Dickinson Bayou: Bacteria in Waters Used for Contact Recreation

- **Eight TMDLs Adopted February 8, 2012**
  Approved by EPA June 6, 2012
- **Three TMDLs Added by Addendum July 2016**
  Approved by EPA September 30, 2016 (scroll to view or print this addendum)

Prepared by the:
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Addendum One to Eight Total Maximum Daily Loads for Indicator Bacteria in Dickinson Bayou and Three Tidal Tributaries

Three Total Maximum Daily Loads for Indicator Bacteria in Dickinson Bayou

For Segments 1103, 1103D, and 1103E

Assessment Units 1103_01, 1103D_01, and 1103E_01

Introduction

The Texas Commission on Environmental Quality (TCEQ) adopted *Eight Total Maximum Daily Loads for Indicator Bacteria in Dickinson Bayou and Three Tidal Tributaries: Segments 1103, 1103A, 1103B, 1103C, 1104* (TCEQ, 2012a) on February 8, 2012. The total maximum daily loads (TMDLs) were approved by the United States Environmental Protection Agency (EPA) on June 6, 2012. This document represents an addendum to the original TMDL document.

This addendum includes information specific to three additional assessment units (AUs) located within the watershed of the approved TMDL project for bacteria in Dickinson Bayou. Concentrations of indicator bacteria in these AUs exceed the criteria used to evaluate attainment of the contact recreation standard. This addendum presents the new information associated with the three additional AUs. For background or other explanatory information, please refer to the *Technical Support Document for Three Total Maximum Daily Loads for Indicator Bacteria in Dickinson Bayou: Segments 1103, 1103D, and 1103E* (Painter and Hauck, 2014). Refer to the original, approved TMDL document for details related to the overall Dickinson Bayou watershed as well as the methods and assumptions used in developing all of these TMDLs.

This addendum focuses on the subwatersheds of three additional AUs. These subwatersheds, including the regulated facilities within them, were addressed

in the original TMDL. This addendum provides the details related to developing the TMDL allocations for these additional AUs, which were not specifically addressed in the original document.

Problem Definition

The TCEQ first identified the bacteria impairments within the Dickinson Bayou Tidal segment included within this addendum in 1996, and within the Gum Bayou and Cedar Creek segments, which are also included in this addendum, in 2010 (Table 1). The segments have been listed in each subsequent edition through the *2014 Texas Integrated Report of Surface Water Quality for Clean Water Sections 305(b) and 303(d)* (2014 Integrated Report). The impaired AUs are Dickinson Bayou Tidal (1103_01), Gum Bayou (1103D_01), and Cedar Creek (1103E_01), as shown in Figure 1. While portions of the Dickinson Bayou watershed are in Brazoria County, these TMDL additions are entirely within Galveston County.

Table 1. Synopsis of Integrated Report for addendum water bodies in the subwatersheds of Dickinson Bayou

Water Body	Segment	AU	Parameter	Contact Recreation Use	Year First Impaired	Category
Dickinson Bayou Tidal	1103	1103_01	Enterococcus	Nonsupport	1996	5a
Gum Bayou	1103D	1103D_01	Enterococcus	Nonsupport	2010	5a
Cedar Creek	1103E	1103E_01	*E. coli*	Nonsupport	2010	5a

The Texas surface water quality standards (TSWQS; TCEQ, 2010) provide numeric and narrative criteria to evaluate attainment of designated uses. The basis for water quality targets for all TMDLs developed in this report will be the numeric criteria for bacterial indicators from the 2010 TSWQS. *Escherichia coli* (*E. coli*) are the preferred indicator bacteria for assessing contact recreation use in freshwater, while Enterococci are preferred for highly saline inland waters and saltwater. *E. coli* are the relevant indicator for Cedar Creek (1103E_01); Enterococci are the relevant indictor for Gum Bayou (1103D_01) and Dickinson Bayou Tidal (1103_01).

Table 2 summarizes the ambient water quality data for the TCEQ water quality monitoring (WQM) stations on each impaired water body, as reported in the 2014 Integrated Report (TCEQ, 2014b). The 2014 assessment data indicates non-support of the primary contact recreation use for the three addendum AUs, because the geometric mean concentrations exceed the geometric mean criterion of 35 most probable number (MPN) per 100 milliliters (mL) Enterococci (Dickinson Bayou Tidal 1103_01 and Gum Bayou 1103D_01) or 126 MPN/100 mL *E. coli* (Cedar Creek 1103E_01).

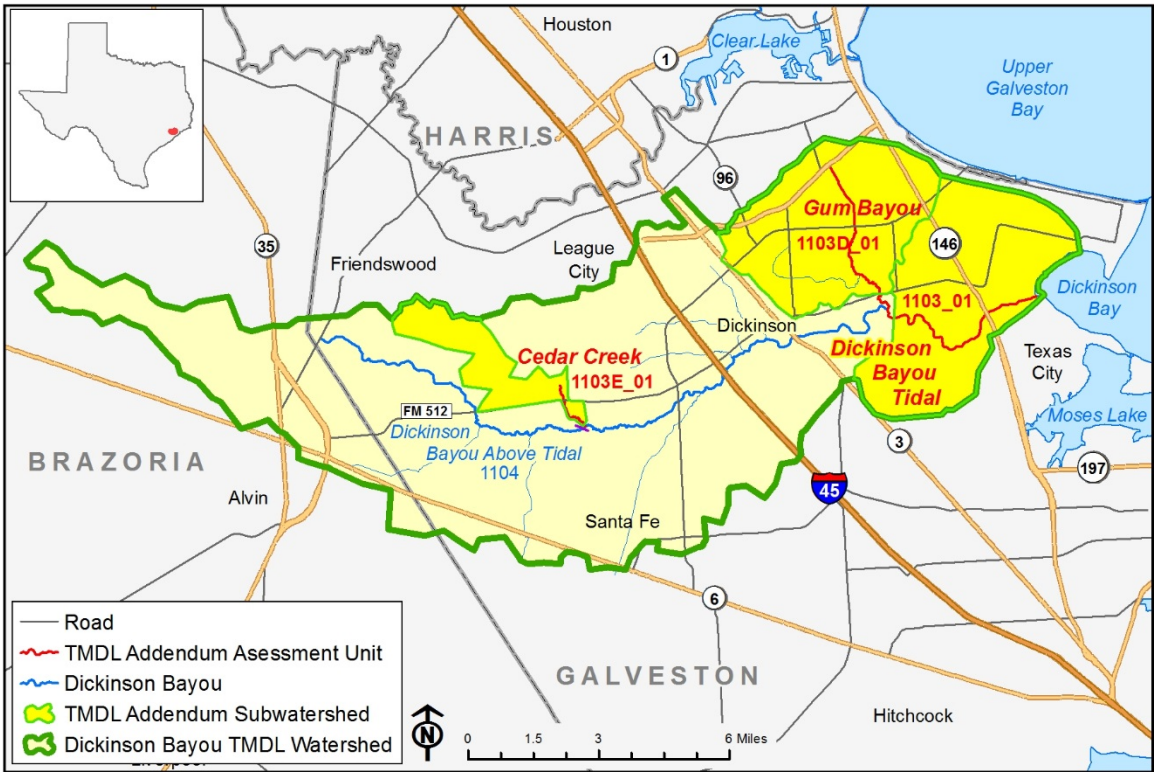

Figure 1. Overview map showing the entire Dickinson Bayou watershed, along with the TMDL addendum subwatersheds, including AUs 1103_01 (Dickinson Bayou Tidal), 1103D_01 (Gum Bayou), and 1103E_01 (Cedar Creek)

Sources: Assessment Units (TCEQ, 2011), Watershed boundaries adapted from (TCEQ, 2012a)

Table 2. 2014 Integrated Report summary for the addendum TMDL AUs

(The geometric mean criterion for primary contact recreation use is 35 MPN/100 mL for Enterococci and 126 MPN/ 100 mL for *E. coli.*)

Source: (TCEQ, 2014b)

Water Body	**AU**	**Parameter**	**No. of Samples**	**Data Range**	**Station Geometric Mean** (MPN/100 mL)
Dickinson Bayou Tidal	1103_01	Enterococcus	32	2005 –2012	72.75
Gum Bayou	1103D_01	Enterococcus	32	2005 –2012	112.42
Cedar Creek	1103E_01	*E. coli*	30	2005 –2012	126.62

Watershed Overview

Dickinson Bayou, located along the Texas Gulf Coast in the southeastern portion of the Greater Houston metropolitan area, is composed of both freshwater and tidal segments. The above-tidal portion of the bayou is a perennial freshwater stream, while the below-tidal portion is influenced by seawater from lower Galveston Bay. For the purpose of this addendum, the entire watershed of Dickinson Bayou is considered in this overview section. The remainder of this document will focus on the water bodies of the bacteria impairments — the most-downstream AU of Dickinson Bayou Tidal (1103_01) and two tributaries to the tidal segment: Gum Bayou (1103D_01) and Cedar Creek (1103E_01) (Figure 1).

Cedar Creek (1103E_01) is a freshwater stream that extends 1.3 miles to its confluence with Dickinson Bayou Above Tidal and drains an area of 4.2 square miles. Gum Bayou (1103D_01) is a tidal tributary stream that is 4.4 miles in length and drains an area of 13.7 square miles. The furthest downstream AU of Dickinson Bayou Tidal (1103_01) is 5.0 miles in length and drains an immediate area of 15.8 square miles.

The 2014 Integrated Report (TCEQ, 2014a) provides the following segment and detailed AU descriptions for the water bodies considered in this document:

- Segment 1103 Dickinson Bayou Tidal – From the Dickinson Bay confluence 2.1 km (1.3 miles) downstream of State Highway (SH) 146 in

Galveston County to a point 4.0 km (2.5 miles) downstream of FM 517 in Galveston County

- AU_ID: 1103_01 – From the Dickinson Bay confluence (downstream of SH 146) upstream to the Gum Bayou confluence

- Segment 1103D (Same as AU 1103D_01) Gum Bayou – From the Dickinson Bayou Tidal confluence to SH 96 in Galveston County
- Segment 1103E (Same as AU 1103E_01) Cedar Creek – From the Dickinson Bayou Tidal confluence to a point 0.63 km (0.39 mi) upstream of FM 517 in Galveston County

The Dickinson 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). For the period from 1981 to 2010, average annual precipitation over the entire Dickinson Bayou watershed was 56.1 inches (PRISM, 2012).

In League City, the location of the Houston National Weather Service Office (NWSO), the average high temperatures generally reach their peak of 91°F in July and August, and highs above 100ºF are common in June, July, and August. Fair skies generally accompany the highest temperatures of summer when nightly average lows drop to about 73ºF (NOAA, 2014). During winter, the average low temperature bottoms out at 43ºF in January (NOAA, 2014). The frost-free period in the region generally lasts for about 303 days, with the average last frost occurring February 12 and the average first frost occurring on December 12 (SRCC, 1994). At the Houston NWSO station, the wettest month is normally September (7.2 in), and the driest month is normally February (2.9 inches), although rainfall typically occurs year-round (NOAA, 2014) (Figure 2).

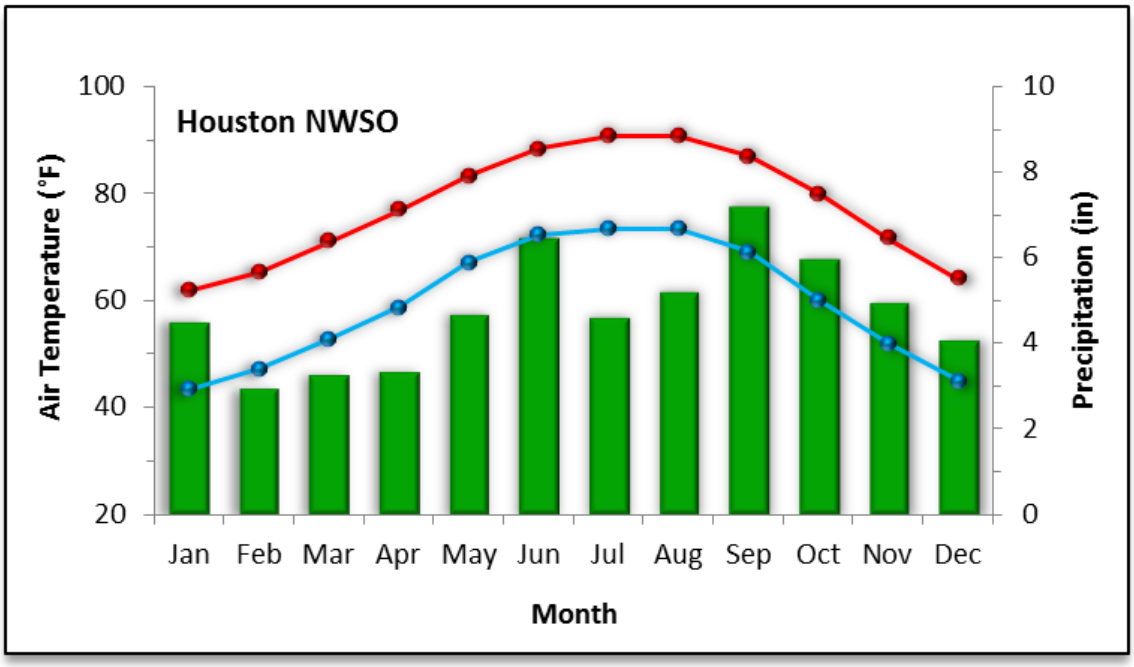

Figure 2: Average minimum (blue line) and maximum (red line) air temperatures, and total precipitation (green bars) by month over 1981-2010 for the Dickinson Bayou area

Source: (NOAA, 2014)

The land use / land cover data for the Dickinson Bayou watershed, obtained from the 2011 National Land Cover Database (NLCD), is displayed in Table 3 and shown in Figure 3. The dominant land uses in the area encompassing the entire Dickinson Bayou watershed, (including portions not in this TMDL addendum) are Hay/Pasture (23%) followed by Developed, Open Space (19%). While the watershed is predominantly rural in land use, the total of development classes is 39% (the sum of Developed Open Space, Developed Low Intensity, Developed Medium intensity, and Developed High Intensity). In the Dickinson Bayou Tidal subwatershed (1103_01), the predominant NLCD classification is Hay/Pasture (32%); in the Gum Bayou subwatershed, the predominant classification is Low Intensity Developed (23%); and in the Cedar Creek subwatershed (1103E_01), the predominant classification is Cultivated Crops (70%).

Table 3. Land use / land cover within the three TMDL addendum subwatersheds and Dickinson Bayou

Source: (USGS, 2011)

2011 NLCD	Dickinson Bayou Tidal Subwatershed (1103_01)		Gum Bayou Subwatershed (1103D_01)		Cedar Creek Subwatershed (1103E_01)		Entire Dickinson Bayou Watershed[a]	
Classification	**mi^2**	**% of Total**	**mi^2**	**% of Total**	**mi^2**	**% of Total**	**mi^2**	**% of Total**
Barren Land	0.3	2%	0.1	1%	0.0	0%	0.8	1%
Cultivated Crops	0.0	0%	0.0	0%	2.9	70%	10.7	10%
Deciduous Forest	0.8	5%	0.7	5%	0.1	2%	5.5	5%
Developed, High Intensity	0.1	1%	0.4	3%	0.0	0%	1.7	2%
Developed, Low Intensity	1.4	9%	3.1	23%	0.0	0%	11.5	11%
Developed, Medium Intensity	0.6	4%	2.1	16%	0.0	0%	7.0	7%
Developed, Open Space	1.9	11%	3.0	22%	0.1	2%	20.0	19%
Emergent Herbaceous Wetlands	1.0	6%	0.4	3%	0.0	0%	2.4	2%
Evergreen Forest	0.1	1%	0.0	0%	0.1	2%	2.4	2%
Hay/Pasture	5.2	32%	2.0	15%	0.5	12%	24.1	23%
Herbaceous	1.4	9%	0.5	4%	0.0	0%	5.5	5%
Mixed Forest	0.0	0%	0.0	0%	0.0	0%	0.5	0%
Open Water	1.6	10%	0.2	1%	0.0	0%	2.5	2%
Shrub/Scrub	0.9	6%	0.2	1%	0.2	5%	5.8	5%
Woody Wetlands	0.6	4%	0.8	6%	0.3	7%	6.1	6%
Total[b]	**15.8**	**100%**	**13.7**	**100%**	**4.2**	**100%**	**106.5 [a]**	**100%**

[a]Includes AUs not in this TMDL addendum

[b]Some totals affected slightly by rounding within individual land use/land cover classes

mi^2 – square miles

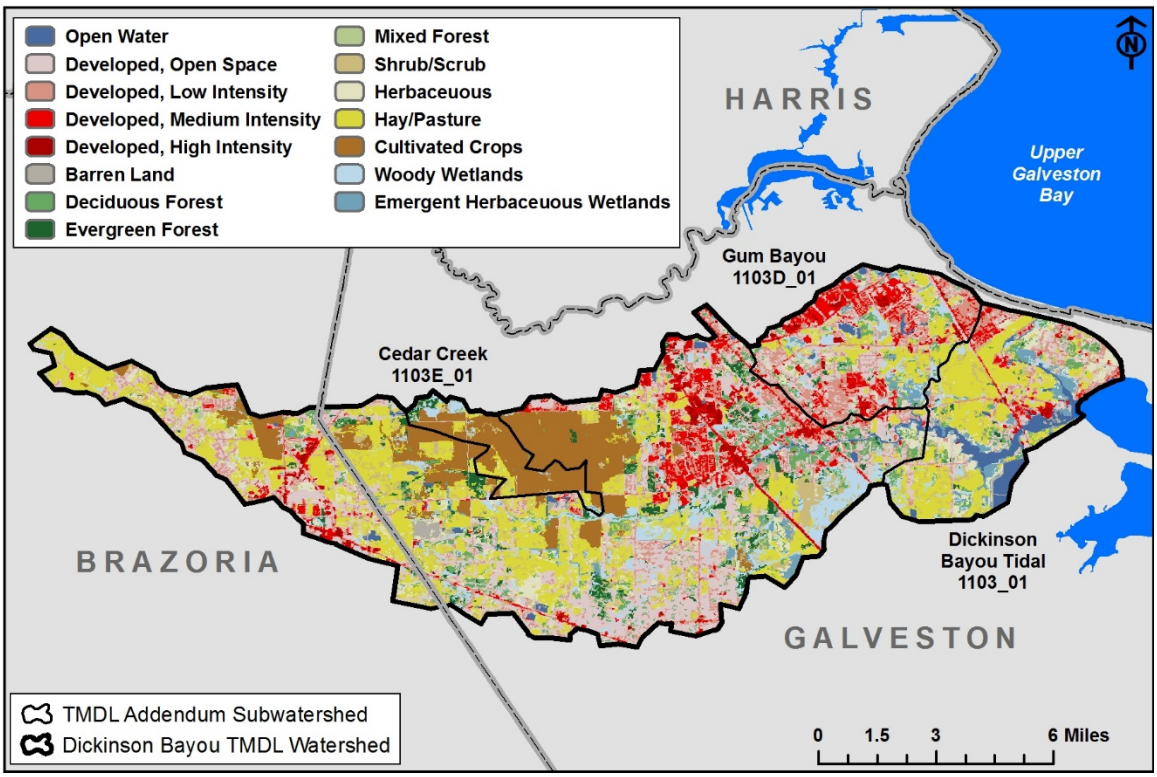

Figure 3. 2011 land use / land cover within the Dickinson Bayou watershed

Source: (USGS, 2011)

Endpoint Identification

The water quality target for the Dickinson Bayou and Gum Bayou TMDLs is to maintain concentrations of Enterococci below the saline geometric mean criterion of 35 MPN/100 mL. This endpoint is identical to the geometric mean criterion in the 2010 TSWQS (TCEQ, 2010) for primary contact recreation in saline water bodies.

The water quality target for the Cedar Creek TMDL is to maintain concentrations of *E. coli* below the freshwater geometric mean criterion of 126 MPN/100 mL. This endpoint is the geometric mean criterion in the 2010 TSWQS (TCEQ, 2010) for primary contact recreation in freshwater bodies.

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. Wastewater treatment facility (WWTF) outfalls and stormwater discharges from industries represent the regulated sources in the Dickinson Bayou watershed.

Domestic and Industrial Wastewater Treatment Facilities

As shown in Figure 4 and Table 4, six WWTFs discharge to the addendum subwatersheds: Sea Lion Technology Inc., Bayou Development LLC, Hillman Shrimp and Oyster Co., South Central Water Company, United Development Funding LP, and Clean Harbors San Leon Inc. (previously DuraTherm Inc.)

Three facilities exclusively treat domestic wastewater: Bayou Development LLC, United Development Funding LP, and South Central Water Company. Two additional facilities discharge both industrial stormwater and wastewater: Sea Lion Technology Inc. and Hillman Shrimp and Oyster Co. Currently, Clean Harbors San Leon Inc. only discharges industrial stormwater.

However, on December 14, 2015, Clean Harbors San Leon Inc. applied for an amendment to TPDES permit WQ0004086000 to discharge an additional 105,000 gallons per day of non-bacterial industrial process wastewater. If approved, this amendment will not add a bacteria load to the addendum AUs.

Note that while the Sea Lion Technology facility is located outside of the subwatersheds, it discharges into a canal that flows into Dickinson Bayou Tidal. Conversely, two facilities: Bacliff MUD WQ0010612000 and San Leon MUD WQ0011546000 are located within the Dickinson Bayou Tidal subwatershed, but discharge directly into Galveston Bay and do not add a bacteria load to the addendum AUs.

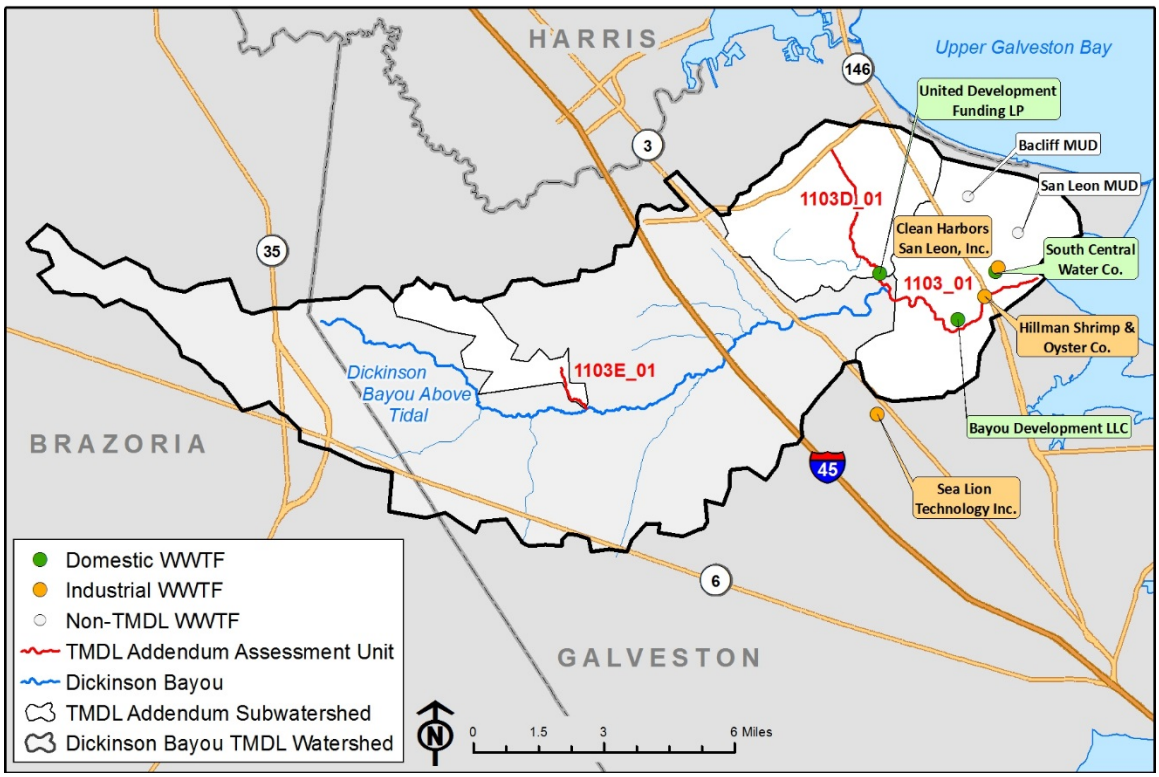

Figure 4. Dickinson Bayou addendum subwatersheds showing WWTFs. Sea Lion Technology facility is outside of Dickinson Bayou Tidal, but discharges into it. Conversely, Bacliff MUD and San Leon MUD are located within Dickinson Bayou Tidal, but discharge directly to Galveston Bay.

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. A summary of the SSO incidents that occurred within the Dickinson Bayou watershed between October 2004 and January 2012 is presented in Table 5. The only facility reporting spills was Galveston County Water Control and Improvement District 1, which is in the Dickinson Bayou watershed, but not in the addendum subwatersheds.

Table 4. Permitted WWTFs in the TMDL Addendum subwatersheds

Source: Individual TPDES Permits

AU	TPDES Permit No.	NPDES Permit No.	Facility	Permit Held By	Discharge Type	Final Permitted Discharge (mgd)[a]	Recent Discharge (mgd)[b]
1103_01	WQ0003479000	TX0108367	Sea Lion Technology	Sea Lion Technology Inc.	Non-process area stormwater runoff, utility wastewater	n/a for Outfalls 001, 101 0.02 for Outfall 201	0.103
1103_01	WQ0003749000	TX0112861	Galveston Co. Plant	Hillman Shrimp and Oyster Co.	Seafood washwater, domestic wastewater and effluent	0.07	0.000
1103_01	WQ0004086000	TX0117757	Clean Harbors San Leon, Inc.[c]	Clean Harbors San Leon, Inc.[c]	Stormwater associated with industrial activity[d]	n/a	0.528
1103_01	WQ0014326001	TX0124761	Galveston Bay RV	Bayou Development LLC	Treated domestic wastewater	0.02	0.002
1103_01	WQ0014804001	TX0129631	Dolphin Cove WWTF	South Central Water Company	Treated domestic wastewater	0.95	no data
1103D_01	WQ0014570001	TX0127248	Marlin Atlantis White WWTF	United Development Funding LP	Treated domestic wastewater	0.5	no data

[a] Significant figures reflect million gallons per day (mgd) presented in TPDES permits

[b] Average measured discharge from Jan. 2009 through Dec. 2013, as available

[c] Previously known as DuraTherm, Inc.

[d] Currently only stormwater, but there is a wastewater permit application pending.

Table 5. Summary of SSO incidents reported in the Dickinson Bayou watershed from Oct. 2004 – Jan. 2012

(Incidents are in the Dickinson Bayou watershed, but outside of the TMDL addendum subwatersheds.)

Source: TCEQ Region 12

AU	Number of Incidents	Total Gallons	Max Gallons	Average Gallons
1103_03	23	257,440	96,580	11,193

TPDES-Regulated Stormwater

The geographic region of the TMDL addendum subwatersheds covered by Phase I and II municipal separate storm sewer system (MS4) permits is that portion of the area within the jurisdictional boundaries of the regulated entities. For Phase I permits, the jurisdictional area is defined by the city limits. However, 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.

No Phase I individual permits exist in the Dickinson Bayou watershed. For the TMDL addendum subwatersheds containing entities with Phase II general permits, the areas included under these MS4 permits were used to estimate the areas under stormwater regulation for construction, industrial, and MS4 permits, as shown in Figure 5.

The regulated area for the Phase II permits was based on the 2010 Urbanized Area from the U.S. Census Bureau. The entities regulated under MS4 permits for the Dickinson Bayou subwatersheds are provided in Table 6. The AUs were identified using geographic information system (GIS) analysis, which consisted of interpreting the permitted site descriptions using relevant GIS coverages for 2010 Urbanized Areas, city boundaries, and drainage district boundaries. The associated AUs were those that either intersected the identified areas or immediately drained the identified areas. The percentage of land area under jurisdiction of stormwater permits for each of the TMDL addendum subwatersheds is presented in Table 7.

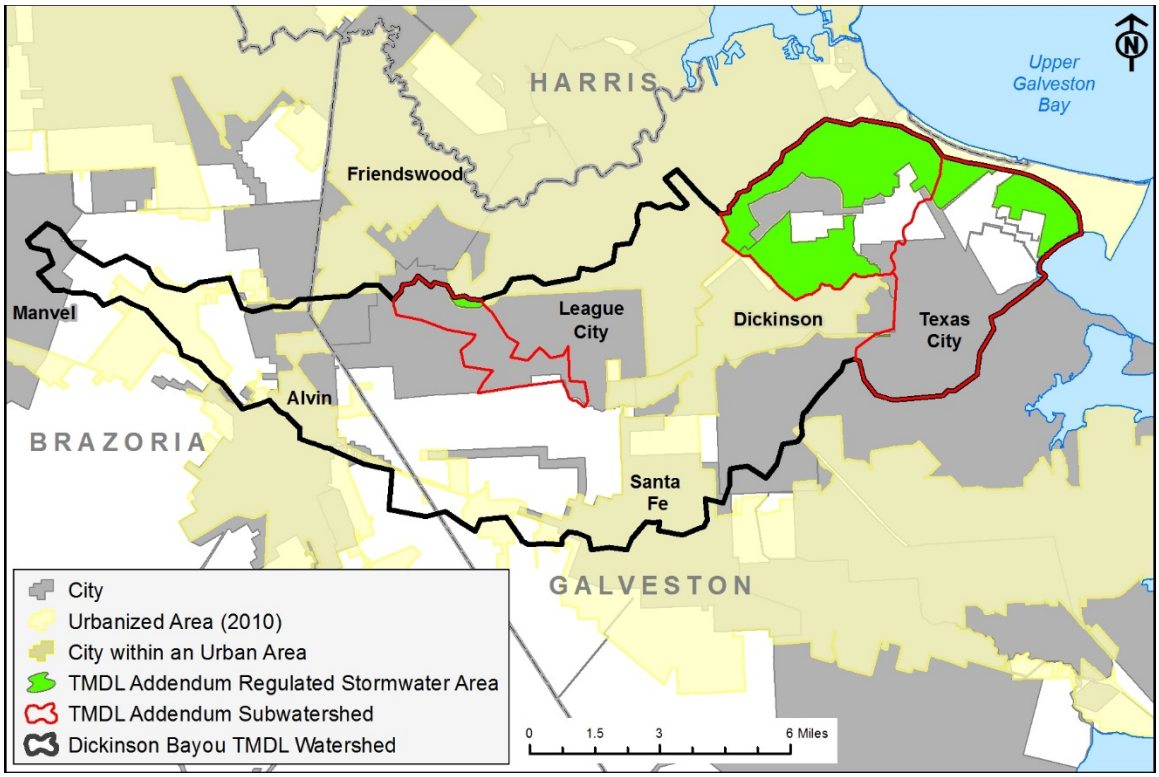

Figure 5. TMDL addendum subwatersheds showing areas under stormwater regulation

Source: (USCB, 2010)

Unregulated Sources

Unregulated sources of indicator bacteria are generally nonpoint and can emanate from wildlife (including 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

Currently there are insufficient data available to estimate populations and spatial distribution of wildlife and avian species by subwatershed. Consequently, it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category.

Table 6. TPDES MS4 permits associated with Dickinson Bayou AUs.

Permit Number	Entity	Subwatershed	AUs
TXR040138	City of Alvin	Other[a]	1104_01
			1104A_02
TXR040271	City of Dickinson	Dickinson Bayou Tidal	1103_01
		Other [a]	1103_02
			1103_03
			1103A_01
			1103B_01
			1103C_01
			1103F_01
TXR040233	City of Friendswood	Other[a]	1104_02
TXR040193	City of Santa Fe	Other[a]	1103F_01
			1104B_01
TXR040364	Galveston County	Other[a]	1103_04
			1103B_01
		Gum Bayou	1103D_01
		Other[a]	1103F_01
			1104B_01
TXR040067	Galveston County Consolidated Drainage District	Other[a]	1104_02
TXR040203	Galveston County Drainage District 1	Dickinson Bayou Tidal	1103_01
		Other[a]	1103_02
			1103_03
			1103F_01
			1104_01
			1104A_01
			1104B_01
TXR040024	City of Texas City	Dickinson Bayou Tidal	1103_01
		Other[a]	1103_02
			1103_03
			1103_04
TXR040249	City of League City	Cedar Creek	1103E_01

[a] Other portions of Dickinson Bayou watershed not included in this TMDL addendum

Table 7. Estimated area under stormwater permit regulations for TMDL addendum subwatersheds

Source: (USCB, 2010)

Subwatershed	AU	AU Urbanized Area (mi^2)	AU Subwatershed Area (mi^2)	Percentage Stormwater Regulation (%)
Dickinson Bayou Tidal	1103_01	2.68	15.81	16.95%
Gum Bayou	1103D_01	9.12	13.67	66.72%
Cedar Creek	1103E_01	0.15[a]	4.16	3.61%

[a] Too small to see clearly in Figure 5

Domesticated Animals

The estimated livestock numbers in Table 8 are provided to demonstrate that livestock are a potential source of bacteria in all three of the subject subwatersheds. These numbers, however, are not used to develop an allocation of allowable bacteria loading to livestock.

Table 8. Livestock population estimates for TMDL addendum subwatersheds

Subwater-shed	AU	Cattle and Calves	Goats	Hogs and Pigs	Horses and Ponies	Mules, Burros and Donkeys	Poultry	Sheep and Lambs
Dickinson Bayou Tidal	1103_01	1,018	45	21	71	8	176	17
Gum Bayou	1103D_01	375	16	8	26	3	64	6
Cedar Creek	1103E_01	93	4	2	6	1	14	1

For livestock other than cattle, the animal population was estimated by allocating the county animal population from the 2012 Census of Agriculture (USDA, 2012). The cattle population was estimated from stock rates and pasture area. Stock rates were provided by the Natural Resources Conservation Service (NRCS, 2015), and reviewed by the Texas State Soil and Water Conservation Board (TSSWCB, 2015).

On-site Sewage Facilities

Estimates of the number of OSSFs in the impaired subwatersheds were determined using Houston-Galveston Area Council (H-GAC) supplied data (H-GAC, 2014) for OSSFs registered since 1985. In addition, H-GAC estimated

OSSF locations that pre-dated registration requirements by using maps and aerial photography to identify dwellings without access to WWTF service. The combined dataset is shown in Table 9 and Figure 6.

Table 9. OSSF estimate for TMDL addendum subwatersheds

Subwatershed	AU	OSSFs
Dickinson Bayou Tidal	1103_01	72
Gum Bayou	1103D_01	393
Cedar Creek	1103E_01	3

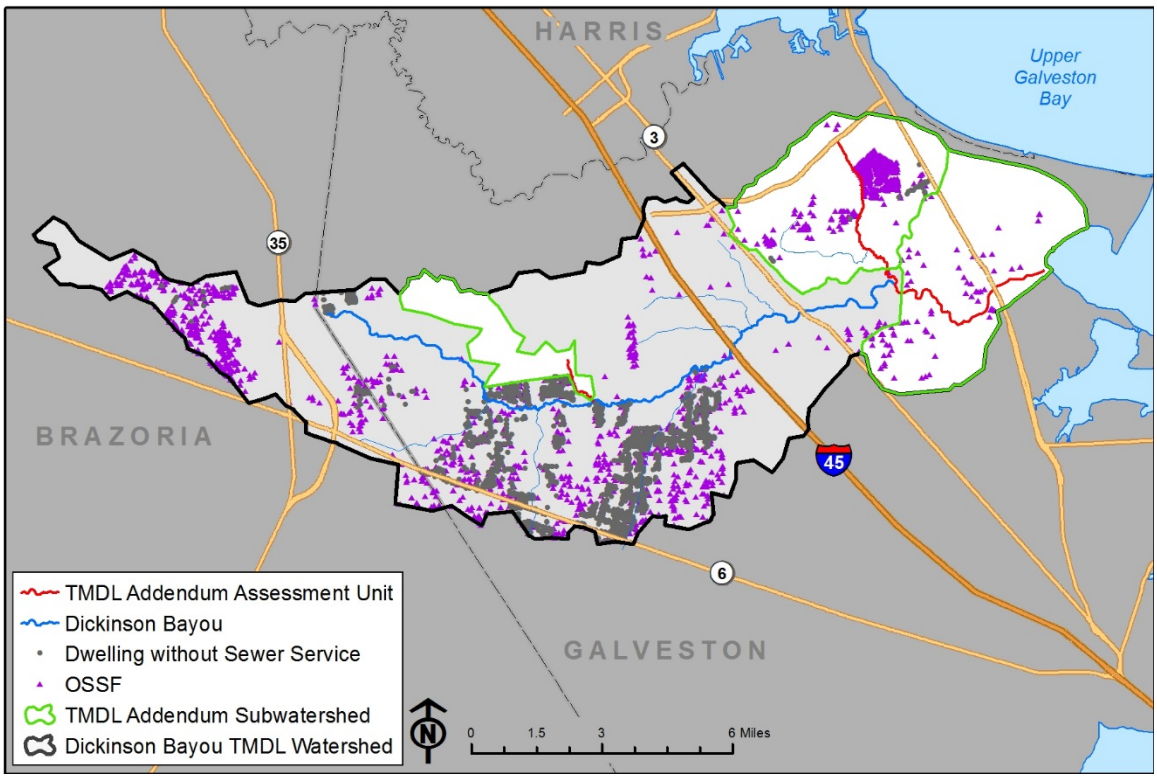

Figure 6. OSSF locations within the Dickinson Bayou watershed

Source: (H-GAC, 2014)

Domestic Pets

Fecal matter from dogs and cats is transported to streams by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 10 summarizes the estimated number of dogs and cats for each AU of the TMDL addendum subwatersheds. Pet population estimates were calculated as the estimated number of dogs (0.584) and cats (0.632) per

household (AVMA, 2012). The actual contribution and significance of fecal coliform loads reaching the water bodies of the impaired subwatersheds is unknown.

Table 10. Estimated households and pet populations for TMDL addendum subwatersheds

Subwatershed	AU	Estimated Number of Households	Estimated Dog Population	Estimated Cat Population
Dickinson Bayou Tidal	1103_01	1,831	1,069	1,157
Gum Bayou	1103D_01	7,545	4,406	4,768
Cedar Creek	1103E_01	37	22	23

Linkage Analysis

For Cedar Creek, load duration curve (LDC) analysis was used to examine the relationship between instream water quality and the source of indicator bacteria loads. For Dickinson Bayou and Gum Bayou, the combined tools of Hydrological Simulation Program - Fortran (HSPF) and a tidal prism model (TPM) were used to establish the linkage between instream water quality and the source of indicator bacteria loads. The Technical Support Document (Painter and Hauck, 2014) provides details about the analyses, tools, and their applications.

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 TMDLs covered by this report incorporate an explicit MOS by setting a target for indicator bacteria loads that is 5 percent lower than the geometric mean criterion.

Pollutant Load Allocation

For each addendum TMDL subwatershed, pollutant load allocations are developed for the most-downstream sampling location that is routinely sampled. This establishes a distinct TMDL for each of these 303(d)-listed water bodies. For Dickinson Bayou Tidal the station is 11455, for Gum Bayou the station is 11436, and for Cedar Creek the station is 11434 (Figure 7).

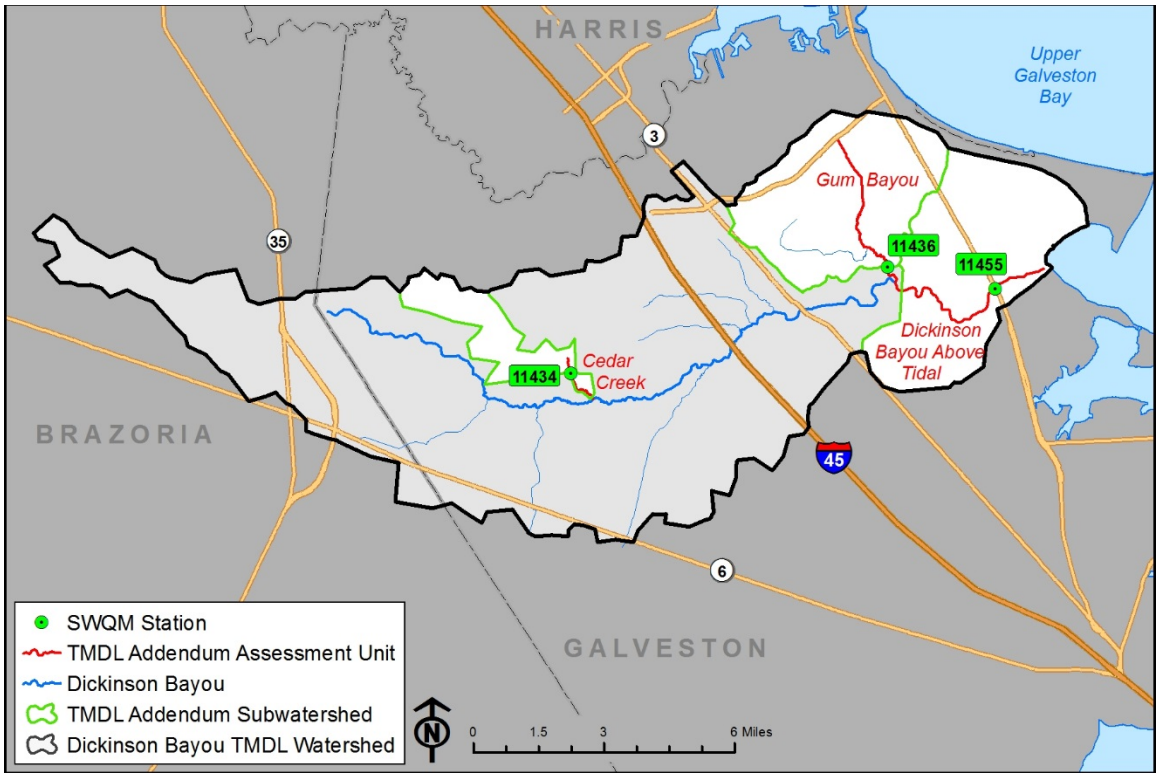

Figure 7. Dickinson Bayou watershed showing TCEQ surface water quality monitoring (SWQM) stations for the impaired AUs

Source: SWQM stations (TCEQ, 2012b)

Pollutant load allocations for Cedar Creek (1103E_01) are developed using analysis of the LDC method for the 9.5-year period of June 1999 through December 2008, which is consistent with the period used for the previously completed TMDLs. To calculate the bacteria load at the criterion for AU1103E_01, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (24,465,755 100 mL/cubic foot × seconds/day) and the *E. coli* criterion. This calculation produces the maximum bacteria load in the stream without exceeding the instantaneous standard over the range of flow conditions. As shown in Figure 8, *E. coli* loads are plotted versus flow exceedance percentiles as an LDC. The x-axis indicates the flow exceedance percentile, while the y-axis is expressed in terms of bacteria load.

Existing loads for the Cedar Creek subwatershed are estimated by pairing bacteria observations with the flows measured in that segment on the same date. Pollutant loads are then calculated by multiplying the measured bacteria concentration by the flow rate and a unit conversion factor of 24,465,755 100 mL/cubic foot × seconds/day. The associated flow exceedance percentile is then matched with the measured flow. The observed

bacteria loads are added to the LDC plot as points. These points represent individual ambient water quality samples of bacteria. Points above the LDC indicate the bacteria instantaneous standard was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample met the criterion.

The LDC approach recognizes that the assimilative capacity of a non-tidally influenced water body depends on the flow, and that maximum allowable loading varies with flow condition. Existing loading and loads that meet the TMDL water quality target can also be calculated under different flow conditions.

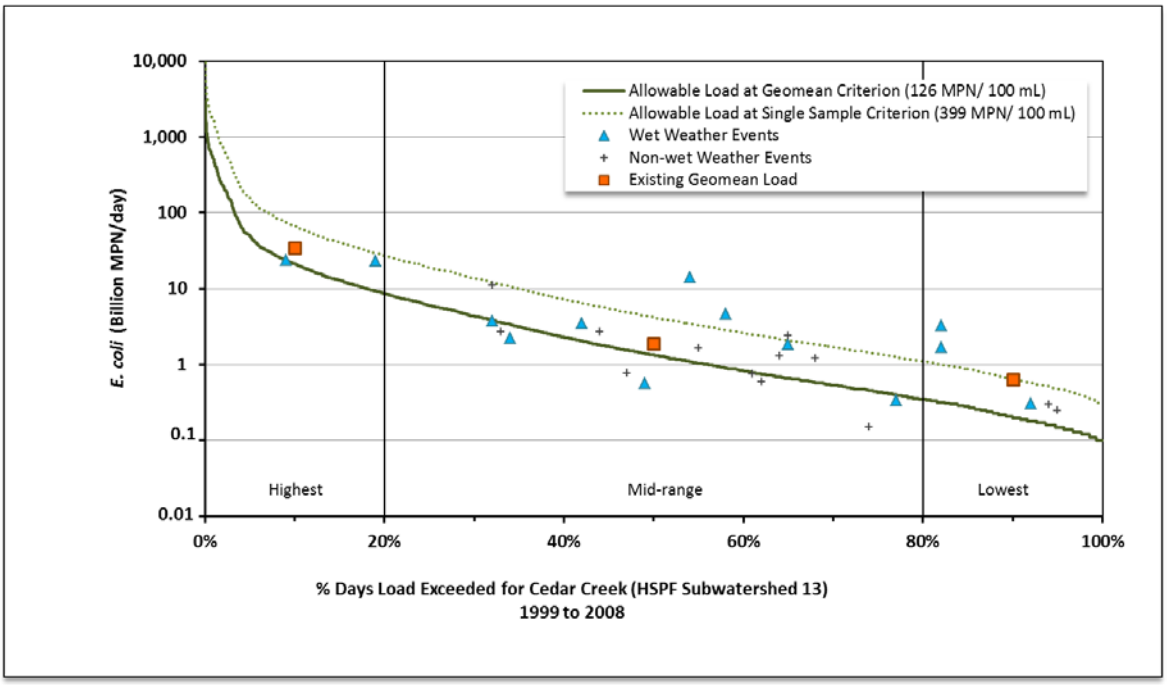

Figure 8. Load duration curves at Station 11434 on Cedar Creek for June 1, 1999 through December 31, 2008.

The load allocation goal for the Cedar Creek AU is based on data analysis using the geometric mean criterion (126 MPN/100mL), since it is assumed that achieving the geometric mean over an extended period of time will likely ensure that the single sample criterion (399 MPN/100 mL) will also be achieved.

The LDC (Figure 8) for Cedar Creek (1103E_01) is based on *E. coli* bacteria measurements at sampling location 11434. Also, consistent with the previously completed TMDLs, the mid-range flow regime (20th – 80th percentile) was selected as most representative and protective of the primary

contact recreation use. Swimming is not expected to occur during high flows because of dangerous conditions, or low flows because of the lack of water. The Cedar Creek TMDL was derived using the median (50th percentile) within this flow regime.

The LDC (Figure 8) also indicates that *E. coli* loadings and concentrations do not greatly exceed the geometric mean criterion and rarely exceed the single sample criterion. For the highest and mid-range flow regimes, the geometric mean of the measured data is slightly above the geometric mean criterion. The highest exceedance of the geometric mean criterion occurs in the lowest flow regime.

For the tidal water bodies of Dickinson Bayou Tidal (1103_01) and Gum Bayou (1103D_01), TPM analyses were used to examine the relationship between instream water quality and the broad sources of indicator bacteria loads, and are the basis of the TMDL allocations. The required freshwater inputs to the TPM were provided through HSPF. One strength of these TMDLs is the use of mechanistic models and actual calibration and verification of modeled results against measured data. This results in a reasonable representation of bacteria and flows in the tidal portion of Dickinson Bayou and its tributaries, as performed for tidal water bodies under the previously completed TMDLs. The development of this combined modeling system of HSPF and TPM was provided at an overview level for AUs 1103_01 and 1103D_01 in the two Technical Support Documents (Painter and Hauck, 2014) and (U of H and CDM, 2012), and in the previous TMDL document (TCEQ, 2012a).

The TMDLs for Dickinson Bayou (1103_01) and Gum Bayou (1103D_01) were derived using the median simulated flow from the approximately 30-month period of June 1999 through November 2001 used for the simulation. This approach remains consistent with that used with the tidal water bodies of the previously completed TMDLs.

Wasteload Allocation

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

WWTFs

TPDES-permitted WWTFs are allocated a daily wasteload (WLA_{WWTF}) calculated as their permitted discharge flow rate multiplied by one-half the instream water quality criterion. One-half of the criterion is used as the target to provide consistency with the previously developed TMDLs. The WLA_{WWTF} for the non-tidal portion of the subwatershed is calculated using the *E. coli* criterion (i.e., 63 MPN/100 mL). For the tidal portion of the subwatershed, the Enterococci geometric mean criterion (i.e., 17.5 MPN/100 mL) is used. To remain consistent with the previously completed TMDL, "Eight Total Maximum Daily Loads for Indicator Bacteria in Dickinson Bayou and Three Tidal Tributaries" (TCEQ, 2012a), the average reported flows in the original TMDLs were used in this document in the computations for WWTFs without permitted flow data (i.e., WQ0004086000 and WQ0003479000).

Table 11 presents the bacteria WLAs for each individual WWTF located within the TMDL addendum subwatersheds. To remain consistent with the methods of the previously completed TMDLs (TCEQ, 2012a), the WLA_{WWTF} for each AU includes the sum of the WWTF allocations for only those facilities in each AU.

Regulated Stormwater

Stormwater discharges from MS4, industrial, and construction areas are considered permitted or regulated point sources. Therefore, the WLA calculations must also include an allocation for permitted stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA for these areas was used in the development of these TMDLs due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of stormwater loading.

Table 11. Bacteria wasteload allocations for TPDES-permitted WWTFs

AU	Subwatershed[a]	TPDES Permit	NPDES Permit	Facility	Final Permitted Discharge (mgd)[b]	WLA_{WWTF} (Enterococci) (Billion MPN / day)[c]
1103_01	Dickinson Bayou Tidal	WQ0003479000	TX0108367	Sea Lion Technology	n/a for Outfalls 001, 101 0.02 for Outfall 201	0[d]
1103_01	Dickinson Bayou Tidal	WQ0003749000	TX0112861	Galveston Co Plant	0.07	0.046
1103_01	Dickinson Bayou Tidal	WQ0004086000	TX0117757	Clean Harbors San Leon[e]	n/a	0[d]
1103_01	Dickinson Bayou Tidal	WQ0014326001	TX0124761	Galveston Bay RV	0.02	0.013
1103_01	Dickinson Bayou Tidal	WQ0014804001	TX0129631	Dolphin Cove WWTF	0.95	0.629
1103D_01	Gum Bayou	WQ0014570001	TX0127248	Marlin Atlantis White WWTF	0.50	0.331

a No TPDES-permitted WWTFs in Cedar Creek 1103E_01

b Decimal places as shown in permit

c WLA_{WWTF} = 1/2 *Criterion * Flow * Conversion Factor; where Criterion from Table 2;
Conversion Factor = 1.54723 cfs/MGD * 283.168 (100 mL)/ft3 * 86,400 sec/day * billion/109

d Industrial process not associated with indicator bacteria

e Previously known as Duratherm, Inc.

The percentage of the land area included in each AU subwatershed that is under the jurisdiction of stormwater permits (i.e., 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. For the AUs addressed in this TMDL, the urbanized area and percent of each subwatershed within the urbanized area was previously provided in Table 7.

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 allocations from the total TMDL allocation.

Allowance for Future Growth

As described in the original TMDL document, future growth of existing or new point sources is not limited by these TMDLs as long as the sources do not cause indicator bacteria to exceed the limits. The assimilative capacity of streams increases as the flow increases. Consequently, increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard. New or amended permits for wastewater discharge facilities will be evaluated on a case-by-case basis.

Currently, four facilities that treat domestic wastewater are located within the impaired subwatersheds: three in the Dickinson Bayou Tidal subwatershed (1103_01), one in the Gum Bayou subwatershed (1103D_01), and none in the Cedar Creek subwatershed. To account for the future growth component of AUs 1103_01 and 1103D_01, the loading from only the WWTFs with outlets located within their respective subwatersheds are included in the future growth computation, which maintains consistency with the previously completed TMDLs. For these WWTFs, the 2050 permitted flow was computed using the method and population growth from the original TMDLs. For the newly permitted Dolphin Cove WWTF (WQ0014804001), the percent increase in future growth was calculated using the same method as other municipal waste facilities in Galveston County (outside of any city limits).

Because future growth from WWTFs could occur anywhere in the Dickinson Bayou subwatershed where conditions are amenable for new development, Cedar Creek was not considered exempted from that possibility. However, the absence of existing WWTFs in the Cedar Creek subwatershed precluded the standard approach to perform the future growth computations. In lieu of any specific information on future growth in Cedar Creek, a simplistic approach was used to compute a loading for this subwatershed. For the

Cedar Creek subwatershed, it was assumed that a new WWTF, equal in size to the smallest domestic facility in Dickinson Bayou watershed (i.e., Via Bayou RV Park with full permitted flow of 0.02 mgd), would constitute its future growth 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 TMDLs in this document will result in protection of existing designated uses and conform to Texas's antidegradation policy.

TMDL Calculations

Table 12 summarizes the TMDL calculations for the impaired subwatersheds. Each of the TMDLs was calculated based on either (1) the median load value from the TPM, or (2) the median load value in the 20-80 percentile range (50th percentile exceedance, mid-range flow regime) for load exceedance from the LDC analysis. Allocations are based on the current geometric mean criterion of either 35 MPN/100 mL for Enterococci or 126 MPN/100 mL for *E. coli* for each component of the TMDL.

The final TMDL allocations (Table 13) needed to comply with the requirements of the Title 40 Code of Federal Regulations (CFR) Section 130.7 (40 CFR §130.7) include the future growth (FG) component.

TMDL values and allocations in Table 13 are derived from calculations using the existing water quality criteria for Enterococci and *E. coli*. However, designated uses and water quality criteria for these water bodies are subject to change through the TCEQ TSWQS revision process. Figures A-1 through A-3 were developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of proposed water quality criteria for Enterococci and *E. coli*. The equations provided along with Figures A-1 through A-3 allow the calculation of new TMDLs and pollutant load allocations based on any potential new water quality criteria for Enterococci and *E. coli*.

Table 12. Load allocation calculations for impaired subwatersheds

All loads expressed as billion MPN/day

AU	Stream Name	Indicator	TMDL[a]	MOS[b]	WLA_{WWTF}[c]	WLA_{SW}[d]	LA[e]	FG[f]
1103_01	Dickinson Bayou Tidal	Enterococci	922.405	46.120	0.688	148.390	727.068	0.139
1103D_01	Gum Bayou	Enterococci	7.585	0.379	0.331	3.925	1.958	0.992
1103E_01	Cedar Creek	*E. coli*	1.342	0.067	0[g]	0.044[h]	1.183	0.048[i]

[a] TMDL = Median load from TPM (Painter and Hauck, 2014, Table 15) for AUs 1103_01 and 1103D_01, or median load in the 20-80 percentile range (50th percentile exceedance) from LDC for AU 1103E_01

[b] MOS = 0.05 × TMDL

[c] Total WLA_{WWTF} = $\sum WLA_{WWTF}$ from Table 11

[d] WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) × FDA_{SWP}; FDA_{SWP} = Percentage Stormwater Regulation from Table 7

[e] LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS

[f] Future Growth =1/2 × Criterion × [$\%POP_{2010-2050}$ × $WWTF_{FP}$] × Conversion Factor; Conversion Factor = 1.54723 cfs/mgd × 283.168 100 mL/ft3; $WWTF_{FP}$ is full permitted flows; for AU 1103E_01 see text

[g] No WWTF in 1103E_01

[h] Allocation for future development; currently no MS4s

[i] FG from (Painter and Hauck, 2014, Table 19); see text under "Allowance for Future Growth" for details of calculation

Table 13. Final TMDL allocations for the impaired subwatersheds within Dickinson Bayou

All loads expressed as billion MPN/day

AU	Stream Name	Indicator	TMDL	MOS	WLA_{WWTF}[a]	WLA_{SW}	LA
1103_01	Dickinson Bayou Tidal	Enterococci	922.405	46.120	0.827	148.390	727.068
1103D_01	Gum Bayou	Enterococci	7.585	0.379	1.323	3.925	1.958
1103E_01	Cedar Creek	*E. coli*	1.342	0.067	0.048	0.044	1.183

[a] WLA_{WWTF} = WLA_{WWTF} from Table 12 + FG from Table 12

Seasonal Variation

Federal regulations in 40 CFR §130.7(c)(1) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. All available data were used to simulate a wide range of seasonal and flow conditions, as shown in Table 14.

Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing *E. coli* and Enterococci concentrations obtained from routine monitoring collected in the warmer months (May - September) against those collected during the cooler months (November - March).

The months of April and October were considered transitional between the warm and cool seasons and were excluded from the seasonal analysis. Differences in indicator bacteria concentrations obtained in warmer versus cooler months were then evaluated by performing a Wilcoxon Rank Sum test on the original dataset. The nonparametric Wilcoxon Rank Sum test was selected, because even with a logarithmic transformation, the bacteria data were non-normally distributed. This analysis of bacteria data indicated that there was no significant difference in indicator bacteria between cool and warm weather seasons for all three of the impaired AUs (1103E_01, 1103D_01, 1103_01), signifying that seasonality was not detected.

Table 14. Seasonal variation data range

AU	Stream	Seasonal Analysis
1103_01	Dickinson Bayou Tidal	2003 – 2008
1103D_01	Gum Bayou	2003 – 2008
1103E_01	Cedar Creek	2005 - 2008

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.

Over the course of the Dickinson Bayou TMDL study, public participation has been an important component of the project. Members of the project stakeholder group represent government, permitted facilities, agriculture, businesses, environmental interests, and community interests in the Dickinson Bayou watershed.

As part of the TMDL and addendum processes, the TCEQ and the Dickinson Bayou Watershed Partnership held a series of meetings with stakeholders to solicit their advice on elements of the original TMDL project and to keep stakeholders informed of progress. This is an ongoing process, so notice of the public comment period for this addendum will be sent to the Dickinson Bayou Watershed Partnership group and posted on the TCEQ's TMDL program online News 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>.

The technical support document for these TMDL additions (Painter and Hauck, 2014) was posted on the TMDL project page at: <www.tceq.texas.gov/assets/public/waterquality/tmdl/80dickinsonbac/80-DickinsonAddendumTSD2014Sept.pdf> on May 21, 2015. The public will have an opportunity to comment on this addendum during a 30-day Water Quality Management Plan public comment period (August 5-September 6, 2016).

TCEQ accepted public comments on the original TMDLs during the period September 16, 2011 through October 17, 2011. Of the 16 comments submitted, none of them referred directly to the AUs in these TMDL additions. However, in response to a comment about tidal influence, TCEQ mentioned Gum Bayou as an example of a tidally influenced water body, and Cedar Creek as an example of a non-tidal water body.

Implementation and Reasonable Assurance

The three segments and AUs covered by this addendum are within the existing bacteria TMDL watersheds of Dickinson Bayou, composed of tidal and non-tidal waters that drain to Dickinson Bay. These subwatersheds are within the area covered by the implementation plan (I-Plan) developed by the Dickinson Bayou Watershed Partnership. The I-Plan (TCEQ, 2014c) was approved by the TCEQ on January 15, 2014. 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.

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Abbreviations

AU	assessment unit
AVMA	American Veterinary Medical Association
CDM	CDM Smith
CFR	Code of Federal Regulations
cfs	cubic feet per second
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency
FG	future growth
FM	farm to market road
GIS	geographic information system
H–GAC	Houston–Galveston Area Council
HSPF	Hydrological Simulation Program - FORTRAN
I-Plan	implementation plan
LA	load allocation
LDC	load duration curve
mgd	million gallons per day
mL	milliliter
MOS	margin of safety
MPN	most probable number
MS4	municipal separate storm sewer system
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NWSO	National Weather Service Office
OSSF	onsite sewage facility
SH	state highway
SRCC	Southern Regional Climate Center
SSO	sanitary sewer overflow
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TPM	tidal prism model
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas Surface Water Quality Standards
U of H	University of Houston
USGS	United States Geological Survey
WLA	wasteload allocation

WQMP	Water Quality Management Plan
WWTF	wastewater treatment facility

Appendix A
Equations for Calculating TMDL Allocations for Contract Recreation Standard Changes

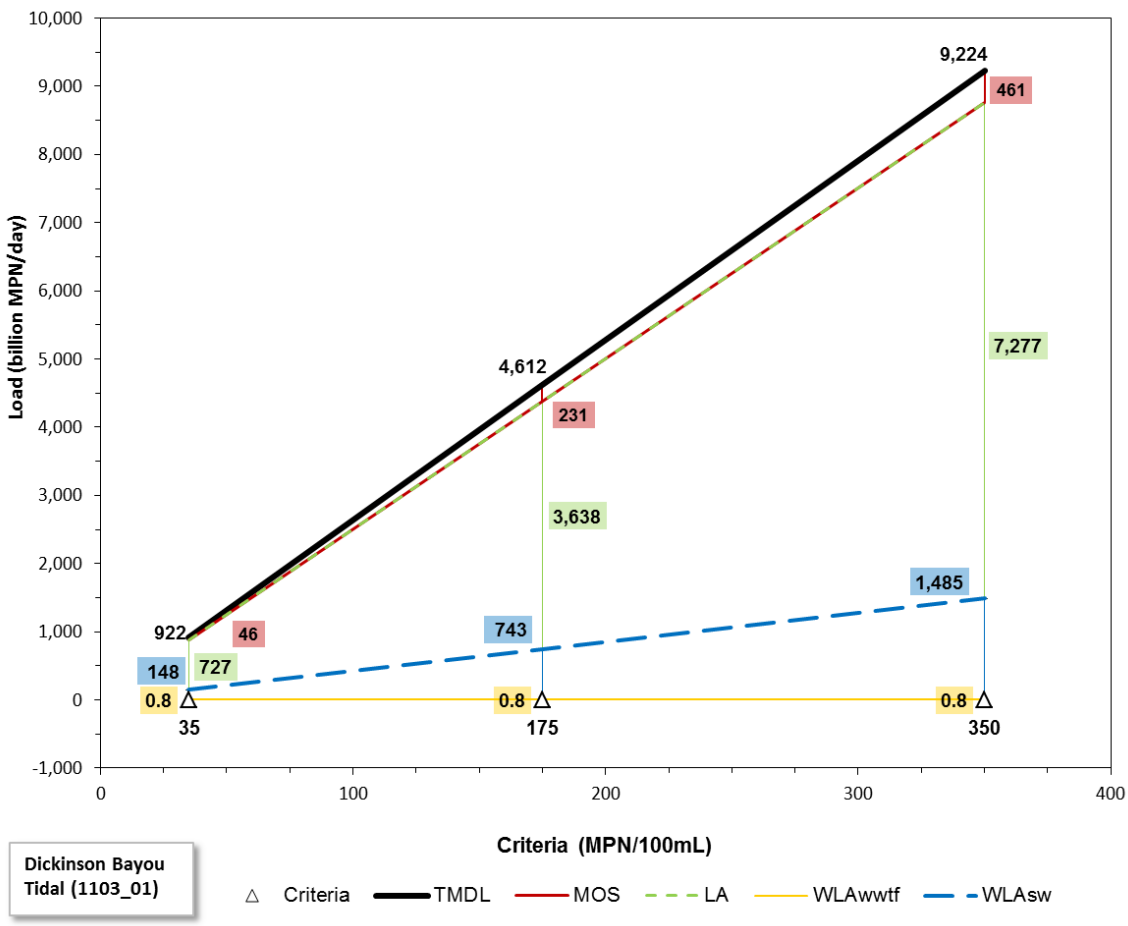

Figure A-1. Allocation loads for Dickinson Bayou Tidal (1103_01) as a function of water quality criteria

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

$$TMDL = WQ_{Std} \times 26.354429$$
$$MOS = WQ_{Std} \times 1.317724$$
$$LA = WQ_{Std} \times 20.792984 - 0.687361$$
$$WLA_{WWTF} = 0.8280$$
$$WLA_{SW} = WQ_{Std} \times 4.243721 - 0.140180$$

Where:

WQ_{Std} = Revised Contact Recreation Standard
MOS = Margin of Safety
LA = Total Load Allocation (unregulated source contributions)
WLA_{WWTF} = Wasteload Allocation (permitted WWTF load + future growth)
WLA_{SW} = Load Allocation (permitted stormwater)

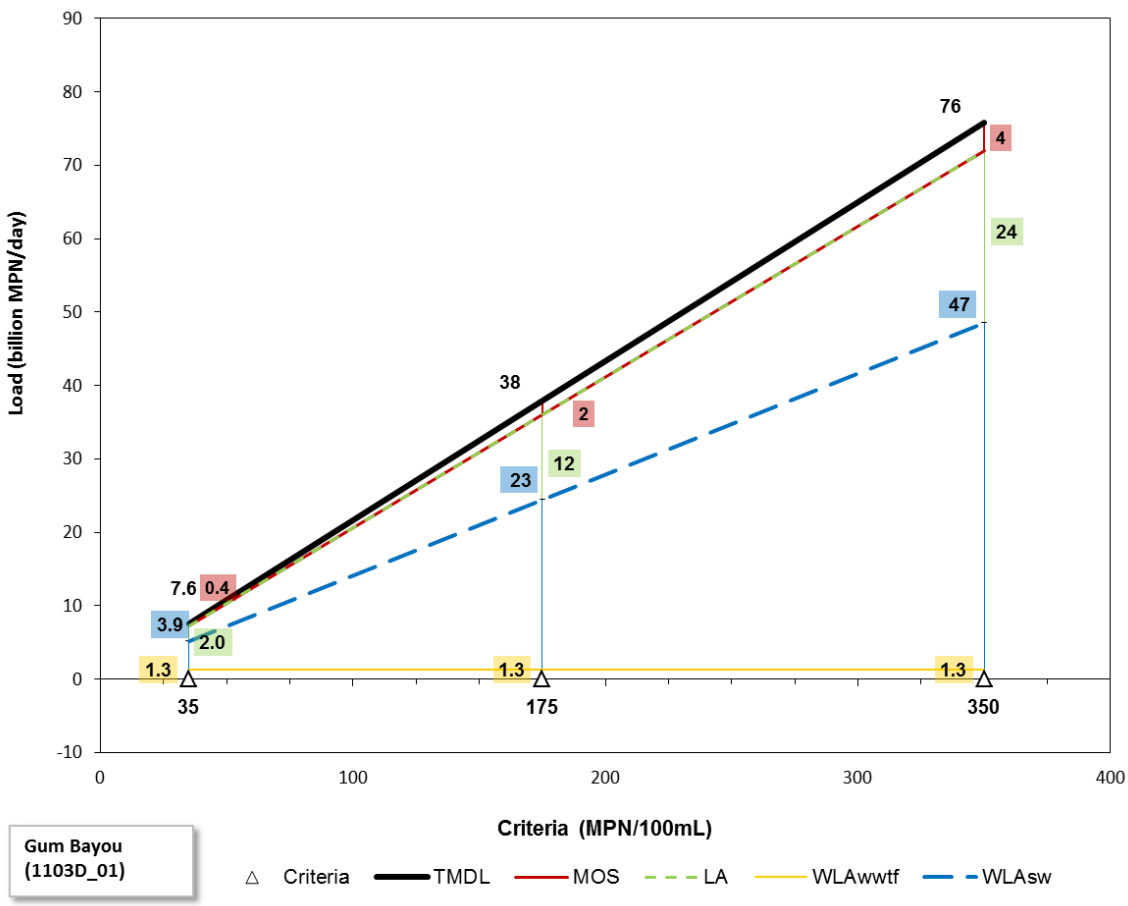

Figure A-2. Allocation loads for Gum Bayou (1103D_01) as a function of water quality criteria

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

$$TMDL = WQ_{Std} \times 0.216714$$
$$MOS = WQ_{Std} \times 0.010838$$
$$LA = WQ_{Std} \times 0.068514 - 0.440000$$
$$WLA_{WWTF} = 1.3230$$
$$WLA_{SW} = WQ_{Std} \times 0.137362 - 0.882541$$

Where:

WQ_{Std} = Revised Contact Recreation Standard
MOS = Margin of Safety
LA = Total Load Allocation (unregulated source contributions)
WLA_{WWTF} = Wasteload Allocation (permitted WWTF load + future growth)
WLA_{SW} = Wasteload Allocation (permitted stormwater)

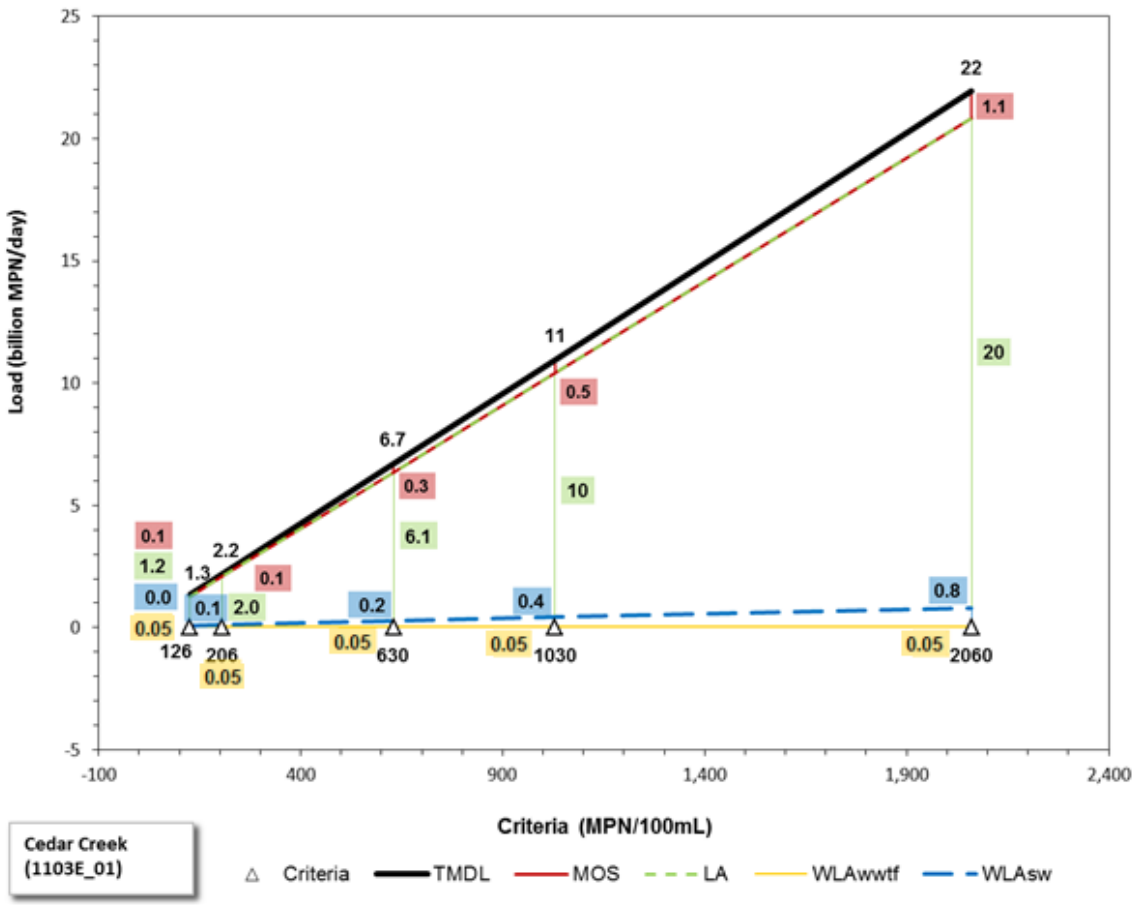

Figure A-3. Allocation loads for Cedar Creek (1103E_01) as a function of water quality criteria

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

$$TMDL = WQ_{Std} \times 0.0106476$$
$$MOS = WQ_{Std} \times 0.0005325$$
$$LA = WQ_{Std} \times 0.0097500 - 0.0457933$$
$$WLA_{WWTF} = 0.0480$$
$$WLA_{SW} = WQ_{Std} \times 0.0003651 - 0.0020729$$

Where:

WQ_{Std} = Revised Contact Recreation Standard
MOS = Margin of Safety
LA = Total Load Allocation (unregulated source contributions)
WLA_{WWTF} = Wasteload Allocation (permitted WWTF load + future growth)
WLA_{SW} = Wasteload Allocation (permitted stormwater)