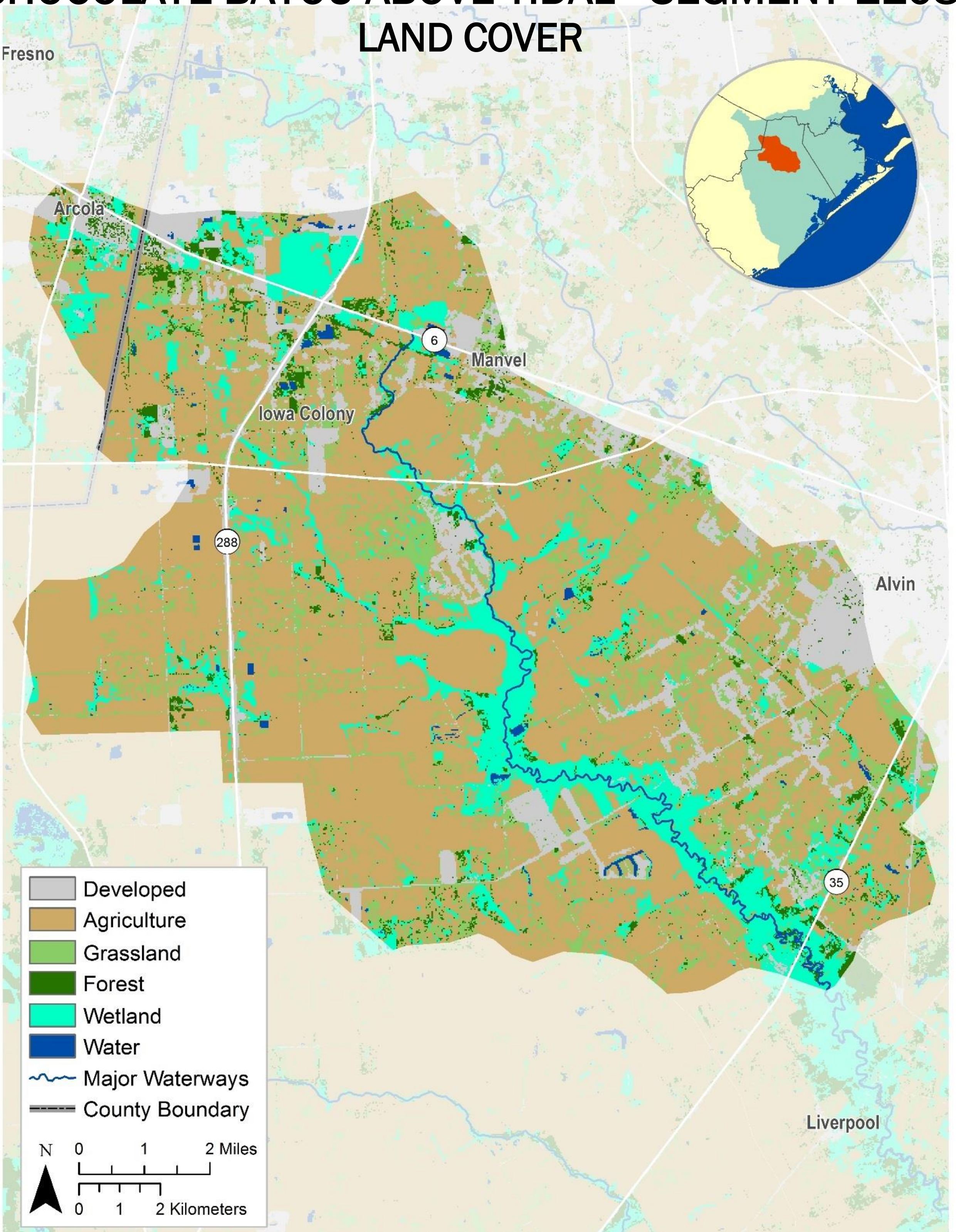
Recommendations
Address concerns found in this segment summary through stakeholder participation during TMDL development.
Continue collecting water quality data to support actions associated with TMDL development and any future WPP development.
Pursue a new local partner to Clean Rivers Program to collect additional data that would help better isolate problem areas.
Engage local stakeholders to implement best practices to reduce bacteria levels.
Segment along with the Chocolate Bayou Above Tidal segment, presents TCEQ TMDL Program as a potential TMDL project candidate as there are sufficient bacteria and continuous flow data available and no formal organized water quality based organization seeking development of a watershed protection plan.

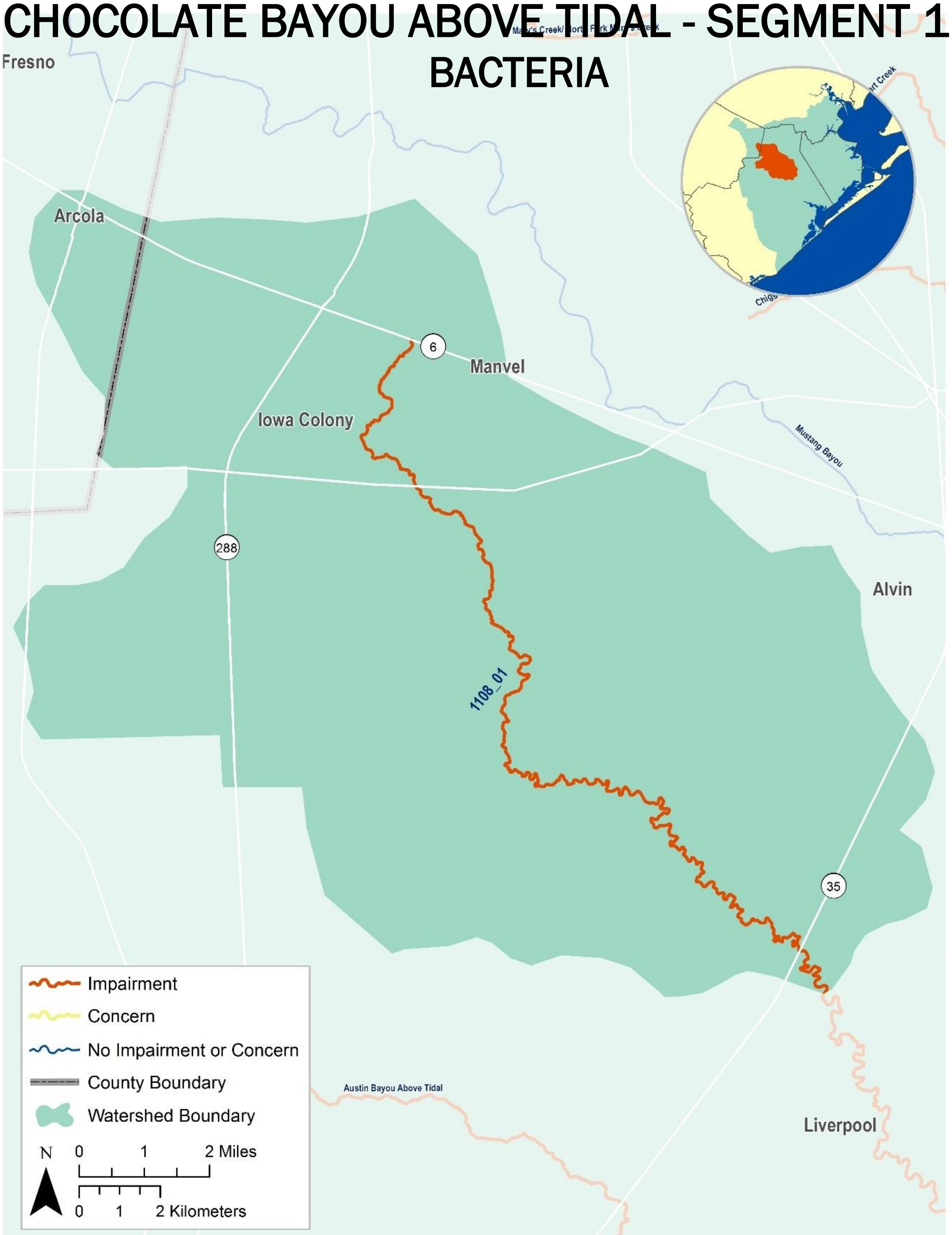
B7. CHOCOLATE BAYOU ABOVE TIDAL – SEGMENT 1108



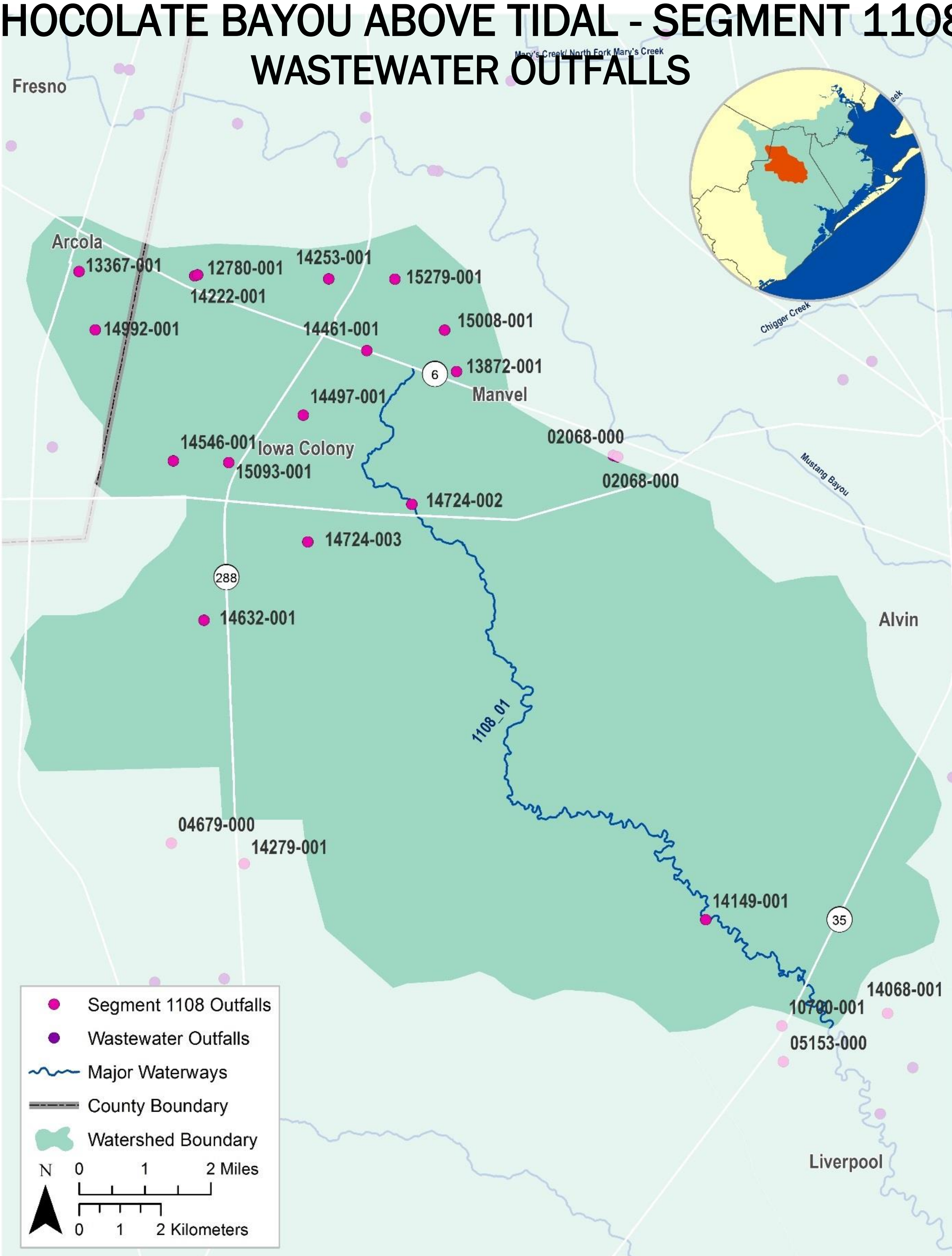
CHOCOLATE BAYOU ABOVE TIDAL - SEGMENT 1108
LAND COVER



CHOCOLATE BAYOU ABOVE TIDAL - SEGMENT 1108
BACTERIA



CHOCOLATE BAYOU ABOVE TIDAL - SEGMENT 1108
WASTEWATER OUTFALLS



Segment Number:	1108	Name:	Chocolate Bayou Above Tidal		
Length:	22 miles	Watershed Area:	110 square miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life Use
Number of Active Monitoring Stations:	1	Texas Stream Team Monitors:	1	Permitted Outfalls:	19
Description:	From a point 4.2 km (2.6 mi) downstream of SH 35 in Brazoria County to SH 6 in Brazoria County.				

Percent of Stream Impaired or of Concern	
Segment ID	Bacteria
1108	100

Segment 1108			
Standards	Perennial Stream	Screening Levels	Perennial Stream
Temperature (°C/°F):	32 / 90	Ammonia (mg/L):	0.33
Dissolved Oxygen *(24-Hr Average)* (mg/L):	5.0	Nitrate-N (mg/L):	1.95
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.37
pH (standard units):	6.5-9.0	Total Phosphorus (mg/L):	0.69
E. coli (MPN/100 mL) (grab):	399	Chlorophyll-*a* (µg/L):	14.1
E. coli (MPN/100 mL) (geometric mean):	126		
Chloride (mg/L as Cl):	200		
Sulfate (mg/L as SO_4):	100		
Total Dissolved Solids (mg/L):	900		

FY 2016 Active Monitoring Stations				
Site ID	**Site Description**	**Frequency**	**Monitoring Entity**	**Parameter Groups**
11484	Chocolate Bayou at FM 1462	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll-*a*, Flow

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Levels of Indicator Bacteria	1108 I	▪ Animal waste from agricultural production, hobby farms, and riding stables ▪ Rapid urbanization and increased impervious cover ▪ Constructed stormwater controls failing ▪ Developments with malfunctioning OSSFs ▪ Improper or no pet waste disposal ▪ Direct and dry weather discharges ▪ Waste haulers illegal discharges/improper disposal ▪ Poorly operated or undersized WWTFs ▪ WWTF non-compliance, overflows, and collection system by-passes	▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Create and implement Water Quality Management Plans for individual agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Add water quality features to stormwater systems ▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education on pet waste disposal

			▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Impose new or stricter bacteria limits than currently designated by TCEQ ▪ Increase monitoring requirements for self-reporting

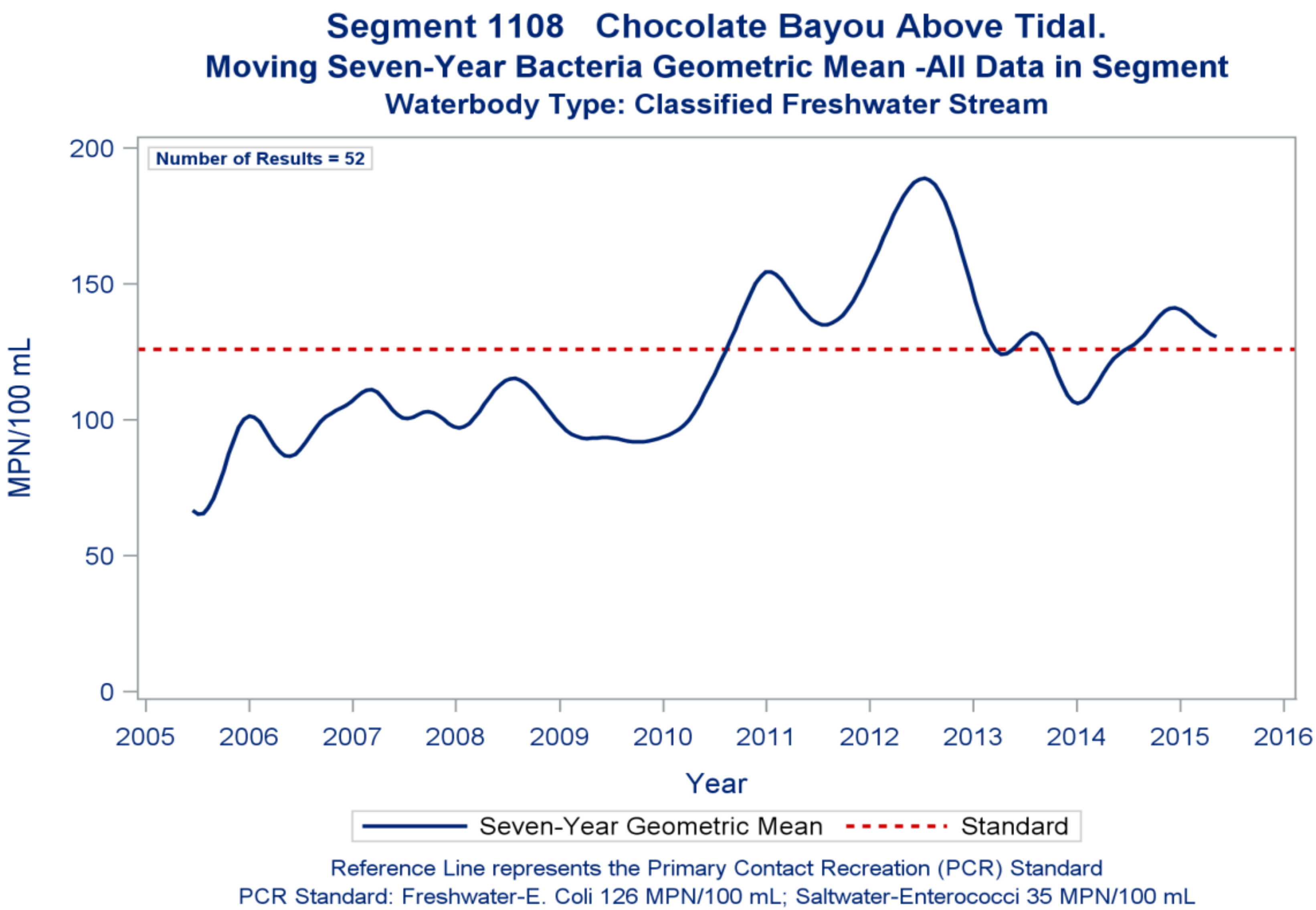
Segment Discussion:

Watershed Characteristics: This watershed is largely undeveloped with the exception of a few small population centers at Arcola, Manvel, Iowa Colony, and part of Alvin. More growth has occurred as development has spread south down Texas Highway 288 in recent years. The major land use is agriculture, and there are many farms in the area. There are also a number of irrigation canals that run through the watershed.

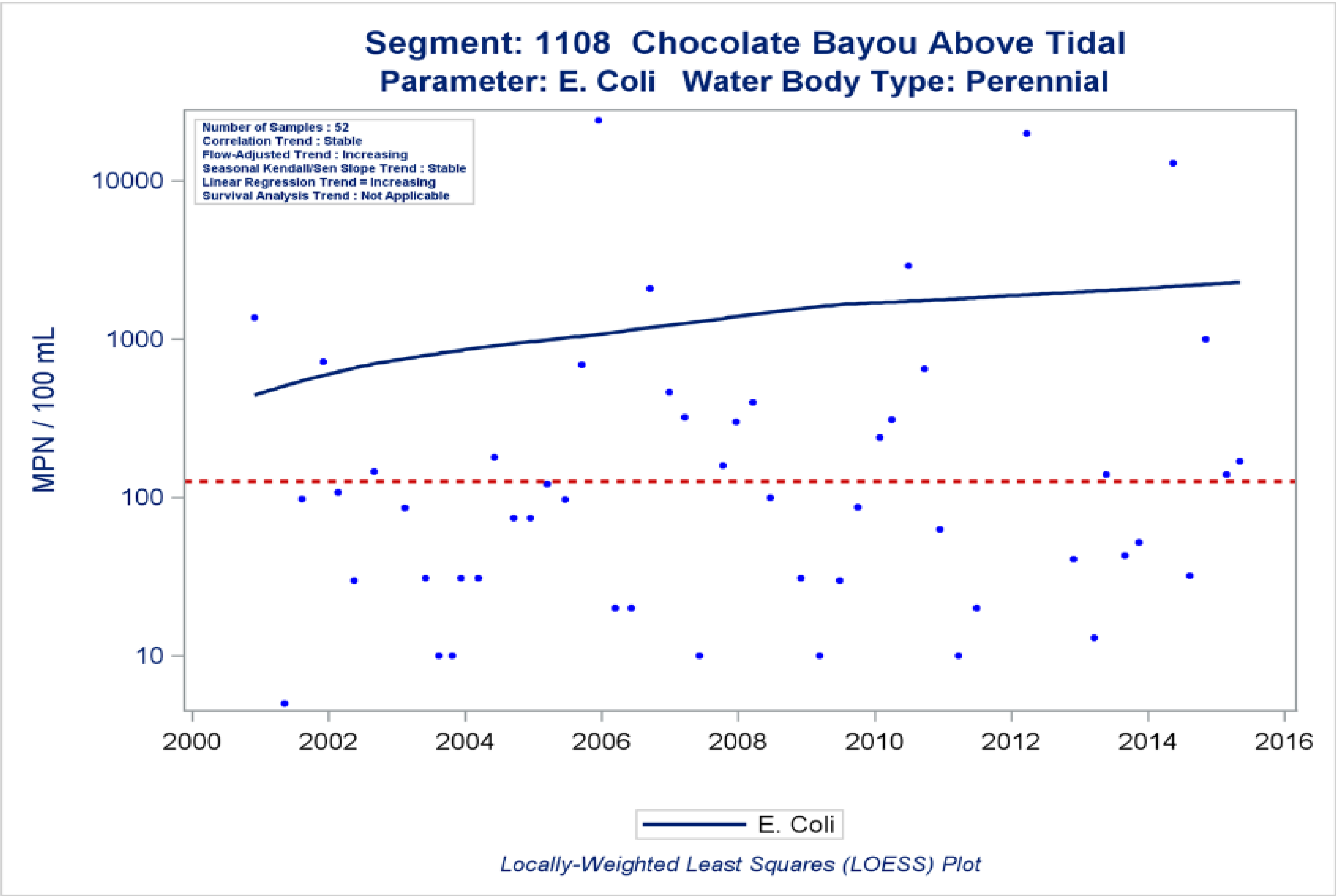
Water Quality Issues: The 2014 Integrated Report designates this segment for the first time as impaired for contact recreation due to elevated levels of *E. coli* bacteria.

Special Studies/Projects: H-GAC is working with the TCEQ TMDL Program and local stakeholders to draft a Chocolate Bayou TMDL and I-Plan for 1107 and 1108. The draft Technical Support Document (TSD) has been completed and submitted to the TCEQ. The next steps will include the completion of the TMDL using the TSD and drafting the I-Plan with stakeholder participation. Texas AgriLife is facilitating the Galveston – Brazoria County Coalition of Watersheds to bring stakeholders involved in TMDL I-Plan and WPP implementation, including this watershed, together to build cooperation on common bacteria issues and BMPs. The goal is a regional watershed planning group that will elevate issues and attract funding.

Trends: Currently, there is only one station in this watershed and based on regression analysis no significant change was observed in *E. coli* concentrations over the past 15 years and levels remain significantly higher than the 126 MPN/100 mL standard. A plot of Bacteria versus Days since last rain for this station supports this finding.

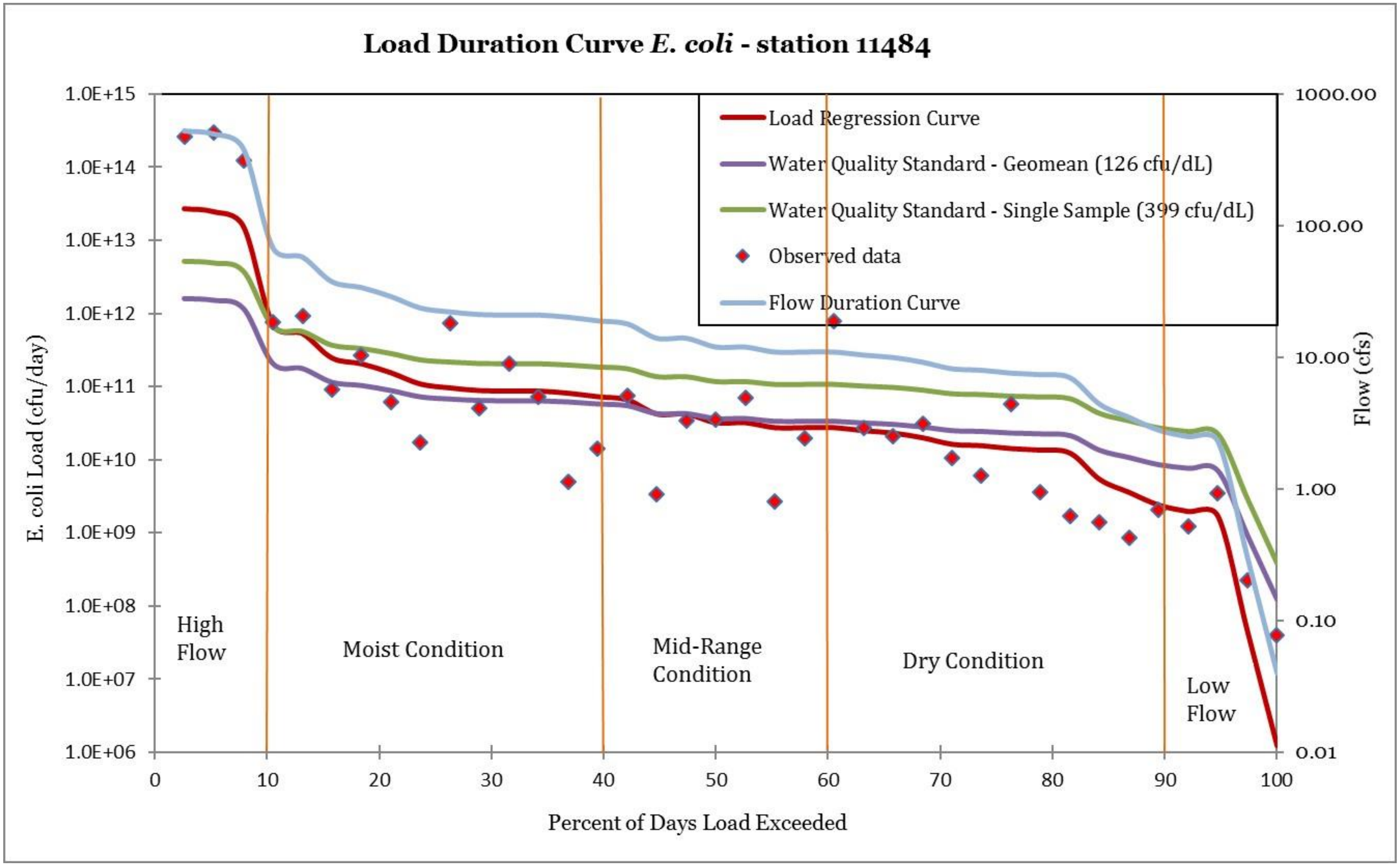


Segment 1108 Chocolate Bayou Above Tidal.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Classified Freshwater Stream
Number of Results = 52
MPN/100 mL
200
150
100
50
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

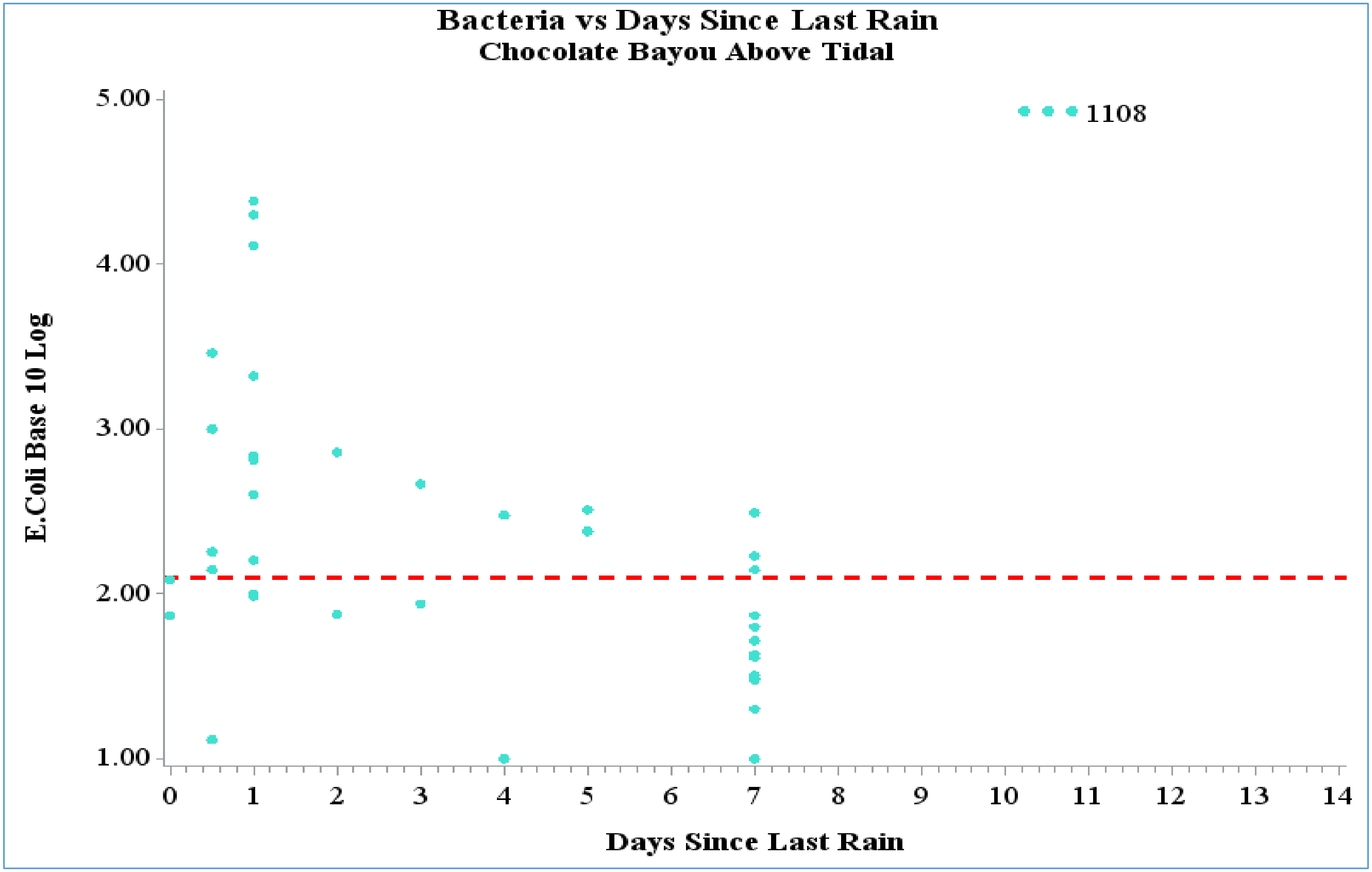

Segment: 1108 Chocolate Bayou Above Tidal
Parameter: E. Coli Water Body Type: Perennial
Number of Samples : 52
Correlation Trend : Stable
Flow-Adjusted Trend : Increasing
Seasonal Kendall/Sen Slope Trend : Stable
Linear Regression Trend = Increasing
Survival Analysis Trend : Not Applicable
MPN / 100 mL
10000
1000
100
10
2000
2002
2004
2006
2008
2010
2012
2014
2016
E. Coli
Locally-Weighted Least Squares (LOESS) Plot

Load Duration Curve

Available flow data and bacteria date were sufficient to complete an LDC for the lone station in this segment. Using the results of the LDC and the Days Since Last Rain, factors affecting bacteria levels in this segment do not appear to correlate with waste loads from WWTFs and OSSFs during dry periods. Reading the LDC, the Load Regression Curve for bacteria data plotted exceeds the geomean standard and single grab standard approximately 10 percent of the time during the wettest period. The bacteria regression curve quickly falls below the Single Standard curve following the highest flow period and falls below the Geomean Standard curve during moderate conditions nearly 50% of days load exceeded where it remains as conditions shift to dry. If wastewater treatment and OSSF were contributing to exceedances, then the expected LDC load regression curve would be found continually above the standard during dry weather conditions. The Days Since Last Rain support this as the observed data at seven days rarely exceeds the standard while at an average of one day or less, nearly all bacteria data exceed the standard (dashed red line).



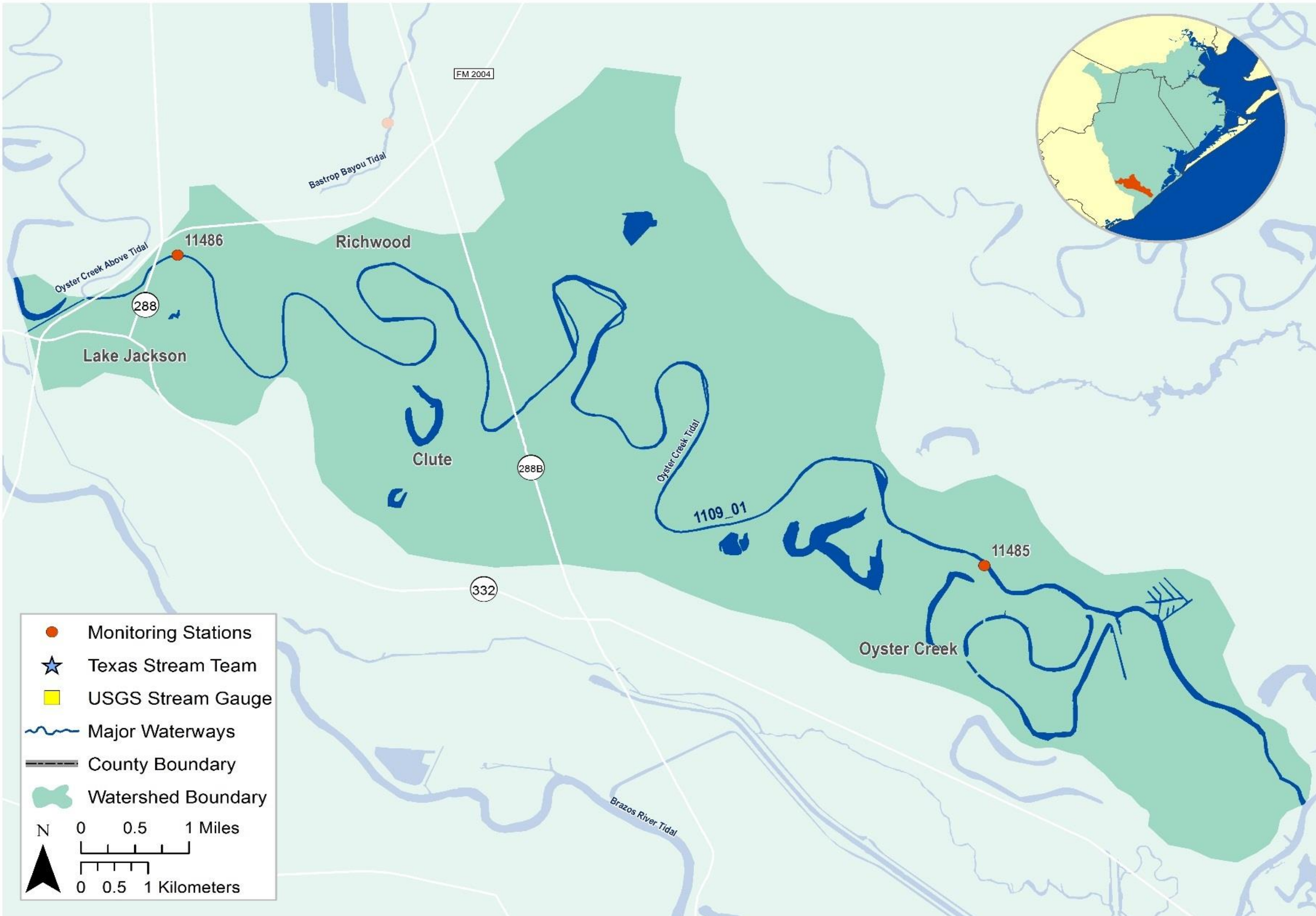
Load Duration Curve E. coli - station 11484
1.0E+15
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
1.0E+06
E. coli Load (cfu/day)
1000.00
100.00
10.00
1.00
0.10
0.01
Flow (cfs)
Load Regression Curve
Water Quality Standard - Geomean (126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow
0
10
20
30
40
50
60
70
80
90
100
Percent of Days Load Exceeded



Bacteria vs Days Since Last Rain
Chocolate Bayou Above Tidal
1108
E.Coli Base 10 Log
5.00
4.00
3.00
2.00
1.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Days Since Last Rain

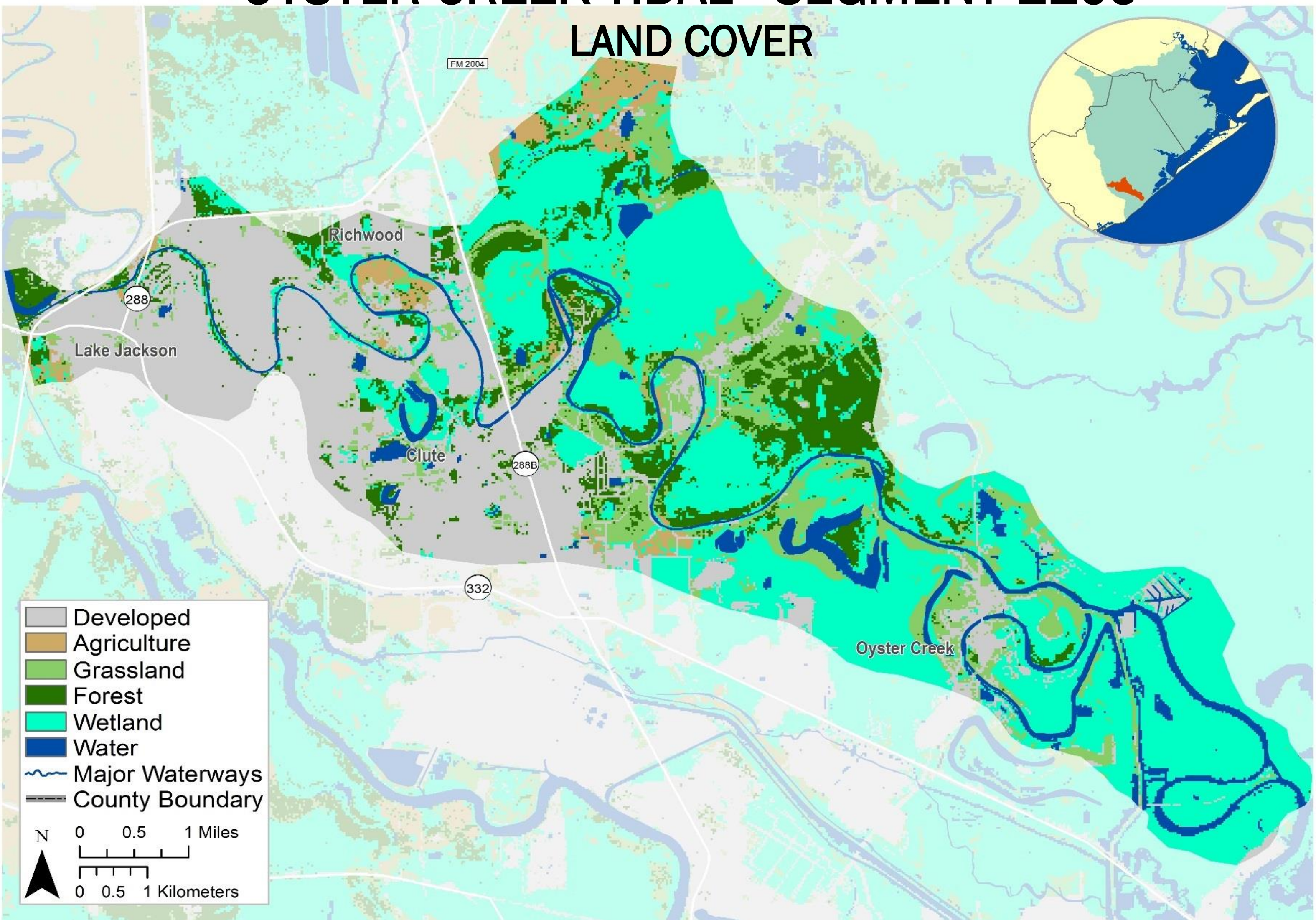
Recommendations
Continue collecting water quality and discharge monitoring report (DMR) data to support actions associated with TMDL development and possible modeling.
Pursue a new local partner to Clean Rivers Program to collect additional data that would help better isolate problem areas.
Engage local stakeholders to encourage the use of best practices and begin lowering sources of bacteria.
Segment along with the Chocolate Bayou Tidal segment, presents TCEQ TMDL Program as a potential TMDL project candidate as there are sufficient bacteria and continuous flow data available and no formal organized water quality based organization seeking development of a watershed protection plan.

B8. OYSTER CREEK TIDAL - SEGMENT 1109



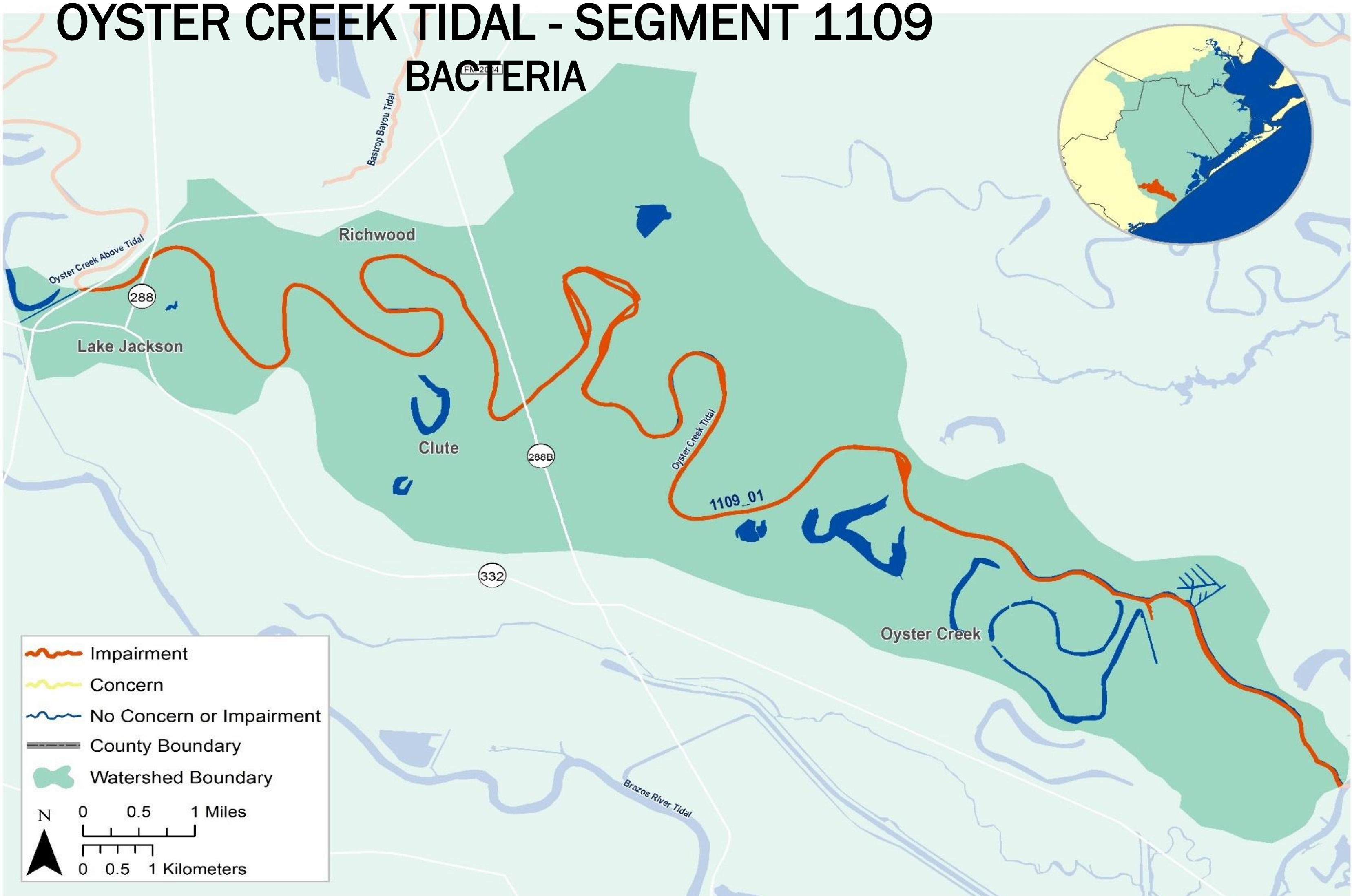
OYSTER CREEK TIDAL - SEGMENT 1109

LAND COVER

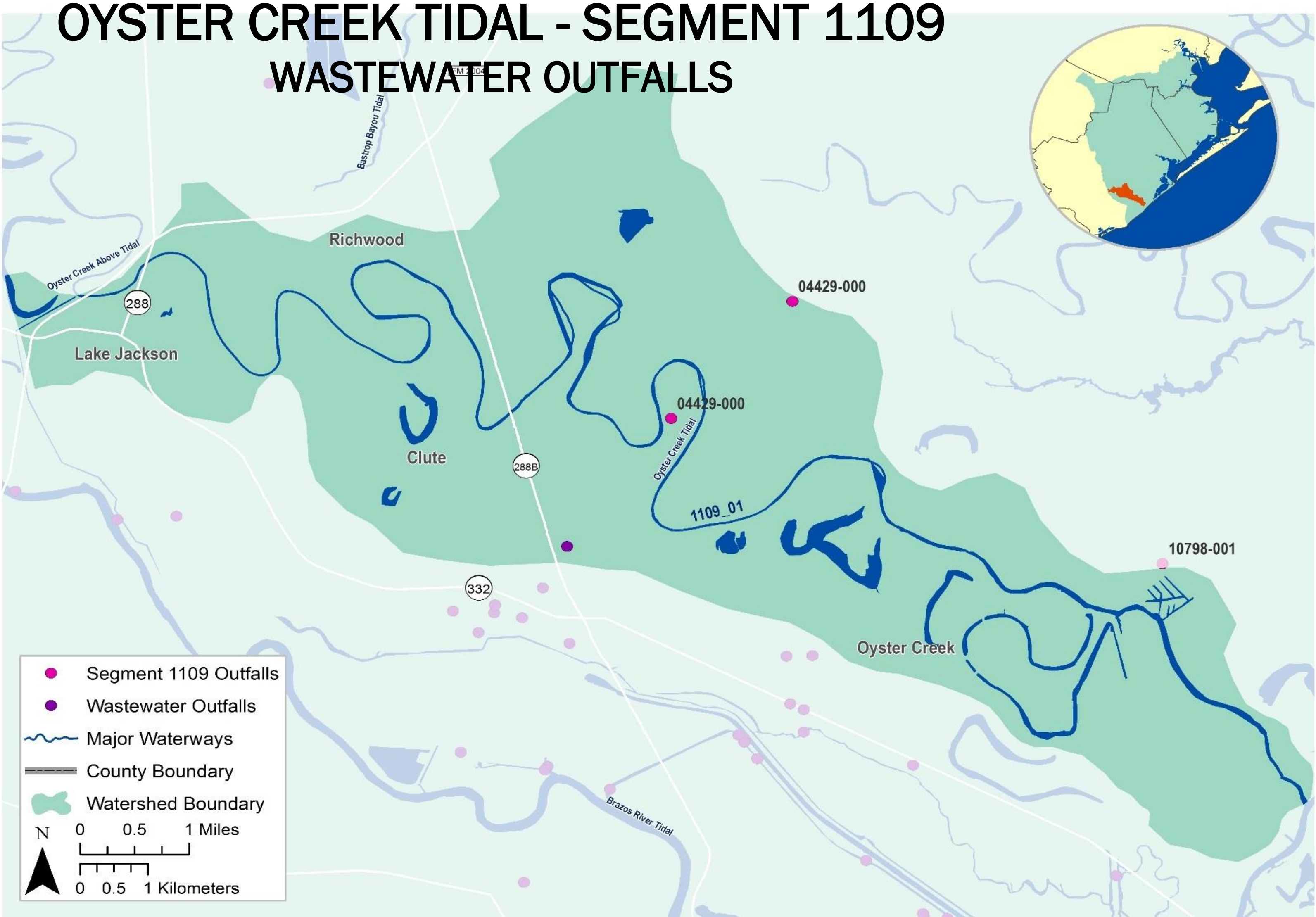


OYSTER CREEK TIDAL - SEGMENT 1109

BACTERIA



OYSTER CREEK TIDAL - SEGMENT 1109
WASTEWATER OUTFALLS



Segment Number:	1109	Name:	Oyster Creek Tidal		
Length:	25 miles	**Watershed Area:**	32 square miles	**Designated Uses:**	Primary Contact Recreation 1; Aquatic Life Use
Number of Active Monitoring Stations:	2	**Texas Stream Team Monitors:**	0	**Permitted Outfalls:**	3
Description:	From the Intracoastal Waterway confluence in Brazoria County to a point 100 meters (110 yards) upstream of FM 2004 in Brazoria County.				

Percent of Stream Impaired or of Concern	
Segment ID	**Bacteria**
1109	100

Segment 1109

Standards	Tidal Stream	Screening Levels	Tidal Stream
Temperature (°C/°F):	35 / 95	Ammonia-N (mg/L):	0.46
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	Nitrate-N (mg/L):	1.10
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.46
pH (standard units):	6.5-9.0	Total Phosphorus-P (mg/L):	0.66
Enterococci (MPN/100mL) (grab):	104	Chlorophyll-*a* (µg/L):	21
Enterococci (MPN/100mL) (geometric mean):	35		

FY 2016 Active Monitoring Stations

Site ID	Site Description	Frequency	Monitoring Entity	Parameter Groups
11485	Oyster Creek at FM 523	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
11486	Oyster Creek at That-Way Drive	Quarterly	UI	Field, Conventional, Bacteria

Water Quality Issues Summary

Issue	2014 Assessment *I – Impaired* *C – Of Concern*	Possible Causes / Influences / Concerns Voiced by Stakeholders	Possible Solutions / Actions To Be Taken
Elevated Levels of Indicator Bacteria	1109 I	▪ Rapid urbanization and increased impervious cover ▪ Animal waste from agricultural production, hobby farms, and riding stables ▪ Constructed stormwater controls failing ▪ Improper or no pet waste disposal ▪ Developments with malfunctioning OSSFs ▪ Direct and dry weather discharges ▪ Poorly operated or undersized WWTFs ▪ Waste haulers illegal discharges/improper disposal ▪ WWTF non-compliance, overflows, and collection system by-passes	▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Add water quality features to stormwater systems ▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Create and implement Water Quality Management Plans for individual agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ More public education on pet waste disposal ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education regarding OSSF operation and maintenance

			▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Impose new or stricter bacteria limits than currently designated by TCEQ ▪ Increase monitoring requirements for self-reporting

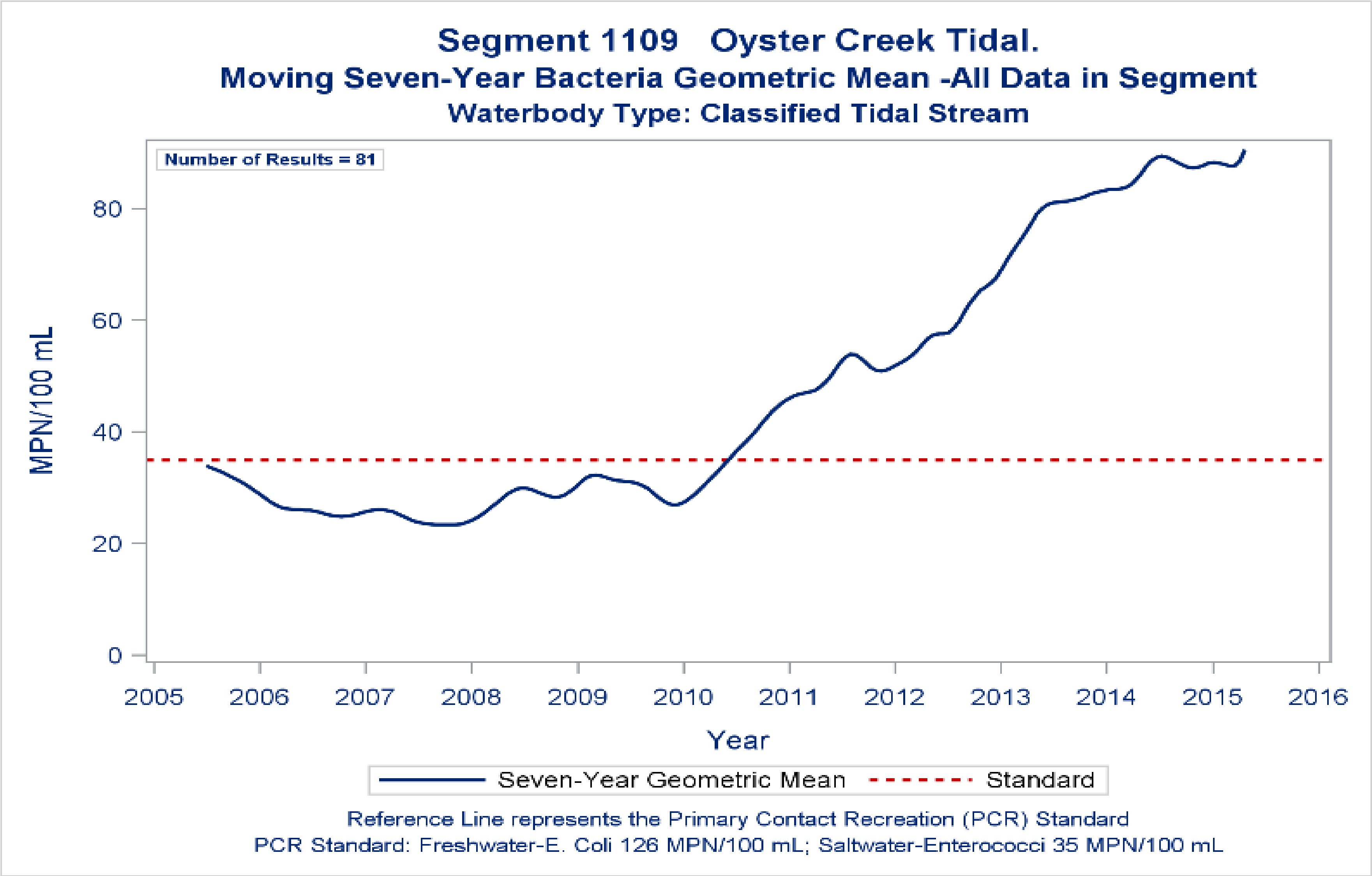
Segment Discussion:

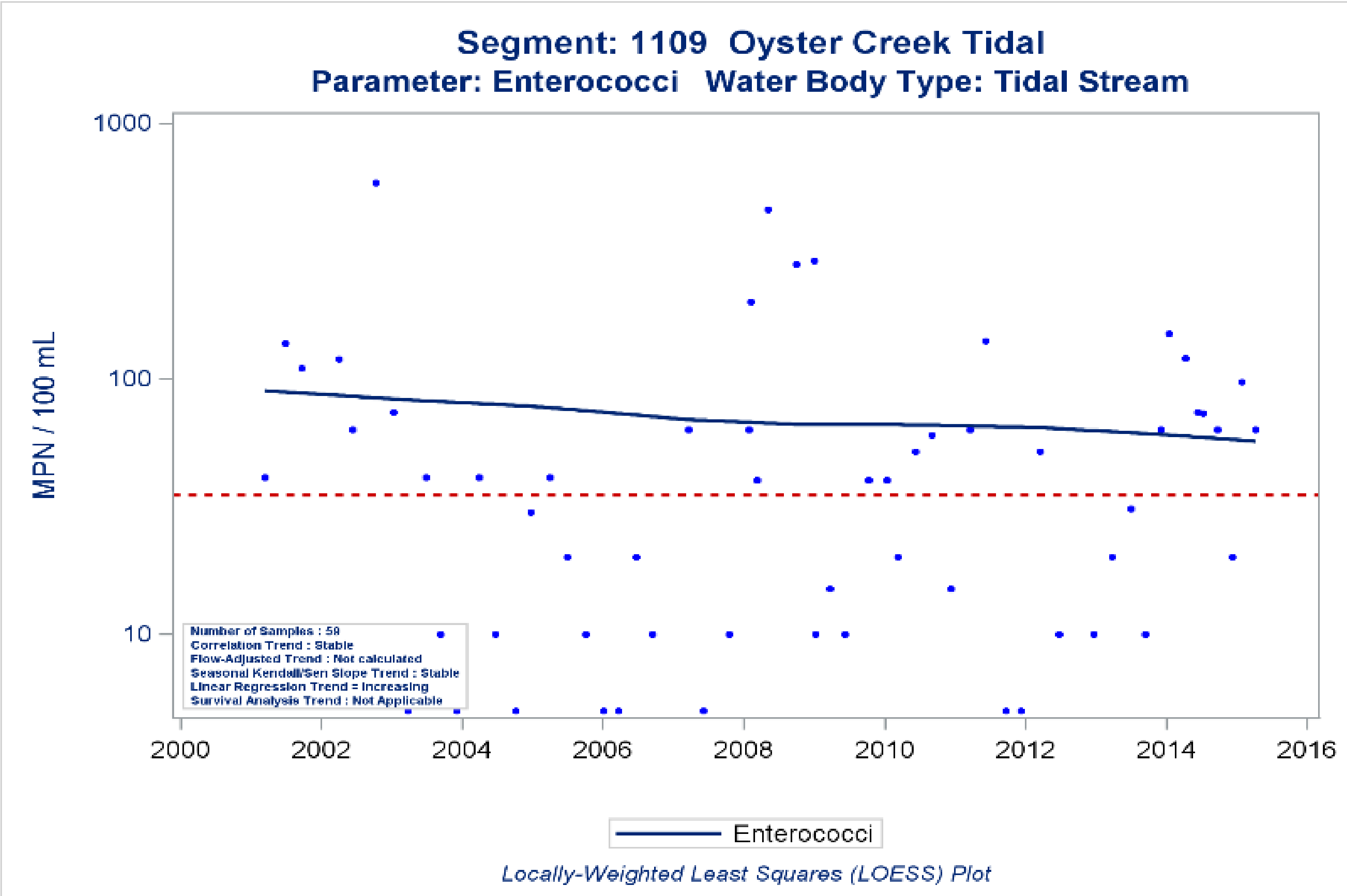
Watershed Characteristics: The Oyster Creek Tidal Watershed is primarily characterized by natural, undeveloped land uses including forests and grasslands. There are many oxbow lakes and extensive coastal wetlands in the southern and northeastern portions of the watershed. Urban centers in this watershed include Richwood, Clute, and Lake Jackson in the northwestern portions of the watershed. There are also a few pockets of development at Oyster Creek and along CR226 to the east of Clute. Small plots of agricultural lands are also present in the northern reaches of the watershed.

Water Quality Issues: The 2014 Texas Integrated Report (IR) lists the assessment unit 1109_01 as impaired for contact recreation due to elevated levels of enterococci bacteria. According to the TCEQ assessment, the geomean for this assessment unit is 73 MPN/100ml, which is more than twice the geomean standard of 35 MPN/100ml for enterococci. Due to the bacteria impairment, this segment does not fully meet the primary contact recreation designation; however, it does fully support high aquatic life use.

Special Studies/Projects: H-GAC with the TCEQ TMDL Program began a project in FY2017 to collect continuous flow data on Oyster Creek. The station was placed in 1110_02. The flow data will be used to complete tidal LDCs for 1109 and complete a TSD for Oyster Creek in FY2018. Texas AgriLife is facilitating the Galveston – Brazoria County Coalition of Watersheds to bring stakeholders involved in TMDL I-Plan and WPP implementation, including this watershed, together to build cooperation on common bacteria issues and BMPs. The goal is a regional watershed planning group that will elevate issues and attract funding.

Trends: The moving geometric means for enterococci show significant increases in bacteria levels with mean concentrations consistently exceeding the 35 MPN/100 mL standard since 2010. Enterococci concentrations plotted over time show approximately half of the samples collected since 2000 out of compliance with state bacteria standards and half of the samples in compliance. This relatively equal distribution of enterococci levels has resulted in an overall stable trend in enterococci over time; however, exceedances have sporadically reached such high levels that the overall geometric means for enterococci remain significantly higher than the state water quality standard.

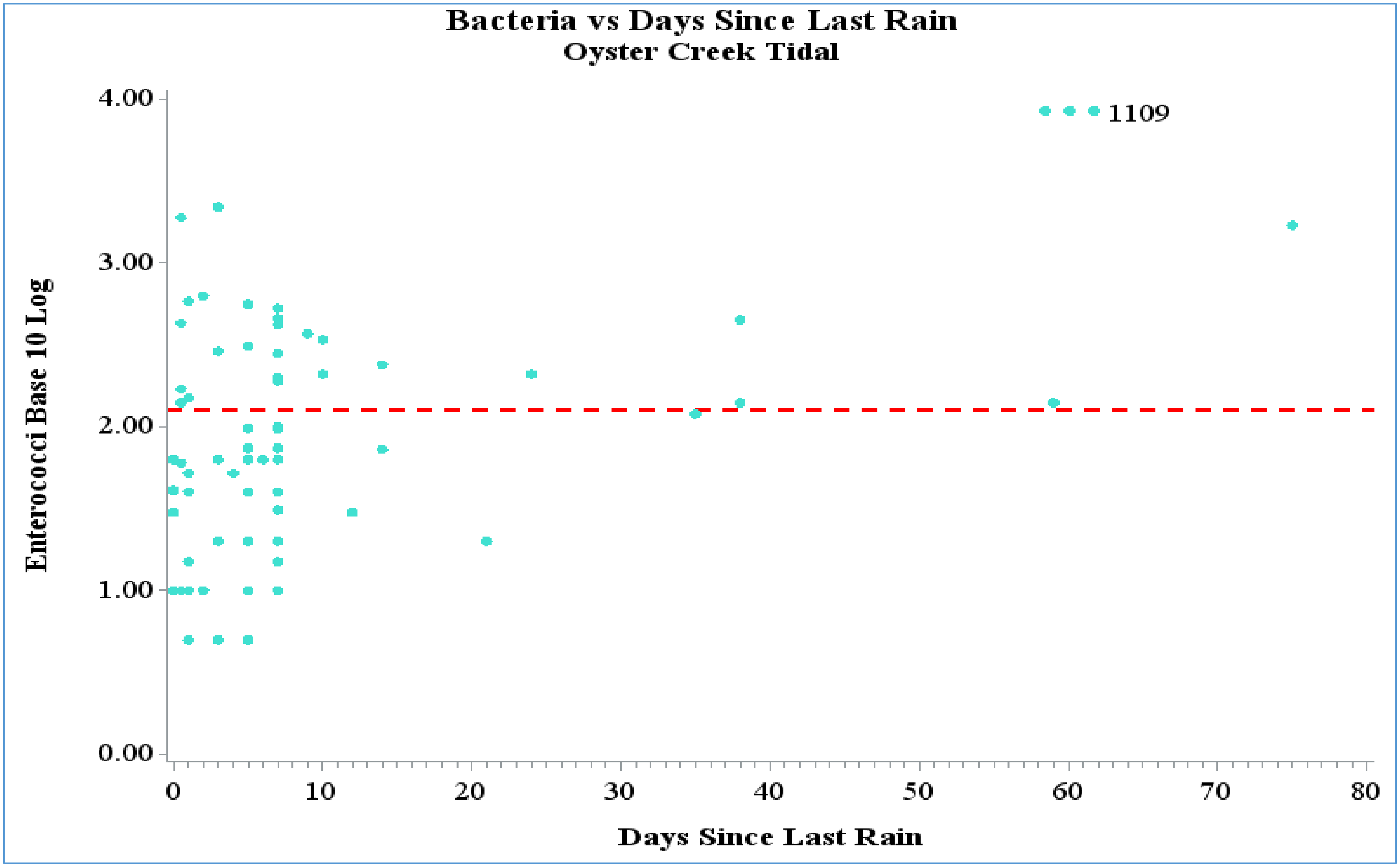

Segment 1109 Oyster Creek Tidal.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Classified Tidal Stream
Number of Results = 81
MPN/100 mL
0
20
40
60
80
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL



Segment: 1109 Oyster Creek Tidal
Parameter: Enterococci Water Body Type: Tidal Stream
1000
100
10
MPN / 100 mL
Number of Samples : 58
Correlation Trend : Stable
Flow-Adjusted Trend : Not calculated
Seasonal Kendall/Sen Slope Trend : Stable
Linear Regression Trend = Increasing
Survival Analysis Trend : Not Applicable
2000
2002
2004
2006
2008
2010
2012
2014
2016
Enterococci
Locally-Weighted Least Squares (LOESS) Plot

Load Duration Curves

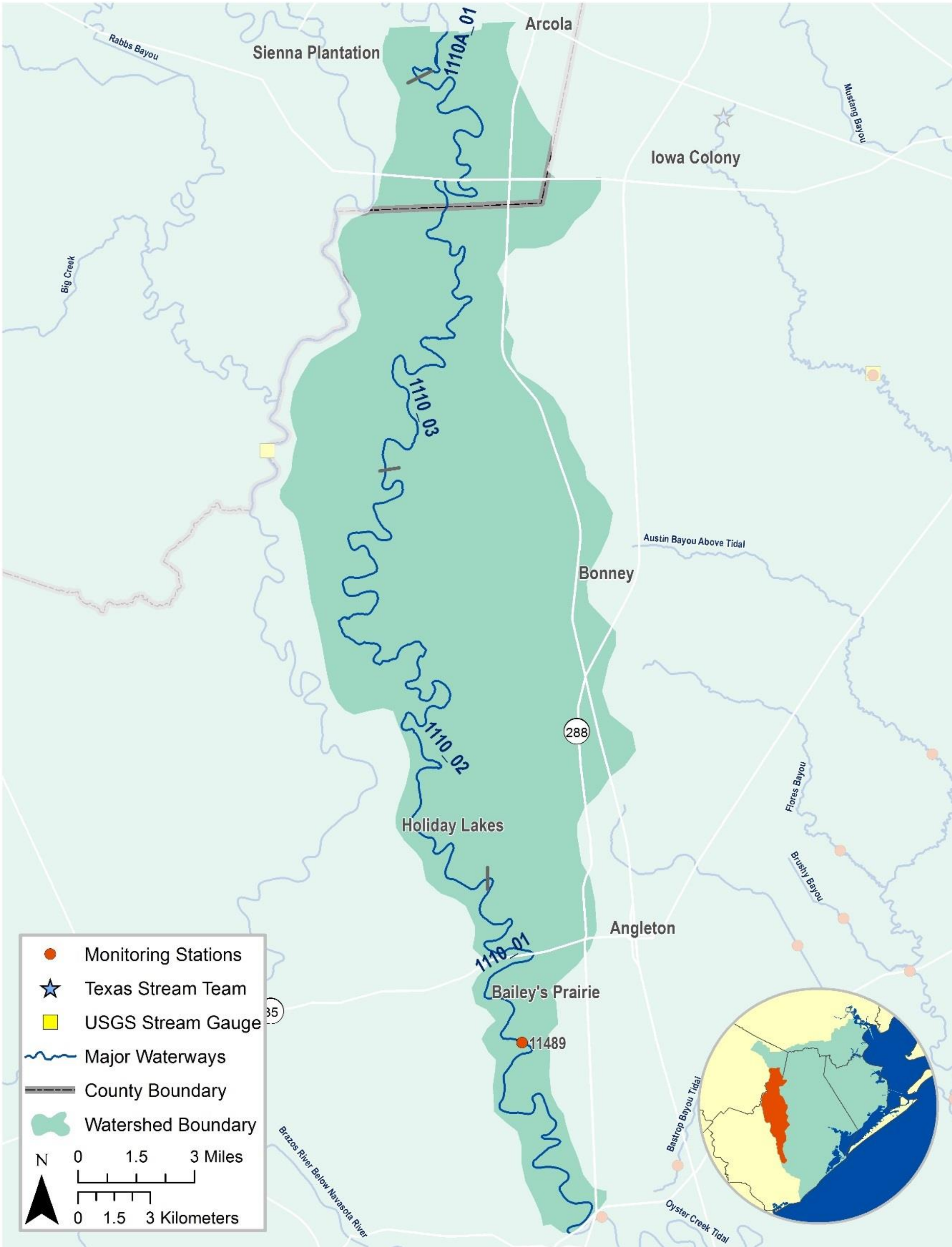
While there was sufficient bacteria data to complete a LDC, the tidal influence prohibited development of a simple LDC for this segment. Using the Days Since Last Rain plot as a surrogate until a more complex LDC or development of a model suggest that bacteria generally declines as the day the data was collected since rainfall is registered, increases. Days Since Last Rain is problematic as a surrogate as the bacteria data collected cannot be framed within the ambient conditions present as derived by flow conditions (i.e. extreme wet, wet, moderate, dry, extreme dry). A data point could be collected thirty days since the last rain event even while conditions for the watershed are still considered wet. Likewise, a bacteria sample could be collected a day after a rain event while the pervasive conditions are drought for the watershed. However, several samples were collected thirty or more days since last rainfall that were recorded above the standard (dashed red line) suggesting possible influence by permitted sources such as WWTFs due to the absence of nonpoint sources of bacteria as a result of possible dry conditions. As Days Since Last Rain cannot be used to explain the watersheds conditions when the data was collected (wet to dry), it is a far weaker argument when compared to a LDC, to say that bacteria loads are less of a problem during dry conditions due to bacteria generated by WWTFs or failing OSSFs.



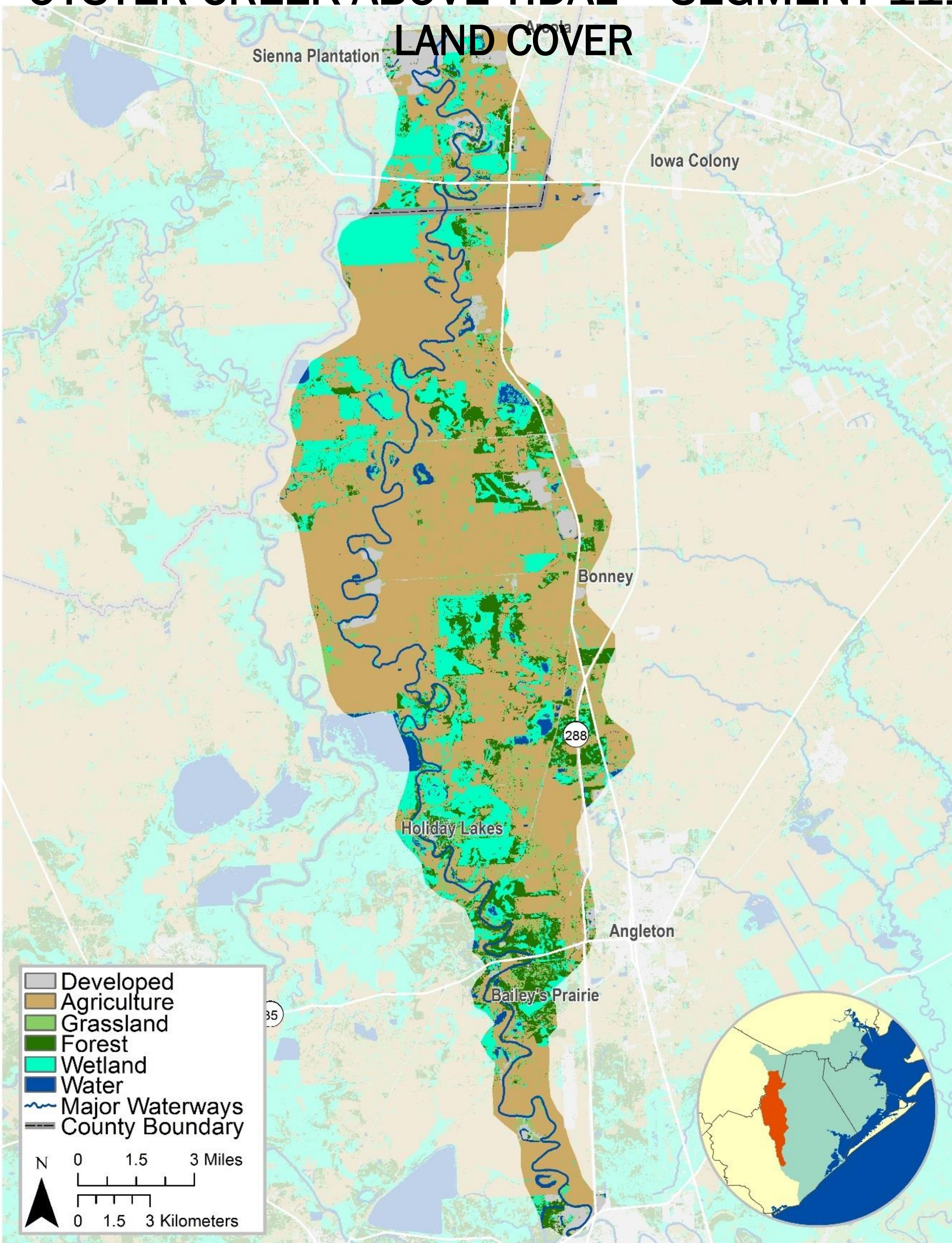
Bacteria vs Days Since Last Rain
Oyster Creek Tidal
1109
Enterococci Base 10 Log
4.00
3.00
2.00
1.00
0.00
0
10
20
30
40
50
60
70
80
Days Since Last Rain

Recommendations
Continue collecting water quality data to support actions associated with any future watershed protection plan development and possible modeling.
Facilitate discussions with local stakeholders to avoid impairment and concerns in the future.
Pursue a new local partner to Clean Rivers Program to collect additional data that would help better isolate problem areas.
Engage local stakeholders to implement best practices to reduce bacteria levels.

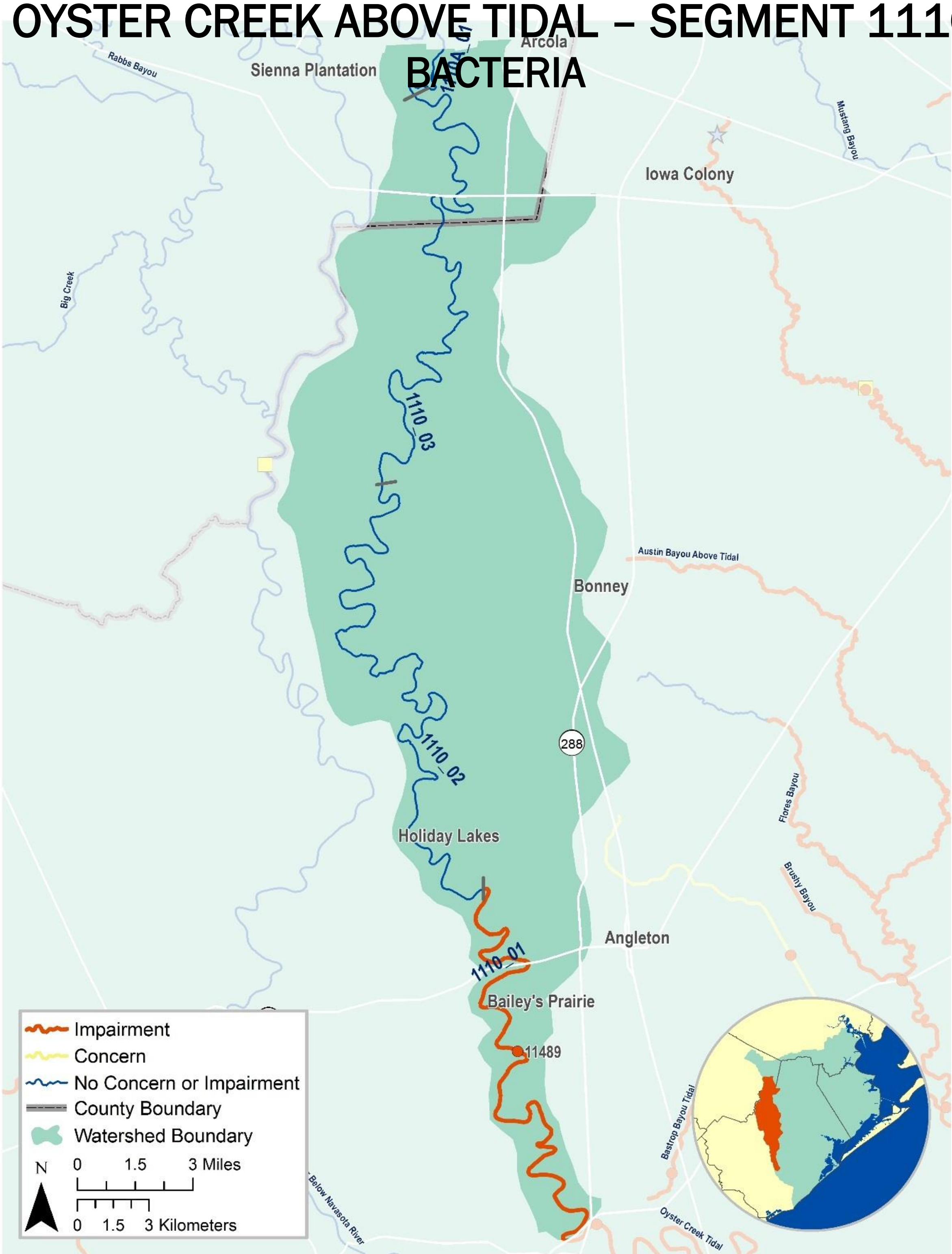
B9. OYSTER CREEK ABOVE TIDAL - SEGMENT 1110



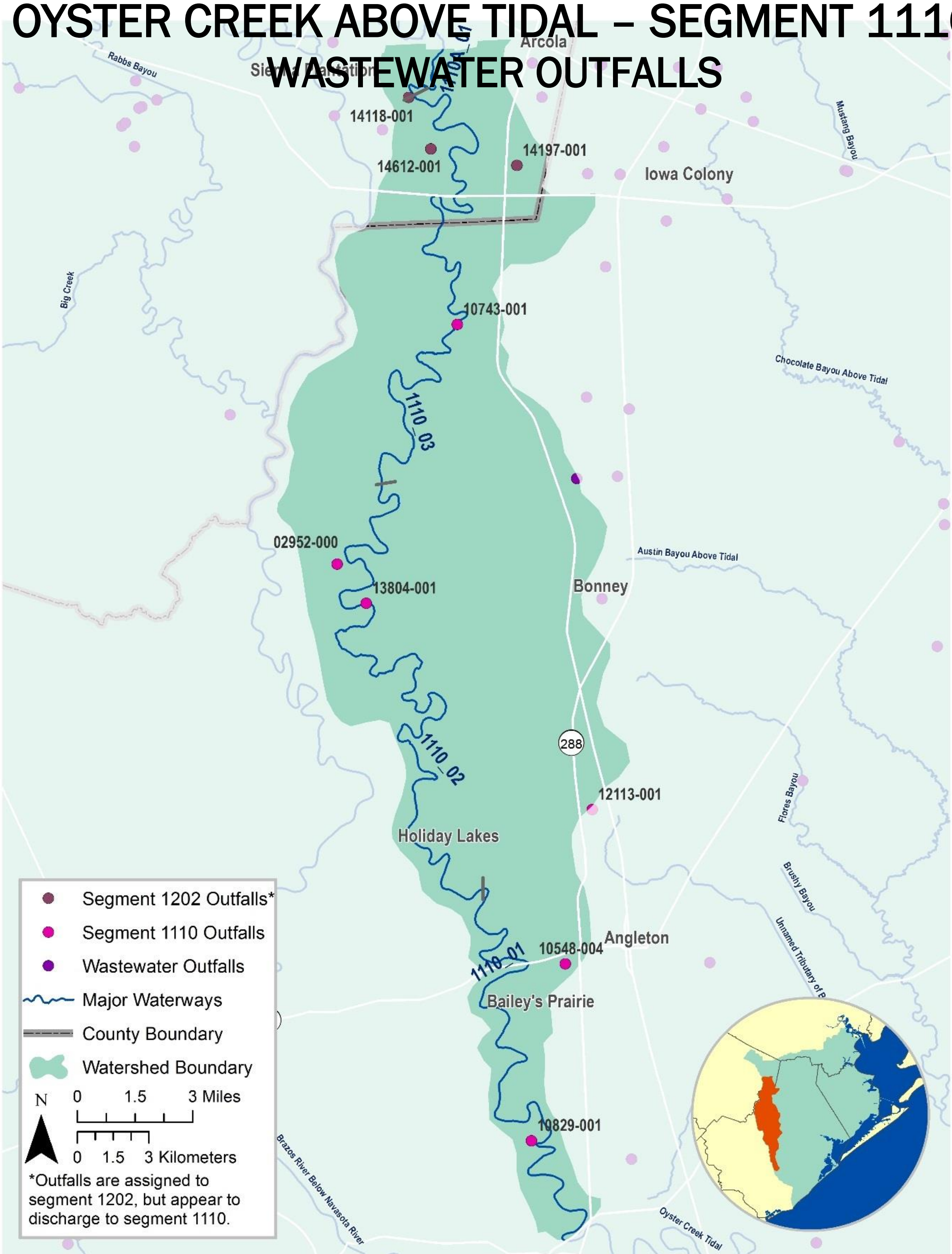
OYSTER CREEK ABOVE TIDAL – SEGMENT 1110
LAND COVER



OYSTER CREEK ABOVE TIDAL – SEGMENT 1110 BACTERIA



OYSTER CREEK ABOVE TIDAL – SEGMENT 1110
WASTEWATER OUTFALLS



Segment Number:	1110	Name:	Oyster Creek Above Tidal		
Length:	78 miles	**Watershed Area:**	167 square miles	**Designated Uses:**	Primary Contact Recreation 1; High Aquatic Life; Public Water Supply
Number of Active Monitoring Stations:	1	**Texas Stream Team Monitors:**	1	**Permitted Outfalls:**	15

Description: From a point 100 meters (110 yards) upstream of FM 2004 in Brazoria County to a point 4.3 km (2.7 mi) upstream of Scanlan Road in Fort Bend County

Segment 1110A (Perennial Stream w/ high ALU): Upper Oyster Creek Above Tidal (unclassified water body) – From a point 4.3 km (2.7 mi) upstream of Scanlan Road in Fort Bend County upstream to the confluence with Middle Oyster Creek approximately 325 m south of McKeever Road In Fort Bend County

Percent of Stream Impaired or of Concern	
Segment ID	**Bacteria**
1110	42

Segment 1109

Standards	Perennial Stream	Screening Levels	Perennial Stream
Temperature (°C):	32 / 90	Ammonia (mg/L):	0.33
Dissolved Oxygen *(24-Hr Average)* (mg/L):	5.0	Nitrate-N (mg/L):	1.95
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.37
pH (standard units):	6.5-9.0	Total Phosphorus (mg/L):	0.69
E. coli (MPN/100 mL) (grab):	399	Chlorophyll-*a* (µg/L):	14.1
E. coli (MPN/100 mL) (geometric mean):	126		
Chloride (mg/L as Cl):	300		
Sulfate (mg/L as SO_4):	150		
Total Dissolved Solids (mg/L):	750		

FY 2016 Active Monitoring Stations				
Site ID	**Site Description**	**Frequency**	**Monitoring Entity**	**Parameter Groups**
11489	Oyster Creek downstream of Walker St.	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*

Water Quality Issues Summary				
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern*		**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Levels of Indicator Bacteria	1110	I	▪ Animal waste from agricultural production and domestic animal facilities ▪ Rapid urbanization and increased impervious cover ▪ Constructed stormwater controls failing ▪ Developments with malfunctioning OSSFs ▪ Improper or no pet waste disposal ▪ Poorly operated or undersized WWTFs ▪ WWTF non-compliance, overflows, and collection system by-passes ▪ Direct and dry weather discharges ▪ Waste haulers illegal discharges/improper disposal	▪ Create and implement Water Quality Management Plans for individual agricultural properties ▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems ▪ More public education regarding OSSF operations and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education on pet waste disposal ▪ Regionalize chronically non-compliant WWTFs

			▪ Increase monitoring requirements for self-reporting ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Impose new or stricter bacteria limits than currently designated by TCEQ

Segment Discussion:

Watershed Characteristics: The majority of the watershed is not developed and is used for agricultural purposes. Much of the area is bottomland forest, grassland, and wetland habitat with numerous oxbow lakes. There are a few pockets of development associated with Arcola, Sienna Plantation, Fresno, Bailey's Prairie, Bonney Village, Angleton, Holiday Lakes, and Lake Jackson. The very top of the watershed is highly developed and is part of Sugar Land and Missouri City.

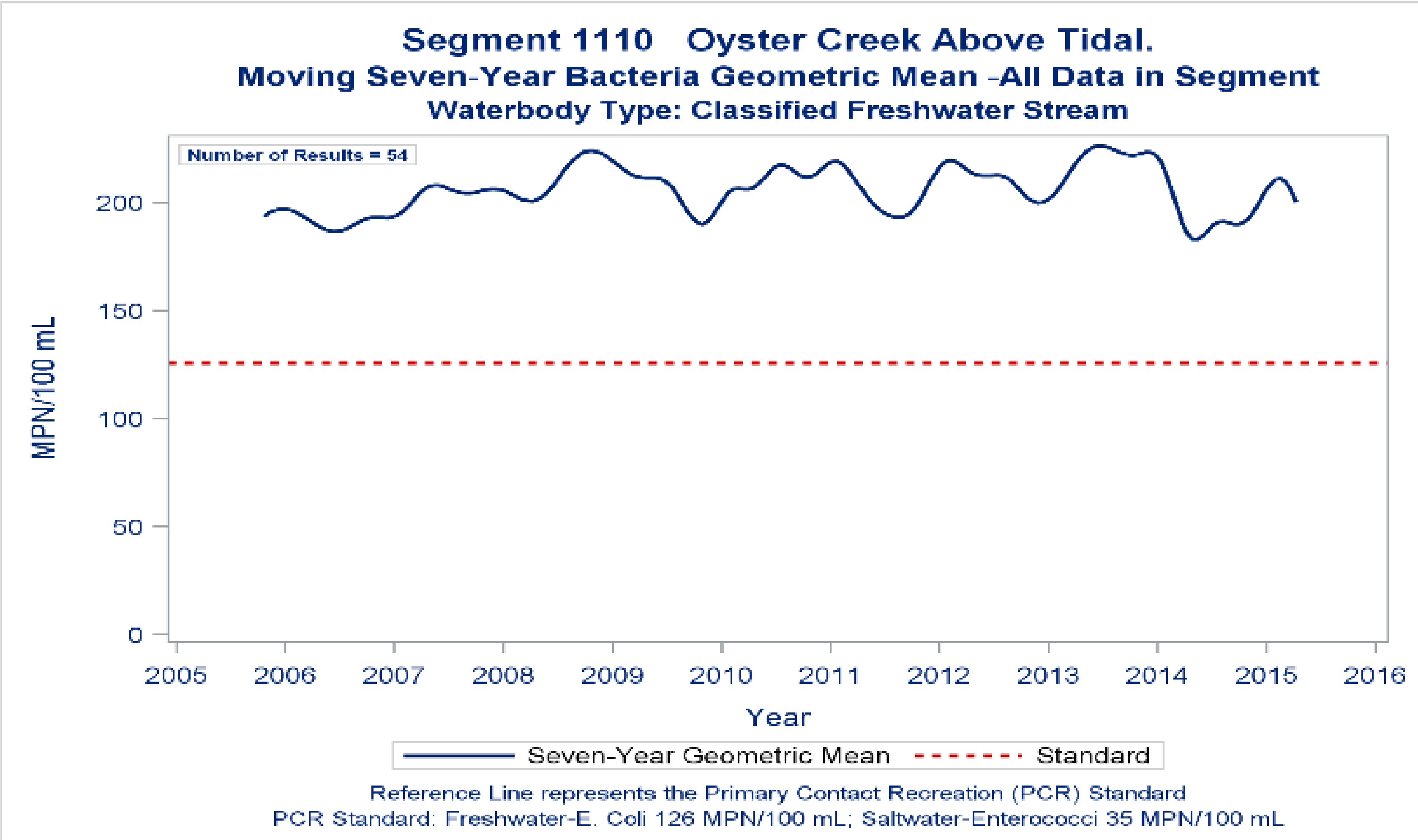
Water Quality Issues: The Texas Integrated Report lists the assessment unit 1110_01 as impaired for contact recreational use due to elevated levels of E. coli bacteria. The TCEQ assessment data and H-GAC analyses are summarized below:

Assessment Unit	TCEQ Assessment (2005-2012) Geomean (MPN/100 mL) / % Grab Exceedance	HGAC Analysis 2001-2008 Geomean (MPN/100 mL) / % Grab Exceedance	HGAC Analysis 2008-2015 Geomean (MPN/100 mL) / % Grab Exceedance
1110_01	201 / NA	209 / 12.0	200 / 18.5

This segment does not fully support its contact recreation.

Special Studies/Projects: H-GAC with the TCEQ TMDL Program began a project in FY2017 to collect continuous flow data on Oyster Creek. The station was placed in 1110_02. Additional bacteria data was collected in FY2017 at an established CRP station in 1110_01 and at a new station in 1110_02. The bacteria and flow data will be used to complete LDCs and a draft TSD for Oyster Creek in FY2018. Texas AgriLife is facilitating the Galveston – Brazoria County Coalition of Watersheds to bring stakeholders involved in TMDL I-Plan and WPP implementation, including this watershed, together to build cooperation on common bacteria issues and BMPs. The goal is a regional watershed planning group that will elevate issues and attract funding. One TMDL for bacteria and two TMDLs for dissolved oxygen (DO) were conducted for a segment above 1110 in 2011 (Upper Oyster Creek, 1245). H-GAC and TCEQ partnered with local stakeholders to develop an Implementation Plan to address these issues, which was approved in early 2014. The resulting implementation elements have taken on a phased approach since then. Though still hydrologically connected to Oyster Creek Above Tidal, much of the flow to and from Upper Oyster Creek is via hydrologic connections with the Brazos River (Basin 12).

Trends: The 2014 Texas Integrated Report designates this segment as impaired for bacteria. Moving seven-year geometric mean plots for *E. coli* show fluctuations over time with mean bacteria levels hovering around twice the state limit of 126 MPN/100 mL.


Segment 1110 Oyster Creek Above Tidal.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Classified Freshwater Stream
Number of Results = 54
MPN/100 mL
0
50
100
150
200
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

Load Duration Curves

While there was sufficient bacteria data to complete a LDC, the lone station in Segment 1110 lack continuous flow data. In reviewing alternative methods for approximating flow, this segment did not compare well to other watersheds with sufficient flow data due to the size of segment, predominant land cover/land uses and intermittent connection with the Brazos River above this segment's reach.

Using the Days Since Last Rain plot as a surrogate until sufficient data is available to complete an LDC suggest that bacteria declines though remains mostly above the standard (dashed red line) as the data is collected the farther away since the last rainfall was registered. Little data was recorded past seven days since last rainfall. Days Since Last Rain is problematic as a surrogate as the bacteria data collected cannot be framed within the ambient conditions present as derived by flow conditions (i.e. extreme wet, wet, moderate, dry, extreme dry). A data point could be collected thirty days since the last rain event even while conditions for the watershed are still considered wet. Likewise, a bacteria sample could be collected a day after a rain event while the pervasive conditions are drought for the watershed. As Days Since Last Rain cannot be used to explain the watersheds conditions when the data was collected, it is a far weaker argument compared to the use of LDCs, to say that bacteria loads in this case are a problem during dry conditions for this segment from bacteria generated by WWTFs or failing OSSFs.

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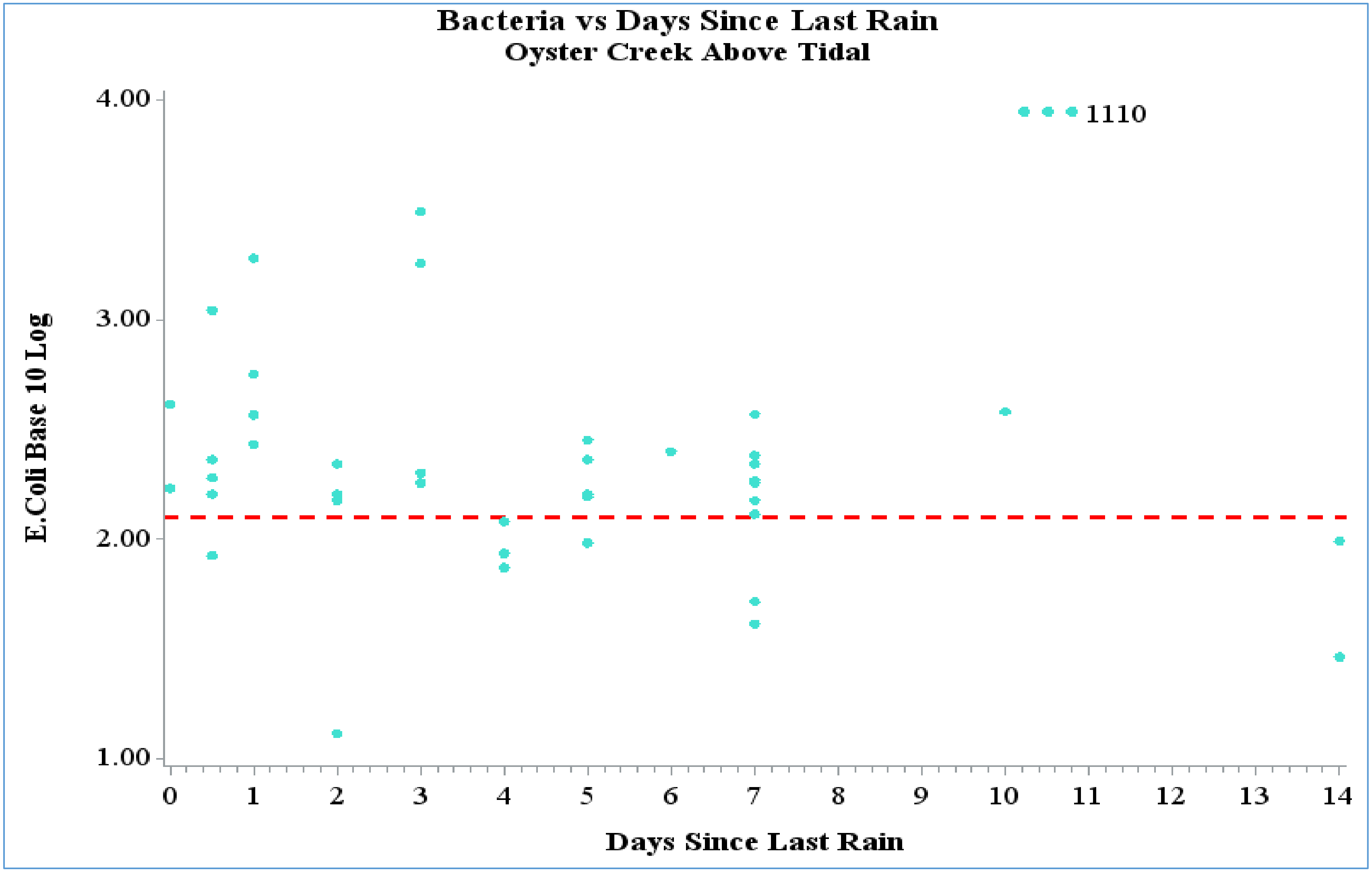
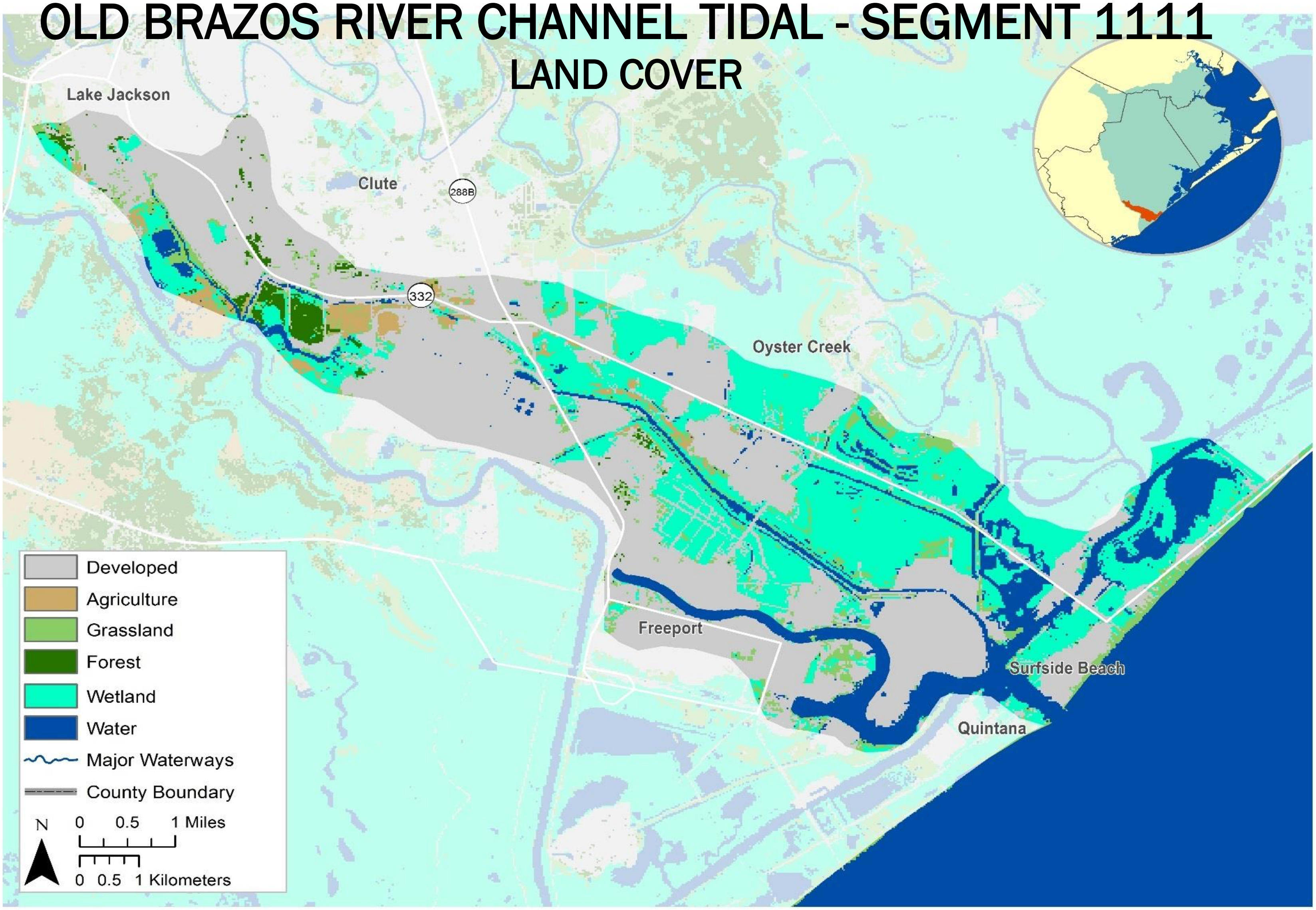

Bacteria vs Days Since Last Rain
Oyster Creek Above Tidal
1110
E.Coli Base 10 Log
4.00
3.00
2.00
1.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Days Since Last Rain

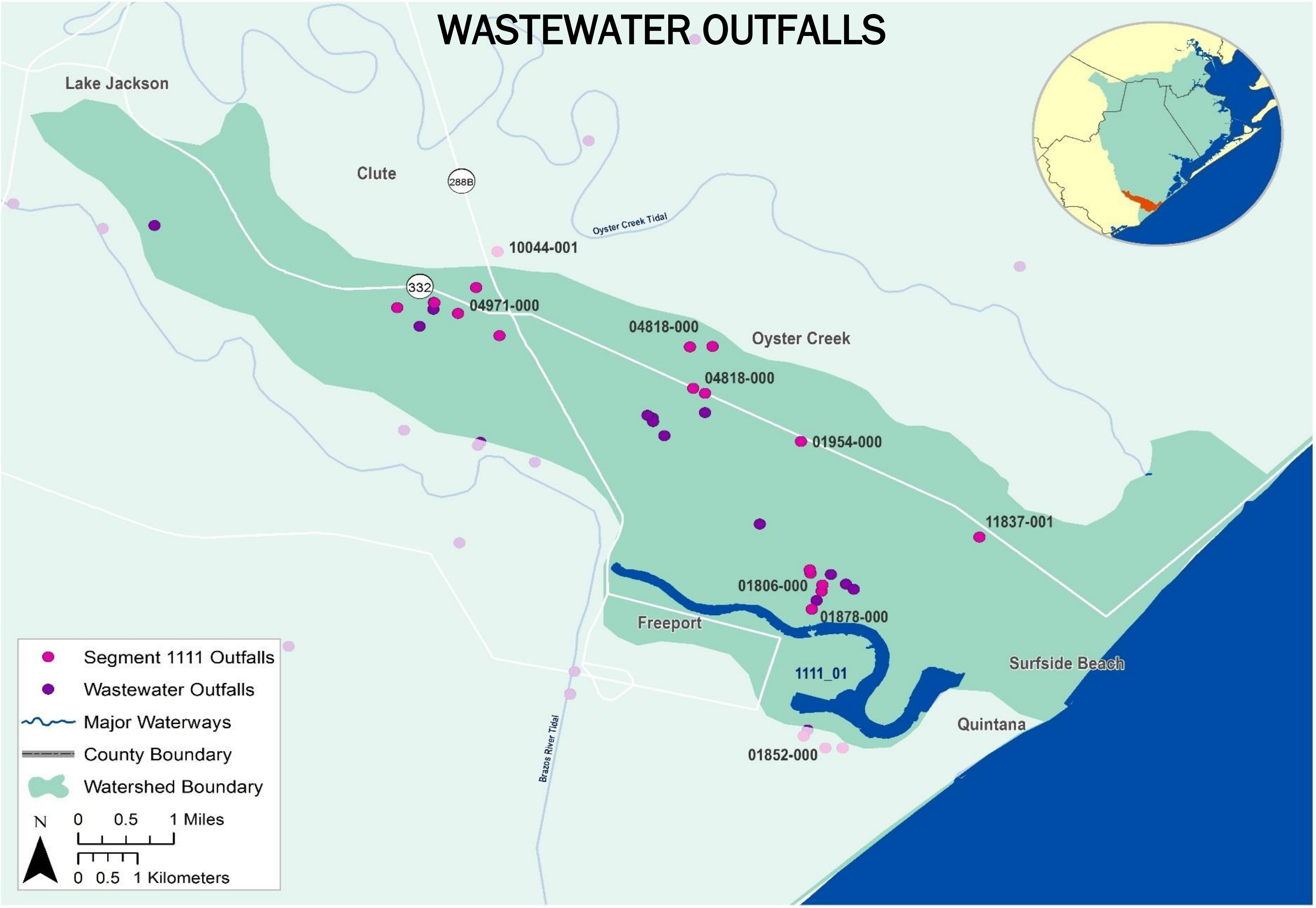
Recommendations
Address concerns found in this segment summary through facilitating stakeholder participation in a water quality planning effort.
Continue collecting water quality data, add additional monitoring stations to AUs not currently monitored and address a lack of flow data to support actions associated with any future Implementation Plan or TMDL development and future modeling.
Evaluate the impact of increasing flows as a result of increased pumping of Brazos River Water into the Upper Oyster Creek System by the Gulf Coast Water Authority to serve surface water conversion efforts in Fort Bend and other counties.
Pursue new local partners, including the Brazos River Authority, to assist Clean Rivers Program in collecting addition data that would help better isolate problem areas.

B10. OLD BRAZOS RIVER CHANNEL TIDAL - SEGMENT

OLD BRAZOS RIVER CHANNEL TIDAL - SEGMENT 1111
LAND COVER



OLD BRAZOS RIVER CHANNEL TIDAL - SEGMENT 1111
WASTEWATER OUTFALLS



Segment Number:	1111	Name:	Old Brazos River Channel Tidal		
Length:	6 miles	Watershed Area:	30 square miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life;
Number of Active Monitoring Stations:	1	Texas Stream Team Monitors:	0	Permitted Outfalls:	34
Description:	From the Intracoastal Waterway confluence to SH 288 in Brazoria County.				

Percent of Stream Impaired or of Concern	
Segment ID	Bacteria
1111	-

Segment 1111			
Standards	Estuary	Screening Levels	Estuary
Temperature (°C/°F):	35 / 95	Ammonia-N (mg/L):	0.10
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	Nitrate-N (mg/L):	0.17
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.19
pH (standard units):	6.5-9.0	Total Phosphorus-P (mg/L):	0.21
Enterococci (MPN/100mL) (grab):	104	Chlorophyll-*a* (µg/L):	11.6
Enterococci (MPN/100mL) (geometric mean):	35		

FY 2016 Active Monitoring Stations				
Site ID	**Site Description**	**Frequency**	**Monitoring Entity**	**Parameter Groups**
11498	Old Brazos River Channel midway between mouth and terminus	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
11498	Old Brazos River Channel midway between mouth and terminus	Twice / Year	TCEQ	Metals & Organics in Sediment

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern* *N- No Issue*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Levels of Indicator Bacteria	1111 N	▪ Developments with malfunctioning OSSFs ▪ Improper or no pet waste disposal ▪ Direct and dry weather discharges ▪ Poorly operated or undersized WWTFs ▪ Waste haulers illegal discharges/improper disposal ▪ WWTF non-compliance, overflows, and collection system by-passes	▪ Install and/or conserve vegetative buffer areas along all waterways ▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Add water quality features to stormwater systems ▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education on pet waste disposal ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Increase monitoring requirements for self-reporting

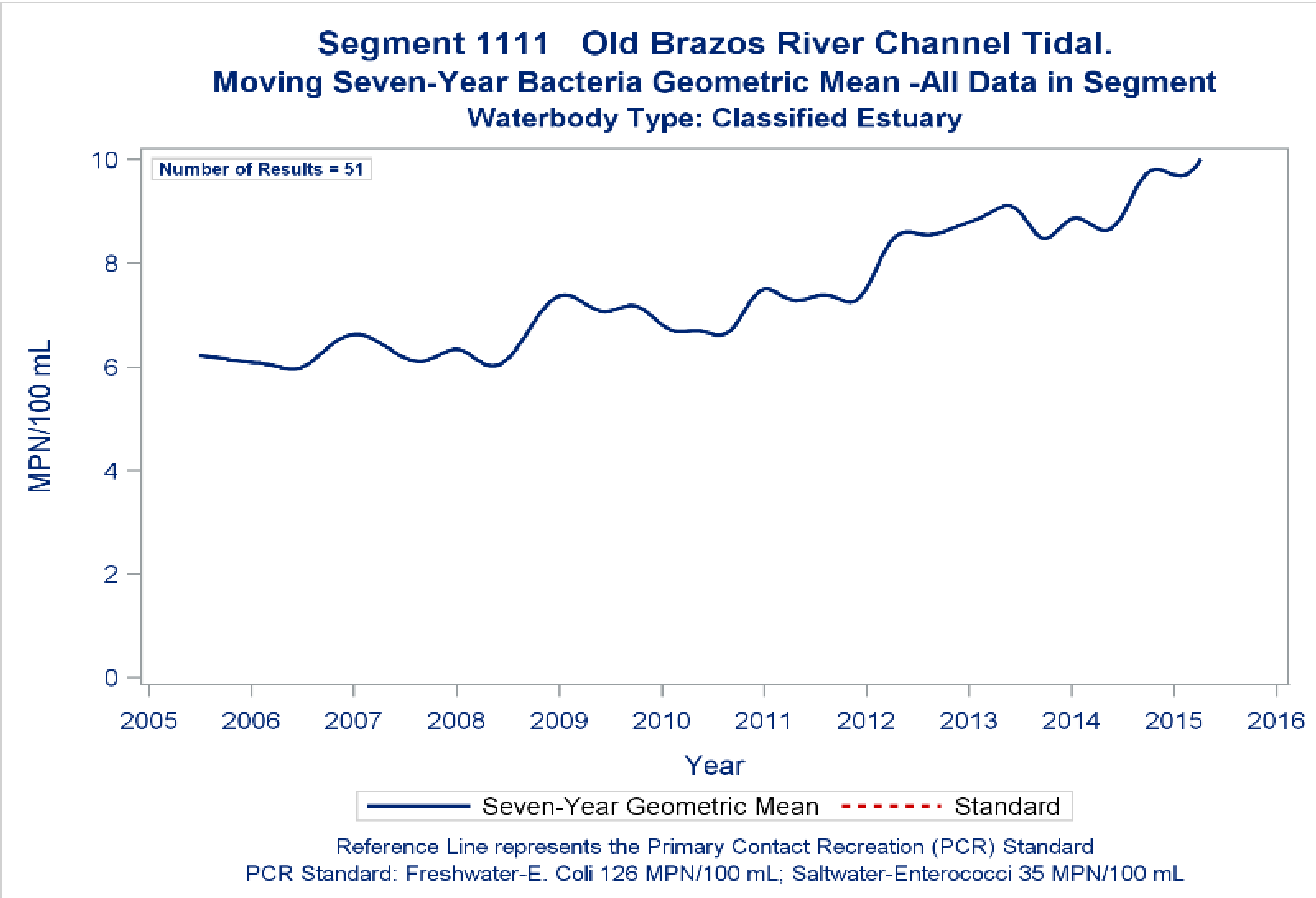
Segment Discussion:

Watershed Characteristics: This small watershed comprises what was once the mouth of the Brazos River, in southern Brazoria County. The watershed is home to the Freeport petrochemical complex, which dominates the landscape. Beachfront residential development along with water recreational activities are present in the lower reaches of the watershed at Surfside Beach and Quintana. There are large expanses of wetlands within and surrounding the watershed.

Water Quality Issues: Recreation use is fully supported.

Special Studies/Projects: No recent special studies or projects were found for this segment.

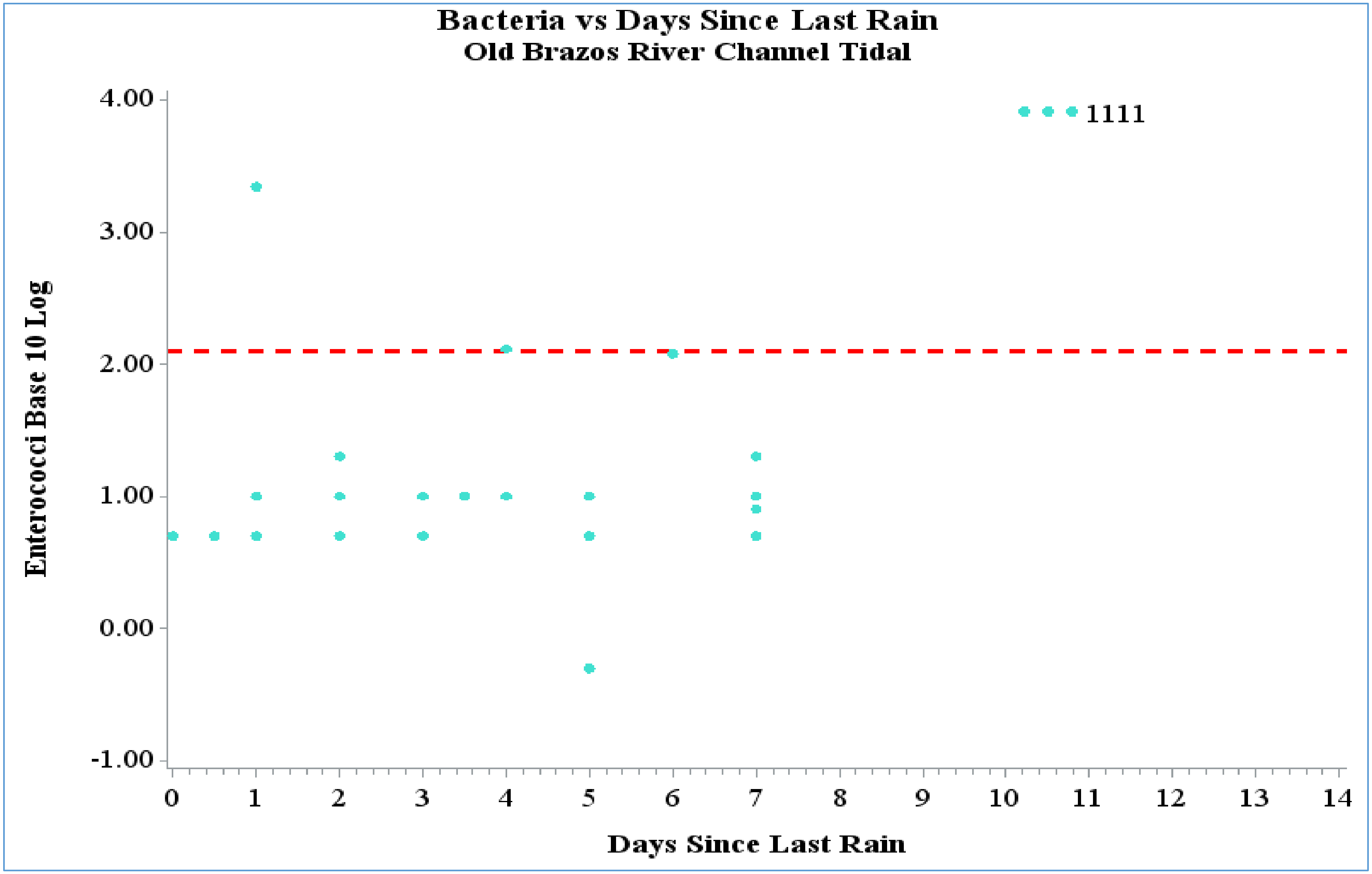
Trends: Although a slight increase in mean enterococci levels are observed in the moving seven-year bacteria geometric means plot for this segment, levels remain significantly lower than the 35 MPN/100 mL water quality standard and are not of concern at this time.



Segment 1111 Old Brazos River Channel Tidal.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Classified Estuary
Number of Results = 51
10
8
6
4
2
0
MPN/100 mL
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

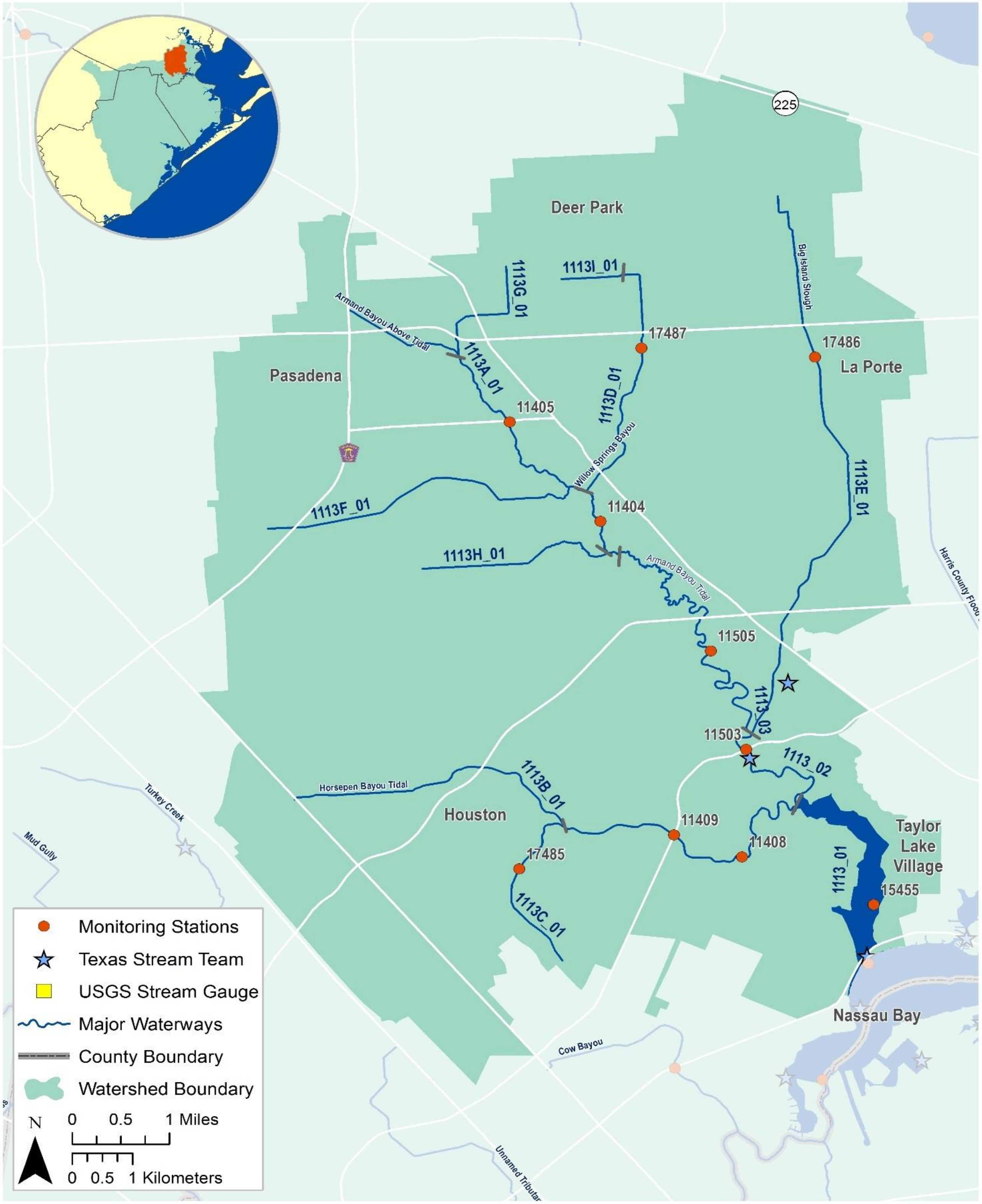
Load Duration Curves

While there was sufficient bacteria data to complete a LDC, the tidal influence prohibited development of a simple LDC for this segment. Using the Days Since Last Rain plot as a surrogate until a more complex LDC or development of a model suggest that bacteria stays at or below the standard (dashed red line) as bacteria data is collected the greater number of days since last rainfall was registered. Days Since Last Rain is problematic as a surrogate as the bacteria data collected cannot be framed within the ambient conditions present as derived by flow conditions (i.e. extreme wet, wet, moderate, dry, extreme dry). A data point could be collected thirty days since the last rain event even while conditions for the watershed are still considered wet. Likewise, a bacteria sample could be collected a day after a rain event while the pervasive conditions are drought for the watershed. As Days Since Last rain cannot be used to explain the watersheds conditions when the data was collected, it is a far weaker argument compared to the use of LDCs, to say that bacteria loads are less of a problem in this case during dry conditions due to bacteria generated by WWTFs or failing OSSFs.

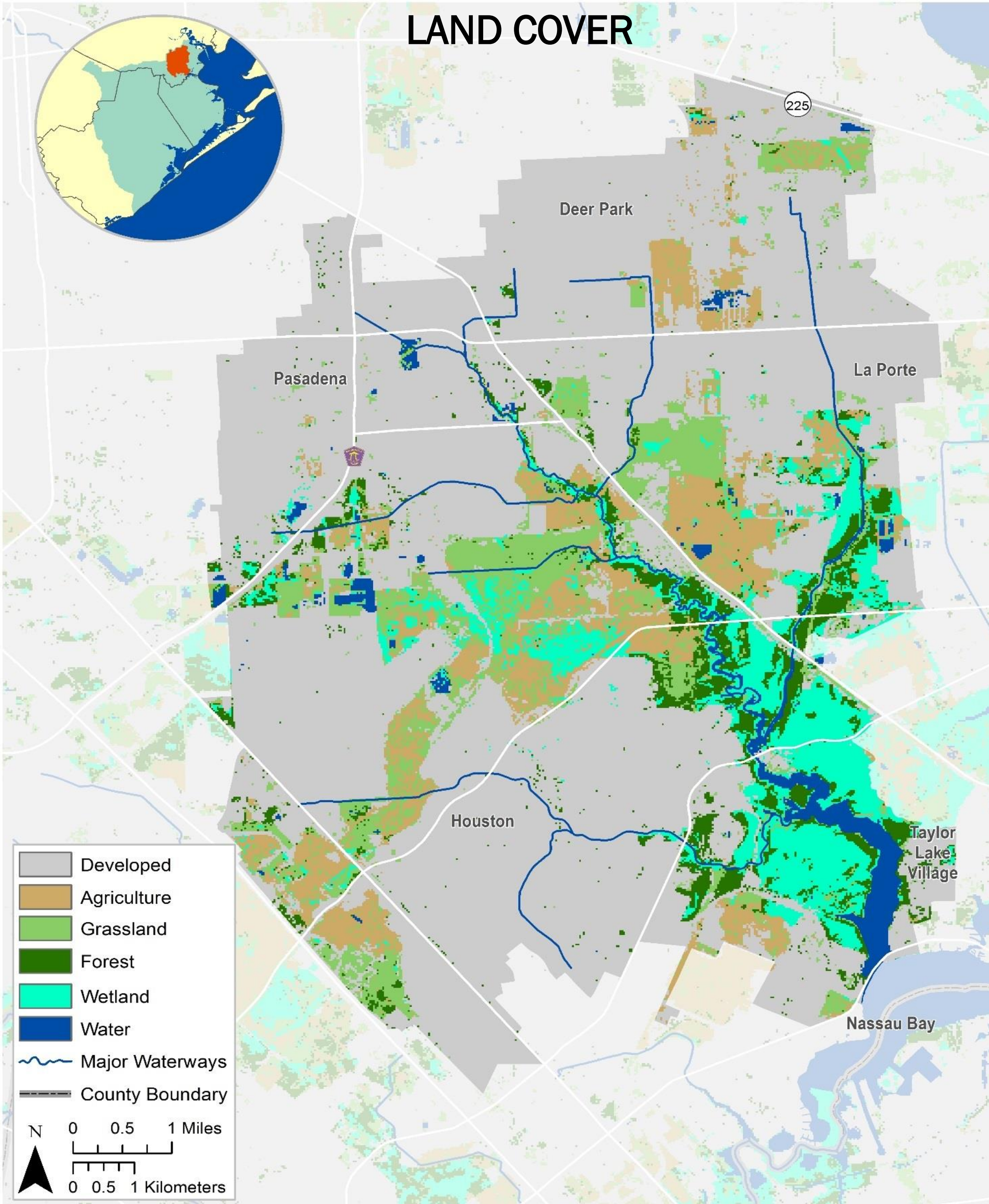

Bacteria vs Days Since Last Rain
Old Brazos River Channel Tidal
1111
Enterococci Base 10 Log
4.00
3.00
2.00
1.00
0.00
-1.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Days Since Last Rain

Recommendations
Provide bacteria outreach in this segment through stakeholder participation.
Continue collecting water quality data to support actions should they be needed in the future associated with TMDL development or any future watershed protection plan development and possible modeling.

B11. ARMAND BAYOU TIDAL - SEGMENT 1113

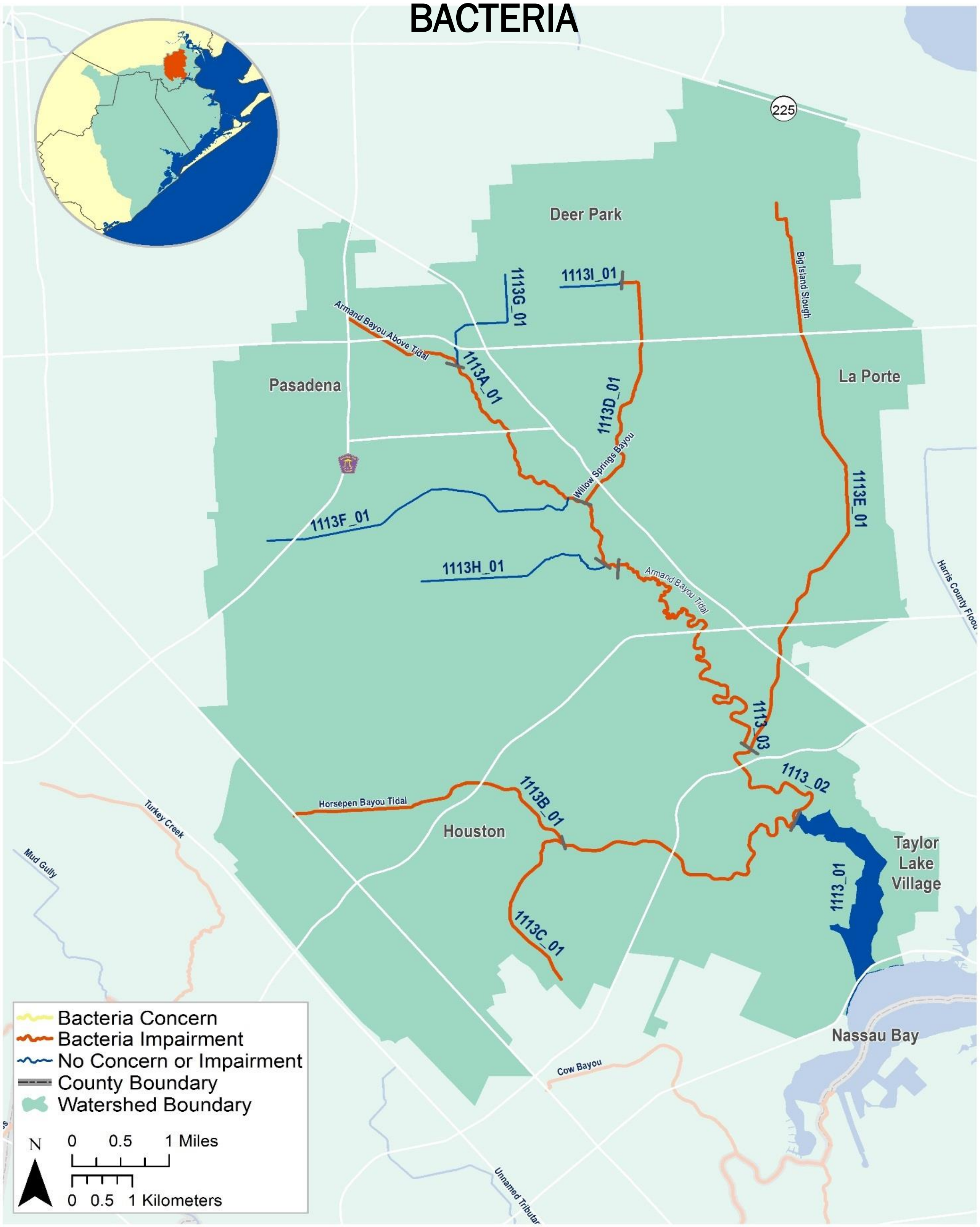


ARMAND BAYOU TIDAL - SEGMENT 1113



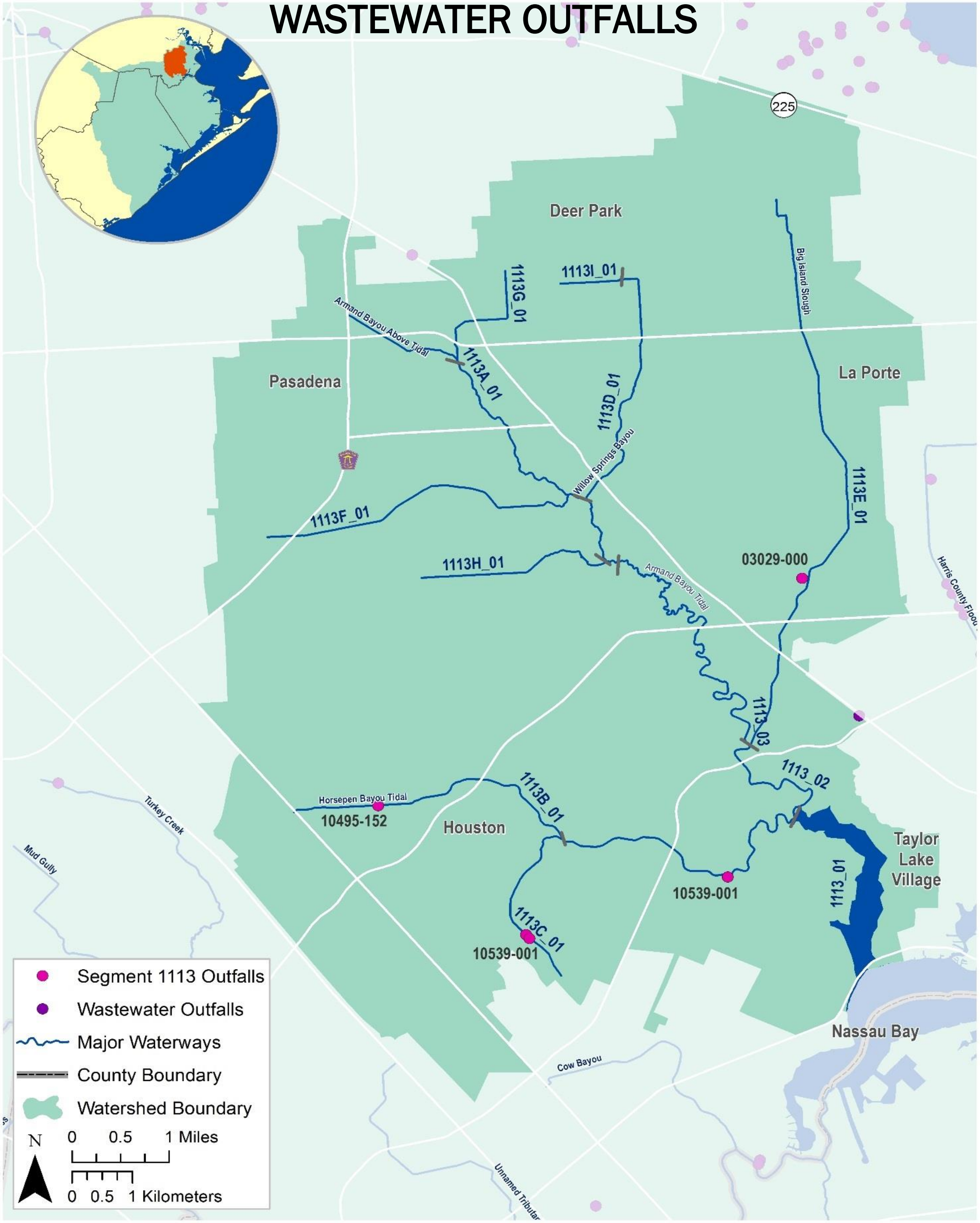
ARMAND BAYOU TIDAL - SEGMENT 1113

BACTERIA



ARMAND BAYOU TIDAL - SEGMENT 1113

WASTEWATER OUTFALLS



Segment Number:	1113	Name:	Armand Bayou Tidal		
Length:	9 miles	Watershed Area:	59 square miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life
Number of Active Monitoring Stations:	10	Texas Stream Team Monitors:	1	Permitted Outfalls:	5

Description:	Segment 1113 (Tidal Stream w/ high ALU): From the Clear Lake confluence (at NASA Road 1 bridge) in Harris County to a point 0.8 km (0.5 mi) downstream of Genoa-Red Bluff Road in Pasadena in Harris County (includes Mud Lake/Pasadena Lake) Segment 1113A (Perennial Stream w/ high ALU): Armand Bayou Above Tidal (unclassified water body) — From the upper segment boundary of Armand Bayou Tidal, 0.8 km (0.5 mi) downstream of Genoa-Red Bluff Road), upstream to Beltway 8 in Harris County Segment 1113B (Tidal Stream w/ high ALU): Horsepen Bayou (unclassified water body) — From the Armand Bayou confluence to the SH 3 Segment 1113C (Perennial Stream w/ intermediate ALU): Unnamed tributary to Horsepen Bayou (unclassified water body) — From the Horsepen Bayou confluence to Reseda Road Segment 1113D (Tidal Stream w/ high ALU): Willow Springs Bayou (unclassified water body) — From the Armand Bayou confluence to a point 2.8 km (1.8 mi) upstream to an unnamed tributary Segment 1113E (Tidal Stream w/ high ALU): Big Island Slough (unclassified water body) – From the Armand Bayou confluence upstream to a point 2.4 km (1.5 mi) north of Spencer Hwy Segment 1113F (Perennial Stream w/ high ALU): Unnamed Tributary of Armand Bayou Above Tidal (unclassified water body) – From the Armand Bayou Above Tidal confluence upstream to an unnamed tributary 0.48 km (0.3 mi) upstream of Beltway 8 Segment 1113G (Perennial Stream w/ high ALU): Unnamed Tributary of Armand Bayou Above Tidal (unclassified water body) – From the Armand Bayou Above Tidal confluence upstream to an unnamed tributary 1.4 km (0.86 mi) upstream of Red Bluff Road

	Segment 1113H (Perennial Stream w/ high ALU): Unnamed Tributary of Armand Bayou Above Tidal (unclassified water body) – From the Armand Bayou Above Tidal to the confluence of an unnamed tributary 3.4 km (2.1 mi) upstream and south of Genoa-Red Road 1113I (Perennial Stream w/ high ALU): Unnamed Tributary of Willow Springs Bayou (unclassified water body) – From the Will Springs Bayou confluence upstream to a point 0.37 km (0.23 mi) east of Center Street

Percent of Stream Impaired or of Concern	
Segment ID	**Bacteria**
1113	48
1113A	100
1113B	100
1113C	100
1113D	100
1113E	100

Segment 1113

Standards	Tidal Stream	Perennial Stream	Screening Levels	Tidal Stream	Perennial Stream
Temperature (°C/°F):	35/ 95	35 / 95	Ammonia-N (mg/L):	0.46	0.33
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	5.0 / 4.0	Nitrate-N (mg/L):	1.10	1.95
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	3.0	Orthophosphate Phosphorus (mg/L):	0.46	0.37
pH (standard units):	6.5-9.0	6.5-9.0	Total Phosphorus-P (mg/L):	0.66	0.69
Enterococci (MPN/100mL) (grab):	104		Chlorophyll-*a* (µg/L):	21	14.1
Enterococci (MPN/100mL) (geometric mean):	35				
E. coli (MPN/100 mL) (grab):		399			
E. coli (MPN/100 mL) (geometric mean):		126			

FY 2016 Active Monitoring Stations				
Site ID	**Site Description**	**Frequency**	**Monitoring Entity**	**Parameter Groups**
11404	Armand Bayou at Genoa-Red Bluff	Nine Times / Year	COH / HHS	Field, Conventional, Bacteria
11405	Armand Bayou at Fairmont Parkway	Nine Times / Year	COH / HHS	Field, Conventional, Bacteria
11408	Horsepen Bayou downstream of Middlebrook Dr.	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
11409	Horsepen Bayou at Bay Area Blvd	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
11503	Armand Bayou at Bay Area Blvd.	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
11503	Armand Bayou at Bay Area Blvd.	Nine Times / Year	COH / HHS	Field, Conventional, Bacteria
11503	Armand Bayou at Bay Area Blvd.	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
11505	Armand Bayou tidal at Exxon Oil Rd.	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
15455	Armand Bayou tidal at Clear Lake Park of Fishing Pier in Mud Lake/Pasadena Lake	Monthly	HCPHES	Field, Conventional, Bacteria
17485	Unnamed Trib Horsepen at Penn Hills	Nine Times / Year	COH / HHS	Field, Conventional, Bacteria
17486	Big Island Slough at Hillridge	Nine Times / Year	COH / HHS	Field, Conventional, Bacteria
17487	Willow Spring at Bandridge	Nine Times / Year	COH / HHS	Field, Conventional, Bacteria

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Levels of Indicator Bacteria	1113 I 1113A I 1113B I 1113C I 1113D I 1113E I	▪ Rapid urbanization and increased impervious cover ▪ Constructed stormwater controls failing ▪ Animal waste from hobby farms ▪ Improper or no pet waste disposal ▪ Poorly operated or undersized WWTFs ▪ WWTF non-compliance, overflows, and collection system by-passes	▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Encourage Water Quality Management Plans or similar projects for agricultural properties ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems

		▪ Direct and dry weather discharges ▪ Waste haulers illegal discharges/improper disposal ▪ Developments with malfunctioning OSSFs	▪ More public education on pet waste disposal ▪ Impose new or stricter bacteria limits than currently designated by TCEQ ▪ Increase monitoring requirements for self-reporting ▪ Regionalize chronically non-compliant WWTFs ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs

Segment Discussion:

Watershed Characteristics: The majority of this watershed is densely developed and includes portions of the Cities of Houston, La Porte, Deer Park, and Pasadena. In addition to residential and commercial development, there are also a number of large industrial facilities, as well as Ellington Air Field. The main segment is primarily lined with forestlands and wetlands while grasslands and agricultural land uses are common throughout the central portions of the watershed. The Johnson Space Center, University of Houston-Clear Lake, and the Armand Bayou Nature Center are located in the southern reaches. The vast majority of this watershed is served by WWTFs, although there are a few scattered areas of OSSFs present as well.

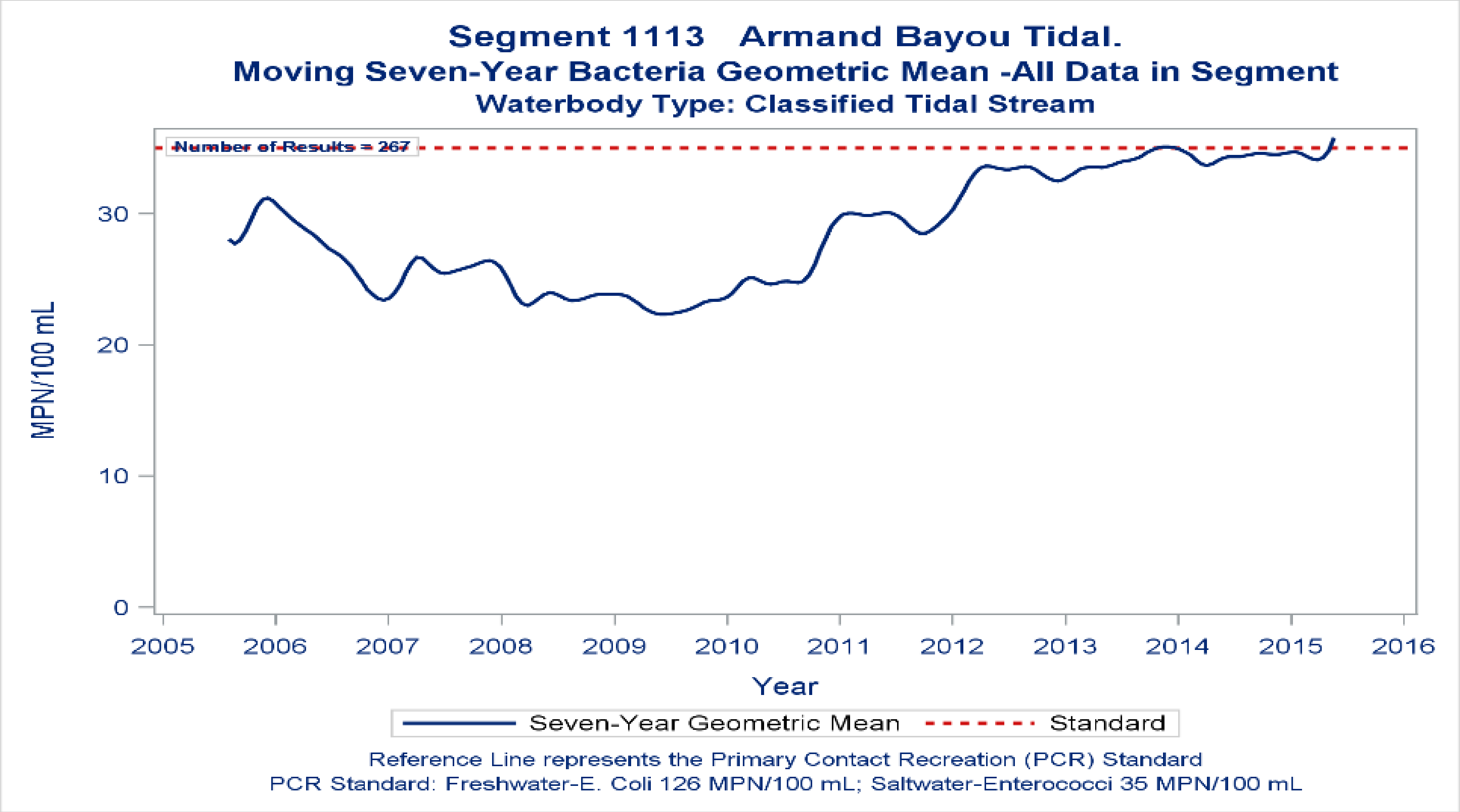
Water Quality Issues: The 2014 Texas Integrated Report (IR) lists two assessment units of the classified water body (segment 1113), and three tributaries (1113B_01, 1113D_01, and 1113E_01) as impaired for contact recreation due to elevated levels of Enterococci. Two unclassified segments (1113A_01 and 1113C_01) are also impaired for contact recreation due to elevated levels of *E. coli*. The TCEQ assessment data and H-GAC analyses are summarized below:

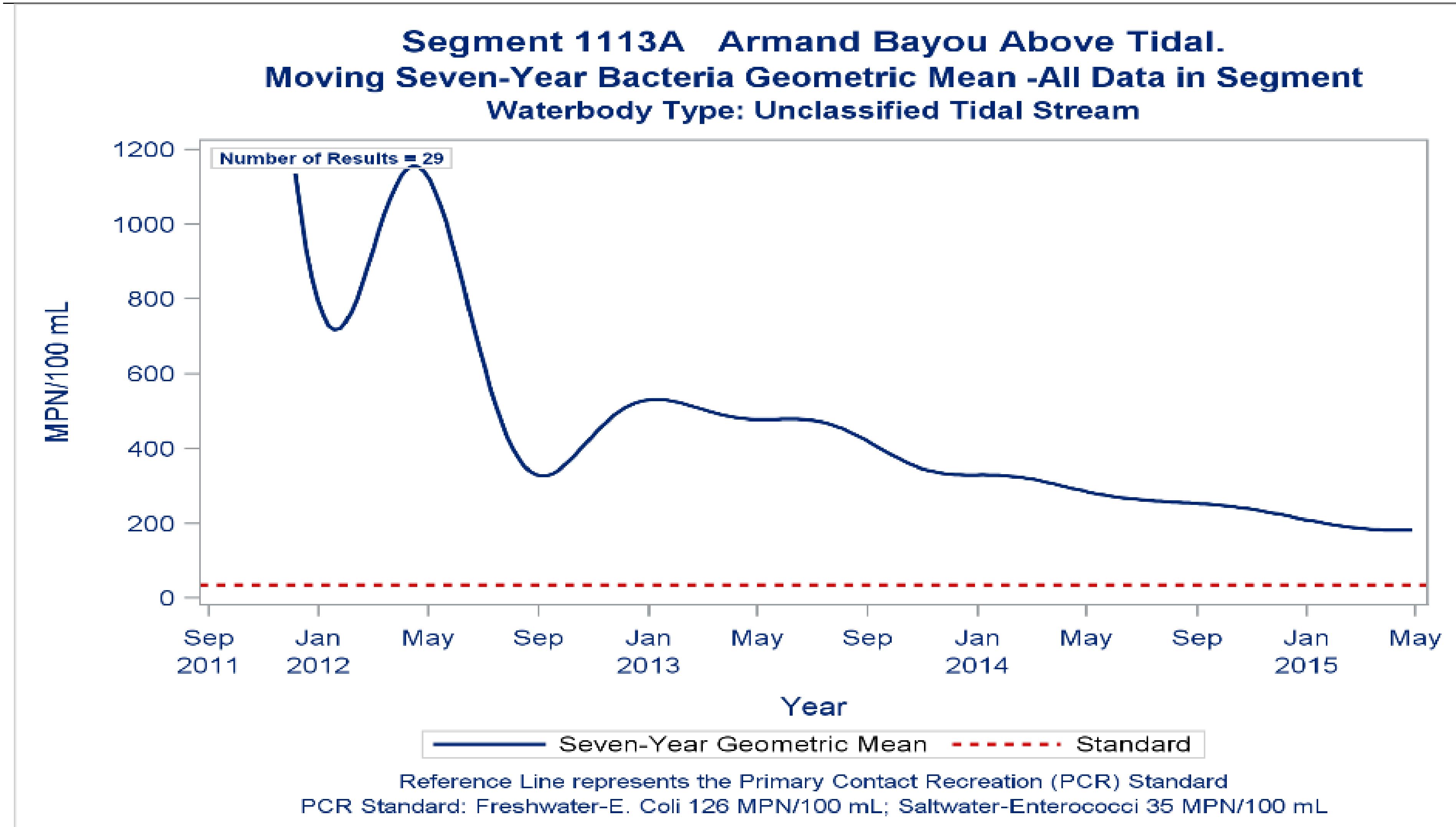
Assessment Unit	TCEQ Assessment (2005-2012) Geomean (MPN/100 mL) / % Grab Exceedance	HGAC Analysis 2001-2008 Geomean (MPN/100 mL) / % Grab Exceedance	HGAC Analysis 2008-2015 Geomean (MPN/100 mL) / % Grab Exceedance
1113_01	27 / NA	NA / NA	16 / 10.0
1113_02	41 / NA	26 / 20.0	44 / 29.3
1113_03	48 / NA	22 / 20.0	67 / 21.7
1113A_01	345 / NA	254 / 41.4	140 / 21.2
1113B_01	67 / NA	36 / 21.6	109 / 46.4
1113C_01	187 / NA	243 / 32.4	152 / 27.9
1113D_01	709 / NA	881 / 77.5	557 / 51.6
1113E_01	501 / NA	776 / 70.4	261 / 36.2

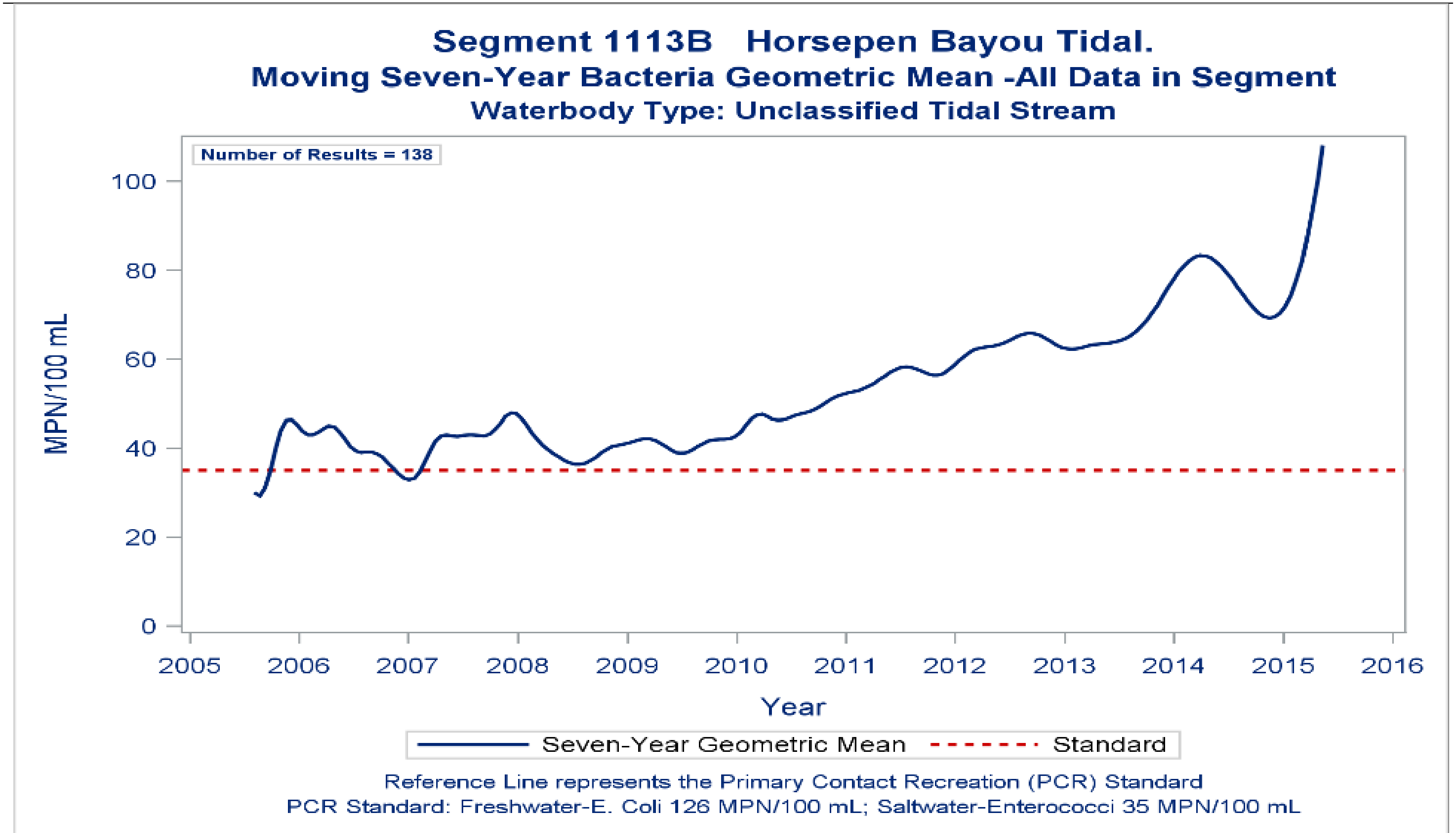
Special Studies/Projects: A TMDL was completed and approved by the TCEQ in August 2015. Stakeholders within the watershed decided to join the Bacteria Implementation Group (BIG) in implementing the BIG Implementation Plan rather than developing an Armand Bayou specific implementation plan. Stakeholders have begun to track implementation measures and participate in BIG meetings. Segment ends in Clear Lake, a segment with active participants in the UGCOWs TMDL I-Plan. A RUAA survey was completed for Armand Bayou Above Tidal and is currently being reviewed by the TCEQ. TCEQ will make available any approved RUAA survey and any subsequent recommendations to the public for public comment. Stakeholders along with Texas AgriLife (formerly Texas Cooperative Extension) initiated in November 2002 a WPP for the segment which resulted in Phase I of the Armand Bayou Watershed Plan - http://www.h-gac.com/community/water/watershed_protection/armand-bayou.aspx. The Armand Bayou Watershed Partnership, as the stakeholders called themselves, continued to meet off and on, more recently in 2012, in an attempt to attract funding to complete the second phase of the plan.

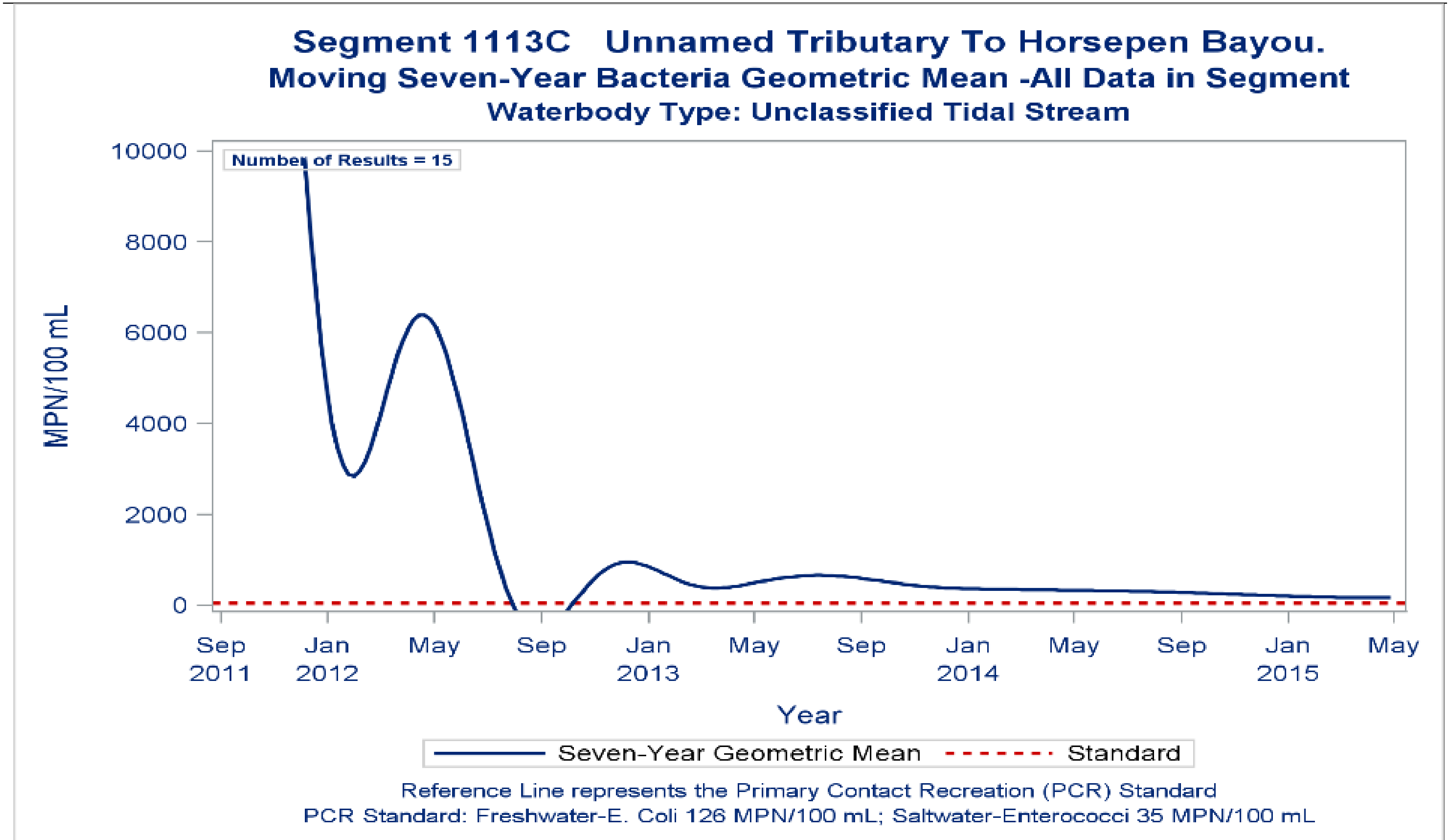
Trends: Regression analysis of bacteria data for Segment 1113 revealed four bacteria trends. Segment 1113A demonstrated a decreasing trends for *E. coli*. Regression analysis for segment 1113B data revealed an increasing trend in enterococci. Segment 1113C it was found that *E. coli* levels are increasing over time. Finally, regression analysis for segment 1113E data revealed decreasing *E. coli*.

The entire watershed is currently listed as impaired for bacteria in the 2014 Texas Integrated Report. Moving seven-year bacteria geometric mean plots show a gradual improvement in bacteria levels in four out of six segments in the watershed. Increasing mean enterococci levels have been approaching the 35 MPN/100 mL standard over time for the main segment of Armand Bayou Tidal, but the majority of samples collected during the period of record fall at or below the standard. Segment 1113B, Horsepen Bayou, shows mean enterococci concentrations increasing well above the 35 MPN/100 mL standard. Overall, bacteria levels for freshwater segments that use *E. coli* as the indicator bacteria are showing improvements while tidal streams in this watershed that use enterococci as the indicator bacteria are experiencing gradual increases over time.

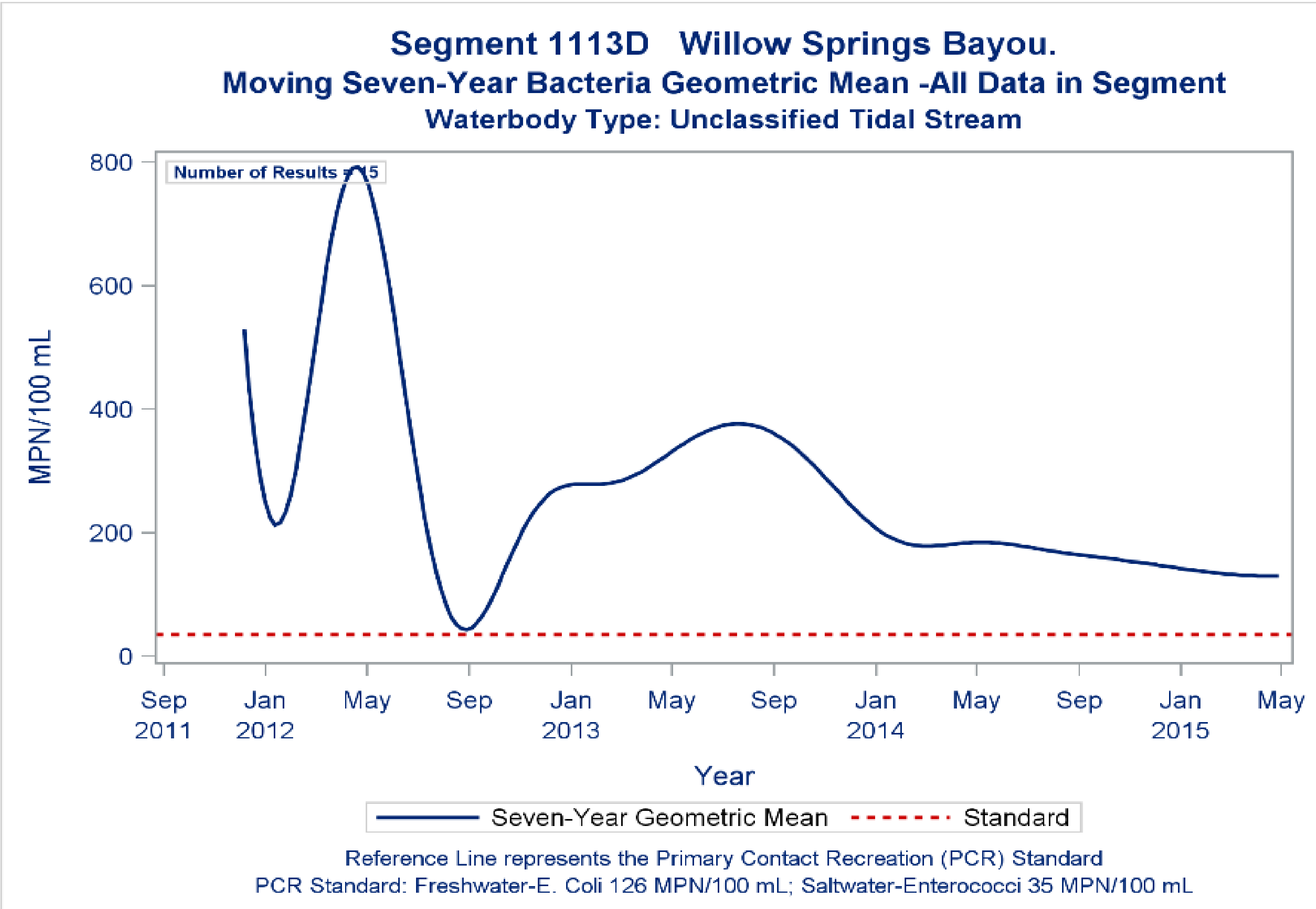

Segment 1113 Armand Bayou Tidal.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Classified Tidal Stream
Number of Results = 267
MPN/100 mL
0
10
20
30
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

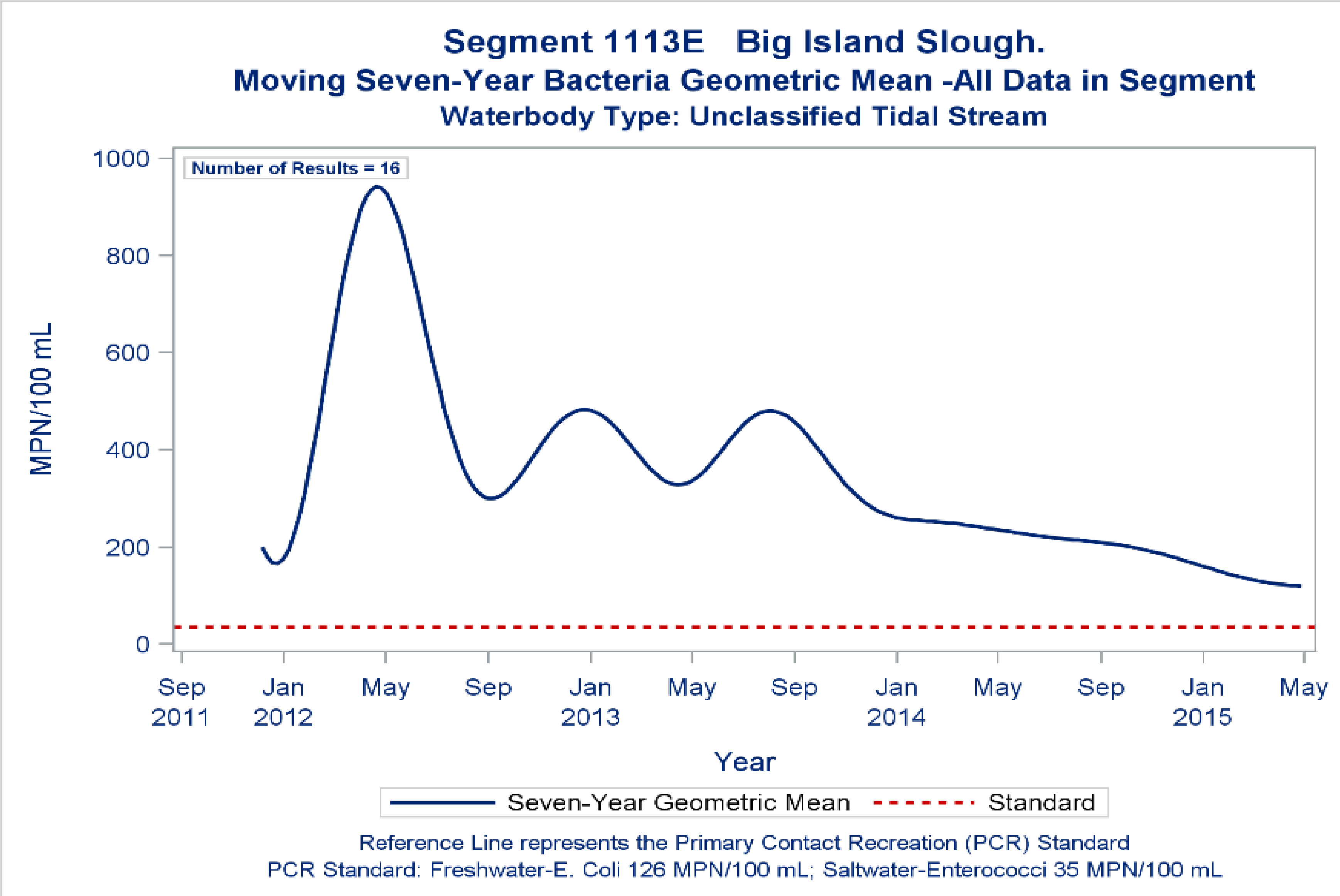

Segment 1113A Armand Bayou Above Tidal.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 29
MPN/100 mL
1200
1000
800
600
400
200
0
Sep 2011
Jan 2012
May
Sep
Jan 2013
May
Sep
Jan 2014
May
Sep
Jan 2015
May
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL


Segment 1113B Horsepen Bayou Tidal.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 138
MPN/100 mL
0
20
40
60
80
100
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL



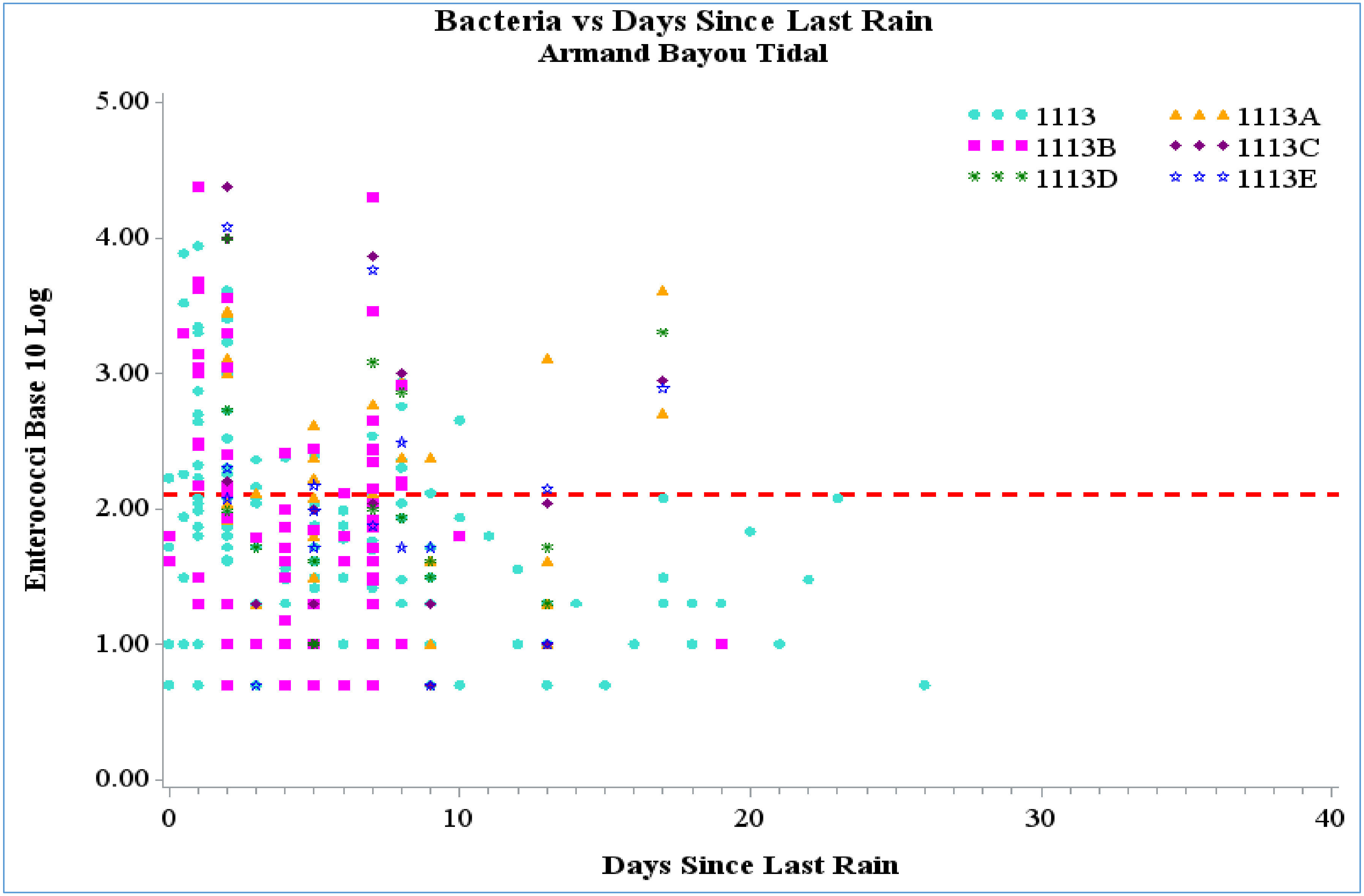
Segment 1113C Unnamed Tributary To Horsepen Bayou.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 15
MPN/100 mL
10000
8000
6000
4000
2000
0
Sep 2011
Jan 2012
May
Sep
Jan 2013
May
Sep
Jan 2014
May
Sep
Jan 2015
May
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL


Segment 1113D Willow Springs Bayou.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 15
MPN/100 mL
800
600
400
200
0
Sep 2011
Jan 2012
May
Sep
Jan 2013
May
Sep
Jan 2014
May
Sep
Jan 2015
May
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL


Segment 1113E Big Island Slough.
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 16
1000
800
600
400
200
0
MPN/100 mL
Sep 2011
Jan 2012
May
Sep
Jan 2013
May
Sep
Jan 2014
May
Sep
Jan 2015
May
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

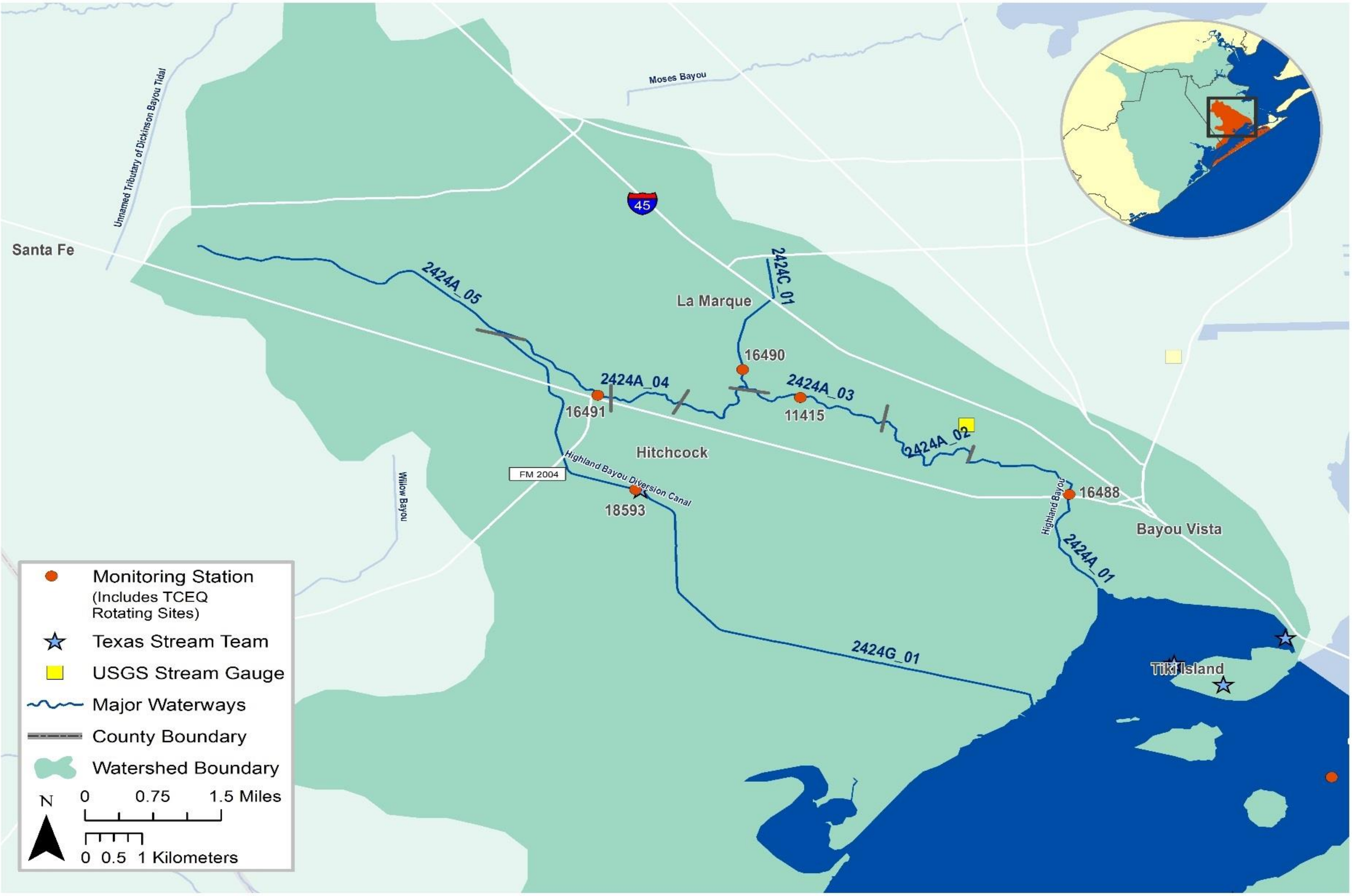
Load Duration Curve

While there was sufficient bacteria data to complete a LDC, the tidal influence prohibited development of a simple LDC for much of this segment. In the above tidal portion, 1113A, flow data was not available to construct a LDC. Using the Days Since Last Rain plot as a surrogate until a more complex LDC or development of a model suggest that overall, bacteria declines as bacteria data is collected the greater number of days since last rainfall was registered. AU 1113A is potentially interesting as several data points between 10 and 20 days since recorded rainfall events, were still above the standard (dashed red line). This suggest the potential for attributing some of the bacteria load to WWTF and/or OSSFs. Days Since Last Rain is problematic as a surrogate as the bacteria data collected cannot be framed within the ambient conditions present as derived by flow conditions (i.e. extreme wet, wet, moderate, dry, extreme dry). A data point could be collected thirty days since the last rain event even while conditions for the watershed are still considered wet. Likewise, a bacteria sample could be collected a day after a rain event while the pervasive conditions are drought for the watershed. As Days Since Last rain cannot be used to explain the watersheds conditions when the data was collected, it is a far weaker argument compared to the use of LDCs, to say that bacteria loads are a problem in this case during dry conditions due to bacteria contributions by WWTFs or failing OSSFs.


Bacteria vs Days Since Last Rain
Armand Bayou Tidal
Enterococci Base 10 Log
Days Since Last Rain
1113
1113A
1113B
1113C
1113D
1113E
0.00
1.00
2.00
3.00
4.00
5.00
0
10
20
30
40

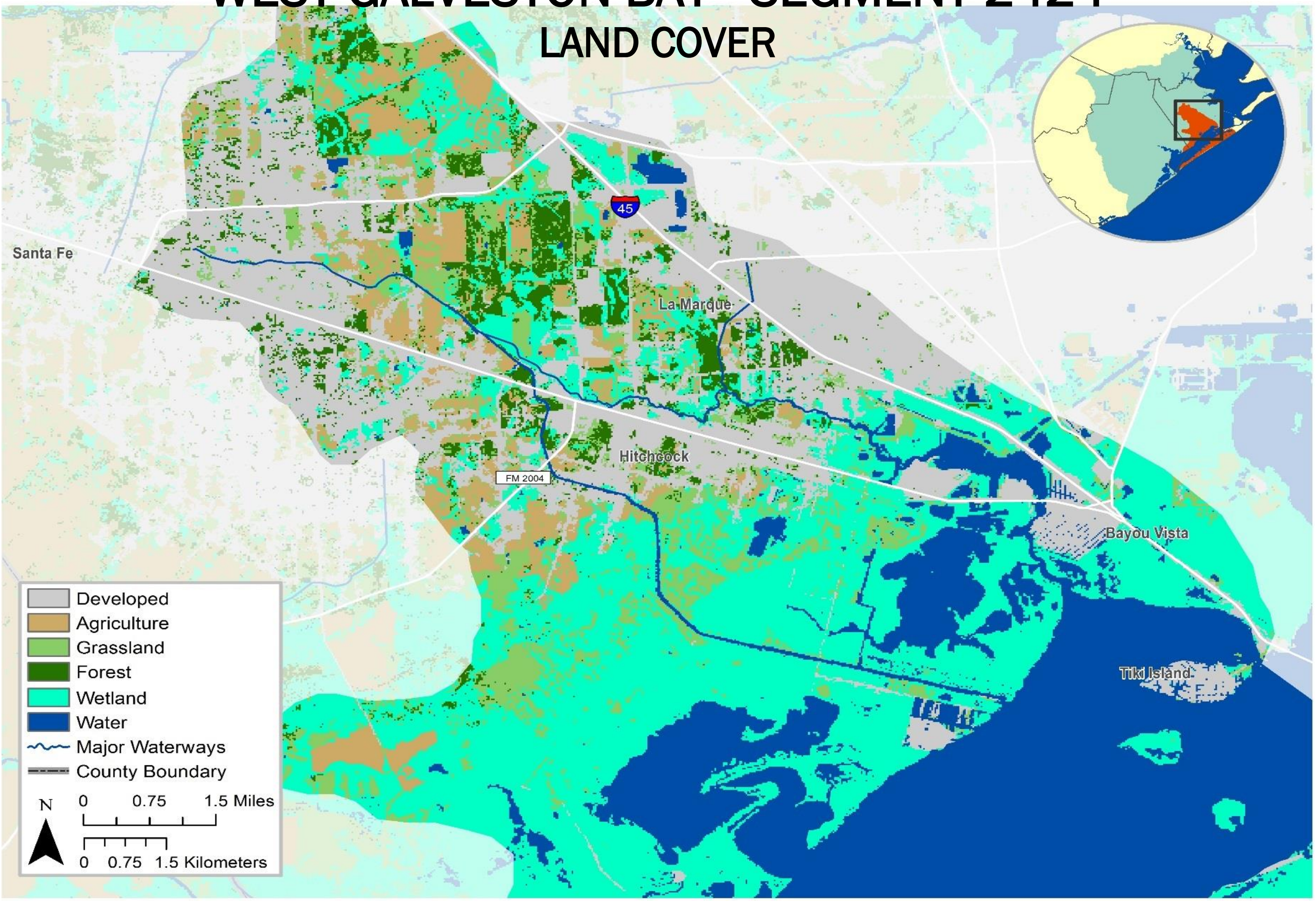
Recommendations
Address concerns found in this segment summary through stakeholder participation.
Continue collecting water quality data to support actions associated with tracking BIG implementation efforts. Consider address a lack of flow data by establishing a continuous flow gauge in 1113A.
Support BIG implementation efforts to reduce bacteria levels in the segment.

B12. WEST GALVESTON BAY - SEGMENT 2424

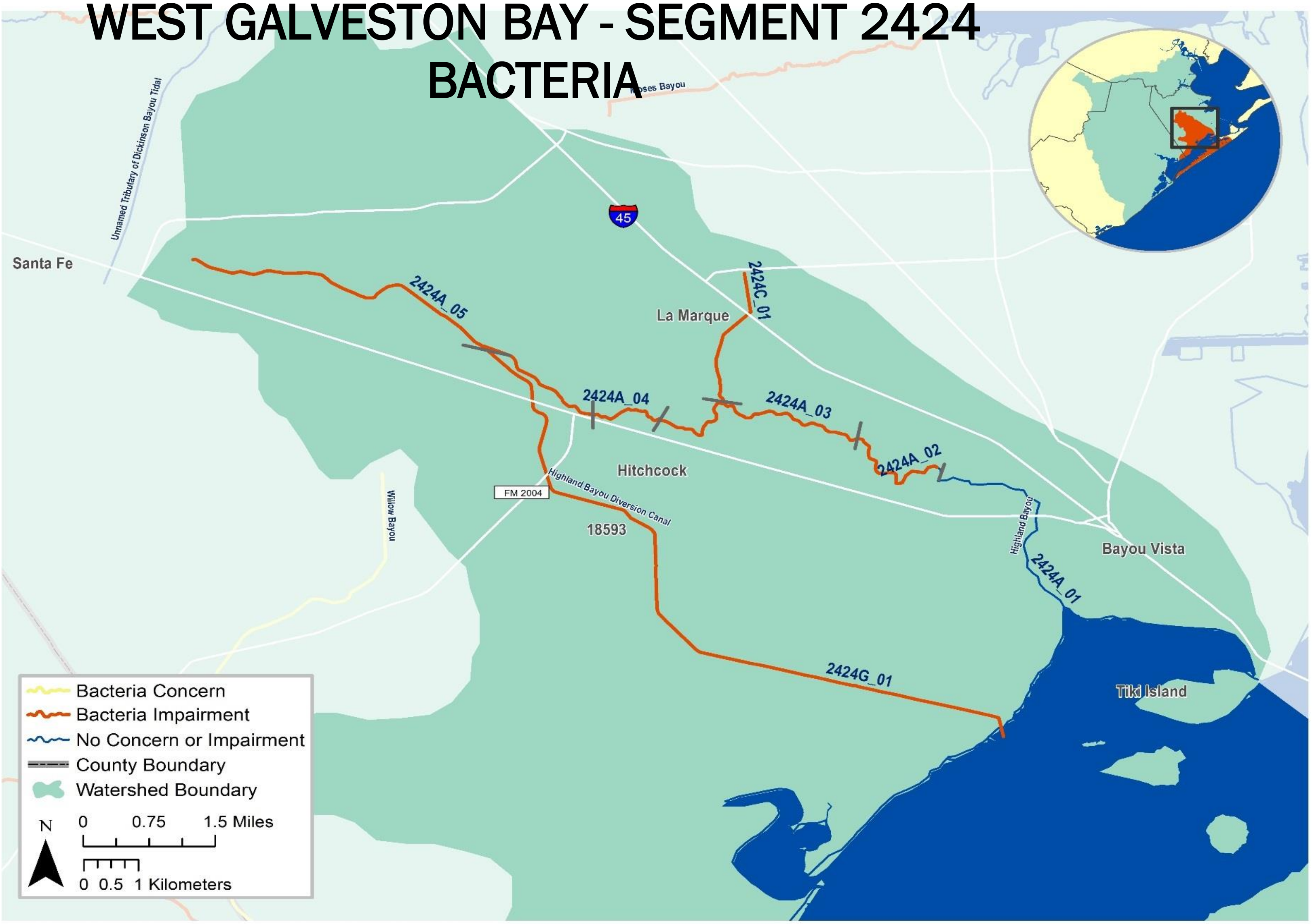


WEST GALVESTON BAY - SEGMENT 2424

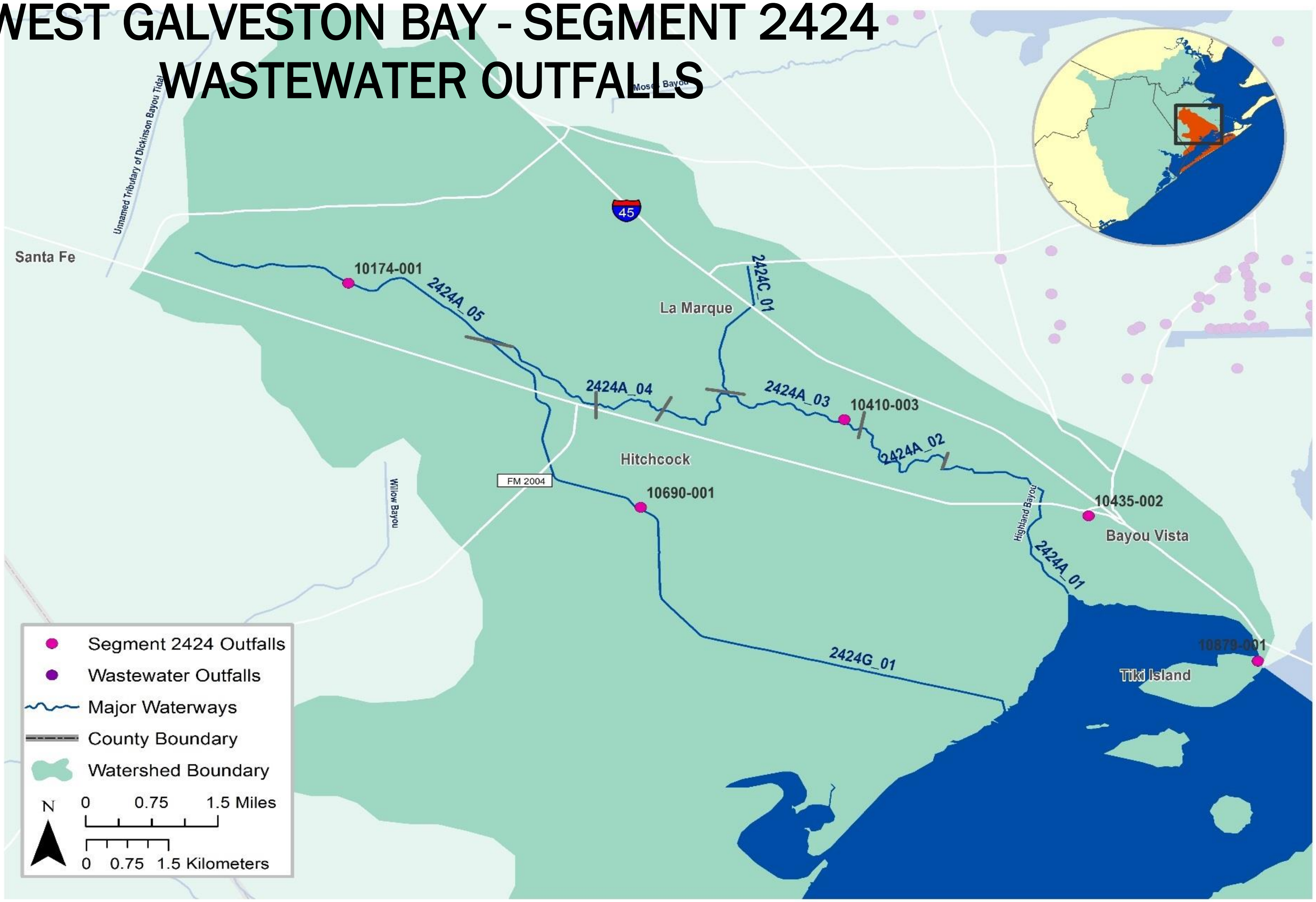
LAND COVER



WEST GALVESTON BAY - SEGMENT 2424
BACTERIA



WEST GALVESTON BAY - SEGMENT 2424
WASTEWATER OUTFALLS



Segment Number:	2424	Name:	West Galveston Bay		
Area: 74 square miles	Miles of shoreline	172 miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life Use; Oyster Waters	
Number of Active Monitoring Stations:	14	Texas Stream Team Monitors:	13	Permitted Outfalls:	9
Description:	Segment 2424: A 179.5 square kilometer (69.3 square mile) portion of the Galveston Bay system located on the landward side of Galveston Island, extending from the Galveston Causeway (IH-45) in Galveston County to the western side of San Luis Pass and the eastern shore of Mud Island in Brazoria County Segment 2424A (Tidal Stream w/ high ALU): Highland Bayou (unclassified water body) — From Jones Bay confluence to Avenue Q 0.8 km (0.5 mi) north of SH 6 between Arcadia and Alta Loma in Galveston County Segment 2424C (Tidal Stream w/ high ALU): Marchand Bayou (unclassified water body) — From Highland Bayou confluence to 0.72 km (0.45 mi) north of IH 45 in Galveston County Segment 2424G (Tidal Stream w/ high ALU): Highland Bayou Diversion Canal (unclassified water body) – From the confluence with an unnamed tributary adjacent to Jones Bayou upstream to the Highland Bayou confluence Segment 2424O: Oyster Waters				

Percent of Stream Impaired or of Concern	
Segment ID	**Bacteria**
2424	-
2424A	45.6
2424C	100
2424G	100
2424OW	100

Segment 2424

Standards	Bays & Estuaries	Tidal Streams	Screening Levels	Bays & Estuaries	Tidal Streams
Temperature (°C/°F):	35	35 / 95	Ammonia-N (mg/L):	0.10	0.46
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	4.0	Nitrate-N (mg/L):	0.17	1.10
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	3.0	Orthophosphate Phosphorus (mg/L):	0.19	0.46
pH (standard units):	6.5-9.0	6.5-9.0	Total Phosphorus-P (mg/L):	0.21	0.66
Enterococci (MPN/100mL) (grab):	104	104	Chlorophyll *a* (μg/L):	11.6	21
Enterococci (MPN/100mL) (geometric mean):	35	35			
Fecal Coliform in Oyster Waters (CFU/100mL) (median/grab):	14/43				

FY 2016 Active Monitoring Stations				
Site ID	Site Description	Frequency	Monitoring Entity	Parameter Groups
11415	Highland Bayou at Fairwood Rd	Quarterly	EIH	Field, Conventional, Bacteria, Chlorophyll a
16488	Highland Bayou upstream of SH 6 bridge	Quarterly	EIH	Field, Conventional, Bacteria, Chlorophyll a
16490	Marchand Bayou tidal at FM 519	Quarterly	EIH	Field, Conventional, Bacteria
16491	Highland Bayou at FM 2004	Quarterly	EIH	Field, Conventional, Bacteria

Water Quality Issues Summary			
Issue	2014 Assessment *I – Impaired* *C – Of Concern*	Possible Causes / Influences / Concerns Voiced by Stakeholders	Possible Solutions / Actions To Be Taken
Elevated Levels of Indicator Bacteria and in Oyster Waters	2424A I 2424C I 2424G I 2424OW I	▪ Rapid urbanization and increased impervious cover ▪ Constructed stormwater controls failing ▪ Animal waste from agricultural production, hobby farms, and riding stables ▪ Improper disposal of waste from boats ▪ Developments with malfunctioning OSSFs ▪ Improper or no pet waste disposal ▪ Waste haulers illegal discharges/improper disposal ▪ Direct and dry weather discharges ▪ Poorly operated or undersized WWTFs ▪ WWTF non-compliance, overflows, and collection system by-passes	▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems ▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Create and implement Water Quality Management Plans for individual agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ More public education on proper boat waste disposal ▪ More public education regarding OSSF operations and maintenance ▪ More public education on pet waste disposal ▪ Impose new or stricter bacteria limits than currently designated by TCEQ ▪ Increase monitoring requirements for self-reporting ▪ Regionalize chronically non-compliant WWTFs ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations

Segment Discussion:

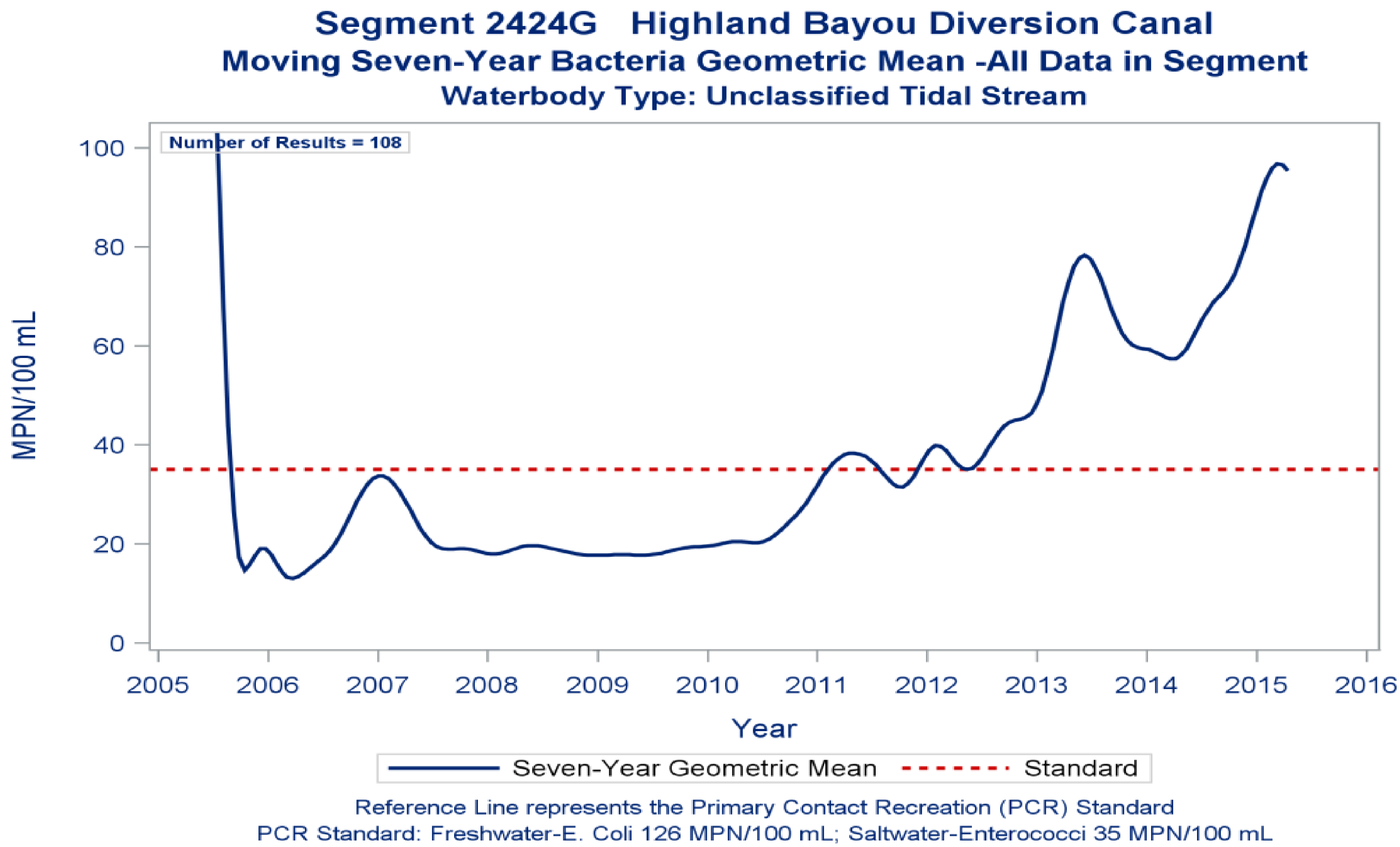
Watershed Characteristics: The West Galveston Bay watershed encompasses the bay side of Galveston Island, a barrier island and many coastal wetlands on the landward side of the bay. For this project, the bay side of Galveston Island and West Bay were not studied. There are several classified and unclassified bays and tributaries that drain into the bay system. On the mainland, the communities of Hitchcock, La Marque, Bayou Vista, and Tiki Island, are located west of IH-45 and are drained by Highland and Marchand Bayous to Jones Bay. Most of the land cover in this sub-watershed is low intensity, mixed residential and commercial development. Grazing lands and domestic animal facilities are common in the southwestern and northwestern portions of the sub-watershed.

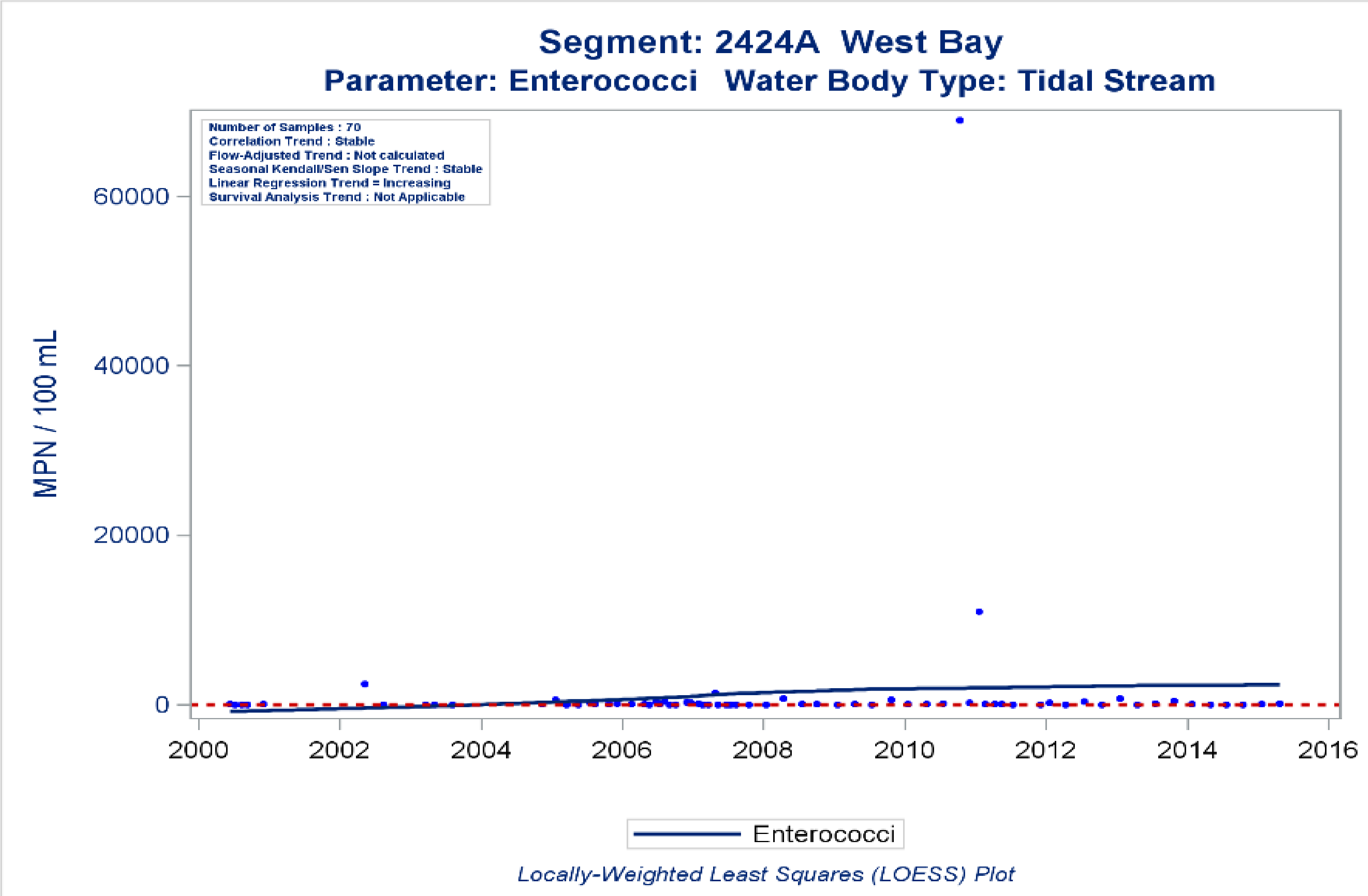
Water Quality Issues: The 2014 Texas IR lists Highland Bayou (Assessment units 2424A_02 – 2424A_05), Marchand Bayou (2424C_01), and the Highland Bayou Diversion Canal (2424G_01) as impaired for contact recreation due to elevated levels of enterococci bacteria. The Highland Bayou Diversion Canal is a new addition to the 303(d) list. While not the focus of this study, Assessment unit 2424OW_02, which is the area of the bay adjacent to Lower Galveston Bay and Galveston Island, is listed in the 2014 IR as impaired for oyster waters due to elevated levels of fecal coliform bacteria. This area is closed by the Seafood Safety Division of the Texas Department of State Health Services for the harvesting of oysters and other shellfish for direct marketing.

Assessment Unit	TCEQ Assessment (2005-2012)	HGAC Analysis 2001-2008	HGAC Analysis 2008-2015
	Geomean (MPN/100 mL) / % Grab Exceedance	Geomean (MPN/100 mL) / % Grab Exceedance	Geomean (MPN/100 mL) / % Grab Exceedance
2424A_01	30 / NA	25 / 14.5	26 / 14.3
2424A_03	78 / NA	58 / 37.5	106 / 35.5
2424A_05	184 / NA	166 / 64.6	503 / 77.4
2424C_01	139 / NA	84 / 46.9	161 / 57.1
2424G_01	38 / NA	19 / 23.8	85 / 35.7

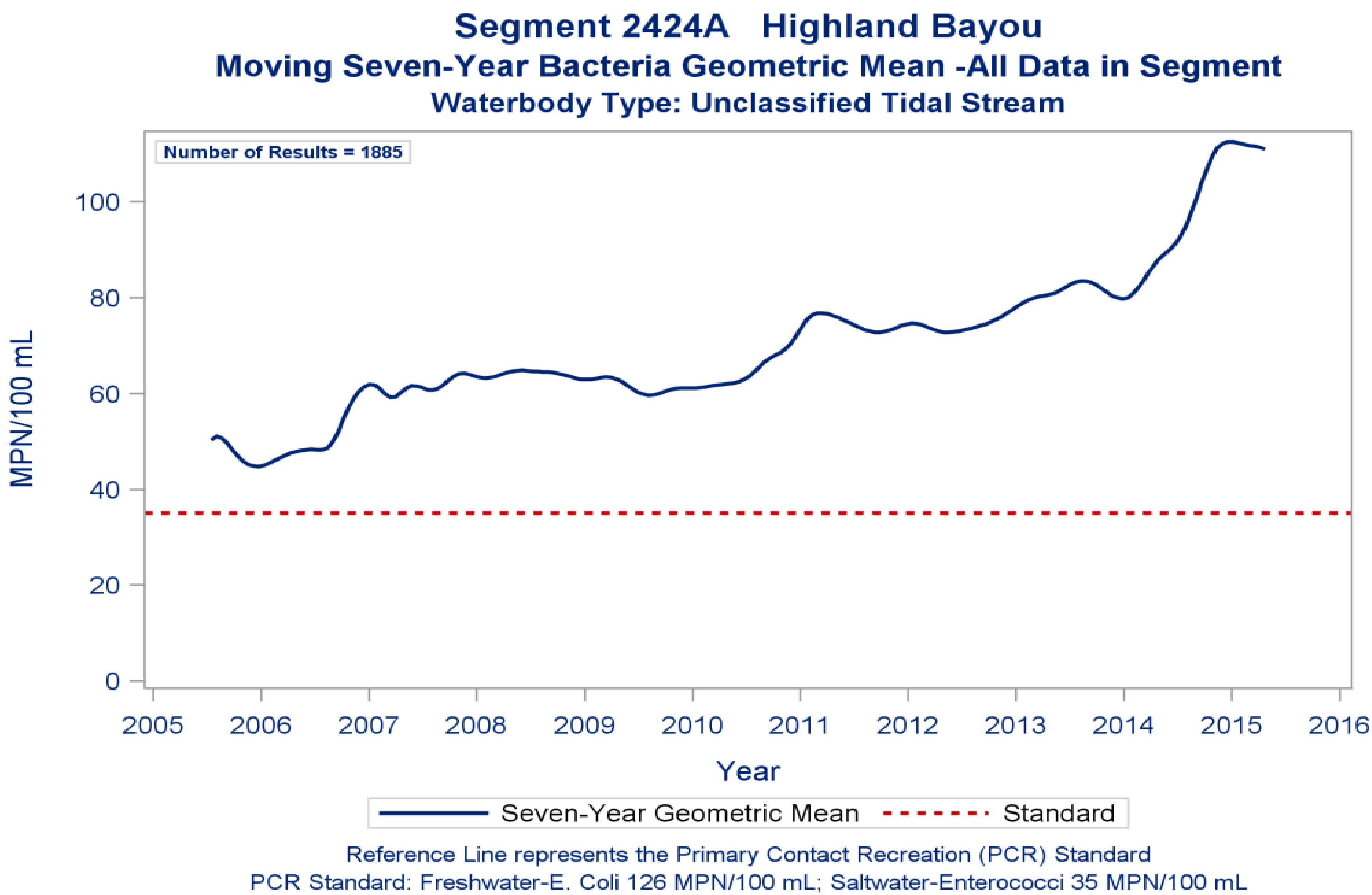
Special Studies/Projects: A watershed protection plan is currently being developed for Highland and Marchand Bayous. Texas AgriLife is the project lead for this effort. Lack of continuous flow data has hampered efforts to better model bacteria in this area. In FY 20-17, Texas AgriLife began working with the Texas Institute for Applied Environmental Research to address the lack of flow. Texas AgriLife is facilitating the Galveston – Brazoria County Coalition of Watersheds to bring stakeholders involved in TMDL I-Plan and WPP implementation, including this watershed, together to build cooperation on common bacteria issues and BMPs. The goal is a regional watershed planning group that will elevate issues and attract funding. This segment includes portions of West Galveston Bay which is part of the UGCOWs I-Plan for bacteria. The UGCOWs I-Plan began in 2010 after the TMDL was approved by the EPA. The draft I-Plan was submitted to the TCEQ in August of 2014 and final approval of the draft was given in August of 2015. While not the focus of this study, improving stormwater run-off and effluent water quality from the mainland could benefit this TMDL.

Trends: The 2014 Texas Integrated Report lists the majority of unclassified segments in the West Bay watershed as impaired for elevated levels of indicator bacteria in oyster waters. Regression analysis of enterococci data for the impaired segments show relatively stable bacteria levels over time, however, extreme spikes continue to occur on an infrequent basis with levels reaching as high as 60,000 MPN/100 mL during the period of record.


Segment 2424G Highland Bayou Diversion Canal
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 108
MPN/100 mL
0
20
40
60
80
100
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL



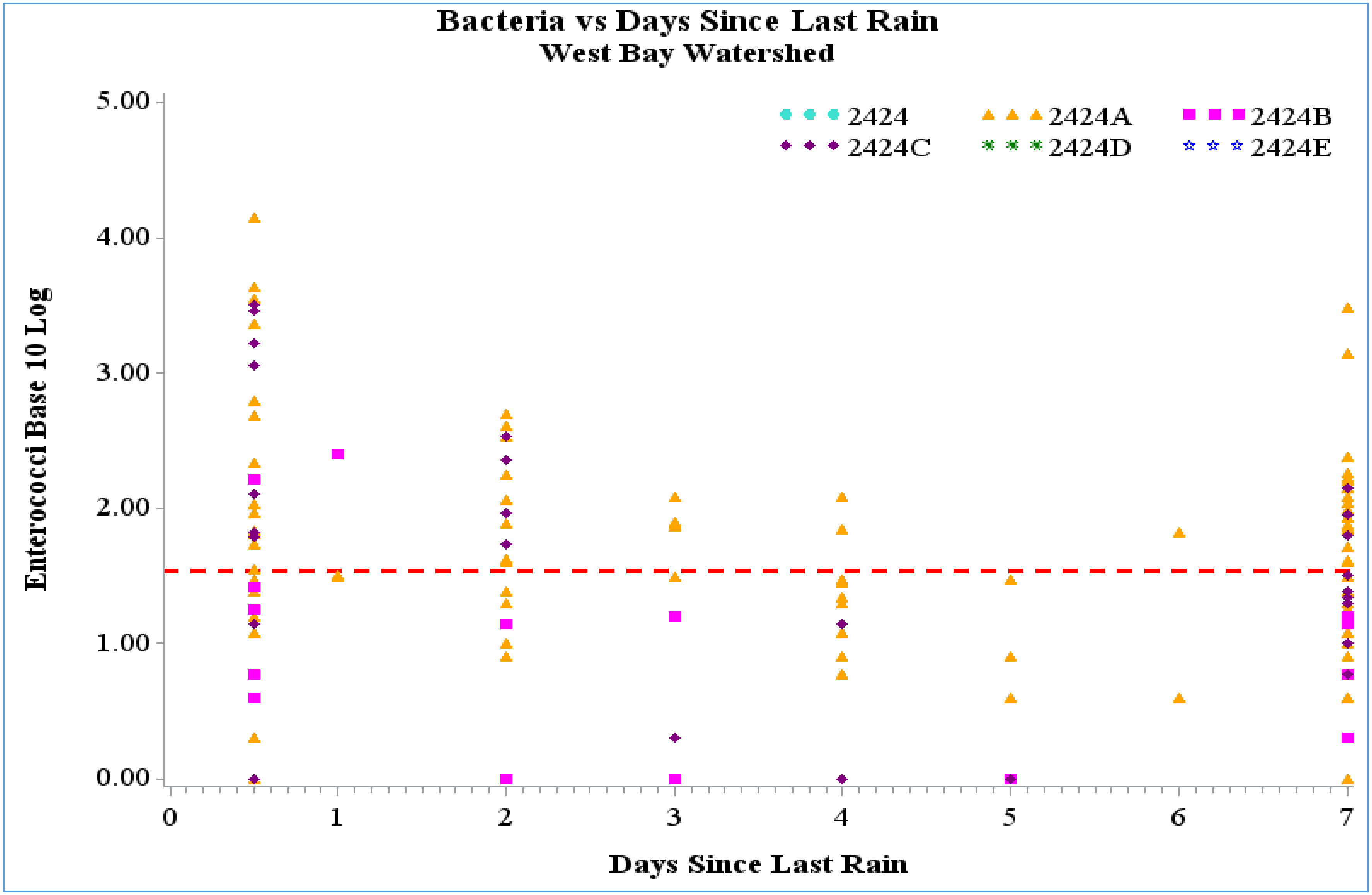
Segment: 2424A West Bay
Parameter: Enterococci Water Body Type: Tidal Stream
Number of Samples : 70
Correlation Trend : Stable
Flow-Adjusted Trend : Not calculated
Seasonal Kendall/Sen Slope Trend : Stable
Linear Regression Trend = Increasing
Survival Analysis Trend : Not Applicable
MPN / 100 mL
60000
40000
20000
0
2000
2002
2004
2006
2008
2010
2012
2014
2016
Enterococci
Locally-Weighted Least Squares (LOESS) Plot



Segment 2424A Highland Bayou
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 1885
MPN/100 mL
0
20
40
60
80
100
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

Load Duration Curves

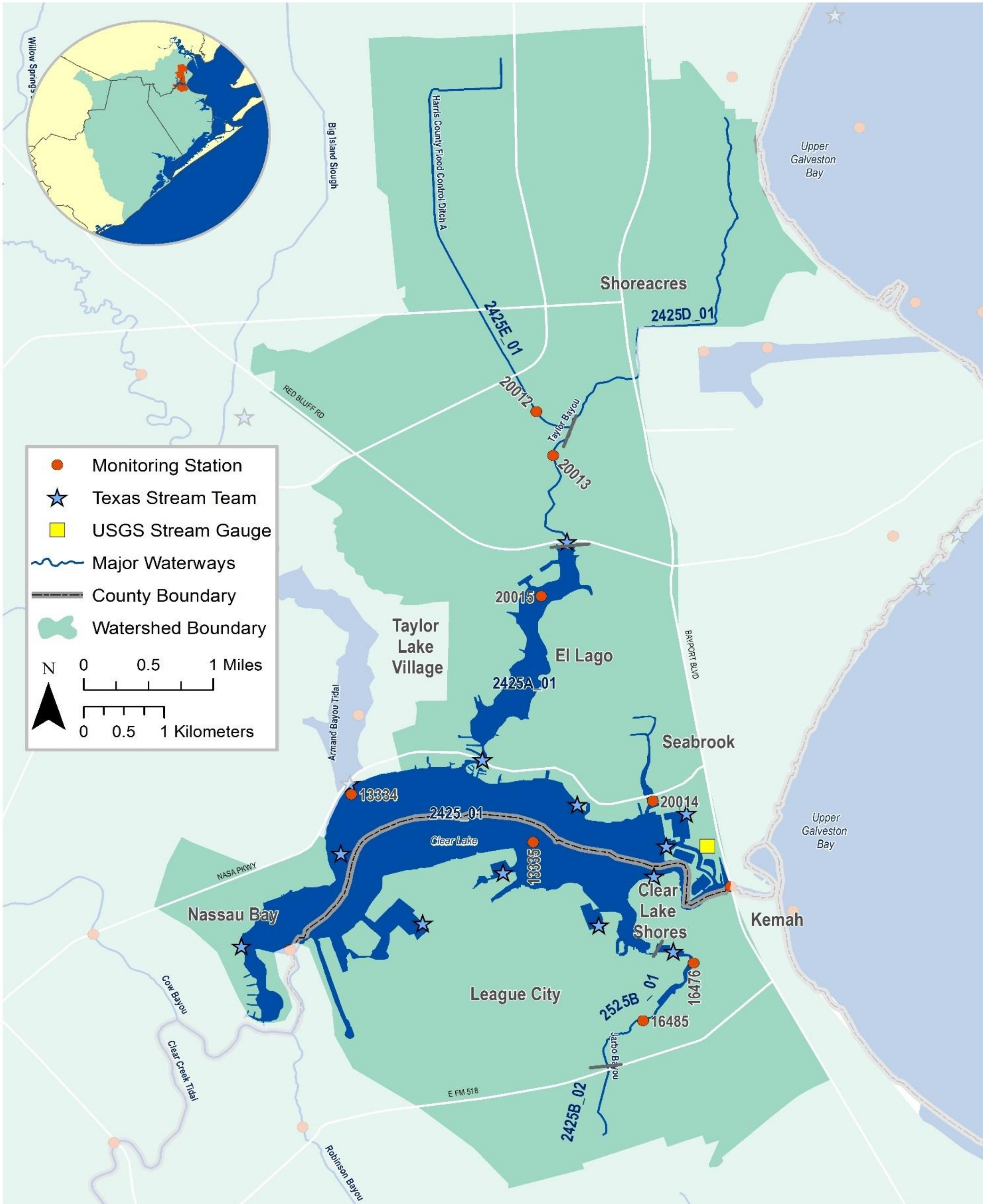
While there was sufficient bacteria data to complete a LDC, the tidal influence prohibited development of a simple LDC for this segment. Using the Days Since Last Rain plot as a surrogate until a more complex LDC or development of a model suggest that bacteria concentration declines as bacteria data is collected the greater number of days since last rainfall is registered. It is notable that collection does not appear to happen or is never recorded as happening past seven days since last recorded rainfall. This hampers the usefulness of this particular method even further since Days Since Last Rain is problematic as a surrogate as the bacteria data collected cannot be framed within the ambient conditions present as derived by flow conditions (i.e. extreme wet, wet, moderate, dry, extreme dry). A data point could be collected thirty days since the last rain event even while conditions for the watershed are still considered wet. Likewise, a bacteria sample could be collected a day after a rain event while the pervasive conditions are drought for the watershed. As Days Since Last rain cannot be used to explain the watersheds conditions when the data was collected, it is a far weaker argument compared to the use of LDCs, to say that bacteria loads are less of a problem during dry conditions due to bacteria generated by WWTFs or failing OSSFs.



Bacteria vs Days Since Last Rain
West Bay Watershed
2424
2424A
2424B
2424C
2424D
2424E
Enterococci Base 10 Log
5.00
4.00
3.00
2.00
1.00
0.00
0
1
2
3
4
5
6
7
Days Since Last Rain

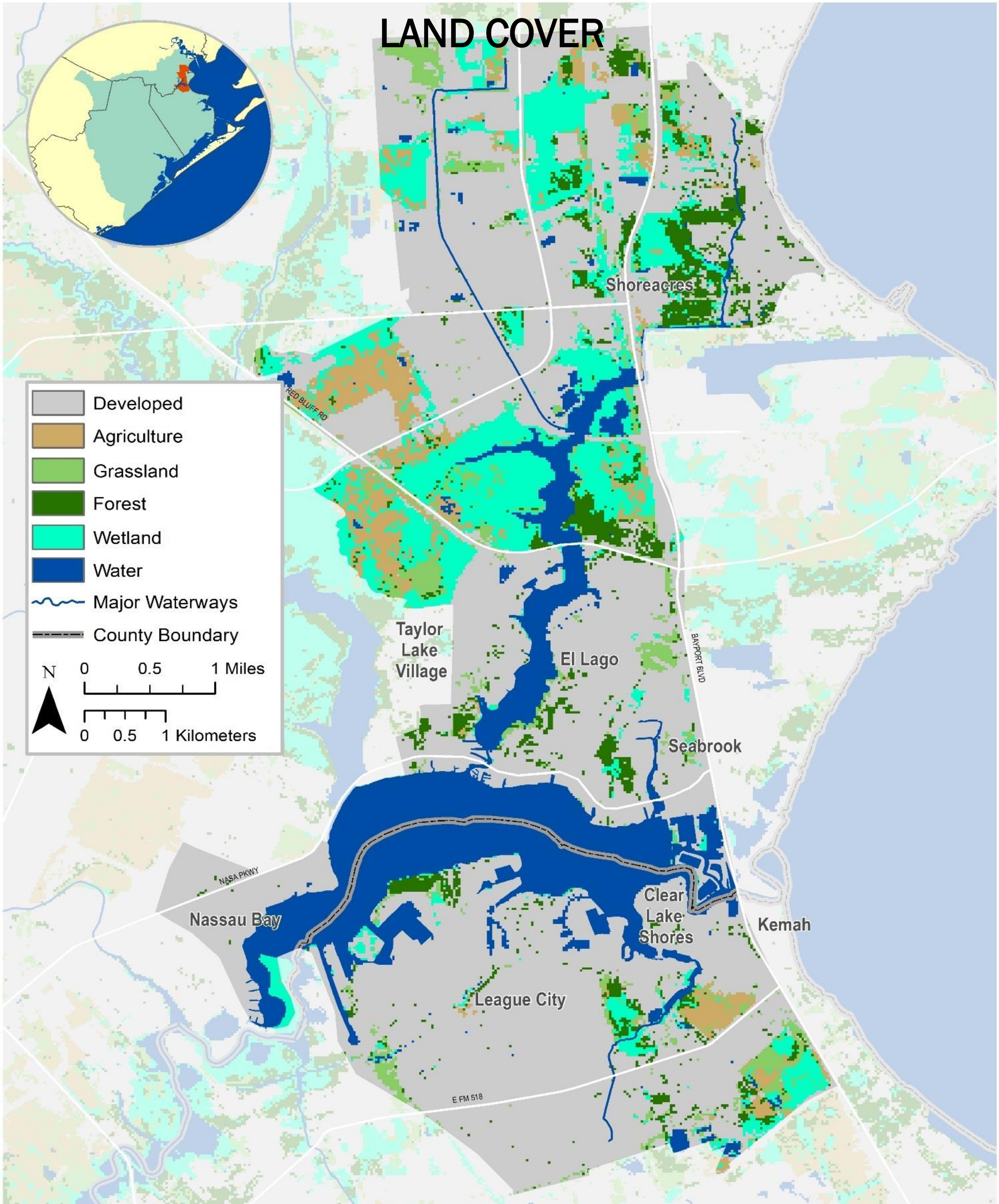
Recommendations
Address concerns found in this segment summary through stakeholder participation.
Continue collecting water quality data to support actions associated with any future watershed protection plan development and possible modeling. Work with TX AgriLife to address continuous flow data need.
Increase the number of yearly representative stations to provide consistent time series. Need fewer stations with more data.
Support TX AgriLife to complete the Highland and Marchand Bayou Watershed Protection Plan.
Support Galveston Bay Foundations efforts to implement the UGCOWs TMDL – I Plan on this segment.

B13. CLEAR LAKE - SEGMENT 2425

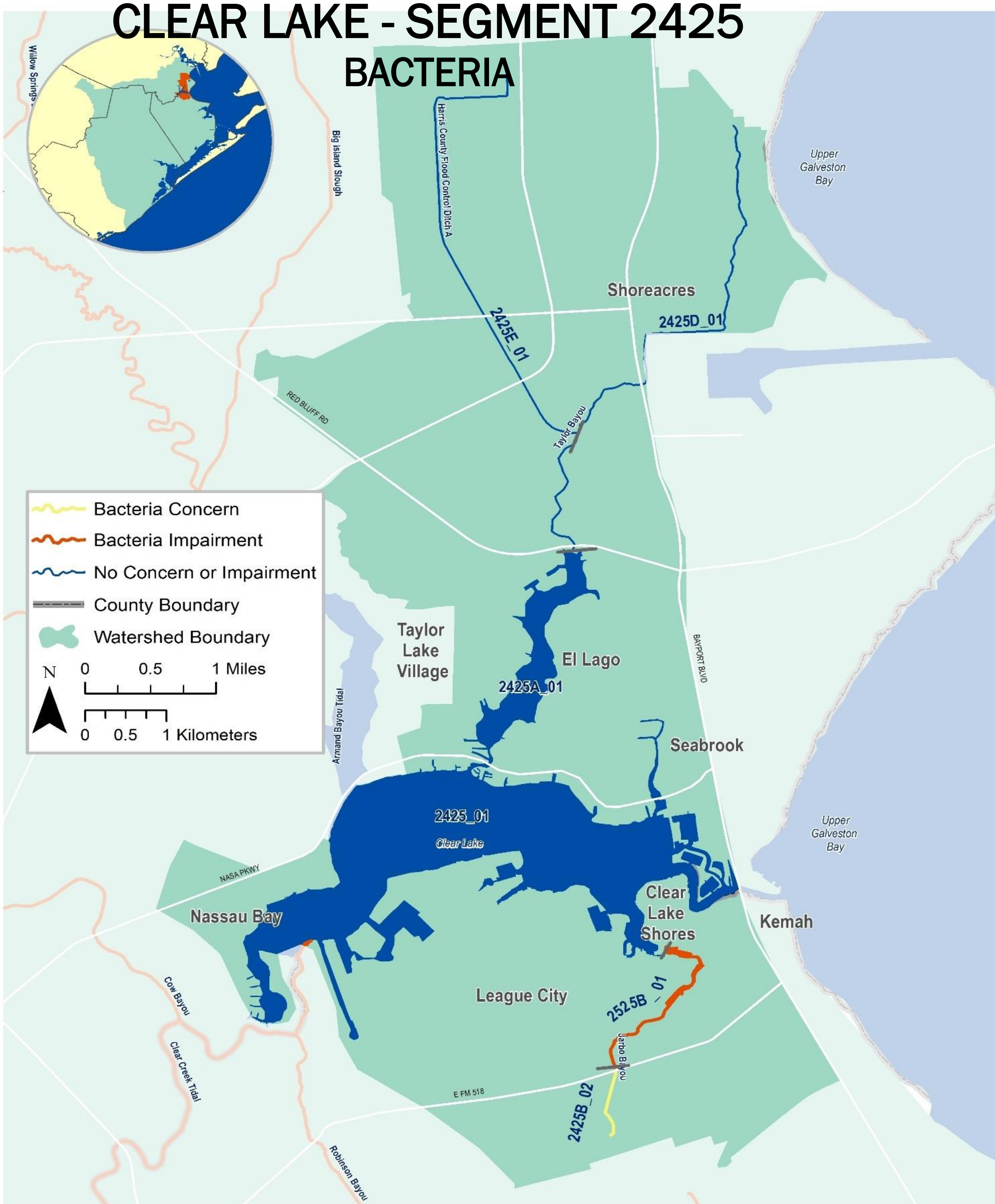


CLEAR LAKE - SEGMENT 2425

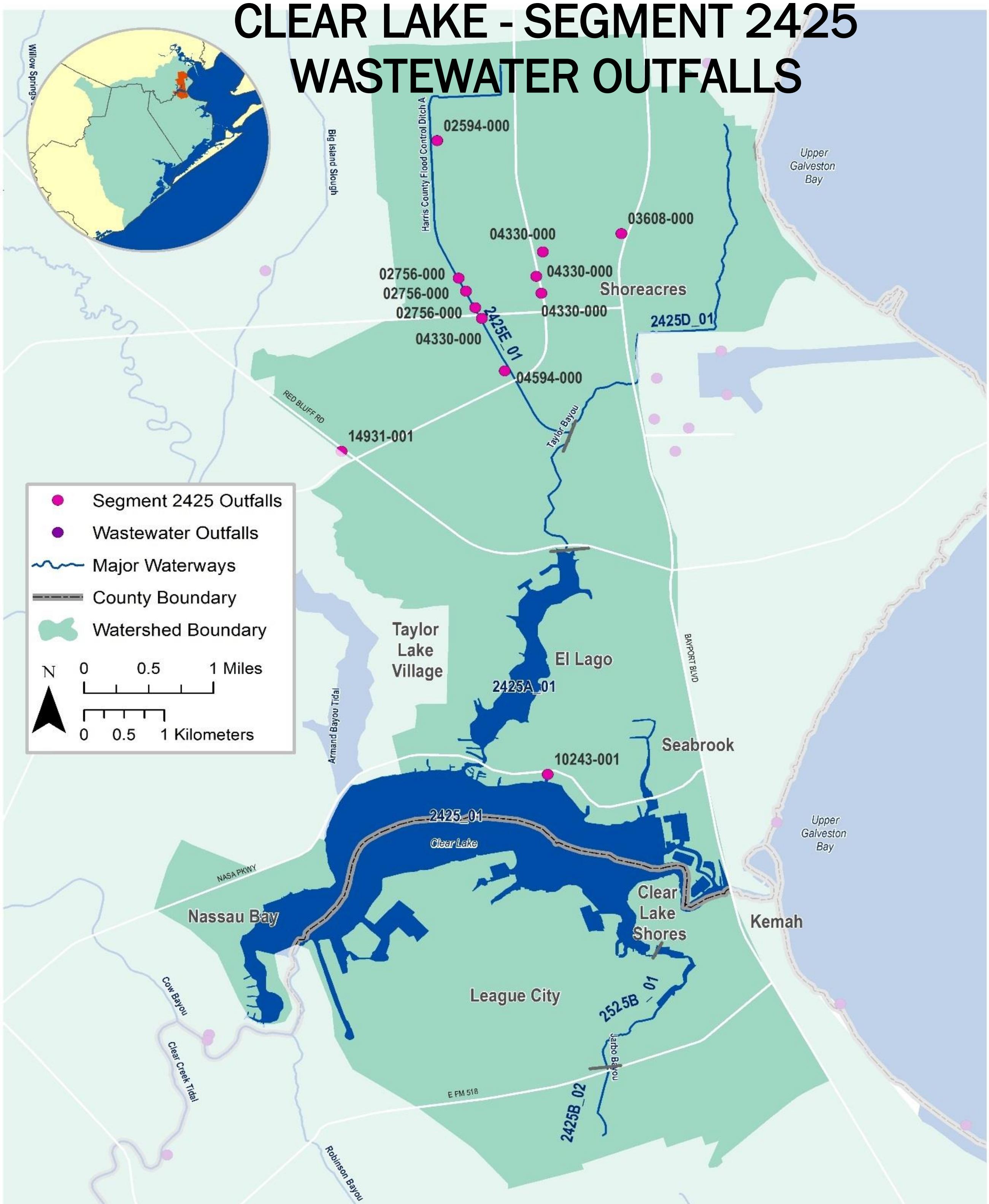
LAND COVER



CLEAR LAKE - SEGMENT 2425
BACTERIA



CLEAR LAKE - SEGMENT 2425
WASTEWATER OUTFALLS



Segment Number:	2425	Name:	Clear Lake		
Area:	3 square miles	Miles of Shoreline:	31.6 miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life Use
Number of Active Monitoring Stations:	9	Texas Stream Team Monitors:	12	Permitted Outfalls:	1

Description:

Segment 2425: A 5.2 square kilometer (2.0 square mile) brackish, tidally influenced water body on the western shore of Upper Galveston Bay that receives inflows from Clear Creek, Jarbo Bayou, Armand Bayou, and Taylor Lake, and also serves as the boundary between Galveston and Harris Counties.

Segment 2425A (Estuary w/ high ALU): Taylor Lake (unclassified water body) — From the confluence with Clear Lake upstream to the terminus of Taylor Bayou south of Bay Forest Golf Club in La Porte in Harris County

Segment 2425B (Tidal Stream w/ high ALU): Jarbo Bayou (unclassified water body) — From Clear Lake confluence with Clear Lake to 1.1 km (0.67 mi) upstream of FM 518 in Galveston County

Segment 2425D (Tidal Stream w/ high ALU): Taylor Bayou (unclassified water body) — From the Taylor Lake confluence to a point 4.6 km (2.8 mi) upstream of State Hwy 146

Segment 2425E (Tidal Stream w/ high ALU): Harris County Flood Control Ditch A (unclassified water body) – From the Taylor Bayou confluence to a point 0.28 km (0.17 mi) downstream of Fairmont Parkway

Percent of Stream Impaired or of Concern	
Segment ID	Bacteria
2425	-
2425A	-
2425B	100
2425D	-
2425E	-

Segment 2425

Standards	Bays & Estuaries	Tidal Streams	Screening Levels	Bays & Estuaries	Tidal Streams
Temperature (°C/°F):	35 / 95	35 / 95	Ammonia-N (mg/L):	0.10	0.46
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	4.0	Nitrate-N (mg/L):	0.17	1.10
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	3.0	Orthophosphate Phosphorus (mg/L):	0.19	0.46
pH (standard units):	6.5-9.0	6.5-9.0	Total Phosphorus-P (mg/L):	0.21	0.66
Enterococci (MPN/100mL) (grab):	104	104	Chlorophyll *a* (μg/L):	11.6	21
Enterococci (MPN/100mL) (geometric mean):	35	35			

FY 2016 Active Monitoring Stations

Site ID	Site Description	Frequency	Monitoring Entity	Parameter Groups
13332	Clear Lake at SH 146	Bi-Monthly	HCPHES	Field, Conventional, Bacteria, Chlorophyll *a* (Qrtly)
13334	Clear Lake at NASA Rd 1 bridge	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
13335	Clear Lake at CM 17	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
13335	Clear Lake at CM 17	Twice / Year	TCEQ	Metals in Water
13335	Clear Lake at CM 17	Once / Year	TCEQ	Benthics, Metals in Sediment
16476	Jarbo Bayou at FM 2094	Quarterly	EIH	Field, Conventional, Bacteria
16485	Jarbo Bayou at Lawrence Rd	Quarterly	EIH	Field, Conventional, Bacteria
20012	Harris County Flood Control Ditch A Tributary to Taylor Bayou, 385 M upstream of confluence	Bi-Monthly	HCPHES	Field, Conventional, Bacteria

20013	Taylor Bayou at mid Channel 400 M downstream of Port Road Bridge	Bi-Monthly	HCPHES	Field, Conventional, Bacteria
20014	Clear Lake Unnamed Inlet 115 M southwest of the intersection of NASA Road 1 and Oceanview Drive	Bi-Monthly	HCPHES	Field, Conventional, Bacteria
20015	Taylor Lake mid lake at blue windows 230 M south of Lakeway Drive dead end	Bi-Monthly	HCPHES	Field, Conventional, Bacteria

Water Quality Issues Summary				
Issue	2014 Assessment *I – Impaired* *C – Of Concern*		Possible Causes / Influences / Concerns Voiced by Stakeholders	Possible Solutions / Actions To Be Taken
Elevated Levels of Indicator Bacteria	2425B	I	▪ Rapid urbanization and increased impervious cover ▪ Constructed stormwater controls failing ▪ Animal waste from agricultural production, hobby farms, and riding stables ▪ Improper or no pet waste disposal ▪ Developments with malfunctioning OSSFs ▪ Waste haulers illegal discharges/improper disposal ▪ Direct and dry weather discharges ▪ Poorly operated or undersized WWTFs	▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems ▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Create and implement Water Quality Management Plans for individual agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways

		▪ WWTF non-compliance, overflows, and collection system by-passes	▪ More public education on pet waste disposal ▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ Increase monitoring requirements for self-reporting ▪ Regionalize chronically non-compliant WWTFs ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Impose new or stricter bacteria limits than currently designated by TCEQ

Segment Discussion:

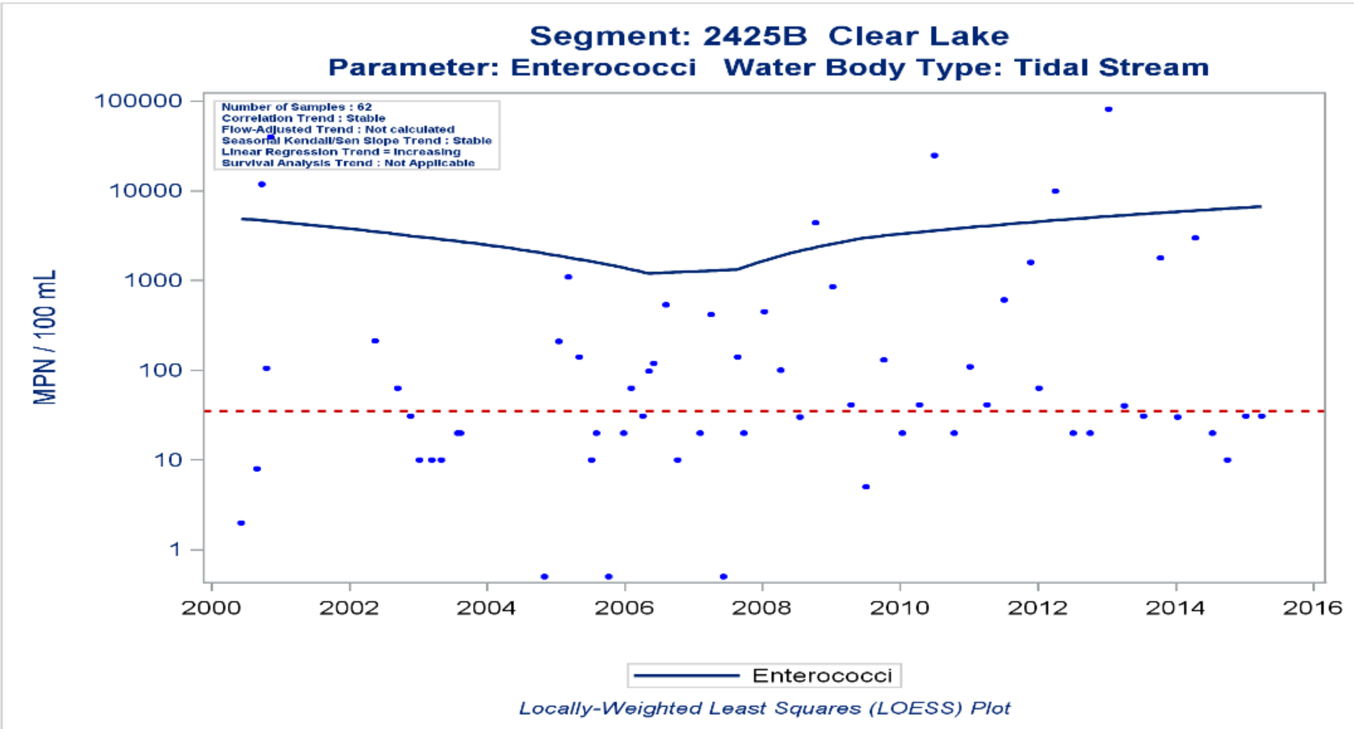
Watershed Characteristics: Clear Lake is home to one of the most concentrated fleets of recreational boats in Texas and the United States. Clear Lake is considered a 'No Discharge Zone' meaning boats must dispose of untreated human wastes at boater pump out stations, utilize mobile pump out services or outside of the lake boundaries. Numerous marinas are located around the lake providing easy access to Upper Galveston Bay. On the south shore of Clear Lake, the watershed encompasses the Cities of League City, Clear Lake Shores and Kemah. High and low intensity residential and mixed commercial developments are the prominent land use for the majority of the south shore. The exception is an area of homes and businesses on small acreages in the southeast portion of the watershed.

The Cities of Nassau Bay, Pasadena, Taylor Lake Village, El Lago, and Seabrook border the lake on the north shore. These cities are heavily urbanized with high and low intensity developments. Upstream of Red Bluff Road, the Taylor Lake (2425A) sub-watershed is mostly undeveloped with large tracts of wetlands, grasslands and forested land. Large industrial facilities are located along the major highway corridors of Bay Area Boulevard and Port Road in the upper reaches of the sub-watershed. The majority of the watershed developments are serviced by municipal wastewater collection and treatment systems.

Water Quality Issues: The 2014 Texas IR lists the downstream assessment unit of Jarbo Bayou (2425B_01) as impaired for contact recreation due to elevated levels of the indicator species enterococci bacteria. According to the TCEQ assessment, the geomean for this assessment unit is 99 MPN/100 ml, which is more than two and half times the geomean standard of 35 MPN/100 ml. The upstream assessment unit of Jarbo Bayou (2425_02) is listed in the 2014 IR for a concern for near nonattainment due to elevated levels of enterococci.

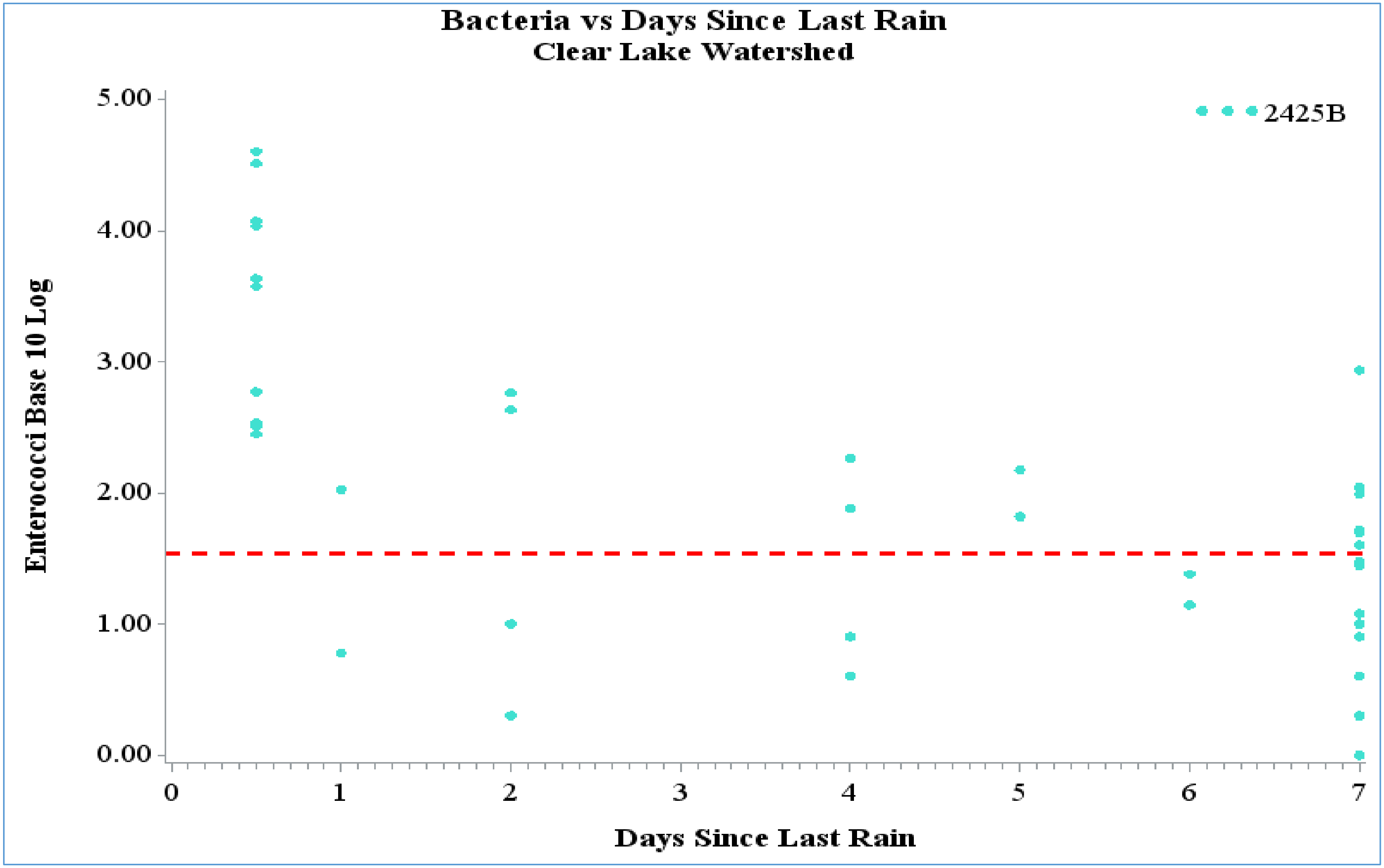
Special Studies/Projects: Clear Lake empties into Upper Galveston Bay. Upper Galveston Bay was part of the Upper Texas Gulf Coast Oyster Waters TMDL and I-Plan project. The TMDL and I-Plan were approved in 2015. During the development of the I-Plan, the Galveston Bay Foundation developed outreach programs centered on Clear Lake to address boater wastes and encourage appropriate disposal. Jarbo Bayou (2525B) is undergoing a TMDL project to address the bacteria impairment. The TMDL study is nearly complete and stakeholders decided to join the BIG and implement the BIG I-Plan rather than developing a Jarbo Bayou specific implementation plan. The TCEQ required modifications to the TMDL study in FY 2017. The revised TMDL document and stakeholder I-Plan approach is expected to go before the TCEQ Commissioners in the fall of 2017. Texas AgriLife is facilitating the Galveston – Brazoria County Coalition of Watersheds to bring stakeholders involved in TMDL I-Plan and WPP implementation, including this watershed, together to build cooperation on common bacteria issues and BMPs. The goal is a regional watershed planning group that will elevate issues and attract funding.

Trends: Regression analysis of water quality data revealed a decreasing trend in enterococci in segments 2425D and 2425E. The 2014 Texas Integrated Report lists Jarbo Bayou as impaired for elevated levels of indicator bacteria. Regression analysis identified a relatively stable trend in bacteria levels for this segment, however, the majority of concentrations have remained significantly greater than the 35 MPN/100 standard during the period of record.



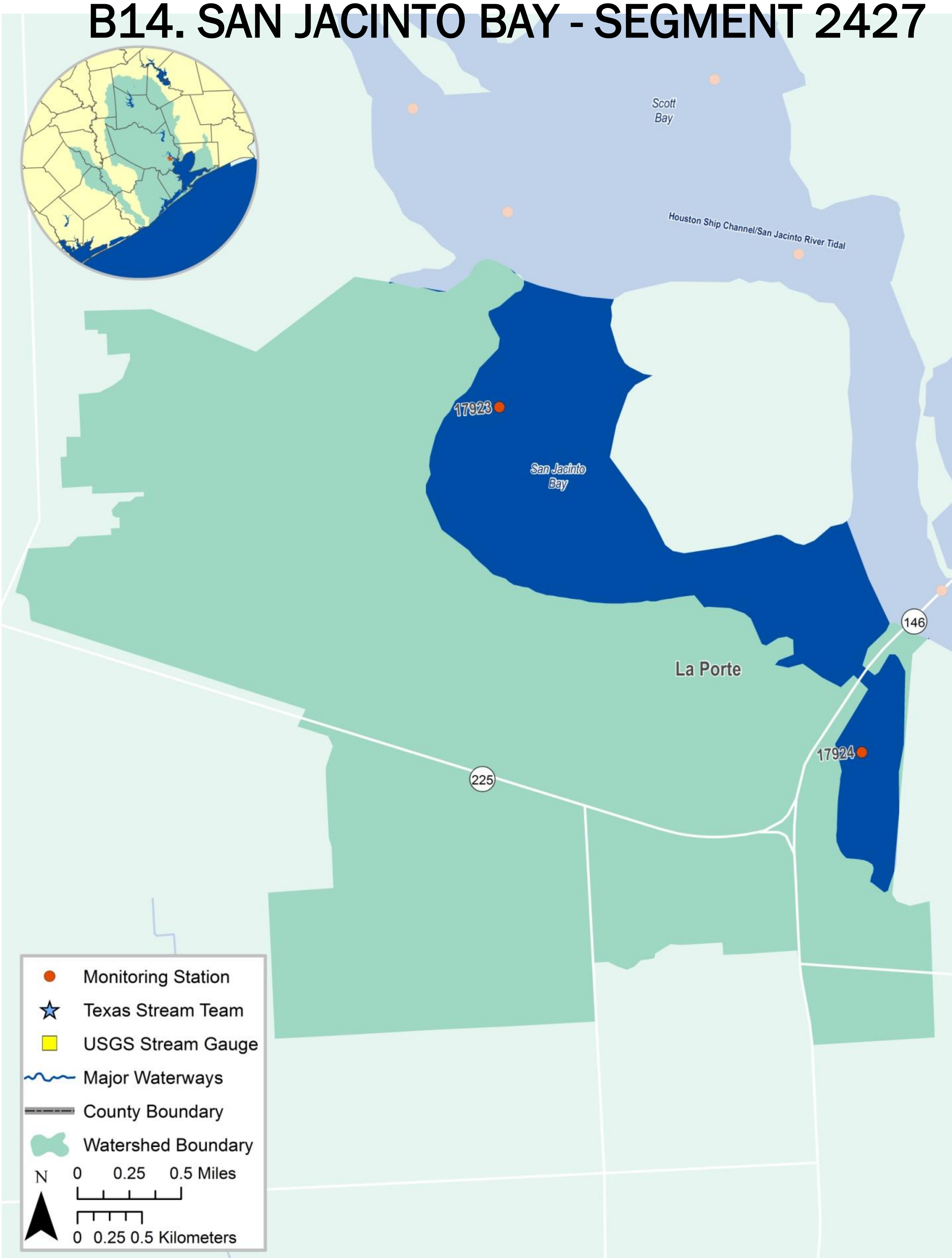
Load Duration Curves

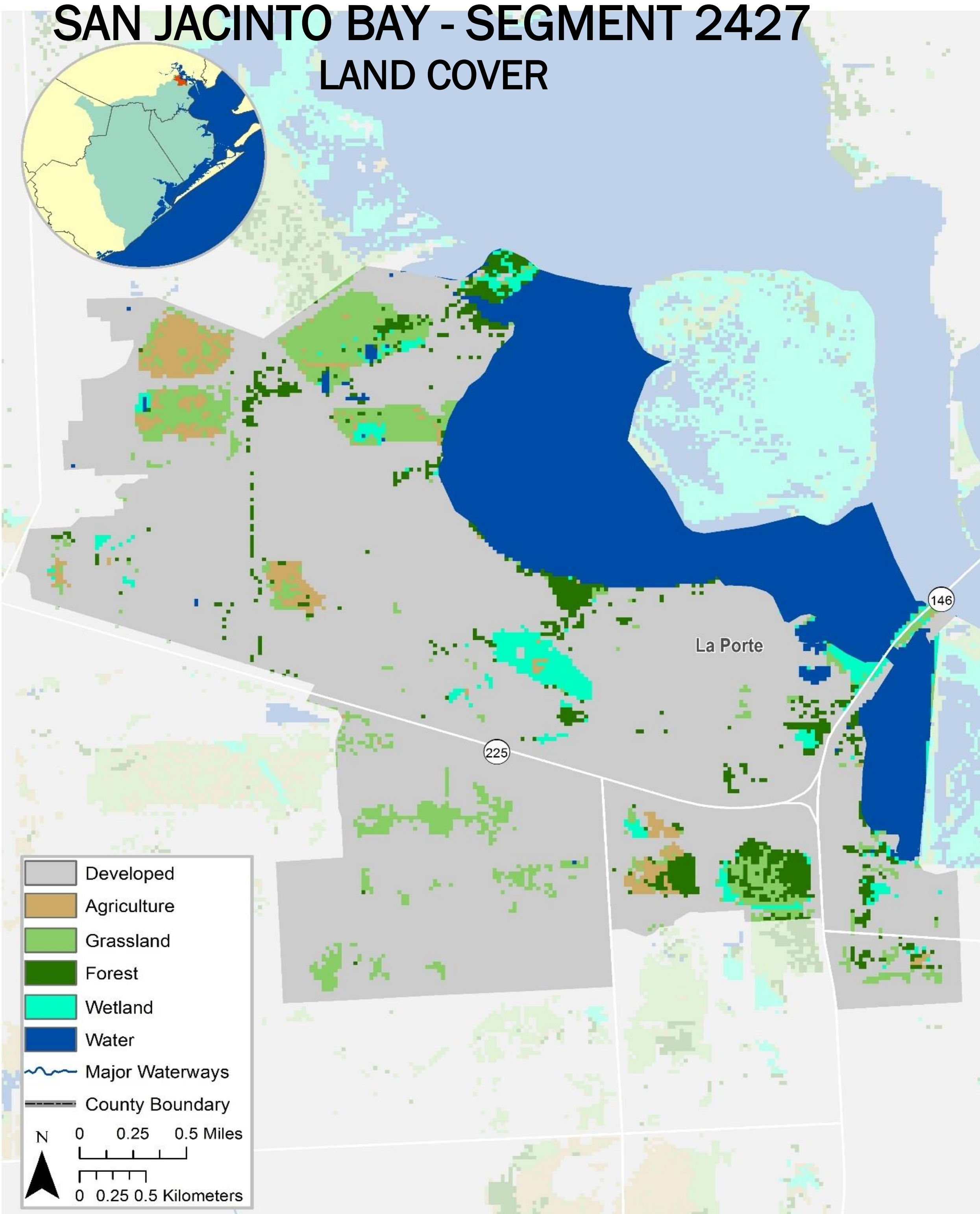
While there was sufficient bacteria data to complete a LDC, the tidal influence prohibited development of a simple LDC for this segment. Using the Days Since Last Rain plot as a surrogate until a more complex LDC or development of a model suggest that bacteria declines as bacteria data is collected the greater number of days since last rainfall was registered. Days Since Last Rain is problematic as a surrogate as the bacteria data collected cannot be framed within the ambient conditions present as derived by flow conditions (i.e. extreme wet, wet, moderate, dry, extreme dry). A data point could be collected thirty days since the last rain event even while conditions for the watershed are still considered wet. Likewise, a bacteria sample could be collected a day after a rain event while the pervasive conditions are drought for the watershed. As Days Since Last rain cannot be used to explain the watersheds conditions when the data was collected, it is a far weaker argument compared to the use of LDCs, to say that bacteria loads are less of a problem during dry conditions due to bacteria generated by WWTFs or failing OSSFs.

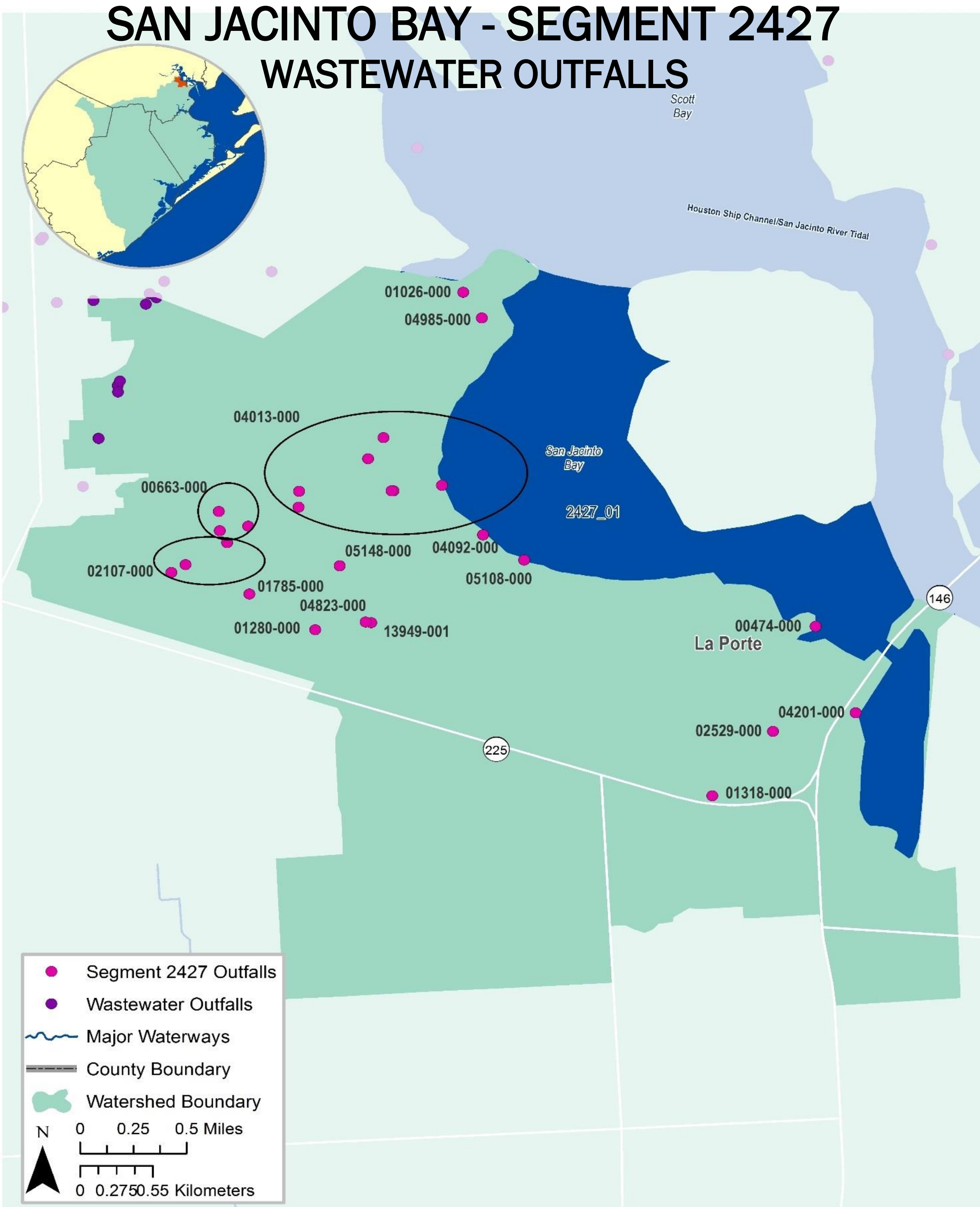

Bacteria vs Days Since Last Rain
Clear Lake Watershed
2425B
Enterococci Base 10 Log
5.00
4.00
3.00
2.00
1.00
0.00
0
1
2
3
4
5
6
7
Days Since Last Rain

Recommendations
Continue collecting water quality data to support actions associated with any future watershed protection plan development and possible modeling.
Coordinate education efforts with the BIG and OW TMDL projects. Track implementation and document any bacteria reductions.
Pursue a new local partner to Clean Rivers Program to collect additional data that would help better isolate problem areas.

B14. SAN JACINTO BAY - SEGMENT 2427




SAN JACINTO BAY - SEGMENT 2427
LAND COVER
La Porte
146
225
Developed
Agriculture
Grassland
Forest
Wetland
Water
Major Waterways
County Boundary
N
0 0.25 0.5 Miles
0 0.25 0.5 Kilometers


SAN JACINTO BAY - SEGMENT 2427
WASTEWATER OUTFALLS
Scott Bay
Houston Ship Channel/San Jacinto River Tidal
01026-000
04985-000
04013-000
San Jacinto Bay
2427_01
00663-000
02107-000
05148-000
04092-000
05108-000
01785-000
04823-000
01280-000
13949-001
00474-000
La Porte
146
04201-000
02529-000
225
01318-000
Segment 2427 Outfalls
Wastewater Outfalls
Major Waterways
County Boundary
Watershed Boundary
N
0 0.25 0.5 Miles
0 0.275 0.55 Kilometers

Segment Number:	2427	Name:	San Jacinto Bay

Area:	2 square miles	Miles of Shoreline:	4.9	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life Use
Number of Active Monitoring Stations:	2	Texas Stream Team Monitors:	0	Permitted Outfalls:	35
Description:	A side bay located on the west side of the Houston Ship Channel/tidal San Jacinto River near Highway 146 bridge to the City of Baytown. There is the Upper San Jacinto Bay and the Lower San Jacinto Bay				

Percent of Stream Impaired or of Concern						
Segment ID	PCBs/Dioxin	Bacteria	Dissolved Oxygen	Nutrients	Chlorophyll *a*	Other
2427	100	-	-	100	-	100

Segment 2427			
Standards	Bays & Estuaries	Screening Levels	Bays & Estuaries
Temperature (°C/°F):	35 / 95	Ammonia-N (mg/L):	0.10
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	Nitrate-N (mg/L):	0.17
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.19
pH (standard units):	6.5-9.0	Total Phosphorus-P (mg/L):	0.21
Enterococci (MPN/100mL) (grab):	104	Chlorophyll *a* (µg/L):	11.6
Enterococci (MPN/100mL) (geometric mean):	35		

FY 2016 Active Monitoring Stations				
Site ID	Site Description	Frequency	Monitoring Entity	Parameter Groups
17923	Upper San Jacinto Bay under electrical transmission lines	Bi-Monthly	HCPHES	Field, Conventional, Bacteria, Chlorophyll *a* (Qrtrly)
17924	Lower San Jacinto Bay S of SH 146	Bi-Monthly	HCPHES	Field, Conventional, Bacteria, Chlorophyll *a* (Qrtrly)

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Nutrients	2427 C	▪ Fertilizer runoff from urbanized properties, such as landscaped areas, residential lawns, and sport fields ▪ Agricultural runoff from row crops, fallow fields, and animal operations ▪ Nutrient loading from WWTF effluent, sanitary sewer overflows, and malfunctioning OSSFs	▪ Implement YardWise and Watersmart landscape practices ▪ Encourage Water Quality Management Plans or similar projects for agricultural properties ▪ Install and/or maintain riparian buffer areas between agricultural fields and waterways ▪ Monitor phosphorus levels at WWTFs to determine if controls are needed
PCBs/Dioxin in Edible Fish Tissue	2427 I	▪ Concentrated deposits outside boundaries of the waste pits located adjacent to San Jacinto River and I-10 bridge ▪ Unknown industrial or urban sources	▪ Remove or contain contamination from locations already identified ▪ Encourage additional testing to locate all unknown sources/deposits
Pesticides in Edible Fish Tissue	2427 I	▪ Runoff from upstream agricultural areas. ▪ Contaminated groundwater discharging into surface waters	▪ Educate agricultural producers about proper pesticide application. ▪ Promote conservation practices like riparian buffers that help reduce runoff pollutants in agricultural areas. ▪ Encourage additional testing to locate all unknown sources.

Segment Discussion:

Watershed Characteristics: This watershed is predominantly developed with mixed residential, commercial, and industrial land uses. The Cities of La Porte and Morgan Point make up the majority of development in the area, but small plots of undeveloped and agricultural lands are scattered throughout. Additionally, the Houston Ship Channel supports heavy boat and barge traffic on a consistent basis throughout the year.

Water Quality Issues: This segment is not consider designated for contract recreation use by the TCEQ. The 2014 Texas IR lists segment 2427 San Jacinto Bay as impaired for fish consumption due to PCBs, Dioxin, and the pesticides chlordane, dieldrin, and heptachlor epoxide found in edible fish tissue. The Texas Department of State Health Services issued a Limited Consumption Fish Advisory for this bay segment.

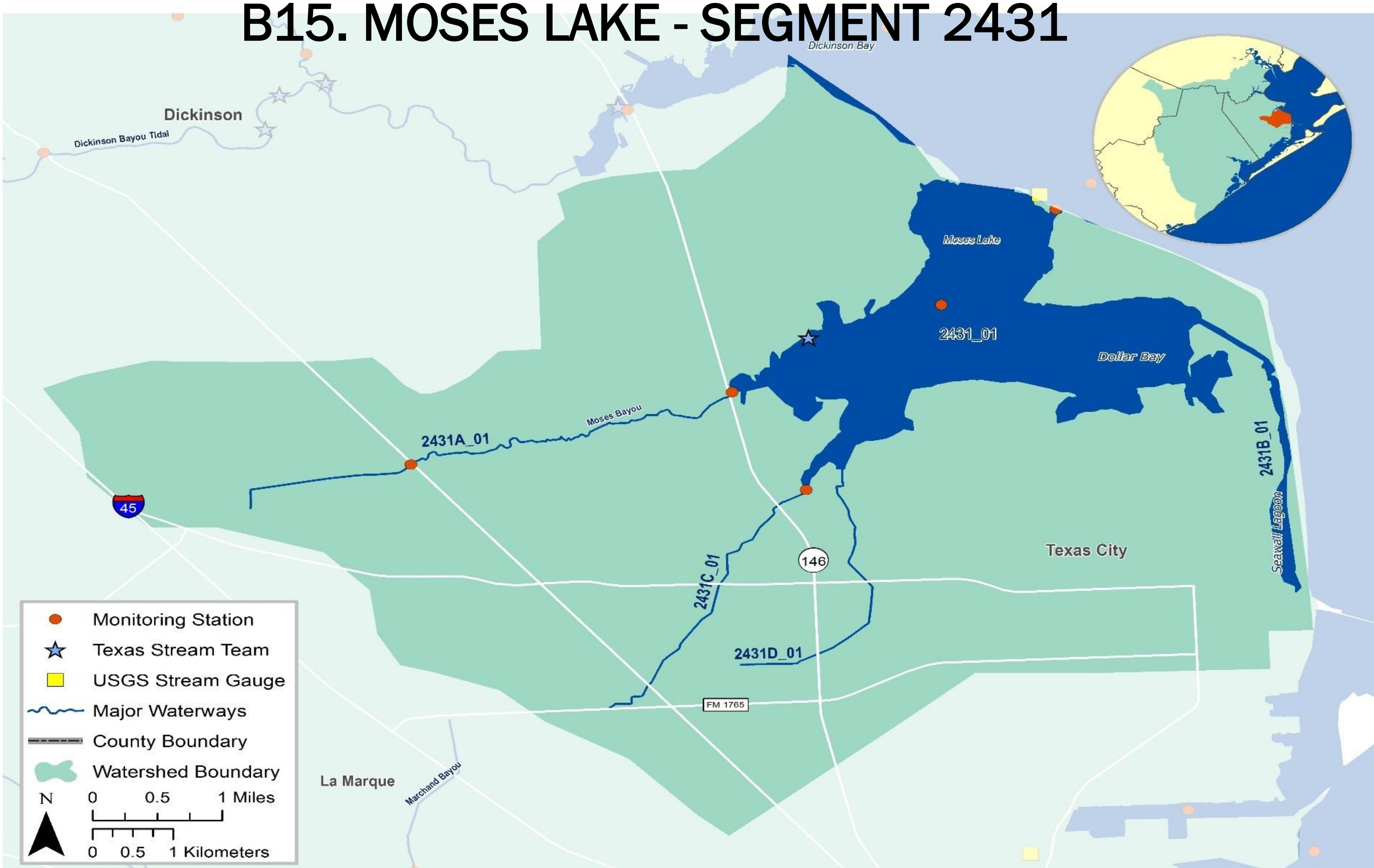
Additionally, San Jacinto Bay is listed on the 2014 IR for concerns for water quality based upon screening criteria levels for ammonia nitrogen, nitrate nitrogen, and total phosphorus. Almost 99% of nitrate nitrogen samples exceed the water quality screening criteria level of 0.17 mg/L, 98% of total phosphorus samples exceeded the screening criteria level of 0.21 mg/L, and 54% of ammonia nitrogen samples exceeded the screening criteria level of 0.10 mg/L.

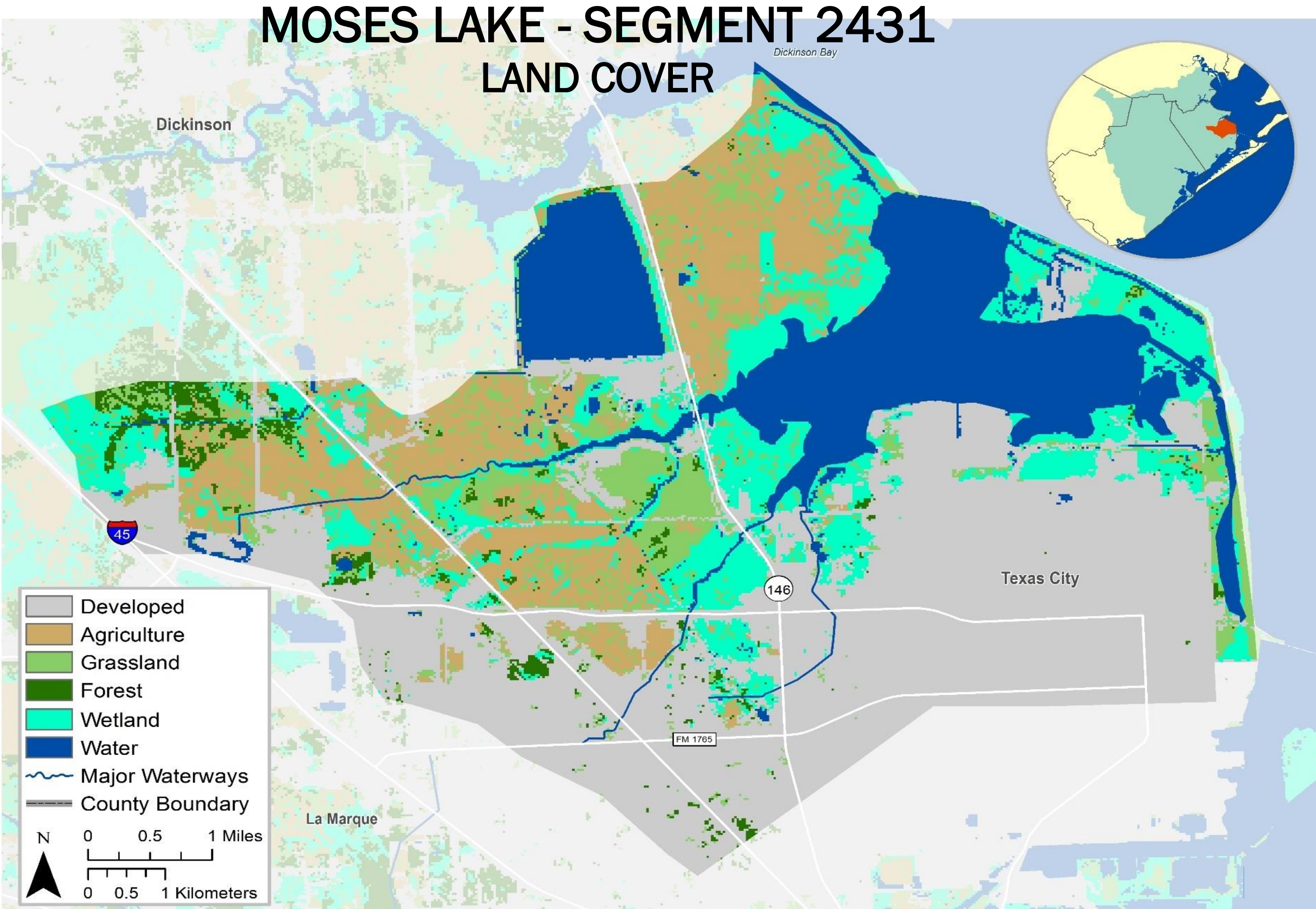
Special Studies/Projects: This segment is included in two TMDL projects, the Houston Ship Channel and Upper Galveston Bay TMDL for PCBs in Fish Tissue and the Houston Ship Channel TMDL for Dioxin, which are currently under way. For more information, please refer to the detailed discussions located in the Public Involvement and Outreach section of the 2016 Basin Summary Report regarding the dioxin and PCB TMDLs.

Trends: Regression analysis of water quality data revealed seven statistically significant parameter trends for the San Jacinto Bay watershed including increasing salinity, Secchi transparency, specific conductance (SPCond), total dissolved solids (TDS), and total phosphorous (TP) while chlorophyll *a* and enterococci concentrations are decreasing over time. In addition to the PCB/dioxin and pesticides in edible fish tissue impairments, this segment is also listed as having a concern for elevated nutrient concentrations. Regression analysis of nutrient data for San Jacinto Bay revealed a statistically significant trend in TP while nitrate concentrations have remained relatively stable during the period of record. However, the majority of nutrient samples collected since 2002 remain well above the set screening criteria for each parameter. The same is true for ammonia concentrations in San Jacinto Bay.

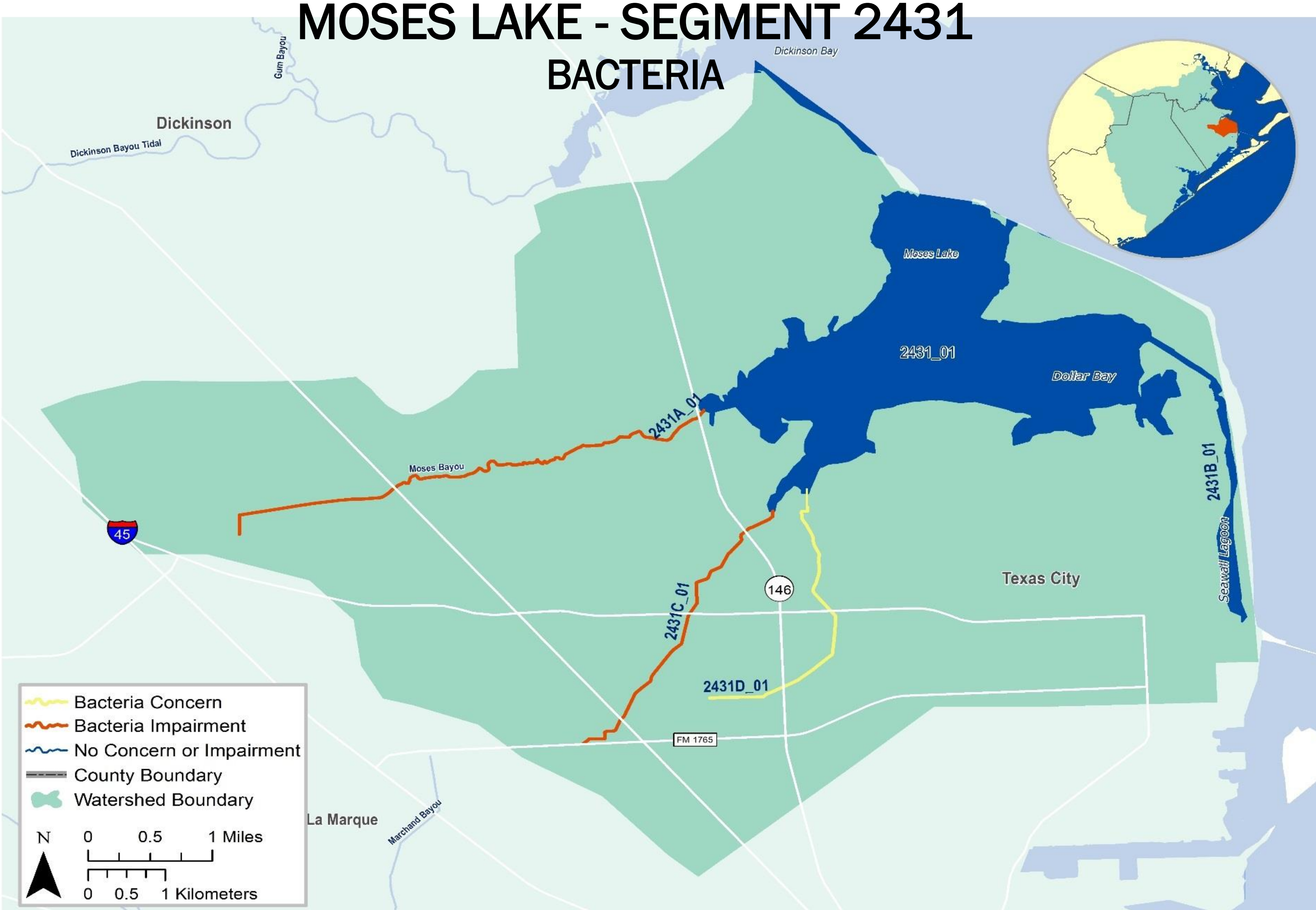
Recommendations
Continue collecting water quality data to support actions associated with any future watershed protection plan development and possible modeling.
Coordinate education efforts with other local TMDL and watershed protection plan efforts.
Pursue a new local partner to Clean Rivers Program to collect additional data that would help better isolate problem areas.
Support additional sampling to investigate sources of elevated dioxin and PCB levels.

B15. MOSES LAKE - SEGMENT 2431

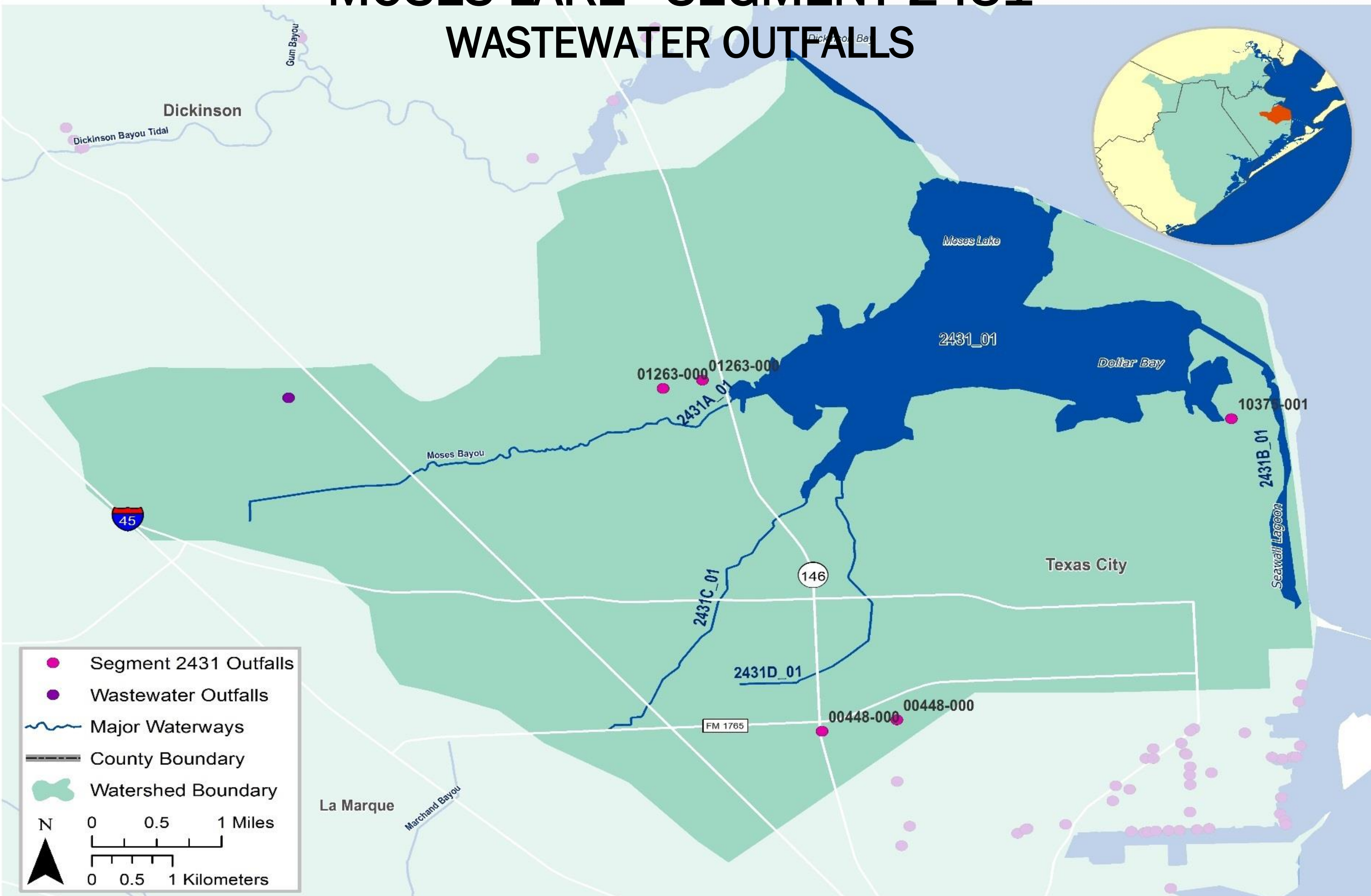



MOSES LAKE - SEGMENT 2431
LAND COVER
Dickinson Bay
Dickinson
45
146
Texas City
FM 1765
La Marque
Developed
Agriculture
Grassland
Forest
Wetland
Water
Major Waterways
County Boundary
N
0 0.5 1 Miles
0 0.5 1 Kilometers

MOSES LAKE - SEGMENT 2431
BACTERIA



MOSES LAKE - SEGMENT 2431
WASTEWATER OUTFALLS



Segment Number:	2431	Name:	Moses Lake

Area:	4 square miles	Miles of Shoreline:	10.7 miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life Use
Number of Active Monitoring Stations:	5	Texas Stream Team Monitors:	1	Permitted Outfalls:	5

Description:	An 8.5 square kilometer (3.3 square mile) water body on the western shore of Lower Galveston Bay entirely enclosed by the Texas City levee system immediately north of the urbanized portion of the City of Texas City, south of and adjacent to Dickinson Bay in Galveston County Segment 2431A (Tidal Stream w/ high ALU): Moses Bayou (unclassified water body) — From Moses Lake confluence to 2.2 km (1.4 mi) upstream of SH 3 in Galveston County Segment 2431B (Estuary w/ high ALU): Seawall Lagoon (unclassified water body) – Located approximately 1.9 km (1.2 mi) south of Dollar Point adjacent to Bay Street N in Galveston County Segment 2431C (Tidal Stream w/ high ALU): Unnamed Tributary to the Southern Arm (west) of Moses Lake (unclassified water body) – From the confluence with the southern arm (west) of Moses Lake to a point 0.45 mi upstream of State Highway 3 near La Marque Segment 2431D (Tidal Stream w/ high ALU): Unnamed Tributary to the Southern Arm (east) of Moses Lake (unclassified water body) – From the confluence with the southern arm (east) of Moses Lake to a point 0.6 mi upstream of State Highway 146 in Texas City

Percent of Stream Impaired or of Concern	
Segment ID	**Bacteria**
2431	55
2431A	100

Segment 2431

Standards	Bays & Estuaries	Tidal Streams	Screening Levels	Bays & Estuaries	Tidal Streams
Temperature (°C/°F):	35 / 95	35 / 95	Ammonia-N (mg/L):	0.10	0.46
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	4.0	Nitrate-N (mg/L):	0.17	1.10
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	3.0	Orthophosphate Phosphorus (mg/L):	0.19	0.46
pH (standard units):	6.5-9.0	6.5-9.0	Total Phosphorus-P (mg/L):	0.21	0.66
Enterococci (MPN/100mL) (grab):	104	104	Chlorophyll *a* (µg/L):	11.6	21
Enterococci (MPN/100mL) (geometric mean):	35	35			

FY 2016 Active Monitoring Stations				
Site ID	**Site Description**	**Frequency**	**Monitoring Entity**	**Parameter Groups**
11400	Moses Bayou at SH 146 Bridge	Quarterly	EIH	Field, Conventional, Bacteria
13345	Moses Lake at CM 9	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16551	Moses Lake at Galveston Bay	Quarterly	EIH	Field, Conventional, Bacteria, Chlorophyll *a*
17910	Moses Bayou at SH 3	Quarterly	EIH	Field, Conventional, Bacteria
18592	Trib of Moses Lake at Loop 197 North	Quarterly	EIH	Field, Conventional, Bacteria

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Levels of Indicator Bacteria	2431A I 2431C I 2431D I	▪ Rapid urbanization and increased impervious cover ▪ Constructed stormwater controls failing ▪ Animal waste from agricultural production, hobby farms, and riding stables ▪ Improper or no pet waste disposal ▪ Developments with malfunctioning OSSFs ▪ Waste haulers illegal discharges/improper disposal ▪ Direct and dry weather discharges ▪ Poorly operated or undersized WWTFs ▪ WWTF non-compliance, overflows, and collection system by-passes	▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems ▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Encourage Water Quality Management Plans or similar projects for agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ More public education on pet waste disposal ▪ More public education regarding OSSF operations and maintenance ▪ Ensure proper citing of new or replacement OSSFs

			▪ Regionalize chronically non-compliant WWTFs ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Impose new or stricter bacteria limits than currently designated by TCEQ ▪ Increase monitoring requirements for self-reporting

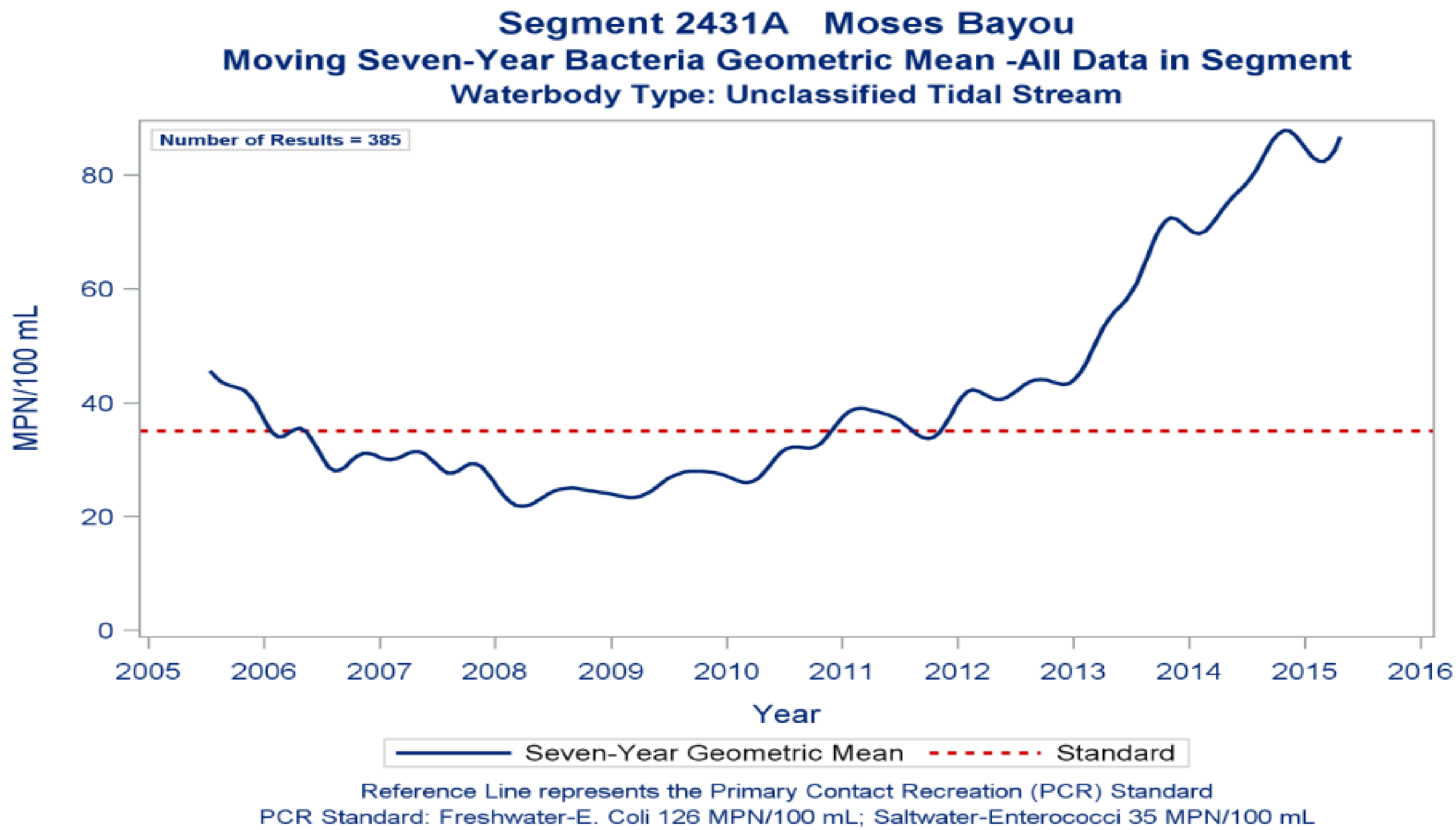
Segment Discussion:

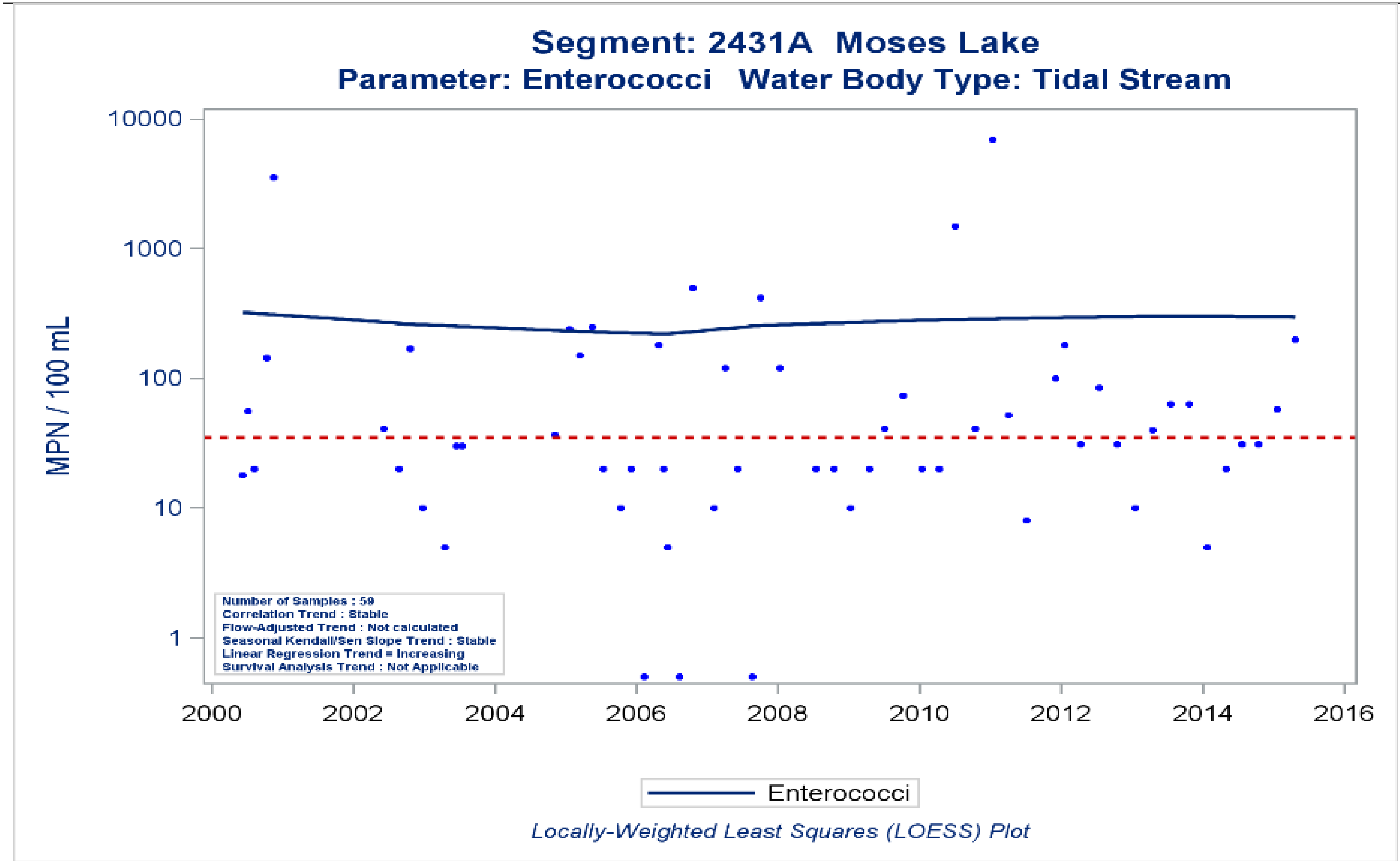
Watershed Characteristics: The northeastern and northwestern portions of the watershed consist mostly of grasslands and forested lands. Ranchettes are the common semi-rural development in this area. Large tracts of undisturbed wetlands and marsh habitats surround Moses Lake and Dollar Bay, an adjacent lagoon. In contrast, the southern section of the watershed is highly urbanized and includes a part of the Texas City petrochemical complex. Development is also concentrated along the major thoroughfares that run through the watershed. Only the urbanized areas of Texas City and La Marque are serviced by municipal wastewater collection and treatment systems. The remaining developments rely on OSSFs.

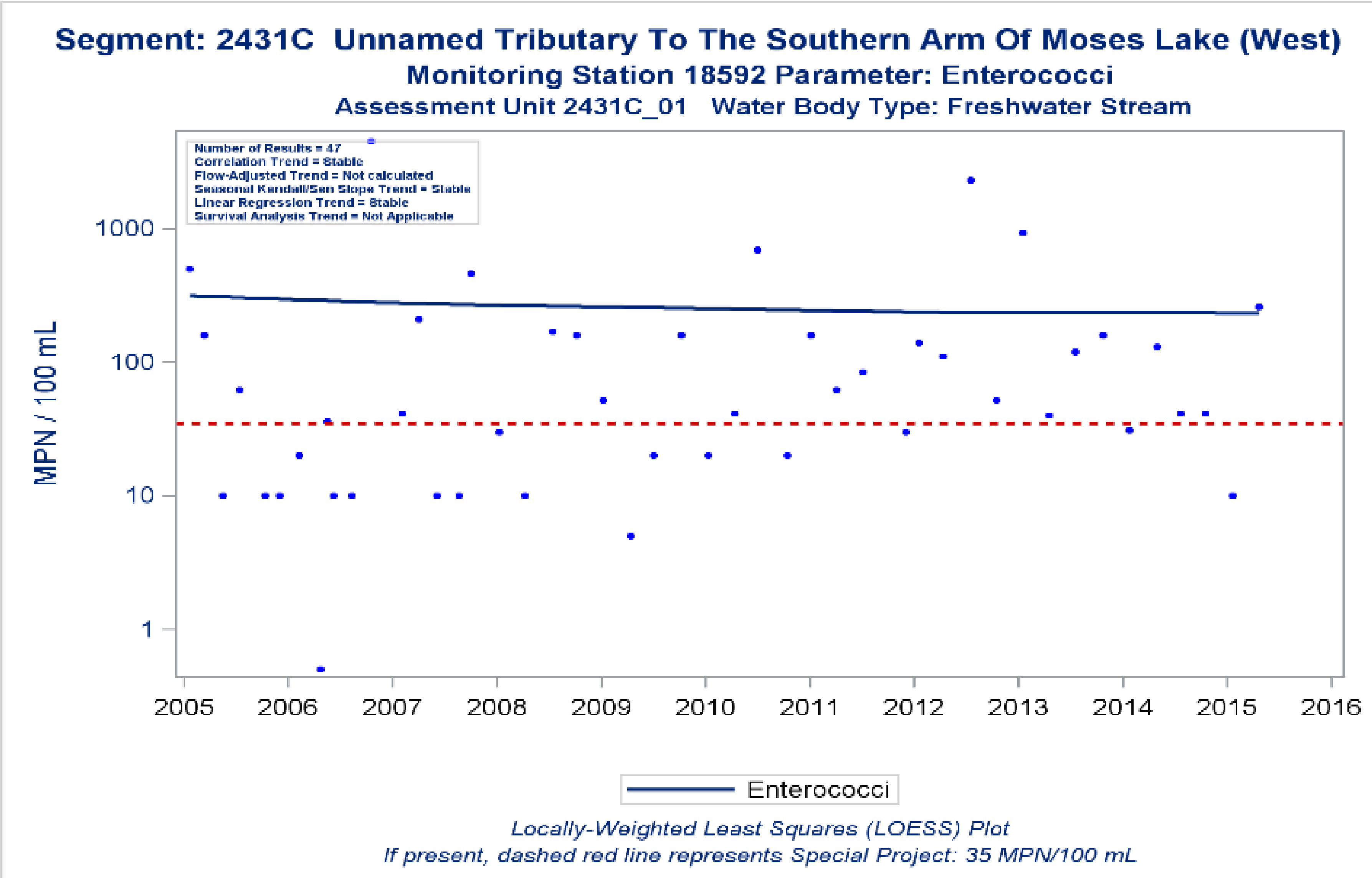
Water Quality Issues: The 2014 Texas IR lists unclassified segments 2431A and 2431C as impaired for contact recreation due to high levels of enterococci bacteria. The 2014 IR also lists 2431D as having a concern for near non-attainment for contact recreation due to high levels of enterococci. 2431A is a new addition to the 303(d) list for bacteria. Refer to the moving seven year bacteria geometric mean plot for segment 2431A to the right for more information about enterococci geometric means over time.

Special Studies/Projects: TX AgriLife has included Moses Bayou and Moses Lake in their Highland and Marchand Bayou watershed protection plan study area. Texas AgriLife is facilitating the Galveston – Brazoria County Coalition of Watersheds to bring stakeholders involved in TMDL I-Plan and WPP implementation, including this watershed, together to build cooperation on common bacteria issues and BMPs. The goal is a regional watershed planning group that will elevate issues and attract funding.

Trends: The 2014 Texas Integrated report list Moses Lake and Moses Bayou as impaired for PCBs and dioxin in edible fish tissue. Refer to the water quality discussion above for more information about these impairments. A bacteria impairment is also listed for segments 2431A, 2431C, and 2431D. Regression analysis of enterococci data revealed relatively stable bacteria trends over time for these segments with nearly half of all samples collected during the period of record exceeding the 35 MPN/100 mL geometric mean standard for enterococci.


Segment 2431A Moses Bayou
Moving Seven-Year Bacteria Geometric Mean -All Data in Segment
Waterbody Type: Unclassified Tidal Stream
Number of Results = 385
MPN/100 mL
0
20
40
60
80
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year
Seven-Year Geometric Mean
Standard
Reference Line represents the Primary Contact Recreation (PCR) Standard
PCR Standard: Freshwater-E. Coli 126 MPN/100 mL; Saltwater-Enterococci 35 MPN/100 mL

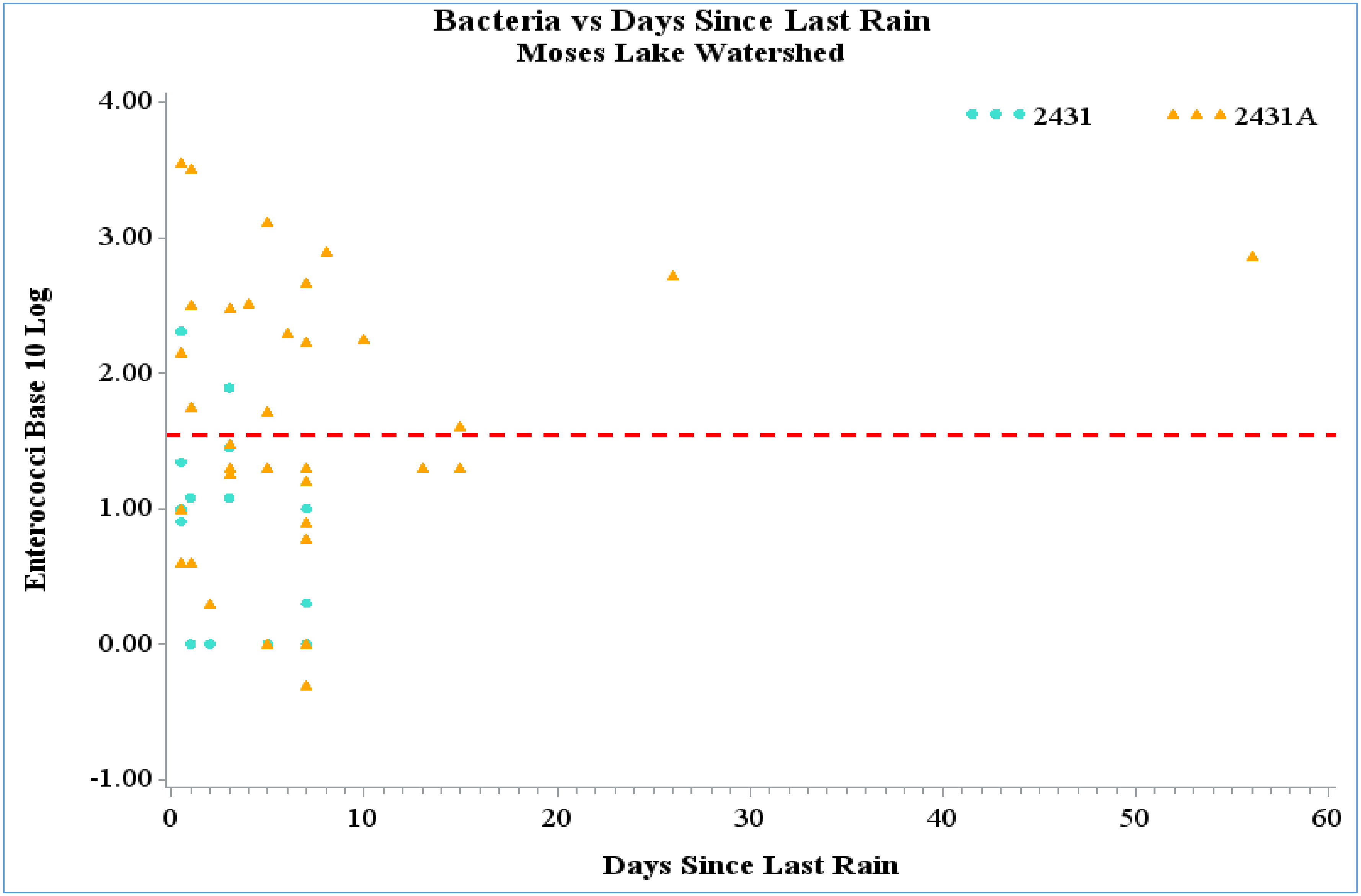

Segment: 2431A Moses Lake
Parameter: Enterococci Water Body Type: Tidal Stream
MPN / 100 mL
10000
1000
100
10
1
Number of Samples : 59
Correlation Trend : Stable
Flow-Adjusted Trend : Not calculated
Seasonal Kendall/Sen Slope Trend : Stable
Linear Regression Trend = Increasing
Survival Analysis Trend : Not Applicable
2000
2002
2004
2006
2008
2010
2012
2014
2016
Enterococci
Locally-Weighted Least Squares (LOESS) Plot



Segment: 2431C Unnamed Tributary To The Southern Arm Of Moses Lake (West)
Monitoring Station 18592 Parameter: Enterococci
Assessment Unit 2431C_01 Water Body Type: Freshwater Stream
Number of Results = 47
Correlation Trend = Stable
Flow-Adjusted Trend = Not calculated
Seasonal Kendall/Sen Slope Trend = Stable
Linear Regression Trend = Stable
Survival Analysis Trend = Not Applicable
MPN / 100 mL
1000
100
10
1
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Enterococci
Locally-Weighted Least Squares (LOESS) Plot
If present, dashed red line represents Special Project: 35 MPN/100 mL

Load Duration Curves

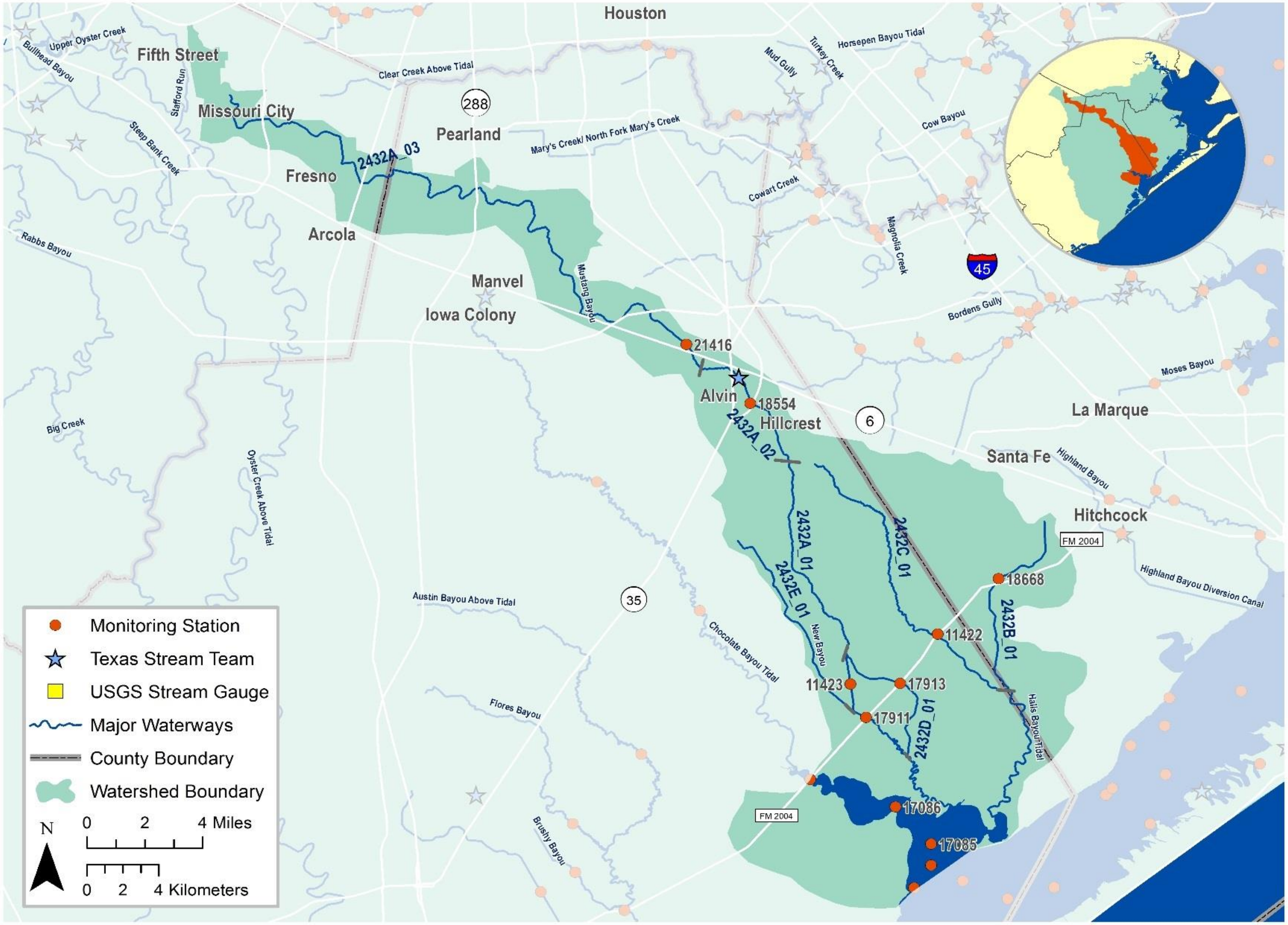
While there was sufficient bacteria data to complete a LDC, the tidal influence prohibited development of a simple LDC for this segment. Using the Days Since Last Rain plot as a surrogate until a more complex LDC or development of a model suggest that bacteria declines as bacteria data is collected the greater number of days since last rainfall was registered. It is notable that a couple of elevated values were recorded past the 20th day since recorded rainfall that while insufficient in the number of total data values, they were significantly above the standard (dashed red line). Days Since Last Rain is problematic as a surrogate as the bacteria data collected cannot be framed within the ambient conditions present as derived by flow conditions (i.e. extreme wet, wet, moderate, dry, extreme dry). A data point could be collected thirty days since the last rain event even while conditions for the watershed are still considered wet. Likewise, a bacteria sample could be collected a day after a rain event while the pervasive conditions are drought for the watershed. As Days Since Last rain cannot be used to explain the watersheds conditions when the data was collected, it is a far weaker argument compared to the use of LDCs, to say that bacteria loads are less of a problem during dry conditions due to bacteria generated by WWTFs or failing OSSFs.



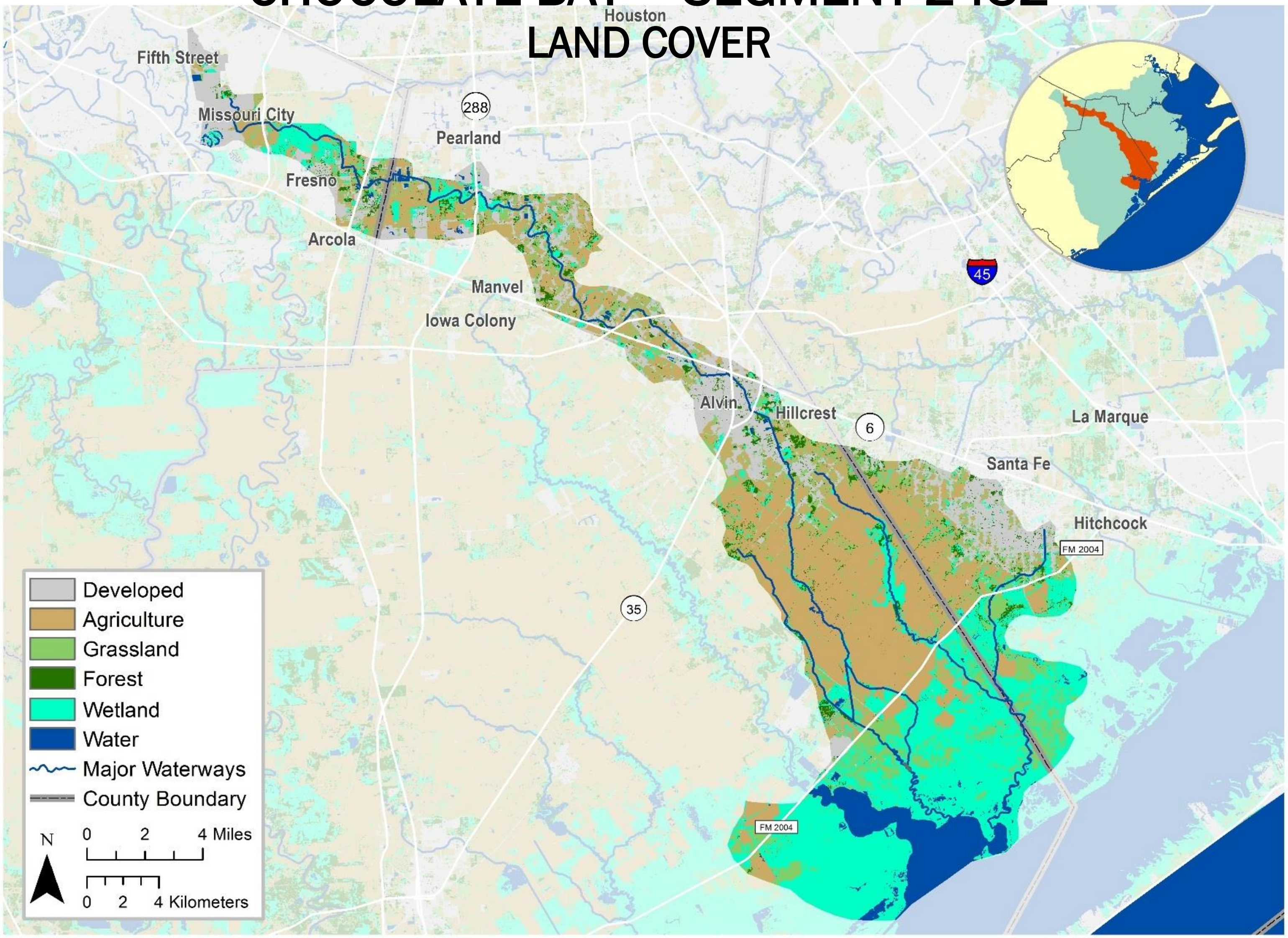
Bacteria vs Days Since Last Rain
Moses Lake Watershed
2431
2431A
Enterococci Base 10 Log
4.00
3.00
2.00
1.00
0.00
-1.00
0
10
20
30
40
50
60
Days Since Last Rain

Recommendations
Continue collecting water quality data to support actions associated with any future watershed protection plan development and possible modeling.
Coordinate education efforts with TX AgriLife watershed protection plan efforts.
Pursue a new local partner to Clean Rivers Program to collect additional data that would help better isolate problem areas.

B16. CHOCOLATE BAY - SEGMENT 2432

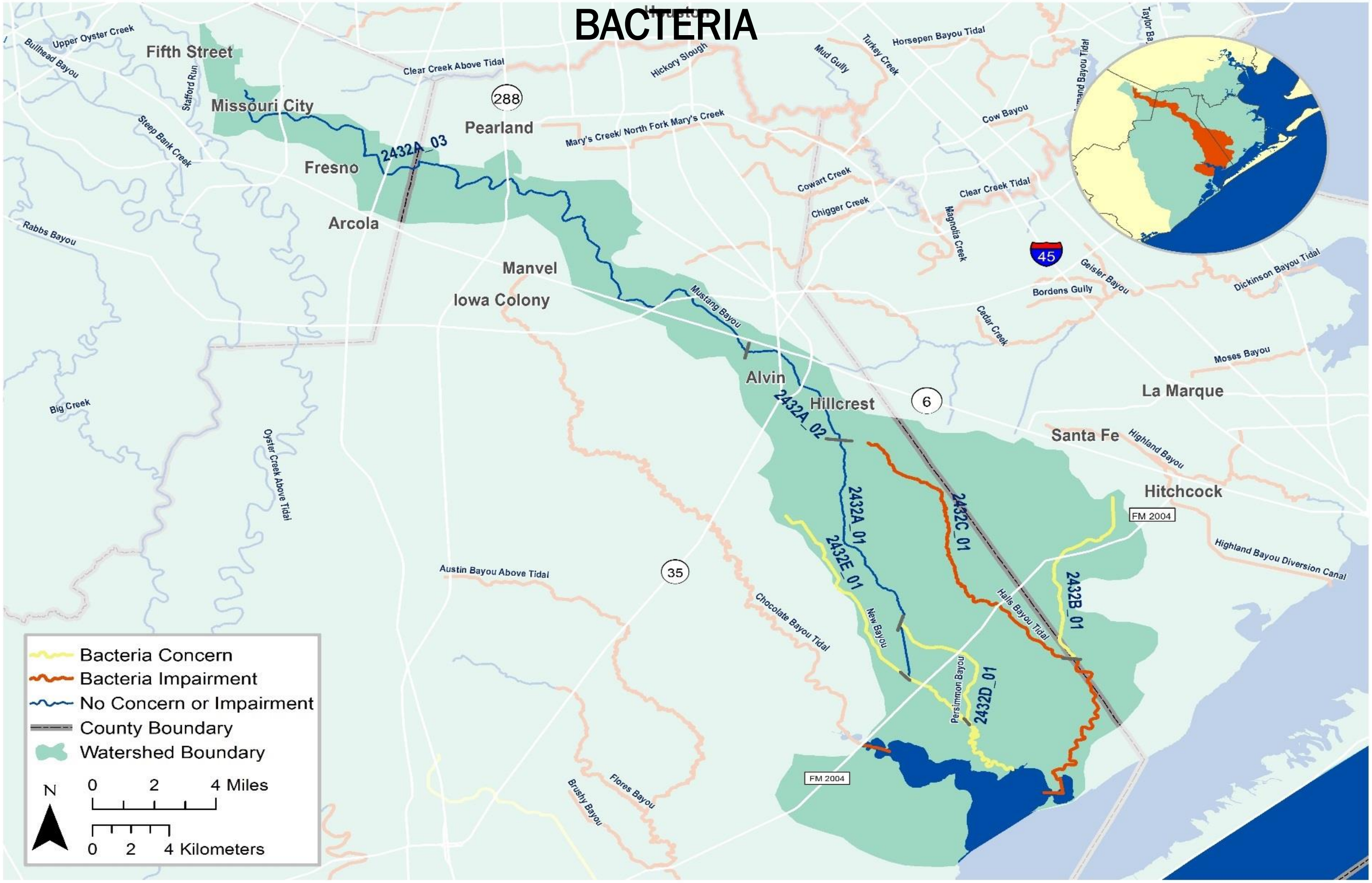


CHOCOLATE BAY – SEGMENT 2432
LAND COVER

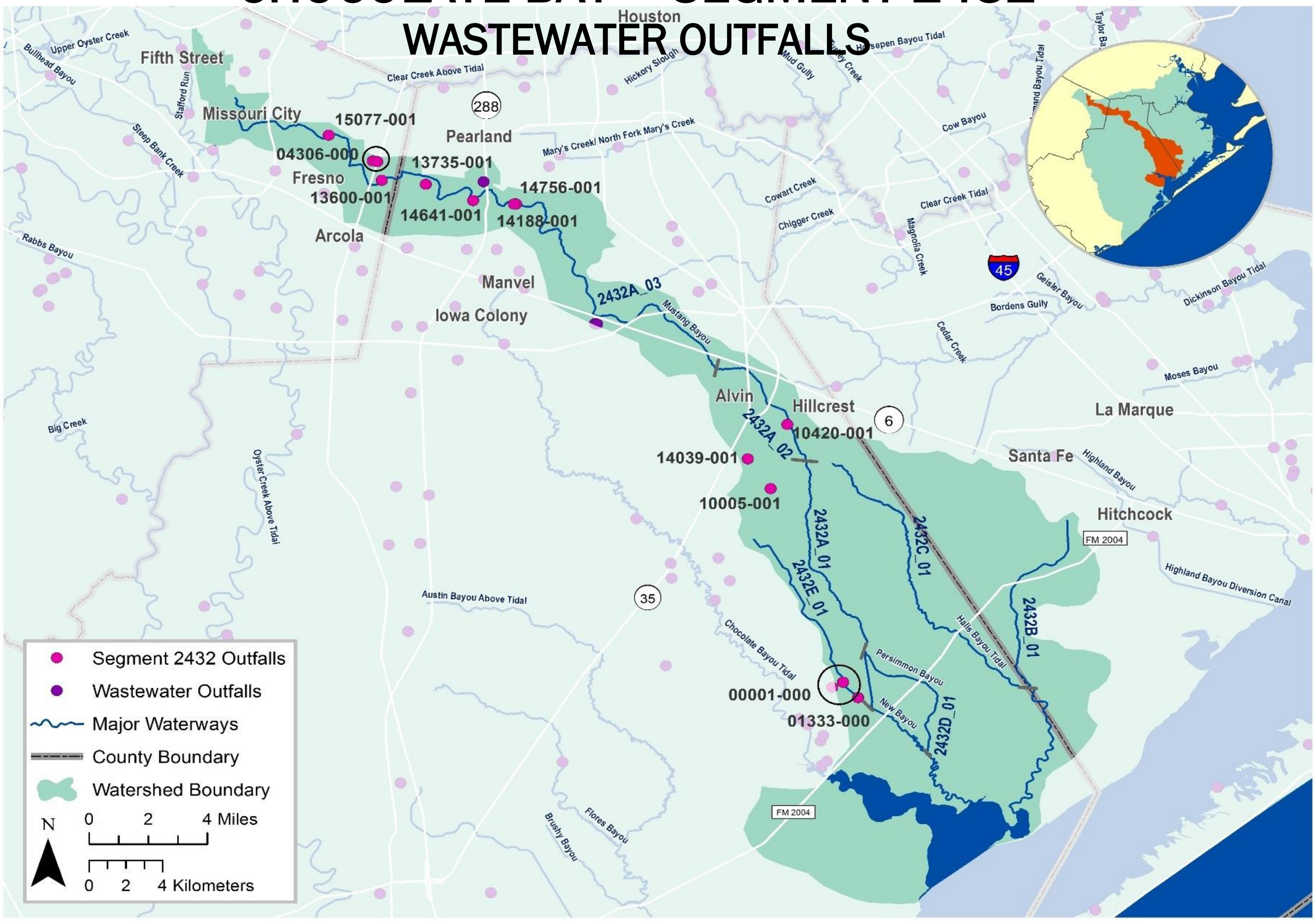


CHOCOLATE BAY – SEGMENT 2432

BACTERIA



CHOCOLATE BAY – SEGMENT 2432
WASTEWATER OUTFALLS



Segment Number:	2432	Name:	Chocolate Bay

Area:	7.4 square miles	Miles of Shoreline:	25 miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life Use; Oyster Waters
Number of Active Monitoring Stations:	10	Texas Stream Team Monitors:	0	Permitted Outfalls:	18

Description:	Adjoining the northwest side of West Galveston Bay at the Gulf Intracoastal Waterway and extending upstream to confluence with Chocolate Bayou approximately ¾ mile downstream of FM 2004 in southeast Brazoria County Segment 2432A (Perennial Stream w/ intermediate ALU): Mustang Bayou (unclassified water body) – From the New Bayou confluence upstream to an unnamed tributary 0.3 km (0.19 mi) upstream of State Hwy 35 to an unnamed tributary downstream of Cartwright Road Segment 2432B (Perennial Stream w/ high ALU): Willow Bayou (unclassified water body) – From the Halls Bayou confluence to a point 9.7 km (6 mi) upstream Segment 2432C (Tidal Stream w/ high ALU): Halls Bayou Tidal (unclassified water body) — From the Chocolate Bay confluence upstream to a point 31.5 km (19.6 mi) upstream Segment 2432D (Perennial Stream w/ high ALU): Persimmon Bayou (unclassified water body)—From the New Bayou confluence upstream to the Mustang Bayou confluence Segment 2432E (Perennial Stream w/ high ALU): New Bayou (unclassified water body)—From the Chocolate Bay confluence upstream 25.4 km (15.8 mi) to an unnamed tributary Segment 2432OW (Oyster Water)

Percent of Stream Impaired or of Concern

Segment ID	Bacteria
2432	-
2432B	100
2432C	100
2432D	100
2432E	100

Segment 2432							
Standards	Bays & Estuaries	Tidal Streams	Perennial Stream	**Screening Levels**	Bays & Estuaries	Tidal Streams	Perennial Stream
Temperature (°C/°F):	35 / 95	35 / 95	35 / 95	Ammonia-N (mg/L):	0.10	0.46	0.33
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	4.0	5.0 / 4.0	Nitrate-N (mg/L):	0.17	1.10	1.95
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	3.0	3.0 / 3.0	Orthophosphate Phosphorus (mg/L):	0.19	0.46	0.37
pH (standard units):	6.5-9.0	6.5-9.0	6.5-9.0	Total Phosphorus-P (mg/L):	0.21	0.66	0.69
Enterococci (MPN/100mL) (grab):	104	104	104	Chlorophyll *a* (µg/L):	11.6	21	14.1
Enterococci (MPN/100mL) (geometric mean):	35	35	35				
Fecal Coliform in Oyster Waters (CFU/100mL) (median/grab):	14/43						

FY 2016 Active Monitoring Stations				
Site ID	**Site Description**	**Frequency**	**Monitoring Entity**	**Parameter Groups**
11422	Halls Bayou at FM 2004	Quarterly	EIH	Field, Conventional, Bacteria
11422	Halls Bayou at FM 2004	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll a
11423	Mustang Bayou at FM 2917	Quarterly	EIH	Field, Conventional, Bacteria
16228	Chocolate Bay at 97gb034	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll a
17085	Chocolate Bay Near Wharton Bayou	Quarterly	EIH	Field
17086	Chocolate Bay NW of Horse Grove Point	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll a
17911	New Bayou at FM 2004	Quarterly	EIH	Field, Conventional, Bacteria
17913	Persimmon Bayou at FM 2004	Quarterly	EIH	Field, Conventional, Bacteria
18554	Mustang Bayou at SH 35	Quarterly	EIH	Field, Conventional, Bacteria
18668	Willow Bayou at Baker Street	Quarterly	EIH	Field, Conventional, Bacteria
21416	Mustang Bayou at Heights-Manvel Rd	Quarterly	EIH	Field, Conventional, Bacteria

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Levels of Indicator Bacteria in Recreational and Oyster Waters	2432B I 2432C I 2432D C 2432E C 2432OW I	▪ Animal waste from agricultural production, hobby farms, and riding stables ▪ Rapid urbanization and increased impervious cover ▪ Constructed stormwater controls failing ▪ Developments with malfunctioning OSSFs ▪ Improper or no pet waste disposal ▪ Waste haulers illegal discharges/improper disposal ▪ Direct and dry weather discharges ▪ Poorly operated or undersized WWTFs ▪ WWTF non-compliance, overflows, and collection system by-passes	▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Encourage Water Quality Management Plans or similar projects for agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems ▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education on pet waste disposal ▪ Increase monitoring requirements for self-reporting ▪ Regionalize chronically non-compliant WWTFs ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Impose new or stricter bacteria limits than currently designated by TCEQ

Segment Discussion:

Watershed Characteristics: The Chocolate Bay Watershed is on the northwest side of West Galveston Bay at the Gulf Intercoastal Waterway and extends upstream to the confluence with Chocolate Bayou in Brazoria County. Wetlands and grasslands surround this segment which supports barge traffic servicing the petrochemical industries located upstream. Agriculture, including ranching, is the primary land use throughout the watershed. There are two urban areas in the watershed including the City of Alvin, which is centrally located, and Missouri City, which is located to the north.

Water Quality Issues: The 2014 Texas IR lists 2432C_01 Halls Bayou Tidal as impaired for contact recreation due to high levels of enterococci bacteria. The 2014 IR also lists assessment units 2432B_01, 2432D_01, and 2432E_01 as having concerns for near non attainment due to elevated levels of *E. coli*. Mustang Bayou (AUs 2432A_01 and 2432A_02) was not assessed in 2014; however, the E. coli data collected suggests that this water body is highly impaired for recreational use.

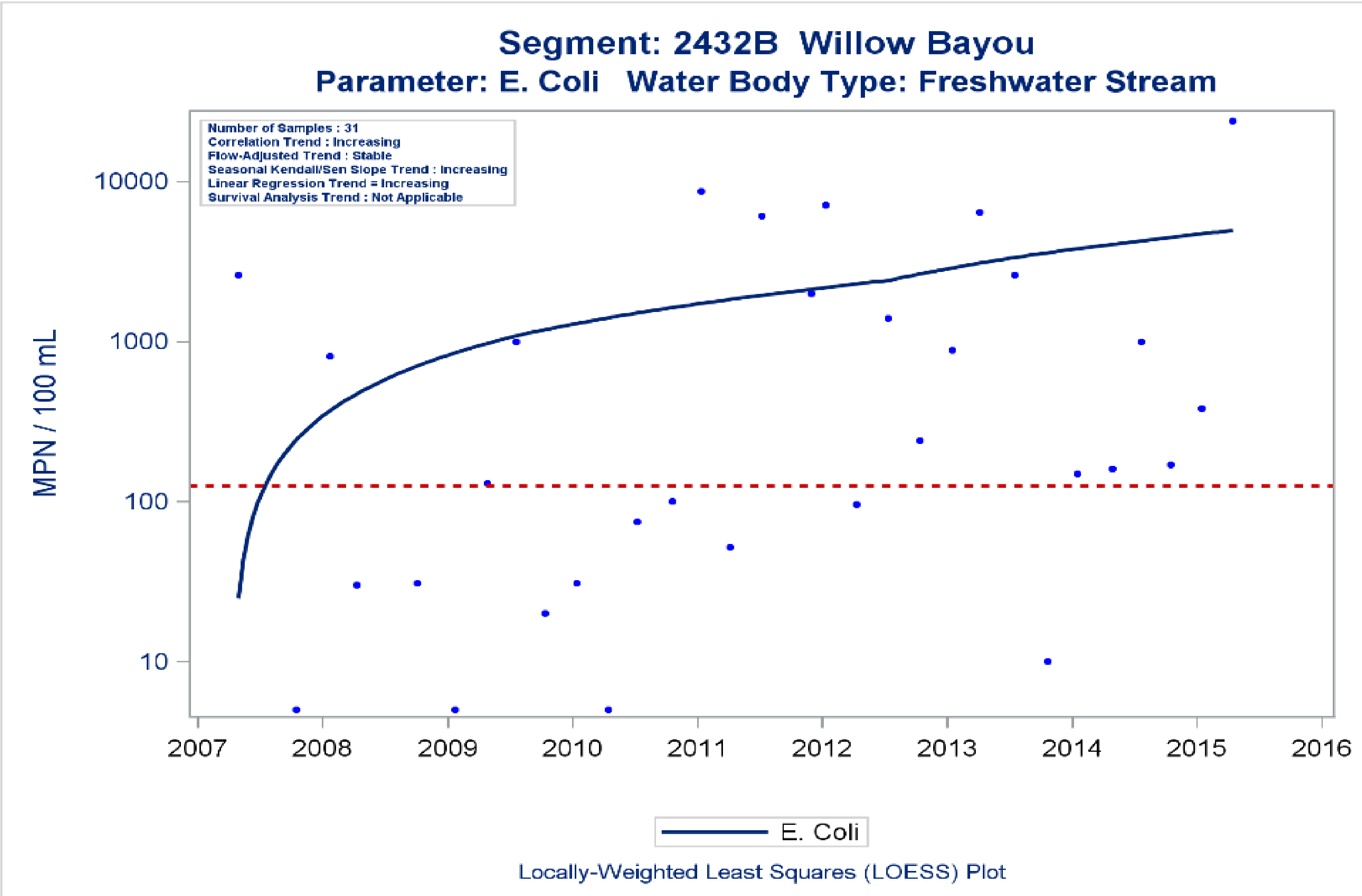
Assessment Unit	TCEQ Assessment (2005-2012)	HGAC Analysis 2001-2008	HGAC Analysis 2008-2015
	Geomean (MPN/100 mL) / % Grab Exceedance	Geomean (MPN/100 mL) / % Grab Exceedance	Geomean (MPN/100 mL) / % Grab Exceedance
2432_01	12 / NA	5 / 10.3	17 / 13.0
2432A_01	280 / NA	NA / NA	411 / 33.3
2432A_02	6041 / NA	NA / NA	2144 / 85.7
2432B_01	254 / NA	133 / 50.0	291 / 40.7
2432C_01	94 / NA	29 / 15.8	188 / 56.8
2432D_01	180 / NA	77 / 52.6	994 / 100.0
2432E_01	182 / NA	65 / 47.4	445 / 78.6

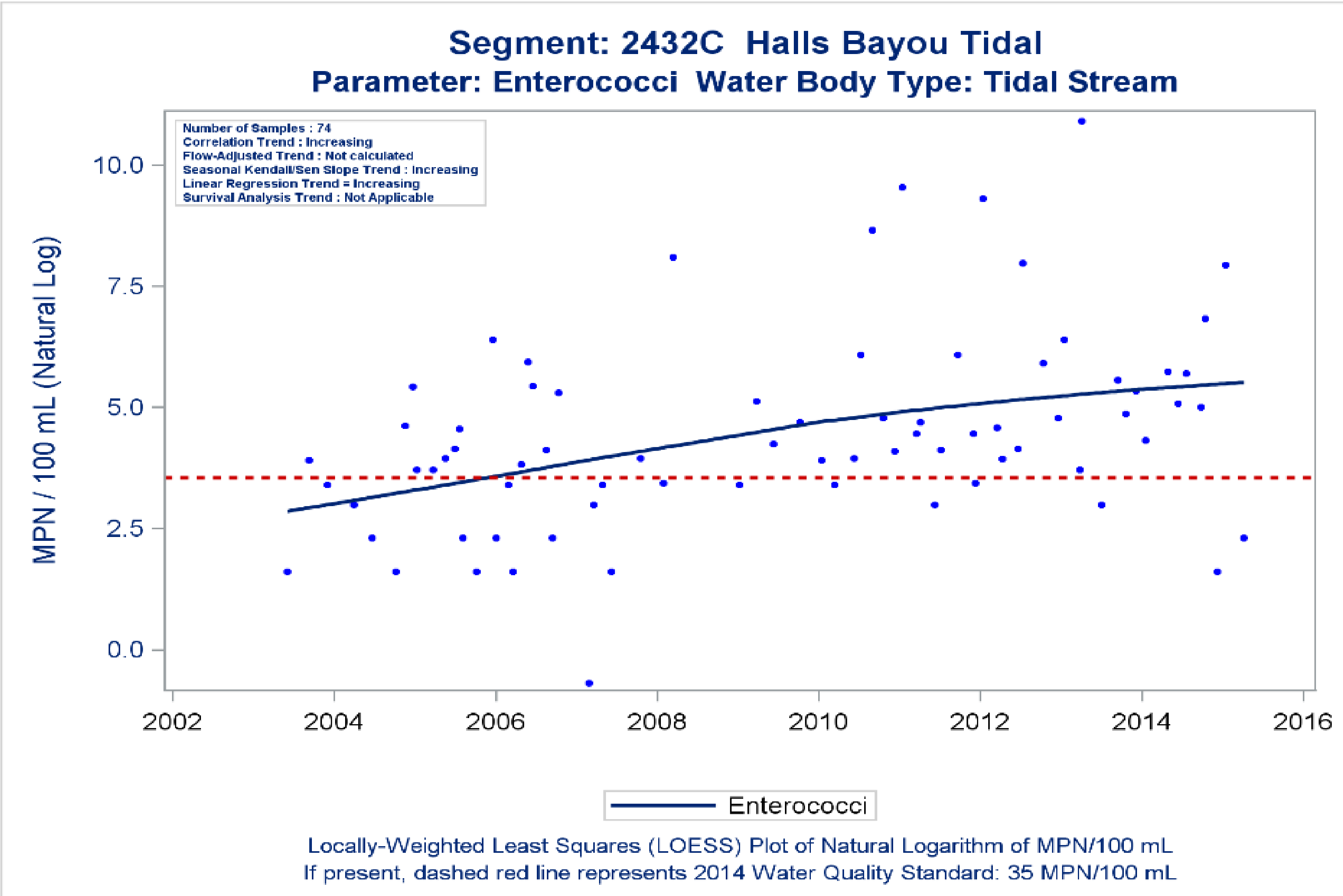
While not a focus for this project it is worth noting that Assessment Unit 2432OW_01, which consists of the entire area of Chocolate Bay, is listed in the 2014 IR as impaired for oyster waters due to elevated levels of fecal coliform bacteria. This assessment unit is closed by the Seafood Safety Division of the Texas Department of State Health Services for the harvesting of oysters and other shellfish for direct marketing.

Special Studies/Projects: Chocolate Bay is included in the Oyster Waters I-Plan for bacteria which began in 2010 after the TMDL was approved by the EPA. The final draft I-Plan was submitted to the TCEQ in August of 2014 and final approval of the draft was given in August of 2015. This process is mentioned here as any work upstream of this segment that addresses bacteria sources could benefit implementation of the UGCOWs I-Plan. The TCEQ TMDL Program has asked H-GAC to begin to characterize the Halls Bayou watershed in FY 2018. Texas AgriLife is facilitating the Galveston – Brazoria County Coalition of Watersheds to bring stakeholders involved in TMDL I-Plan and WPP implementation, including this watershed, together to build cooperation on common bacteria issues and BMPs. The goal is a regional watershed planning group that will elevate issues and attract funding.

Trends: Regression analysis of water quality data revealed 3 statistically significant trends for bacteria in classified and unclassified segments located in the Chocolate Bay watershed. The main Chocolate Bay segment had a significant trend increasing enterococci. While no trends were detected for Mustang Bayou, this assessment is based on a small sample size with large gaps in data availability. Additional long term monitoring on Mustang Bayou is recommended for better evaluation of trends over time. Data for segment 2432B, Willow Bayou, revealed increasing E. coli trends. Increasing enterococci trend was detected for segment 2432C, Halls Bayou Tidal.

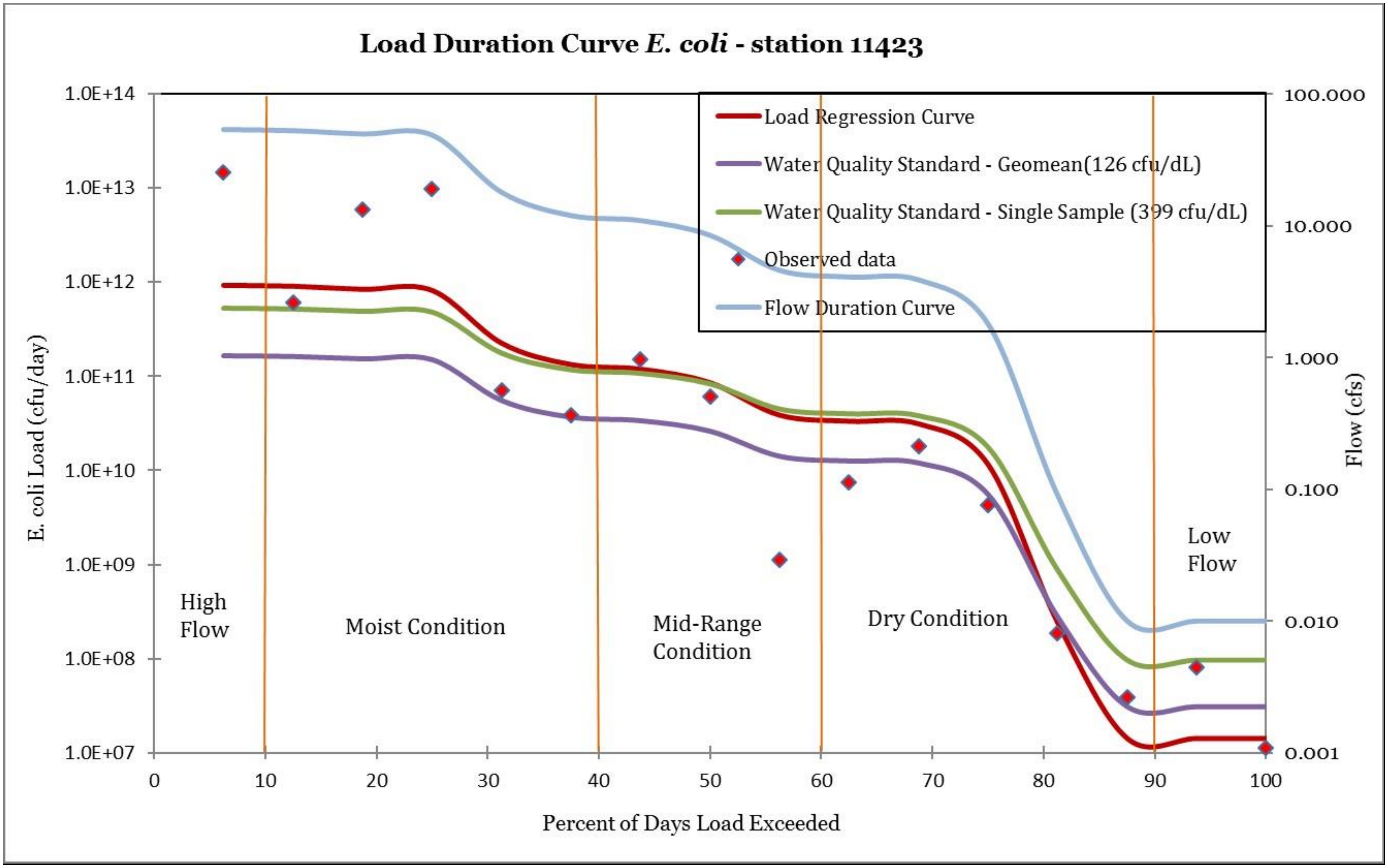
The 2014 Texas Integrated Report lists all unclassified assessment units and Chocolate Bay oyster waters as either impaired or of concern for elevated levels of indicator bacteria. Regression analysis of bacteria data for the impaired segments (2432B and 2432C) show gradual increasing trends in bacteria with more than half of the samples collected during the period of record exceeding 35 MPN/100 mL enterococci standard. Additional data collection is required for segments 2432D and 2432E to better evaluate changes in bacteria over time.

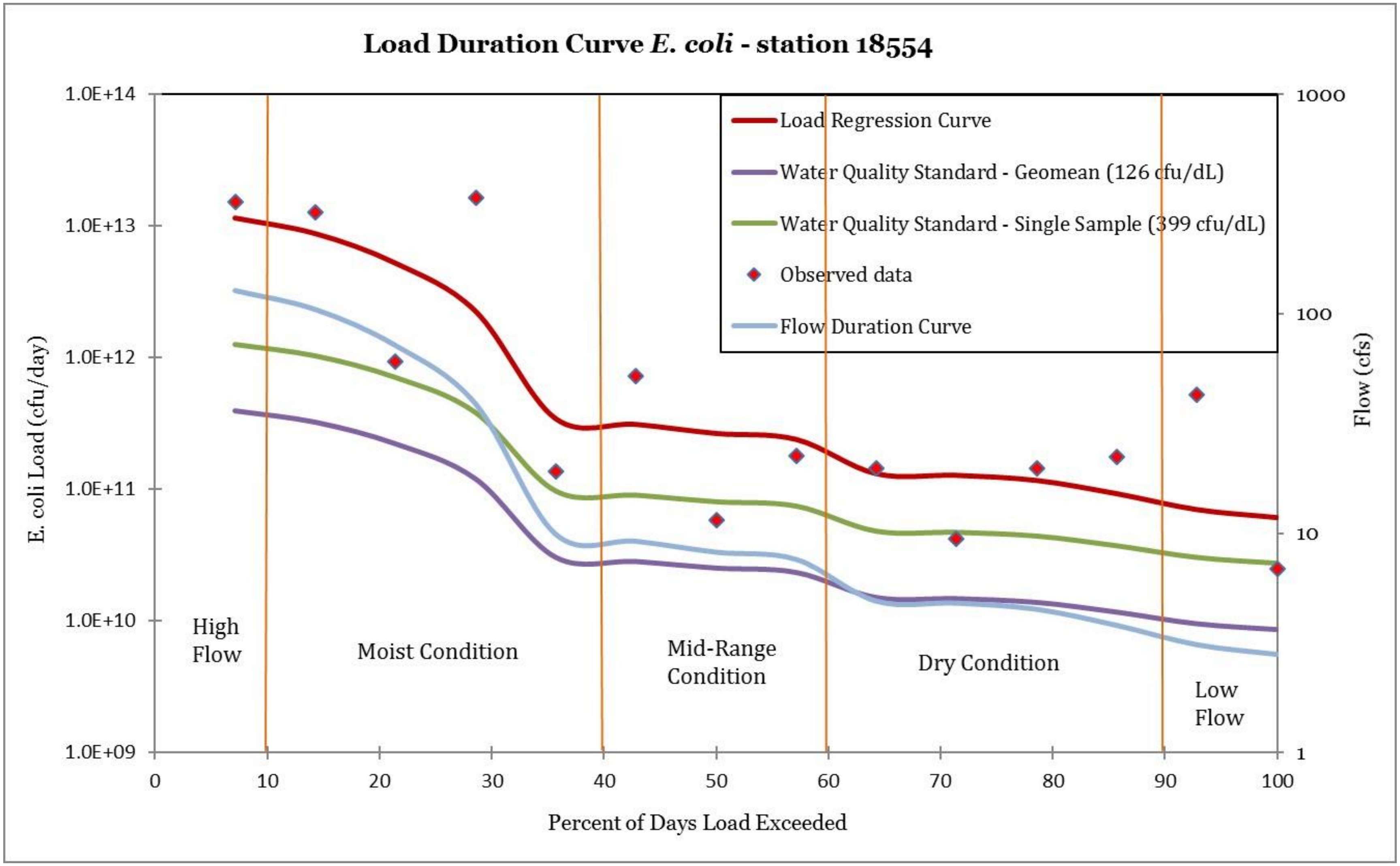

Segment: 2432B Willow Bayou
Parameter: E. Coli Water Body Type: Freshwater Stream
Number of Samples : 31
Correlation Trend : Increasing
Flow-Adjusted Trend : Stable
Seasonal Kendall/Sen Slope Trend : Increasing
Linear Regression Trend = Increasing
Survival Analysis Trend : Not Applicable
MPN / 100 mL
10000
1000
100
10
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
E. Coli
Locally-Weighted Least Squares (LOESS) Plot

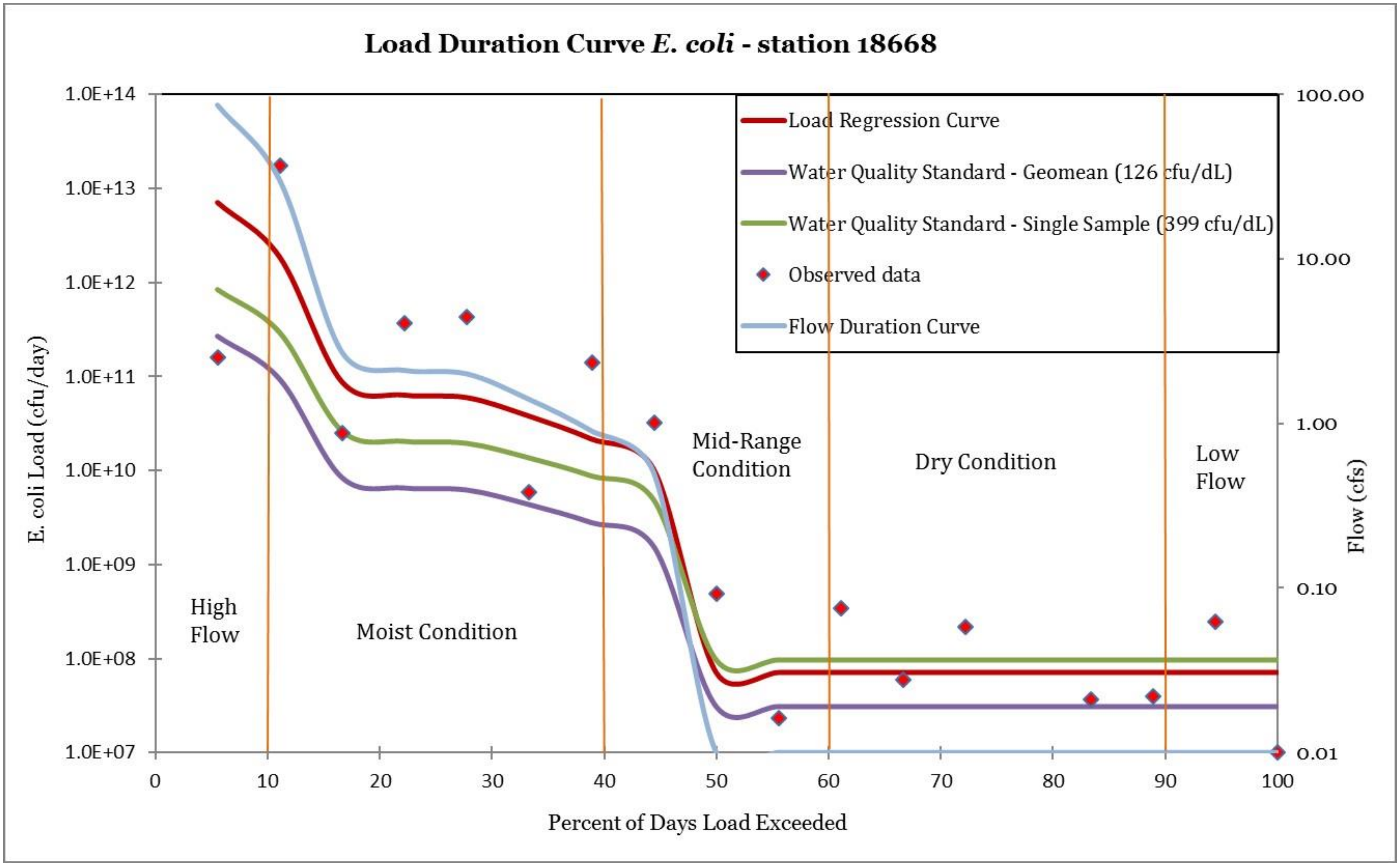

Segment: 2432C Halls Bayou Tidal
Parameter: Enterococci Water Body Type: Tidal Stream
Number of Samples : 74
Correlation Trend : Increasing
Flow-Adjusted Trend : Not calculated
Seasonal Kendall/Sen Slope Trend : Increasing
Linear Regression Trend = Increasing
Survival Analysis Trend : Not Applicable
MPN / 100 mL (Natural Log)
10.0
7.5
5.0
2.5
0.0
2002
2004
2006
2008
2010
2012
2014
2016
Enterococci
Locally-Weighted Least Squares (LOESS) Plot of Natural Logarithm of MPN/100 mL
If present, dashed red line represents 2014 Water Quality Standard: 35 MPN/100 mL

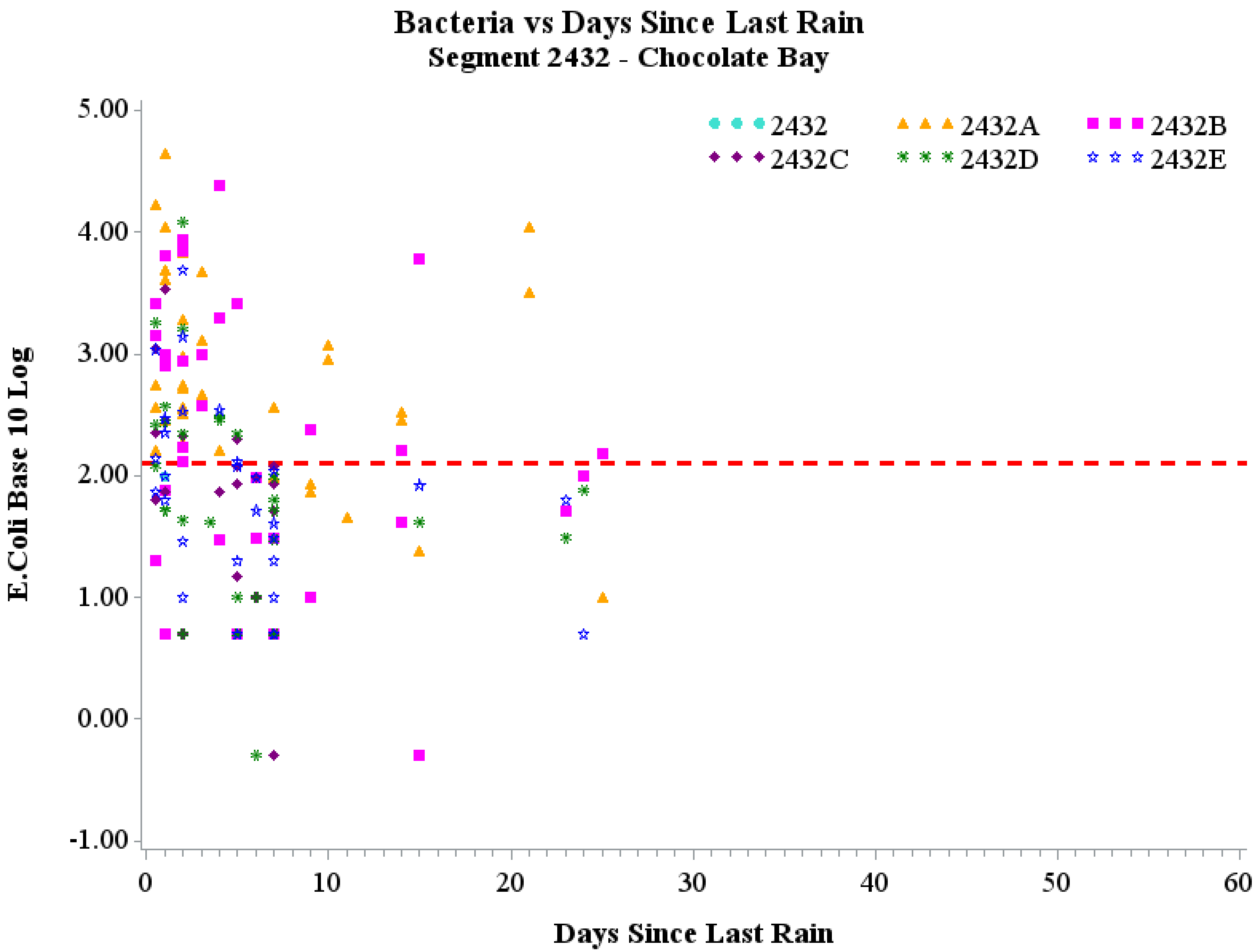
Load Duration Curves

Available flow data and bacteria date were sufficient to complete an LDC for the three freshwater stations in this segment, stations 11423, 18554 and 18668, on Mustang and Willow bayous. Using the results of the LDC and the Days Since Last Rain, factors affecting bacteria levels in this segment do appear to correlate with potential waste loads from WWTFs and OSSFs. The Load Regression Curve for station 11423 remains above the Single Grab Standard curve till 50 Percent of Days Load Exceeded and does not cross below the Geomean Standard curve till 80 Percent of Days Load Exceeded. The Load Regression Curve for the LDC from the other station on Mustang Bayou, 18554, never crosses either the Single Grab or Geomean Standard curves. It should be noted that this is for a relatively small sample size. Station 18668 on Willow Bayou exhibits a similar Load Regression pattern to that of 11423, where the curve does not fall below the Single Grab Standard curve till 50 Percent of Days Load Exceeded, though it never does fall below the Geomean Standard curve. We expect wastewater treatment and OSSF as likely contributors to bacteria exceedances when the LDC load regression curve is found above the standard during dry and very dry weather conditions, when nonpoint sources are little to non-existent. The Days Since Last Rain for support this as the observed bacteria data past ten days out is can be found above the standard since last recorded rainfall (dashed red line), particularly for 2432A and 2432B, Mustang and Willow Bayou, respectively.


Load Duration Curve *E. coli* - station 11423
Load Regression Curve
Water Quality Standard - Geomean(126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve
E. coli Load (cfu/day)
Flow (cfs)
Percent of Days Load Exceeded
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
100.000
10.000
1.000
0.100
0.010
0.001
0 10 20 30 40 50 60 70 80 90 100


Load Duration Curve E. coli - station 18554
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
E. coli Load (cfu/day)
1000
100
10
1
Flow (cfs)
0
10
20
30
40
50
60
70
80
90
100
Percent of Days Load Exceeded
Load Regression Curve
Water Quality Standard - Geomean (126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow

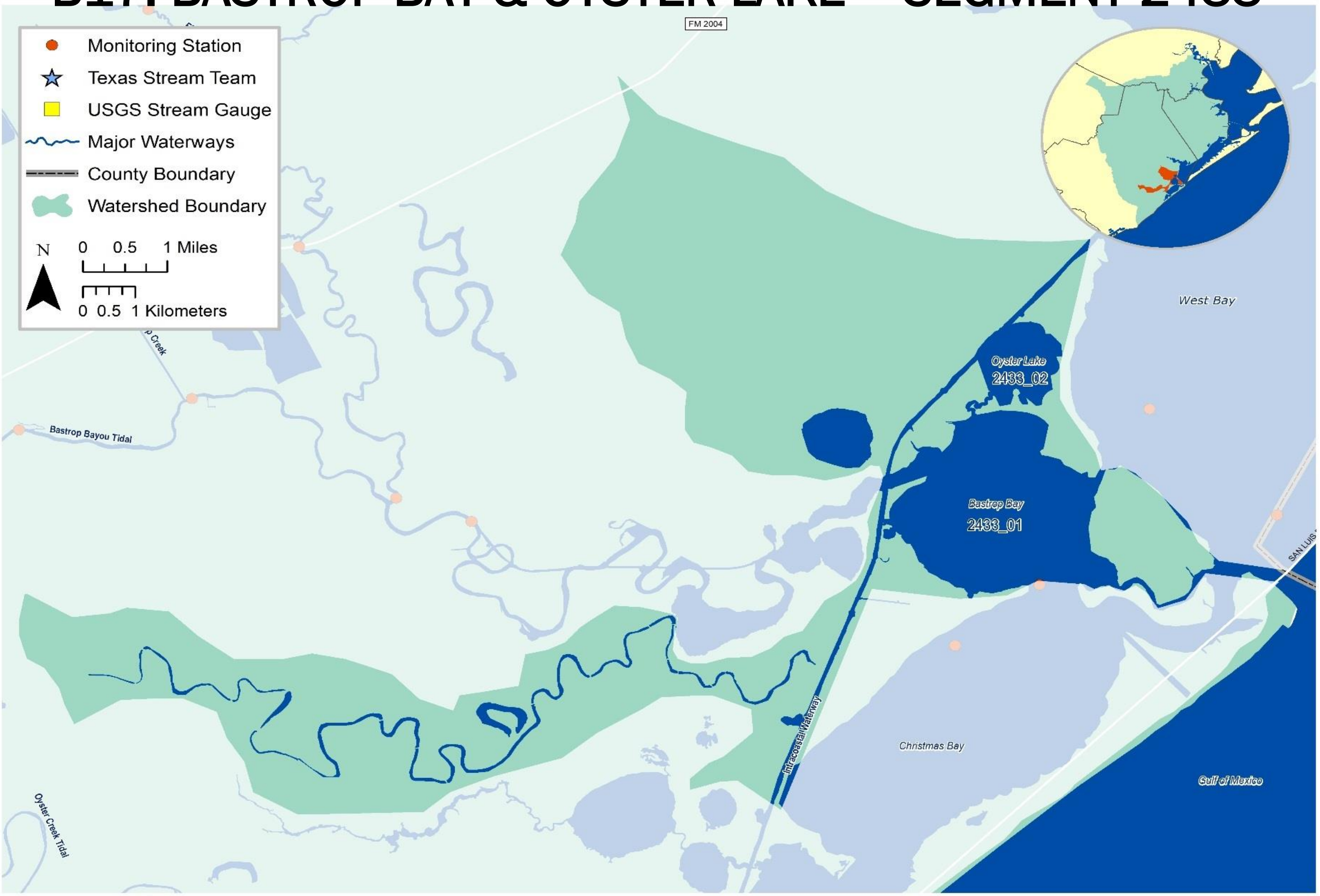

Load Duration Curve E. coli - station 18668
1.0E+14
1.0E+13
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
E. coli Load (cfu/day)
100.00
10.00
1.00
0.10
0.01
Flow (cfs)
0
10
20
30
40
50
60
70
80
90
100
Percent of Days Load Exceeded
Load Regression Curve
Water Quality Standard - Geomean (126 cfu/dL)
Water Quality Standard - Single Sample (399 cfu/dL)
Observed data
Flow Duration Curve
High Flow
Moist Condition
Mid-Range Condition
Dry Condition
Low Flow



Bacteria vs Days Since Last Rain
Segment 2432 - Chocolate Bay
2432
2432A
2432B
2432C
2432D
2432E
E.Coli Base 10 Log
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
0
10
20
30
40
50
60
Days Since Last Rain

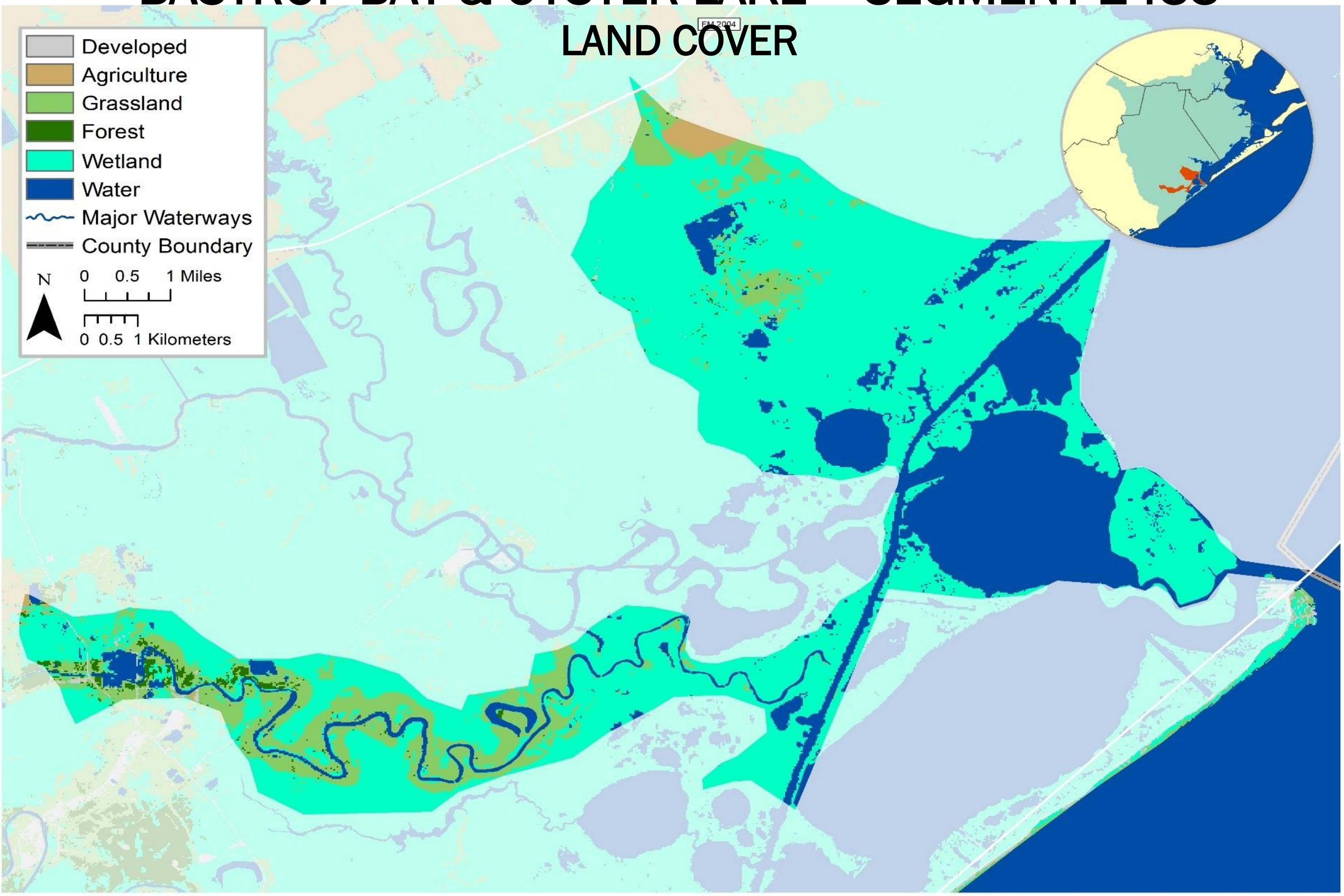
Recommendations
Continue collecting water quality data to support actions associated with any future TMDL I-Plan or watershed protection plan development and possible modeling.
Coordinate education efforts with UGCOWs TMDL Implementation Plan.
Pursue a new local partner to Clean Rivers Program to collect additional data that would help better isolate problem areas. Particularly collect additional ambient data on Mustang Bayou.

B17. BASTROP BAY & OYSTER LAKE – SEGMENT 2433



BASTROP BAY & OYSTER LAKE – SEGMENT 2433

LAND COVER



Segment Number:	2433	Name:	Bastrop Bay / Oyster Lake		
Area:	5 square miles	Miles of Shoreline:	18 miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life Use; Oyster Waters
Number of Active Monitoring Stations:	0	Texas Stream Team Monitors:	0	Permitted Outfalls:	0
Description:	Located immediately west and north of Mud Island at the western end of West Galveston Bay, Bastrop Bay is connected to Oyster Lake via the Gulf Intracoastal Waterway or directly to West Galveston Bay via a cut on the north end of Mud Island in Brazoria County. Assessment Unit 2433OW_01: Bastrop Bay (Oyster Waters) Assessment Unit 2433OW_02: Oyster Lake (Oyster Waters)				

Percent of Stream Impaired or of Concern

Segment ID	PCBs/Dioxin	Bacteria	Dissolved Oxygen	Nutrients	Chlorophyll *a*	Other
2433	-	-	-	-	-	-
2433OW	-	100	-	-	-	-

Segment 2433			
Standards	**Bays & Estuaries**	**Screening Levels**	**Bays & Estuaries**
Temperature (°C/°F):	35 / 95	Ammonia-N (mg/L):	0.10
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	Nitrate-N (mg/L):	0.17
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.19
pH (standard units):	6.5-9.0	Total Phosphorus-P (mg/L):	0.21
Enterococci (MPN/100mL) (grab):	104	Chlorophyll *a* (μg/L):	11.6
Enterococci (MPN/100mL) (geometric mean):	35		
Fecal Coliform in Oyster Waters (CFU/100mL) (median/grab):	14/43		

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Levels of Indicator Bacteria in Oyster Waters	24330 I W	▪ Animal waste from agricultural production, ranchettes and hobby farms ▪ Rapid urbanization and increased impervious cover ▪ Constructed stormwater controls failing ▪ Developments with malfunctioning OSSFs ▪ Improper or no pet waste disposal ▪ Waste haulers illegal discharges/improper disposal ▪ Direct and dry weather discharges	▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Encourage Water Quality Management Plans or similar projects for agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Improve construction oversight to minimize TSS discharges to waterways

		▪ Poorly operated or undersized WWTFs ▪ WWTF non-compliance, overflows, and collection system by-passes	▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education on pet waste disposal ▪ Add water quality features to stormwater systems ▪ Increase monitoring requirements for self-reporting ▪ Regionalize chronically non-compliant WWTFs ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Impose new or stricter bacteria limits than currently designated by TCEQ

Segment Discussion:

Watershed Characteristics: Bastrop Bay and Oyster Lake are surrounded by wetlands, coastal grasslands, and the Brazoria National Wildlife Refuge. There are also islands of forested lands and cultivated areas surrounding the bay. The area is home to many species of birds, fish, crustaceans, mollusks, and seagrass.

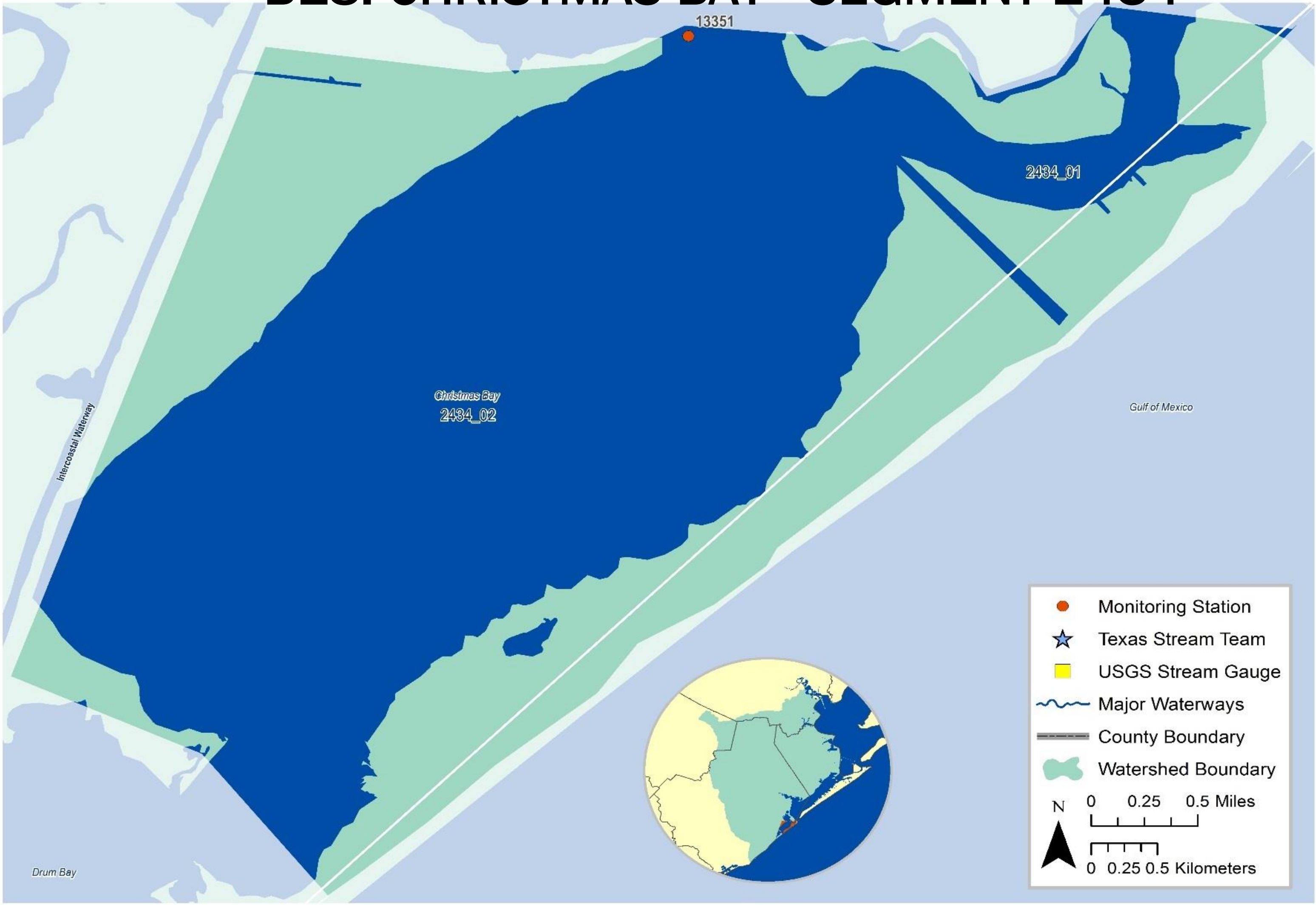
Water Quality Issues: Assessment unit 2433OW_02 Oyster Lake is listed in the 2014 IR as impaired for oyster waters due to elevated levels of fecal coliform bacteria. This assessment unity is closed by the Seafood Safety Division of the Texas Department of State Health Services for the harvesting of oysters and other shellfish for direct marketing. This segment completely supports the primary contact and high aquatic life use designations.

Special Studies/Projects: Bastrop Bay and Oyster Lake are included in the UGCOWs I-Plan for bacteria which began in 2010 after the TMDL was approved by the EPA. The final draft I-Plan was submitted to the TCEQ in August of 2014 and final approval of the draft was given in August of 2015. For more information about this project, please refer to the detailed discussion located in the Public Involvement and Outreach section of the 2016 Basin Summary Report.

Trends: The most recent routine monitoring data in the TCEQ database was collected in 2001. Water quality trends in this watershed were not evaluated.

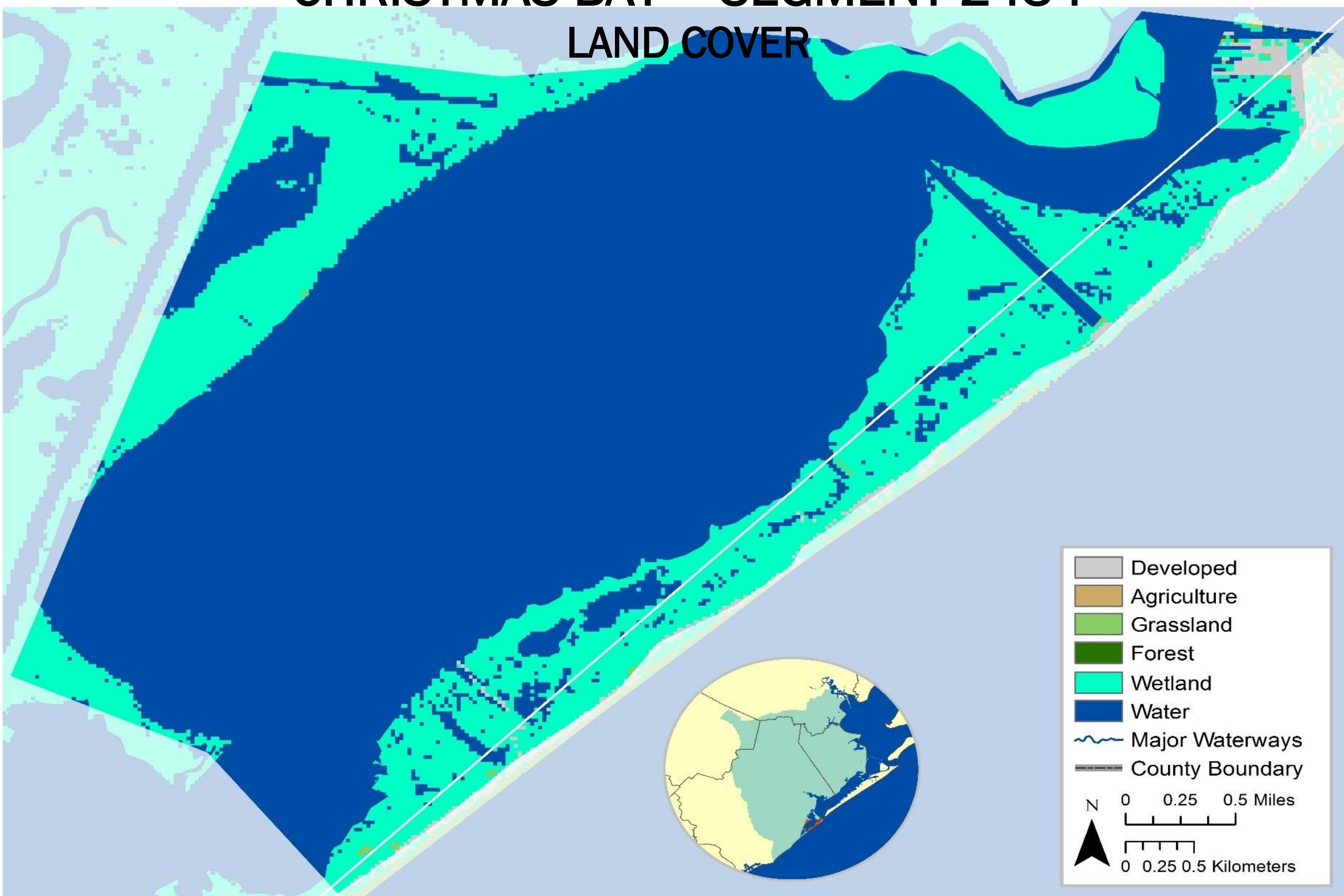
Recommendations
Coordinate education efforts with other local TMDL and watershed protection plan efforts.
Look for a Clean Rivers Program partner to begin routine monitoring at least quarterly since there has been no regular sampling since 2001.

B18. CHRISTMAS BAY - SEGMENT 2434



CHRISTMAS BAY – SEGMENT 2434

LAND COVER



CHRISTMAS BAY – SEGMENT 2434
WASTEWATER OUTFALLS

Segment Number:	2434	Name:	Christmas Bay

Area:	9.3 square miles	Miles of Shoreline:	26.1 miles	Designated Uses:	Primary Contact Recreation 1; High Aquatic Life Use; Oyster Waters
Number of Active Monitoring Stations:	1	Texas Stream Team Monitors:	0	Permitted Outfalls:	0

Description:	Segment 2434: Located on the landward side of Follet's Island in Brazoria County and southwest of Mud Island, it drains into Bastrop Bay to the northeast or directly to West Galveston Bay via a channel on the south side of Mud Island. Segment 2434OW (Oyster Waters)

Percent of Stream Impaired or of Concern

Segment ID	PCBs/Dioxin	Bacteria	Dissolved Oxygen	Nutrients	Chlorophyll *a*	Other
2434	-	-	-	-	-	-
2434OW	-	100	-	-	-	-

Segment 2434

Standards	Bays & Estuaries	Screening Levels	Bays & Estuaries
Temperature (°C/°F):	35 / 95	Ammonia-N (mg/L):	0.10
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	Nitrate-N (mg/L):	0.17
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.19
pH (standard units):	6.5-9.0	Total Phosphorus-P (mg/L):	0.21
Enterococci (MPN/100mL) (grab):	104	Chlorophyll *a* (µg/L):	11.6
Enterococci (MPN/100mL) (geometric mean):	35		
Fecal Coliform in Oyster Waters (CFU/100mL) (median/grab):	14/43		

FY 2016 Active Monitoring Stations

Site ID	Site Description	Frequency	Monitoring Entity	Parameter Groups
13351	Christmas Bay at Christmas Pt	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Levels of Indicator Bacteria in Oyster Waters	24340 I W	▪ Animal waste from cattle grazing ▪ Developments with malfunctioning OSSFs ▪ Year-round and migratory bird populations ▪ Improper or no pet waste disposal ▪ Waste haulers illegal discharges/improper disposal ▪ Direct and dry weather discharges	▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Encourage Water Quality Management Plans or similar projects for agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems ▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education on pet waste disposal ▪ Regionalize chronically non-compliant WWTFs

Segment Discussion:

Watershed Characteristics: Christmas Bay is surrounded by herbaceous wetlands and is bordered by Mud Island and Follets Island, a barrier island, to the southwest. To the northwest the Bay is bordered by the Brazoria National Wildlife Refuge. Christmas Bay is isolated from the other surrounding Bays with no direct access to the Intracoastal Waterway. Christmas Bay is a Coastal Preserve and is part of the Texas General Land Office/Texas Parks and Wildlife Department Coastal Preserves Program. The Bay is one of the most pristine areas in the Galveston Bay system and is home to numerous species of birds, fish, crustaceans, mollusks, and several species of seagrass. While isolated from most development, there are two canal communities on Follets Island which drain directly to the bay. These communities exclusively use OSSFs.

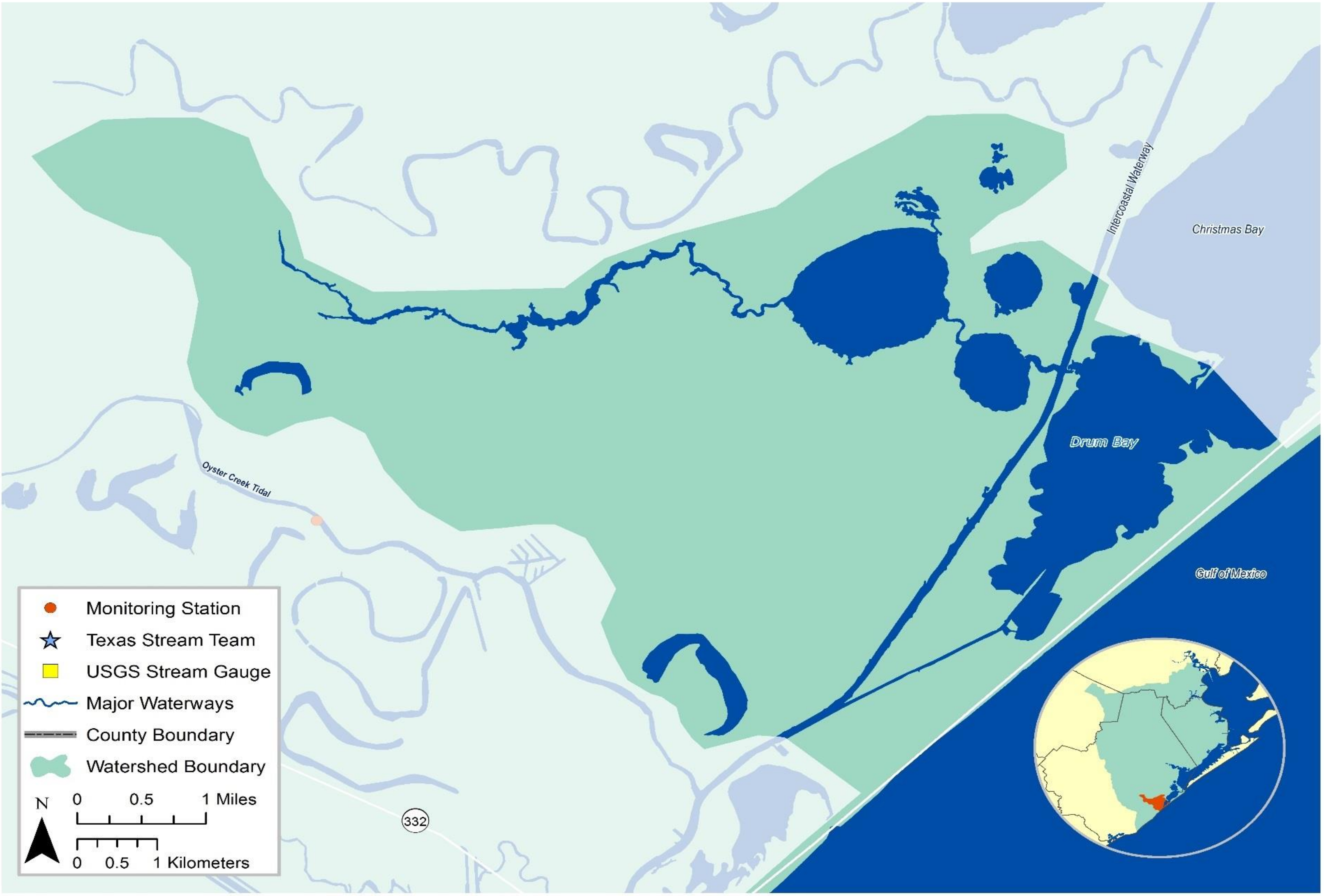
Water Quality Issues: Assessment unit 2434OW_01, which is the area of Christmas Bay adjacent to West Bay, is listed in the 2014 IR as impaired for oyster waters due to elevated levels of fecal coliform bacteria. This assessment unity is closed by the Seafood Safety Division of the Texas Department of State Health Services for the harvesting of oysters and other shellfish for direct marketing. This segment fully supports the primary contact and high aquatic life use designations.

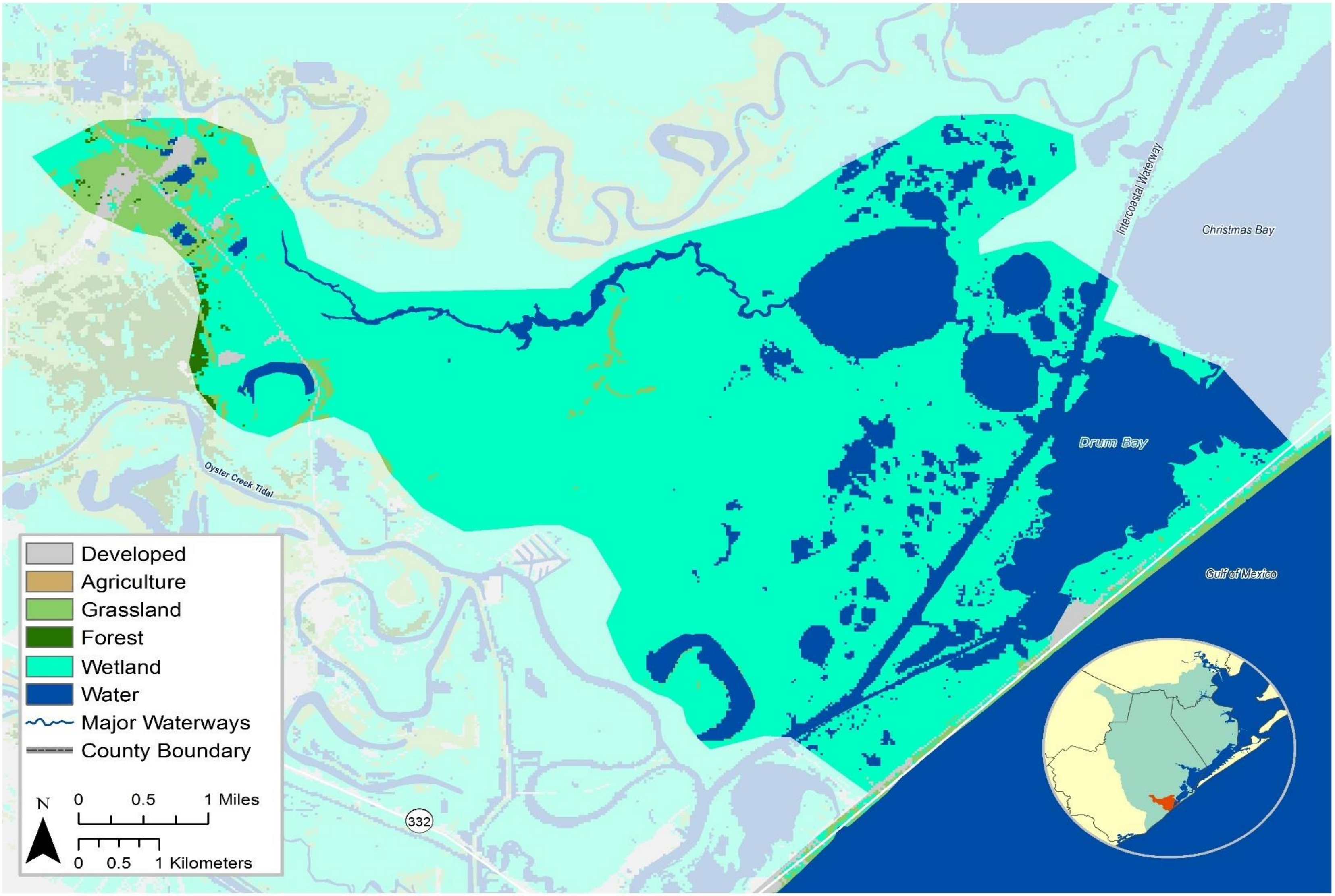
Special Studies/Projects: Christmas Bay is included in the UGCOWs I-Plan for bacteria which began in 2010 after the TMDL was approved by the EPA. The final draft I-Plan was submitted to the TCEQ in August of 2014 and final approval of the draft was given in August of 2015. For more information about the project, please refer to the detailed discussion located in the Public Involvement and Outreach section of the 2016 Basin Summary Report.

Trends: Regression analysis of water quality data for Christmas Bay identified two statistically significant parameter trends – increasing pH and decreasing total Kjeldahl nitrogen (TKN). The only impairment listed in the 2014 Texas Integrated Report for this segment is for elevated levels of fecal coliform bacteria in oyster waters. The clean rivers program does not collect fecal coliform data, but regression analysis of enterococci shows healthy concentrations that remain consistently below the 35 MPN/100 mL water quality standard during the period of record which supports this segments primary contact recreation and high aquatic life use designations.

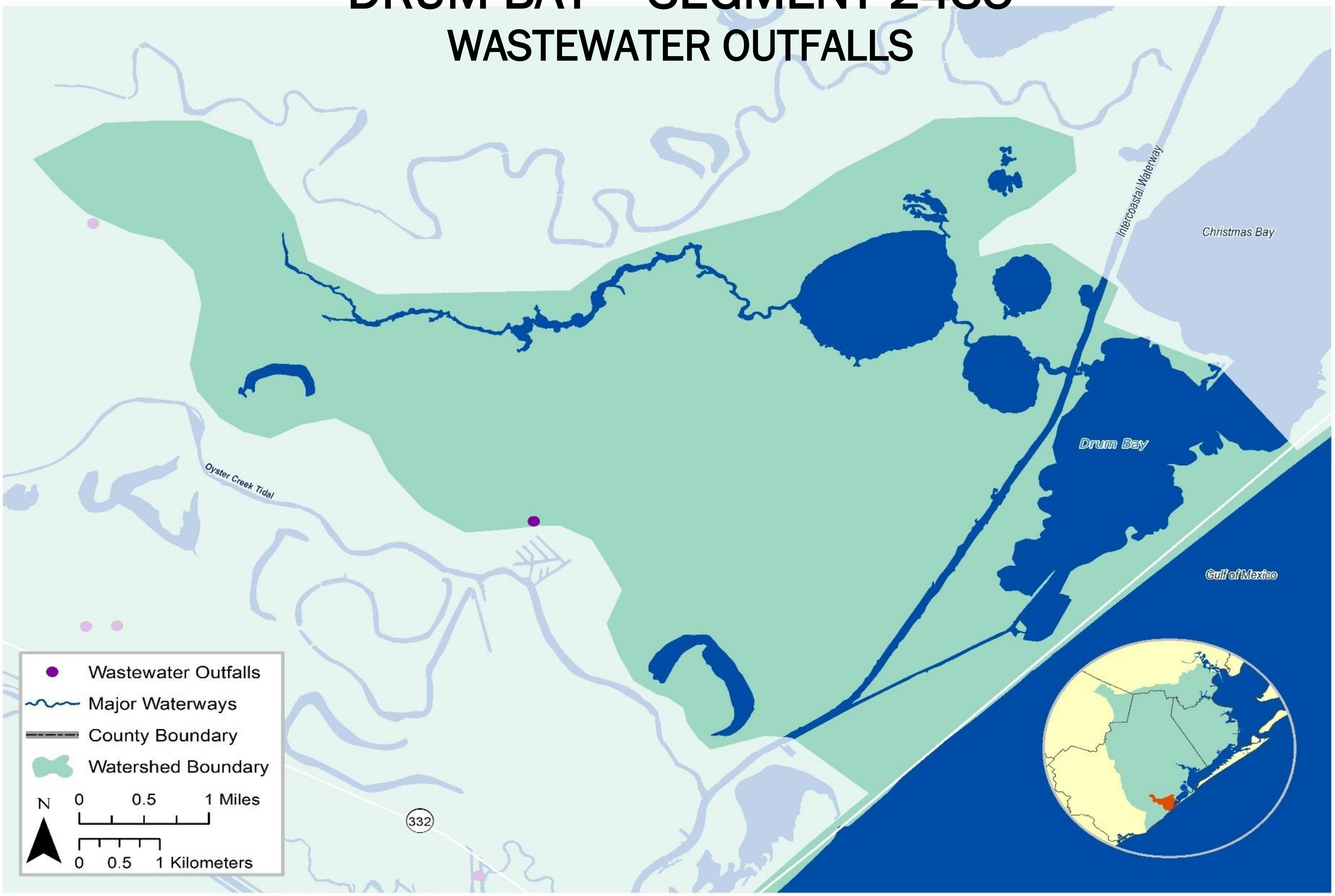
Recommendations
Continue collecting water quality data to support actions associated with any future watershed protection plan development and possible modeling.
Coordinate education efforts with other local TMDL and watershed protection plan efforts.
Pursue a new local partner to Clean Rivers Program to collect additional data that would help better isolate problem areas.

B19. DRUM BAY - SEGMENT 2435




Intercoastal Waterway
Christmas Bay
Drum Bay
Gulf of Mexico
Oyster Creek Tidal
332
Developed
Agriculture
Grassland
Forest
Wetland
Water
Major Waterways
County Boundary
N
0 0.5 1 Miles
0 0.5 1 Kilometers

DRUM BAY – SEGMENT 2435
WASTEWATER OUTFALLS



Segment Number:	2435	Name:	Drum Bay		
Area: 2 square miles	**Miles of Shoreline:**	12.2 miles	**Designated Uses:**	Primary Contact Recreation 1; High Aquatic Life Use; Oyster Waters	
Number of Active Monitoring Stations:	0	**Texas Stream Team Monitors:**	0	**Permitted Outfalls:**	0
Description:	Segment 2435: Located on the landward side of Follet's Island in Brazoria County extending southwest from the confluence with Christmas Bay, it is connected to the Gulf Intracoastal Waterway via a cut on the far western end and via a cut from the north called Nick's Cut. Segment 2435OW (Oyster Waters)				

Percent of Stream Impaired or of Concern						
Segment ID	**PCBs/Dioxin**	**Bacteria**	**Dissolved Oxygen**	**Nutrients**	**Chlorophyll *a***	**Other**
2435	-	-	-	-	-	-
2435OW	-	100	-	-	-	-

Segment 2435

Standards	Bays & Estuaries	Screening Levels	Bays & Estuaries
Temperature (°C/°F):	35 / 95	Ammonia-N (mg/L):	0.10
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	Nitrate-N (mg/L):	0.17
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.19
pH (standard units):	6.5-9.0	Total Phosphorus-P (mg/L):	0.21
Enterococci (MPN/100mL) (grab):	104	Chlorophyll *a* (µg/L):	11.6
Enterococci (MPN/100mL) (geometric mean):	35		

Water Quality Issues Summary

Issue	2014 Assessment	Possible Causes / Influences / Concerns Voiced by Stakeholders	Possible Solutions / Actions To Be Taken
Elevated Levels of Indicator Bacteria in Oyster Waters	24340 I W	▪ Animal waste from cattle grazing ▪ Developments with malfunctioning OSSFs ▪ Year-round and migratory bird populations ▪ Improper or no pet waste disposal ▪ Waste haulers illegal discharges/improper disposal ▪ Direct and dry weather discharges ▪ Poorly operated or undersized WWTFs	▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Encourage Water Quality Management Plans or similar projects for agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems

			▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education on pet waste disposal ▪ Regionalize chronically non-compliant WWTFs

Segment Discussion:

Watershed Characteristics: Drum Bay is located on the landward side of Follet's Island in Brazoria County and extends southwest from its confluence with Christmas Bay. It is connected to the Gulf Intracoastal Waterway via a cut on the far western end and on the north shore via two shallow washovers. The area is surrounded by herbaceous wetlands and by the Brazoria National Wildlife Refuge.

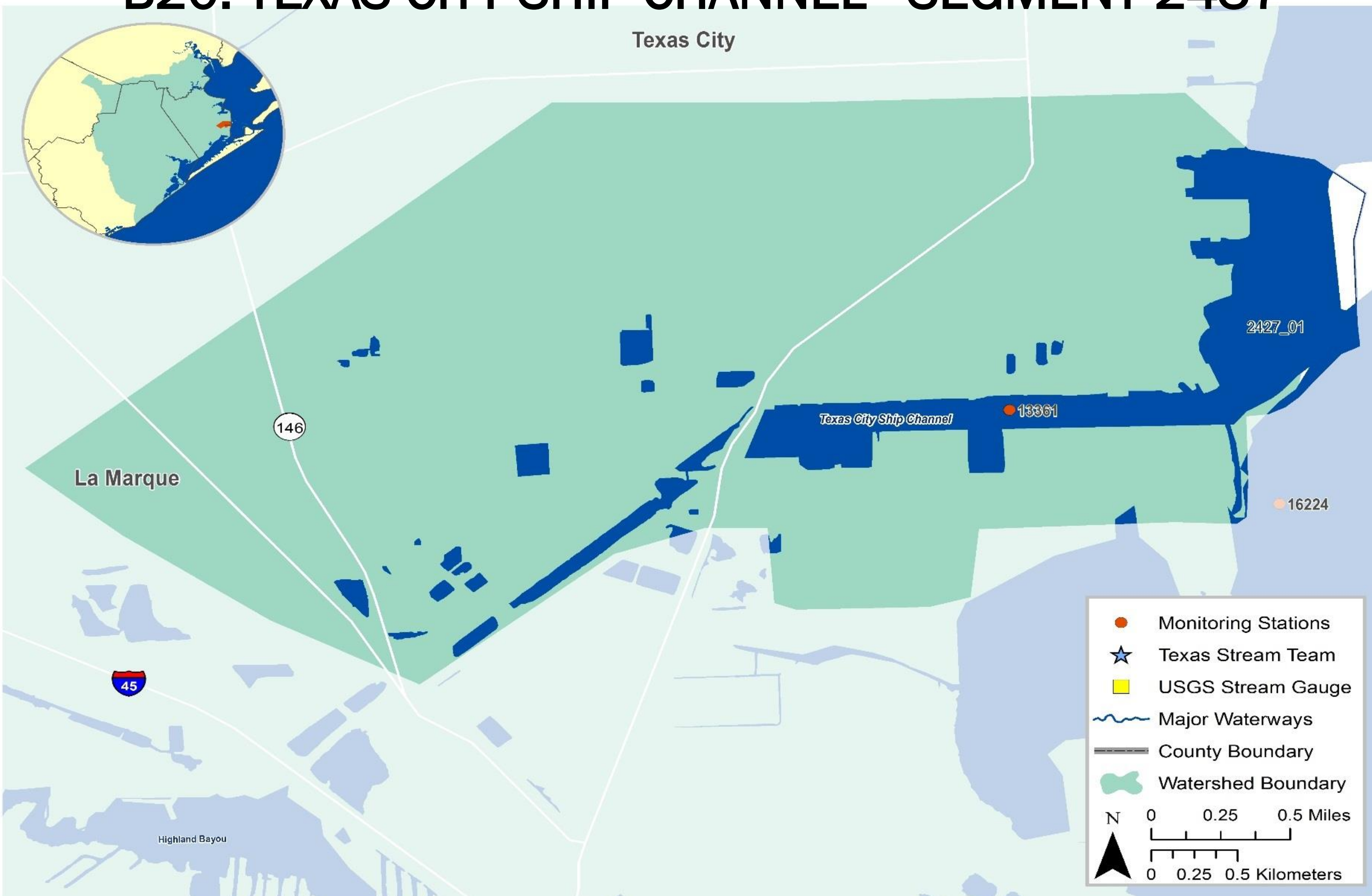
Water Quality Issues: Assessment unit 2435OW_01, which is the area of the bay adjacent to Christmas Bay, is listed in the 2014 IR as impaired for oyster waters due to elevated levels of fecal coliform bacteria. This area is closed by the Seafood Safety Division of the Texas Department of State Health Services for the harvesting of oysters and other shellfish for direct marketing. This segment fully supports the primary contact and high aquatic life use designations.

Special Studies/Projects: Drum Bay is included in the UGCOWs I-Plan for bacteria which began in 2010 after the TMDL was approved by the EPA. The final draft I-Plan was submitted to the TCEQ in August of 2014 and final approval of the draft was given in August of 2015. For more information about the project, please refer to the detailed discussion located in the Public Involvement and Outreach section of the 2016 Basin Summary Report.

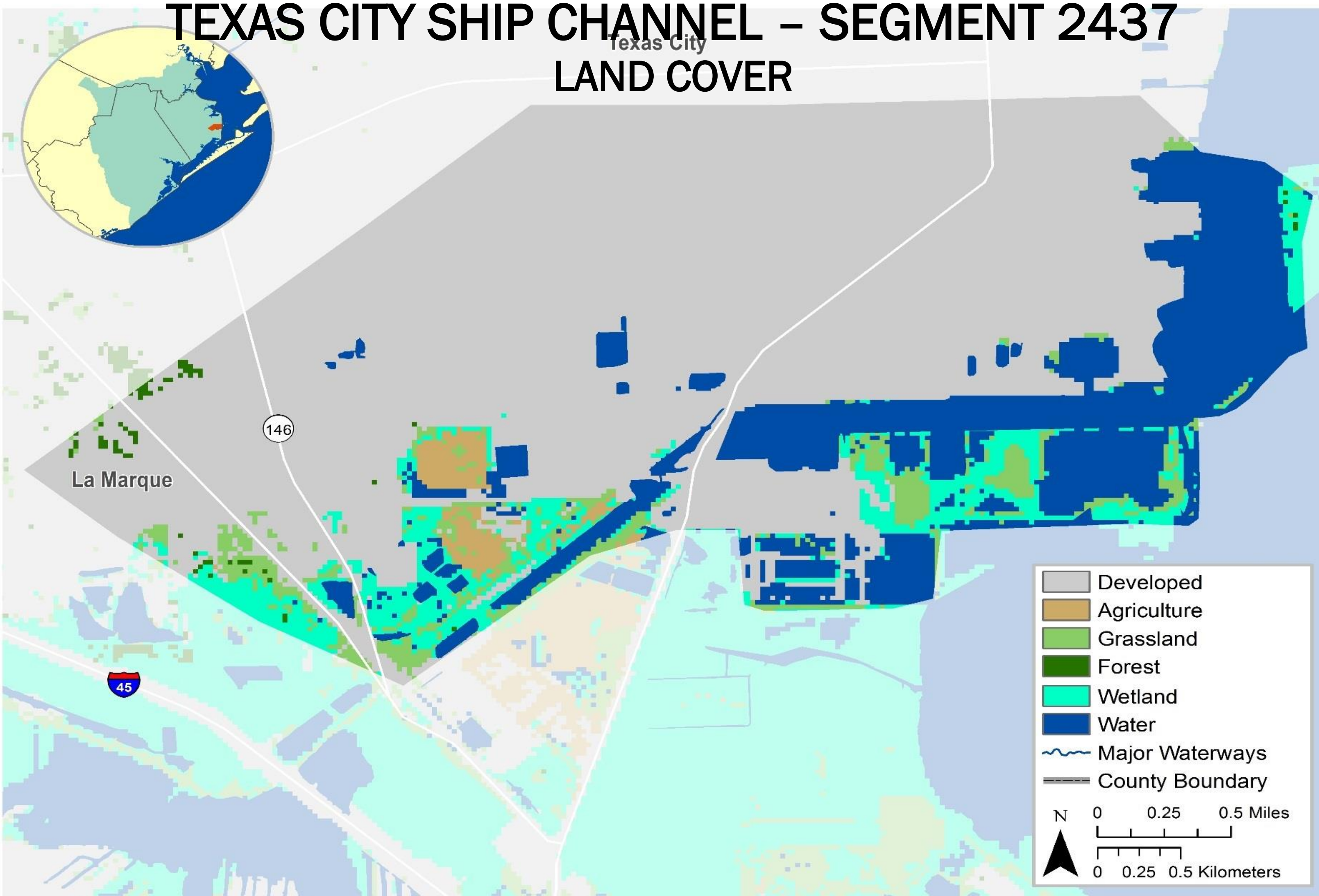
Trends: The most recent routine monitoring data in the TCEQ database was collected in 2001. Water quality trends in this watershed were not evaluated.

Recommendations
Coordinate education efforts with other local TMDL and watershed protection plan efforts.
Look for a Clean Rivers Program partner to begin routine monitoring at least in Nick's Cut since there has been no regular sampling since 2001.

B20. TEXAS CITY SHIP CHANNEL - SEGMENT 2437

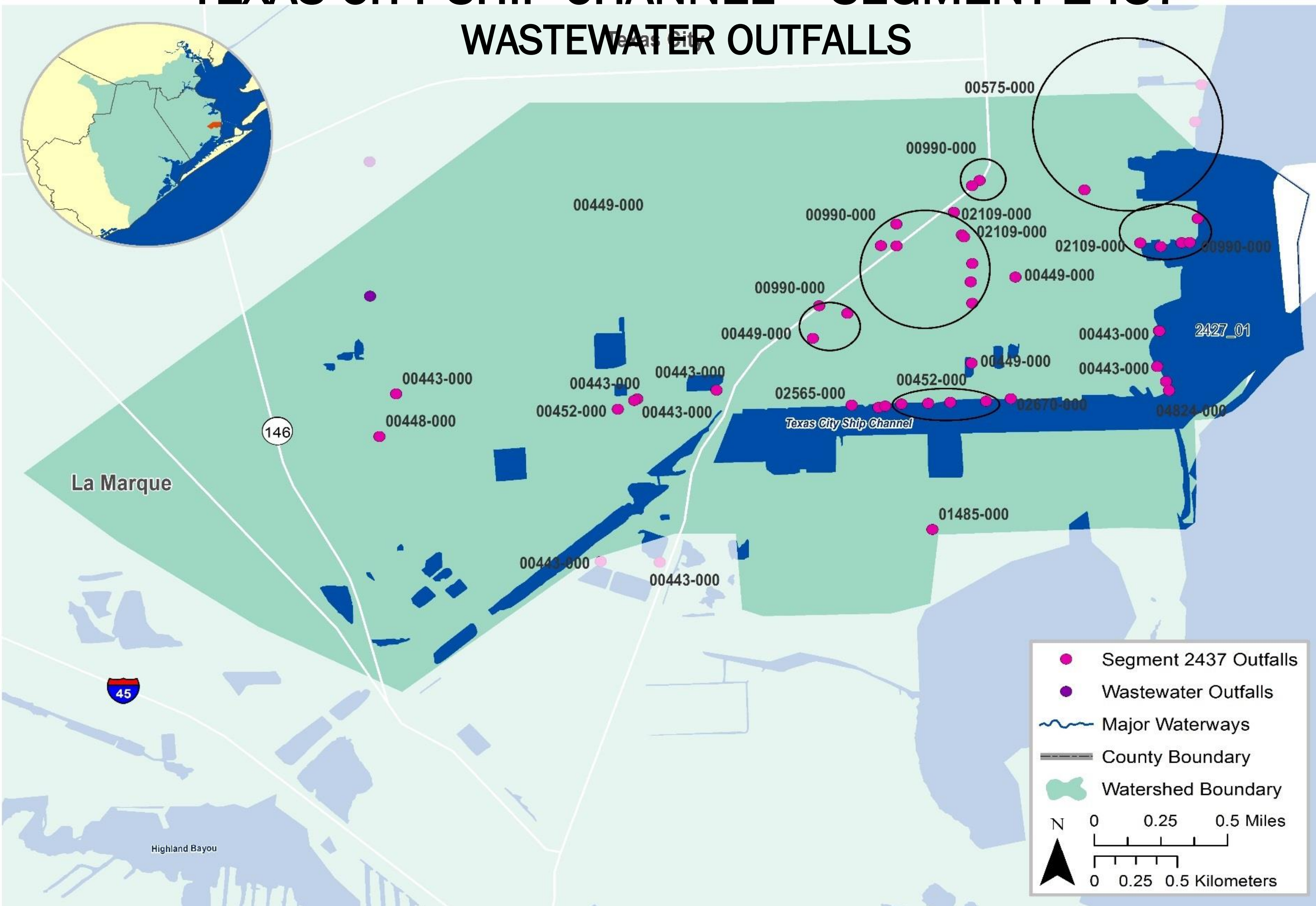


TEXAS CITY SHIP CHANNEL – SEGMENT 2437
LAND COVER



TEXAS CITY SHIP CHANNEL – SEGMENT 2437

WASTEWATER OUTFALLS



Segment Number:	2437	Name:	Texas City Ship Channel

Area:	0.7 square miles	Miles of Shoreline:	9 miles	Designated Uses:	Noncontact Recreation; High Aquatic Life
Number of Active Monitoring Stations:	1	Texas Stream Team Monitors:	0	Permitted Outfalls:	44

Description:	A 1.6 square kilometer (0.6 square mile) navigation channel immediately south of the Texas City Dike on the western shore of Lower Galveston Bay in Galveston

Percent of Stream Impaired or of Concern

Segment ID	PCBs/Dioxin	Bacteria	Dissolved Oxygen	Nutrients	Chlorophyll *a*	Other
2437	100	-	-	100	100	-

Segment 2437

Standards	Bays & Estuaries	Screening Levels	Bays & Estuaries
Temperature (°C/°F):	35 / 95	Ammonia-N (mg/L):	0.10
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	Nitrate-N (mg/L):	0.17
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.19
pH (standard units):	6.5-9.0	Total Phosphorus-P (mg/L):	0.21
Enterococci (MPN/100mL) (grab):	104	Chlorophyll *a* (µg/L):	11.6
Enterococci (MPN/100mL) (geometric mean):	35		

FY 2016 Active Monitoring Stations				
Site ID	**Site Description**	**Frequency**	**Monitoring Entity**	**Parameter Groups**
13361	TSCS Texas City Canal Midpoint	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
13361	TSCS Texas City Canal Midpoint	Once / Year	TCEQ	Metals & Organics in Sediment

Water Quality Issues Summary				
Issue	**2014 Assessment** *I – Impaired* *C - Of Concern*		**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Nutrients	2437	C	▪ Fertilizer runoff from urbanized properties, such as landscaped areas, residential lawns, and sport fields ▪ Nutrient loading from WWTF effluent, sanitary sewer overflows, and malfunctioning OSSFs	▪ Implement YardWise and Watersmart landscape practices ▪ Encourage Water Quality Management Plans or similar projects for agricultural properties ▪ Monitor phosphorus levels at WWTFs to determine if controls are needed
Elevated Chlorophyll *a* Concentrations	2437	C	▪ Excess nutrients from residential lawns ▪ Fertilizer runoff from surrounding watershed promote algal growth in waterways ▪ Nutrient loading from WWTF effluent, sanitary sewer overflows, and malfunctioning OSSFs promotes algal growth	▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Add water quality features to stormwater systems ▪ Educate residents about excessive fertilizer use ▪ Reduce or manage fertilizer runoff from agricultural areas ▪ More public education regarding nutrients
PCBs/Dioxin in Edible Fish Tissue	2437	I	▪ Concentrated deposits outside boundaries of the waste pits located adjacent to San Jacinto River and I-10 bridge	▪ Remove or contain contamination from locations already identified

		▪ Unknown industrial or urban sources	▪ Encourage additional testing to locate all unknown sources/deposits

Segment Discussion:

Watershed Characteristics: The Texas City petrochemical complex makes up the majority this watershed. Texas City Ship Channel supports heavy barge and ship traffic on a regular basis with docks used to load and unload raw materials and finished products occupying the entire north shoreline and area around the turning basin. An off-plant disposal area (OPDA) is situated on the south shore leaving only portions of Shoal Point/Snake Island, a dredge spoil disposal area, undeveloped. A small residential and commercial area of the City of La Marque located in the western portion of the watershed drains stormwater into the channel via the Industrial Canal. The ship channel receives stormwater and wastewater discharges from the industrial complex.

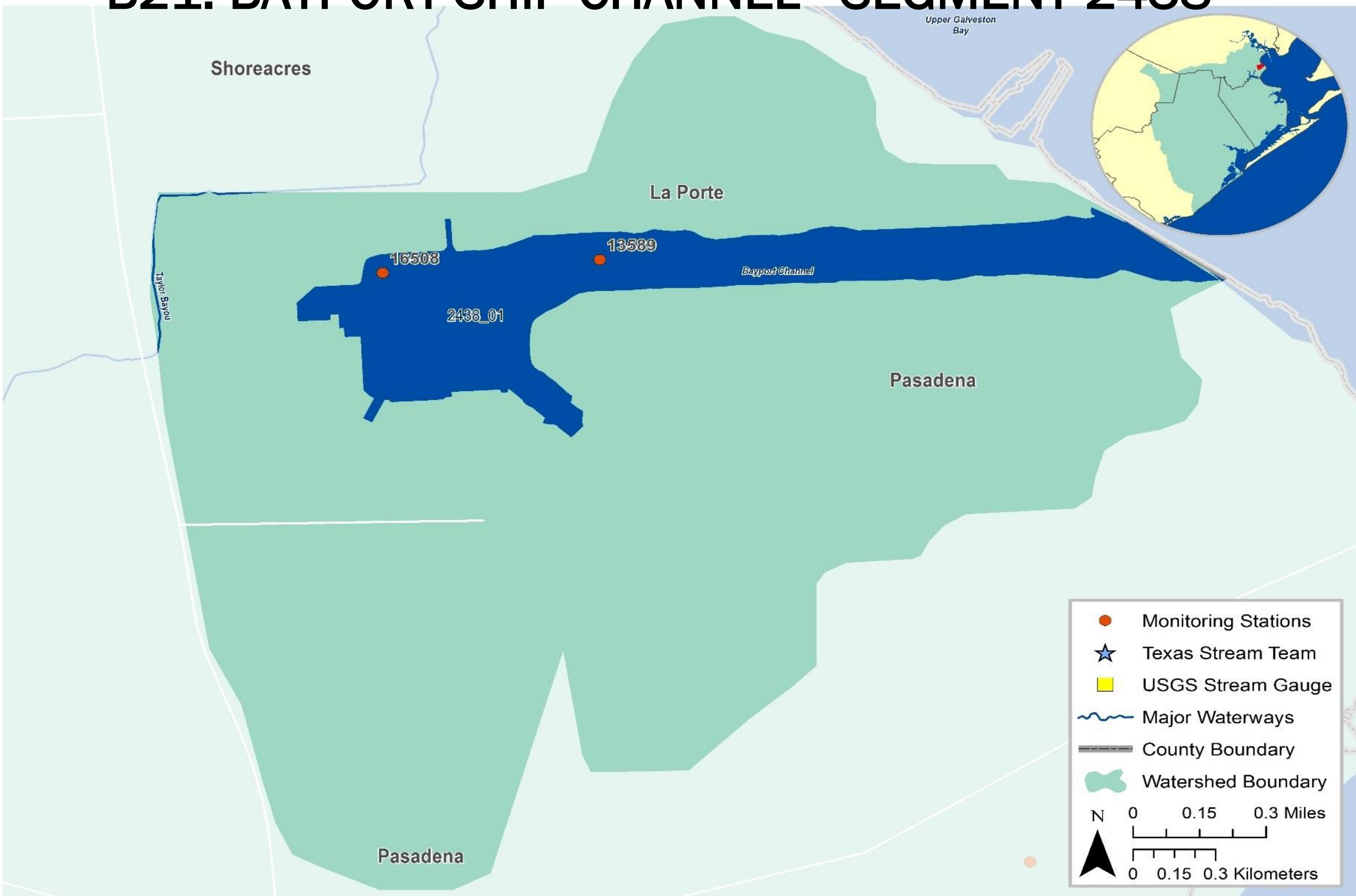
Water Quality Issues: Segment 2437 is impaired for fish consumption due to high levels of PCBs and dioxin found in edible fish tissue. The Texas Department of State Health Services has issued a Limited Consumption Fish Advisory for this segment. The 2014 IR lists the Texas City Ship Channel as having concerns for water quality screening levels for ammonia nitrogen, nitrate nitrogen, and chlorophyll a. Over 44 percent of ammonia nitrogen samples exceeded the screening criteria level of 0.10 mg/L, 36 percent of nitrate nitrogen samples exceeded the screening criteria level of 0.17 mg/L, and 36% of chlorophyll *a* samples exceeded the screening criteria level of 11.6 micrograms/L.

Special Studies/Projects: This segment is included in one TMDL project, the Galveston Bay System Survey for Dioxin and PCBs, which is currently under way. For more information, please refer to the detailed discussions located in the Public Involvement and Outreach section of the 2016 Basin Summary Report regarding dioxin and PCB TMDLs.

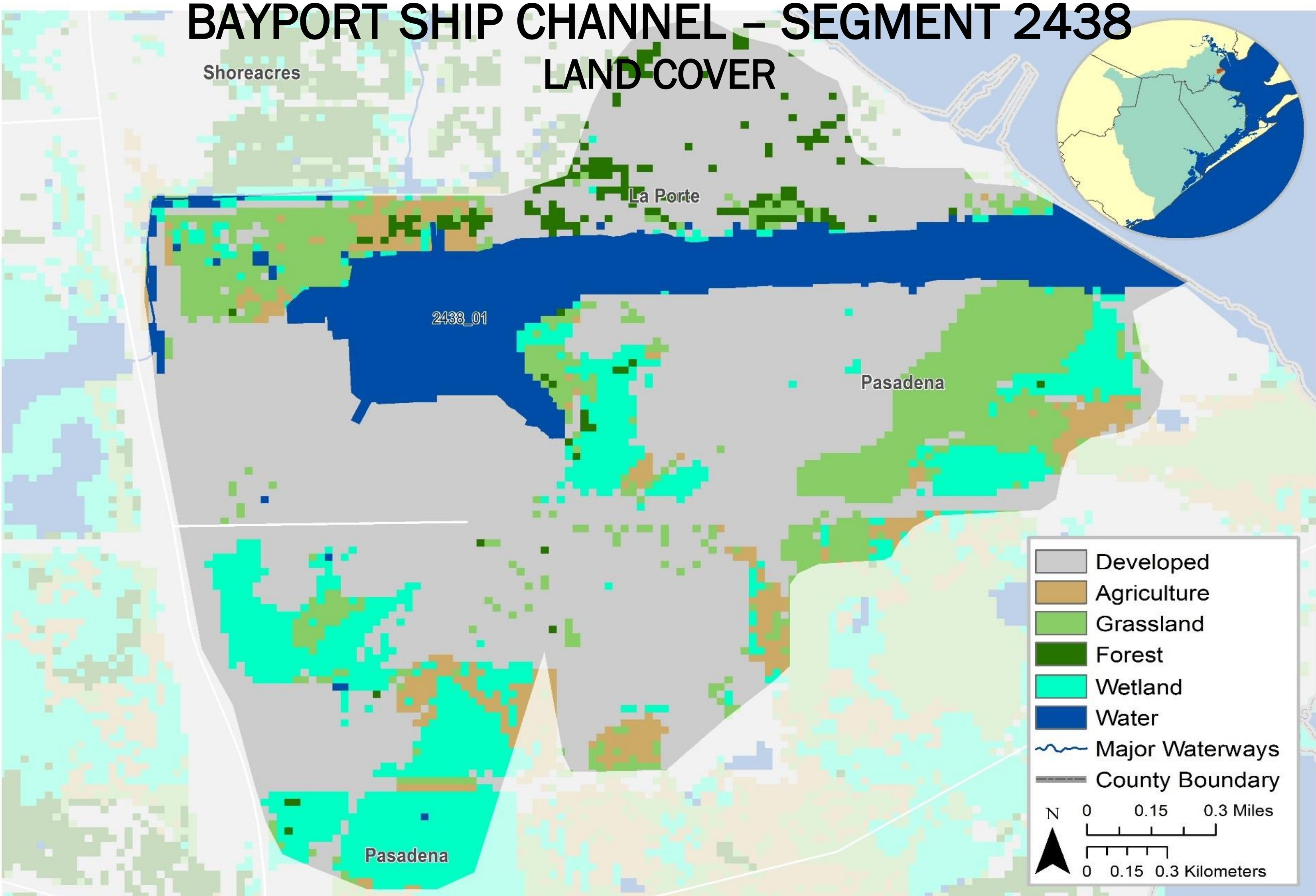
Trends: Regression analysis of water quality data for the Texas City Ship Channel watershed revealed six statistically significant parameter trends including increasing sulfate, enterococci, and chloride while total phosphorous (TP), total Kjeldahl nitrogen (TKN), and Secchi transparency are decreasing over time. The 2014 Texas Integrated Report lists this segment as having a concern for elevated nutrient levels. Concentrations of TP seem to be improving while nitrate levels have remained relatively stable since 2000. However, nutrient levels exceeding the recommended screening criteria continue to occur on an infrequent basis. Chlorophyll *a* levels also revealed a stable trend over time with nearly half of the samples collected since 2000 exceeding the 11.6 µg/L screening criteria.

Recommendations
Address concerns found in this segment summary through stakeholder participation.
Continue collecting water quality data to support actions associated with any future watershed protection plan development and possible modeling.
Pursue a new local partner to Clean Rivers Program to collect additional data that would help better isolate problem areas.

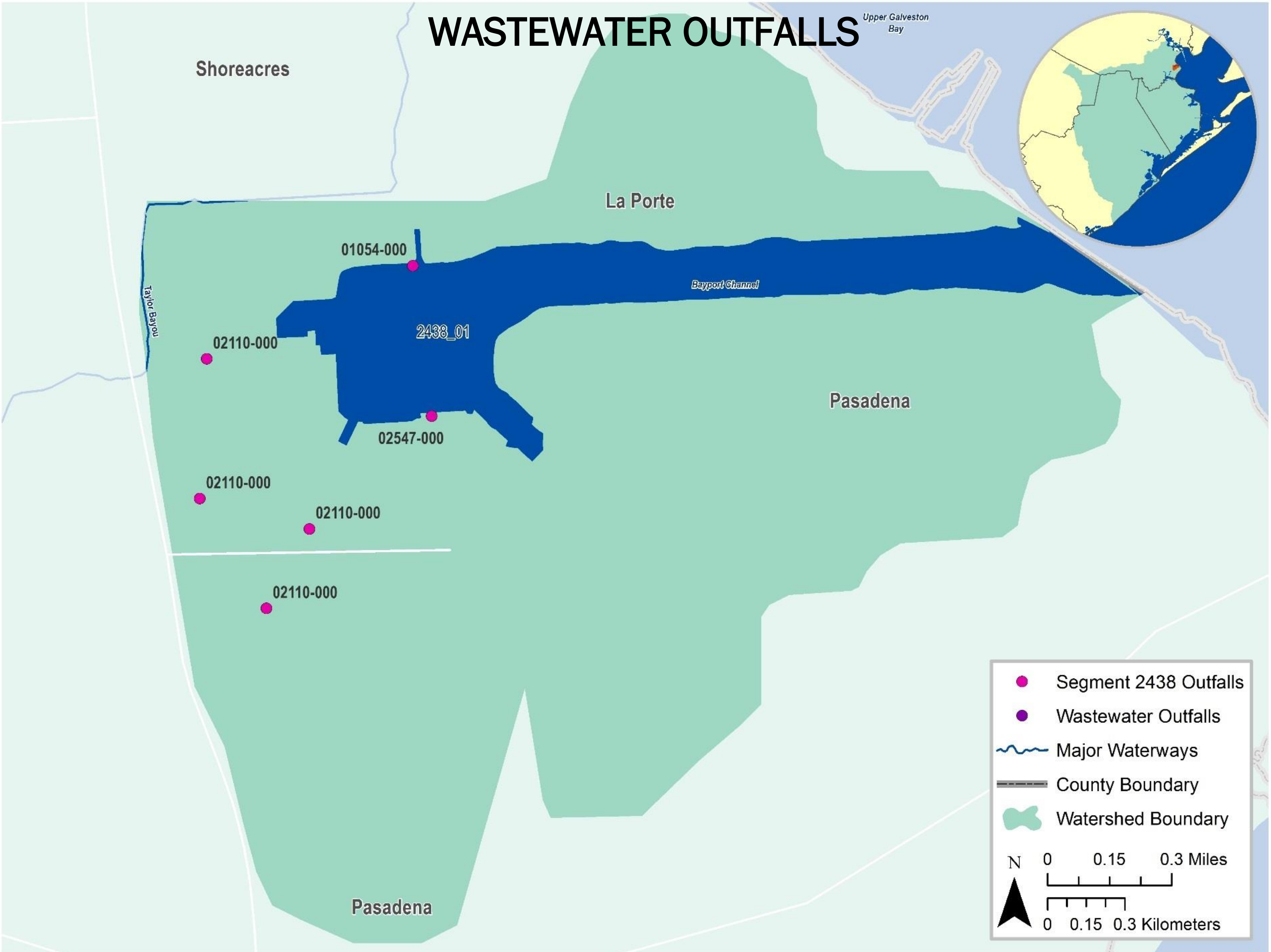
B21. BAYPORT SHIP CHANNEL - SEGMENT 2438



BAYPORT SHIP CHANNEL – SEGMENT 2438
LAND COVER



BAYPORT SHIP CHANNEL – SEGMENT 2438
WASTEWATER OUTFALLS



Segment Number:	2438	Name:	Bayport Ship Channel

Length:	0.3 square miles	Miles of Shoreline:	5 miles	Designated Uses:	Noncontact Recreation; High Aquatic Life Use
Number of Active Monitoring Stations:	2	Texas Stream Team Monitors:	0	Permitted Outfalls:	6

Description:	Located on the western shore of Upper Galveston Bay from confluence with Galveston Bay extending west approximately 2 miles to the terminus in the turning basin immediately south of the Cities of La Porte and Shoreacres.

Percent of Stream Impaired or of Concern

Segment ID	PCBs/Dioxin	Bacteria	Dissolved Oxygen	Nutrients	Chlorophyll *a*	Other
2438	100	-	100	100	100	-

Segment 2438

Standards	Bays & Estuaries	Screening Levels	Bays & Estuaries
Temperature (°C/°F):	35 / 95	Ammonia-N (mg/L):	0.10
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	Nitrate-N (mg/L):	0.17
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.19
pH (standard units):	6.5-9.0	Total Phosphorus-P (mg/L):	0.21
Enterococci (MPN/100mL) (grab):	104	Chlorophyll *a* (µg/L):	11.6
Enterococci (MPN/100mL) (geometric mean):	35		

FY 2016 Active Monitoring Stations				
Site ID	**Site Description**	**Frequency**	**Monitoring Entity**	**Parameter Groups**
13589	Bayport Channel at Turning Basin	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
13589	Bayport Channel at Turning Basin	Twice / Year	TCEQ	Metals in Water
13589	Bayport Channel at Turning Basin	Once / Year	TCEQ	Metals in Sediments, Organics in Sediment
16508	Bayport Channel near 98GB015	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*, Metals

Water Quality Issues Summary			
Issue	**2014 Assessment** *I – Impaired* *C – Of Concern*	**Possible Causes / Influences / Concerns Voiced by Stakeholders**	**Possible Solutions / Actions To Be Taken**
Elevated Nutrients	2438 C	▪ Fertilizer runoff from urbanized properties, such as landscaped areas, residential lawns, and sport fields ▪ Nutrient loading from WWTF effluent, sanitary sewer overflows, and malfunctioning OSSFs	▪ Implement YardWise and Watersmart landscape practices ▪ Monitor phosphorus levels at WWTFs to determine if controls are needed
Elevated Chlorophyll *a* Concentrations	2438 C	▪ Excess nutrients from residential lawns ▪ Fertilizer runoff from surrounding watershed promotes algal growth in waterways ▪ Nutrient loading from WWTF effluent, sanitary sewer overflows, and malfunctioning OSSFs promotes algal growth	▪ Educate residents about excessive fertilizer use ▪ Reduce or manage fertilizer runoff from agricultural areas ▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Add water quality features to stormwater systems ▪ More public education regarding nutrients
Dissolved Oxygen Concentrations	2438 C	▪ Excessive nutrients from domestic lawn fertilizers ▪ Excessive nutrients and organic matter from WWTF effluent, SSOs, malfunctioning OSSFs, illegal disposal of grease trap waste,	▪ More public education regarding fertilizer use ▪ Improve compliance and enforcement of existing stormwater quality permits ▪ Encourage Water Quality Management Plans or similar projects for agricultural properties

		and biodegradable solid waste (e.g., grass clippings and pet waste) ▪ High temperature discharges from industrial WWTFs ▪ Vegetative canopy removed	▪ Install and/or maintain riparian buffer areas between agricultural fields and waterways ▪ More public education on pet waste disposal ▪ More public education regarding OSSF operation and maintenance ▪ More public education regarding disposal of household fats, oils, and grease ▪ Improve operation and maintenance of existing WWTF and collection systems ▪ Regionalize chronically non-compliant WWTFs ▪ Conserve or restore trees and habitat along waterways to maintain/create shade to cool water ▪ Work with drainage districts and agencies to change practices of clear cutting and channelizing waterways to protect from solar heating
PCBs/Dioxin in Edible Fish Tissue	2438 I	▪ Concentrated deposits outside boundaries of the waste pits located adjacent to San Jacinto River and I-10 bridge ▪ Unknown industrial or urban sources	▪ Remove or contain contamination from locations already identified ▪ Encourage additional testing to locate all unknown sources/deposits

Segment Discussion:

Watershed Characteristics: This watershed is located on the western shore of Upper Galveston Bay from the confluence with Galveston Bay extending west approximately two miles to the terminus in the turning basin. The Channel is used primarily by barges transporting petrochemical feed stocks and related products. The surrounding watershed is heavily developed with industrial activities and residential and commercial uses. The area just northwest of the Channel has been more heavily developed in the past five years. A cruise ship terminal sits at the mouth of the channel but is considered upper Galveston Bay.

Water Quality Issues: This segment is not supporting its fish consumption use due to high levels of PCBs and dioxin found in edible fish tissue. For this reason, the Texas Department of State Health Services has issued a Limited Consumption Fish Advisory for this water body. The 2014 IR lists this segment as having water quality screening level concerns for the nutrients ammonia nitrogen, nitrate nitrogen, and total phosphorus. Over 50% of samples exceeded the ammonia nitrogen screening criteria level of 0.10 mg/L. This segment is also listed as having a chlorophyll *a* concern with 71% of samples exceeding the screening criteria of 11.6 micrograms per liter. Additionally this segment has a concern for water quality screening levels for dissolved oxygen grab with over 14 percent of measurements lower than the 3.0 minimum.

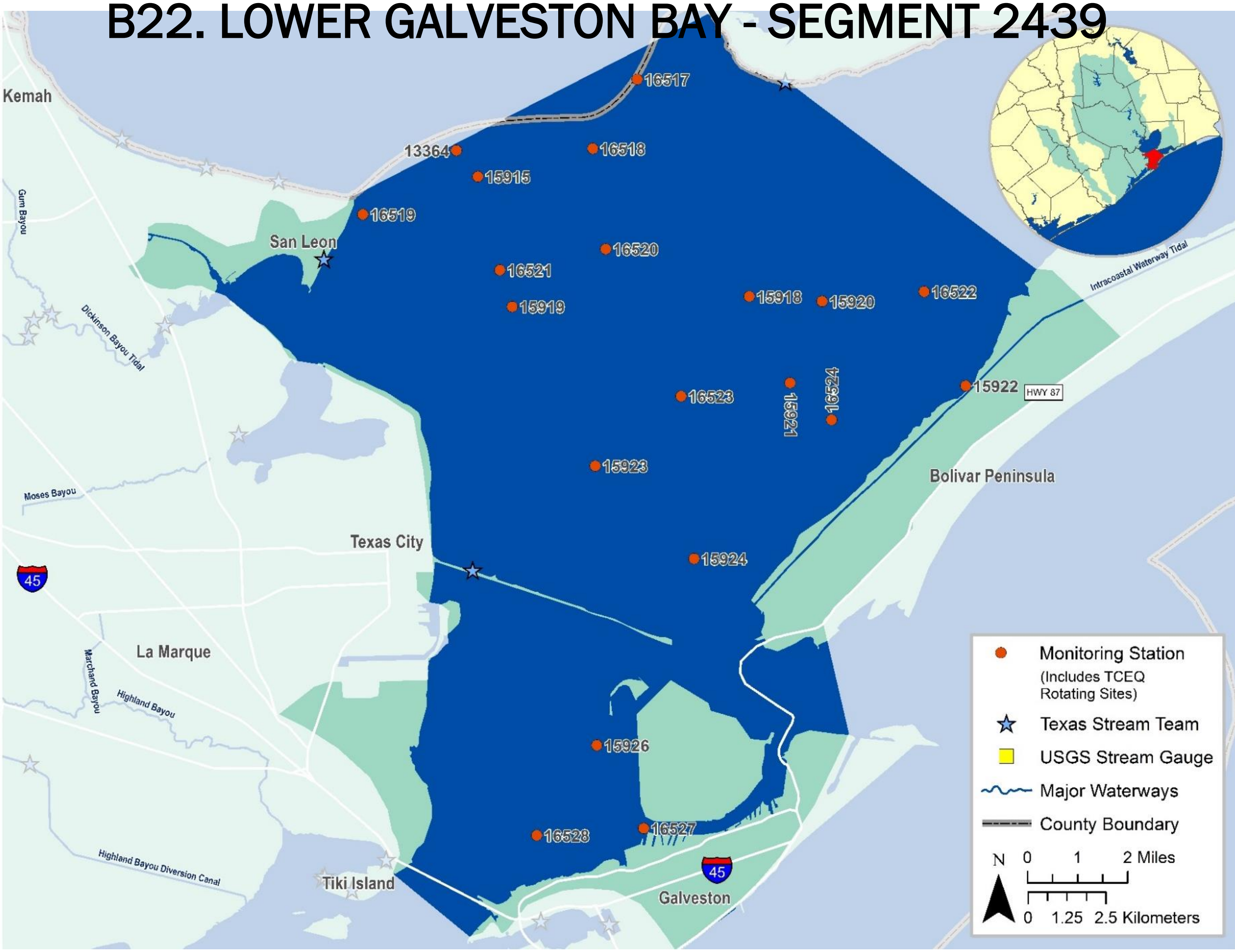
Special Studies/Projects: This segment is included in three TMDL projects: the Houston Ship Channel and Upper Galveston Bay TMDL for PCBs in Fish Tissue, the Houston Ship Channel TMDL for Dioxin, and the Galveston Bay System Survey for Dioxin and PCBs, which are currently under way. For more information, please refer to the detailed discussions located in the Public Involvement and Outreach section of the 2016 Basin Summary Report regarding dioxin and PCB TMDLs.

Trends: Regression analysis of water quality data for the Bayport Ship Channel watershed revealed four statistically significant parameter trends including increasing sulfate, specific conductance (SPCond), and chloride while total Kjeldahl nitrogen (TKN) is decreasing over time. The 2014 Texas Integrated Report lists this segment as having a concern for elevated nutrient levels. Analysis of total phosphorous (TP), nitrate, and ammonia levels revealed relatively stable trends over time with the majority of samples collected during the period of record exceeding the recommended screening criteria for each parameter.

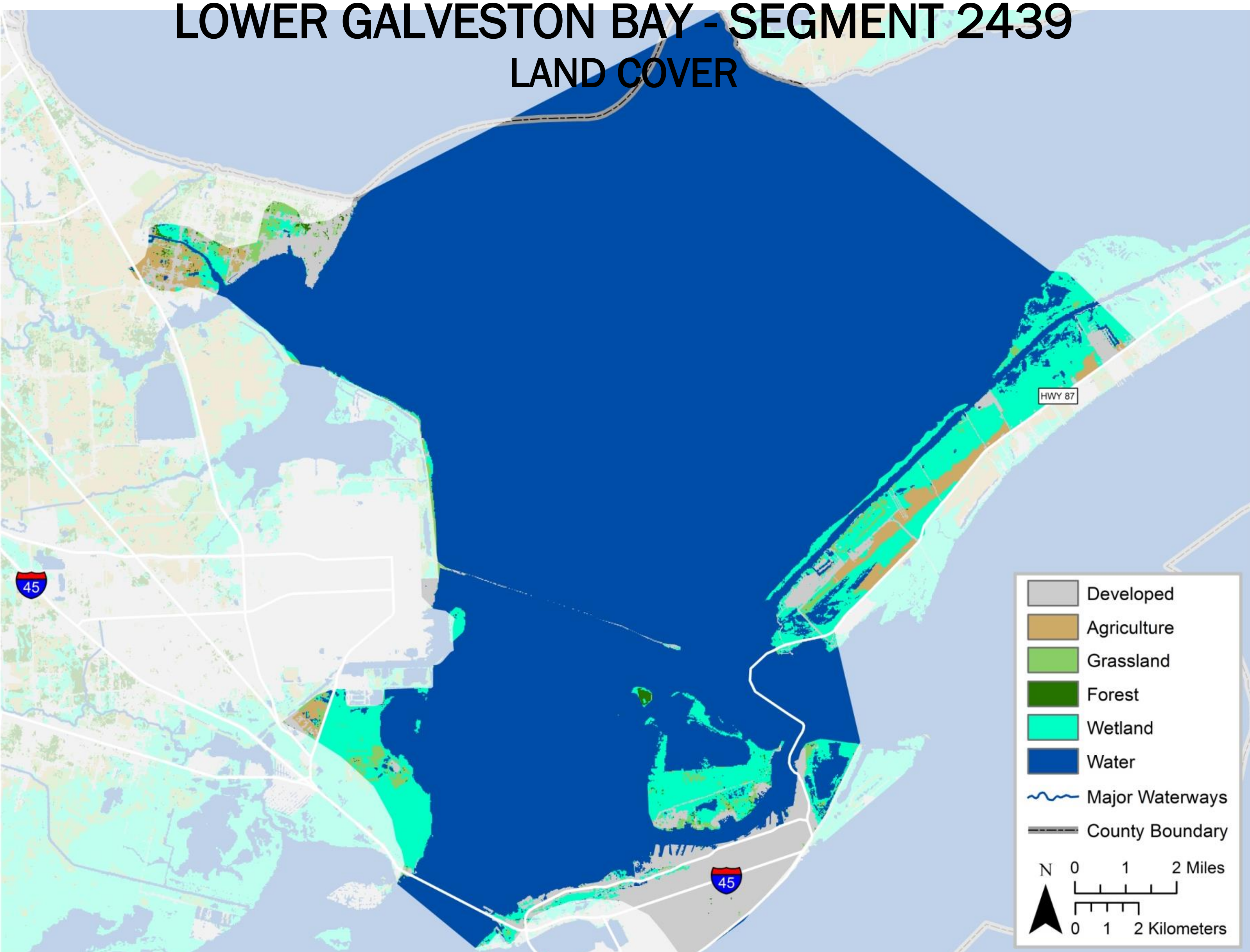
A concern for chlorophyll *a* levels also exists for this segment. A statistically significant trend was not detected for chlorophyll *a* data over time for the Bayport Ship Channel, however, more than half of the samples collected since 2000 have exceeded the 11.6 µg/L screening criteria. Analysis of dissolved oxygen (DO) data for this segment revealed that most samples collected during the period of record have remained in compliance with state water quality standards with only one grab sample falling below the 3.0 mg/L minimum standard in the past 15 years.

Recommendations
Address concerns found in this segment summary through stakeholder participation.
Continue collecting water quality data to support actions associated with any future watershed protection plan development and possible modeling.
Support all TMDLs being conducted around this water body.

B22. LOWER GALVESTON BAY - SEGMENT 2439



LOWER GALVESTON BAY - SEGMENT 2439
LAND COVER



Segment Number:	2439	Name:	Lower Galveston Bay

Area: 361.6 square miles **Miles of Shoreline:** 70.1 miles **Designated Uses:** Primary Contact Recreation; High Aquatic Life Use; Oyster Waters

Number of Active Monitoring Stations: 13 **Texas Stream Team Monitors:** 3 **Permitted Outfalls:** 14

Description: Segment 2439: A 361.6 square kilometer (139.2 square mile) portion of Galveston Bay located entirely within Galveston County extending eastward from the Galveston Causeway (IH-45) past Bolivar Roads (the pass between Galveston Island and Bolivar Peninsula) to an imaginary north-south line from Smith Point to approximately ½ mile east of Pepper Grove Cove on Elm Grove Point and east of Bluewater Subdivision on Bolivar Peninsula. And south of the imaginary line between Eagle Pt and Redfish Reef near the community of San Leon in Galveston County and Smith Point in Chambers County.

Segment 2439OW (Oyster Waters)

Percent of Stream Impaired or of Concern

Segment ID	PCBs/Dioxin	Bacteria	Dissolved Oxygen	Nutrients	Chlorophyll *a*	Other
2439	100	-	-	-	100	-
2439OW	-	100	-	-	-	-

Segment 2439

Standards	Bays & Estuaries	Screening Levels	Bays & Estuaries
Temperature (°C/°F):	35 / 95	Ammonia-N (mg/L):	0.10
Dissolved Oxygen *(24-Hr Average)* (mg/L):	4.0	Nitrate-N (mg/L):	0.17
Dissolved Oxygen *(Absolute Minima)* (mg/L):	3.0	Orthophosphate Phosphorus (mg/L):	0.19
pH (standard units):	6.5-9.0	Total Phosphorus-P (mg/L):	0.21
Enterococci (MPN/100mL) (grab):	104	Chlorophyll *a* (µg/L):	11.6
Enterococci (MPN/100mL) (geometric mean):	35		
Fecal Coliform in Oyster Waters (CFU/100mL) (median/grab):	14/43		

FY 2016 Active Monitoring Stations

Site ID	Site Description	Frequency	Monitoring Entity	Parameter Groups
13364	Lower Galveston Bay at CM 2	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
13364	Lower Galveston Bay at CM 2	Once / Year	TCEQ	Benthics, Metals in Sediment
16517	Lower Galveston Bay at 98GB023	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16517	Lower Galveston Bay at 98GB023	Once / Year	TCEQ	Benthics, Metals in Sediment
16518	Lower Galveston Bay at 98GB025	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16519	Lower Galveston Bay at 98GB026	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16520	Lower Galveston Bay at 98GB027	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16521	Lower Galveston Bay at 98GB028	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16521	Lower Galveston Bay at 98GB028	Once / Year	TCEQ	Benthics, Metals in Sediment
16522	Lower Galveston Bay at 98GB029	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16523	Lower Galveston Bay at 98GB030	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16524	Lower Galveston Bay at 98GB031	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16524	Lower Galveston Bay at 98GB031	Once / Year	TCEQ	Benthics, Metals in Sediment
16525	Lower Galveston Bay at 98GB032	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16526	Lower Galveston Bay at 98GB033	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16527	Lower Galveston Bay at 98GB034	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16528	Lower Galveston Bay at 98GB035	Quarterly	TCEQ	Field, Conventional, Bacteria, Chlorophyll *a*
16528	Lower Galveston Bay at 98GB035	Once / Year	TCEQ	Benthics, Metals in Sediment

Water Quality Issues Summary

Issue	2014 Assessment *I – Impaired* *C – Of Concern*		Possible Causes / Influences / Concerns Voiced by Stakeholders	Possible Solutions / Actions To Be Taken
Elevated Levels of Indicator	2439OW	I	▪ Rapid urbanization and increased impervious cover	▪ Improve compliance and enforcement of existing stormwater quality permits

Bacteria in Oyster Waters		▪ Animal waste from agricultural production and hobby farms ▪ Constructed stormwater controls failing ▪ Improper disposal of waste from boats ▪ Developments with malfunctioning OSSFs ▪ Improper or no pet waste disposal ▪ Waste haulers illegal discharges/improper disposal ▪ Direct and dry weather discharges ▪ Poorly operated or undersized WWTFs ▪ WWTF non-compliance, overflows, and collection system by-passes	▪ Improve construction oversight to minimize TSS discharges to waterways ▪ Add water quality features to stormwater systems ▪ Implement stream fencing or alternative water supplies to keep livestock out of or away from waterways ▪ Encourage Water Quality Management Plans or similar projects for agricultural properties ▪ Install and/or conserve vegetative buffer areas along all waterways ▪ More public education on proper boat waste disposal ▪ More public education regarding OSSF operation and maintenance ▪ Ensure proper citing of new or replacement OSSFs ▪ More public education on pet waste disposal ▪ Regionalize chronically non-compliant WWTFs ▪ Require all systems to develop and implement a utility asset management program and protect against power outages at lift stations ▪ Impose new or stricter bacteria limits than currently designated by TCEQ ▪ Increase monitoring requirements for self-reporting

Segment Discussion:

Watershed Characteristics: This segment primarily receives flow from other bodies of water such as Upper Galveston Bay, East Bay, West Bay and the Gulf of Mexico. The land portion of the watershed includes parts of the Cities of Galveston and Texas City, and the unincorporated communities of San Leon and Port Bolivar. The eastern end of Galveston Island is heavily urbanized with commercial shipping operations located along both the north and south shores of the Galveston Ship Channel. A large portion of Pelican Island, located to the north of the channel, is used for dredge disposal and contains a great deal of wetland habitat. Likewise, the east end of the Galveston Island on the bay side of the seawall is a dredge disposal area.

While Texas City is heavily industrialized with a high concentration of refineries and related petrochemical installations, only a relatively small area drains directly to Lower Galveston Bay. Most of the City of Texas City drains through Moses Lake via pumping stations located on the city lagoons. In addition to the wetlands and grasslands, this area also includes several other industrial operations such as landfills, offsite disposal areas, and a superfund site. The other Texas City land area draining to the Bay is the Texas City Dike and all the bay shoreline along the seawall levee north of the dike. A few shrimp boats dock along the Dike but there are no permanently located businesses on the dike. This area supports public recreation such as swimming, wade fishing and wind surfing.

North of Texas City is the unincorporated community of San Leon. It is moderately developed with a mix of residential and commercial land uses. Though smaller in size, the community of Pt. Bolivar on Bolivar Peninsula is also a year round community of mixed residential and commercial uses. Farther east along the peninsula are large tracts of undeveloped land supporting wetland, marsh and grassland habitats intersected with small residential developments and a few canal communities. Many of these houses are vacation homes without year round occupants.

Lower Galveston Bay is a crossroads of many waterways. It supports high volumes of ocean-going ships and barge traffic, particularly along the ship channels and the Intracoastal Waterway. Extensive commercial oyster beds are located across the upper portion of Lower Galveston Bay while the entire bay is used extensively for recreational activities such as boating, fishing and birding.

Water Quality Issues: Assessment unit 2439OW_01, which is the area of Lower Galveston Bay located near the Texas City Ship Channel and Moses Lake, is listed in the 2014 IR as impaired for oyster waters due to elevated levels of fecal coliform bacteria. This assessment unity is closed by the Seafood Safety Division of the Texas Department of State Health Services for the harvesting of oysters and other shellfish for direct marketing.

Special Studies/Projects: Lower Galveston Bay is also included in the UGCOWs I-Plan for bacteria which began in 2010 after the TMDL was approved by the EPA. The final draft I-Plan was submitted to the TCEQ in August of 2014 and final approval of the draft was given in August of 2015.

Trends: Regression analysis of water quality data revealed statistically significant trend for the Lower Galveston Bay watershed for enterococci. This segment is currently listed as impaired for indicator bacteria in oyster waters. Refer to the water quality issues discussion above for more information about these impairments.

Recommendations
Continue collecting water quality data to support actions associated with any future watershed protection plan development and possible modeling.
Coordinate education efforts with other local TMDL and watershed protection plan efforts.
Increase the frequency of sampling at representative stations in the watershed to decrease data gaps.
Pursue a new local partner to Clean Rivers Program to collect additional data that would help better isolate problem areas.

APPENDIX E

Basin 11 Permitted Waste Water Treatment Facilities

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
WQ0002544000	TX0087971	Solvay Chemicals, Inc.	Industrial	0.434	.	1005_01	No DMR Data
WQ0002406000	TX0084808	Metton America, Inc.	Industrial	0.01	.	1005_01	No DMR Data
WQ0000544000	TX0006033	INEOS USA LLC	Industrial	3.5	.	1005_01	No DMR Data
WQ0012822001	TX0094226	Aqua Utilities, Inc	Private	0.035	0.0324	1101B_01	
WQ0010568008	TX0133043	City of League City	Municipal	12	1.340667	1101_01	
WQ0010526001	TX0023833	Nassau Bay, City of	Municipal	2.66	0.658593	1101_01	
WQ0010568003	TX0071447	League City, City of	Municipal	1.32	0.277722	1101_01	
WQ0011571001	TX0069728	Gulf Coast Waste Disposal Authority	Municipal	9.25	5.841083	1101_01	
WQ0010520001	TX0024589	City of Webster	Municipal	3.3	1.33675	1101_01	
WQ0010568005	TX0085618	City of League City	Municipal	19.5	7.877583	1101_01	
WQ0012680001	TX0092614	H & R Realty Investments, LLC	Private	0.012	0.00832	1102B_01	
WQ0010134007	TX0116581	Pearland, City of	Municipal	8	2.870833	1102B_01	
WQ0012332001	TX0086118	Brazoria County MUD No. 3	Municipal	2.4	1.158083	1102B_01	
WQ0012849001	TX0094463	Yes Companies, LLC	Private	0.075	0.034	1102C_01	
WQ0015237001	TX0135283	Forester Estates, LLC	Municipal	0.049	0.025	1102_01	
WQ0010134002	TX0032735	Pearland, City of	Municipal	7.6	1.763417	1102_03	
WQ0010134008	TX0117501	Pearland, City of	Municipal	4	2.13725	1102_03	

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
WQ0012295001	TX0085383	Pearland, City of	Municipal	0.95	0.503917	1102_03	
WQ0012939001	TX0095842	Harris County Water Control and Improvement District No. 89	Municipal	0.95	0.44215	1102_03	
WQ0010495075	TX0063070	Houston, City of	Municipal	6.14	4.593083	1102_04	
WQ0010134010	TX0032743	Pearland, City of	Municipal	2.5	2.545417	1102_04	
WQ0010495079	TX0035009	City of Houston	Municipal	10.66	4.245167	1102_04	
WQ0014326001	TX0124761	Bayou Develeopment, LLC	Private	0.02	0.003799	1103_01	
WQ0014804001	TX0129631	SOUTH CENTRAL WATER COMPANY	Municipal	.	.	1103_01	No DMR Data
WQ0000377000	TX0003727	Calumet Penreco, LLC	Industrial	0.075	.	1103_01	No DMR Data
WQ0003479000	TX0108367	Sea Lion Technology	Industrial	0.02	.	1103_01	No DMR Data
WQ0003749000	TX0112861	Hillman Shrimp & Oyster Co	Industrial	0.07	.	1103_01	No DMR Data
WQ0014570001	TX0127248	United Development Funding, LP	Private	0.125	.	1103_01	No DMR Data
WQ0010173001	TX0023655	Galveston County Water Control and Improvement District No. 1	Municipal	4.8	2.712727	1103_01	
WQ0003416000	TX0119458	Waste Management of Texas, Inc	Industrial	.	.	1104_01	No DMR Data

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
WQ0013632001	TX0109886	Meadowland Utility Corporation	Private	0.0234	0.00645	1104_02	
WQ0012935001	TX0095770	K. C. Utilities, Inc.	Private	0.05	0.016128	1104_02	
WQ0010158001	TX0056707	Danbury, City of	Municipal	0.504	0.185333	1105A_03	
WQ0012113001	TX0079260	Orbit Systems, Inc	Private	0.1	0.014917	1105A_03	
WQ0014991001	TX0132861	The Cardon Group, L.L.C.	Municipal	0.24	.	1105C_01	No DMR Data
WQ0003116000	TX0105261	Best Sea-Pack of Texas, Inc.	Industrial	0.26	0.004059	1105C_01	
WQ0014279001	TX0119547	Aqua Development, Inc	Private	0.15	0.009667	1105C_01	
WQ0004679000	TX0078646	Schulmberger Technology Corporation	Industrial	0.5028	.	1105C_01	No DMR Data
WQ0005149000	TX0135950	Mammoet USA Inc.	Industrial	0.002	.	1105_01	No DMR Data
WQ0012420001	TX0088366	Orbit Systems, Inc.	Private	0.0175	0.0052	1105_01	
WQ0014939001	TX0131971	Lake Jackson Mobile Home Park & RV, LLC	Private	0.03	.	1105_01	No DMR Data
WQ0003903000	TX0114995	Allied Petrochemical, LLC	Industrial	0.025	.	1107_01	No DMR Data
WQ0014324001	TX0119041	Aqua Utilities, Inc	Private	0.05	0.012975	1107_01	
WQ0013367001	TX0102385	Arcola, City of	Municipal	0.95	0.204432	1108_01	
WQ0014222001	TX0123633	Brazoria County MUD 21	Municipal	1.2	0.24825	1108_01	
WQ0013872001	TX0118397	Manvel, City of	Municipal	0.5	0.145667	1108_01	

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
WQ0012780001	TX0093823	Gulf Coast Utility Co, Inc	Private	0.145	.	1108_01	No DMR Data
WQ0015093001	TX0134562	AUC Group, LP	Private	0.125	.	1108_01	No DMR Data
WQ0014992001	TX0132896	Skymark Development Company, Inc.	Municipal	0.07	.	1108_01	No DMR Data
WQ0014068001	TX0117927	Ricetec, Inc.	Private	0.025	0.002225	1108_01	
WQ0014546001	TX0126951	Brazoria County Municipal Utility District No. 31	Private	0.24	0.148358	1108_01	
WQ0014724003	TX0129470	AUC GROUP LP	Municipal	0.98	.	1108_01	No DMR Data
WQ0014149001	TX0123994	SP Utility Company, Inc.	Private	0.2	0.007117	1108_01	
WQ0014253001	TX0124001	Brazoria County MUD 29	Municipal	0.225	0.169072	1108_01	
WQ0015279001	TX0135577	Brazoria County MUD No. 43	Municipal	0.3	.	1108_01	No DMR Data
WQ0015088001	TX0134511	Brazoria County MUD No. 61	Municipal	0.15	.	1108_01	No DMR Data
WQ0010700001	TX0023337	Oak Manor MUD	Municipal	0.08	0.08	1108_01	
WQ0014461001	TX0126055	Brazoria County Municipal Utiilty District No. 30	Municipal	0.25	.	1108_01	No DMR Data
WQ0014724002	TX0129453	AUC Group, L.P.	Municipal	1.155	.	1108_01	No DMR Data

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
WQ0014497001	TX0126365	Gulf Coast Utility Co, Inc	Private	0.099	.	1108_01	No DMR Data
WQ0010798001	TX0025283	Commodore Cove Improvement District	Municipal	0.06	0.029	1109_01	
WQ0014118001	TX0119539	Sienna Plantation MUD 1	Municipal	1.2	1.007608	1110_01	
WQ0010086001	TX0021458	Fort Bend County Water Control and Improvement District No. 2	Municipal	6	4.049667	1110_01	
WQ0010548004	TX0056316	Angelton, City of	Municipal	7.2	2.102417	1110_01	
WQ0014064001	TX0117358	Stafford Mobile Home Park, Inc.	Private	0.05	0.024	1110_01	
WQ0013804001	TX0115169	Texas Department Criminal Justice	Municipal	2	1.488967	1110_01	
WQ0011046001	TX0035220	Quail Valley Utility District	Municipal	4	1.739833	1110_01	
WQ0002952000	TX0103896	Texas Department of Criminal Justice	Industrial	0.25	.	1110_01	No DMR Data
WQ0010829001	TX0031658	Texas Department of Criminal Justice	Municipal	0.45	0.345917	1110_01	
WQ0010743001	TX0031585	Texas Department of. Criminal Justice	Municipal	0.8	0.701833	1110_01	
WQ0012701001	TX0093068	City of Missouri City	Municipal	0.95	0.525973	1110_01	
WQ0012672001	TX0092401	Orbit Systems Inc.	Private	0.07	0.029875	1110_01	
WQ0012937001	TX0090484	Palmer Plantation Municipal Utility District No. 1	Municipal	0.6	0.275547	1110_01	
WQ0014197001	TX0123137	Fort Bend County MUD No. 131	Municipal	0.16	0.06115	1110_01	
WQ0011999001	TX0074233	Fort Bend County Municipal Utility District No 23	Municipal	1.8	1.0275	1110_01	

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
WQ0014612001	TX0127876	Sienna Plantation MUD 1	Municipal	3.5	.	1110_01	No DMR Data
WQ0004818000	TX0053813	Shintech Incorporated	Industrial	3.27	.	1111_01	No DMR Data
WQ0001878000	TX0046906	Chemical Specialties, LLC	Industrial	0.27	.	1111_01	No DMR Data
WQ0003977000	TX0008788	BASF Corporation	Industrial	7.464	.	1111_01	No DMR Data
WQ0010044001	TX0034436	City of Clute	Municipal	4	3.241667	1111_01	
WQ0001806000	TX0008761	Nalco Company	Industrial	0.0536	.	1111_01	No DMR Data
WQ0001954000	TX0065021	Air Liquide Large Industries U.S. LP	Industrial	0.46	.	1111_01	No DMR Data
WQ0004971000	TX0133264	Infinity Construction Services, LP	Industrial	.	.	1111_01	No DMR Data
WQ0011837001	TX0072591	Oyster Creek, City of	Municipal	0.5	.	1111_01	No DMR Data
WQ0010539001	TX0022543	Clear Lake Water Authority	Municipal	10	6.306541	1113_01	
WQ0004362000	TX0124427	Shin-Etsu Silicones of America, Inc.	Industrial	0.7	.	1201_01	No DMR Data
WQ0001961000	TX0067946	SI Group, Inc	Industrial	1.5	.	1201_01	No DMR Data

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
WQ0001861000	TX0034738	Gulf Chemical & Metallurgical Co	Industrial	0.35	.	1201_01	No DMR Data
WQ0002656000	TX0095605	BASF Corporation	Industrial	.	.	1201_01	No DMR Data
WQ0001822000	TX0008737	Vencorex US, Inc.	Industrial	0.125	.	1201_01	No DMR Data
WQ0002216000	TX0064912	DSM Nutritional Products,LLC	Industrial	0.19	.	1201_01	No DMR Data
WQ0000007000	TX0006483	Dow Chemical Co	Industrial	2466.4	.	1201_01	No DMR Data
WQ0004696000	TX0126322	Texas Barge & Boat, Inc.	Industrial	.	.	1201_01	No DMR Data
WQ0010206001	TX0022799	LaPorte, City of	Municipal	7.56	4.385833	2421_01	
WQ0010671001	TX0022250	Seabrook, City of	Municipal	2.5	1.447833	2421_01	
WQ0010770001	TX0021822	Bayview Municipal Utility District	Municipal	0.3	0.15375	2421_01	
WQ0010627001	TX0021369	Baycliff MUD	Municipal	1.24	0.969583	2421_01	
WQ0012039001	TX0078441	Galveston County Water Control and Improvement District No. 12	Municipal	1	0.627417	2421_01	
WQ0014980001	TX0132748	OCEAN MOBILE HOME PARK LLC	Municipal	0.03	.	2421_01	No DMR Data
WQ0011546001	TX0071978	San Leon MUD	Municipal	0.95	0.896636	2421_01	

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
WQ0013643001	TX0042081	Nerro Supply, LLC	Private	0.1	0.021326	2422_01	
WQ0010690001	TX0062243	Hitchcock, City of	Municipal	3	1.843159	2424_01	
WQ0010410003	TX0114821	La Marque, City of	Municipal	6	.	2424_01	
WQ0010435002	TX0020311	Galveston County Municipal Utility District No. 12	Municipal	0.8	0.311317	2424_01	
WQ0010879001	TX0020079	Galveston County Fresh Water Supply District No. 6	Municipal	0.32	0.133512	2424_01	
WQ0010174001	TX0023671	Galveston County WCID 8	Municipal	1.5	1.187417	2424_01	
WQ0003608000	TX0111350	Bayshore Industrial LP	Industrial	0.15502	.	2425_01	No DMR Data
WQ0004330000	TX0102296	Air Liquids Large Industires US LP	Industrial	0.072	.	2425_01	No DMR Data
WQ0002756000	TX0030228	Lyondell Chemical Company	Industrial	.	.	2425_01	No DMR Data
WQ0010243001	TX0027146	Harris County Water Control and Improvement District No. 50	Municipal	0.54	0.26775	2425_01	
WQ0014931001	TX0131806	Bay Bluff, L.P.	Private	0.05	0.006425	2425_01	
WQ0001026000	TX0006378	NRG Texas Power LLC	Industrial	1480.4	.	2427_01	No DMR Data
WQ0004201000	TX0122335	D.B. Western, Inc. - Texas	Industrial	1.5	.	2427_01	No DMR Data
WQ0004013000	TX0119792	Equistar Chemicals, L.P. and LyondellBasell Acetyls, LLC	Industrial	5.1	.	2427_01	No DMR Data

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
	TX0006157	Gulbrandsen Technologies, Inc.	Industrial	.	0.079866	2427_01	No DMR Data
WQ0004092000	TX0118389	Linde Gas North America LLC	Industrial	1.069	.	2427_01	No DMR Data
WQ0001318000	TX0008184	Ohmstede Ltd	Industrial	0.045	.	2427_01	No DMR Data
WQ0002529000	TX0088510	Praxair, Inc	Industrial	0.54	.	2427_01	No DMR Data
WQ0001280000	TX0004944	Air Products & Chemicals	Industrial	0.5	.	2427_01	No DMR Data
WQ0013949001	TX0008001	Greif Packaging, LLC	Private	0.003	0.0014	2427_01	
WQ0005148000	TX0135933	Mobley Industrial Services	Industrial	.	.	2427_01	No DMR Data
WQ0005108000	TX0135101	Linde LLC	Industrial	0.25	.	2427_01	No DMR Data
WQ0004985000	TX0133540	Battleground Oil Specialty Terminal Company LLC	Industrial	.	.	2427_01	No DMR Data
WQ0000663000	TX0002933	Dow Chemical Company	Industrial	0.75	0.178167	2427_01	
WQ0000474000	TX0007293	E.I. Du Pont de Nemours & Co	Industrial	20.767	.	2427_01	No DMR Data
WQ0002107000	TX0074276	Braskem America, Inc	Industrial	0.622	.	2427_01	No DMR Data

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
WQ0000448000	TX0002852	Union Carbide Corporation	Industrial	.	.	2431_01	No DMR Data
WQ0001263000	TX0007323	ISP Technologies, Inc.	Industrial	1.58	.	2431_01	No DMR Data
WQ0010375001	TX0023949	Texas City, City of	Municipal	12.4	6.0335	2431_01	
WQ0014322001	TX0124737	Brazoria County MUD 25	Municipal	0.24	0.216966	2432A_02	
WQ0014188001	TX0122823	Manvel Utilities Limited Partnership	Private	0.099	0.025017	2432A_02	
WQ0013735001	TX0118001	Rancho La Fuente Partners, LLC	Private	0.021	0.028	2432A_02	
WQ0000001000	TX0003875	Ascend Perormance Materials Operations LLC and Equistar Chemicals, LP	Industrial	11.8	.	2432A_02	No DMR Data
WQ0004306000	TX0112461	Nalco Company	Industrial	0.055	.	2432A_02	No DMR Data
WQ0013600001	TX0094790	Aqua Utilities, Inc	Private	0.0225	0.013933	2432A_02	
WQ0015077001	TX0134333	AUC Group, L.P.	Private	0.125	.	2432A_02	No DMR Data
WQ0001333000	TX0004821	INEOS USA LLC	Industrial	8	.	2432A_02	No DMR Data
WQ0014756001	TX0129178	MA Sedona Lakes, LP	Municipal	0.15	0.048583	2432A_02	
WQ0014641001	TX0128163	2006 MUSTANG CREEK DEVELOPMENT INC	Municipal	0.125	.	2432A_02	No DMR Data

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
WQ0002068000	TX0072168	Keeshan & Bost Chemical Co., Inc.	Industrial	0.033	.	2432A_02	No DMR Data
WQ0010420001	TX0056057	Hillcrest Village, City of	Municipal	0.15	.	2432D_01	No 2015 Data
WQ0014039001	TX0117234	Aqua Utilities, Inc	Private	0.0924	0.050342	2432D_01	
WQ0010005001	TX0024554	Alvin, City of	Municipal	5	3.401	2432D_01	
WQ0015303001	TX0135828	Follets Island Custom Homes Inc	Private	0.048	.	2434_01	No DMR Data
WQ0000452000	TX0004766	BP Amoco Chemical Co	Industrial	.	.	2437_01	No DMR Data
WQ0001485000	TX0057843	Gulf Coast Waste Disposal Authority	Industrial	15.7	.	2437_01	No DMR Data
WQ0000443000	TX0003522	Blanchard Refining Company LLC	Industrial	117.36	13.05017	2437_01	
WQ0000449000	TX0006009	Valero Refining.- Texas LP	Industrial	9	.	2437_01	No DMR Data
WQ0000575000	TX0005762	Eastman Chemical Texas City, Inc.	Industrial	208.24	.	2437_01	No DMR Data
WQ0002670000	TX0094129	Oxbow Energy Solutions LLC	Industrial	.	.	2437_01	No DMR Data
WQ0000990000	TX0003697	Marathon Peetroleum Company, LP	Industrial	6.6	0.286937	2437_01	
WQ0002109000	TX0075311	NuStar Terminals Partners TX L.P.	Industrial	0.084	.	2437_01	No DMR Data

TCEQ Permit Number	EPA Permit Number	Permittee	Permit Type	Permitted Flow (MGD)	Average Flow in 2015 (MGD)	Assessment Unit	Note
WQ0001054000	TX0005380	Gulf Coast Waste Disposal Authority	Industrial	25	.	2438_01	No DMR Data
WQ0002547000	TX0089192	Odfjell Terminals (Houston)	Industrial	.	.	2438_01	No DMR Data
WQ0002110000	TX0075302	LBC Houston, L.P.	Industrial	.	.	2438_01	No DMR Data

APPENDIX F

Basin 11 Municipal Separate Storm Sewer System Permittees

BASIN 11: MS4 PERMITTED AREAS		
NAME	**MS4_Permit_Number**	**Area (Acres)**
Houston	WQ0004685-000	34053.20
Pasadena	WQ0004524-000	14576.33
Hitchcock	RN105477434	4091.71
Bayou Vista	RN105477566	383.86
Texas City	RN105479513	8529.67
Deer Park	RN105484307	3751.28
Galveston Consolidated DD	RN105485353	9628.31
Webster	RN105487318	3525.75
Kemah	RN105498216	1001.97
Seabrook	RN105499289	2918.43
Sugar Land	RN105507925	2857.78
La Porte	RN105510440	8310.97
Freeport	RN105523328	2946.87
Angleton	RN105523401	4963.34
Angleton Drainage District	RN105523484	5408.47
Alvin	RN105523526	7174.93
Clute	RN105523575	2820.95
Lake Jackson	RN105523617	5677.68

BASIN 11: MS4 PERMITTED AREAS		
NAME	**MS4_Permit_Number**	**Area (Acres)**
Richwood	RN105523625	824.42
Velasco Drainage District	RN105523658	13841.07
Brazoria Drainage District 4	RN105523708	26854.54
Brazoria County Reclamation District	RN105526552	7109.35
La Marque	RN105538763	4531.67
Santa Fe	RN105550107	7327.38
Galveston Co DD 1	RN105551048	13819.16
Clear Lake Shores	RN105551337	229.90
Pearland	RN105552335	18428.83
NASA	RN105552723	1510.86
Hunter's Glen	RN105555783	10.96
BC 1 & 2	RN105557284	705.70
Brazoria County MUD #16	RN105558043	288.26
Brazoria County MUD 6	RN105558092	416.72
Friendswood	RN105562086	10486.08
League City	RN105569735	13559.96
Stafford	RN105569842	1678.84
Dickinson	RN105576581	4967.09

BASIN 11: MS4 PERMITTED AREAS		
NAME	**MS4_Permit_Number**	**Area (Acres)**
FT BEND MUD 47	RN105586374	234.56
FT BEND MUD 48	RN105586457	267.76
FIRST COLONY MUD 9	RN105586507	672.48
FORT BEND CO MUD 42	RN105586598	530.86
Fort Bend County MUD 26	RN105588222	290.95
MEADOWCREEK MUD	RN105588248	235.33
Missouri City	RN105588297	7227.00
Brazoria County MUD #4	RN105589196	482.44
First Colony Levee ID	RN105589766	1313.01
Fort Bend Co LID 2	RN105591069	764.05
Nassau Bay	RN105591226	881.54
Fort Bend County MUD 23	RN105591234	898.30
Taylor Lake Village	RN105597496	837.81
Quail Valley UD	RN105604813	1574.40
Thunderbird UD	RN105604839	688.29
Palmer Plantation MUD 1	RN105604870	417.75
PALMER PLANTATION MUD 02	RN105604904	318.13
FORT BEND CO MUD 49	RN105604912	170.10

BASIN 11: MS4 PERMITTED AREAS		
NAME	**MS4_Permit_Number**	**Area (Acres)**
FORT BEND CO MUD 46	RN105608384	6.62
Fort Bend Co DD	RN105706519	17041.61
Robert T. Savely Water Reclamation Facility Wastewater Treatment Facility	RN105774152	10971.67
Harris Co WCID 50	RN105915904	439.04
Port of Houston Authority - MS4	WQ0004421000	161.13
Total MS4 Area in Basin 11		295637.12