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AS-480
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Two Total Maximum Daily Loads for Indicator Bacteria in the Oyster Creek Watershed

Assessment Units 1109_01 and 1110_01

Water Quality Planning Division, Office of Water

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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Abbreviations

AA	authorized agents
AU	assessment unit
BMP	best management practice
CAFO	concentrated animal feeding operations
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming units
CGP	Construction General Permit
E. coli	*Escherichia coli*
EPA	(United States) Environmental Protection Agency
FDC	flow duration curve
FG	future growth
FM	Farm to Market Road
GIWW	Gulf Intracoastal Waterway
H-GAC	Houston-Galveston Area Council
H3M	hexagonal grid of three-square miles
I-Plan	implementation plan

IW	industrial wastewater
Km	kilometers
LA	load allocation
LDC	load duration curve
MCM	minimum control measure
MGD	million gallons per day
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
MSGP	Multi-Sector General Permit
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSSF	on-site sewage facility
SSO	sanitary sewer overflow
SSURGO	Soil Survey Geographic Database
SW	stormwater
SWMP	Stormwater Management Program
SWQM	surface water quality monitoring
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TDCJ	Texas Department of Criminal Justice
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TxDOT	Texas Department of Transportation
UA	urbanized area
U.S.	United States
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	wasteload allocation
WLA_{SW}	wasteload allocation from regulated stormwater
WLA_{WWTF}	wasteload allocation from wastewater treatment facilities
WQBELs	water quality-based effluent limits
WQMP	Water Quality Management Plan
WW	domestic wastewater treatment plant
WWTF	wastewater treatment facility

Executive Summary

This report describes the total maximum daily loads (TMDLs) for the Oyster Creek watershed where concentrations of indicator bacteria exceed the criteria used to evaluate attainment of the primary contact recreation 1 use. The Texas Commission on Environmental Quality (TCEQ) first identified the impairment to Oyster Creek Above Tidal in the 2006 Texas Water Quality Inventory and 303(d) List (TCEQ, 2008), now called the *Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d)* (Texas Integrated Report). The impairment for Oyster Creek Tidal was later identified in the 2012 Texas Integrated Report (TCEQ, 2013).

This report will consider two bacteria impairments in two assessment units (AUs) of the Oyster Creek watershed. The impaired water body and identifying AUs are:

- Oyster Creek Tidal (AU 1109_01)
- Oyster Creek Above Tidal (AU 1110_01)

The 146.7-square mile Oyster Creek watershed comprises three water bodies: Oyster Creek Tidal (Segment 1109), Oyster Creek Above Tidal (Segment 1110), and an unclassified waterbody, Upper Oyster Creek Above Tidal (1110A) (Figure 1). Oyster Creek is approximately 95 miles long, originates at the confluence with Middle Oyster Creek in southeastern Fort Bend County, and travels southward through central Brazoria County before turning southeast at the city of Lake Jackson. From there, Oyster Creek meanders and broadens across the Texas coastal plain before terminating at the Gulf Intracoastal Waterway (GIWW) near the cities of Brazosport and Surfside Beach.

Escherichia coli (E. coli) and Enterococci are widely used as indicator bacteria to determine attainment of the contact recreation use in freshwater and saltwater, respectively. The criterion for determining attainment of the contact recreation use is expressed as the number of bacteria, typically given as colony forming units (cfu) in 100 milliliters (mL) of water. The primary contact recreation 1 use is not supported in freshwater when the geometric mean of all samples for the assessment period exceeds 126 cfu per 100 mL. Similarly, the primary contact recreation 1 use is not supported in saltwater when the geometric mean of all samples for the assessment period exceeds 35 cfu per 100 mL.

E. coli and Enterococci data were collected at four TCEQ surface water quality monitoring (SWQM) stations in the impaired AUs over a seven-year period from December 1, 2013 through November 30, 2020. These data were used in assessing attainment of the primary contact recreation 1 use and were reported in the 2022 Texas Integrated Report (TCEQ, 2022a). The assessed data indicate non-attainment of the contact recreation standard in AUs 1109_01 and 1110_01.

Within the Oyster Creek watershed, probable sources of bacteria include domestic and industrial wastewater treatment facilities (WWTFs), regulated stormwater runoff, sanitary sewer overflows (SSOs), illicit discharges, on-site sewage facilities (OSSFs), agricultural activities, and contributions from wildlife and domesticated animals.

A load duration curve (LDC) analysis (for AU 1110_01) and a modified LDC analysis (for AU 1109_01) was done for the Oyster Creek watershed to quantify allowable pollutant loads, as well as allocations for point and nonpoint sources of bacteria. Wasteload allocations (WLAs) were established for WWTFs discharging to the AUs. The WLA was calculated as the full permitted daily-average flow rate multiplied by the geometric mean criterion. Future growth (FG) of existing or new domestic point sources was determined for the watershed using population growth projections.

The TMDL calculations in this report will guide determination of the assimilative capacity of each water body under changing conditions, including FG. WWTFs will be evaluated case by case.

Introduction

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. States must develop a TMDL for each pollutant that contributes to the impairment of a water body included on a state's 303(d) list of impaired waters. 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 particular pollutant that a water body can receive and still meet applicable water quality standards. TMDLs are the best possible estimates of the 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.

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 (water bodies) in, or bordering on, the state of Texas. The program's primary objective is to restore and maintain water quality uses—such as drinking water supply, recreation, support of aquatic life, or fishing—of impaired or threatened water bodies.

This TMDL report addresses impairments to the primary contact recreation 1 use due to elevated levels of indicator bacteria in Oyster Creek (Segments 1109 and 1110). This TMDL takes a watershed approach to addressing indicator bacteria impairments. While TMDL allocations were developed only for the impaired AUs identified in this report, the entire project watershed (Figure 1) and all WWTFs that discharge within it are included within the scope of this TMDL. Information in this TMDL report was derived from the *Technical Support Document for Two Total Maximum Daily Loads for Indicator Bacteria in the Oyster Creek Watershed* (H-GAC, 2023).[a]

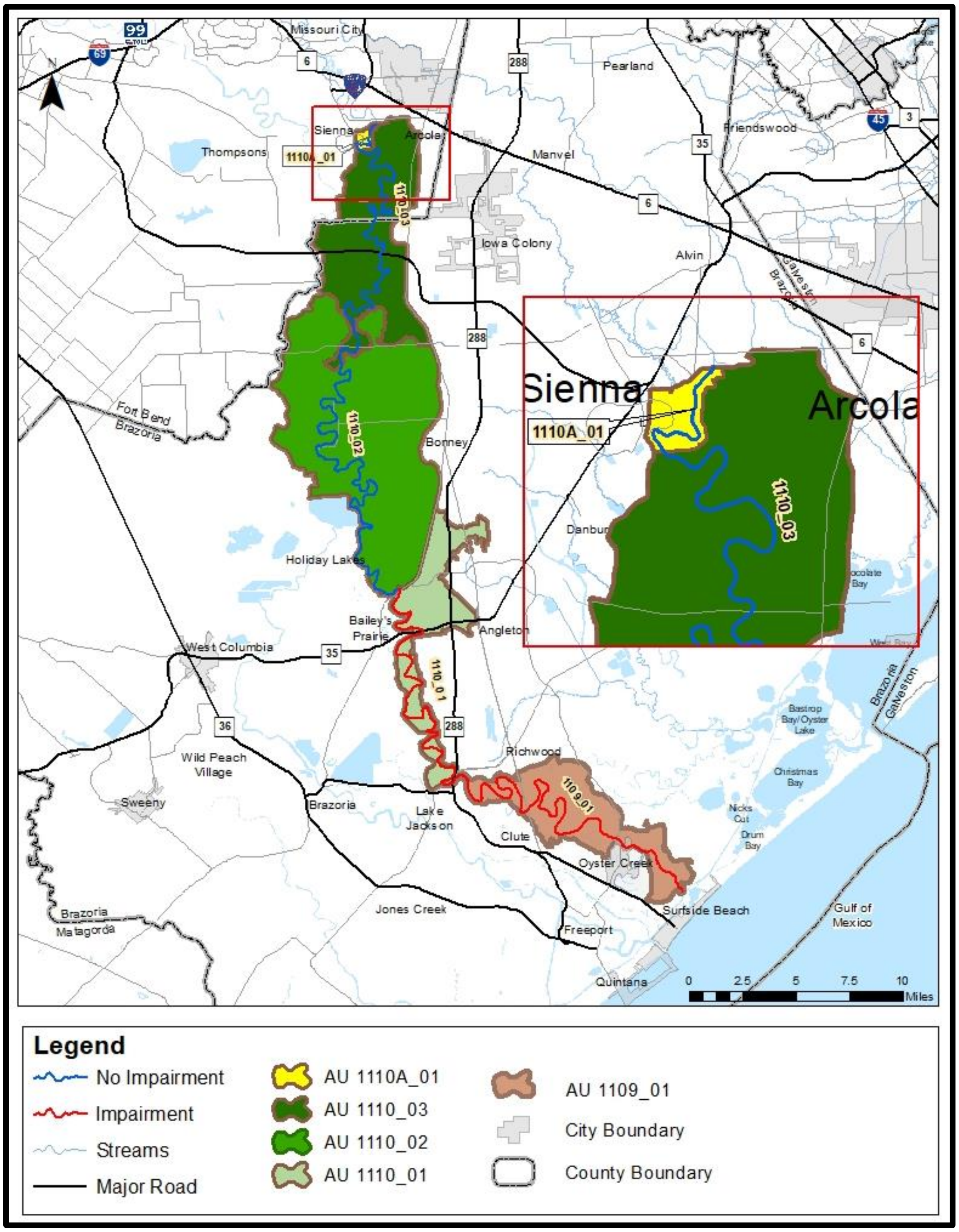

Figure 1. Map of the Oyster Creek watershed

[a] www.tceq.texas.gov/downloads/water-quality/tmdl/oyster-creek-recreational-114/tsd_oystercreek_as-478.pdf/

Section 303(d) of the Clean Water Act and the implementing regulations of the United States (U.S.) Environmental Protection Agency (EPA) in Title 40 of the Code of Federal Regulations (CFR), Chapter 1, Part 130 (40 CFR Part 130) describe the statutory and regulatory requirements for acceptable TMDLs. EPA provides further direction in its *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA, 1991). This TMDL report has been prepared in accordance with those regulations and guidelines.

TCEQ must consider certain elements in developing a TMDL. They are described in the following sections of this report:

- Problem Definition
- Endpoint Identification
- Source Analysis
- Linkage Analysis
- Margin of Safety
- Pollutant Load Allocation
- Seasonal Variation
- Public Participation
- Implementation and Reasonable Assurance

Upon adoption of the TMDL report by the commission and subsequent EPA approval, these TMDLs will become an update to the state's Water Quality Management Plan (WQMP).

Problem Definition

TCEQ first identified the impairment of the primary contact recreation 1 use within Oyster Creek Above Tidal in the 2006 Texas Integrated Report (TCEQ, 2008), and again in each subsequent edition through the EPA-approved 2022 Texas Integrated Report (TCEQ, 2022a). The impairment of the primary contact recreation 1 use in Oyster Creek Tidal was first identified in the 2012 Texas Integrated Report (TCEQ, 2013), and then in each subsequent edition through the EPA-approved 2022 Texas Integrated Report (TCEQ, 2022a).

Recent surface water *E. coli* and Enterococci monitoring within the TMDL watershed has occurred at four TCEQ SWQM stations (Table 1, Figure 2, and Figure 3). The ambient *E. coli* and Enterococci data included in this report were obtained from TCEQ's Surface Water Quality Monitoring Information System between 2004 and 2020 and were used to determine the attainment of primary contact recreation 1 uses reported in the 2022 Texas Integrated Report (TCEQ, 2022a). Data assessed indicate that primary contact recreation 1 use is not supported because the geometric mean of available samples exceeds the geometric mean criterion of 126 cfu/100 mL for *E. coli* and 35 cfu/100 mL for Enterococci, as summarized in Table 1.

Table 1. 2022 Texas Integrated Report Summary for the impaired AUs

Water Body	AU	Parameter	Date Range	TCEQ SWQM Station	No. Samples	Geometric mean (cfu/100mL)
Oyster Creek Tidal	1109_01	Enterococci	12/01/13-11/30/20	11485, 11486	47	59.87
Oyster Creek Above Tidal	1110_01	*E. coli*	12/01/13-11/30/20	11489	26	239.33

Watershed Overview

The Oyster Creek watershed comprises 146.7 square miles within Fort Bend and Brazoria counties and is composed of three waterbodies: Oyster Creek Tidal (Segment 1109), Oyster Creek Above Tidal (Segment 1110) and an unclassified waterbody, Upper Oyster Creek Above Tidal (1110A) (Figure 1). Oyster Creek Tidal is composed of a single AU (1109_01) that begins in the City of Lake Jackson and traverses about 25 miles southeast to its confluence with the GIWW. The tidal AU has a watershed area of 23.6 square miles. Other cities that are found in the Oyster Creek Tidal watershed include Clute and Richwood.

Oyster Creek Above Tidal is comprised of three AUs (1110_01, 1110_02, and 1110_03) that begins south of Upper Oyster Creek Above Tidal (1110A) and travels to the City of Lake Jackson where it terminates at its confluence with Oyster Creek Tidal (Segment 1109). Segment 1110 has a watershed area of 123.1 square miles, including Upper Oyster Creek Above Tidal (1110A). The Oyster Creek Above Tidal watershed contains all or part of six cities, towns, and villages: Rosharon, Bonney, Holiday Lakes, Angleton, Bailey’s Prairie, and Lake Jackson.

The 2022 Texas Integrated Report (TCEQ, 2022a) has the following water body and AU descriptions:

- Segment 1109 Oyster Creek Tidal – From the confluence with the Intracoastal Waterway in Brazoria County to a point 100 meters (110 yards) upstream of Farm to Market Road (FM) 2004 in Brazoria County.
    - AU 1109_01 – From the confluence with the Intracoastal Waterway in Brazoria County to a point 100 meters (110 yards) upstream of FM 2004 in Brazoria County.
- Segment 1110 Oyster Creek Above Tidal – From a point 100 meters (110 yards) upstream of FM 2004 in Brazoria County to a point

4.3 kilometers (km) (2.7 miles) upstream of Scanlan Road in Fort Bend County.
    - AU 1110_01 – From a point 100 meters (110 yards) upstream of FM 2004 in Brazoria County upstream to the Styles Bayou confluence.
    - AU 1110_02 – From Styles Bayou upstream to an unnamed tributary [2.9 km (1.8 miles) downstream of FM 1462].
    - AU 1110_03 – From an unnamed tributary [2.9 km (1.8 miles) downstream of FM 1462] upstream to a point 4.3 km (2.7 miles) upstream of Scanlan Road in Fort Bend County.

- Unclassified Waterbody 1110A Upper Oyster Creek Above Tidal – From a point 4.3 km (2.7 miles) upstream of Scanlan Road in Fort Bend County upstream to the confluence with Middle Oyster Creek approximately 325 meters south of McKeever Road in Fort Bend County.
    - AU 1110A_01 – From a point 4.3 km (2.7 miles) upstream of Scanlan Road in Fort Bend County upstream to the confluence with Middle Oyster Creek approximately 325 meters south of McKeever Road in Fort Bend County.

Future references to Segment 1110 will incorporate analysis for Upper Oyster Creek Above Tidal (1110A), unless otherwise mentioned, due to its small size. Due to the hydrologic modifications discussed in the *Technical Support Document for Two Total Maximum Daily Loads for Indicator Bacteria in the Oyster Creek Watershed* (H-GAC, 2023), the Houston-Galveston Area Council (H-GAC) has modified the National Hydrologic Dataset Plus (NHDPlus, USGS, 2021) to delineate the watershed boundaries for use in this report. Modifications include the removal of the town of Oyster Creek from the watershed that was included in the NHDPlus version of the watershed.

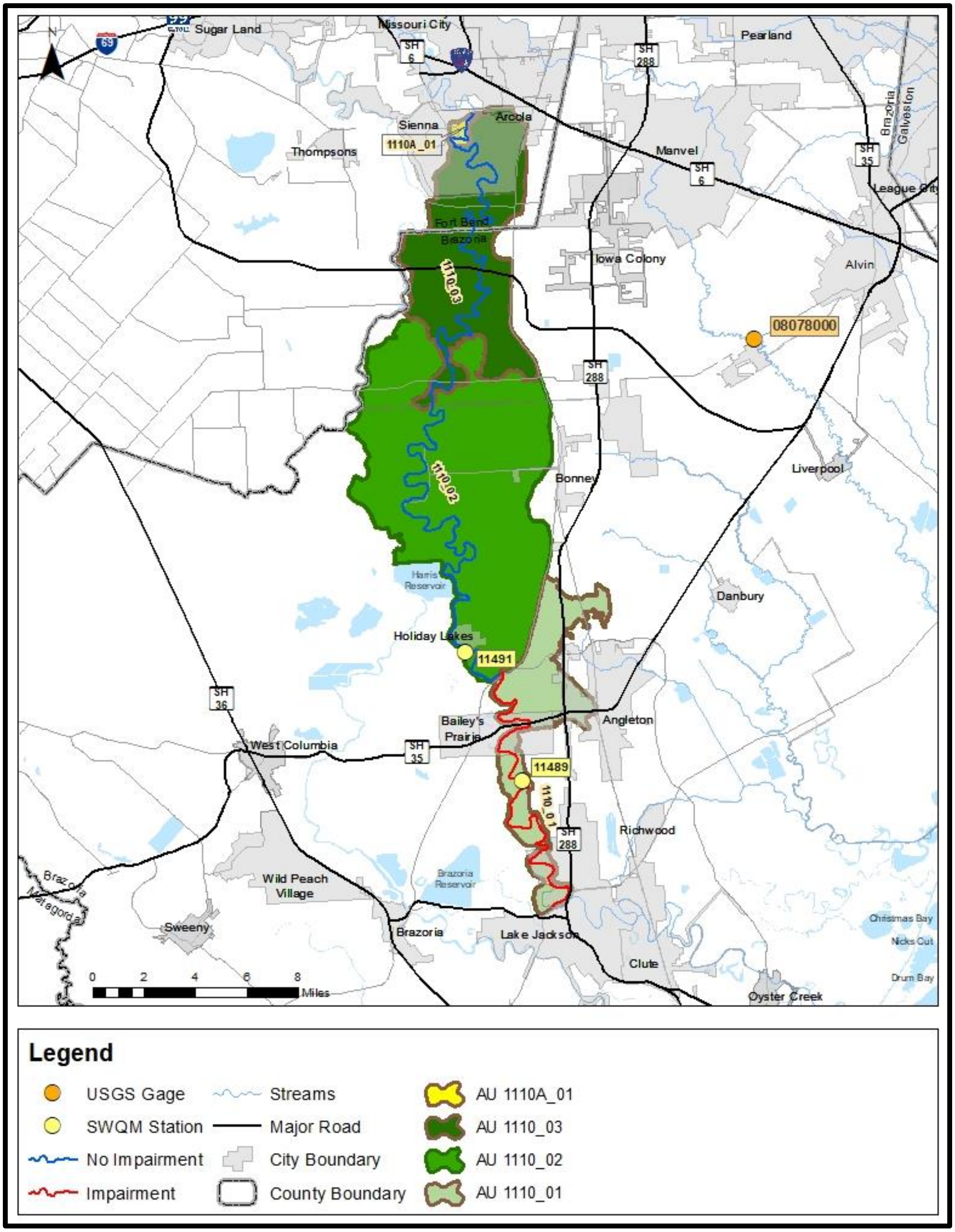

Figure 2. Active TCEQ SWQM and U.S. Geological Survey monitoring stations in Oyster Creek Above Tidal

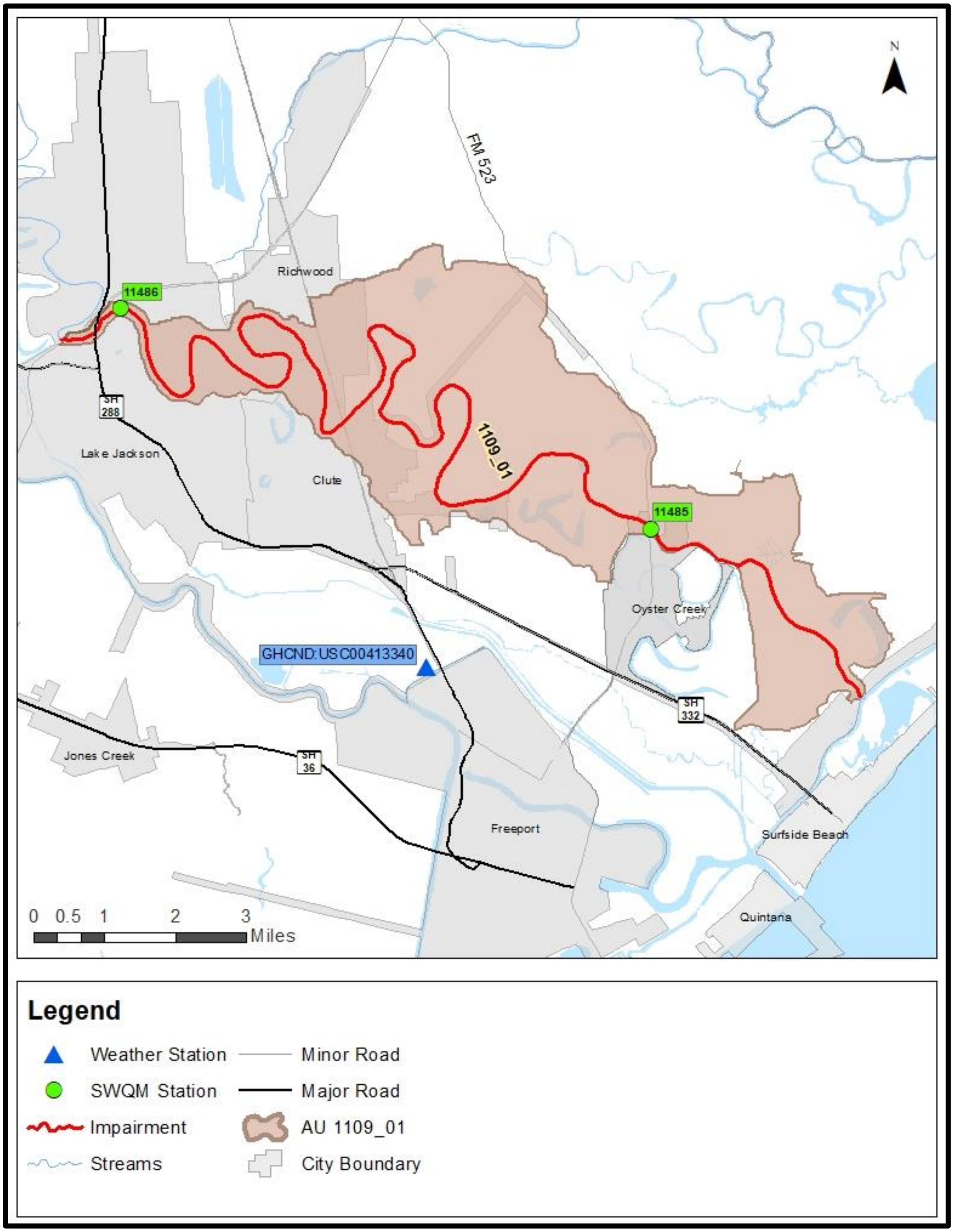

Figure 3. Active TCEQ SWQM and weather stations in Oyster Creek Tidal

Climate and Hydrology

Average precipitation recorded between 2004 and 2020 is 47.78 inches per year (Table 2, NOAA, 2022). The highest average monthly precipitation occurred in September, while the lowest average monthly precipitation occurred in February (Figure 4). Average monthly precipitation ranges were measured from just above two inches to slightly under six and a half inches. Average monthly air temperature ranges were measured from slightly below 50 F in the winter months to slightly above 90 F in the summer months (NOAA, 2022).

Table 2. Average annual rainfall recorded at a gage near the Oyster Creek watershed

Station	Station Name	Latitude	Longitude	Average Annual Rainfall (inches)
GHCND: USC00413340	FREEPORT 2 NW TX US	28.9845	-95.3809	47.78

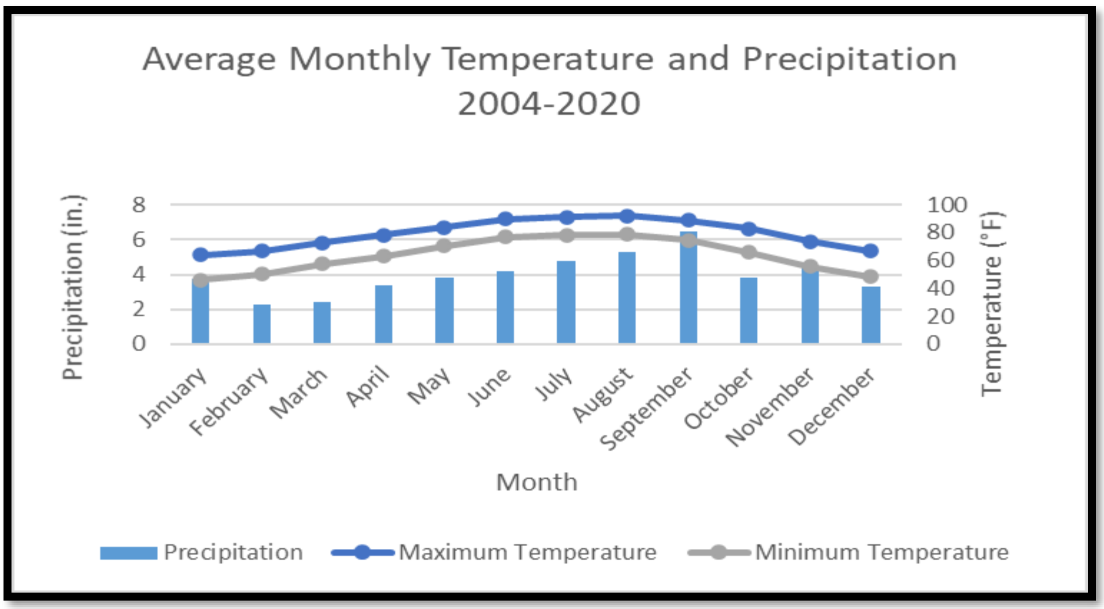

Figure 4. Average monthly temperature and precipitation from 2004 through 2020 at Freeport 2 NW, Texas Station USC00413340

Population and Population Projections

Watershed population estimates were developed using H-GAC's Regional Growth Forecast (H-GAC, 2021a). The most recent analysis was based on the U.S. Census Bureau's (USCB's) 2020 Decadal Census (USCB, 2020; H-GAC, 2021b). The TMDL watershed's 2020 population was estimated to be 26,611 people for AU 1110_01 and 12,376 people in AU 1109_01 (Table 3)

Using Regional Growth Forecast methodology outlined in Appendix (H-GAC, 2018), the regional population and household growth was estimated out to the year 2050.

Table 3. Population estimates and projections

Subwatershed	AU	2020	2050	% Change
Oyster Creek Tidal	1109_01	12,376	21,222	71.48%
Oyster Creek Above Tidal	1110_01	26,611	43,579	63.76%
Total		**38,987**	**64,801**	**66.21%**

Land Cover

H-GAC used LANDSAT imagery to categorize the Houston-Galveston region into 10 classes of land cover (H-GAC, 2020). The definitions for the 10 land cover types are:

- **High Intensity Development** – Contains significant land area that is covered by concrete, asphalt, and other constructed materials. Vegetation, if present, occupies < 20% of the landscape. Constructed materials account for 80 to 100% of the total cover. This class includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of land uses.
- **Medium Intensity Development** – Contains area with mixture of constructed materials and vegetation or other cover. Constructed materials account for 50 to 79% of the total area. This class commonly includes multi- and single-family housing areas, especially in suburban neighborhoods, but may include all types of land use.
- **Low Intensity Development** – Contains areas with a mixture of constructed materials and substantial amounts of vegetation or other cover. Constructed materials account for 21 to 49% of total area. This subclass commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.
- **Open Space Development** – Contains areas with a mixture of some constructed materials, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. These areas are maintained by human activity such as fertilization and irrigation, are distinguished by enhanced biomass productivity, and can be recognized through vegetative indices based on spectral characteristics. Constructed surfaces account for less than 20% of total land cover.

- **Cultivated Crops** – Contains areas intensely managed to produce annual crops. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
- **Pasture/Grasslands** – This is a composite class that contains both Pasture/Hay lands and Grassland/Herbaceous.
    a. *Pasture/Hay* – Contains areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle and not tilled. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
    b. *Grassland/Herbaceous* – Contains areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling but can be utilized for grazing.
- **Barren Lands** – This class contains both barren lands and unconsolidated shore land areas.
    a. *Barren Land* – Contains areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earth material. Generally, vegetation accounts for less than 10% of total cover.
    b. *Unconsolidated Shore* – Includes material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Substrates lack vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable.
- **Forest/Shrubs** – This is a composite class that contains all three forest land types and shrub lands.
    a. *Deciduous Forest* – Contains areas dominated by trees generally greater than five meters tall and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
    b. *Evergreen Forest* – Contains areas dominated by trees generally greater than five meters tall and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
    c. *Mixed Forest* – Contains areas dominated by trees generally greater than five meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than

75% of total tree cover. Both coniferous and broad-leaved evergreens are included in this category.

d. *Scrub/Shrub* – Contains areas dominated by shrubs less than five meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

- **Open Water** – This is a composite class that contains open water and both palustrine and estuarine aquatic beds.

  a. *Open Water* – Include areas of open water, generally with less than 25% cover of vegetation or soil.

  b. *Palustrine Aquatic Bed* - Includes tidal and non-tidal wetlands and deep-water habitats in which salinity due to ocean-derived salts is below 0.5% and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages. Total vegetation cover is greater than 80%.

  c. *Estuarine Aquatic Bed* – Includes tidal wetlands and deep-water habitats in which salinity due to ocean-derived salts is equal to or greater than 0.5% and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, kelp beds, and rooted vascular plant assemblages. Total vegetation cover is greater than 80%.

- **Wetlands** – This is a composite class that contains all the palustrine and estuarine wetland land types.

  a. *Palustrine Forested Wetland* – Includes tidal and non-tidal wetlands dominated by woody vegetation greater than or equal to five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean derived salts is below 0.5%. Total vegetation coverage is greater than 20%.

  b. *Palustrine Scrub/Shrub Wetland* – Includes tidal and non-tidal wetlands dominated by woody vegetation less than five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5%. Total vegetation coverage is greater than 20%. Species present could be true shrubs, young trees and shrubs, or trees that are small or stunted due to environmental conditions.

c. *Palustrine Emergent Wetland (Persistent)* – Includes tidal and non-tidal wetlands dominated by persistent emergent vascular plants, emergent mosses, or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5%. Total vegetation cover is greater than 80%. Plants generally remain standing until the next growing season.

d. *Estuarine Forested Wetland* – Includes tidal wetlands dominated by woody vegetation greater than or equal to five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5%. Total vegetation coverage is greater than 20%.

e. *Estuarine Scrub / Shrub Wetland* – Includes tidal wetlands dominated by woody vegetation less than five meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5%. Total vegetation coverage is greater than 20%.

f. *Estuarine Emergent Wetland* – Includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens). Wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5% and that are present for most of the growing season in most years. Total vegetation cover is greater than 80%. Perennial plants usually dominate these wetlands.

A summary of the land cover data is provided in Table 4. The Oyster Creek watershed covers 93,883.40 total acres, with 15,086.60 acres in the Oyster Creek Tidal subwatershed (AU 1109_01) and 78,796.80 acres in the Oyster Creek Above Tidal subwatershed (AU 1110_01). As depicted in Table 4 and Figures 5 and 6, the dominant land uses are Pasture/Grasslands and Wetlands in the AU 1109_01 and AU 1110_01 subwatersheds.

Table 4. Land cover percentages

Land Cover Type	Oyster Creek Tidal (acres)	Oyster Creek Tidal (%)	Oyster Creek Above Tidal (acres)	Oyster Creek Above Tidal (%)	Total (acres)	Total (%)
High Intensity Development	104.60	0.69%	165.10	0.21%	269.70	0.29%
Medium Intensity Development	557.40	3.69%	1,125.00	1.43%	1,682.40	1.79%
Low Intensity Development	1,425.20	9.45%	2,435.00	3.09%	3,860.20	4.11%
Open Space Development	1,841.40	12.21%	5,413.30	6.87%	7,254.70	7.73%
Barren Lands	84.10	0.56%	19.40	0.02%	103.50	0.11%
Forest/Shrubs	942.80	6.25%	7,665.60	9.73%	8,608.40	9.17%
Pasture/Grasslands	4,080.30	27.05%	38,124.30	48.38%	42,204.60	44.95%
Cultivated Croplands	74.70	0.50%	9,678.90	12.28%	9,753.60	10.39%
Wetlands	4,963.90	32.90%	12,473.00	15.83%	17,436.90	18.57%
Open Water	1,012.20	6.71%	1,697.20	2.15%	2,709.40	2.89%
Total	**15,086.60**	**100.00%**	**78,796.80**	**100.00%**	**93,883.40**	**100.00%**

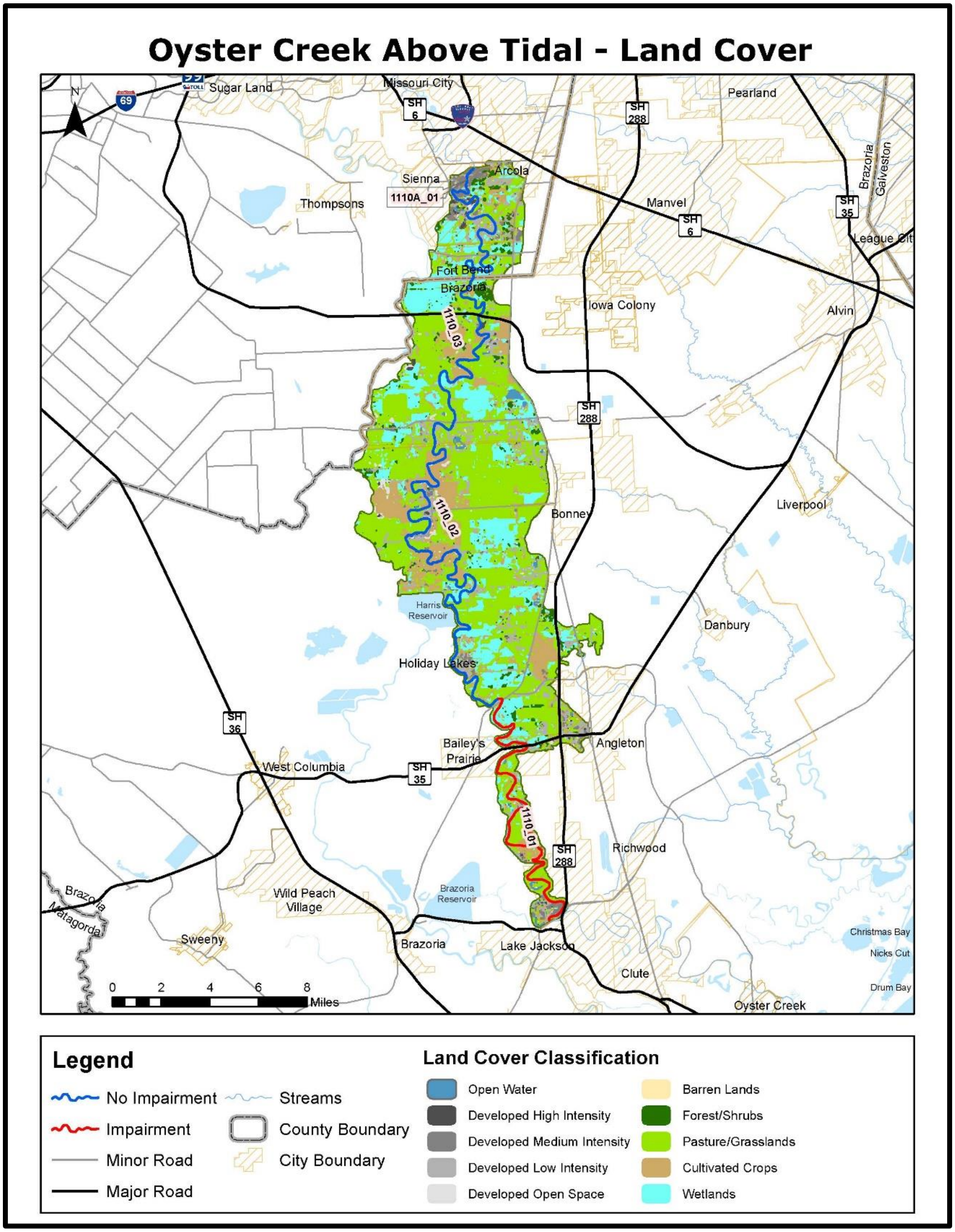

Figure 5. 2020 land cover map for Oyster Creek Above Tidal

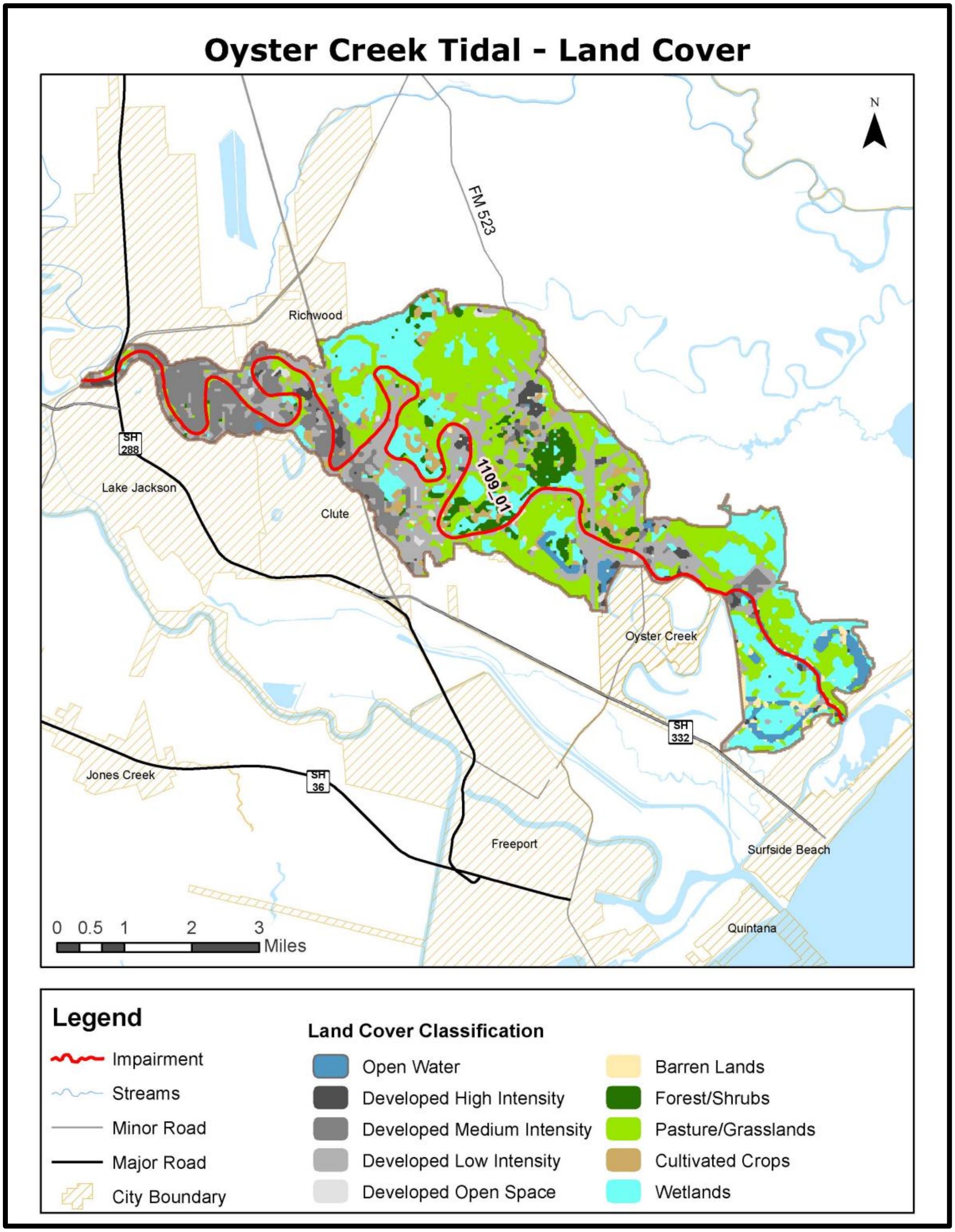

Figure 6. 2020 land cover map for Oyster Creek Tidal

Soils

Soils within the TMDL watershed are characterized by hydrologic groups that describe infiltration and runoff potential. These data are provided by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic database (SSURGO) (NRCS, 2015). The SSURGO data assigns different soils to one of seven possible runoff potential classifications or hydrologic groups. These classifications are based on the estimated rate of water infiltration when soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The four main groups are A, B, C, and D, with three dual classes (A/D, B/D, C/D). The SSURGO database defines the following classifications.

- **Group A** – Soils having high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well-drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.
- **Group B** – Soils having a moderate infiltration rate when thoroughly wet. These consist of moderately deep or deep, moderately well-drained or well-drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
- **Group C** – Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
- **Group D** – Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.
- Soils with dual hydrologic groupings indicate that drained areas are assigned the first letter, and the second letter is assigned to undrained areas. Only soils that are in group D in their natural condition are assigned to dual classes.

The predominant soil group within the Oyster Creek watershed is Group D at 74.25% which is typical of Texas coastal areas which are made up of slow draining alluvial clays (Table 5, Figures 7 and 8). The second largest soil group is that of Group B at 18.44%. These soils are consistent with alluvial silt and loam deposits laid down by rivers and common in stream banks and adjacent to oxbows. Oxbows are a common occurrence in the Oyster Creek watershed.

Table 5. Hydrologic soil groups

Hydrologic Group	Oyster Creek Tidal (acres)[a]	Oyster Creek Tidal (%)	Oyster Creek Above Tidal (acres)[a]	Oyster Creek Above Tidal (%)	Total (acres)	Total (%)
A	0.00	0.00%	153.96	0.20%	153.96	0.16%
B	3,207.17	21.26%	14,109.56	17.91%	17,316.73	18.44%
C	1.46	0.01%	3,155.07	4.00%	3,156.53	3.36%
C/D	1,355.61	8.99%	2,193.38	2.78%	3,548.99	3.78%
D	10,522.49	69.75%	59,185.59	75.11%	69,708.08	74.25%
Total	**15,086.73**	**100.00%**	**78,797.56**	**100.00%**	**93,884.29**	**100.00%**

[a] Acreage for the TMDL watersheds differ from previously listed totals in the report due to calculations that included different sources for data.

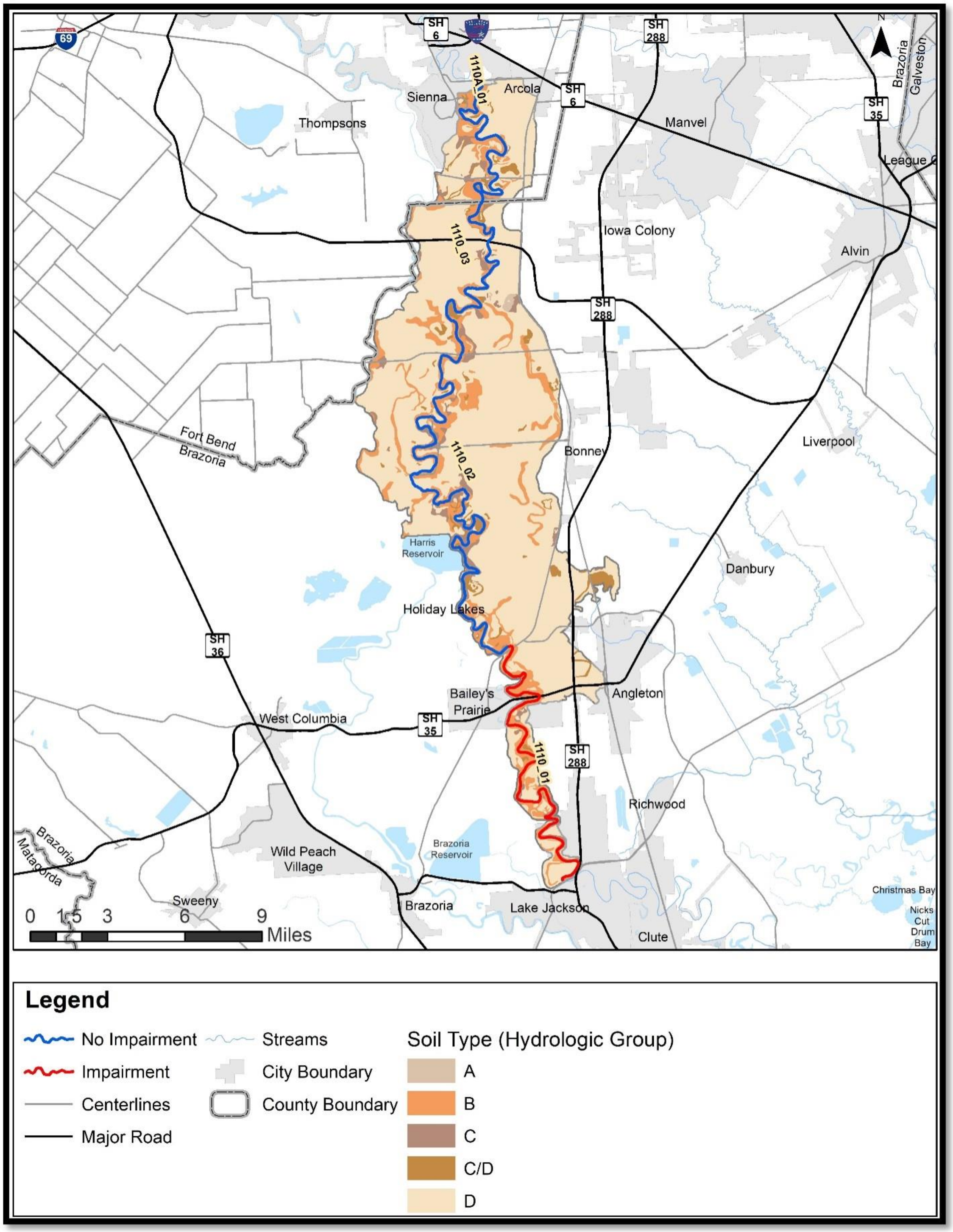

Figure 7. Hydrologic soil groups in Oyster Creek Above Tidal

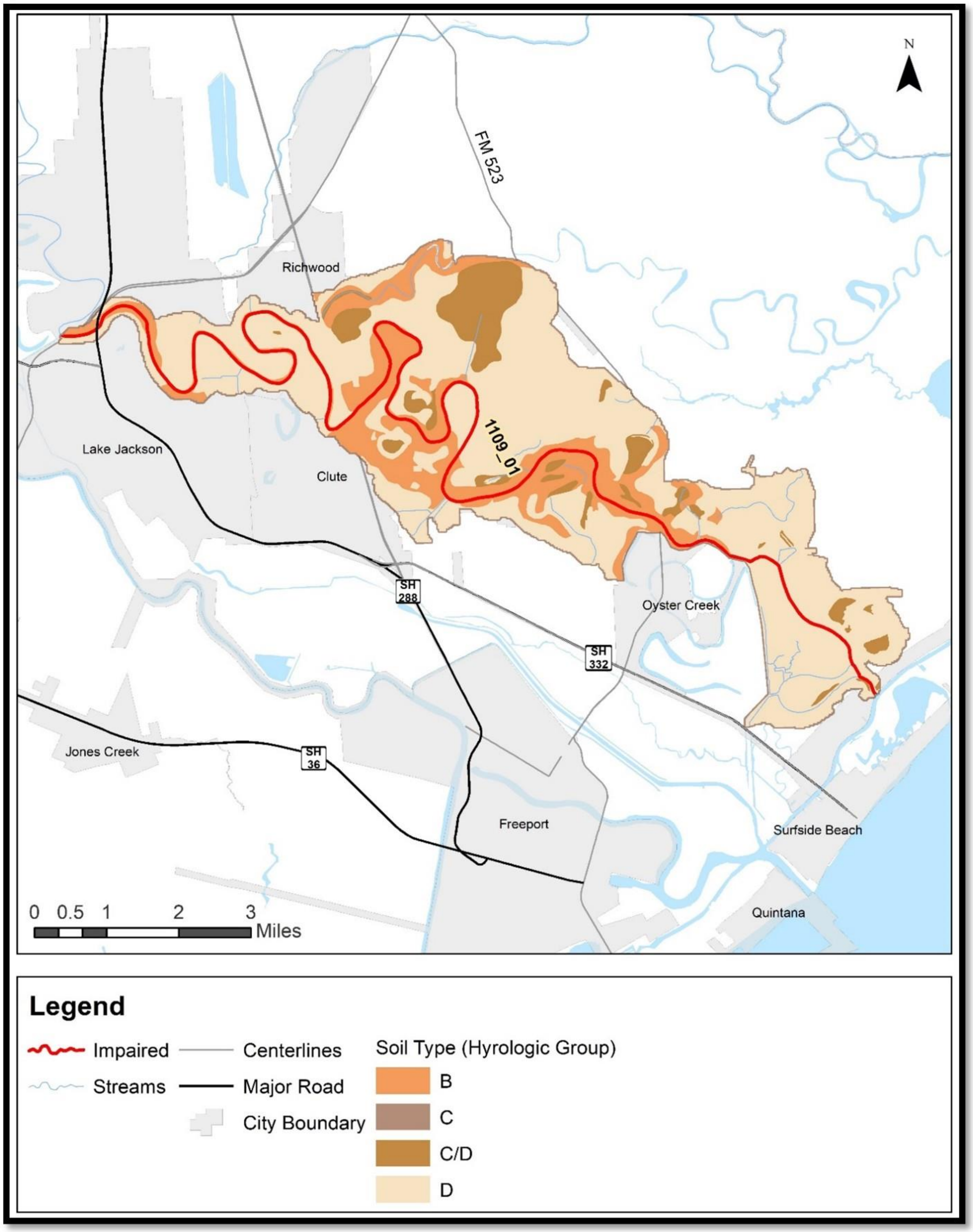

Figure 8. Hydrologic soil groups in Oyster Creek Tidal

Water Rights Review

Surface water rights in Texas are administered and overseen by TCEQ. Water rights were reviewed for U.S. Geological Survey (USGS) flow gage 08078000, which are used to develop flow on Oyster Creek, and at SWQM station 11491 in Oyster Creek.

Water rights for Oyster Creek were reviewed at TCEQ SWQM Station 11491 in AU 1110_01. Two water rights were found. These rights were appropriated in relation to the Harris Reservoir which supplies water for domestic and industrial uses during times of drought. The reservoir captures water from the Brazos River and releases it into the Oyster Creek system above TCEQ SWQM Station 11491. The flow was not removed from developing naturalized flow at TCEQ SWQM Station 11491 as it has a similar impact on flow at TCEQ SWQM Station 11489.

Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be performed and acts as a criterion against which future conditions can be evaluated.

The endpoint for the TMDLs in this report is to maintain the concentrations of *E. coli* in freshwater and Enterococci in tidal waters below the geometric mean criterion of 126 cfu/100 mL or 35 cfu/100 mL, respectively, which is protective of the primary contact recreation 1 use (TCEQ, 2018).

Source Analysis

Pollutants may come from several sources, both regulated and unregulated. Regulated pollutants, referred to as “point sources,” come from a single definable point, such as a pipe, and are regulated by permit under the Texas Pollutant Discharge Elimination System (TPDES) program. WWTFs and stormwater discharges from industries, construction activities, and the separate storm sewer systems of cities are considered point sources of pollution.

Unregulated sources are typically nonpoint source in origin, meaning the pollutants originate from multiple locations and rainfall runoff washes them into surface waters. Nonpoint sources are not regulated by permits.

Except for WWTFs, which receive individual wasteload allocations (WLAs) (see the “WLA” section), the regulated and unregulated sources in this section are presented to give a general account of the different sources of bacteria expected in the watershed. These are not meant to be used for allocating bacteria loads or interpreted as precise inventories and loadings.

Regulated Sources

Regulated sources are controlled by permit under the TPDES program. The regulated sources in the TMDL watersheds include domestic and industrial WWTF outfalls, SSOs, and stormwater discharges from regulated construction sites, industrial sites, and municipal separate storm sewer systems (MS4s).

Domestic and Industrial Wastewater Treatment Facilities

As of May 2022, seven wastewater permits were active within the Oyster Creek watershed, discharging through eight permitted outfalls (Table 6, Figures 9 and 10). Five of the discharge permits have bacteria limits. The remaining two discharge permits do not have bacteria limits, and is excluded from further analysis (TCEQ, 2022c).

The permit held by the Texas Department of Criminal Justice (TDCJ) Terrell Unit was removed from further analysis as the cannery is permitted for industrial wastewater and the effluent does not include fecal bacteria. However, the effluent is discharged to a pond and may include bacteria through vegetable wash-water that during high rainfall events or flooding may be released to Oyster Creek.

The Dow Chemical Company Stratton Ridge Plant Site holds a permit for the discharge of stormwater into the watershed. This facility is included in the stormwater allocation analysis and is not included here.

Additionally, the Oyster Creek watershed includes WWTFs that are not included in the WLA analysis as they discharge outside of the TMDL watershed. Sienna MUD Number 1 and Fort Bend County MUD 131 operate WWTFs located in the watershed but the treated effluent is discharged outside of the watershed to channels of Middle Oyster Creek (Segment 1258). The Lake Jackson WWTF discharges outside of the watershed to the Brazos River (Segment 1201). The City of Clute WWTF also discharges outside of the watershed to Old Brazos River Channel (Segment 1111). These WWTFs are not included in the WWTF analysis; however, their sanitary sewer lines run through the watershed and should be considered a potential source of SSOs.

The five permittees identified for the WLA analysis hold bacteria limits in their permits and discharge to Oyster Creek Tidal or Oyster Creek Above Tidal (Table 6).

Table 6. Permitted domestic and industrial WWTFs

Subwatershed	AU	TPDES/NPDES[a] Number	Permittee	Facility Name	Facility Type[b]	Outfall Number	Bacteria Limit	Average Daily Discharge (MGD)[c]	Full Permitted Discharge (MGD)
Oyster Creek Tidal	1109_01	WQ0010798001/ TX0025283	Commodore Cove Improvement District	Commodore Cove Improvement District WWTF	WW	1	35 (Enterococci)	0.02	0.06
Oyster Creek Tidal	1109_01	WQ0004429000/ TX00124915	The Dow Chemical Company	Stratton Ridge Plant Site Salt Dome Operations	SW	001, 002	n/a	n/a	Intermittent and Flow Variable
Oyster Creek Above Tidal	1110_01	WQ0010548004/ TX0056316	City of Angleton	Oyster Creek WWTF	WW	1	126 (*E. coli*)	1.85	3.6
Oyster Creek Above Tidal	1110_01	WQ0012113001/ TX0079260	Undine Texas Environmental, LLC	Beechwood WWTF	WW	1	126 (*E. coli*)	0.02	0.1
Oyster Creek Above Tidal	1110_02	WQ0013804001/ TX0115169	TDCJ	Terrell Unit WWTF	WW	1	126 (*E. coli*)	1.54	2.0
Oyster Creek Above Tidal	1110_02	WQ0002952000/ TX0103896	TDCJ	TDCJ Terrell Cannery	IW	1	n/a	n/a	0.25
Oyster Creek Above Tidal	1110_03	WQ0010743001/ TX0031585	TDCJ	TDCJ Darrington WWTF	WW	1	126 (*E. coli*)	0.68	0.8

[a] NPDES: National Pollutant Discharge Elimination System

[b] WW= domestic wastewater treatment plant, IW= industrial wastewater, SW= stormwater

[c] MGD: million gallons per day

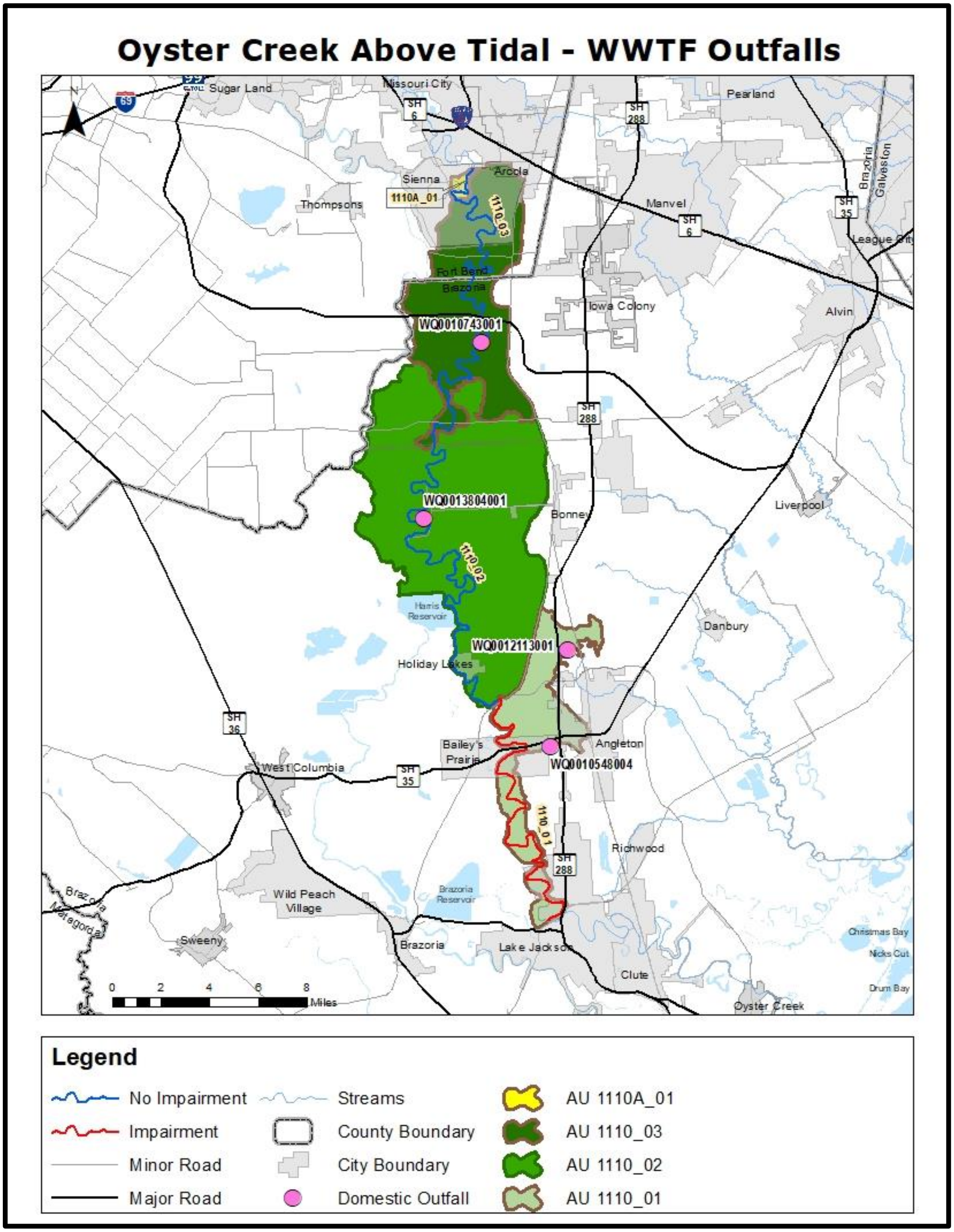

Figure 9. Regulated sources in Oyster Creek Above Tidal

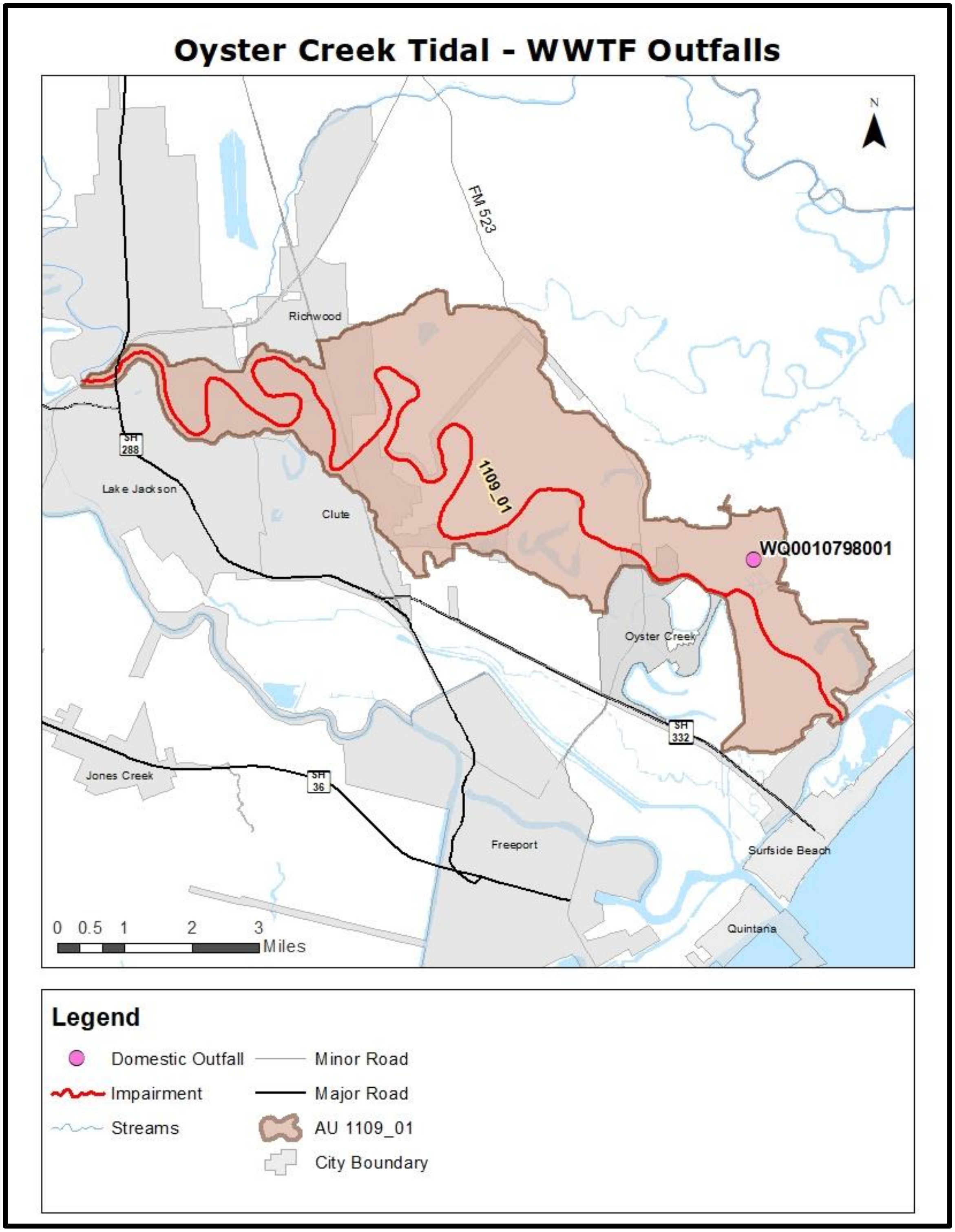

Figure 10. Regulated sources in Oyster Creek Tidal

TCEQ/TPDES Water Quality General Permits

Certain types of activities must be covered by one of several TCEQ/TPDES wastewater general permits:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production
- TXG340000 – petroleum bulk stations and terminals
- TXG640000 – conventional water treatment plants
- TXG670000 – hydrostatic test water discharges
- TXG830000 – water contaminated by petroleum fuel or petroleum substances
- TXG870000 – pesticides (application only)
- TXG920000 – concentrated animal feeding operations (CAFOs)
- WQG100000 – wastewater evaporation
- WQG200000 – livestock manure compost operations (irrigation only)

The following general permit authorizations are not considered to affect the bacteria loading in the TMDL watershed and were excluded from this investigation:

- TXG640000 – conventional water treatment plants
- TXG670000 – hydrostatic test water discharges
- TXG830000 – water contaminated by petroleum fuel or petroleum substances
- TXG870000 – pesticides (application only)
- WQG100000 – wastewater evaporation

A review of active general permit coverage (TCEQ, 2022d) in the Oyster Creek watershed as of May 2022, found one concrete production facility within the Oyster Creek Tidal subwatershed (Segment 1109). This facility does not have bacteria reporting requirements or limits in their authorization. The effluent is assumed to contain inconsequential amounts of indicator bacteria; therefore, it was unnecessary to allocate a bacteria load to this facility. Because the concrete production facility is authorized to discharge stormwater, they will be considered in the stormwater allocation analysis.

Three CAFO general permit authorizations were found in the Oyster Creek Above Tidal subwatershed (Segment 1110), however they are not authorized to discharge wastewater except under chronic or catastrophic conditions and are required to contain waste onsite. The CAFOs are not expected to be a significant source of indicator bacteria and were not used in the allocation analysis as they do not discharge wastewater.

Sanitary Sewer Overflows

SSOs are unauthorized discharges that must be addressed by the responsible party, either the TPDES permittee or the owner of the collection system that is connected to the permitted system. During dry weather, these overflows are most often the result of blockages in the sewer collection pipes caused by tree roots, grease, and other debris. Inflow and infiltration are typical causes of overflows under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the inflow and infiltration problem. Other causes, such as a collapsed sewer line, may occur under any condition.

A review of SSOs reported to TCEQ Region 12 by permit holders in Oyster Creek found 91 SSOs reported for the period of 2016-2021 (TCEQ, 2022e). Total volume was estimated at 241,321 gallons. The reported causes for the SSOs were dominated by infiltration and inflow (36 SSOs), power outages (18 SSOs), and equipment failure (12 SSOs).

TPDES-Regulated Stormwater

When evaluating stormwater for a TMDL allocation, a distinction must be made between stormwater originating from an area under a TPDES-regulated discharge permit and stormwater originating from areas not under a TPDES - regulated discharge permit. Stormwater discharges fall into two categories:

1) Stormwater subject to regulation, which is any stormwater originating from TPDES-regulated MS4 entities, stormwater discharges associated with regulated industrial activities, and construction activities.
2) Stormwater runoff not subject to regulation.

TPDES MS4 Phase I and II rules require municipalities and certain other entities to obtain permit coverage for their stormwater systems. A regulated MS4 is a publicly owned system of conveyances and includes ditches, curbs, gutters, and storm sewers that do not connect to a sanitary wastewater collection system or treatment facility. Phase I permits are individual permits for large and medium-sized MS4s with populations of 100,000 or more based on the 1990 U.S. Census, whereas the Phase II MS4 General Permit regulates other MS4s within an urbanized area (UA) as defined by the USCB.

The purpose of an MS4 permit is to reduce the discharges of pollutants in stormwater to the “maximum extent practicable” by developing and implementing a stormwater management program (SWMP). The SWMP describes the stormwater control practices that the regulated entity will implement, consistent with permit requirements, to minimize the discharge of pollutants. The MS4 permits require that SWMPs specify the best management practices (BMPs) to meet several minimum control measures (MCMs) that, when implemented in concert, are expected to result in significant reductions of pollutants discharged into receiving water bodies. Phase II MS4 MCMs include all of the following:

- Public education, outreach, and involvement.
- Illicit discharge detection and elimination.
- Construction site stormwater runoff control.
- Post-construction stormwater management in new development and redevelopment.
- Pollution prevention and good housekeeping for municipal operations.
- Industrial stormwater sources (only required for MS4s serving a population of 100,000 people or more in the urban area).
- Authorization for construction activities where the small MS4 is the site operator (*optional*)[b].

Phase I MS4 individual permits have their own set of MCMs that are similar to the Phase II MCMs, but Phase I permits have additional requirements to perform water quality monitoring and implement a floatables program. The Phase I MCMs include all of the following:

- MS4 maintenance activities.
- Post-construction stormwater control measures.
- Detection and elimination of illicit discharges.
- Pollution prevention and good housekeeping for municipal operations.
- Limiting pollutants in industrial and high-risk stormwater runoff.
- Limiting pollutants in stormwater runoff from construction sites.
- Public education, outreach, involvement, and participation.
- Monitoring, evaluating, and reporting.

Discharges of stormwater from a Phase II MS4 area, regulated industrial facility, construction area, or other facility involved in certain activities must be covered under the following TCEQ/TPDES general permits:

- TXR040000 – Phase II MS4 General Permit for MS4s located in UAs
- TXR050000 – Multi-Sector General Permit (MSGP) for industrial facilities
- TXR150000 – Construction General Permit (CGP) for construction activities disturbing more than one acre or are part of a common plan of development disturbing more than one acre

A review of active permits in the TCEQ Central Registry found that there are 31 active Phase II MS4 permit authorizations and a statewide combined Phase I and II MS4 individual permit held by the Texas Department of Transportation (TxDOT) for rights-of-way in their MS4 regulated areas in the Oyster Creek

[b] MCM only applies to Phase II MS4s which serve a population of 100,000 or more.

watershed (Table 7) (TCEQ, 2022d). Data from USCB covering UAs was used to map potential MS4 coverage area for the watershed and to determine the likely area under the MS4 Phase II permit (USCB, 2010). Approximately 6,632.99 acres or 6.85% of the Oyster Creek watershed is under a stormwater permit. Of this total, 3,582.09 acres and 3,050.90 acres were found in the Oyster Creek Above Tidal and Oyster Creek Tidal subwatersheds, respectively (Figures 11 and 12).

Table 7. MS4 permit authorizations

Segments	Entity	Authorization Type	TPDES Authorization or Permit No./ EPA ID	Location
1109/1110	Texas Department of Transportation	Combined Phase I/II MS4	WQ0005011000/ TXS002101	Area within TXDOT rights-of-way located within Phase I and Phase II urbanized areas
1109/1110	City of Clute	Phase II MS4 General Permit TXR040000	TXR040139/Not applicable	Area within the Clute City limits that is located within the Lake Jackson Angleton Urbanized Area
1109/1110	City of Lake Jackson	Phase II MS4 General Permit TXR040000	TXR040140/Not applicable	Area within the City of Lake Jackson limits that is located within the Lake Jackson Angleton Urbanized Area
1109/1110	City of Richwood	Phase II MS4 General Permit TXR040000	TXR040141/Not applicable	Area within the City of Richwood limits that is located within the Lake Jackson Angleton Urbanized Area
1109/1110	Velasco Drainage District	Phase II MS4 General Permit TXR040000	TXR040142/Not applicable	Area within the Velasco Drainage District limits that is located within Lake Jackson Angleton Urbanized Area
1109/1110	Brazoria County	Phase II MS4 General Permit TXR040000	TXR040154/Not applicable	Area within the Brazoria County limits that is located within the Lake Jackson Angleton Urbanized Area
1110	City of Angleton	Phase II MS4 General Permit TXR040000	TXR040136/Not applicable	Area within the City of Angleton limits that is located within Lake Jackson Angleton Urbanized Area
1110	Angleton Drainage District	Phase II MS4 General Permit TXR040000	TXR040137/Not applicable	Area within the Angleton Drainage District limits that is located within Lake Jackson Angleton Urbanized Area
1110	City of Missouri City	Phase II MS4 General Permit TXR040000	TXR040298/Not applicable	Area within the City of Missouri City limits that's located within the Houston Urbanized Area

Segments	Entity	Authorization Type	TPDES Authorization or Permit No./ EPA ID	Location
1110	First Colony MUD 9	Phase II MS4 General Permit TXR040000	TXR040292/Not applicable	Area of First Colony MUD 9 service boundary located within the Houston Urbanized Area
1110	Fort Bend County	Phase II MS4 General Permit TXR040000	TXR040045/Not applicable	Area within the County of Fort Bend that is located within the Houston Urbanized Area
1110	Fort Bend County MUD 23	Phase II MS4 General Permit TXR040000	TXR040316/Not applicable	Area outside the City of Fresno limits that is located within City of Houston Urbanized Area
1110	Fort Bend County MUD 24	Phase II MS4 General Permit TXR040000	TXR040519/Not applicable	Area outside the City of Fresno limits that is located within City of Houston Urbanized Area
1110	Fort Bend County MUD 26	Phase II MS4 General Permit TXR040000	TXR040295/Not applicable	Area of Fort Bend County MUD 26 within the City of Missouri City limits within the Houston Urbanized Area
1110	Fort Bend County MUD 42	Phase II MS4 General Permit TXR040000	TXR040293/Not applicable	Area within the City of Missouri City limits that's located within the Houston Urbanized Area
1110	Fort Bend County MUD 46	Phase II MS4 General Permit TXR040000	TXR040579/Not applicable	Area within the City of Missouri City limits that's located within the Houston Urbanized Area
1110	Fort Bend County MUD 47	Phase II MS4 General Permit TXR040000	TXR040290/Not applicable	Area within the City of Missouri City limits that's located within the Houston Urbanized Area
1110	Fort Bend County MUD 49	Phase II MS4 General Permit TXR040000	TXR040363/Not applicable	Area within the boundaries of Fort Bend County MUD 49 within the City of Missouri City limits within the Houston Urbanized Area
1110	Fort Bend County MUD 115	Phase II MS4 General Permit TXR040000	TXR040297/Not applicable	Area within the City of Missouri City limits that's located within the Houston Urbanized Area
1110	Meadowcreek MUD	Phase II MS4 General Permit TXR040000	TXR040296/Not applicable	Area of Meadowcreek MUD within the City of Missouri City limits within the Houston Urbanized Area
1110	Blue Ridge West MUD	Phase II MS4 General Permit TXR040000	TXR040219/Not applicable	Area of Blue Ridge MUD within the City of Missouri City limits within the Houston Urbanized Area

Segments	Entity	Authorization Type	TPDES Authorization or Permit No./ EPA ID	Location
1110	Fort Bend County Drainage District	Phase II MS4 General Permit TXR040000	TXR040383/Not applicable	Area within Fort Bend County that is located within the Houston Urbanized Area
1110	Quail Valley Utility District	Phase II MS4 General Permit TXR040000	TXR040359/Not applicable	Area within the boundaries of Qual Valley Utility District within the City of Missouri City limits within the Houston Urbanized Area
1110	Thunderbird Utility District	Phase II MS4 General Permit TXR040000	TXR040360/Not applicable	Area within legal boundaries of Thunderbird Utility District located within the Houston Urbanized Area
1110	Palmer Plantation MUD1	Phase II MS4 General Permit TXR040000	TXR040361/Not applicable	Area within the Velasco Drainage District limits that is located within the Houston Urbanized Area
1110	Palmer Plantation MUD2	Phase II MS4 General Permit TXR040000	TXR040362/Not applicable	Area within the boundaries of Palmer Plantation MUD 2 that is located within the City of Missouri City limits within the Houston Urbanized Area
1110	Sienna Management District	Phase II MS4 General Permit TXR040000	TXR040513/Not applicable	Area within the City of Missouri City limits that's located within the Houston Urbanized Area
1110	Sienna LID	Phase II MS4 General Permit TXR040000	TXR040514/Not applicable	Area within the City of Missouri City limits that's located within the Houston Urbanized Area
1110	Sienna MUD 1	Phase II MS4 General Permit TXR040000	TXR040515/Not applicable	Area within the City of Missouri City limits that's located within the Houston Urbanized Area
1110	Sienna MUD 2	Phase II MS4 General Permit TXR040000	TXR040516/Not applicable	Area within the City of Missouri City limits that's located within the Houston Urbanized Area
1110	Sienna MUD 3	Phase II MS4 General Permit TXR040000	TXR040517/Not applicable	Area within the City of Missouri City limits that's located within the Houston Urbanized Area
1110	Sienna MUD 10	Phase II MS4 General Permit TXR040000	TXR040518/Not applicable	Area within the City of Missouri City limits that's located within the Houston Urbanized Area

MSGPs were reviewed in TCEQ's Central Registry in May 2022 for active permits within the Oyster Creek Tidal and Oyster Creek Above Tidal subwatersheds (TCEQ, 2022d). A total of seven active MSGPs were found within the Oyster Creek watershed, four in the Oyster Creek Tidal subwatershed and three in the Oyster Creek Above Tidal subwatershed. To eliminate the possibility of over counting the stormwater permit area, only the area of MSGPs located outside of UAs are included. All three MSGPs found within the Oyster Creek Above Tidal subwatershed are outside the UA, totaling 173.88 acres (Figure 11). Three of the four MSGPs in the Oyster Creek Tidal subwatershed were found to have boundaries outside the UA for a total of 2,511.73 acres (Figure 12). The total Oyster Creek watershed area under MSGPs was estimated at 2,685.61 acres.

It was previously noted that permit TX00124915 refers to an individual industrial wastewater permit for two stormwater outfalls. As this permit is for stormwater, the permit is included in the MSGPs calculation. The acreages were estimated by reviewing county appraisal parcel data and/or importing the location information associated with the authorization into a Geographic Information System and measuring the facility area. Once calculated, the area for each MSGP was used in the development of the TMDL allocations.

Construction activities found in the Oyster Creek watershed are constantly changing due to the short-term nature of most construction activities. The permit data is only considered accurate for the date the data was accessed. A review of the TCEQ Central Registry (TCEQ, 2022d) in May 2022 for a period of 2016 through 2021 found a yearly average of 66 active construction activities, 18 in the Oyster Creek Tidal subwatershed and 48 in the Oyster Creek Above Tidal subwatershed.

Due to the variable nature of the stormwater construction permits, the acres recorded serve only as a representative estimate of the acres of land disturbed. Additionally, other construction activities may be occurring in the watershed that are not required to have a CGP authorization or are not regulated.

For the 66 CGP permits found, there was a total annual estimated area of 2,992.26 acres under a construction permit, 384.11 acres in the Oyster Creek Tidal subwatershed and 2,608.15 acres in the Oyster Creek Above Tidal subwatershed. A final step was taken to remove those construction activities found within the UA to prevent over counting. After that step, the estimated construction activity within the Oyster Creek watershed was estimated at 1,163.15 acres, with 152.3 acres in the Oyster Creek Tidal subwatershed and 1,010.85 acres in the Oyster Creek Above Tidal subwatershed.

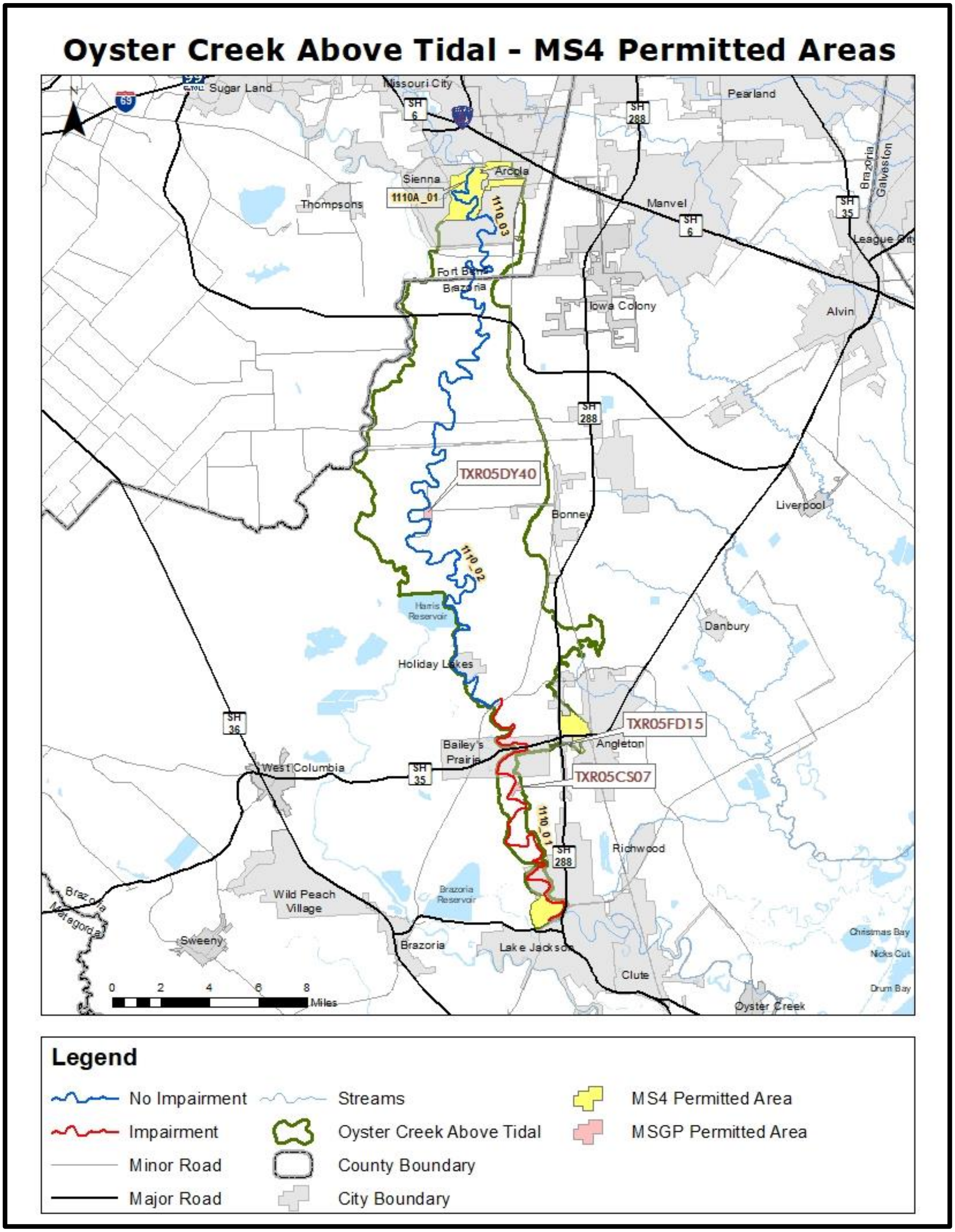

Figure 11. Regulated stormwater area based on MS4s and MSGPs in Oyster Creek Above Tidal

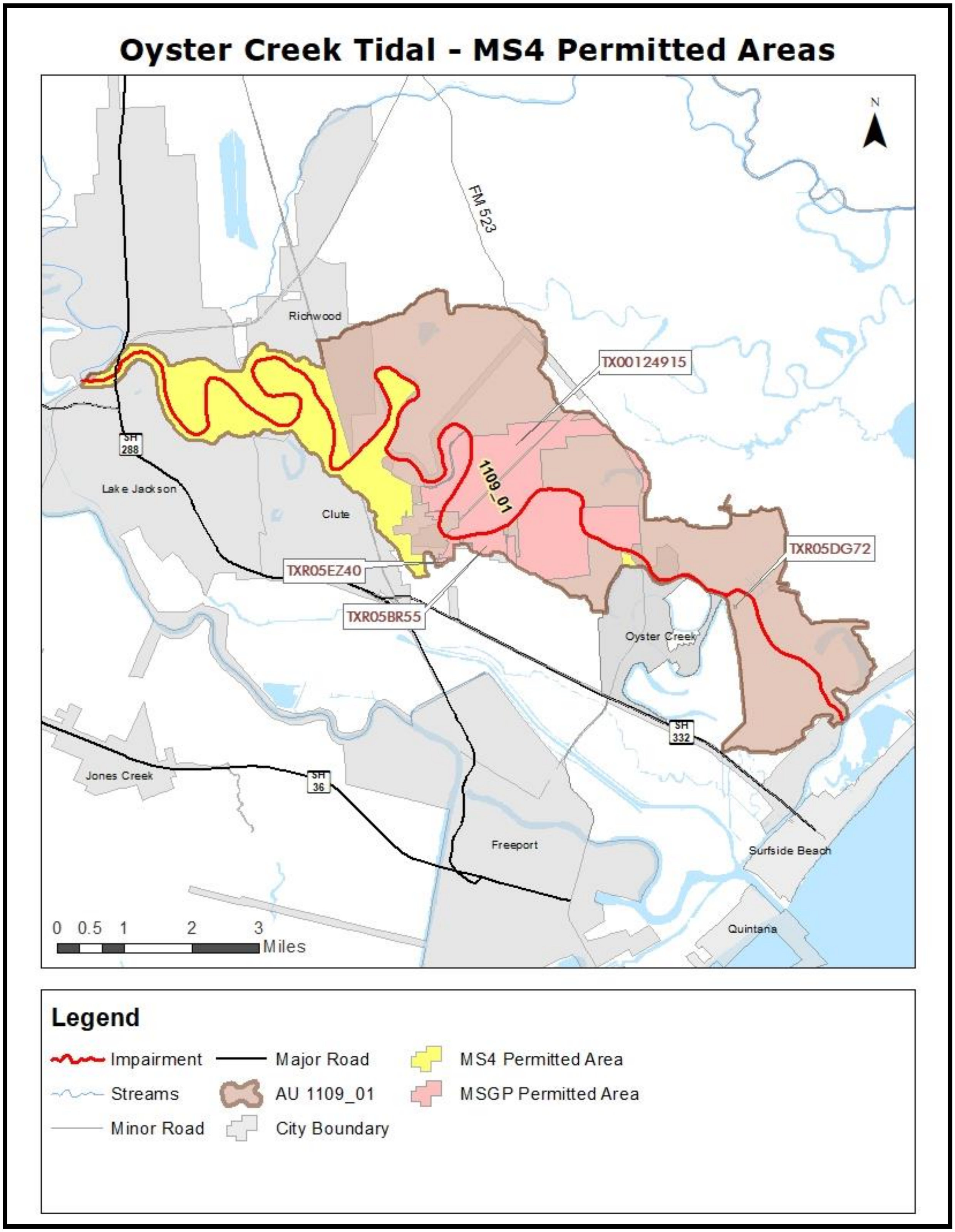

Figure 12. Regulated stormwater area based on MS4s and MSGPs in Oyster Creek Tidal

Illicit Discharges

Pollutant loads can enter water bodies from MS4 outfalls that carry authorized sources, as well as illicit discharges under both dry- and wet-weather conditions. The term "illicit discharge" is defined in TPDES General Permit TXR040000 for Phase II MS4s as "Any discharge to a municipal separate storm sewer system that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities." Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges identified in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC, 2003) include:

Direct Illicit Discharges

- Sanitary wastewater piping that is directly connected from a home to a storm sewer.
- Materials that have been dumped illegally into a storm drain catch basin.
- A shop floor drain that is connected to a storm sewer.
- A cross-connection between a sanitary sewer and storm sewer systems.

Indirect Illicit Discharges

- An old and damaged sanitary sewer line that is leaking fluids into a cracked storm sewer line.
- A failing septic system that is leaking into a cracked storm sewer line or causing surface discharge into a storm sewer.

Unregulated Sources

Unregulated sources of bacteria are generally nonpoint. Nonpoint source loading enters the impaired water body through distributed, nonspecific locations, which may include urban runoff not covered by a permit, wildlife, various agricultural activities, agricultural animals, land application fields, failing OSSFs, unmanaged and feral animals, and domestic pets.

Unregulated Agricultural Activities and Domesticated Animals

A number of agricultural activities that do not require permits can be potential sources of fecal bacteria loading. Activities, such as livestock grazing close to water bodies and the use of manure as fertilizer, can contribute *E. coli* and Enterococci to nearby water bodies. Livestock are present throughout the more rural portions of the project watershed.

Table 8 provides estimated numbers of selected livestock in the TMDL watershed based on the county level data for Brazoria and Fort Bend counties collected in the 2017 Census of Agriculture conducted by USDA (USDA NASS, 2019). These estimations were calculated by applying a ratio of watershed land area compared to county land area multiplied by the livestock numbers. Applicable watershed land area was determined as an equal distribution of livestock across land cover types: emergent wetland, shrub/scrub, and pasture/grasslands (Table 4). The Texas State Soil and Water Conservation Board (TSSWCB) staff reviewed the watershed estimated livestock numbers. These livestock numbers, however, were not used to develop an allocation of allowable bacteria loading to livestock.

Table 8. Estimated livestock population

AU	Area (Acres)	Cattle and Calves	Hogs and Pigs	Sheep and Goats	Equine	Poultry
1109_01	7,060	1,102	61	78	73	1,988
1110_01	38,200	6,015	235	352	394	7,690
Total	**45,260**	**7,117**	**296**	**430**	**467**	**9,678**

Fecal matter from dogs and cats is transported to water bodies by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 9 summarizes the estimated number of dogs and cats in the TMDL watershed. Pet population estimates were calculated as the estimated number of dogs (0.614) and cats (0.457) per household (AVMA, 2018). The actual contribution and significance of bacteria loads from pets reaching the water bodies of the watershed is unknown.

Table 9. Estimated households and pet population

AU	Estimated Households	Estimated Dog Population	Estimated Cat Population
1109_01	4,569	2,805	2,088
1110_01	9,823	6,032	4,489
Total	**14,392**	**8,837**	**6,577**

Wildlife and Unmanaged Animals

Fecal bacteria are common inhabitants of the intestines of all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify, by watershed, the potential for bacteria contributions from wildlife. Wildlife are naturally attracted to riparian corridors of water bodies. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria loading to a water body. Fecal bacteria from wildlife are also deposited onto land surfaces, where they may be washed into nearby water bodies by rainfall runoff.

Most avian and mammalian wildlife, including invasive species, are difficult to estimate as long-term monitoring data or literature values indicating historical baselines are lacking. However, the White-Tailed Deer Program of the Texas Parks and Wildlife Department (TPWD) estimates deer populations for their Resource Management Units. In the ecoregion surrounding Oyster Creek, TPWD deer population estimates recorded from 2008 through 2020 average 0.03957 deer for every acre, regardless of land cover type (TPWD, 2020). By applying this factor to the acreage in the Oyster Creek watershed, the white-tailed deer population is estimated at 3,715 (Table 10).

Table 10. Estimated deer population

AU	Suitable Habitat (acres)	Estimated Deer Population
1109_01	15,086.60	597
1110_01	78,796.80	3,118
Total	**93,883.40**	**3,715**

Feral hogs are a non-native, invasive species, which likely impact the watershed with fecal waste contamination. Like deer, factors for estimating feral hog populations based on land area are available. These factors vary depending on land cover types and range between 8.9 and 16.4 hogs per square mile (Timmons, et. al., 2012). Feral hog population estimates may be weighted more heavily in riparian areas where animals are protected from the stresses associated with development and have more direct access to available food and water resources. The 8.9 hogs per square mile population estimate was applied to Barren, Cropland, and Developed Low Intensity land cover types and is considered to be low quality habitat. The 16.4 hogs per square mile population estimate was applied to Open Space Development, Forest/Shrub, Pasture/Grassland and Wetland land cover types and is considered to be high quality habitat. Under these assumptions, feral hogs were estimated to have a total population of 2,126 within the Oyster Creek watershed (Table 11).

Table 11. Estimated feral hog population

AU	Low Quality Habitat (acres)	Estimated Feral Hogs	High Quality Habitat (acres)	Estimated Feral Hogs	Total Estimated Feral Hogs
1109_01	1,584.00	22	11,828.40	303	325
1110_01	12,133.30	169	63,676.20	1,632	1,800
Total	**13,717.30**	**191**	**75,504.60**	**1,935**	**2,126**

On-Site Sewage Facilities

Private residential on-site sewage facilities (OSSFs), commonly referred to as septic systems, consist of various designs based on the physical conditions of the local soils. Typical designs consist of 1) one or more septic tanks and a drainage or distribution field (anaerobic system) and 2) aerobic systems that have an aerated holding tank and often an above ground sprinkler system for distributing the liquid. In simplest terms, household waste flows into the septic tank or aerated tank, where solids settle out. The liquid portion of the water flows to the distribution system, which may consist of buried perforated pipes or an above ground sprinkler system.

Several pathways of the liquid waste in OSSFs afford opportunities for bacteria to enter ground and surface waters if the systems are not properly operating. However, properly designed and operated OSSFs contribute virtually no fecal bacteria to surface waters. For example, less than 0.01% of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drainfield of a septic system (Weiskel et. al., 1996). Reed, Stowe, and Yanke LLC (2001) provide estimated failure rates of OSSFs for different regions of Texas. The TMDL watershed is located within the Region IV area, which has a reported failure rate of about 12%, providing insight into expected failure rates for the area.

Some OSSFs in the TMDL watershed are operated under permit; however, some units are unregistered or not consistently reported. For the purposes of this report, all OSSFs will be treated as unregulated sources of fecal waste due to the nature of their permits, lack of reported data, and diffuse nature.

The number of permitted and registered OSSFs in this watershed have been compiled by H-GAC in coordination with authorized agents (AA) in H-GAC's service region, which includes the Oyster Creek watershed (H-GAC, 2022a). Brazoria and Fort Bend counties are local AAs who have accepted responsibility from TCEQ to permit OSSFs and enforce laws and rules governing OSSFs on behalf of the State.

There are 1,390 registered OSSFs in the Oyster Creek watershed, 1,321 in the Oyster Creek Above Tidal subwatershed and 69 in the Oyster Creek Tidal subwatershed (Figures 13 and 14).

In addition to permitted systems, there are OSSFs that are not registered. Non-registered OSSF locations were estimated using H-GAC's geographic information database of potential OSSF locations (H-GAC, 2022b) in the Houston-Galveston area using known OSSF locations, 911 addresses, and WWTF service boundaries. Using H-GAC's estimate of non-registered OSSFs, there are likely another 2,144 total OSSFs; 253 in the Oyster Creek Tidal subwatershed and 1,891 in the Oyster Creek Above Tidal subwatershed.

OSSFs can be an appreciable source of fecal waste when not sited or functioning properly, especially when they are close to waterways. Many factors including soil type, design, age, and maintenance can influence the likelihood of an OSSF failure. By applying the estimated 12% failure rate to the 3,534 total OSSFs estimated within the Oyster Creek watershed, 424 OSSFs are projected to be failing.

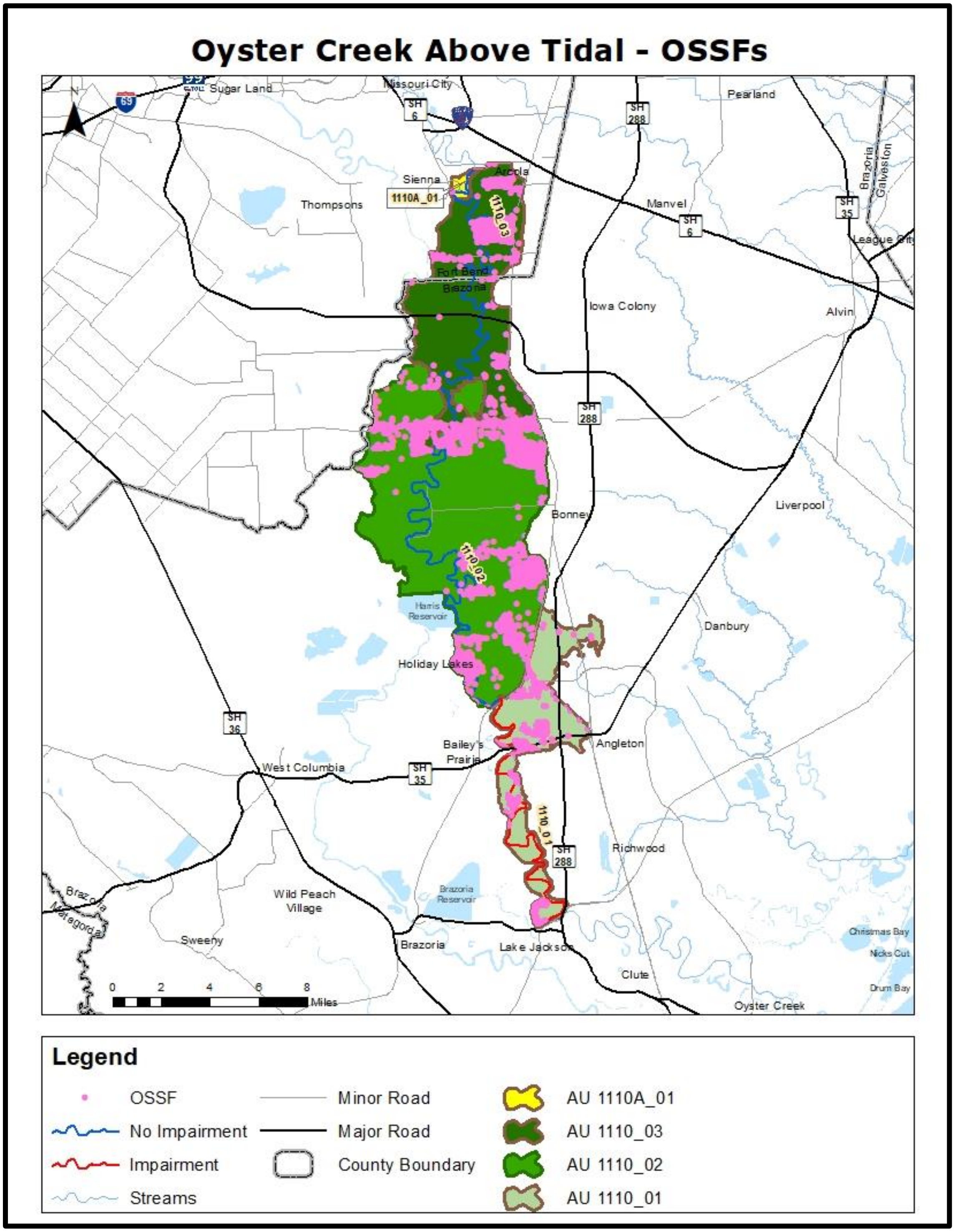

Figure 13. Estimated OSSFs in Oyster Creek Above Tidal

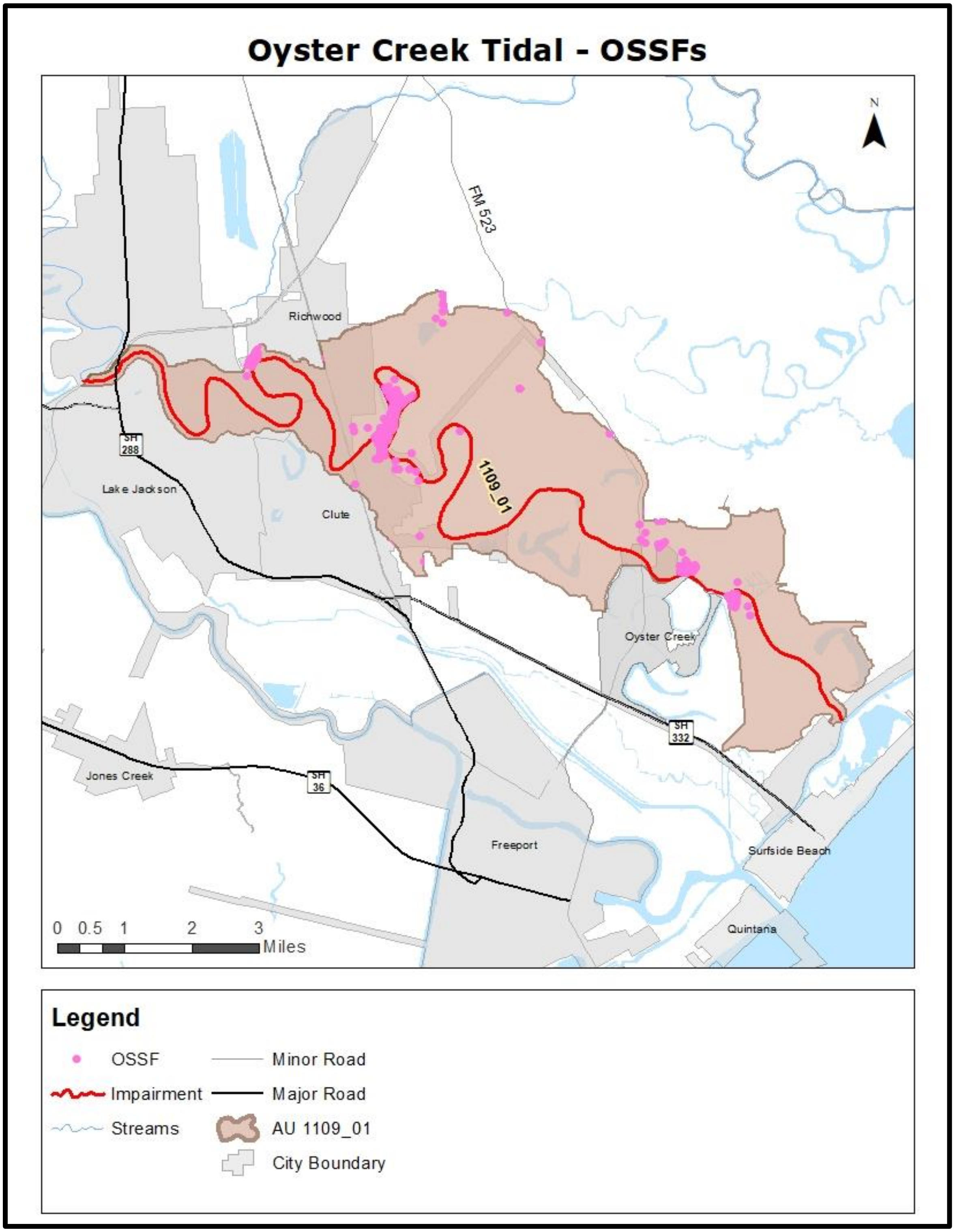

Figure 14. Estimated OSSFs in Oyster Creek Tidal

Bacteria Survival and Die-off

Bacteria are living organisms that survive and die. Certain enteric bacteria can survive and replicate in organic materials if appropriate conditions prevail (e.g., warm temperature). Fecal organisms can survive and replicate from improperly treated effluent during their transport in pipe networks, and they can survive and replicate in organic-rich materials such as improperly treated compost and sewage sludge (or biosolids). While die-off of bacteria has been demonstrated in natural water systems due to the presence of sunlight and predators, the potential for their re-growth is less understood. Both replication and die-off are instream processes and are not considered in the bacteria source loading estimates in the TMDL watershed.

Linkage Analysis

Establishing the relationship between instream water quality and the source of loadings is an important component in developing a TMDL. It allows for the evaluation of management options that will achieve the desired endpoint. This relationship may be established through a variety of techniques.

Generally, if high bacteria concentrations are measured in a water body at low to median flows in the absence of runoff events, the main contributing sources are likely to be point sources and direct deposition. During ambient flows, these inputs to the system will increase pollutant concentrations depending on the magnitude and concentration of the sources. As flows increase in magnitude, the impact of point sources like direct deposition is typically diluted and would therefore be a smaller part of the overall concentrations.

Bacteria load contributions from regulated and unregulated stormwater sources are greatest during runoff events. Rainfall runoff, depending upon the severity of the storm, can carry fecal bacteria from the land surface into the receiving water body. Generally, this loading follows a pattern of higher concentrations in the water body as the first flush of storm runoff enters the receiving water body. Over time, the concentrations decline because the sources of indicator bacteria are attenuated as runoff washes them from the land surface and the volume of runoff decreases following the rain event.

Load Duration Analysis

Load duration curves (LDCs) are graphs of the frequency distribution of loads of pollutants in a water body. LDC analyses are used to examine the relationship between instream water quality and broad sources of bacteria loads which are the basis of the TMDL allocations (Cleland, 2003). In the case of these TMDLs, the loads shown are of *E. coli* bacteria for AU 1110_01 and Enterococci bacteria for AU 1109_01 in cfu/day. Mean daily streamflow data from USGS gage 08078000 and TCEQ SWQM Station 11491 was used to develop the TMDLs for AU 1110_01 and AU 1109_01. TMDLs were developed for station locations within the impaired AUs, TCEQ SWQM stations 11489 in AU

1110_01 and 11486 in AU 1109_01. It should be noted that TCEQ SWQM Station 11486 is not the station located the furthest downstream in AU 1109_01. However, a review of the data at TCEQ SWQM Station 11485, the most downstream station, shows that the impairment is being driven by data collected at TCEQ SWQM Station 11486. For more detail, see Section 3.3 of the *Technical Support Document for Two Total Maximum Daily Loads for Indicator Bacteria in the Oyster Creek Watershed* (H-GAC, 2023).

LDCs and modified LDCs are derived from flow duration curves (FDCs) and modified FDCs. LDCs shown in the following figures represent the maximum acceptable load in the water bodies that will result in the achievement of the TMDL water quality targets. The basic steps to generate LDCs for AU 1110_01 involved:

- Generating a daily flow record – the mean daily streamflow record incorporating full permitted discharges and FG was developed for a TCEQ SWQM station within each TMDL watershed using the drainage area ratio methodology.
- Developing the FDC – the mean daily streamflow is plotted against the exceedance probability of the mean daily streamflow for each day.
- Converting the FDC to an LDC – the mean daily streamflow for each day is multiplied by the primary contact recreation 1 use geometric mean criterion and a conversion factor to produce a graph of the frequency distribution of allowable loads.
- Overlaying the LDC with available indicator bacteria loading measurements to understand under what flow conditions indicator bacteria loading exceeds the primary contact recreation 1 use geometric mean criterion.

The basic steps to generate modified LDCs for AU 1109_01 involved:

- Generating a daily freshwater flow record – the mean daily freshwater flow record incorporating actual daily average permitted discharges was developed for the most downstream TCEQ SWQM station in a neighboring AU using a drainage area ratio methodology and the mean daily streamflow reported at USGS Gage 08078000 on Chocolate Bayou and at TCEQ SWQM Station 11491. The USGS gage was selected due to the lack of available daily streamflow data for the period of 2004 to 2020 at TCEQ SWQM Station 11491. Mean daily stream flow at TCEQ SWQM Station 11491 was limited to the period of 2017 to 2020. The Chocolate Bayou watershed is close to the Oyster Creek watershed, and it has a similar drainage area (Table 12, Figure 15), land cover composition, weather patterns, and watershed land use activities, such as agriculture and industries. A regression analysis was performed using the mean daily stream flows from Chocolate Bayou and Oyster Creek to derive a mean daily stream flow for Oyster Creek covering the period of 2004 to 2020.
- Generating a daily tidal volume record – the daily tidal seawater volume record was generated using salinity to streamflow regressions and mass-balance

equations. The tidal seawater volumes were added to the daily freshwater flow record for the tidal AU.

- Accounting for full permitted discharges – the actual daily average permitted discharges are removed from the streamflow and the full permitted daily average discharges and FG discharges are added.
- Developing the modified FDCs – the mean daily streamflow including seawater volume, full permitted discharges, and FG is plotted against the exceedance probability of the mean daily streamflow for each day for the tidal AU.
- Converting the modified FDCs to modified LDCs – the mean daily streamflow for each day is multiplied by the primary contact recreation 1 use geometric mean criterion and a conversion factor to produce a graph of the frequency distribution of allowable loads.
- Overlaying the modified LDC with available indicator bacteria loading measurements to understand under what flow conditions indicator bacteria loading exceeds the primary contact recreation 1 use geometric mean criterion.

More information explaining the modified LDC method may be found in Chapter 2 and Appendix 1 of the Umpqua Basin Total Maximum Daily Loads and supporting documents (ODEQ, 2006).

Table 12. Catchment area comparison

Waterbody	Station Number	Catchment Area (mi^2)
Chocolate Bayou	08078000	77.54
Oyster Creek	11491	100.77

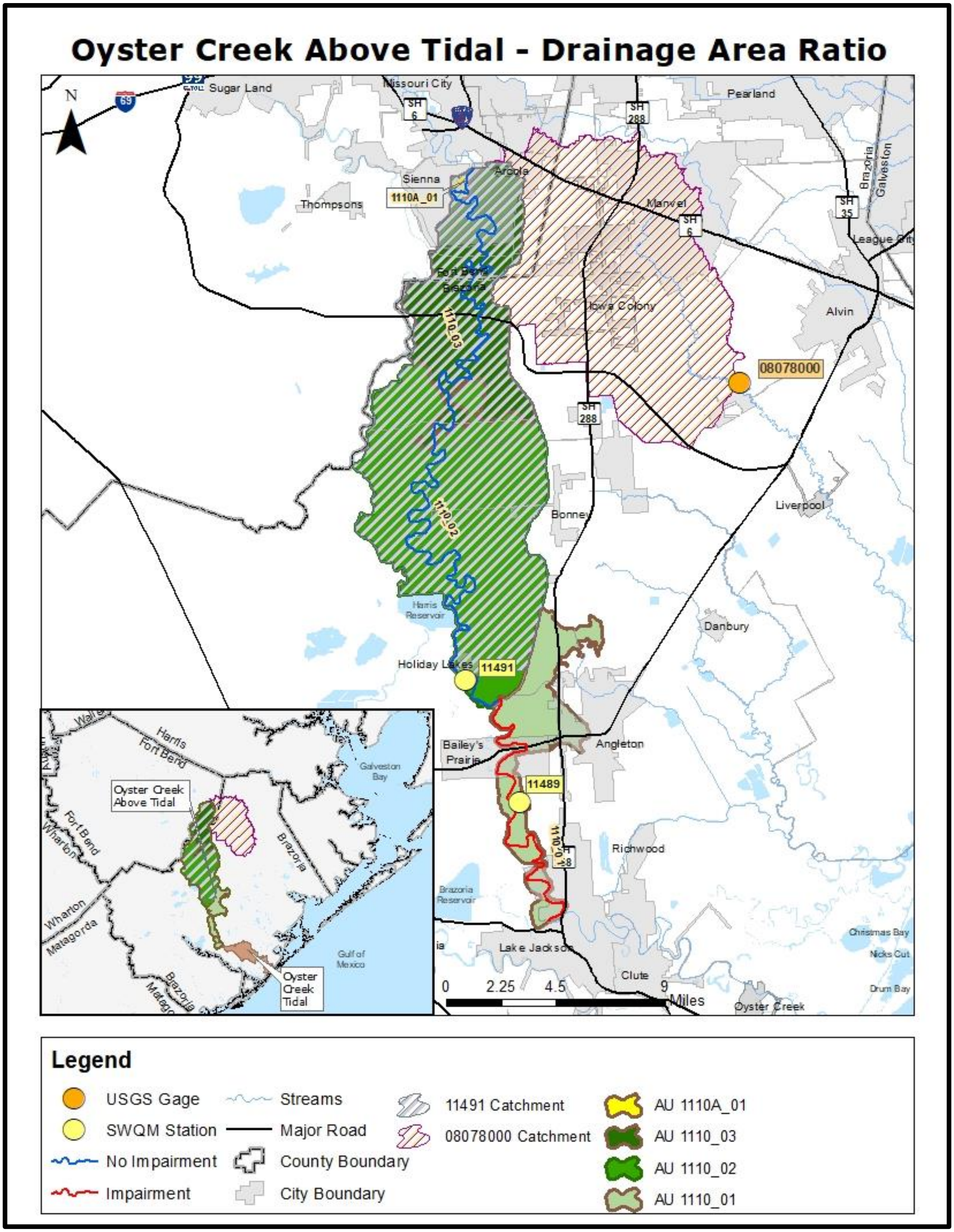

Figure 15. Catchment area comparison

Load Duration Curve Results

Figures 16, 17, and 18, present LDCs for TCEQ SWQM stations 11485, 11486, and 11489, respectively. The figures include the FDC, the geometric mean criterion curves, the single sample criterion curve, the existing load regression curve, the observed bacteria geometric mean load by flow regime (single points), and individual observed bacteria data points.

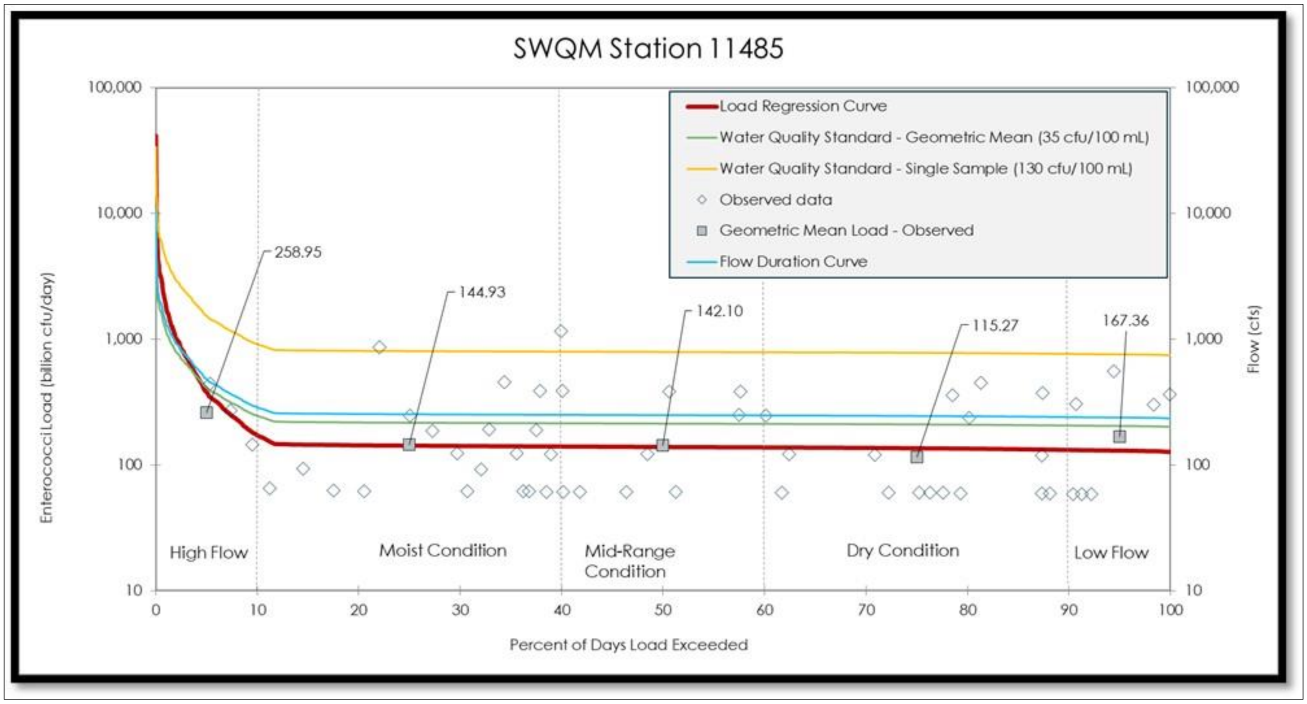

Figure 16. Modified LDC for TCEQ SWQM Station 11485 in Oyster Creek Tidal (AU 1109_01)

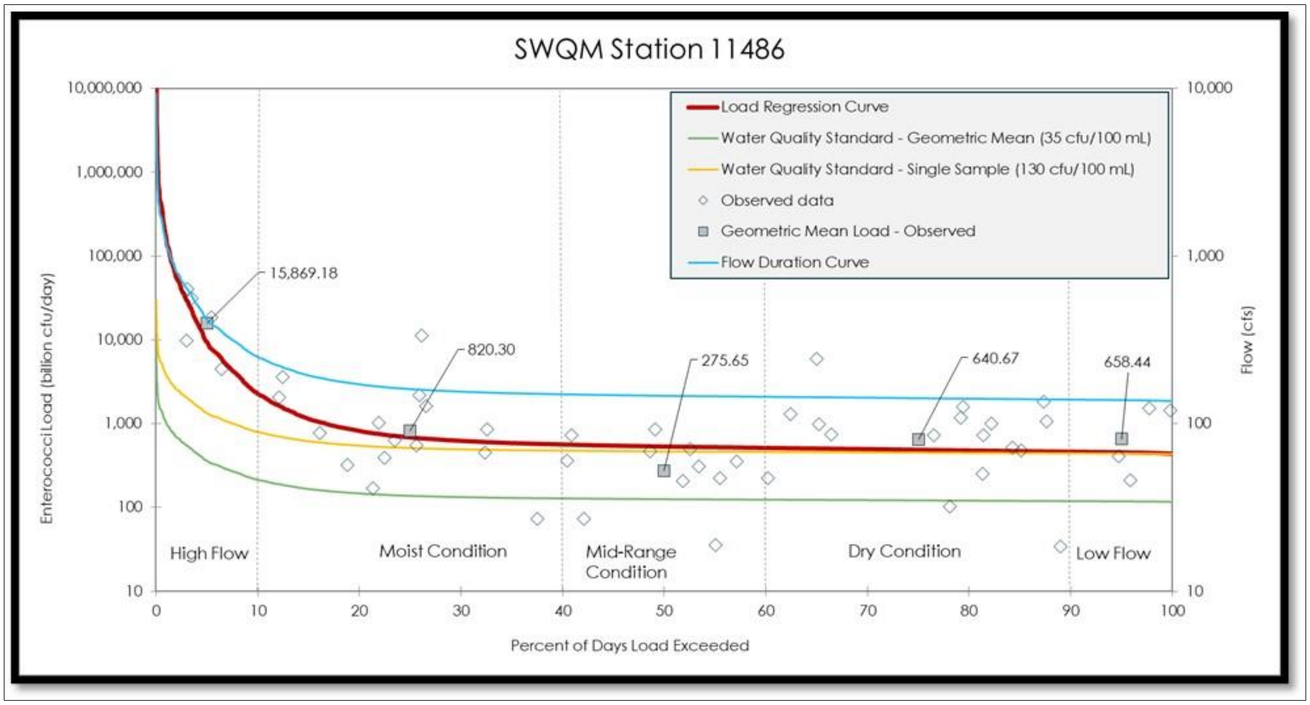

Figure 17. Modified LDC for TCEQ SWQM Station 11486 in Oyster Creek Tidal (AU 1109_01)

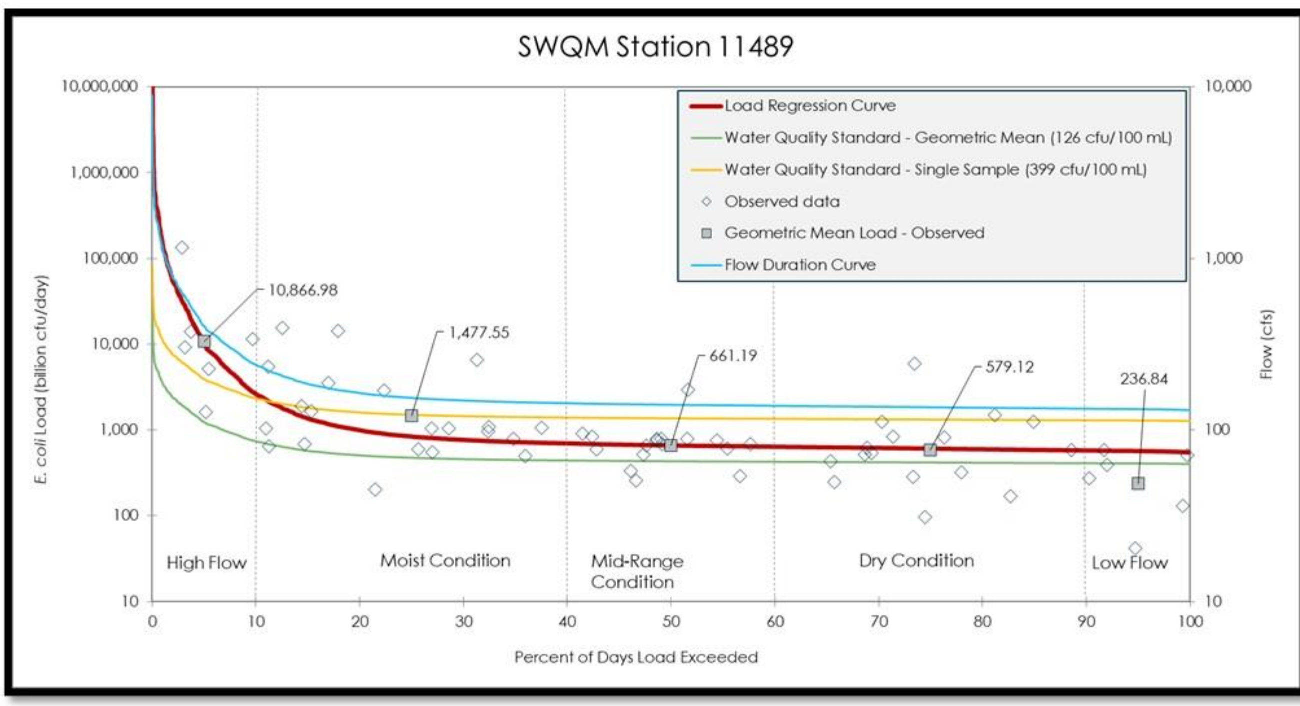

Figure 18. LDC for TCEQ SWQM Station 11489 in Oyster Creek Above Tidal (AU 1110_01)

Margin of Safety

The margin of safety (MOS) is used to account for uncertainty in the analysis used to develop the TMDL and thus provide a higher level of assurance that the goal of the TMDL will be met. It also accounts 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.

According to EPA guidance (EPA, 1991), the MOS can be incorporated into the TMDL using either of the following two methods:

1) Implicitly incorporating the MOS using conservative model assumptions to develop allocations.
2) Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

These TMDLs incorporate an explicit MOS of 5% of the total TMDL allocation.

Pollutant Load Allocation

The TMDL represents the maximum amount of a pollutant that the stream can receive in a single day without exceeding water quality standards. The pollutant load allocations for the selected scenarios were calculated using the following equation:

TMDL = WLA + LA + FG + MOS

Where:

WLA = wasteload allocations, the amount of pollutant allowed by regulated dischargers

LA = load allocations, the amount of pollutant allowed by unregulated sources

FG = loadings associated with future growth from potential regulated facilities

MOS = margin of safety load

TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures [40 CFR 130.2(i)]. For *E. coli* and Enterococci, TMDLs are expressed as cfu/day, and represent the maximum one-day load the stream can assimilate while still attaining the standards for surface water quality.

The TMDL components for the impaired AUs are derived using the median flow within the high-flow regime (or 5% flow) of the LDCs developed for each of the TMDL AUs. For the remainder of this report, each section will present an explanation of the TMDL component first, followed by the results of the calculation for that component. Please note that some calculations completed in the remainder of this report have been rounded and may not lead to the exact final amounts listed in the text, tables, or figures.

Assessment Unit-Level TMDL Calculations

The TMDLs for the impaired AUs were developed as pollutant load allocations based on information from the LDC developed for TCEQ SWQM stations 11486 in AU 1109_01 and 11489 in AU 1110_01 (Figure 17 and Figure 18). The bacteria LDCs were developed by multiplying the streamflow value along the FDC by the primary contact recreation 1 use geometric mean criterion for *E. coli* (126 cfu/100 mL) and Enterococci (35 cfu/100 mL) and by the conversion factor to convert to loading in cfu per day. This effectively displays the LDC as the TMDL curve of maximum allowable loading:

TMDL (billion cfu/day) = Criterion * Flow * Conversion Factor

Where:

Criterion = 35 cfu/100 mL for Enterococci or 126 cfu/100 mL for *E. coli*

Flow = 5% exceedance flow from FDC in cubic feet per second (cfs)

Conversion Factor (to billion cfu/day) = 28,316.8 mL/cubic foot (ft^3) * 86,400 seconds/day (s/d) ÷ 1,000,000,000

Table 13 shows the TMDL values at the 5% load duration exceedance.

Table 13. Summary of allowable loadings

AU	Indicator Bacteria	5% Exceedance Flow (cfs)	TMDL (Billion cfu/day)
1109_01	Enterococci	664.877	569.334
1110_01	*E. coli*	403.715	1,244.524

Margin of Safety Formula

The MOS is applied only to the allowable loading for a watershed. Therefore, the MOS is expressed mathematically as the following:

MOS = 0.05 * TMDL

Where:

TMDL = total maximum daily load

The MOS calculations for each AU are shown in Table 14.

Table 14. MOS calculations

AU	Parameter	Criterion (cfu/100mL)	TMDL	MOS
1109_01	Enterococci	35	569.334	28.467
1110_01	*E. coli*	126	1,244.524	62.226

All loads are expressed in billion cfu/day.

Wasteload Allocation

The WLA is the sum of loads from regulated sources. The WLA consists of two parts – the wasteload that is allocated to TPDES-regulated WWTFs (WLA_{WWTF}) and the wasteload that is allocated to regulated stormwater dischargers (WLA_{SW}).

$WLA = WLA_{WWTF} + WLA_{SW}$

Wastewater Treatment Facilities

Determination of the WLA_{WWTF} requires development of a daily WLA for each TPDES-permitted facility. The full permitted daily average flow of each WWTF is multiplied by the instream geometric criterion for the water body and the conversion factor. This calculation is expressed by:

WLA_{WWTF} (billion cfu/day) = Criterion * Flow * Conversion Factor

Where:

Criterion = 35 cfu/100 mL for Enterococci or 126 cfu/100 mL for *E. coli*

Flow = full permitted flow (MGD)

Conversion Factor (to billion cfu/day) = 3,785,411,800 mL/million gallons ÷ 1,000,000,000

Using this equation, each WWTF's allowable loading was calculated using the permittee's full permitted flow. The individual results were summed for each AU. The criterion was applied based on the indicator bacteria designated for the AU.

Table 15 shows the load allocations for each WWTF and sums the load allocations, providing a total WLA_{WWTF} for the AUs.

Table 15. Wasteload allocations for TPDES-permitted facilities

AU	TPDES No.	Permittee	Bacteria Limit (cfu/100 mL)	Full Permitted Flow (MGD) [a]	WLA_{WWTF} (Billion cfu/day E. coli)	WLA_{WWTF} (Billion cfu/day Enterococci)
1109_01	WQ0010798001	Commodore Cove Improvement District WWTF	35 (Enterococci)	0.06	-	0.079
			Total	**0.06**	**-**	**8.691[b]**
1110_01	WQ0010548004	Oyster Creek WWTF	126 (*E. coli*)	3.60	17.171	4.770
1110_01	WQ0012113001	Beechwood WWTF	126 (*E. coli*)	0.10	0.477	0.132
1110_02	WQ0013804001	TDCJ Terrell Unit WWTF	126 (*E. coli*)	2.00	9.539	2.650
1110_03	WQ0010743001	TDCJ Darrington Unit WWTF	126 (*E. coli*)	0.80	3.816	1.060
			Total	**6.50**	**31.003**	**8.612**

[a] Full permitted flow from Table 6.

[b] The value for AU 1109_01 was calculated substituting the Enterococci criterion (35 cfu/100mL) for use in the WLA_{WWTF} for the upstream AUs WWTFs.

Regulated Stormwater

Stormwater discharges from MS4s, industrial facilities, concrete production, and construction activities are considered regulated point sources. Therefore, the WLA calculations must also include an allocation for regulated stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA_{SW} 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.

The percentage of land area included in the watershed that is under the jurisdiction of stormwater permits (i.e., defined as the area designated as urbanized area in the 2010 U.S. Census) was used to estimate the amount of the overall runoff load that should be allocated as the regulated stormwater contribution in the WLA_{SW} component of the TMDL. The load allocation (LA) component of the TMDL corresponds to direct nonpoint source runoff and is the difference between the total load from stormwater runoff and the portion allocated to WLA_{SW}.

WLA_{SW} is the sum of loads from regulated stormwater sources and is calculated as:

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP}$$

Where:

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

FDA_{SWP} = fractional proportion of drainage area under jurisdiction of stormwater permits

The FDA_{SWP} must be calculated to arrive at the fractional proportion of the drainage area under jurisdiction of stormwater permits. FDA_{SWP} was calculated by first totaling the area of each stormwater permit and authorization. The stormwater sources and area estimates were discussed in the "TPDES-Regulated Stormwater" section. Those area estimates were determined for each category and summed up to determine the total area under stormwater jurisdiction in each AU watershed. To arrive at the proportion, the area under stormwater jurisdiction was then divided by the total watershed area. The estimated areas in Table 16 are cumulative, each AU accounts for the upstream area contribution by adding the total area of regulated stormwater for the AU and that of the upstream AU and then dividing by the watershed area.

Table 16. Regulated stormwater FDA_{SWP} calculations

AU	MS4 Area	MSGP Area	CGP Area	Concrete Production Facilities Area	Total Area of Permits [a]	Watershed Area [a]	FDA_{SWP}
1109_01	3,582.09	173.88	1,010.85	0.00	4,766.82	78,694.40	0.061
1110_01	3,419.83	173.88	1,010.85	0.00	4,604.56	75,385.60	0.061

All areas are expressed in acres

[a] Watershed Area and Total Area of Permits were calculated as the sum of those areas of the catchment above the TCEQ SWQM station within the AU and any contributing areas upstream of the AU

A value for FG is necessary to complete the WLA_{SW} calculation. The FG is presented in the "Allowance for Future Growth" section, but the results are included here for continuity. The WLA_{SW} calculations are presented in Table 17.

Table 17. Regulated stormwater load calculations

AU	TMDL	WLA_{WWTF}	FG	MOS	FDA_{SWP}	WLA_{SW}
1109_01	569.334	8.691	5.548	28.467	0.061	31.900
1110_01	1,244.524	31.003	19.768	62.226	0.061	69.114

All loads are expressed in billion cfu/day.

With the WLA_{SW} and WLA_{WWTF} terms calculated, the total WLA term can be determined by adding the two parts (Table 18).

Table 18. WLA calculations

AU	Parameter	Criterion (cfu/100 mL)	WLA_{WWTF}	WLA_{SW}	WLA
1109_01	Enterococci	35	8.691	31.900	40.591
1110_01	*E. coli*	126	31.003	69.114	100.117

In areas currently regulated by an MS4 permit, the development and/or re-development of land must include the implementation of the control measures/programs outlined in an MS4's approved SWMP. Although additional flow may occur from development or redevelopment, loading of the pollutant of concern should be controlled or reduced through the implementation of BMPs as specified in both the TPDES permit and the approved SWMP.

An iterative, adaptive management approach is used to address stormwater discharges. This approach encourages the implementation of structural or non-structural controls, implementation of mechanisms to evaluate the performance of the controls, and the allowance to adjust (e.g., more stringent controls or specific BMPs) as necessary to protect water quality.

Implementation of Wasteload Allocations

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

TCEQ intends to implement the individual WLAs through the permitting process as monitoring requirements, effluent limitations, or both as required by the amendment of Title 30, Texas Administrative Code (TAC) Chapter 319, which became effective November 26, 2009. WWTFs discharging to TMDL water bodies will be assigned an effluent limit based on the TMDL. Monitoring requirements are based on permitted flow rates and are listed in 30 TAC Section 319.9.

Permit requirements are implemented during the routine permit renewal process. However, there may be a more economical or technically feasible means of achieving the goal of improved water quality, and circumstances may warrant changes in individual WLAs after these TMDLs are adopted. Therefore, the individual WLAs, as well as the WLAs for stormwater, are non-binding until implemented via a separate TPDES permitting action, which may involve the preparation of an update to the state's WQMP. Regardless, all permitting actions will comply with the TMDL.

The executive director or commission may establish interim effluent limits, monitoring-only requirements, or both during amendment or renewal of a permit. These interim limits will allow a permittee time to modify effluent quality to attain the final effluent limits necessary to meet TCEQ- and EPA-approved TMDL allocations. The duration of any interim effluent limits may not be any longer than three years from the date of permit re-issuance. Compliance schedules are not allowed for new permits.

Where a TMDL has been approved, domestic WWTF TPDES permits will require conditions consistent with the requirements and assumptions of the WLAs. For TPDES-regulated MS4s, construction stormwater, and industrial stormwater discharges, water quality-based effluent limits (WQBELs) that implement the WLA for stormwater may be expressed as BMPs or other similar requirements, rather than as numeric effluent limits.

EPA's memorandum on establishing WLAs for stormwater sources (published November 26, 2014) states:

> Incorporating greater specificity and clarity echoes the approach first advanced by EPA in the 1996 Interim Permitting Policy, which anticipated that where necessary to address water quality concerns, permits would be modified in subsequent terms to include "more specific conditions or limitations [which] may include an integrated suite of BMPs, performance objectives, narrative standards, monitoring triggers, numeric WQBELs, action levels, etc.

Using this iterative, adaptive BMP approach to the maximum extent practicable is appropriate to address the stormwater component of this TMDL.

Updates to Wasteload Allocations

These TMDLs are, by definition, the sum of the WLA (including FG), the LA, and the MOS. Changes to individual WLAs may be necessary in the future to accommodate growth or other changing conditions. These changes to individual WLAs do not ordinarily require a revision of the TMDL report; instead, changes will be made through updates to the state's WQMP. Any future changes to effluent limitations will be addressed through the permitting process and by updating the WQMP.

Load Allocation

The LA is the sum of loads from unregulated sources, and is calculated as:

LA = TMDL – WLA – FG – MOS

Where:

TMDL = total maximum daily load

WLA = sum of all WLA_{WWTF} loads and WLA_{SW} loads

FG = sum of future growth loads from potential regulated facilities

MOS = margin of safety load

Table 19 summarizes the LA.

Table 19. LA calculations

AU	Criterion (cfu/100mL)	TMDL	WLA_{WWTF}	WLA_{SW}	FG	MOS	LA
1109_01	35	569.334	8.691	31.900	5.548	28.467	494.728
1110_01	126	1,244.524	31.003	69.114	19.768	62.226	1062.413

All loads are expressed in billion cfu/day.

Allowance for Future Growth

The FG component of the TMDL equation addresses the requirement to account for future loadings that may occur due to population growth, changes in community infrastructure, and development. Specifically, this TMDL component considers the probability that new flows from WWTF discharges may occur in the future. The assimilative capacity of water bodies increases as the amount of flow increases.

The allowance for FG results in the protection of existing uses and conforms to Texas' antidegradation policy.

To account for the FG, the loadings from WWTFs are included in the FG computation, which is based on the WLA_{WWTF} formula. The FG equation includes an additional term to account for projected population growth within WWTF service areas between 2020 and 2050 based on H-GAC's Regional Growth Forecast projections (H-GAC, 2018). Table 20 presents the FG calculations.

FG (billion cfu/day) = Criterion * ($\%POP_{2020\text{-}2050}$ * $WWTF_{FP}$) * Conversion Factor

Where:

Criterion = 126 cfu/100 mL (*E. coli*) or 35 cfu/100 mL (Enterococci)

$\%POP_{2020\text{-}2050}$ = estimated percentage increase in population between 2020 and 2050

$WWTF_{FP}$ = full permitted discharge (MGD)

Conversion Factor (to billion cfu/day) = 3,785,411,800 mL/million gallons ÷ 1,000,000,000

Table 20. FG calculations

AU	Indicator Bacteria	Criterion (cfu/100 mL)	% Population Change (2020-2050)	Full Permitted Discharge (MGD)	FG (MGD)	FG	FG[a]
1109_01	Enterococci	35	71.48%	0.06	0.043	0.057	5.548
1110_01	*E. coli*	126	63.76%	6.5	4.145	19.768	-

All loads are expressed in billion cfu/day.

[a] FG in AU 1109_01 is the sum of FG values calculated for each WWTF in Segment 1110 using Enterococci criterion (35 cfu/100 mL).

Compliance with these TMDLs is based on keeping the bacteria concentrations in the selected waters below the limits that were set as criteria for the individual sites. FGs of existing or new point sources are not limited by these TMDLs if the sources do not cause bacteria to exceed the limits. The assimilative capacity of water bodies increases as the amount of flow increases; consequently, increases in flow allow for increased loadings. The LDC and tables in this TMDL report will guide determination of the assimilative capacity of the water body under changing conditions, including FG.

Summary of TMDL Calculations

The TMDLs were calculated based on the median flow in the 0–10 percentile range (5% exceedance, high flow regime) for flow exceedance based on the LDCs developed at TCEQ SWQM stations 11486 and 11489.

Allocations are based on the current geometric mean criterion for *E. coli* or Enterococci at 126 cfu/100 mL or 35 cfu/100 mL, respectively, for each component of the TMDLs. The TMDL allocation summary for the Oyster Creek TMDL watershed is summarized in Table 21.

Table 21. TMDL allocations

AU	Criterion (cfu/100mL)	TMDL	WLA_{WWTF}	WLA_{SW}	LA	FG	MOS
1109_01	35	569.334	8.691	31.900	494.728	5.548	28.467
1110_01	126	1,244.524	31.003	69.114	1,062.413	19.768	62.226

All loads are expressed in billion cfu/day.

The final TMDL allocations (Table 22) needed to comply with the requirements of 40 CFR 130.7 include the FG component within the WLA_{WWTF}.

Table 22. Final TMDL allocations

AU	Criterion (cfu/100mL)	TMDL	WLA_{WWTF} [a]	WLA_{SW}	LA	MOS
1109_01	35	569.334	14.239	31.900	494.728	28.467
1110_01	126	1,244.524	50.771	69.114	1,062.413	62.226

All loads are expressed in billion cfu/day.

[a] WLA_{WWTF} includes the FG component.

Seasonal Variation

Federal regulations require that TMDLs account for seasonal variation in watershed conditions and pollutant loading [40 CFR Section 130.7(c)(1)].

Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing *E. coli* and Enterococci concentrations obtained from 16 years (2004 through 2020) of routine monitoring data collected in the warmer months (May through September) against those collected during the cooler months (November through March). The months of April and October were considered transitional between warm and cool seasons and were excluded from the seasonal analysis.

Differences in *E. coli* and Enterococci concentrations obtained in warmer versus cooler months were then evaluated by performing a Wilcoxon Rank Sum test (also known as the "Mann-Whitney" test). This analysis of *E. coli* and Enterococci data indicated that there was no significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for the Oyster Creek watershed. Seasonal variation was also addressed by using all available flow and indicator bacteria records (covering all seasons) from the period of record used in LDC development for this project.

Public Participation

TCEQ maintains an inclusive public participation process. From the inception of the investigation, the 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.

A variety of stakeholder engagement methods were employed to generate and maintain stakeholder interest since 2016. Direct e-mail, letters, and phone calls were made with identified stakeholders to provide information and encourage participation in future meetings. Press releases and general e-mails were created by H-GAC to cast a broad net using listservs and news outlets. Project webpages and informational brochures were developed to provide information, meeting notifications, and project updates. Stakeholders that could potentially be impacted by the TMDL and future implementation plan (I-Plan) were contacted, and one-on-one meetings were held with some to foster interest, build support, and generate trust.

TCEQ and H-GAC held a series of fourteen meetings between 2016 and 2023 to make the public, local governments, businesses, non-profits, agriculture producers, and others, aware of the TMDLs, initiate I-Plan development, and develop management measures to include in the I-Plan. Notices of meetings were posted on the TCEQ and H-GAC project webpages and on the TMDL program's online calendar. To ensure that absent or new stakeholders could get information about past meetings and pertinent material, the H-GAC project webpage [c]. provides meeting summaries, presentations, ground rules, and documents produced for review.

Public meetings were convened early in the project: Dec. 6, 2016; Aug. 10, 2017; and Nov. 8, 2018. All three meetings were held within the San Jacinto Brazos Coastal Basin (Basin 11) with the last meeting held at the Brazoria County Public Library in Lake Jackson, TX. These initial public meetings were used to:

- Introduce the TCEQ's basin approach to improving water quality.
- Review the status of water quality impairments in Basin 11.
- Discuss potential watershed management tools to improve water quality.
- Highlight water bodies, e.g., Oyster Creek, to employ watershed management tools.
- Form a TMDL coordination committee.

[c] www.h-gac.com/watershed-based-plans/san-jacinto-brazos-coastal-basin-tmdl-and-implementation-plan

The Oyster Creek Coordination Committee was formed in 2019 to review and discuss the developing TMDL and future I-Plan. The committee formed three work groups—Nonpoint Source, Point Source, and Outreach—to steer the development of management measures. Additionally, in 2019 local governments and business leaders were brought in at a high level to engage in and highlight the developing TMDLs in Basin 11, which includes Oyster Creek, and to establish expectations on the potential of future I-Plans. Stakeholders completed a survey on pollution source priorities and in 2020, the Oyster Creek Coordination Committee initiated the Oyster Creek I-Plan.

Since 2020, the group has met six times, and the draft Oyster Creek I-Plan has been prepared. The stakeholder group is committed to additional meetings in 2024 to complete the review and acceptance of the Oyster Creek I-Plan.

Implementation and Reasonable Assurance

The issuance of TPDES permits consistent with TMDLs provides reasonable assurance that the WLAs in this TMDL report will be achieved. Per federal requirements, each TMDL is included as a plan element in an update to the Texas WQMP.

The WQMP coordinates and directs the state's efforts to manage water quality and maintain or restore designated uses throughout Texas. The WQMP is continually updated with new, more specifically focused plan elements, as identified in federal regulations [40 CFR 130.6(c)]. Commission adoption of a TMDL is the state's certification of the associated WQMP update.

Because the TMDL does not reflect or direct specific implementation by any single pollutant discharger, TCEQ certifies additional elements to the WQMP after the commission approves the I-Plan. Based on the TMDL and I-Plan, TCEQ will propose and certify WQMP updates to establish required WQBELs for specific TPDES wastewater discharge permits.

For MS4 entities, where numeric effluent limitations are infeasible, the permits require that the MS4 develop and implement BMPs under each MCM, which are a substitute for effluent limitations, as allowed by federal rules. How a regulated MS4 meets each MCM is not prescribed in detail in the MS4 permits but is included in the permittee's SWMP. During the permit renewal process, TCEQ revises its MS4 permits as needed to require a revised SMWP or to require the implementation of other specific BMPs or controls consistent with an approved TMDL and I-Plan.

The state uses an I-Plan to reasonably assure strategies for achieving pollutant loads in TMDLs from both point and nonpoint sources. TCEQ is committed to supporting the implementation of all TMDLs adopted by the commission.

I-Plans for Texas TMDLs use an adaptive management approach that allows for the refinement or addition of methods to achieve environmental goals. This adaptive approach reasonably assures that the necessary regulatory and voluntary activities to achieve pollutant reductions will be implemented. Periodic, repeated evaluations of the effectiveness of implementation methods will ascertain whether progress is occurring and may show that the original distribution of loading among sources should be modified to increase efficiency. I-Plans will be adapted as necessary to reflect the needs identified in future evaluations of progress.

Key Elements of an I-Plan

An I-Plan includes a detailed description and schedule of the regulatory and voluntary management measures needed to implement the WLAs and LAs of particular TMDLs within a reasonable time. I-Plans also identify the organizations responsible for carrying out management measures, and provide a plan for periodic evaluation of progress.

Strategies to optimize compliance and oversight are identified in an I-Plan when necessary. Such strategies may include verifying loading trends with additional monitoring and reporting of effluent discharge quality, adjusting inspection frequency or response protocol due to public complaints, and escalating an enforcement remedy that requires a corrective action from a regulated entity that is contributing to an impairment.

TCEQ works with stakeholders and interested governmental agencies to develop and support I-Plans and track their progress. Work on an I-Plan begins during the development of TMDLs. Because these TMDLs address agricultural sources of pollution, TCEQ works in close partnership with TSSWCB when developing I-Plans. TSSWCB is the lead agency in Texas responsible for planning, implementing, and managing programs and practices that prevent and abate agricultural and silvicultural nonpoint sources of water pollution. The cooperation required to develop an I-Plan is a cornerstone of the shared responsibility necessary to carry it out.

Ultimately, an I-Plan identifies the commitments and requirements to be implemented through specific permit actions and other means. For these reasons, an approved I-Plan may not approximate the predicted loadings identified category by category in the TMDL and its underlying assessment. The I-Plan is adaptive for this very reason; it allows for continuous update and improvement.

In most cases, it is not practical or feasible to approach all TMDL implementation as a one-time, short-term restoration effort. This is particularly true when a challenging wasteload reduction or load reduction is required by the TMDL, there is high uncertainty with the TMDL analysis, there is a need to reconsider or revise the established water quality standard, or the pollutant load reduction would require costly infrastructure and capital improvements.

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Appendix
Population and Population Projections

H-GAC, through its Regional Growth Forecast, routinely assesses the region's population and develops population projections. To estimate future population growth, H-GAC used their Demographic Evolution Model. The model creates a virtual accounting of future people and households within an eight-county area. The model accounts for either the addition or removal of residents due to births, deaths, in-migrants, and out-migrants. The model is a computer simulation which uses a probabilistic approach to imitate both the biologic events and social events that drive the addition and/or removal for the synthesized individuals and households (H-GAC, 2018).

To accommodate the future households and populations, H-GAC developed a Real Estate Development Model that acts like a real estate developer and generates predictions for Single-Family and Multi-Family units on specific parcels, given the physical availability/suitability of land and economic feasibility.

Once the new residential units are built, H-GAC's Household Location Choice Model allocates future households to new housing units using the grid-level (3-mile grid) location probabilities categorized by age-race-household size and income.

Finally, the household and population data are summarized by various geographies including Counties, Cities, Census tracts, three square mile grids, and Traffic Analysis Zone.

The Regional Growth Forecast Methodology[d], a report that fully discusses the steps H-GAC uses to determine future population growth is available on the H-GAC webpage.

The following steps detail the method used to estimate the 2020 and projected 2050 populations in the TMDL Project watershed:

1. The H-GAC regional forecast team obtained USCB 2020 Decadal Census data from the USCB at the block level.

2. The H-GAC regional forecast team used census block data to develop population estimates for a hexagonal grid of three-square miles each (H3M) for the H-GAC region.

3. H-GAC staff estimated watershed populations for 2020 using the H3M data for the portion of the H3M located within the watershed assuming equal distribution.

[d] www.h-gac.com/getmedia/6f706efb-9c6d-4b6a-b3aa-7dc7ad10bd26/read-documentation.pdf

4. Obtained population projections for the year 2050 from the H-GAC regional forecast based on H3M data.

5. Developed population projections using H-GAC regional forecast data for the portion of the H3M located within the watershed assuming equal distribution.

6. Subtracted the 2020 watershed population from the 2050 population projection to determine the projected population increase. Subsequently, the projected population increase was divided by the 2020 watershed population to determine the percent population increase for the TMDL Project watershed.