Armand Bayou: Bacteria in Waters Used for Contact Recreation

- **Six TMDLs Adopted August 5, 2015**
  Approved by EPA October 2, 2015
- **One TMDL Added by Addendum October 2018**
  Approved by EPA February 22, 2019 (scroll to view or print this addendum)

Prepared by the:
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Addendum One to Six Total Maximum Daily Loads for Indicator Bacteria in the Armand Bayou Watershed

One Total Maximum Daily Load for Indicator Bacteria in Armand Bayou Tidal

For Segment 1113

Assessment Unit 1113_03

Introduction

The Texas Commission on Environmental Quality (TCEQ) adopted *Six Total Maximum Daily Loads for Indicator Bacteria in the Armand Bayou Watershed: Segments 1113, 1113A, 1113B, 1113C, 1113D, and 1113E* (TCEQ, 2015a) on August 5, 2015. The total maximum daily loads (TMDLs) were approved by the United States Environmental Protection Agency (USEPA) on October 2, 2015. This document represents an addendum to the original TMDL document.

This addendum includes information specific to one additional assessment unit (AU) of one segment located within the watershed of the approved TMDL project for bacteria in Armand Bayou. Concentrations of indicator bacteria in this AU exceed the criteria used to evaluate attainment of the water quality standard for contact recreation. This addendum presents the new information associated with the additional AU. For background or other explanatory information, please refer to the *Technical Support Document for One Total Maximum Daily Load for Indicator Bacteria in Armand Bayou: Segment 1113* (Brady et al., 2018). Refer to the original, approved TMDL document for details related to the overall Armand Bayou watershed as well as the methods and assumptions used in developing the original TMDLs.

The addendum watershed was addressed in the original TMDL. This addendum provides the details related to developing the TMDL allocation for this additional AU, which was not specifically addressed in the original TMDL document.

Problem Definition

The TCEQ first identified the bacteria impairment within the Armand Bayou AU included within this addendum in the 2014 edition of the *Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303 (d)* (2014 Integrated Report; TCEQ, 2015b). Table 1 provides a summary for the 2014 Integrated Report (the most recent approved version). The impaired AU is

Armand Bayou Tidal (1113_03), as shown in Figure 1. The Armand Bayou Tidal segment has three AUs. The downstream AU (1113_01) is not impaired, and the middle AU (1113_02) was addressed in the original TMDL document. The project watershed is located entirely within Harris County. (The term "project watershed" will be used throughout this document to refer to the watershed for only AU 1113_03. "Armand Bayou watershed" will be used to refer to the entire area addressed by the original TMDL document, which included all AUs of Armand Bayou as well as its tributaries.)

The Texas Surface Water Quality Standards (TSWQS; TCEQ, 2010) provide numeric and narrative criteria to evaluate attainment of designated uses. The basis for the water quality target for the TMDL developed in this report is the numeric criteria for indicator bacteria from the 2010 TSWQS. *Enterococcus* species (Enterococci) are the preferred indicator bacteria for assessing contact recreation use in saltwater.

Table 1. Synopsis of the 2014 Integrated Report for Armand Bayou Tidal (1113_03).

Integrated Report Year	Segment	AU	Parameter	Contact Recreation Use	Year First Impaired	Category
2014	1113	1113_03	Enterococci	Nonsupport	2014	5c

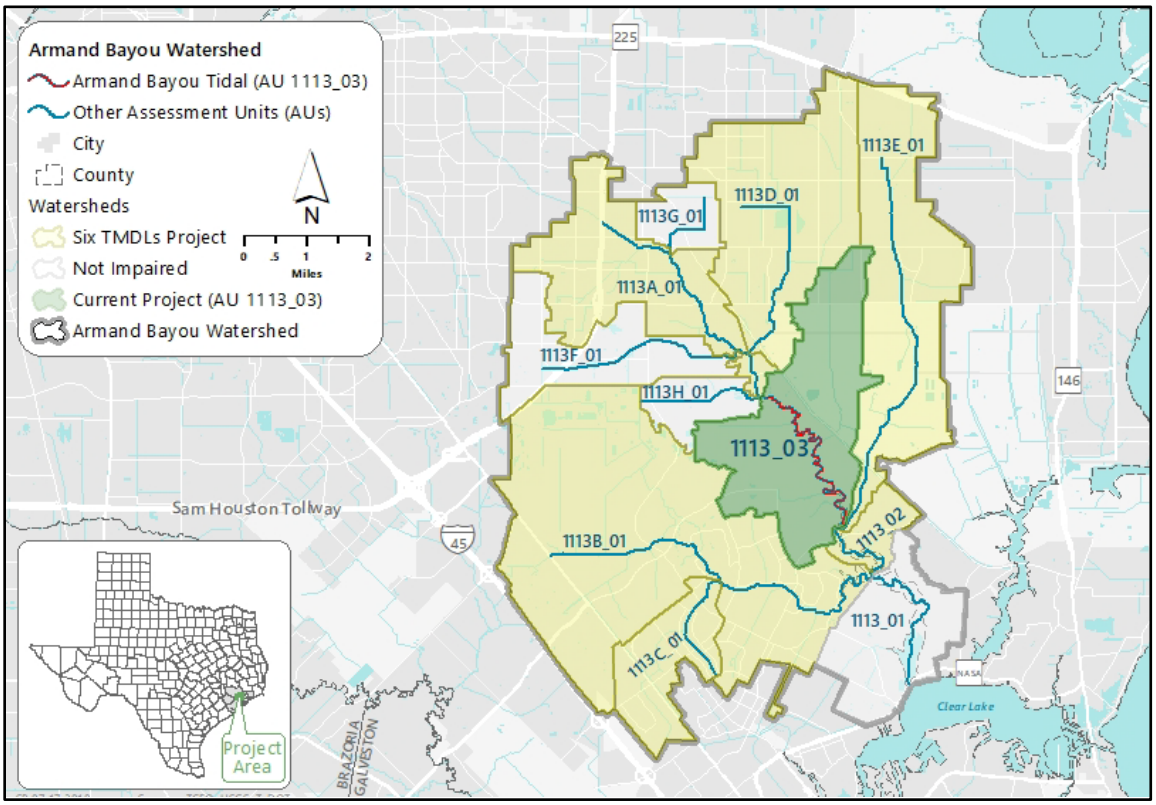

Figure 1. Map showing the full Armand Bayou watershed and the project watershed (for 1113_03) considered in this addendum.

Table 2 summarizes the ambient water quality data for the TCEQ surface water quality monitoring (SWQM) station on the affected AU of Armand Bayou, as reported in the 2014 Integrated Report. The data from the assessment indicate nonsupport of the primary contact recreation use for Armand Bayou, because the geometric mean concentration for Enterococci exceeds the geometric mean criterion of 35 most probable number (MPN)/100 milliliters (mL) in water. Recent environmental monitoring within this AU of Armand Bayou has occurred at TCEQ monitoring station 11505 (Figure 2).

Table 2. 2014 Integrated Report summary for Armand Bayou Tidal (1113_03).

(The geometric mean criterion for Enterococci for primary contact recreation use is 35 MPN/100 mL of water.)

Integrated Report Year	AU	Parameter	Station	Number of Samples	Data Range	Enterococci Geometric Mean (MPN/100 mL)
2014	1113_03	Enterococci	11505	24	2005–2012	47.59

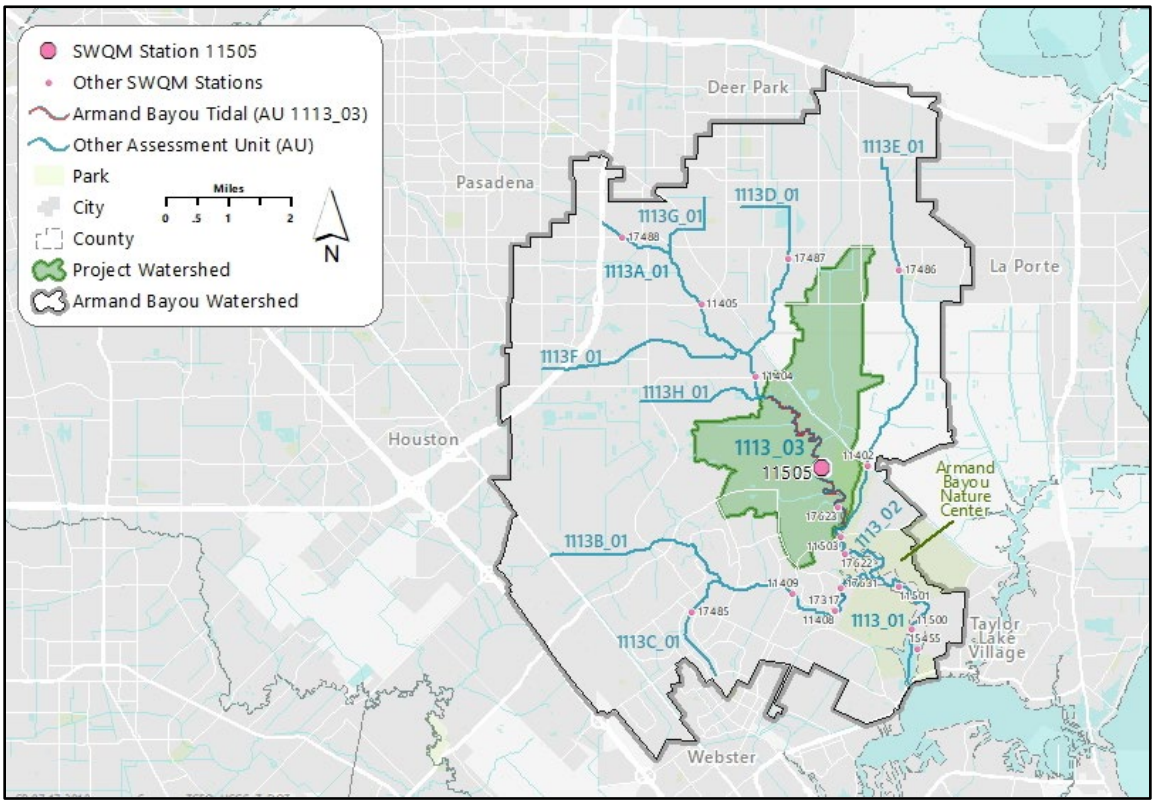

Figure 2. Map showing SWQM stations within the project watershed and the entire Armand Bayou watershed.

Description of the Study Area

Armand Bayou Tidal debouches into Clear Lake (Segment 2425), which connects to the Upper Galveston Bay (Segment 2421) and thence to the Gulf of Mexico.

The entire Armand Bayou Tidal segment comprises three assessment units. The subject AU (1113_03) is the farthest upstream AU. Armand Bayou Tidal AU 1113_03 is approximately 4.82 miles in length and drains an area of 4,580.7 acres. The project watershed makes up 12.11% of the entire Armand Bayou watershed, which covers 37,840.4 acres.

The 2014 Integrated Report (TCEQ, 2015) provides the following segment and AU description for the water body considered in this document:

- Segment 1113 (Armand Bayou Tidal) - From the Clear Lake confluence (at NASA Road 1 bridge) in Harris County to a point 0.8 km (0.5 miles) downstream of Genoa-Red Bluff Road in Pasadena in Harris County (includes Mud Lake/Pasadena Lake)
    - 1113_03 – From the Big Island Slough confluence upstream to a point 0.8 km (0.5 mi) downstream of Genoa-Red Bluff Road

Watershed Climate

The Armand Bayou watershed is located in the eastern portion of the state of Texas, where the climate is classified as “Subtropical Humid” (Larkin & Bomar, 1983). The region’s subtropical climate is caused by the “predominant onshore flow of tropical maritime air from the Gulf of Mexico,” while the increasing moisture content (from west to east) reflects variations in “intermittent seasonal intrusions of continental air” (Larkin & Bomar, 1983). Occasional anomalous climatic events, including floods and droughts, are a feature of the climate.

For the period from 1981 through 2010, average annual precipitation in the project watershed was calculated to be 55.13 inches, which is slightly higher than the average annual total precipitation for the entire Armand Bayou watershed of 55.05 inches (PRISM Climate Group at Oregon State University, 2012). The wettest month is June (7.1 inches), while February and March (both at 3.2 inches) are the driest months, with rainfall occurring throughout the year. Average high temperatures typically peak (93 ˚F) in August. During winter, the average low temperature (45 ˚F) generally occurs in January (Figure 3).

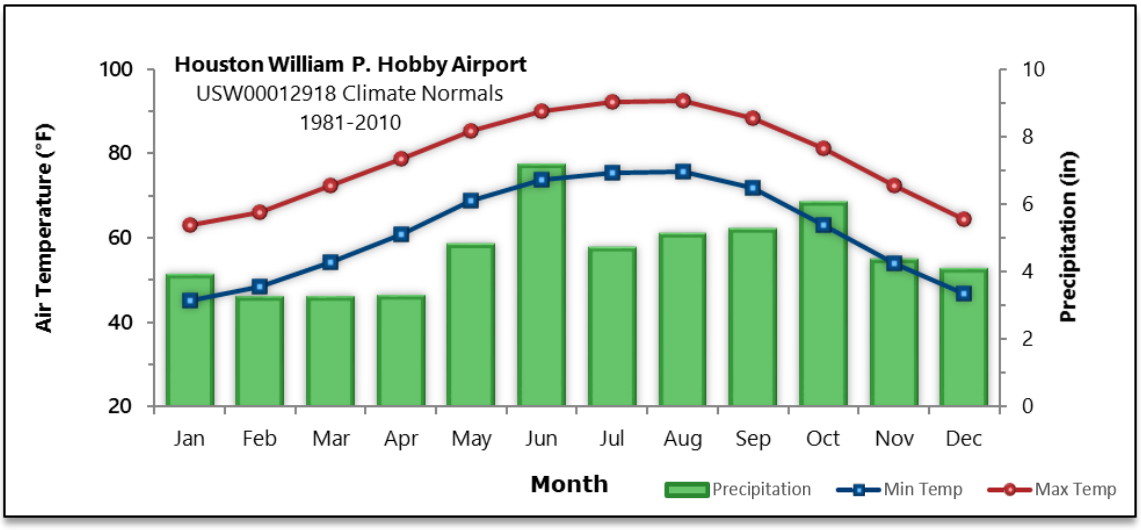

Figure 3. Chart showing the average minimum and maximum air temperature and total precipitation by month from 1981 through 2010 for the Hobby Airport weather station.

Land Use

The land use/land cover data for the project watershed and the entire Armand Bayou watershed were obtained from the Houston-Galveston Area Council (H-GAC) 2015 10 Class Land Cover Data Set (H-GAC, 2017) and are displayed in Figure 4.

As shown in Table 3, the watershed area for the project watershed is 4,580.7 acres. Dominant land uses in the project watershed include Wetlands (22%) and Pasture/Grasslands (17%).

The watershed area encompassing the entire Armand Bayou watershed is about 37,840 acres and the dominant land uses are Developed Medium Intensity (23%) and Developed Low Intensity (22%).

While the project watershed is mostly rural (53%), the entire Armand Bayou watershed is mostly urban, with 72% of the area classified as Developed.

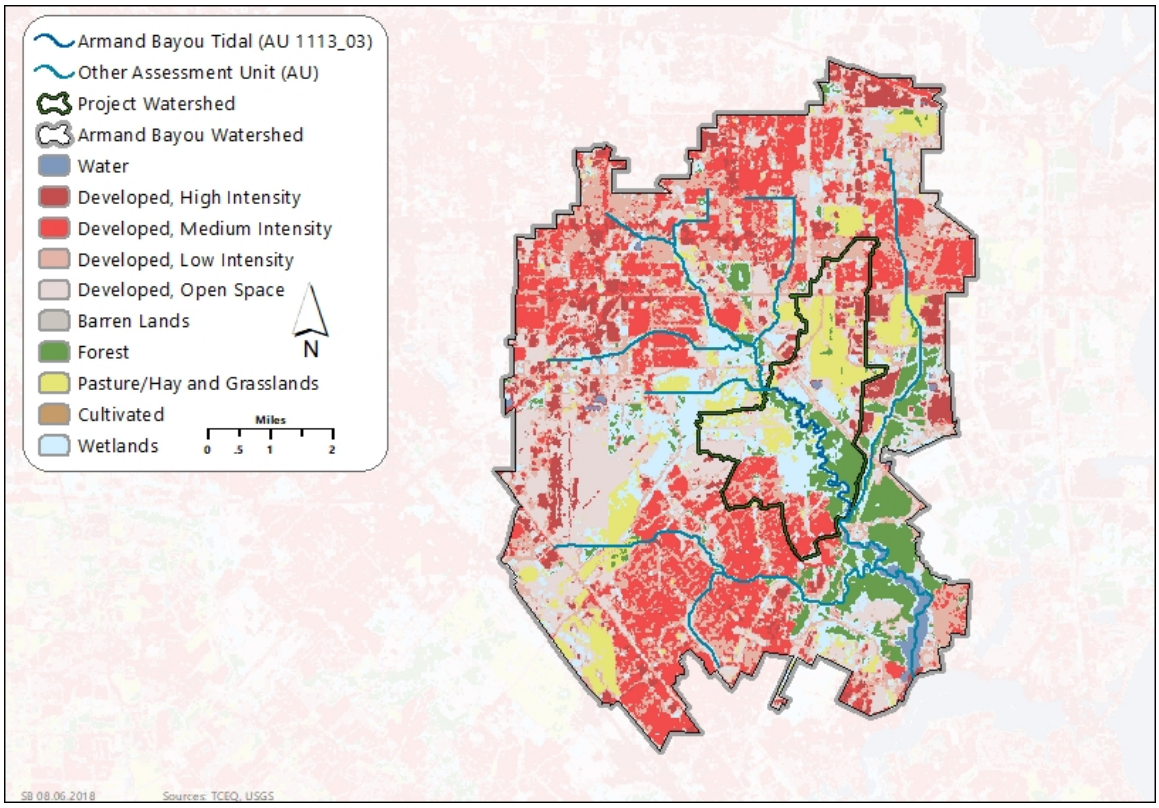

Figure 4. Land use/land cover map showing categories within the project watershed and within the entire Armand Bayou watershed.

Table 3. Land use/land cover within the project watershed.

2011 NLCD Classification	Project Area (Acres)	Percent of Total Project Area	Full Armand Bayou Watershed Area (Acres)	Percent of Full Armand Bayou Watershed
Open Water	16.9	0.4%	450.3	1.2%
Developed High Intensity	143.8	3.1%	2,660.2	7.0%
Developed Medium Intensity	652.3	14.2%	8,544.4	22.6%
Developed Low Intensity	671.1	14.7%	8,290.8	21.9%
Developed Open Space	697.2	15.2%	7,674.0	20.3%
Barren Lands	7.8	0.2%	177.8	0.5%
Forest/Shrubs	609.7	13.3%	2,686.7	7.1%
Pasture/Grasslands	787.0	17.2%	2,838.0	7.5%
Cultivated Crops	0.9	0.0%	7.6	0.0%
Wetlands	994.0	21.7%	4,510.6	11.9%
Total	4,580.7	100.0%	37,840.4	100.0%

Watershed Population and Population Projections

According to the 2010 Census (USCB and TNRIS, 2011), there are an estimated 8,071 people in the project watershed, indicating a population density of 1,127 people/square mile. The entire population of the project watershed lives within either Pasadena (3,242), Houston (2,776) or La Porte (2,053), as shown in Figure 5. Approximately 45 percent of the area of the project watershed is included within the Pasadena city limits, 17 percent is within the Houston city limits, 9 percent is within the La Porte city limits, and 28 percent is located outside of any city limits.

Also, according to the 2010 Census, there are an estimated 125,844 people in the entire Armand Bayou watershed, indicating a population density of 2,128 people/square mile. The majority of the population (47,248 people, or 38 percent) live within the Houston city limits; the remaining residents live within Pasadena (27 percent), La Porte (17 percent), Deer Park (16 percent), Taylor Lake Village (2 percent), and Webster (0.3 percent), as shown in Figure 5. Approximately 10 percent of the area of the entire Armand Bayou watershed is located outside of any city limits.

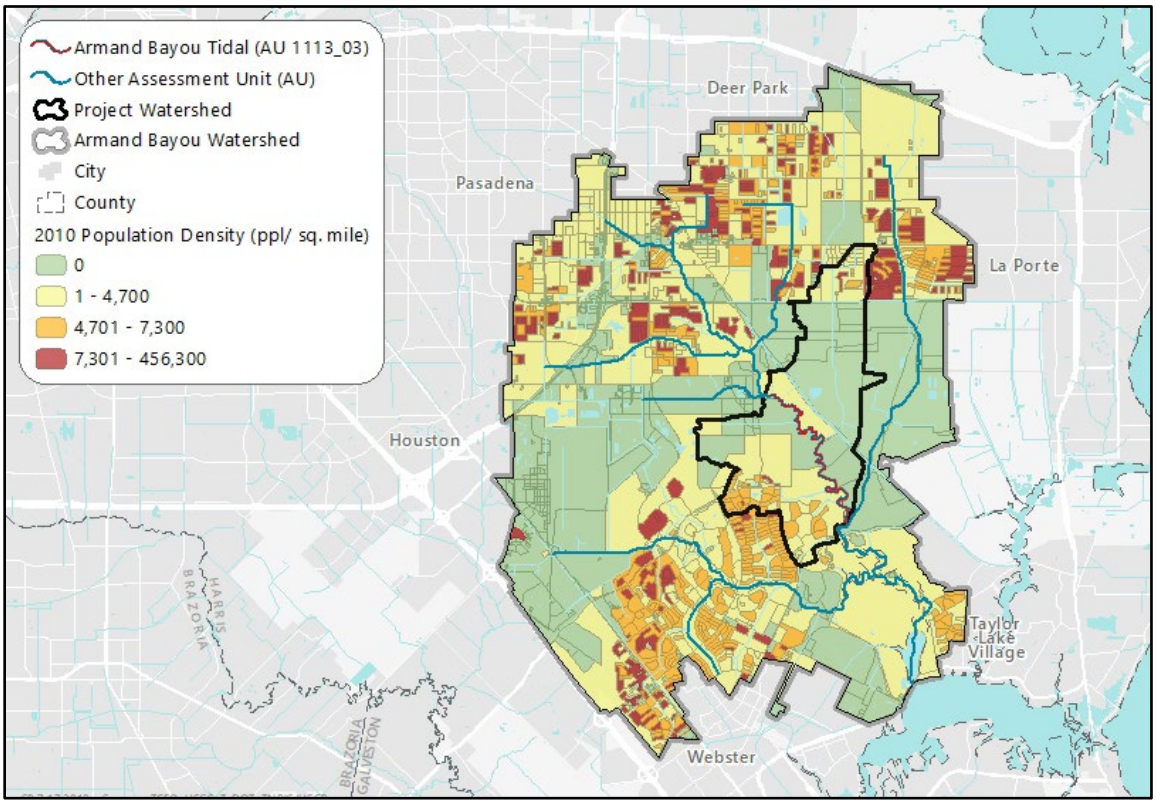

Figure 5. Population density map showing 2010 population by census block within the project watershed and the entire Armand Bayou watershed.

Population projection data, available through the state water planning process via the Office of the State Demographer and the Texas Water Development Board (TWDB, 2013), is based on areas known as Water User Groups (WUGs). Geospatial analysis based on WUGs, which allows a refinement of county and

city-level projections, reveals that populations are predicted to increase 70.2 percent in the project watershed (compared to 31.0 percent for the entire Armand Bayou watershed) between 2010 and 2050 (Table 4).

Table 4. 2010 population and 2050 population projections for the project watershed and full Armand Bayou watershed.

Location	2010 U. S. Census	2050 Population Projection	Projected Population Increase (2010-2050)	Percent Change
Project Watershed	8,071	13,737	5,666	70.2%
Full Armand Bayou Watershed	125,844	164,837	38,993	31.0%

Endpoint Identification

The endpoint for the TMDL is to maintain the concentration of Enterococci below the geometric mean criterion of 35 MPN/100mL. This endpoint is identical to the geometric mean criterion for primary contact recreation in the 2010 TSWQS (TCEQ, 2010).

Source Analysis

Regulated Sources

Permitted sources are regulated under the Texas Pollutant Discharge Elimination System (TPDES) and the National Pollutant Discharge Elimination System (NPDES) programs.

Domestic and Industrial Wastewater Treatment Facilities

Currently, no wastewater treatment facilities (WWTFs) exist within or upstream of the project watershed. There are currently three permitted WWTFs (five outfalls) within the greater Armand Bayou watershed, which are shown in Figure 6; the permits were described in the previously completed TMDL (TCEQ, 2015a).

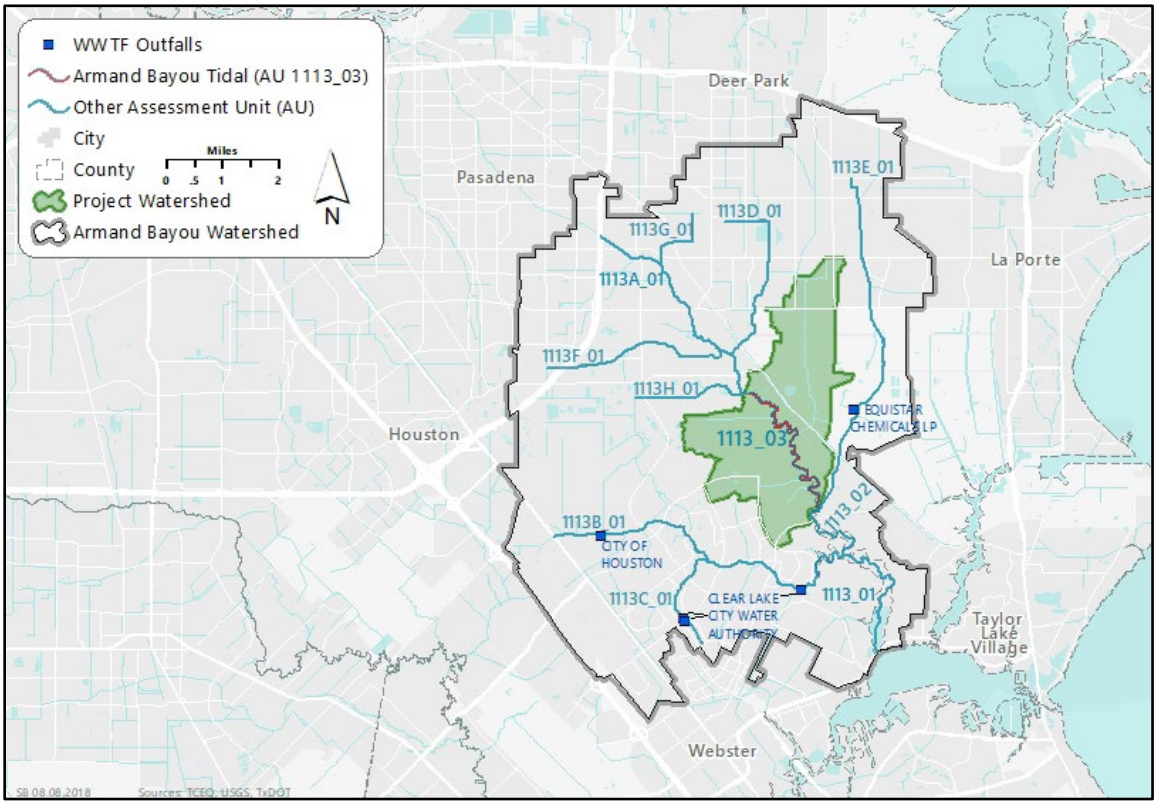

Figure 6. Map showing WWTF outfalls within the greater Armand Bayou watershed, labeled by permittee.

Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) are unauthorized discharges that must be addressed by the responsible party. The TCEQ Region 12 Office maintains a database of SSO data reported by municipalities. These SSO data typically contain estimates of the total gallons spilled, responsible entity, and a general location of the spill. For the period between January 2016 and December 2017, there were zero SSOs reported within the project watershed. A summary of the reports of SSO events that were determined to have occurred within the full Armand Bayou watershed between January 2016 and December 2017 are shown in Table 5.

Table 5. Summary of SSO incidences reported in the project watershed and full Armand Bayou watershed in 2016 and 2017.

Watershed	No. of Incidents	Total Volume (gallons)	Average Volume (gallons)	Minimum Volume (gallons)	Maximum Volume (gallons)
Project Watershed	0	-	-	-	-
Entire Armand Bayou Watershed	6	56,567	9,428	0.0001	34,325

TPDES-Regulated Stormwater

TPDES general permits cover stormwater discharges from Phase II Municipal Separate Storm Sewer Systems (MS4s; General Permit number TXR040000), industrial facilities (General Permit number TXR050000; also known as a multi-sector general permits (MSGPs)), concrete production facilities (General Permit number TXG110000), petroleum bulk stations and terminals (General Permit number TXG340000), and construction sites over one acre (General Permit number TXR150000).

In addition, Phase I MS4 permits are individual permits for large and medium-sized communities with populations exceeding 100,000, whereas Phase II permits are for smaller communities within a USEPA-defined urbanized area that are regulated by a general permit.

Three of these permits (MS4, MSGP, and construction) pertain solely to stormwater discharges. The other two (concrete production facilities and petroleum bulk stations and terminals) also authorize the discharge of process wastewater.

The area of the project watershed is covered by both Phase I and II MS4 permits; the associated permits match the jurisdictional boundaries of the regulated entities. For Phase I permits, the jurisdictional area is defined by the city limits and for Phase II permits, the jurisdictional area is defined as the intersection or overlapping areas of the city limits and the 2010 Census urbanized area.

For the Armand Bayou project watershed entities with Phase I individual permits and Phase II general permits, the areas included under these MS4 permits were used to estimate the regulated stormwater areas for construction, industrial, and MS4 permits. For the project watershed, there is essentially 100 percent coverage by the urbanized area. For this reason, the urbanized area will be used as a surrogate for the area for all regulated stormwater in the project watershed. However, even in highly urbanized areas such as this one, there remain small areas that are not strictly regulated by stormwater permits and which may receive bacteria loadings from unregulated sources such as wildlife and feral hogs. To account for these small unregulated areas in each impaired watershed, the surface area within the channel of the bayou is excluded from the urbanized area and represents an area of unregulated stormwater contribution. This estimation of an area subject to unregulated direct deposition results in an area regulated by MS4 of 4,561.46 acres or 99.58% of the watershed (Figure 7).

A review of Phase I permits and a review of the TCEQ central registry for Phase II MS4 permit coverage in the entire Armand Bayou watershed revealed one Phase I permit and four Phase II permits (Table 6; TCEQ, 2018). For the entire Armand Bayou watershed, the total area under MS4 permits is 35,536.90 acres, or 93.91% of the watershed (Figure 7).

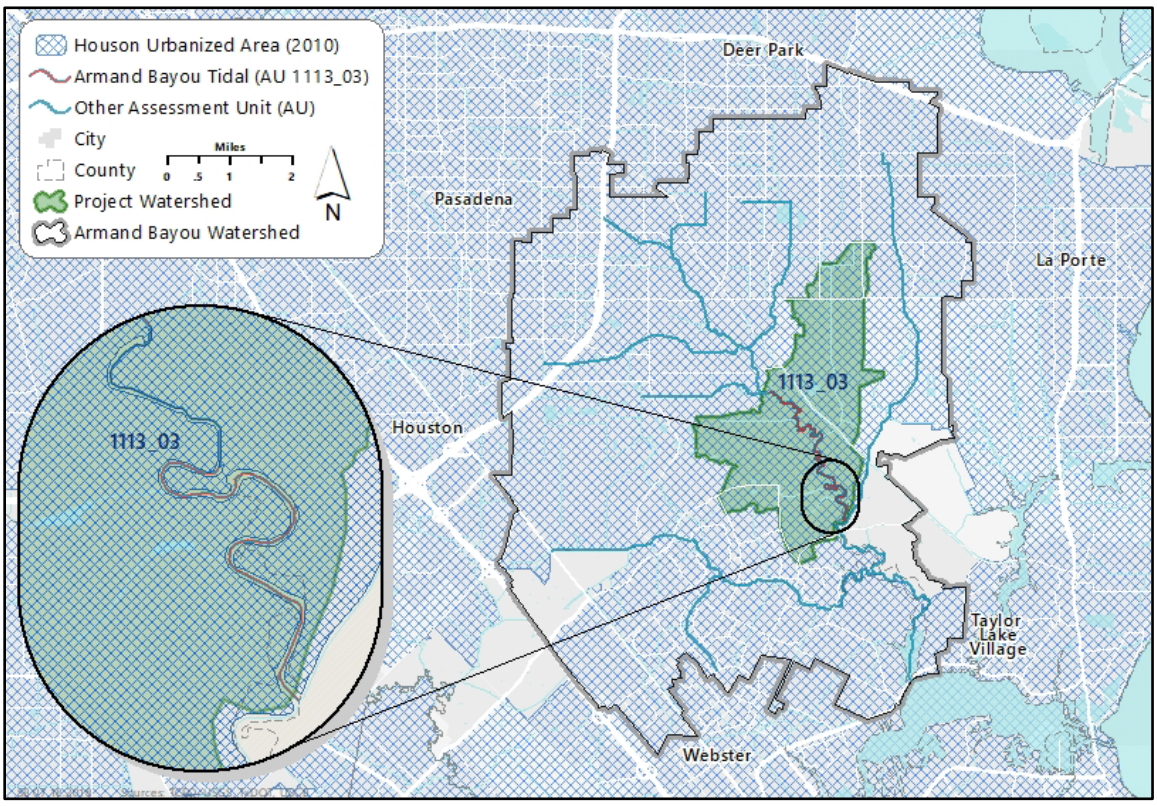

Figure 7. Map showing the regulated stormwater area based on Phase I and Phase II MS4 permits within the Armand Bayou watershed.

Table 6. TPDES and NPDES MS4 permits associated with the Armand Bayou watershed.

Entity/ Permittee	Permitted Area	TPDES Permit	NPDES Permit
City of Houston/Harris County/Harris County Flood Control District/Texas Department of Transportation	Houston	Phase 1	TXS001201
City of Deer Park	Deer Park	Phase II General Permit	TXR040388
City of La Porte	La Porte	Phase II General Permit	TXR040117
National Aeronautics and Space Administration	Houston	Phase II General Permit	TXR040214
Clear Lake City Water Authority	Pasadena, Houston, Webster and Taylor Lake Village	Phase II General Permit	TXR040388

Unregulated Sources

Unregulated sources of indicator bacteria are generally nonpoint and can originate from wildlife and feral hogs, various agricultural activities, agricultural animals, land application fields, urban runoff not covered by a permit, failing on-site sewage facilities (OSSFs), and domestic pets.

Wildlife and Unmanaged Animal Contributions

Indicator bacteria inhabit the intestines of all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify the potential for bacteria contributions from wildlife. Riparian corridors of streams and rivers naturally attract wildlife. With direct access to the stream channel, direct deposition of wildlife waste can be a concentrated source of bacteria loading to a water body. Wildlife also deposit fecal bacteria onto land surfaces, where rainfall runoff may wash bacteria into nearby streams.

Unfortunately, quantitative estimates of wildlife are rare, inexact, and often limited to discrete taxa groups or geographical areas of interest, so that even county-wide approximations of wildlife numbers are difficult or impossible to acquire.

For feral hogs, the Texas A&M Institute of Renewable Natural Resources (IRNR), recently renamed as the Texas A&M Natural Resources Institute, reported a range of feral hog densities within Texas of 1.33 to 2.45 hogs/square mile (IRNR, 2013). The average hog density (1.89 hogs/square mile) was multiplied by the hog habitat area in the project watershed (3.74 square miles). Habitat deemed suitable for hogs followed as closely as possible to the land use selections of the IRNR study and include from the 2015 H-GAC Land Cover dataset: Forest/Shrubs, Pasture/Grasslands, Cultivated Crops, and Wetlands. Using this methodology, there are an estimated 7 feral hogs in the project watershed. For the entire Armand Bayou watershed, the hog habitat was estimated using the same methodology; there is an estimated 15.69 square miles of hog habitat within the entire watershed, resulting in an estimate of 30 feral hogs.

For deer, the Texas Parks and Wildlife Department (TPWD) publishes data showing deer population-density estimates by Deer Management Unit (DMU) for monitored white-tailed deer range across the state (TPWD, 2017). The entire Armand Bayou watershed, as well as the project watershed, is located within the Urban Houston DMU, one of the few regions for which deer-density estimates were not published. Similarly, both the entire Armand Bayou watershed and the project watershed are not located within the monitored white-tailed deer range. While a quantitative estimate for deer within the project watershed could not readily be calculated, indications are that undeveloped areas along Armand Bayou would provide habitat suitable for a small population of deer (City of Houston, 2018).

Domesticated Animals

Livestock are a potential source of bacteria in the project watershed. The number of livestock that are found within the Armand Bayou watershed was estimated from county-level data obtained from the 2012 Census of Agriculture (USDA-NASS, 2014). The county-level data were refined to better reflect actual

numbers within the impaired AU watersheds. The refinement was performed by dividing the total area of the project watershed by the total area of Harris County. This ratio was then applied to the county-level livestock data and presented in Table 7. The livestock numbers below are provided to demonstrate that livestock are a potential source of bacteria in the project watershed. These livestock numbers are not used to develop an allocation of allowable bacteria loading to livestock.

Table 7. Estimated distributed domesticated animal populations within the project watershed and full Armand Bayou watershed, based on proportional area.

Watershed	Cattle and Calves	Deer and Elk (Domestic)	Goats and Sheep	Horses, Ponies, Mules, Burros, and Donkeys	Poultry
Project Watershed	144	8	15	26	40
Full Armand Bayou Watershed	1,189	65	126	218	329

Table 8 summarizes the estimated number of dogs and cats within the Armand Bayou watershed. Pet population estimates were calculated as the estimated number of dogs (0.584) and cats (0.638) per household according to data from the American Veterinary Medical Association (AVMA) 2012 U.S Pet Statistics (AVMA, 2015). The actual contribution and significance of indicator bacteria loads from pets reaching the segments of the Armand Bayou watershed is unknown.

Table 8. Estimated households and pet populations for the project watershed and full Armand Bayou watershed.

Watershed	Estimated Number of Households	Estimated Dog Population	Estimated Cat Population
Project Watershed	2,708	1,581	1,728
Full Armand Bayou Watershed	49,499	28,907	31,580

On-site Sewage Facilities

Estimates of the number of OSSFs in the Armand Bayou watershed were determined using data supplied by H-GAC for Harris County. The H-GAC data indicate that there are no OSSFs located within the project watershed, and only one in the full Armand Bayou watershed.

Linkage Analysis

The load duration curve (LDC) method was used to examine the relationship between instream water quality and the source of indicator bacteria loads. Inherent to the use of LDCs as the mechanism of linkage analysis is the

assumption of a one-to-one relationship between instream loadings and loadings originating from point sources and the landscape as regulated and non-regulated sources. Further, this one-to-one relationship was also inherently assumed when using LDCs to define the TMDL pollutant load allocation. The LDC method allows for estimation of existing and TMDL loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). An adaptation of the LDC method to tidal waters has been successfully developed and applied by the State of Oregon (ODEQ, 2006); this approach is known as the modified LDC method. In addition to estimating stream loads, this method allows for the determination of the hydrologic conditions under which impairments are typically occurring, can give indications of the broad origins of the bacteria (i.e., point source and stormwater), and provides a means to allocate allowable loadings. The technical support document (Brady et al., 2018) provides details about the linkage analysis and the LDC method and its application.

Margin of Safety

The margin of safety (MOS) is designed to account for any uncertainty that may arise in specifying water quality control strategies for the complex environmental processes that affect water quality. Quantification of this uncertainty, to the extent possible, is the basis for assigning an MOS. The TMDL covered by this report incorporates an explicit MOS of 5 percent of the total TMDL allocation.

Pollutant Load Allocation

The TMDL component for the impaired AU covered in this report was derived using the median flow within the High Flows regime (or 10 percent flow) of the LDC developed for the sampling station located within the AU watershed.

Based on the LDC to be used in the pollutant load allocation process with historical Enterococci data added to the graph (Figure 8), the following broad linkage statements can be made. For the project watershed, the historical Enterococci data show a pattern of increasing tendency for the Enterococci event data to plot below the geometric mean criterion allowable loading curve as flows decrease, which is indicated in a left to right direction along the graph. This pattern of decreasing occurrence of exceedances in the event data are summarized by the geometric means of the existing data plotted for each of the three flow regimes as compared to the allowable load line for the geometric mean criterion.

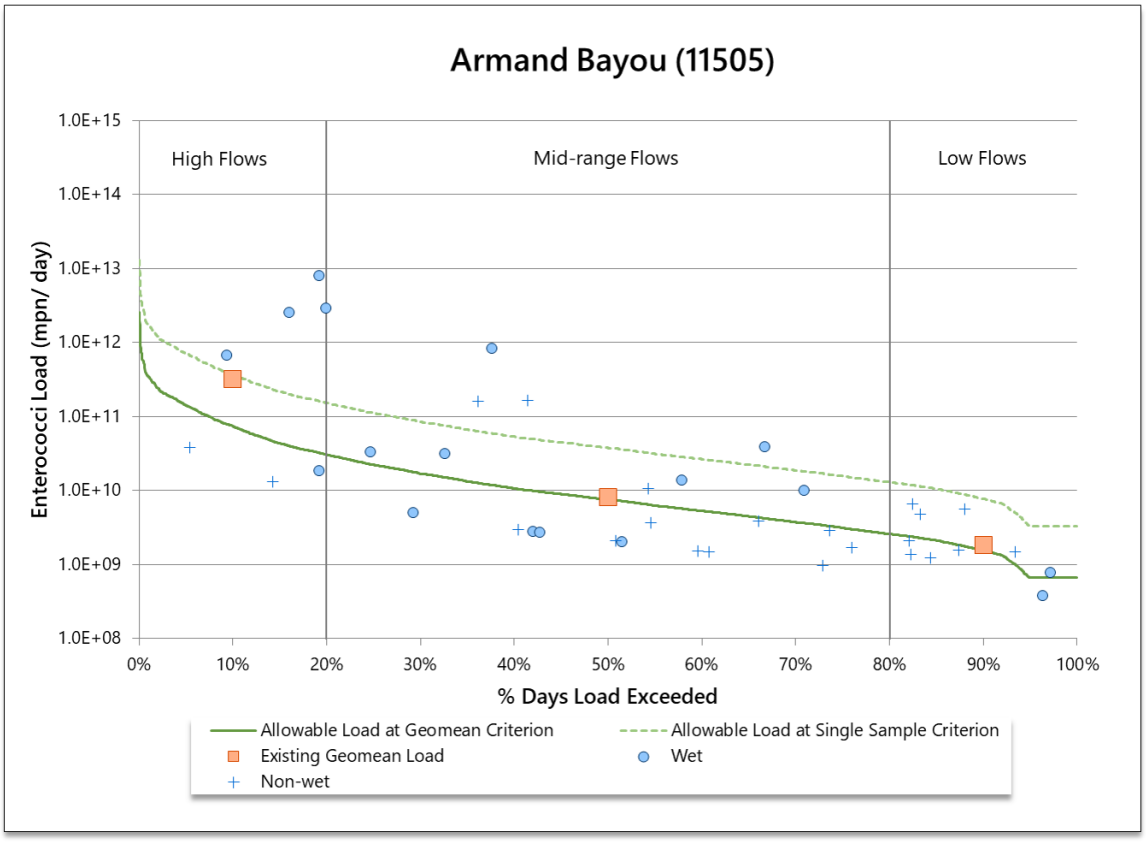

Figure 8. LDC for Armand Bayou AU 1113_03 (Station 11505)

Wasteload Allocation

The wasteload allocation (WLA) is the sum of loads from regulated sources, which are WWTFs and regulated stormwater.

Wastewater Treatment Facilities

TPDES-permitted WWTFs within tidal reaches of the original TMDL watershed were allocated a daily wasteload (WLA_{WWTF}) calculated as their full permitted discharge flow rate multiplied by a reduced portion of the instream geometric mean criterion for Enterococci. This reduction of the water quality criterion (23 MPN/100mL) was used as the WWTF target to provide instream and downstream load capacity. Due to the absence of any permitted dischargers in the project watershed, the WLA_{WWTF} term is zero.

Regulated Stormwater

Stormwater discharges from MS4, industrial, and construction sites are also considered regulated point sources. Therefore, the WLA calculations must also include an allocation for regulated stormwater discharges (WLA_{SW}). The percentage of the land area included in the project watershed that is under the jurisdiction of stormwater permits (defined as the area designated as urbanized area in the 2010 US Census) is used to estimate the amount of the overall runoff

load that should be allocated as the permitted stormwater contribution in the WLA_{SW} component of the TMDL. The percentage of land under the jurisdiction of stormwater permits in the project watershed was 99.58 percent.

Load Allocation

The load allocation (LA) component of the TMDL corresponds to runoff from unregulated sources. It is calculated by subtracting the sum of the WLA_{WWTF}, WLA_{SW}, MOS, and future growth (FG) allocations from the total TMDL allocation.

Future Growth

The FG component of the TMDL equation addresses the requirement of TMDLs to account for future loadings that might occur as a result of population growth, changes in community infrastructure, and development. The assimilative capacity of streams increases as the amount of flow increases. Increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard.

The calculation of a future growth component is typically based on population projections and current permitted wastewater dischargers for the project watershed. Because there are no dischargers to or upstream of impaired AU 1113_03, another method was used. According to Rule Section 217.32 of Texas Administrative Code (TAC), new WWTFs are to be designed for a daily wastewater flow of 75-100 gallons per capita per day (TAC, 2008). Conservatively taking the higher daily wastewater flow capacity (100 gallons) and multiplying it by a potential population change gives an estimated permitted flow for FG. Based on the information in Table 4, the projected population increase for the subject watershed for the 2010 through 2050 time period is 5,666. At the time of this report, only 28% of the project watershed is unincorporated, so a slightly reduced future new service population of 5,000 was assumed. Multiplying that value by the higher daily wastewater flow capacity yields a value of 0.50 million gallons per day. This value would be considered the full permitted discharge of a potential future WWTF. To maintain consistency with the existing TMDLs in Armand Bayou, a reduced Enterococci geometric mean limit for WWTFs of 23 MPN/100 mL was used to calculate the FG component.

The three-tiered antidegradation policy in the TSWQS prohibits an increase in loading that would cause or contribute to degradation of an existing use. The antidegradation policy applies to both point and nonpoint source pollutant discharges. In general, antidegradation procedures establish a process for reviewing individual proposed actions to determine if the activity will degrade water quality. The TMDL in this document will result in protection of existing designated uses and conform to Texas antidegradation policy.

TMDL Calculations

Table 9 summarizes the TMDL calculation for Armand Bayou Tidal AU 1113_03. The TMDL was calculated based on the median flow in the 0-20 percentile range (10 percent exceedance, High Flows flow regime) for flow exceedance from the LDC developed for the SWQM station 11505. Allocations are based on the current geometric mean criterion for Enterococci of 35 MPN/100 mL for each component of the TMDL, with the exception of the WLA_{WWTF} and FG terms, which used 23 MPN/100 mL.

The final TMDL allocations (Table 10) needed to comply with the requirements of 40 Code of Federal Regulations (CFR) Section 103.7 include the FG component within the WLA_{WWTF}.

In the event that the criterion changes due to a change in the designated recreational use, Appendix A provides guidance for recalculating the allocations in Table 10.

Table 9. TMDL allocation summary for Armand Bayou Tidal AU 1113_03.

All loads expressed as billion MPN/day Enterococci

Water Body	AU	TMDL	WLA_{WWTF}	WLA_{SW}	LA	FG	MOS
Armand Bayou Tidal	1113_03	73.838	0	69.418	0.293	0.435	3.692

Table 10. Final TMDL allocations for Armand Bayou Tidal AU 1113_03.

All loads expressed as billion MPN/day Enterococci

Water Body	AU	TMDL	WLA_{WWTF}	WLA_{SW}	LA	MOS
Armand Bayou Tidal	1113_03	73.838	0.435	69.418	0.293	3.692

Seasonal Variation

Federal regulations in 40 CFR Section 130.7(c)(1) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing Enterococci concentrations obtained from 11 years (2006 through 2017) of routine monitoring collected in the warmer months (May through September) against those collected during the cooler months (October through April). Differences in Enterococci concentrations obtained in warmer versus cooler months were then evaluated by performing a t-test on the natural log-transformed dataset. This analysis of Enterococci data indicated that there was no significant difference in indicator bacteria between cool (M = 3.98, SD = 3.30) and warm (M = 4.03, SD = 3.62) weather seasons for Armand Bayou Tidal at station 11505 (two-sample $t(37) = -0.0772$, $\alpha = 0.05$, $p = 0.0938$).

Public Participation

The TCEQ maintains an inclusive public participation process. From the inception of the TMDL study, the TCEQ project team sought to ensure that stakeholders were informed and involved. Communication and comments from the stakeholders in the watershed strengthen TMDL projects and their implementation.

The technical support document for this TMDL addition (Brady et al., 2018) was posted on the TMDL project page at: <www.tceq.texas.gov/assets/public/waterquality/tmdl/89armand/89C-ArmandBayou-TSD-Final.pdf> on August 10, 2018. A presentation on this addendum was given at the annual spring meeting of the Bacteria Implementation Group (BIG) in Houston on June 5, 2018. The public will have an opportunity to comment on this addendum during a 30-day Water Quality Management Plan update public comment period (November 9 through December 11, 2018). This is an ongoing process, so notice of the public comment period for this addendum will be sent to the stakeholders and posted on the TCEQ's TMDL Program online news page at <www.tceq.texas.gov/waterquality/tmdl/tmdlnews.html>, and the document will be posted at <www.tceq.texas.gov/permitting/wqmp/WQmanagement_updates.html>. TCEQ accepted public comments on the original TMDL during the period February 8, 2015 through March 9, 2015. Two comments were submitted, and none of them referred directly to the AU in this TMDL addendum.

Implementation and Reasonable Assurance

The segment covered by this addendum is within the existing bacteria TMDL watershed of Armand Bayou. That TMDL watershed is within the area covered by the Implementation Plan developed by the BIG for bacteria TMDLs throughout the greater Houston area, approved by the TCEQ on January 30, 2013. It outlines an adaptive management approach in which measures are periodically assessed for efficiency and effectiveness. The iterative process of evaluation and adjustment ensures continuing progress toward achieving water quality goals and expresses stakeholder commitment to the process. Please refer to the original TMDL document for additional information regarding implementation and reasonable assurance.

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Appendix A

Equations for Calculating TMDL Allocations for Contact Recreation Standard Changes

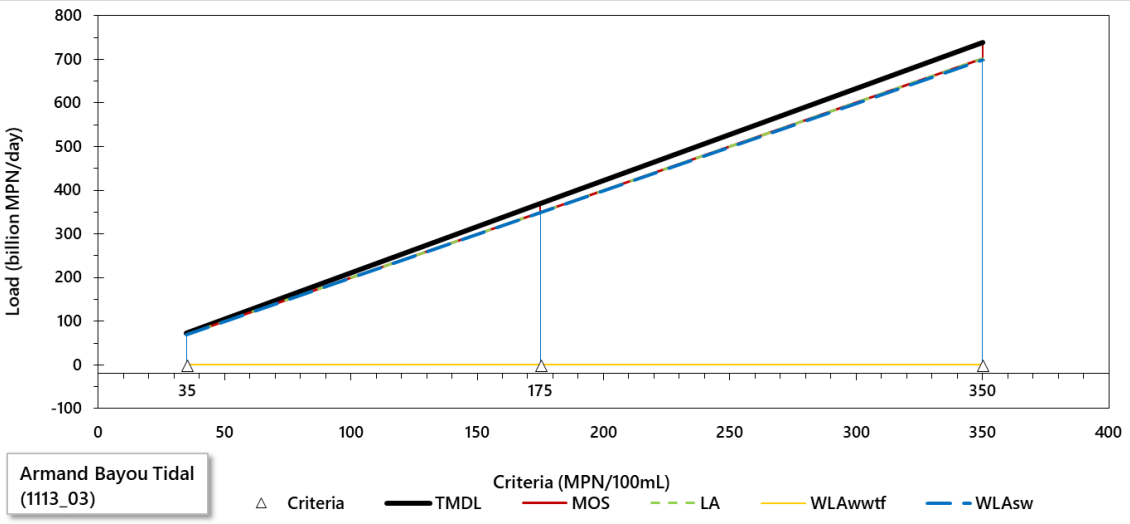

Figure A-1. Allocation loads for Enterococci for Armand Bayou Tidal (1113_03) as a function of water quality criteria.

Equations for calculating new TMDL and allocations (in billion MPN/day Enterococci):

TMDL = 2.10965398 * Std
MOS = 0.10548255 * Std
LA = 0.00841747 * Std - 0.00182787
WLA_{WWTF} = 0.435
WLA_{sw} = 1.99575396 * Std - 0.43317213

Where:

Std = Revised contact recreation standard
MOS = Margin of safety
LA = Total load allocation (unregulated sources)
WLA_{WWTF} = Waste load allocation (permitted WWTF load + future growth)
WLA_{SW} = Waste load allocation (permitted stormwater)

Table A-1. TMDL allocations for the Armand Bayou Tidal (1113_03) watershed for potential changed contact recreation standards.

All loads expressed as billion MPN/day Enterococci

Std (MPN/100mL)	TMDL	WLA_{WWTF}[1]	WLA_{SW}	LA	MOS
35	73.8380	0.4350	69.4180	0.2930	3.6920
175	369.1895	0.4350	348.8238	1.4712	18.4595
350	738.3790	0.4350	698.0807	2.9443	36.9190

[1] WLA_{WWTF} includes the future potential allocation to WWTFs.