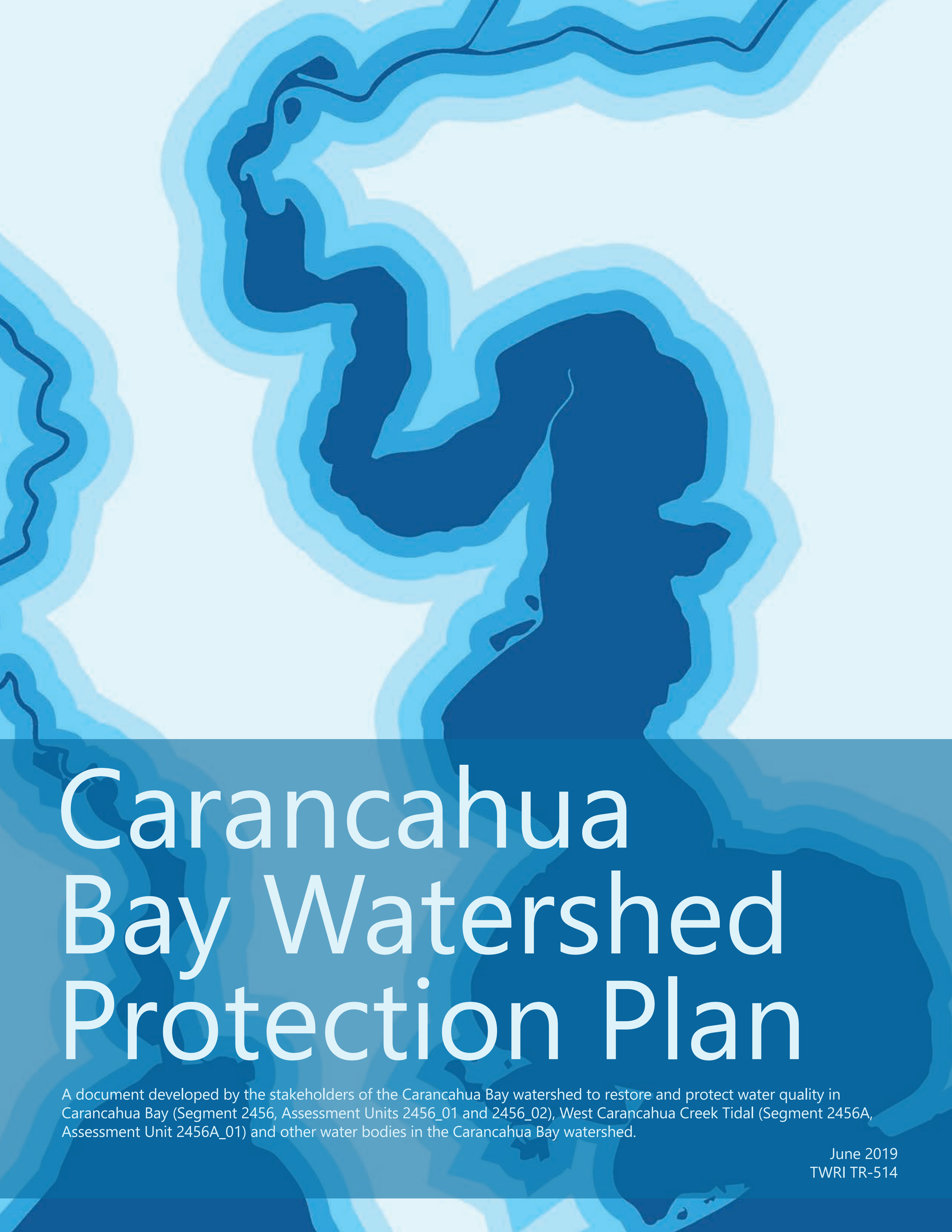


Carancahua Bay Watershed Protection Plan

A document developed by the stakeholders of the Carancahua Bay watershed to restore and protect water quality in Carancahua Bay (Segment 2456, Assessment Units 2456_01 and 2456_02), West Carancahua Creek Tidal (Segment 2456A, Assessment Unit 2456A_01) and other water bodies in the Carancahua Bay watershed.

June 2019
TWRI TR-514

Carancahua Bay Watershed Protection Plan

A document developed by the stakeholders of the Carancahua Bay watershed to restore and protect water quality in Carancahua Bay (Segment 2456, Assessment Units 2456_01 and 2456_02), West Carancahua Creek Tidal (Segment 2456A, Assessment Unit 2456A_01) and other water bodies in the Carancahua Bay watershed.

Authored and prepared by:
Michael Schramm[a], Stephanie deVilleneuve[a], Shubham Jain[a], Allen Berthold[a] and Uvashree Mohandass[b]

[a] Texas Water Resources Institute

[b] Texas A&M University Water Management and Hydrological Science Program

Texas Water Resources Institute Technical Report – 514
June 2019

College Station, Texas

Funding support for this project provided by the Texas Commission on Environmental Quality.

Cover photo: Illustration of Carancahua Bay, by Sarah Richardson, TWRI

Carancahua Bay. Photo by Brian Jonescu.

Acknowledgments

This document presents the strategy developed by the stakeholders of the Carancahua Bay watershed to restore and protect water quality in Carancahua Bay and the water bodies that flow into it. Local stakeholders dedicated considerable time and effort to discussing the watershed, influences on water quality and developing management measures to address water quality concerns. The ultimate success of the Carancahua Bay Watershed Protection Plan depends on the current and continued engagement of local stakeholders with technical and financial support from regional, state and federal agencies.

Special appreciation is extended to the many watershed landowners and residents who attended the numerous meetings and events to provide direct input on the plan. The direct involvement of landowners and residents was critical to ensuring the plan included feasible management measures that address sources of water quality impairments in the watershed. The time and effort of landowners and residents are greatly appreciated and are reflected in the contents of this plan.

Agency support and input was an integral part of the watershed protection plan development process. The following agencies provided technical guidance and willingness to offer specialized knowledge on several topics:

- Jackson Soil and Water Conservation District
- Matagorda Soil and Water Conservation District
- Texas A&M AgriLife Extension Service
- Texas A&M AgriLife Research
- Texas Commission on Environmental Quality
- Texas General Land Office
- Texas Parks and Wildlife Department
- Texas Sea Grant
- Texas State Soil and Water Conservation Board
- U.S. Department of Agriculture Natural Resources Conservation Service

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Acronym	Meaning
ac	Acre
AU	Assessment Unit
BMP	Best Management Practice
CBWPP	Carancahua Bay Watershed Protection Plan
CCA	Coastal Conservation Association
cfu	Colony Forming Unit
CIG	Conservation Innovation Grants
CMP	Coastal Management Program
CRP	Clean Rivers Program
CSP	Conservation Stewardship Program
DMR	Discharge Monitoring Report
DMU	Deer Management Unit
DO	Dissolved Oxygen
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ft	Feet
FDC	Flow Duration Curve
gal	Gallon
hr	Hour
L	Liter
LDC	Load Duration Curve
µg	Microgram
mg	Milligram
mi^2	Square Miles
mL	Milliliter
MGD	Million Gallons Per Day
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer Systems
NASS	National Agriculture Statistics Service
NFWF	National Fish and Wildlife Foundation
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration

Acronym	Meaning
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRDA	Natural Resource Damage Assessment
NPS	Nonpoint Source
OSSF	On-Site Sewage Facility
lbs	Pounds
RCPP	Regional Conservation Partnership Program
s	Second
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SEP	Supplemental Environmental Projects
SSO	Sanitary Sewer Overflow
SSURGO	Soil Survey Geographic Database
SWCD	Soil and Water Conservation District
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TGLO	Texas General Land Office
TIG	Texas Trustee Implementation Group
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
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
TSS	Total Suspended Solids
USDA	U. S. Department of Agriculture
USGS	U.S. Geological Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plan
WWTF	Wastewater Treatment Facility
WWTP	Wastewater Treatment Plant

Executive Summary

A watershed is an area of land that drains to a common body of water. Within a watershed, water follows natural hydrologic boundaries and is influenced by the landscape it flows across and through. Both natural and human-influenced processes that occur within a watershed alter the quantity and quality of water within the system.

This document presents a plan to restore and protect water quality in the Carancahua Bay watershed. By approaching water quality issues at the watershed level rather than political boundaries, this plan holistically identifies potential pollutant sources and solutions. This approach also incorporates the values, visions and knowledge of people with a direct stake in water quality conditions.

Problem Statement

Water quality monitoring indicates Carancahua Bay does not meet water quality standards for recreation because of elevated levels of bacteria. Furthermore, West Carancahua Creek does not meet water quality standards due to depressed dissolved oxygen. Elevated nutrients (phosphorus and chlorophyll-a) are also higher than normal when compared to similar water bodies.

Response

With the water quality impairments comes a need to plan and implement actions that restore water quality and ensure safe and healthy water for stakeholders. To meet this need, an assessment and planning project was undertaken to develop the Carancahua Bay Watershed Protection Plan (CBWPP).

The planning process began with a stakeholder group meeting in summer of 2017 to form and establish stakeholder group structure and rules. Over the next year, Texas Water Resources Institute met with the stakeholder group to provide data and information and receive feedback on approaches used to assess and characterize water quality in the watershed. Stakeholders provided direct input to assumptions used in the pollutant load analysis and decided upon the management measures most likely to be successful and be implemented by the watershed community.

Watershed Protection Plan Overview

This document is a culmination of a stakeholder process to identify sources of pollution and the methods to reduce pollutant loads in Carancahua Bay. By comprehensively considering the multitude of potential pollutant sources in the watershed, this plan describes management strategies that, when implemented, will reduce pollutant loadings in the most cost-effective manners available at the time of planning. Despite the extensive amounts of information gathered during the development of this watershed protection plan, a better understanding of the watershed and the effectiveness of management measures will undoubtedly develop. As such, this plan is a living document that will evolve as needed through the adaptive management process.

Pollutant Reductions

Analysis of water quality and streamflow data indicate a bacteria load reduction of approximately 86% annually is needed to meet water quality standards for recreation in Carancahua Bay. Furthermore, an approximate 36% reduction in phosphorus is required to meet state screening levels for water quality.

No single pollutant source is the primary cause of water quality impairments in Carancahua Bay. A variety of sources, including livestock, wildlife, septic systems and pets, are likely to contribute bacteria and nutrient loads to the watershed. Therefore, stakeholders identified a variety of diverse and feasible management measures that will reduce bacteria and nutrient loads in Carancahua Bay. Full implementation of the management measures over 10 years will reduce potential *Enterococcus* bacteria loads by approximately 6.71×10^5 billion colonies per year, potential nitrogen loads by approximately 68,000 pounds (lbs) per year and potential phosphorus loads by 38,000 lbs per year.

Management Measures

Promote and implement water quality management plans or conservation plans

Bacteria and nutrient loads from agriculture can be managed through a variety of best practices that reduce runoff, retain soil and improve production. Producers can work with their local soil and water conservation district and Natural Resources Conservation Service office to identify, plan and fund the implementation of these practices by developing a water quality management plan (WQMP) or conservation plan. This document establishes a goal of 70 water quality management plans or conservation plans developed across the watershed.

Increase soil testing

Soil testing gives producers detailed soil property profiles. This information can be used with nutrient management plans to determine the appropriate amount and timing of fertilizer applications. With this approach, producers can reduce the amount of fertilizer lost to runoff, decreasing the nitrogen and phosphorus loads, and reduce the amount of fertilizer purchased and applied. This document recommends that all producers test their soil and participate in nutrient management. The creation of a watershed-wide soil testing campaign is also recommended.

Repair and replace septic systems

Stakeholders identified failing and non-existent septic systems (referred to as on-site sewage facilities [OSSFs] in this document) as a prime concern. The exact number of failing OSSFs is unknown, but soils in the watershed are not suitable for conventional OSSFs, and literature suggest that at least 15% of systems in the area are failing. This document recommends repairing and replacing 42 systems across the watershed.

Voluntary OSSF inspection program

Free or reduced cost OSSF inspections provide a way for residents, particularly those with non-permitted systems, to find out if their system is functioning and the opportunity to follow up with appropriate action. This document recommends the creation of a voluntary inspection program to improve maintenance and reduce the prevalence of failing OSSFs.

Promote feral hog removal

Feral hog populations have expanded dramatically across Texas, causing substantial damage to riparian habitat and contributing fecal bacteria loads to water bodies. Furthermore, feral hogs cause substantial damage to crops and pastures. The complete eradication of feral hogs is not feasible; however managing populations is important for water quality and to crop producers. The watershed protection plan recommends continued promotion of feral hog management activities. This includes construction of exclosures around deer feeders, trapping and removal of feral hogs and delivery of feral hog management workshops. The goal of the plan is to reduce and maintain feral hog populations by approximately 15%/year.

Promote effective pet waste management

Relative to other sources of fecal bacteria, pet waste contains high concentrations of fecal bacteria per unit volume. Therefore, dog and cat waste can contribute relatively high amounts of bacteria loading, which can be easily managed. The low residential density and lack of public areas provides a substantial challenge in reaching pet owners and encouraging behavior change. The plan recommends that resident and visitor knowledge about pet waste impacts, especially in subdivisions around Carancahua Bay, be increased by delivery of education and outreach materials. The goal is to change behavior of pet owners in the area, resulting in more pet waste being properly managed.

Restore oyster and coastal wetland habitat

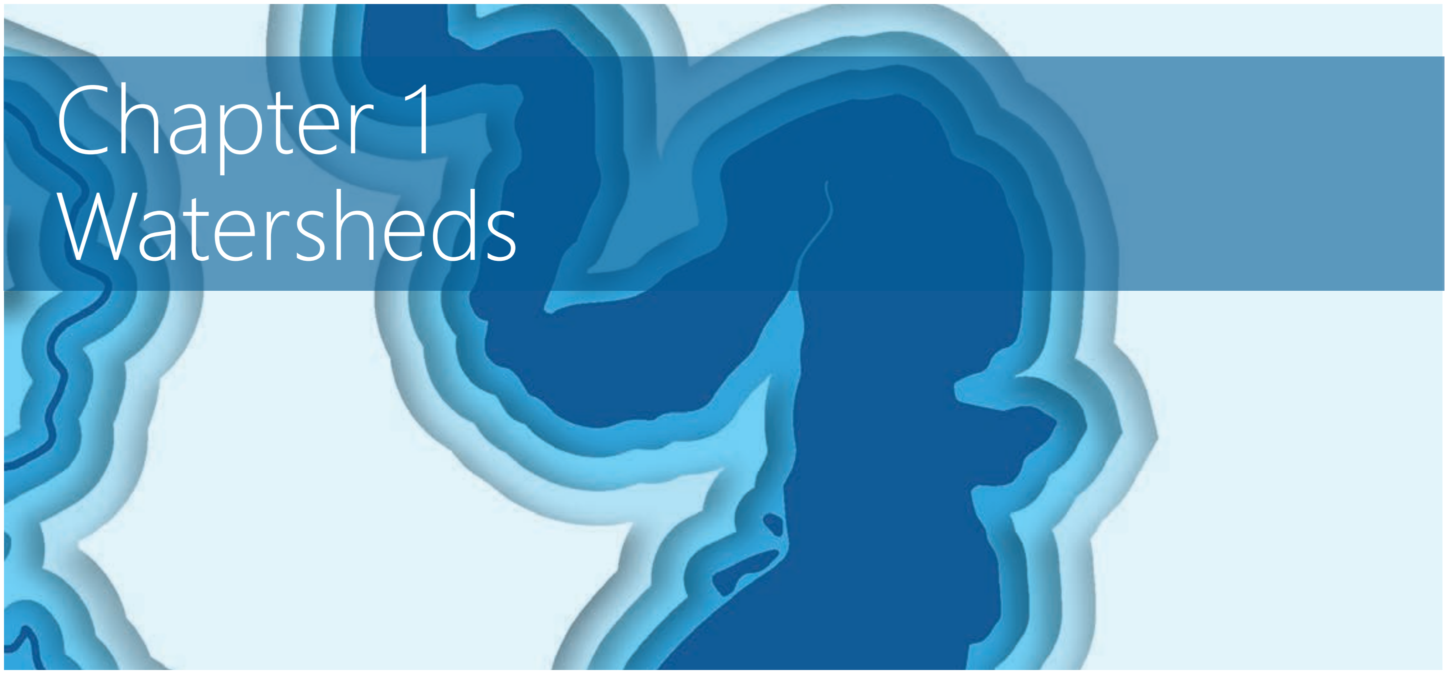
Oysters, oyster reefs and coastal wetlands provide many direct and indirect habitat and water quality benefits. Numerous factors have resulted in decreased oyster populations and wetland habitat in Carancahua Bay. The watershed protection plan recommends continued support of efforts to restore oyster populations and coastal habitat in Carancahua Bay. This includes supporting community oyster gardens at Bayfront properties and supporting efforts to restore oyster reefs and living shorelines in Carancahua Bay.

Goals

The primary goal of the CBWPP is to restore water quality in Carancahua Bay and its tributaries to water quality standards set by the State of Texas through the long-term conservation and stewardship of the watershed's resources.

To achieve this goal, the plan establishes a 10-year implementation schedule with interim milestones and water quality targets to track progress. This plan will also help meet conditions for the state's Coastal Nonpoint Source Pollution Control Program as set forth in Section 6217 of the Coastal Zone Management Act. Since portions of the watershed fall within the Coastal Zone Boundary, the plan will also work to reduce runoff pollutant concentrations and volumes from entering tidal portions of the river and coastal zone.

Ultimately, this plan sets forth an approach to improve stewardship of the watershed resources that allows stakeholders to continue relying on the watershed as part of their livelihood while also restoring the quality of its water resources.



Chapter 1 Watersheds

Introduction

A watershed is the land area surrounding a water body that drains to a common waterway such as a stream, river or lake. All the land surfaces that contribute runoff to a water body are considered part of the watershed. Watersheds can vary greatly in size. Some watersheds can be very small and drain only a few square miles. Conversely, larger watersheds can encompass many smaller watersheds and drain large portions of states or regions of the country.

The Carancahua Bay watershed includes over 205,000 acres (ac) of land that drains into Carancahua Bay. The Carancahua Bay watershed itself is part of the larger Matagorda Bay watershed system. Neighboring watersheds in the Matagorda Bay systems include the Tres Palacios and Lavaca-Navidad River watersheds.

The natural processes and human activities that occur within a watershed have the potential to improve or degrade water quality. For example, rainfall in the watershed can run across agricultural fields, roads, lawns or industrial sites. Along the way, the water has opportunities to either slow down and infiltrate into the soil or speed up as it flows toward the water body while picking up sediment, nutrients or pollutants along the way. The most effective way to address water quality issues in a water body are to examine the natural and human activities occurring in a watershed.

Types of Pollution

The discharge of pollutant from a single point, such as a pipe, outfall or channel is referred to as a point source. Point source discharges require permits through the National Pollutant Discharge Elimination System (NPDES) and Texas Pollutant Discharge Elimination System (TPDES) permitting systems. Examples of permitted point source discharges include wastewater treatment facilities (WWTFs) and industrial dischargers.

Nonpoint source (NPS) pollution, unlike pollution from an industrial facility or WWTF, typically comes from many diffuse sources. NPS pollution is carried by rainfall runoff moving over and through the ground, carrying natural and artificial pollutants and finally depositing into surface waters. Surface water runoff represents a major source of NPS pollution in both urban and rural areas. Runoff from towns and cities can deliver pollutant from roadways and grassed areas. Rural stormwater runoff can transport pollutant loads from cropland, pastures and livestock operations. Additional nonpoint sources can include on-site sewage facilities (OSSFs) that are poorly installed, faulty, improperly located or in close proximity to a stream.

The Watershed Approach

The watershed approach is widely accepted by state and federal water resource management agencies to facilitate water quality management. The U.S. Environmental Protection Agency (EPA) describes the watershed approach as "a flexible framework for managing water resource quality and quantity within a specified drainage area or watershed" (USEPA 2008). The watershed approach requires engaging stakeholders to make management decisions that are backed by sound science. The critical aspect of the watershed approach is the focus on hydrologic boundaries rather than political boundaries to address potential impacts to anyone affected by management decisions.

A Stakeholder is anyone who lives, works or has interest within the watershed. Stakeholders may include people, groups, organizations or agencies. The continuous involvement of stakeholders throughout the watershed approach is critical for effectively selecting, designing and implementing management measures that improve or protect water quality throughout the watershed.

Watershed Protection Plans

Watershed protection plans are locally driven mechanisms for voluntarily addressing complex water quality problems across boundaries. A watershed protection plan serves as a framework to better leverage and coordinate resources of non-governmental organizations, private individuals and governmental agencies.

The Carancahua Bay Watershed Protection Plan (CBWPP) follows EPA's nine key elements designed to provide guidance for the development of an effective watershed protection plan. Watershed protection plans vary in methodology, content and strategy due to local priorities and needs. However, common fundamental elements included in successful plan are identified below:

1. Identification of causes and sources of impairments
2. Expected load reductions from management strategies
3. Proposed management measures
4. Identification of technical and financial assistance to implement management measures
5. Information, education and public participation needed to support implementation
6. Schedule for implementing management measures
7. Milestones to track progress
8. Criteria to determine success
9. Water quality monitoring

Appendix A gives detailed information on EPA's Elements of Successful Watershed Protection Plan. Appendix G links each of the sections and pages that fulfill each element.

Public Participation

Stakeholders have actively participated in the planning process. For the CBWPP process, stakeholders decided upon an informal stakeholder group structure that allowed for open discussion and consensus development during meetings. The Texas Water Resources Institute (TWRI) facilitated the development of the plan and stakeholder meetings in partnership with Texas Commission on Environmental Quality (TCEQ). In addition to local residents and property owners who participated in stakeholder meetings, the following agencies participated in the planning process or were met with separately to gain input to the plan.

- Jackson County
- Jackson Soil and Water Conservation District
- Matagorda Soil and Water Conservation District
- Texas A&M AgriLife Extension Service
- Texas General Land Office (TGLO)
- Texas Parks and Wildlife Department (TPWD)
- Texas Sea Grant
- Texas State Soil and Water Conservation Board (TSSWCB)
- U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS)

Adaptive Management

The process of watershed planning is iterative. Initial management measures might not result in success during the first or second cycles. Therefore, adjustments are expected to be made as new information becomes available. Adaptive management consists of developing a natural resource management strategy to facilitate decision-making based on an on-going science-based process (USEPA 2008). Such an approach includes results of continual testing, monitoring, evaluating applied strategies and revising management approaches to incorporate new information, science and societal needs.

Chapter 2 Carancahua Bay Watershed Characterization

As the management measures identified in the watershed protection plan are put into action, water quality and other measures of success will be monitored and adjusted as needed. The use of an adaptive management approach will help focus effort, implement strategies and maximize impact on pollutant loadings over time.

Introduction

The Carancahua Bay watershed is a small coastal watershed located on the Texas Gulf Coast. Carancahua Bay, named for the Karankawa Indians who lived along the bay, is part of the larger Matagorda Bay system (TSHA 2010a). Portions of Calhoun, Jackson, Wharton and Matagorda counties are drained by the Carancahua Bay watershed. The watershed has a rich history of livestock and agriculture that remains with watershed communities today. The town of La Ward, on the western edge of the watershed, was named after Lafayette Ward, a prominent rancher in the late 1800s who helped introduce Hereford, Brahman and Jersey cattle to Texas (TSHA 2010b).

The Carancahua Bay watershed remains a largely rural and agriculturally dominated watershed. Small communities have developed along the shores of Carancahua Bay catering to full-time and part-time residents drawn to the wildlife and productive fishery found in the Carancahua and Matagorda Bay systems.

Chapter 2 Highlights

1. **Carancahua Bay is a shallow 19.3 square mile bay that captures runoff from 321 square miles of land.**
2. **The Carancahua Bay watershed includes more than 107 miles of perennial and intermittent streams.**
3. **With over 90,000 ac devoted to crop production and over 20,000 head of cattle, agriculture is a vital part of the watersheds landscape and economy.**

Description of the Watershed and Water Bodies

Carancahua Bay is a 19.3 square mile (mi²) tertiary embayment that adjoins Matagorda Bay (Figure 1). Typical depths are from 3 to 6 feet (ft) (Brown et al. 1998). West Carancahua Creek and East Carancahua Creek provide the primary freshwater inflows to Carancahua Bay. West Carancahua Creek begins as a small intermittent stream near the Wharton/Jackson county line and flows generally south toward Carancahua Bay. West Carancahua Creek becomes tidally influenced approximately halfway between Highway 111 and Farm to Market Road 616. Flows from East Carancahua Creek join West Carancahua approximately 2.6 miles (mi) due north of the Cape Carancahua community and flow for a short distance before discharging into Carancahua Bay. In total, the Carancahua Bay watershed encompasses 341 square miles, draining 321 mi² of land surface with about 107 mi of perennial and intermittent streams.

Table 1. Relative watershed land cover distribution.

Land Cover Category	Acres	Square Miles	Percent
Open Water	12,729.64	19.89	6%
Developed, Open Space	6,594.00	10.3	3%
Developed, Low Intensity	572.89	0.9	<1%
Developed, Medium Intensity	37.36	0.06	<1%
Developed, High Intensity	2.22	<0.01	<1%
Barren Land	850.21	1.33	<1%
Deciduous Forest	7,402.18	11.57	3%
Evergreen Forest	7,374.16	11.52	3%
Mixed Forest	2,369.39	3.7	1%
Shrub/Scrub	12,924.90	20.2	6%
Grassland/Herbaceous	4,556.42	7.12	2%
Pasture/Hay	63,100.44	98.59	29%
Cultivated Crops	93,405.69	145.95	43%
Woody Wetlands	3,231.39	5.05	1%
Emergent Herbaceous Wetlands	3,311.23	5.17	2%
Total	218,462	341.35	99%[1]

[1] Percentages total to 99% due to rounding.

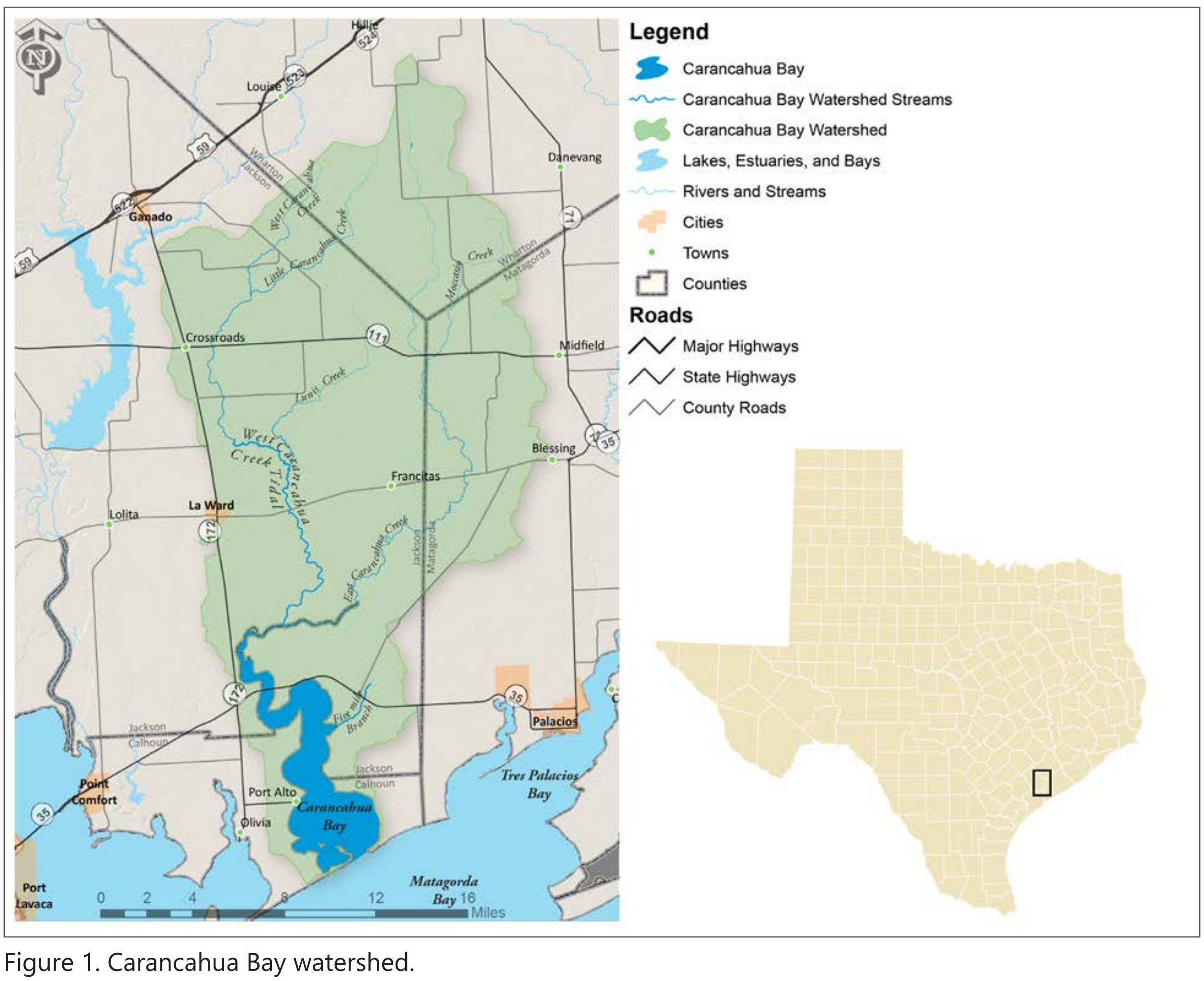


Figure 1. Carancahua Bay watershed.

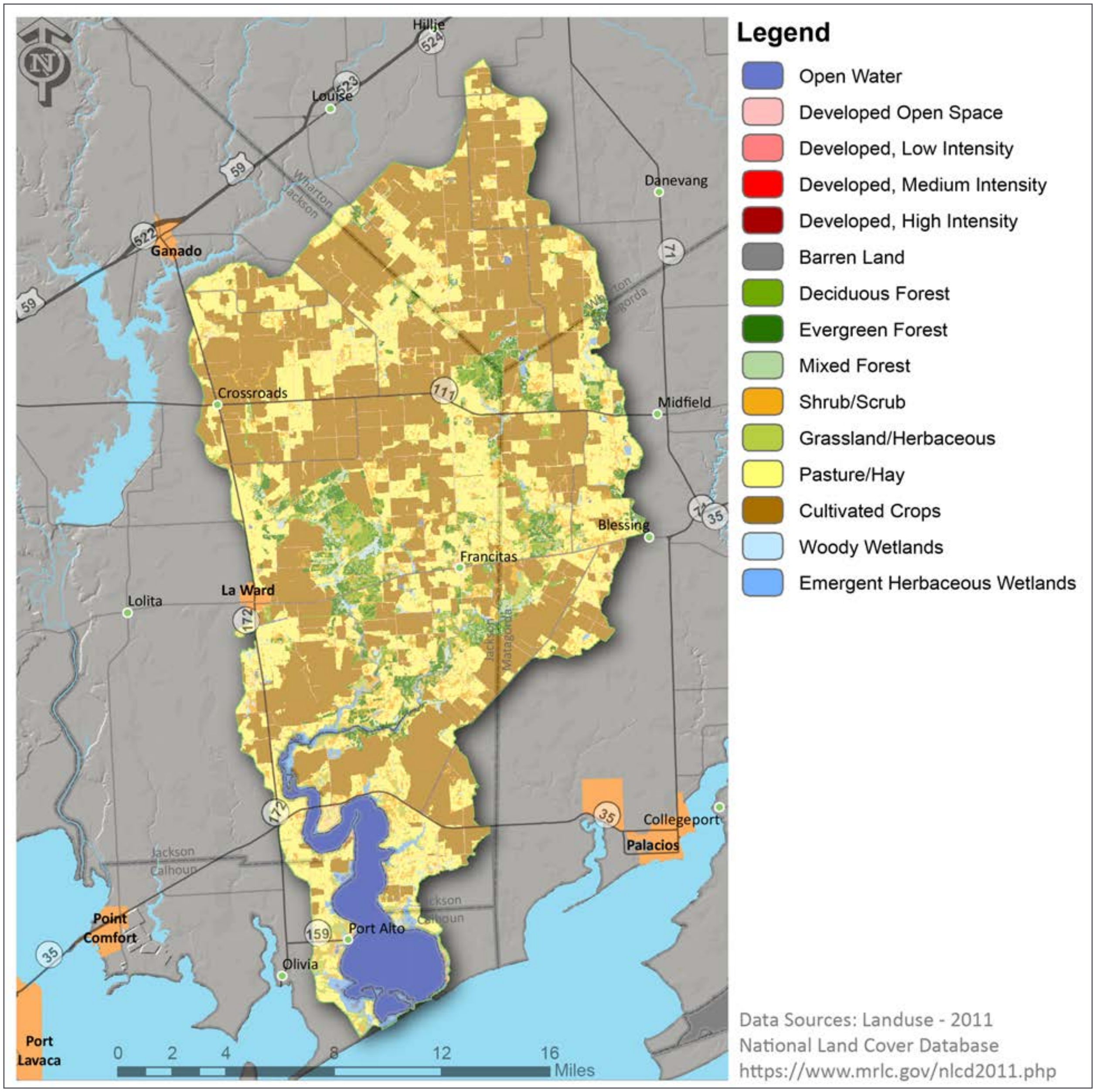


Figure 2. Land cover map.

Ecoregion

Ecoregions are land areas with ecosystems that contain similar quality and quantity of natural resources (Griffith et al. 2007). There are four separate delineated levels of ecoregions; level I is the most unrefined classification, and level IV is the most refined. The Carancahua Bay watershed is located in the Level III Ecoregion 34, known as the Western Gulf Coastal Plain. It is subdivided into the Level IV ecoregion 34a, known as the Northern Humid Gulf Coastal Prairie. The Northern Humid Gulf Coastal Prairie ecoregion encompasses coastal portions of Louisiana and Texas. Most of the landscape in this area is flat with some gently rolling slopes. Poor drainage in this ecoregion can be attributed to the predominantly clay soils. In regard to vegetation type, grasslands are predominant; however, most prairie grasslands have been converted to ranchland, cropland, urban and industrial areas.

Land Use and Land Cover

Watershed land cover data was obtained from the 2011 National Land Cover Database (NLCD) (Homer et al. 2015) and shown in Figure 2. As indicated by the database, cultivated crops (43%) and pasture/hay (29%) are dominate watershed land cover features (Table 1). The watershed is predominantly rural in land use; around 3% of the area is classified as Developed (open space, low intensity, medium intensity and high intensity).

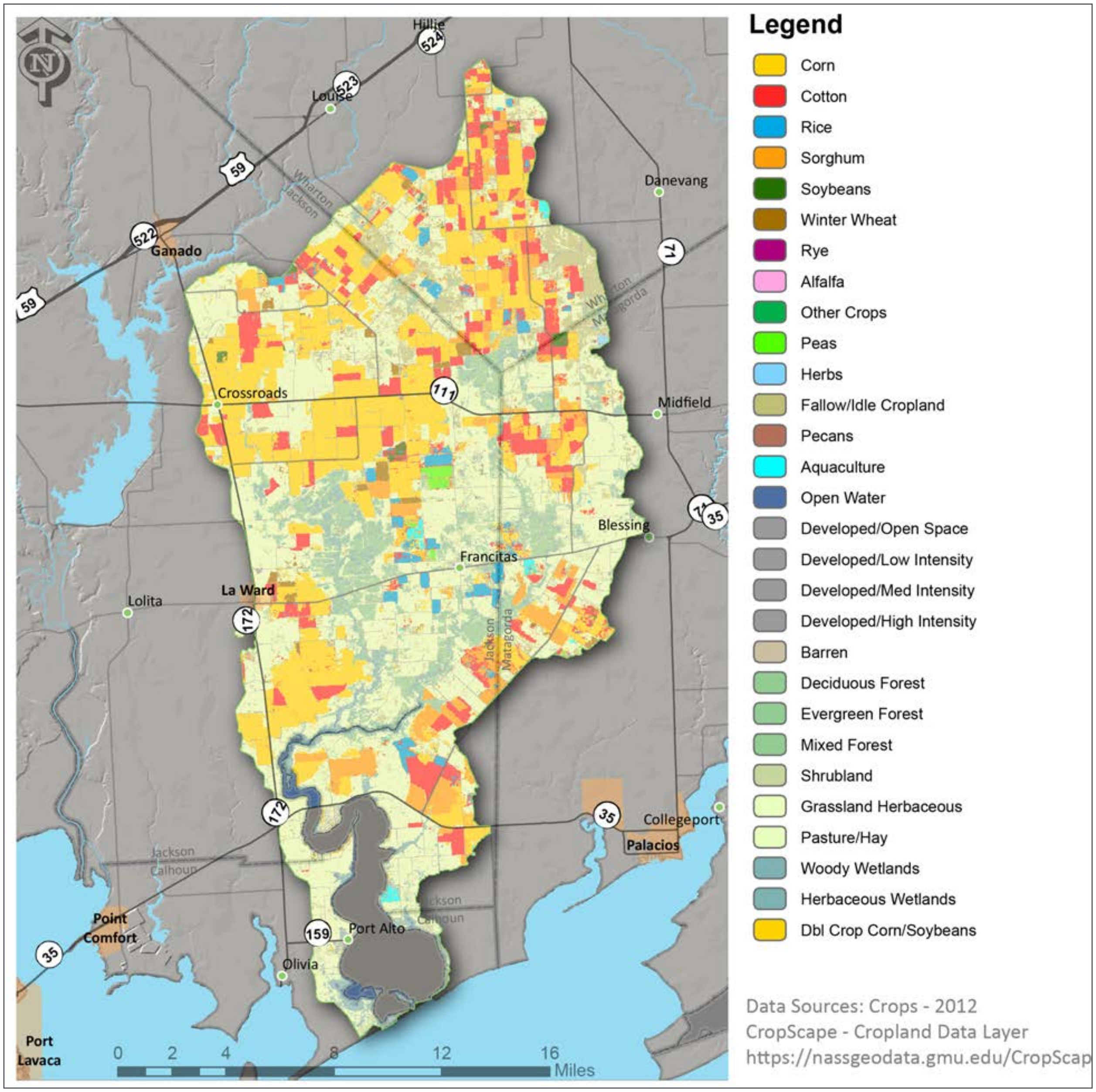


Figure 3. Crop production map.

Although crop production changes frequently based on several factors, corn and cotton remain priority production crops for watershed producers (Figure 3). The USDA National Agricultural Statistics Service (NASS) Cropland Data Layer shows that there were approximately 45,339 ac of corn, 17,837 ac of cotton and 12,530 ac of sorghum in 2012 (USDA NASS 2012).

Soils and Topography

The hydrology of a watershed has many key components, including soil properties and topography. Slope and elevation determine the direction of water flow while elevation and soil properties affect the quantity and speed at which water will infiltrate into, flow over or move through the soil into a water body. Development and other activities may be limited by soil properties in certain areas.

The Carancahua Bay watershed can be characterized as a predominantly flat coastal plain watershed. Much of the watershed has poor to moderate drainage. The watershed has a peak elevation of approximately 100 ft and an average mean elevation of 40 ft [derived from the National Elevation Dataset (Gesch et al. 2002)]. There is an average slope of less than 1% across the watershed, with steeper slopes almost exclusively in areas such as cut banks near the river system. USDA NRCS provides information about soils collected by the National Cooperative Soil Survey, made available through the Soil Survey Geographic Database (SSURGO) (USDA NRCS 2017b). This database contains tabular and

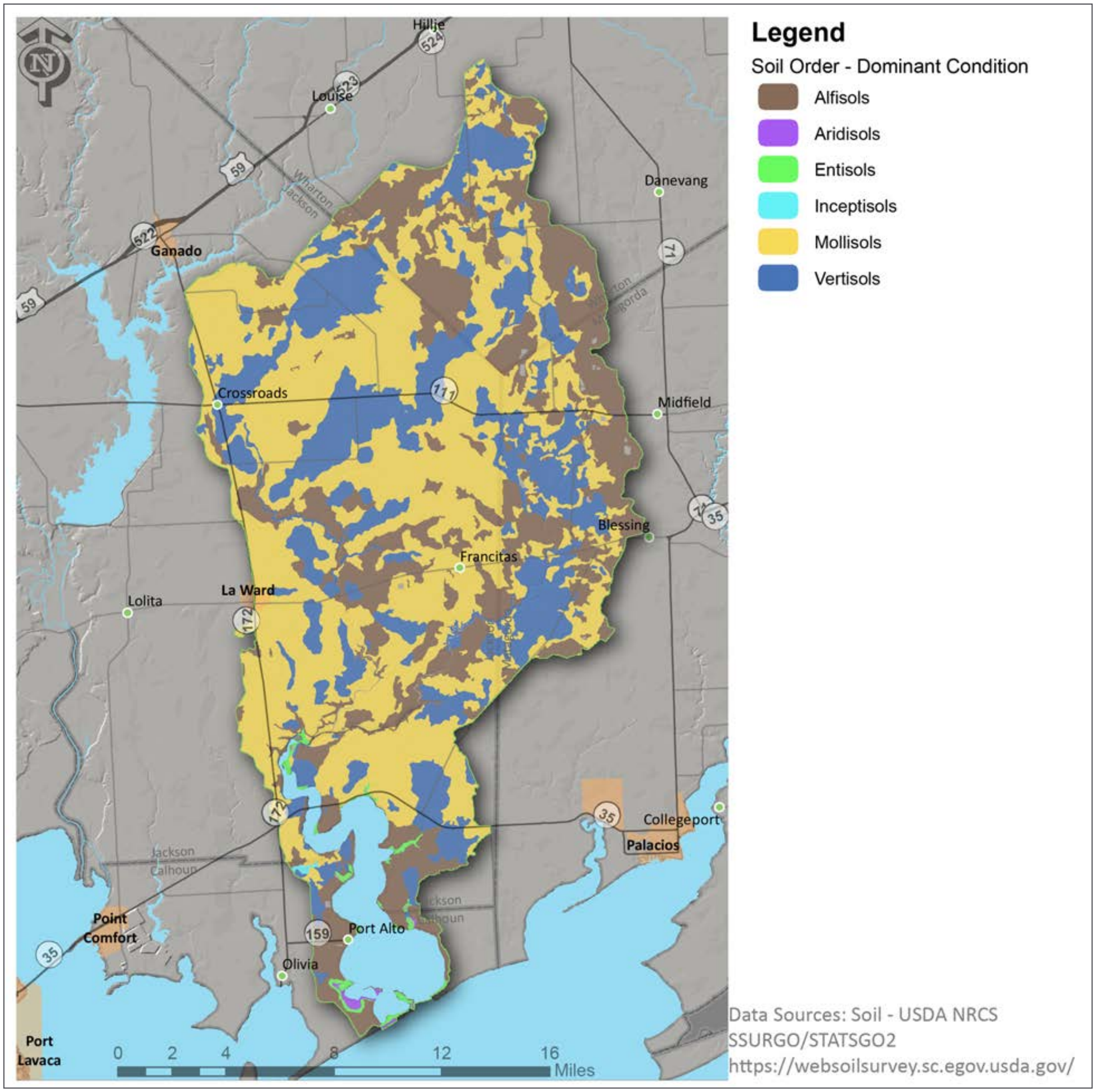


Figure 4. Watershed soil orders.

Table 2. Common watershed soils.

Most Common Soil Orders[1]	Acres
Mollisols	98,083
Alfisols	52,838
Vertisols	52,487
Not rated	13,395

[1] Additional soil orders found in smaller areas within the watershed include Entisols, Aridsols and Inceptisols.

spatial data describing components and properties of soils. Mollisols, Alfisols and Vertisols make up most of the soils in the watershed (Figure 4, Table 2). Mollisols are soils characterized by a dark surface layer indicative of high amounts of organic material and are very fertile and productive for agricultural uses. Alfisols are also a relatively fertile soil suited for agriculture. Vertisols are clay-rich soils that exhibit extensive shrinking and swelling with changes in moisture.

The SSURGO database also provides a hydrologic rating for soils. These are groups of soils with similar runoff properties. These ratings are useful for considering the potential for runoff from properties under consistent rainfall and cover conditions. Within the watershed, nearly all the soils are classified as "Type D" soils, which are indicative of very slow infiltration and having high runoff potential when wet (Figure 5, Table 3). In short, these soils saturate quickly and generate runoff under storm conditions instead of percolating into the ground.

Table 3. Hydrologic soil groups and descriptions.

Hydrologic Soil Group	Acres	Description
Not rated	13,395	Not rated (not surveyed or water body)
A	247	Soils having a 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.
A/D	38	See below[1]
B	0	Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly 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.
B/D	91	See below[1]
C	150	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.
C/D	297	See below[1]
D	204,231	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 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.

[1] Per NRCS (USDA NRCS 2017a), "Certain wet soils are placed in Group D based solely on the presence of a water table within 60 centimeters [24 inches] of the surface, even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils can be adequately drained, they are assigned to dual hydrologic soil groups (A/D, B/D and C/D) based on their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained condition and the second to the undrained condition. For the hydrologic soil group, adequately drained means that the seasonal high water table is kept at least 60 centimeters [24 inches] below the surface in a soil where it would be higher in a natural state."

Table 4. Population projections in the Carancahua Bay watershed.

Group	Population by Year							Percent increase
	2010	2020	2030	2040	2050	2060	2070	
Calhoun County	250	281	314	346	377	408	438	75.2%
Wharton County	215	228	242	254	264	273	282	31.0%
Jackson County	1398	1451	1502	1523	1541	1552	1559	11.5%
Matagorda County	314	335	353	364	373	379	383	22.1%
Total	2177	2295	2411	2488	2555	2613	2662	20.7%

Climate

The Carancahua Bay (AU 2456A) watershed is located in the eastern portion of the state of Texas along the Gulf of Mexico coastline and falls within the subtropical humid climate region as classified by Larkin and Bomar (1983). This regional climate is characterized as a modified marine climate including warm summers with the occasional invasion of drier, cooler continental airflow offsetting the prevailing flow of tropical maritime air from the Gulf of Mexico (Larkin and Bomar, 1983). Monthly normal precipitation, from the Palacios Municipal Airport USW00012935 weather station, located approximately 8 mi east of AU 2456A, indicate the watershed's mean annual rainfall from 1981–2010 was 44.7 inches (Arguez et al. 2010).

As depicted in Figure 6, for the most recent 15-year period from 2002–2016 at the nearest National Oceanic and Atmospheric Administration (NOAA) weather station

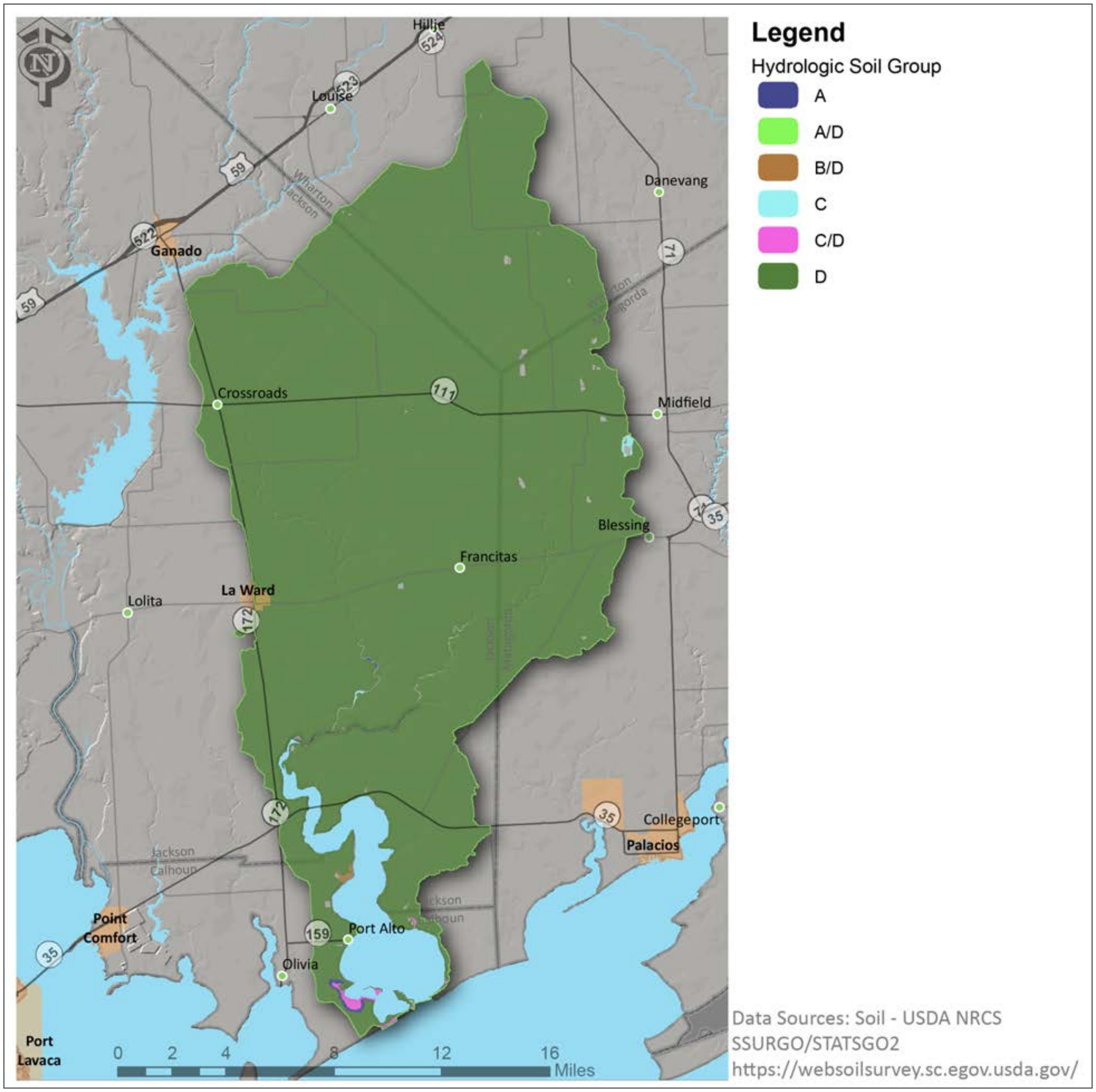


Figure 5. Watershed hydrologic soil groups.

(Palacios Municipal Airport - USW00012935) located approximately 8 mi east of AU 2456_02 (Figure 2), average high temperatures generally peak in August (92.1°F) with average monthly lows ranging from 76.9°F (June) to 78.2°F (August) during the summer months (NOAA 2017). During the winter, the average low temperature is 45.5°F in January. September is the wettest month with an average of 5.8 inches of precipitation and February is the driest month with an average of 1.6 inches. Average annual precipitation values across the study area from the PRISM Climate Group at Oregon State (PRISM Climate Group 2016) indicate average annual rainfall ranges from 43 to 46 in/year across the watershed (Figure 7).

Demographics

As of 2010, the Carancahua Bay watershed population was approximately 2,113 with a population density of six people per square mile (USCB 2011). However, the Calhoun County portion of the watershed has a considerable amount of vacation homes. Therefore, population figures for Calhoun County were adjusted based on stakeholder input. The final total population is estimated at 2,177. Population projections by the Office of the State Demographer and the Texas Water Development Board (TWDB) for counties in the watershed are provided in Table 4 (TWDB 2017). From 2010 to 2070 the population of Calhoun County is expected to increase by approximately 75%, Jackson County is expected to increase by approximately 11%, Matagorda

Table 5. Estimated educational attainment and primary language by county in the Carancahua Bay watershed in 2016.

County	High School Diploma (%)	College Degree (%)	English Primary (%)	Non-English Primary (%)
Calhoun	80.5	15.4	71.4	28.6
Jackson	84.1	17.3	79	21
Matagorda	77.7	15.2	71.4	28.6
Wharton	78	14.5	75	25

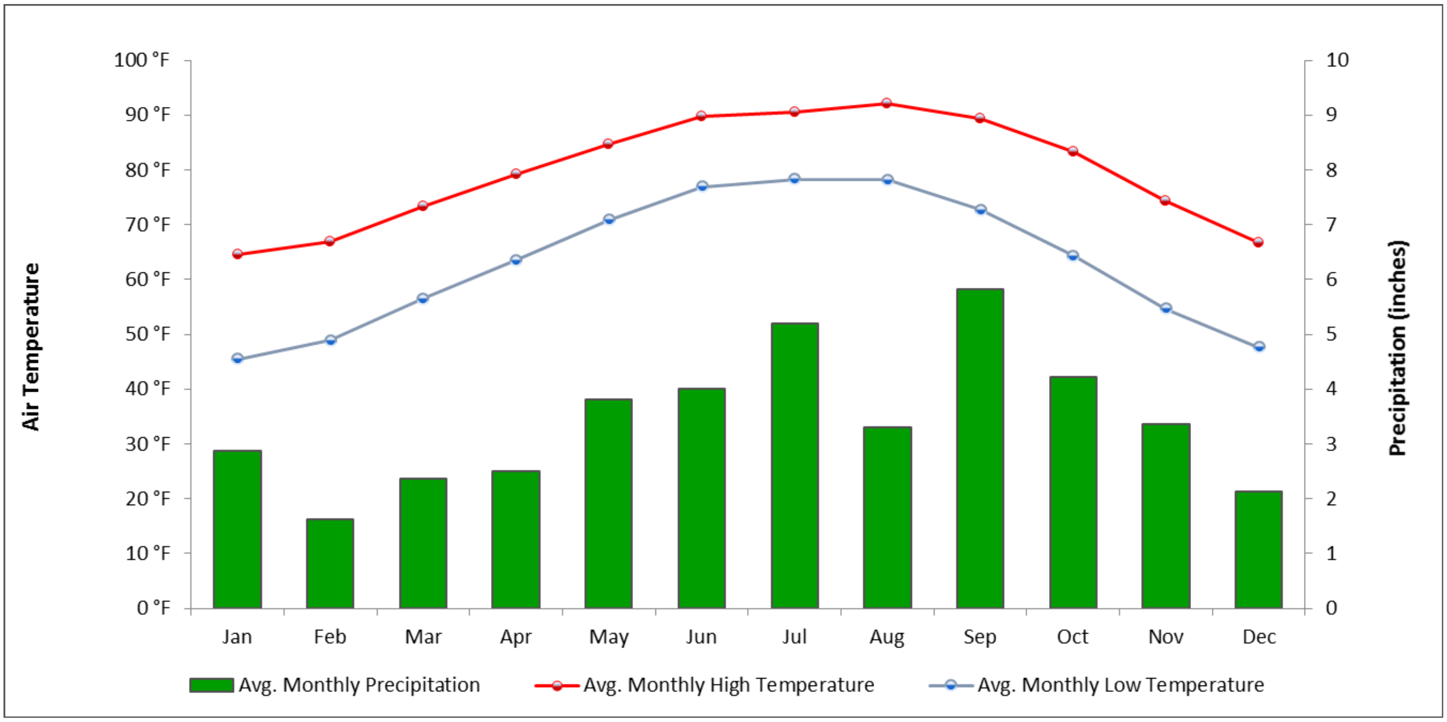


Figure 6. Watershed normal monthly precipitation by month and normal average, maximum and minimum air temperature by month from 2002–2016.

County is expected to increase by approximately 22%, and Wharton County is expected to increase by approximately 31%.

Most of the population in the watershed have at least a high school education and approximately 14–17% of the population have a college degree (Table 5)(USCS 2016). While most residents speak English as a primary language, about a quarter of the population does not speak English as a primary language. These demographics are highlighted because understanding unique and differing needs of target audiences within the watershed is critical to successful stakeholder engagement.

Potential Point Sources

Potential point sources have permits under the TPDES and NPDES programs. WWTF discharges and stormwater discharges from industry, construction and municipal separate storm sewer systems (MS4s) of cities are examples of potential point sources. Within the project watershed, these sources only include a WWTF and regulated stormwater from two construction sites.

Permitted Wastewater Dischargers

As of December 29, 2017, there are three facilities with TPDES/NPDES permits operating within the Carancahua Bay watershed: the Tri County Point Property Owners Association Wastewater Treatment Plant (WWTP), the La Ward WWTF and the Sunilandings WWTP (Figure 8). The Tri County WWTP treats wastewater and discharges into an unnamed drainage ditch, which drains to a small lake, a marsh and then to Carancahua Bay (Segment 2456). The La Ward WWTF treats domestic wastewater and discharges into an unnamed tributary that flows to West Carancahua Creek and eventually into Carancahua Bay (Segment 2456A) (Table 6). The Sunilandings WWTP treats wastewater and discharges directly into Carancahua Bay. Discharge for all three facilities is measured in millions of gallons per day (MGD).

Table 6. Permitted wastewater treatment facilities in the Carancahua Bay watershed.

Facility Name	Receiving Stream	Flow (MGD)		Bacteria (MPN/100 mL)		Number of Quarters in Violation for Exceedance from 10/2014 – 12/2017
		Permitted	Reported (3-year average)	Permitted (daily average)	Reported (3-year average)	
La Ward	unnamed tributary; then to West Carancahua Creek; thence to Carancahua Bay (2456A_01)	0.024	0.0074	126[1]	3.45	**1** (Flow)
Sunilandings	Carancahua Bay (2456A_02)	0.025	0.0023	14[2]	7.33	**4** (2 ammonia daily average, 1 ammonia single grab, 1 *Enterococcus* daily average, 2 TSS)
Tri County	unnamed drainage ditch, to small lake, to marsh, to Carancahua Bay (2456)	0.024	0.024	126[1]	1.08	**2** (1 TSS daily average, 1 minimum pH)

Million gallons per day, MGD; most probably number, MPN; milliliter, mL; total suspended solids, TSS
[1] MPN/100 mL *E. coli*
[2] MPN/100 mL *Enterococcus*

All of the WWTFs have a history of non-compliance issues during the 12-quarter period (three years) October 1, 2014 through December 29, 2017 (USEPA 2017). The La Ward WWTF reported 11 quarters of non-compliance during this time while the Sunilandings WWTP reported three quarters of non-compliance with a significant violation for exceeding the monthly average for total suspended solids (TSS) in the effluent. High bacteria levels occurred for Sunilandings WWTP once throughout the 12-quarter period as well. The Tri County Point Property Owners Association WWTP (formally the Boca Chica Sec 3 PLT from 1/12/2010–1/1/2015) had nine quarters of non-compliance issues during the three-year period.

A review of active general permit coverage (TCEQ 2017) in the Carancahua Bay (AU 2456A) watershed as of December 5, 2017 revealed one aquaculture permittee was covered by the general permit. The aquaculture facility does not have bacteria reporting or limits in its permit. The facility was assumed to contain inconsequential amounts of indicator bacteria in its effluent; therefore, it was unnecessary to allocate bacteria load to the facility. No other active general wastewater permit facilities or operations were found.

Unauthorized Discharges

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 a permitted system. SSOs in dry weather most often result from blockages in sewer pipes caused by tree roots, grease and other debris. Inflow and infiltration are typical causes of SSOs under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the problem. Other causes, such as a collapsed sewer line, may occur under any condition. These overflows and spills can reach water bodies, resulting in significant bacteria loading.

The TCEQ Region 14 Office maintains a database of SSO data reported by municipalities. These SSO data typically contain estimates of the total gallons spilled, responsible entity and a general location of the spill. A search of the database revealed that no SSOs have been reported for the most recent reporting period 2012–2016 (unpublished data file available upon request from TCEQ). It is possible that SSOs are being under-reported in the Carancahua Bay (AU 2456_02) watershed as some data would have been anticipated over the period covered in the dataset.

Permitted Stormwater Discharges

TPDES general permits cover stormwater discharges from Phase II urbanized areas, industrial facilities and construction sites over 1 ac (TCEQ 2017). A review of active stormwater general permits in the watershed resulted in two active construction site permits as of December 5, 2017. The project watershed contained no MS4 permits. The acreage for the construction permits were given as acres disturbed in the authorization details of the permits. The number of acres disturbed was 158 (Table 7).

Table 7. Land area covered by stormwater permits in the watershed as of December 5, 2017.

AU	Industrial General Permits (number)	Industrial General Permit (acres)	Construction Permits (number)	Construction Permits (average acres)	Total Area of Permits (acres)
2456A	0	0	2	79	158

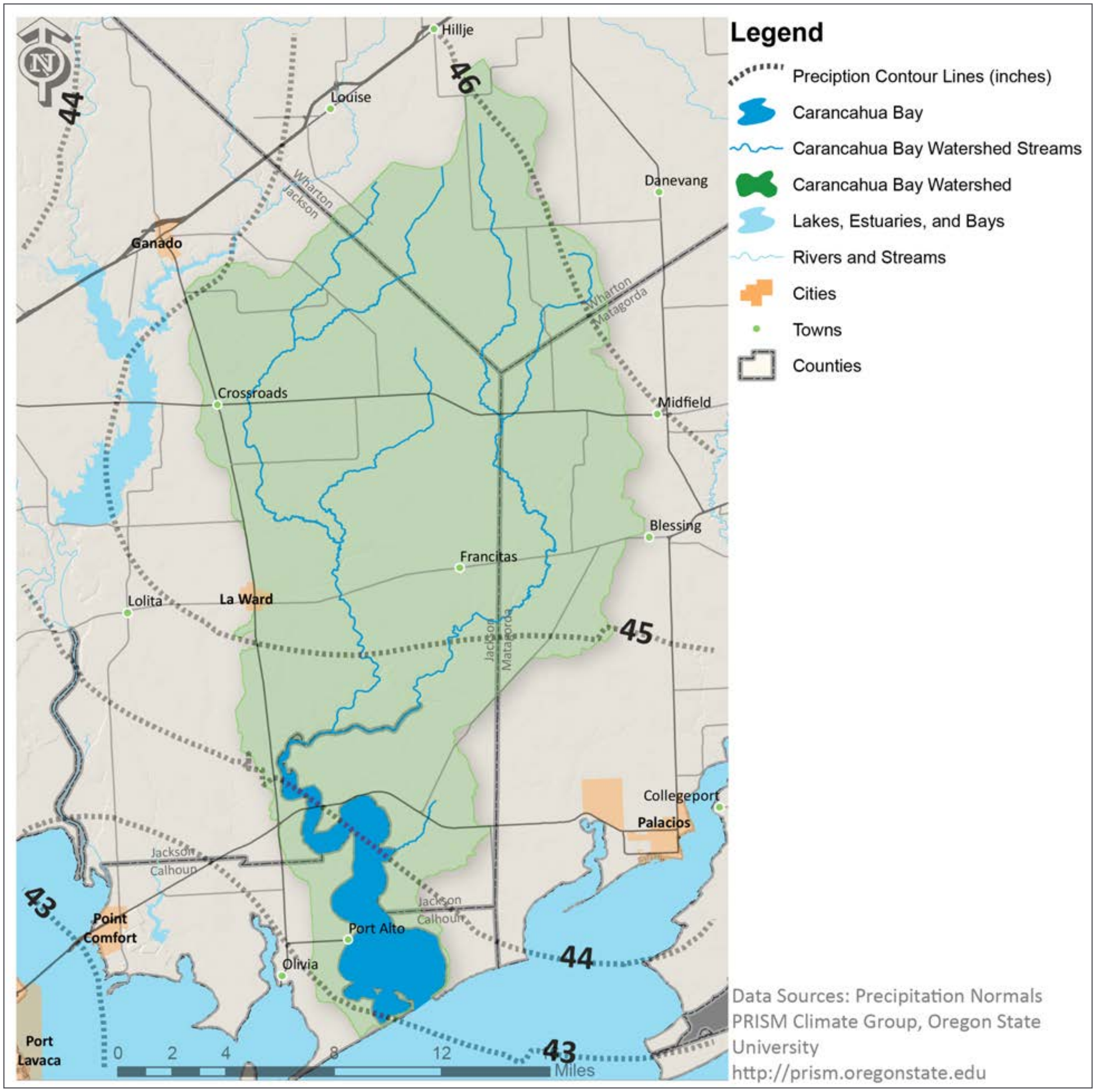


Figure 7. 30-year normal precipitation values.

Potential Nonpoint Sources

Unregulated sources include non-permitted, typically NPS, discharges that can contribute to fecal bacteria and nutrient loading in the watershed. Potential sources include domestic livestock, wildlife, domestic pets and OSSFs.

Domestic Livestock

Domestic livestock farms, particularly cattle, are common throughout the rural watershed. Runoff from rain events can transport fecal matter and bacteria from pastures and rangeland into nearby creeks and streams. Livestock with direct access to streams can also wade and defecate directly into water bodies resulting in direct contributions of bacteria

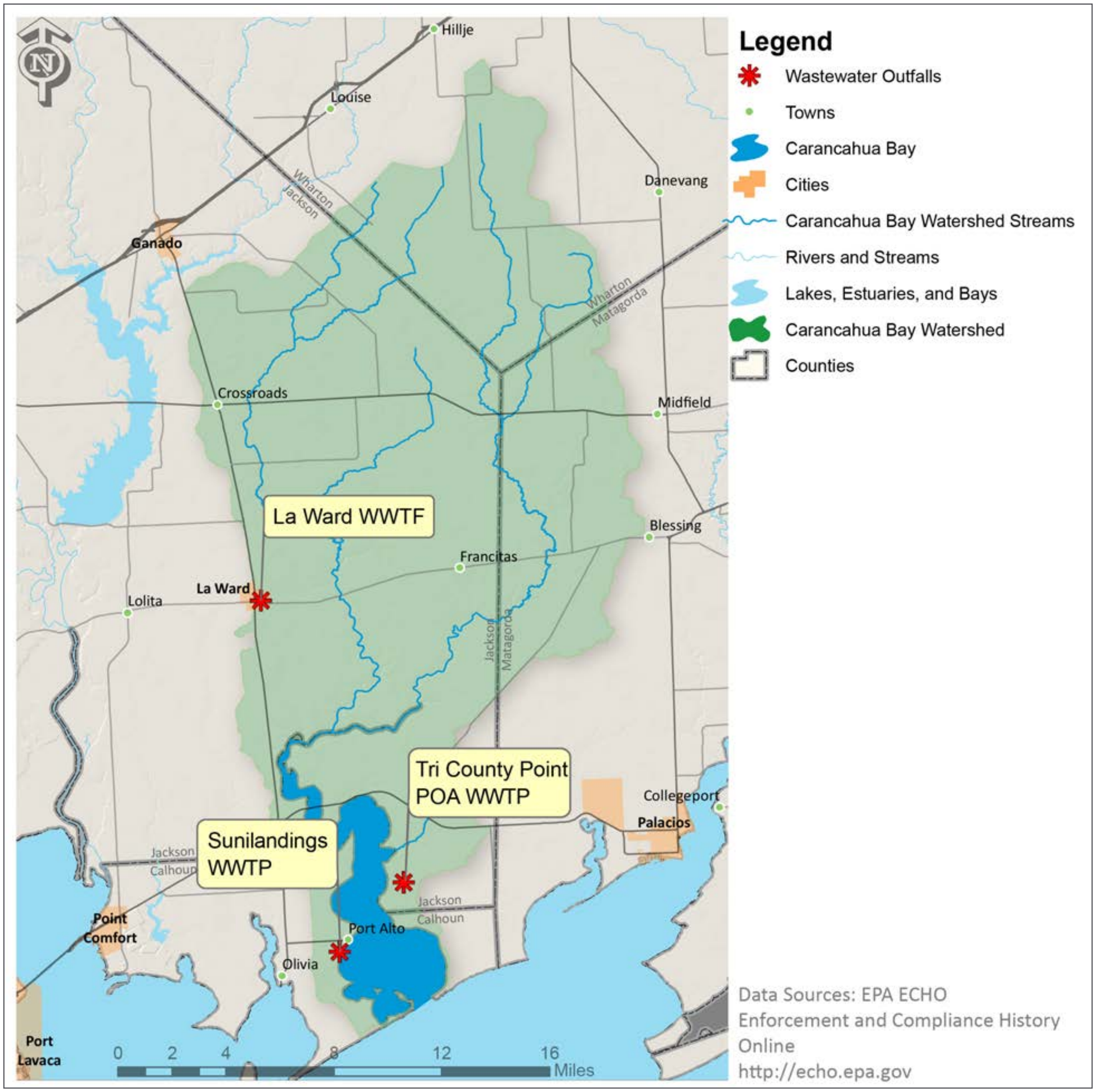


Figure 8. Active permitted wastewater discharge outfall locations.

to the water. Streamside riparian buffers, fencing and grazing practices that reduce the time livestock spend near streams can reduce livestock impacts on water quality.

Because watershed-level livestock numbers are not available, we estimated populations using the USDA NASS and U.S. Geological Survey (USGS) NLCD datasets. We estimated cattle populations with two methods. First, using the USDA NASS dataset, county-level data were multiplied by a ratio based on the acres of grazeable land divided by the total number of acres in the county. Then, the proportion of grazeable acres in the watershed within each county was used to estimate the number of cattle from each county that are in the watershed. The second method used estimated cattle population based on stocking rates that local stakeholders believe are being used. Specifically, cattle were estimated using locally derived stocking rates of one animal unit per 3 ac of improved land (identified as pasture in the NLCD dataset) and one animal unit per 10 ac of unimproved land (identified as forest, shrub/scrub, herbaceous/grassland in the NLCD dataset). Based on these assumptions, we estimated between 15,701 and 24,497 animal units of cattle in the watershed (Table 8).

For other types of livestock, we estimated population for each county using the USDA NASS dataset. This method resulted in estimates of 380 horses and 256 goats in the watershed. Other types of livestock occurred infrequently in the county's NASS data and are not considered likely sources of bacteria.

Table 8. Land area covered by stormwater permits in the watershed as of December 5, 2017.

Livestock	Cattle (NASS estimate)	Cattle (Stakeholder Estimate)	Horses (NASS estimate)	Goats (NASS estimate)
Count	15,701	24,497	380	256
Animal Units	15,701	24,497	475	44

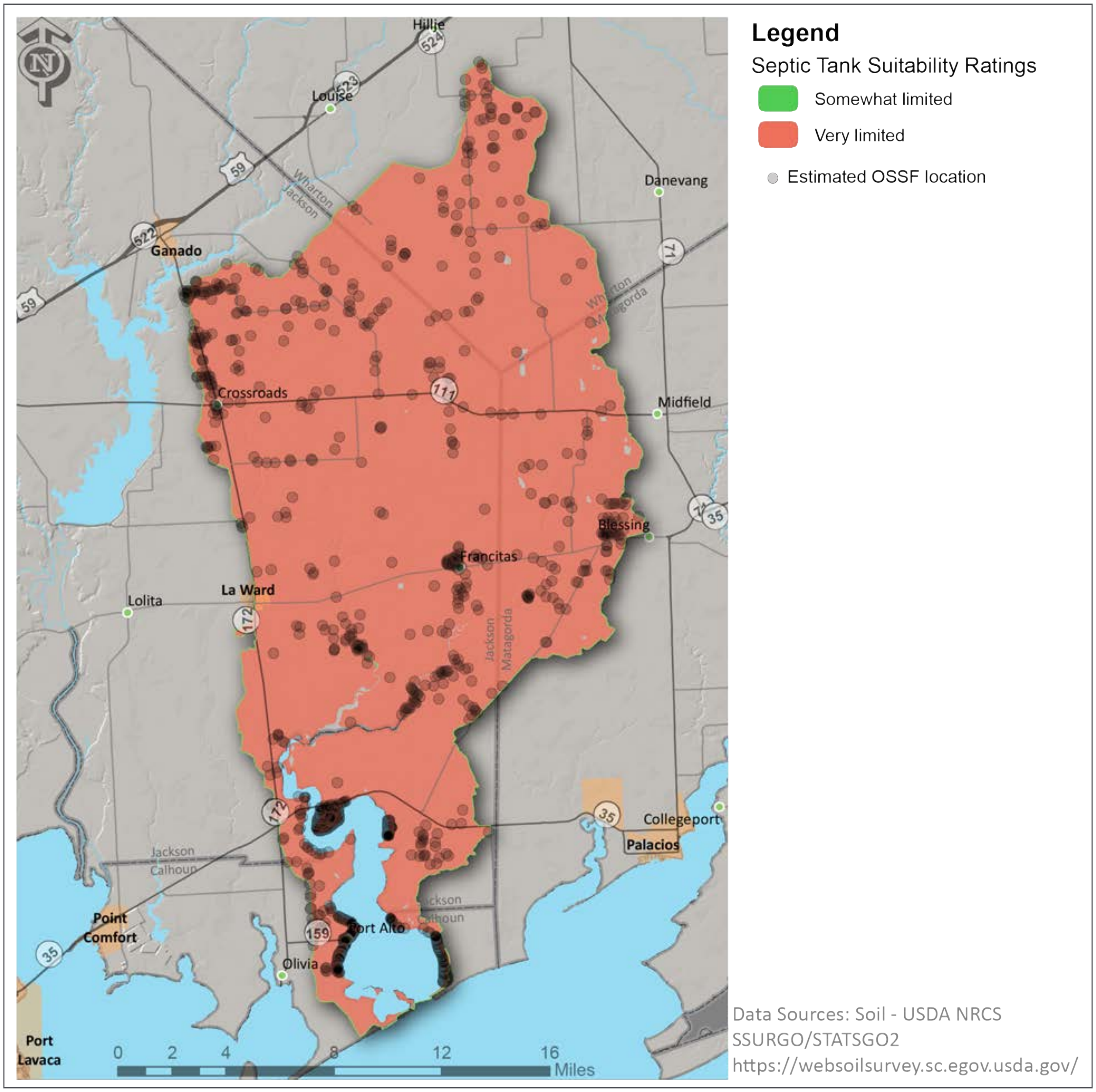


Figure 9. On-Site Sewage Facility (OSSF) locations and suitability ratings.

Wildlife

E. coli are found in the intestines of all warm-blooded animals, including wildlife such as mammals and birds. Fecal wastes can also contribute nutrients in the form of ammonia, nitrite, nitrogen and phosphorous. Wildlife are naturally attracted to the riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria and nutrient loading to a water body. Fecal bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. While several bird and mammal species are likely to contribute bacteria loads in area waterways, feral hogs and white-tailed deer are the only species with reasonable density and population estimates.

Table 9. Estimated watershed wildlife populations.

Wildlife	Estimated Watershed Population	Estimated Animal Units (1,000 pounds of animal)
Feral Hogs	5,936	742
White-tailed Deer	7,924	887

We derived a population estimate for feral hogs using a density rate of 33.3 ac/hog based on studies in the proximate Copano Bay watershed (Wagner and Moench 2009). Applying the estimated density to the total acreage of hay/pasture, cultivated crops, shrub/scrub, herbaceous, deciduous forest, evergreen forest, mixed forest, woody wetlands and emergent herbaceous wetlands identified in the 2011 NLCD data, we estimated 5,936 feral hogs in the watershed (Table 9).

TPWD provided white-tailed deer density estimates, categorized by Deer Management Unit (DMU). The Carancahua Bay watershed, which falls in the DMU 10 area, had an average deer density of 38.4 deer/1,000 ac from 2006–2010. Applying this value to the area of the entire watershed results in 7,924 deer within the Carancahua Bay watershed.

Domestic Pets

Fecal matter from dogs and cats can contribute to bacteria loads in the watershed when not picked up and disposed of properly. In rural areas, such as the Carancahua Bay watershed, pets often spend most of their time roaming around outdoors, making disposal of their waste impractical. The American Veterinary Medical Association estimates there are approximately 0.584 dogs and 0.638 cats per home across the United States (AVMA 2012). Multiplying these ratios with the number of households (1,605) in the watershed suggests there are approximately 937 dogs and 1,024 cats across the watershed.

On-site Sewage Facilities (OSSFs)

Given the rural nature of the watershed, many homes are not connected to centralized sewage treatment facilities and therefore use OSSFs. Typical OSSF designs include either (1) anaerobic systems composed of septic tank(s) and an associated drainage or distribution field or (2) aerobic systems with aerated holding tanks and typically an above ground sprinkler system to distribute the effluent. Failing or undersized OSSFs will contribute direct bacteria loads as the effluent from the systems move through or over the ground into adjacent water bodies.

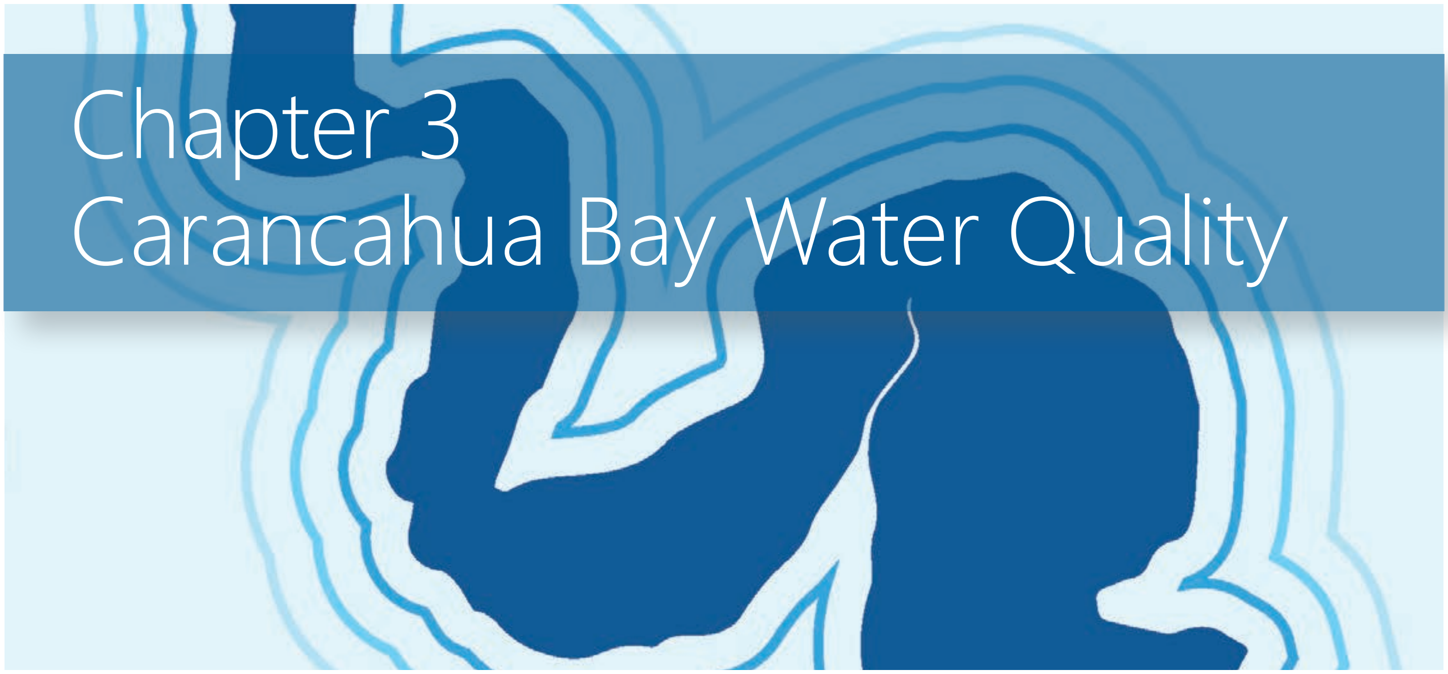
The USDA NRCS SSURGO database (discussed in Chapter 2, page 9) provides suitability ratings for septic tank absorption fields based on soil properties, depth to bedrock or groundwater, hydraulic conductivity and other properties that may impact the absorption of on-site sewage effluent, installation and maintenance. Nearly all the Carancahua Bay watershed is rated as "Very Limited," indicating areas that are unfavorable for OSSF use and expectations of poor performance and high amounts of maintenance (Figure 9).

Based on visually validated county 911 data and areas of existing wastewater service, an estimated 1,389 OSSFs may occur in the watershed (Borel et al. 2012; Gregory et al. 2014). The highest densities of OSSFs appear in the lower portions of the watershed inside or just outside existing service areas (Figure 9). Pockets of high densities also occur in the watershed near Francitas and Crossroads as well as surrounding the southeast portion of Carancahua Bay.

Although most well-maintained OSSFs are likely to function properly, failing OSSFs can leak or discharge untreated waste onto distribution fields. Runoff generated during storm events can transport this waste overland and into nearby water bodies. Untreated OSSF effluent can contribute to levels of indicator bacteria, dissolved oxygen (DO), nutrients and other water quality parameters.

Summary

Carancahua Bay is a largely rural watershed, composed of fertile and slow-draining soils. Agriculture is an important component of the landscape and local economy. Very few industries and permitted discharges occur in the watershed, suggesting NPS runoff is a potential contributor to bacteria and nutrient loadings in the watershed, with minor contributions from permitted dischargers. NPS pollutants can be difficult to manage because of their diffuse nature across the watershed. However, many types of practices can be used to reduce runoff, reduce soil and nutrient loss, improve production and improve water quality. Potential management measures to address nonpoint sources will be presented in Chapter 5.



Chapter 3
Carancahua Bay Water Quality

Introduction

The programs, rules, regulations and standards involved in evaluating water quality involve multiple levels of government, different agencies and multiple stakeholders. While complex, this system establishes methods for ensuring appropriate water quality standards and consistent methodologies are used to assess the health and safety of water bodies throughout the state.

This chapter summarizes the water quality policy and standards as relevant to Carancahua Bay. Currently, Carancahua Bay does not meet state water quality standards established for primary contact recreation due to elevated bacteria. Furthermore, TCEQ identified West Carancahua Creek as not meeting water quality standards for aquatic life due to depressed DO. The remainder of Chapter 3 discusses data used in the water quality assessment, summarizes more recent water quality data and links potential sources and contributors to water quality issues in the Carancahua Bay watershed.

Chapter 3 Highlights

1. **Carancahua Bay does not meet state water quality standards for recreation due to higher than normal levels of bacteria.**
2. **West Carancahua Creek does not meet state water quality standards presumed to protect aquatic life due to low dissolved oxygen levels.**
3. **Both water bodies exceed expected nutrient levels.**

Water Quality Policy and Standards

Under the Federal Clean Water Act section 303(d) and 305(b), the State of Texas is required to identify water bodies that do not meet designated water quality standards. To comply with the Clean Water Act, TCEQ establishes "designated uses" and corresponding water quality standards for streams, rivers, lakes and bays. Title 30, Chapter 307 of the Texas Administrative Code codifies the Texas Surface Water Quality Standards as state rules.[3] These rules provide the narrative and numeric criteria against which water bodies are evaluated as well as the sampling and analytical procedures used to assess attainment of surface water quality standards.

Every two years, TCEQ assesses water quality data to determine which water bodies meet their designated uses based on criteria and procedures in the Texas Surface Water Quality Standards. Based on this assessment, the Texas Integrated Report of Surface Water Quality (sometimes referred to as the Integrated Report) describes the status of water bodies in the state of Texas.[4] "Category 5" of the Integrated Report lists impaired water bodies that do not meet designated uses. This section of the Integrated Report is also known as the 303(d) List. The most recent approved Integrated Report is

[1] The 2014 Texas Surface Water Quality Standards are available at https://www.tceq.texas.gov/waterquality/standards/2014standards.html.

[2] The Texas Integrated Report of Water Quality is available at https://www.tceq.texas.gov/waterquality/assessment.

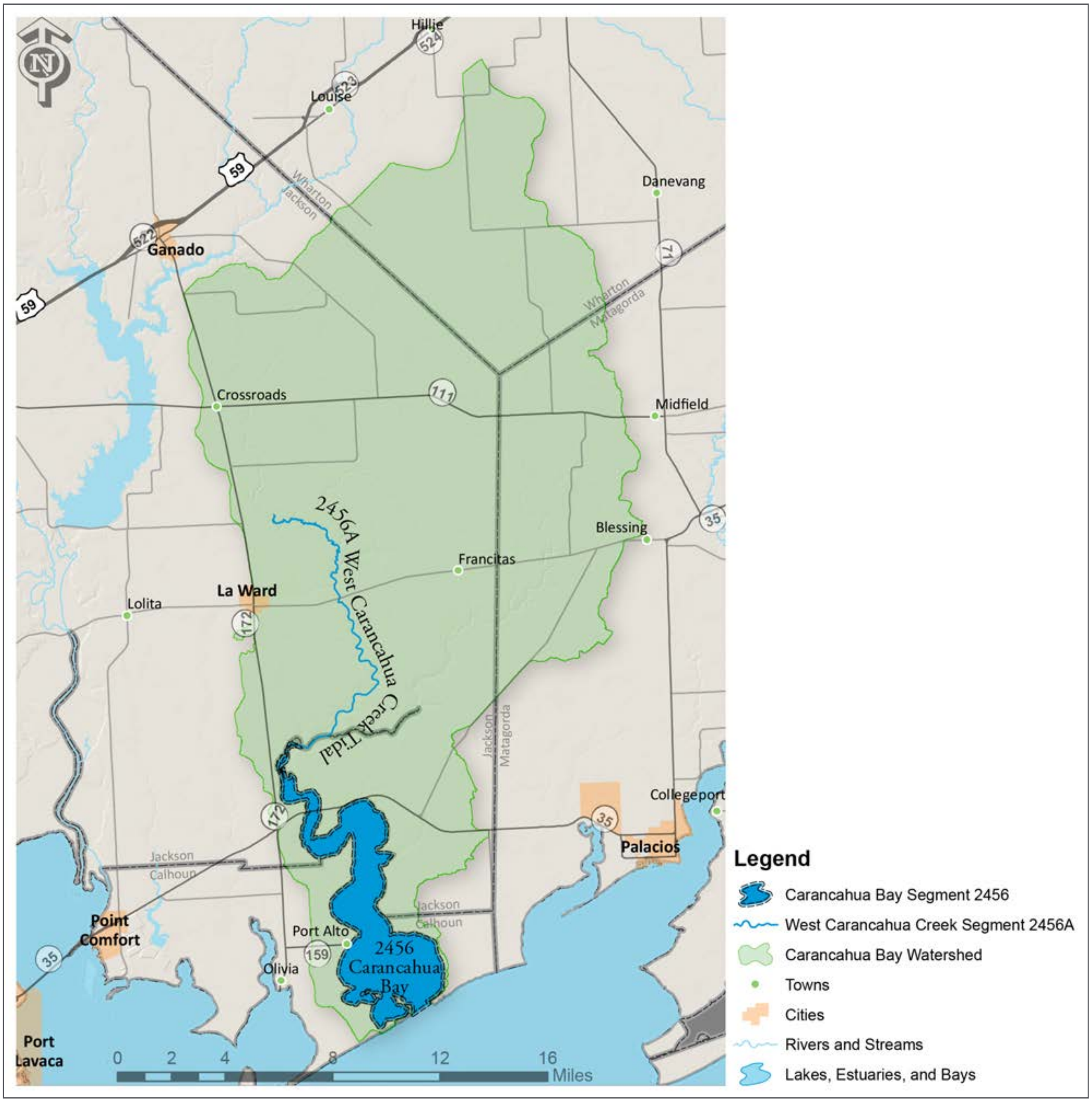


Figure 10. Map of water body segments in the Carancahua Bay watershed.

from 2014 and assessed water quality data collected from 2005 through 2012.

Segments

For assessment purposes, TCEQ divides all water bodies in the state into classified segments based on hydrology and geologic diversity. A segment refers to a defined, basic unit for assigning site-specific standards. Therefore, classified segments are divisions of a water body intended to have similar biological, chemical, hydrological and physical characteristics. These classified segments have designated uses and associated water quality criteria listed in Appendix A of the *Texas Surface Water Quality Standards*. Segment 2456, Carancahua Bay, is the only classified segment within the Carancahua Bay watershed (Figure 10).

Unclassified waters are smaller water bodies that are not designated as segments in Appendix A of the Texas Surface Water Quality Standards. Some unclassified water bodies are listed in Appendix D of the Texas Surface Water Quality Standards and assigned aquatic life uses and DO criterion if sufficient information has been collected. Unclassified water bodies, not included in Appendix D, are assigned a presumed use and associated criteria. Within the Carancahua Bay watershed, West Carancahua Creek Tidal (Segment 2456A) is an unclassified water body.

Table 10. Designated uses and numeric criteria for Carancahua Bay.

Designated Use	Criteria	Assessment Method
Primary Contact Recreation	35 MPN/100 mL *Enterococci* bacteria	Geometric Mean
Exceptional Aquatic Life Use	5 mg/L average DO 4 mg/L minimum DO	Number of exceedances > 10%
General	6.5 – 9.0 pH 95°F	Average

Most probable number, MPN; milliliter, mL; milligram, mg; liter, L; dissolved oxygen, DO

Table 11. Designated uses and numeric criteria for West Carancahua Creek Tidal.

Designated Use	Criteria	Assessment Method
Primary Contact Recreation	35 MPN/100 mL *Enterococci* bacteria	Geometric Mean
High Aquatic Life Use	4 mg/L average DO 3 mg/L minimum DO	Number of exceedances > 10%
General	6.5 – 9.0 pH 95°F	Average

Most probable number, MPN; milliliter, mL; milligram, mg; liter, L; dissolved oxygen, DO

Designated Uses and Water Quality Standards

Water quality standards can be thought of as a combination of a water body's designated use and the water quality criteria required to support and protect that use. These uses may include aquatic life, recreation and/or public water supply. Some of the parameters used to evaluate support of those uses include DO, bacteria, temperature and pH.

DO is the parameter used to evaluate the support of designated aquatic life uses. The concentration of DO determines the ability to support and maintain aquatic life. High DO levels are generally a sign of good water quality. Low DO concentration inhibits aquatic life and may be indicative of limited aeration, excessive temperature, excessive salinity or excess nutrient loads. The criterion used to assess DO is typically the concentration of DO as milligrams (mg) per liter (L) of water, or mg/L.

Enterococci bacteria is the parameter used to evaluate support of primary contact recreation in tidal waters. Most strains of *Enterococci* are not themselves pathogenic; instead, they are used as indicators. That is to say, the presence of *Enterococci* bacteria indicates the presence of fecal contamination in water bodies and increased risk of pathogens. (USEPA 2012). The criteria used to assess fecal bacteria is typically expressed as the number of bacteria (or counts), given as the most probable number (MPN) per unit volume of water. At 35 MPN per 100 milliliters (mL) concentration, the estimated risk of contracting a gastrointestinal illness is 36 individuals per 1,000 individuals engaged in contact recreation (swimming, diving and other activities with increased risk of water ingestion). *Enterococci* concentrations equal to or less than this standard do not necessarily ensure that no risk of illness exists. Conversely, concentrations above this level do not indicate that a person will get sick.

Carancahua Bay's designated uses include primary contact recreation and exceptional aquatic life use (Table 10). The primary contact recreation criterion for saltwater is 35 MPN/100 mL *Enterococci* bacteria. The exceptional aquatic life use criterion is 5 mg/L mean 24-hour (hr) DO and 4 mg/L 24-hr minimum DO.

West Carancahua Creek Tidal Segment 2456A is unclassified and therefore presumed to have both primary contact recreation and high aquatic life uses (Table 11).

Water body assessments

For purposes of assessing water quality data used in TCEQ's Integrated Report, individual segments are further divided into assessment units (AUs). Carancahua Bay is split into two AUs (Figure 11). TCEQ designated Lower Carancahua Bay as AU 2456_01 and Upper Carancahua Bay as AU 2456_02. West Carancahua Creek includes a single AU, 2456A_01. Monitoring stations within each AU are used for independent water quality analysis for each AU within a segment.

Water quality assessments for the Integrated Report are conducted on the most recent seven years of available data. A minimum of 10 data points are required for all water quality parameters except bacteria. Bacteria parameters require a minimum of 20 samples. If more than 10% of the assessed DO samples are below the criterion, the water body is listed as impaired due to depressed DO. If the geometric mean of

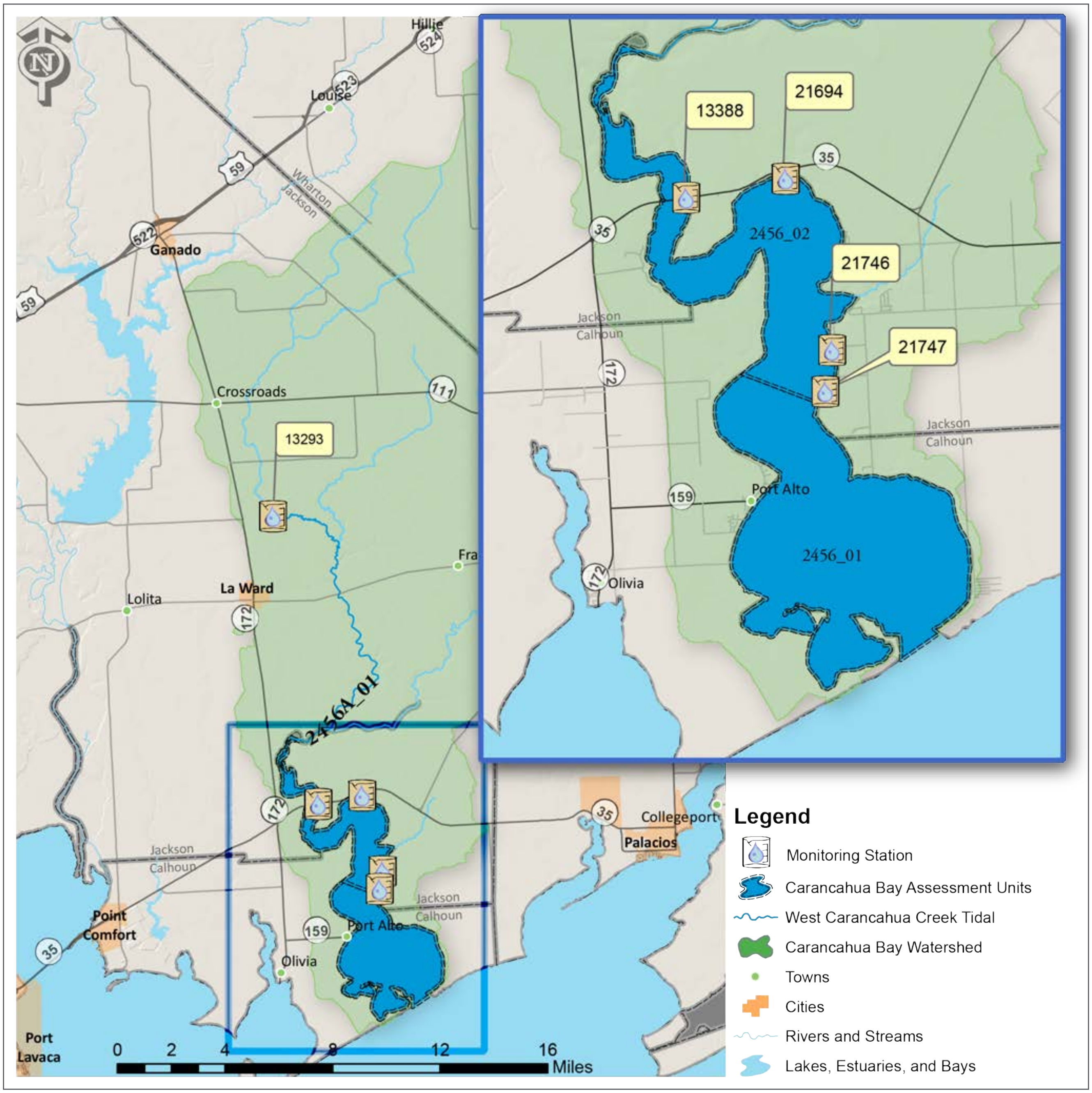


Figure 11. Carancahua Bay watershed assessment units.

the assessed bacteria samples is above the criterion, the water body is listed as impaired due to elevated indicator bacteria.

Current Water Quality Impairments

Bacteria

TCEQ first identified the bacteria impairment within Carancahua Bay AU 2456_02 in the *2006 Texas Water Quality Inventory and 303(d) List* (now known as the Integrated Report). Each subsequent Integrated Report identified Carancahua Bay as impaired due to elevated bacteria.

Enterococci data collected at station 13388 over a seven-year period (December 1, 2005 through November 30 2012) were used in assessing the attainment of the primary contact recreation standard (35 MPN/100 mL) in the most recent 2014 Integrated Report. This data indicated non-support of primary contact recreation use because the geometric mean concentration (123.82 MPN/100 mL) exceeded the geometric mean criteria (Table 12).

Figure 12 shows *Enterococci* bacteria concentrations for the samples assessed in the 2014 Integrated Report for Carancahua Bay. Although there is a great deal of variability in

Table 12. 2014 Integrated report summary for the Upper Carancahua Bay (AU 2456_02) bacteria impairment.

Water Body	Assessment Unit	Parameter	Date Range	Number of Samples	Geometric Mean (MPN/100 mL)
Carancahua Bay	2456_02	*Enterococci*	December 1, 2005– November 30, 2012	20	123.82

Most probable number, MPN; milliliter, mL

Table 13. 2006 Integrated report summary indicating the first time West Carancahua Creek Tidal (AU 2456_01) was identified impaired due to depressed dissolved oxygen (DO).

Water Body	Assessment Unit	Parameter	Date Range	Number of Samples Assessed	Number of Exceedances
West Carancahua Creek Tidal	2456A_01	DO 24-hour average	December 1, 1999–November 30, 2004	12	6
West Carancahua Creek Tidal	2456A_01	DO 24-hour minimum	December 1, 1999–November 30, 2004	12	9

Dissolved oxygen, DO

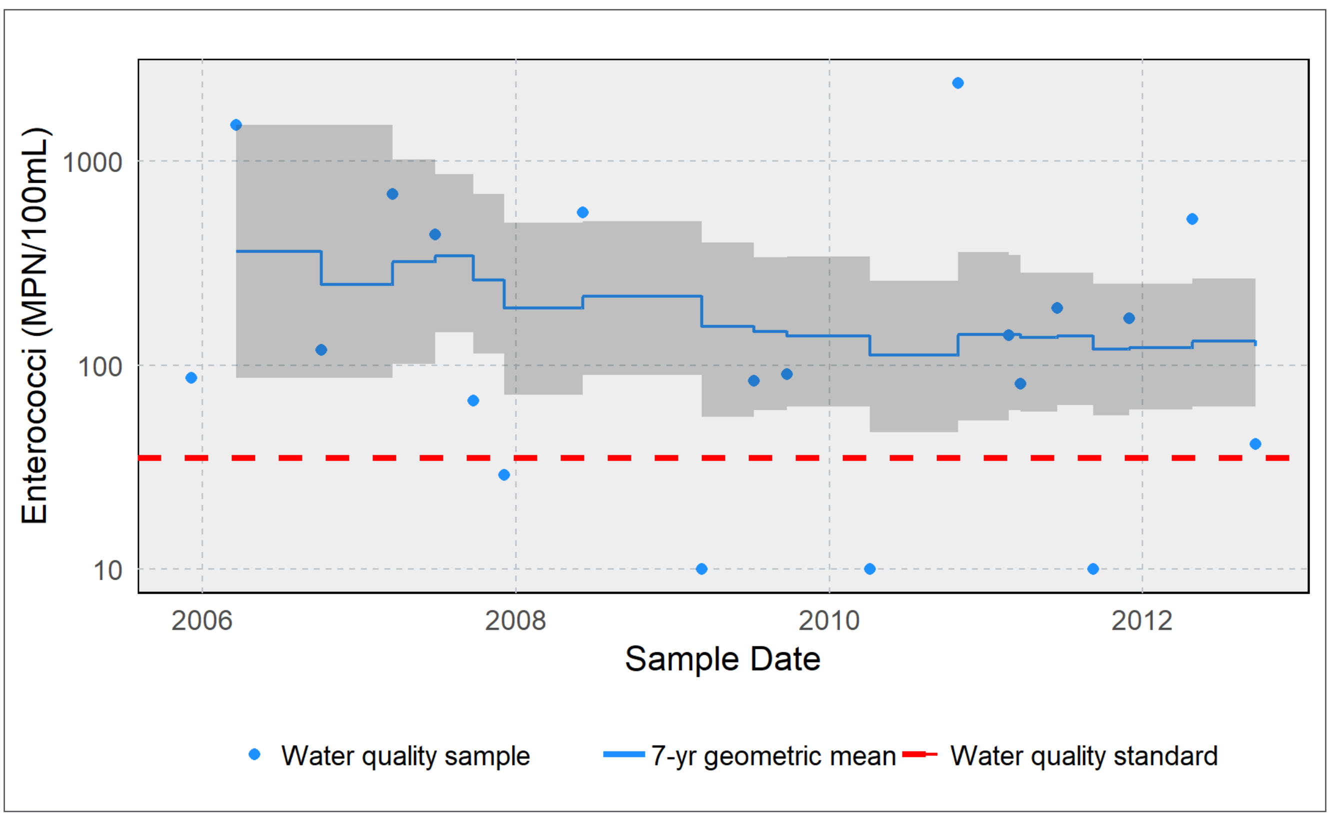


Figure 12. *Enterococci* data assessed for Carancahua Bay in the 2014 Integrated Report (shaded area indicates the 95% confidence interval).

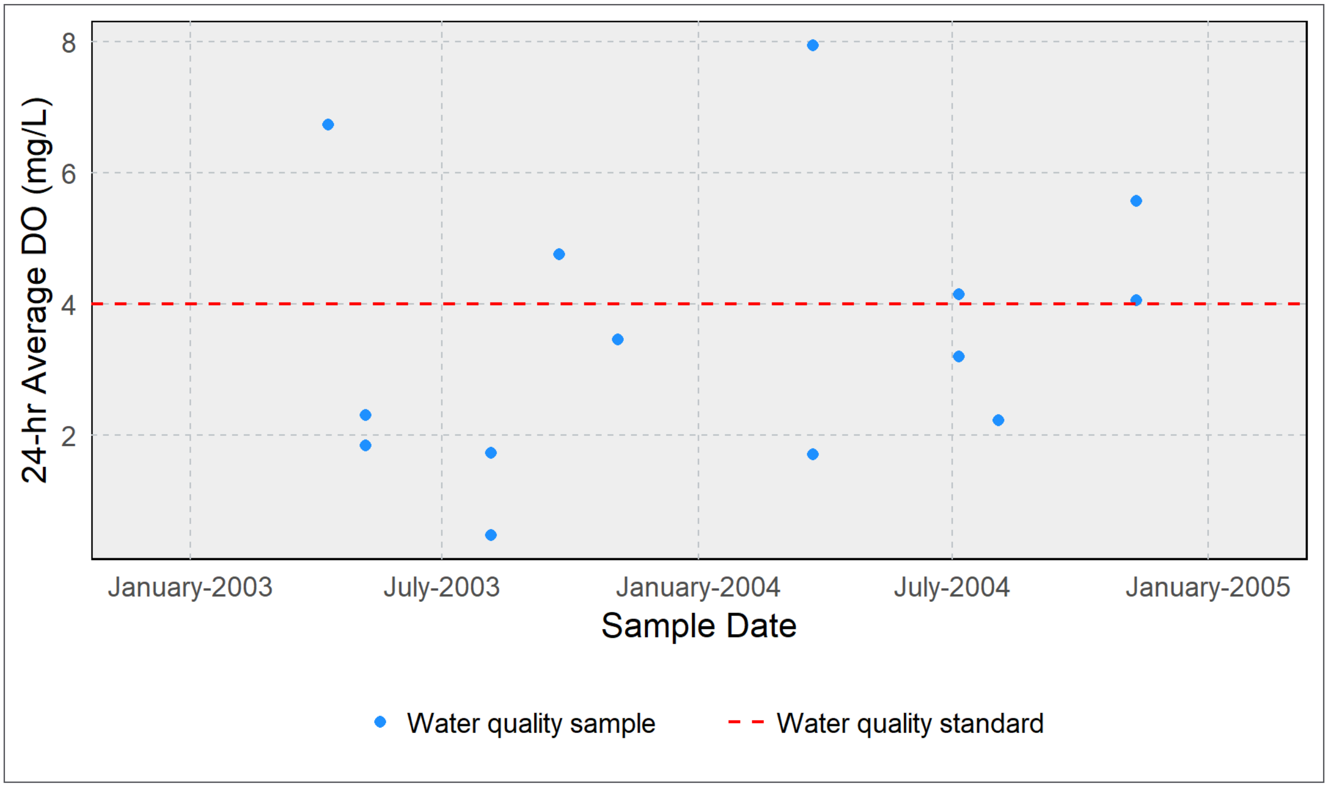


Figure 13. 24-hour (hr) average dissolved oxygen (DO) data collected in West Carancahua Creek.

measured concentrations, most of the samples are well above the 35 MPN/100 mL standard as indicated by the 123.82 MPN/100 mL geometric mean.

Dissolved Oxygen

TCEQ first identified West Carancahua Creek Tidal (AU 2456_01) in the 2006 Texas Water Quality Inventory and 303(d) List for failing to support the designated Aquatic Life Use due to depressed DO. Based on the 2006 assessment, six of twelve 24-hr average DO values (Table 13, Figure 13) fell below 4 mg/L and nine of twelve 24-hr minimum DO values fell below 3 mg/L (Figure 14) established for West Carancahua Creek. West Carancahua Creek Tidal remained on the 2008 and 2010 versions of the Integrated Report based on assessed samples.

24-hr DO sampling has not occurred in West Carancahua Creek Tidal since 2004. Due to the lack of samples for assessment, the DO impairment on West Carancahua Creek Tidal "carried forward" to the 2012 and 2014 versions of the Integrated Report. Additional sampling is needed to assess and possibly delist the water body in the future. This issue is discussed further in Chapter 6 on page 50.

Nutrients

Nutrient standards have not been established in Texas. However, screening levels are set at the 85th percentile for parameters from similar water bodies. If more than 20% of samples from a water body exceed the screening level, that water body is experiencing pollutant concentrations higher than 85% of similar water bodies in Texas and is considered to have an elevated nutrient concentration concern. For Carancahua Bay, the relevant nutrient parameters include nitrate, ammonia, total phosphorus and chlorophyll-a (Table 14).

The 2014 Integrated Report identified screening concerns for total phosphorus and chlorophyll-a in Carancahua Bay (Table 15). There was not enough data to assess West Carancahua Creek; however a screen concern for chlorophyll-a was carried forward to the 2014 Integrated Report.

Summary of Important Water Quality Parameters

Water quality assessments by TCEQ have identified water quality impairments in the Carancahua Bay watershed due to elevated *Enterococci* bacteria and depressed DO. Furthermore, concerns have been identified due to total phosphorus and chlorophyll-a.

Table 14. Nutrient screening criteria for Carancahua Bay water bodies.

Water body	Parameter	Screening Level	Criteria
Carancahua Bay	Ammonia Nitrogen	0.10 mg/L	> 20% exceedance
Carancahua Bay	Nitrate Nitrogen	0.17 mg/L	> 20% exceedance
Carancahua Bay	Total Phosphorus	0.21 mg/L	> 20% exceedance
Carancahua Bay	Chlorophyll-a	11.60 µg/L	> 20% exceedance
West Carancahua Creek	Ammonia Nitrogen	1.10 mg/L	> 20% exceedance
West Carancahua Creek	Nitrate Nitrogen	0.46 mg/L	> 20% exceedance
West Carancahua Creek	Total Phosphorus	0.66 mg/L	> 20% exceedance
West Carancahua Creek	Chlorophyll-a	21.0 µg/L	> 20% exceedance

Milligram, mg; liter, L; microgram, µg

Table 15. 2014 Integrated report summary indicating nutrient level screening concerns in Upper Carancahua Bay and West Carancahua Creek Tidal.

Water Body	Assessment Unit	Parameter	Date Range	Number of Samples Assessed	Number of Exceedances
Carancahua Bay	2456_02	Total Phosphorus	December 1, 2005– November 30, 2012	24	18
Carancahua Bay	2456_02	Chlorophyll-a	December 1, 2005– November 30, 2012	26	23
West Carancahua Creek Tidal	2456A_01	Chlorophyll-a	December 1, 1999– November 30, 2004	-	-

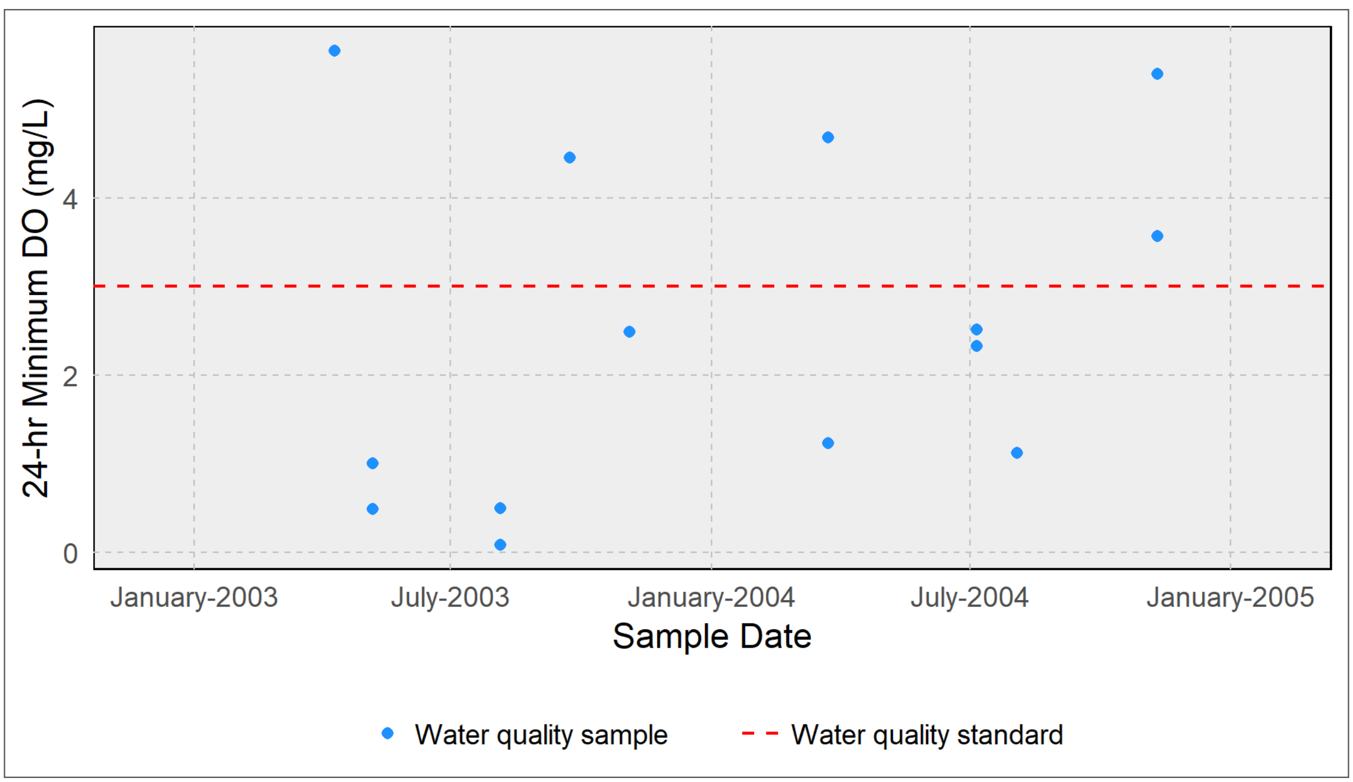


Figure 14. 24-hr minimum dissolved oxygen (DO) data from West Carancahua Creek.

Table 16. Summary of water quality parameters, impacts and potential causes and sources.

Parameter	Impact	Parameter
Chlorophyll-a	• High concentrations typically indicate degraded water quality. • Excessive algal growth can negatively impact water quality, dissolved oxygen and habitat.	• The amount of chlorophyll-a is a function of water clarity, temperature, available nutrients and other ecological factors. • Human sources can include excessive nutrient loads caused by unmanaged runoff, failing septic systems and certain industrial wastes.
Dissolved Oxygen (DO)	• Acceptable ranges of DO are the most important indicator of a water body's ability to support aquatic life.	• Removal of riparian vegetation can increase water temperatures and increase nutrient and sediment runoff leading to decreased DO. • Excessive nutrients, algae and organic matter in water bodies from sediment runoff, over-fertilization and untreated wastewater can lead to decreased DO.
Enterococci	• Excessive *Enterococci* is an indicator of fecal matter contamination, which may contain other pathogens and increase the risk of contracting enteric diseases.	• High numbers of *Enterococci* can indicate the presence of fecal material and associated pathogens in the water body. • *Enterococci* are found in warm-blooded animals and may come from poorly maintained or ineffective septic systems, overflow from domestic wastewater treatment plants and wildlife/pet/ and livestock waste.
Total Phosphorus	• Where it is a limiting nutrient, excessive phosphorus can cause excessive algal growth and depressed DO (known as eutrophication).	• Excess phosphorus can be a result of poorly treated wastewater, residential and agricultural runoff and certain industrial wastes.

As mentioned on pages 21 and 22, *Enterococcus* is a fecal indicator bacteria used to assess the risk of contracting a gastrointestinal illness during recreation in water bodies. The presence of fecal indicator bacteria is associated with fecal contamination of water bodies and the potential presence of pathogens that can cause illness. These indicator bacteria can originate from numerous sources, including humans, livestock, wildlife and pets. Fecal bacteria can enter streams from overland flow that transports livestock, wildlife and pet feces to water bodies. Fecal bacteria can also be transported to streams from failing OSSFs or during wastewater treatment infrastructure overflow events. Summaries of these potential sources are covered in Chapter 2.

DO is measured to evaluate the ability of a water body to sustain aquatic life. When DO levels fall too low, fish and other organisms begin to die off. Natural fluctuations in DO occur daily and seasonally. Over the course of a day, DO increases due to plant photosynthesis (plants consume carbon dioxide and release oxygen). Overnight, DO decreases as both plants and animals respire (consume oxygen and release carbon dioxide). Temperature and tidal fluxes alter expected DO levels as well. Both increased salinity (from incoming tides) and increased temperatures (seasonal water temperature change) decrease the oxygen-holding ability of water and are typically correlated with lower DO concentrations.

Human activities can harm DO levels. Excessive organic matter and nutrients, transported via runoff or directly deposited in streams, results in decreased DO as plant matter and organic matter decomposes. Removal of riparian habitat can result in higher than normal stream temperature and increase the amount of nutrient-laden runoff that enters streams resulting in lower than normal DO.

Eutrophication is the process in which a water body receives excessive nitrogen or phosphorus, resulting in vegetation and algae blooms. Plant and algal blooms produce oxygen during the day, but overnight can consume more DO than is available in the water. Additionally, DO is consumed when plants and algae die and decompose. Potential sources of excessive nutrients can include fertilizers in yard and agricultural runoff, WWTF effluent and failing OSSFs. Chlorophyll-a is the photosynthetic pigment found in plants and algae. Higher than normal levels of chlorophyll-a may result from excessive plant and algae growth and be indicative of eutrophication.

Table 16 summarizes the parameters responsible for water quality impairments and concerns in the Carancahua Bay watershed along with their potential impacts to water and possible sources.

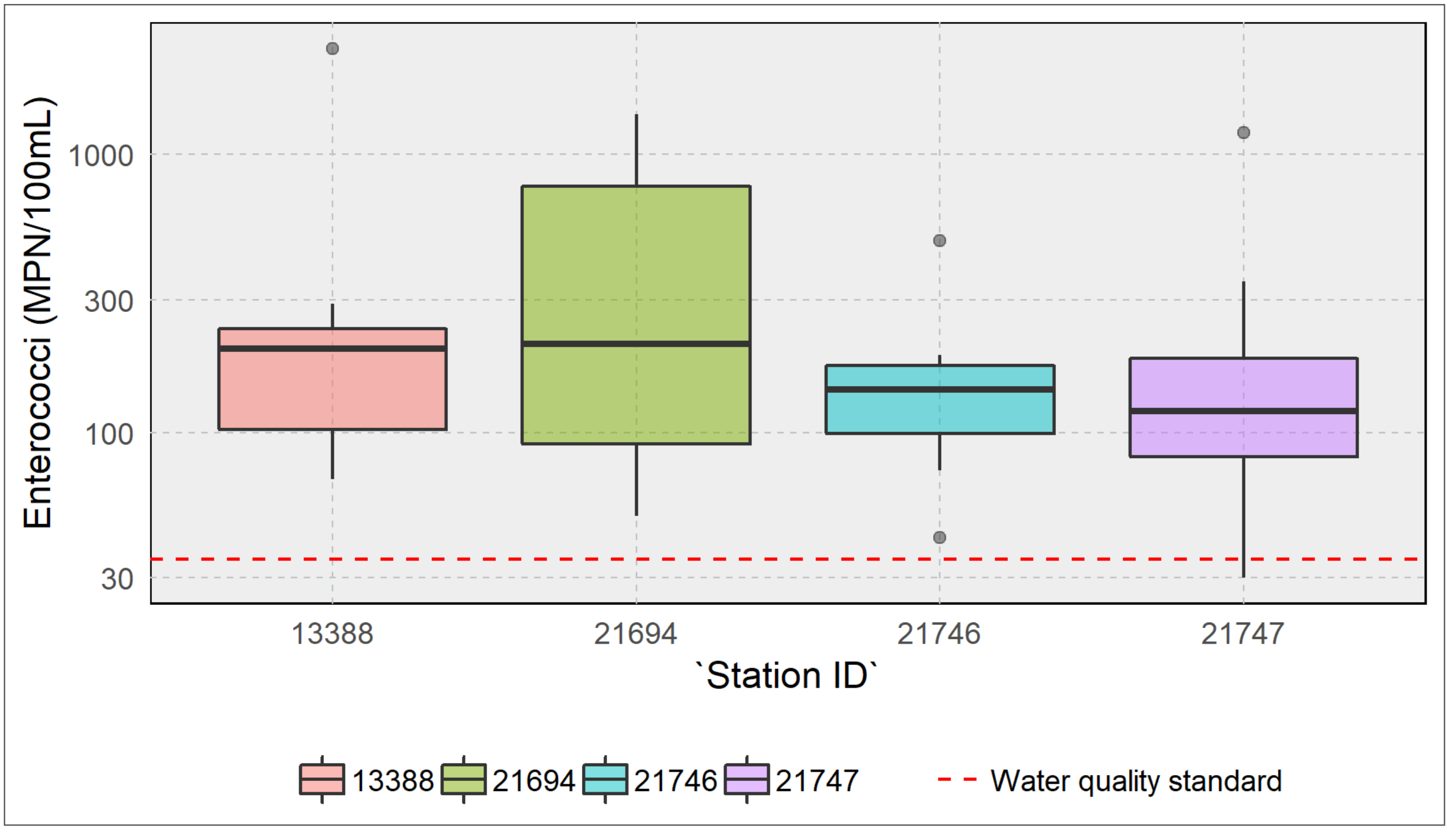


Figure 15. Bacteria sampling results from November 2015 through August 2016.

Recent Water Quality Conditions

Bacteria

The bacteria impairment in Carancahua Bay is based on data collected from December 2005 through November 2012. Since that time, limited water quality sampling has occurred in the Carancahua Bay watershed. To understand if current water quality conditions substantially changed, TWRI conducted additional monthly bacteria sampling at multiple sites within Carancahua Bay from November 2015 through August 2016 (Figure 15).

Figure 15 is a box and whisker plot of bacteria measurements collected from November 2015 through August 2016 by TWRI. Each "box and whisker" depicts a range of information for each sampling site. The ends of each box represent the 25th and 75th percentiles of bacteria concentration values. The solid line in each box represents the median (or middle most value). The whiskers at the end of each box extend to 1.5 times the 25th and 75th percentile values. Any observations beyond the whiskers are typically considered outliers. The individual points on the figure indicate the actual measurement values collected at each sample site. The solid black line near the bottom of the plot indicates the primary contact recreation criterion (35 MPN/100 mL). Nearly all of the sample points at each site are well above the established criterion.

According to this supplemental data, *Enterococci* bacteria levels remain elevated well above the primary contact recreation standard of 35 MPN/100 mL. The geometric mean value for all the stations together was 320.3 MPN/100 mL. For station number 13388, which was used for assessment purposes in the Integrated Report, the geometric mean was 209.8 MPN/100 mL. These elevated bacteria levels substantiate the impairment identified in the 2014 Integrated Report.

Dissolved Oxygen

The aquatic life use impairment in West Carancahua Creek is based on DO data mostly collected in 2003 through 2005. Very limited data collection has occurred in West Carancahua Creek since that time. TWRI collected nine DO grab samples in West Carancahua Creek from November 2015 through August 2016 (Figure 16). Much more sampling is required to adequately assess West Carancahua Creek (sampling ended in August 2016 and it would be useful to have sampling encompassing an entire year). However, it is useful to note that only one sample fell below the 3 mg/L minimum DO criterion.

Table 17. Summary of identified water quality issues in the Carancahua Bay watershed.

Issue	Indicator	Target Value	Importance
Pathogens	*Enterococci* Bacteria	Geometric mean less than 35 MPN/100 mL in Carancahua Bay	Bacterial indicator used to monitor for presence of human/animal waste in water bodies. Can lead to waterborne illness.
Aquatic Life	DO	90% of minimum values greater than 3.0 mg/L and mean 24-hr average values greater than 4.0 mg/L average in West Carancahua Creek	DO is an important measure of aquatic habitat quality and overall aquatic health. Oxygen depletion can indicate undesirable physical, chemical and biological activities.
Eutrophication	Total Phosphorus	80% of measured values less than 0.21 mg/L in Carancahua Bay	Excessive total phosphorus can contribute to excessive plant and algae growth, depressed DO and undesirable conditions.
Eutrophication	Chlorophyll-a	80% of measured values less than 11.6 µg/L in Carancahua Bay and 21 µg/L in West Carancahua Creek	Chlorophyll-a is an indicator of plant and algae mass in a water body contributing to depressed DO and degraded instream habitat.

Most probable number, MPN; milliliter, mL; milligram, mg; liter, L; microgram, µg

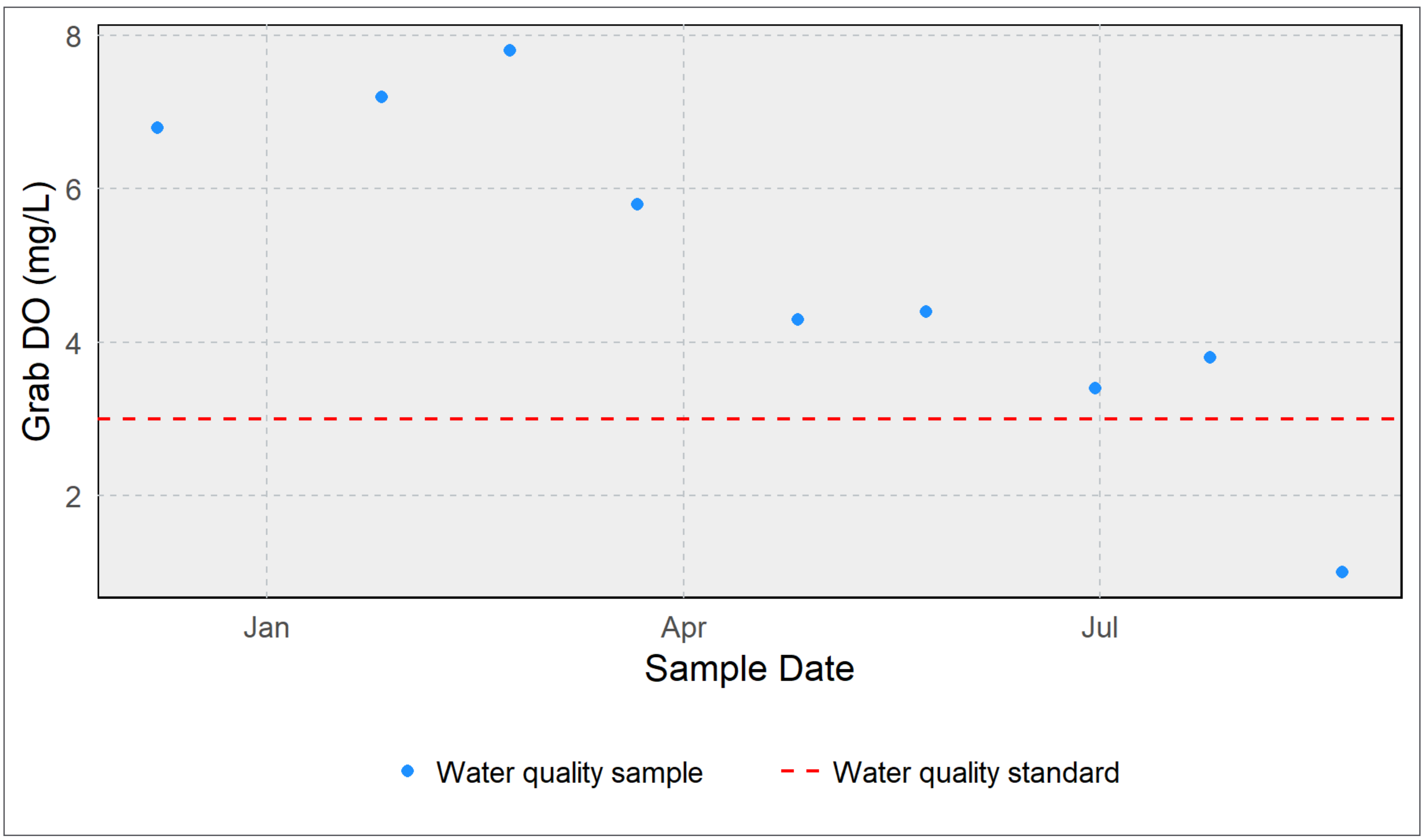


Figure 16. Dissolved oxygen (DO) grab sample results from November 2015 through August 2016.

Nutrients

Ongoing routine water quality sampling in Carancahua Bay does not indicate any substantial changes in nutrient impairments since the 2014 Integrated Report (Figure 17). Recent routine sampling has not occurred in West Carancahua Creek to indicate improvements or degradation in nutrient concentrations.

Summary

Table 17 provides a summary of the identified water quality issues highlighted in this chapter. Based on water quality sampling in Carancahua Bay, elevated *Enterococci* bacteria levels have caused a recreation impairment in Carancahua Bay. The observed elevated levels of this fecal indicator bacte-

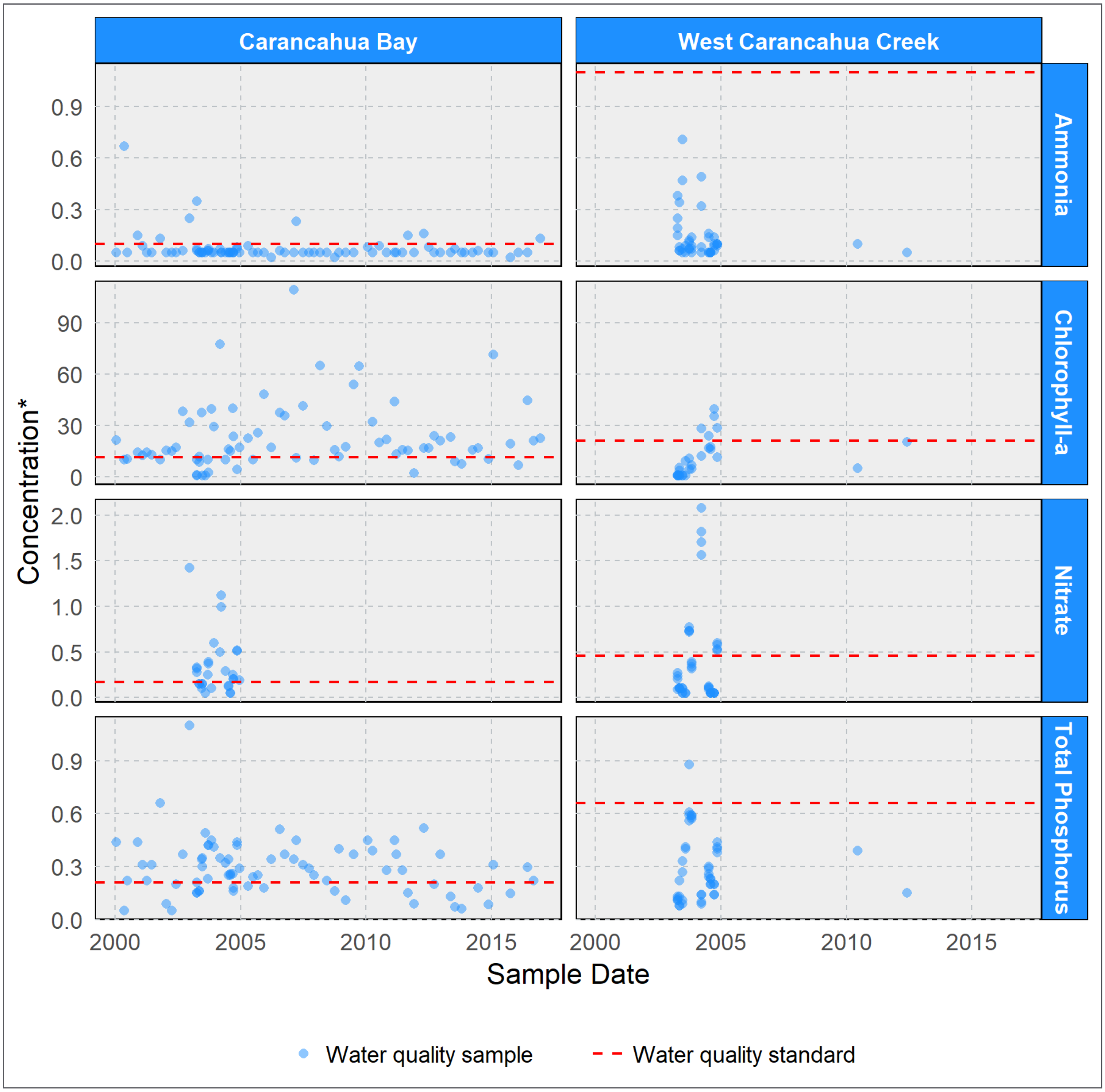
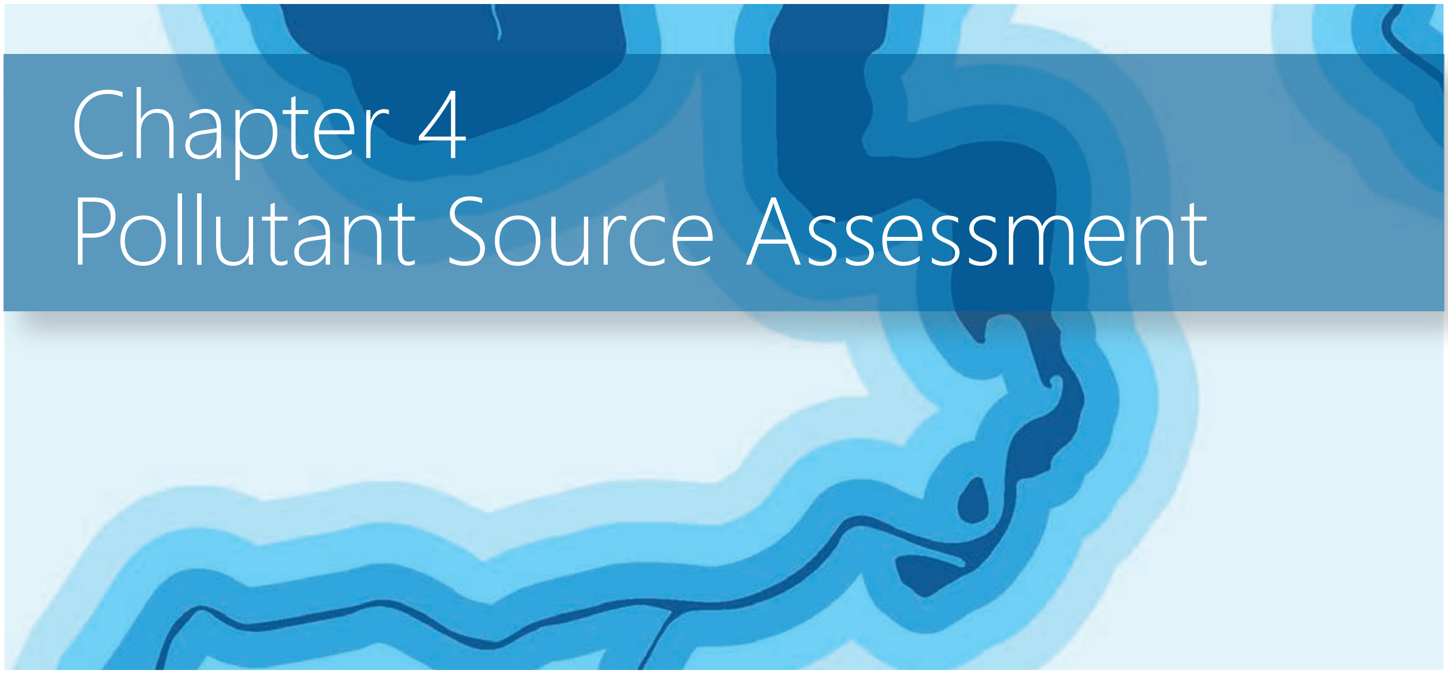


Figure 17. Nutrient sampling data from Carancahua Bay and West Carancahua Creek. *Concentration in units of mg/L for ammonia, nitrate and total phosphorus. Concentration in units of µg/L for chlorophyll-a.

ria are associated with elevated risk for recreational users to contract gastrointestinal illnesses. While the impairment is based on data collected from 2005 through 2012, more recent sampling in the bay substantiates these findings.

The 24-hr DO levels measured in West Carancahua Creek before 2005 indicate that the water body does not meet established aquatic life use standards. Because there has been limited DO monitoring in this water body, further data is required to understand current DO conditions in this water body. However, screening concerns identified for elevated total phosphorus and chlorophyll-a might be indicative of undesirable nutrient conditions that could contribute to depressed DO conditions.

Chapter 4
Pollutant Source Assessment



Introduction

Based on recent and historical water quality sampling, the Upper Carancahua Bay was identified as impaired due to elevated bacteria (See Chapter 3, page 22) and West Carancahua Creek Tidal was identified as impaired due to depressed DO (Chapter 3, page 24). This chapter provides information about the pollutant load reductions required to meet water quality standards and results from spatial analysis of potential bacteria and nutrient sources. This information is critical to prioritize the types and locations of management measures intended to improve and protect water quality.

Load Duration Curve (LDC) Analysis

Bacteria

The relationship between flow and pollutant concentrations can be established using a Load Duration Curve (LDC). This approach allows existing pollutant loads to be calculated and compared to allowable pollutant loads. These comparisons serve as the basis for estimating the load reduction required to meet water quality standards. In 2017, the Texas Institute for Applied Environmental Research in coordination with TWRI and TCEQ, produced a report to provide technical documentation and supporting information for developing the bacteria LDC used in the CBWPP and Carancahua Bay Total Maximum Daily Load (TMDL) (Adams and Hauck 2017).

Chapter 4 Highlights

1. **Bacteria loads need to be reduced by 86% annually to meet water quality standards established for Carancahua Bay.**
2. **Phosphorus loads need to be reduced by 36% annually to meet nutrient screening levels in Carancahua Bay.**

Although LDCs cannot identify specific pollutant sources (urban vs agricultural, etc.), they can identify likely pollutant type (point source vs. NPS). Using the LDC, exceedances occurring under high flow or moist conditions are attributed to NPS. Conversely, exceedances during low flow conditions are attributed to point sources. Detailed information on Carancahua Bay LDC development and interpretation is in Adams and Hauck (2017) and Appendix B.

The Carancahua Bay LDC, shown in Figure 18, shows that bacteria loadings exceeded the allowable pollutant load under all flow conditions. These load exceedances were not restricted to wet weather events. Based on the LDC, we can identify that the most elevated bacteria loads occur under the highest flow conditions and that bacteria loads are below the single sample criterion (104 MPN/100 mL) primarily in mid-range and lower flow conditions. The elevated loadings under low flow conditions are unlikely to be caused by WWTF discharges because of the relatively good compliance history by the La Ward WWTF, the only permitted discharge upstream of the sampling station. The report concludes that other sources of bacteria loadings under low flow conditions are likely contributing bacteria directly to the water, such as direct deposition from wildlife, feral hogs or livestock (Adams and Hauck 2017).

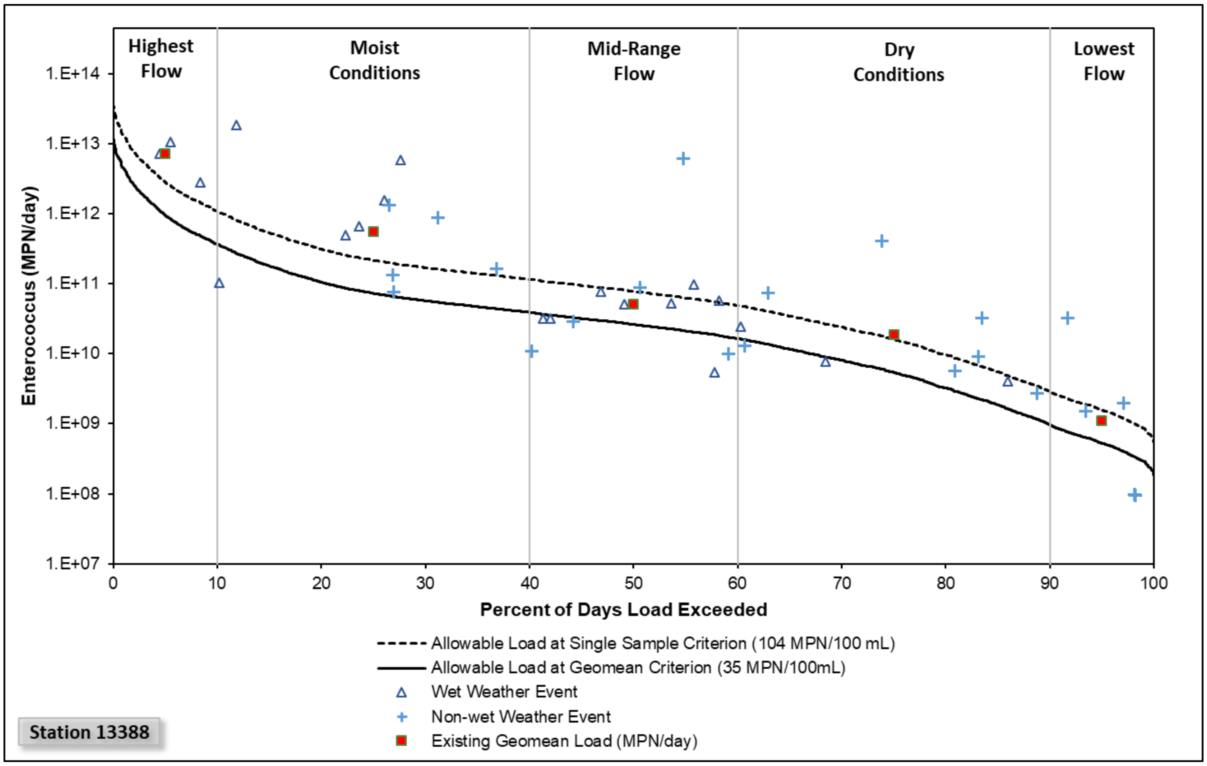


Figure 18. Bacteria Load Duration Curve at Station 13388 on Carancahua Bay for January 1, 2002 through December 31, 2016 (Adams and Hauck 2017).

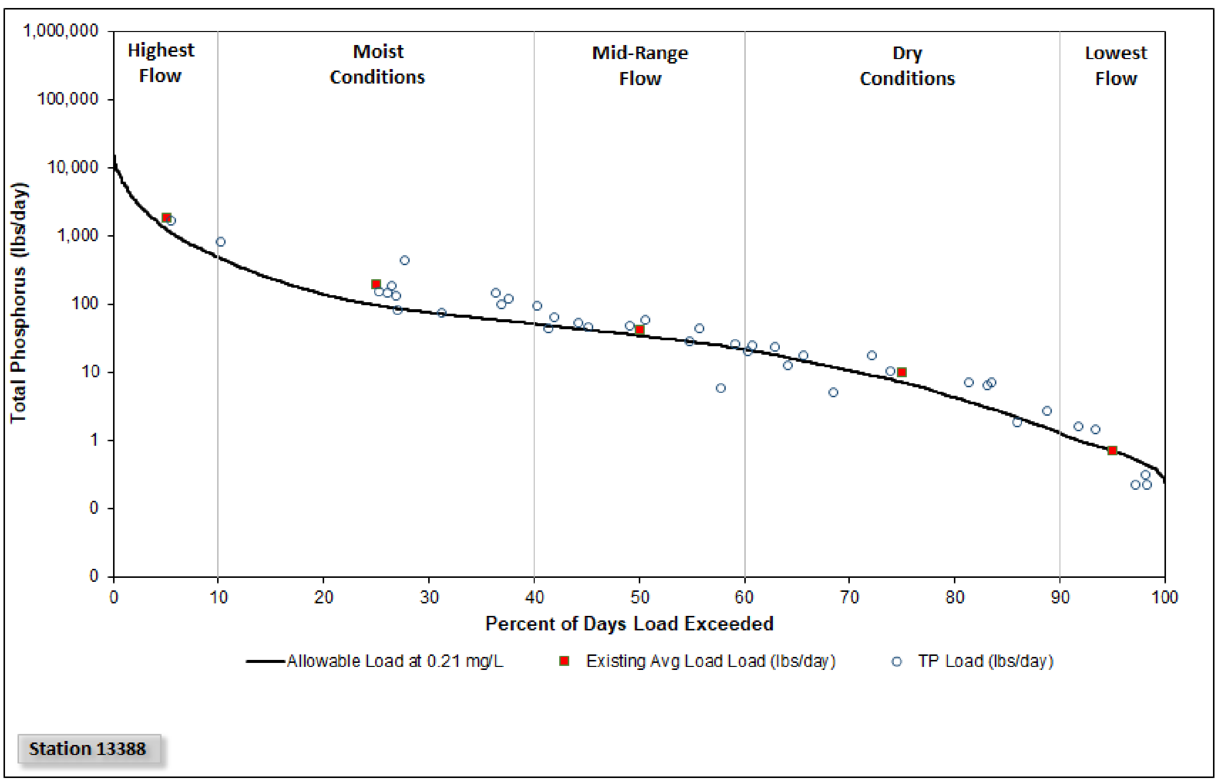


Figure 19. Total Phosphorus Load Duration Curve at Station 13388 on Carancahua Bay for January 1, 2002 through December 31, 2016.

Table 18. Bacteria load reductions required to meet water quality goals in Carancahua Bay.

	Flow Conditions				
	High	Moist	Mid-Range	Dry	Low
Days per year	36.5	109.5	73	109.5	36.5
Median Flow (ft^3/s)[1]	1,106.373	85.056	30.417	6.33	0.612
Existing Geomean Concentration (MPN/100 mL)[1]	268	269	68	122	73
Allowable Daily Load (Billion MPN)	947.387	72.83	26.05	5.42	0.52
Allowable Annual Load (Billion MPN)	34,579.626	7,975.26	1,901.36	593.53	19.13
Existing Daily Load (Billion MPN)	7,254.279	559.78	50.60	18.89	1.09
Existing Annual Load (Billion MPN)	264,452.684	61,295.60	3,694.07	2,068.88	39.90
Annual Load Reduction Needed	229,873.058	53,320.33	1,792.71	1,475.35	20.77
Percent Reduction Needed	86.94%	86.99%	48.53%	71.31%	52.05%
Possible sources	Overland flow Sanitary Sewer Overflows Resuspension				
	Failing or non-existent OSSFs				
		Direct deposition from wildlife, feral hogs, livestock, pets. Illegal dumping			
Total Annual Load (Billion MPN)	331,879.6				
Total Annual Load Reduction (Billion MPN)	286,810.7				
Total Percent Reduction (Billion MPN)	86.4%				

Cubic feet per second, ft3/s; most probable number, MPN; milliliter, mL; on-site sewage facilities, OSSFs

[1] Median flow and geomean concentrations based on data used in Adams and Hauck (2017).

For planning purposes, the loading reductions needed to achieve water quality standards are estimated from the LDC. The total annual load reductions identified in the CBWPP are based on the bacteria exceedances identified at station 13388 in Carancahua Bay. Table 18 lists annual reductions, by flow category and total annual load, required to meet the goal of meeting water quality standards in Carancahua Bay. Based on meeting a 35 MPN/100 mL criterion for *Enterococci* bacteria, total annual loads in Carancahua Bay must be reduced by 286,810.7 billion MPN per year. This equates to approximately an 86% reduction annually in bacteria loads entering Carancahua Bay. Appendix C details the calculations used to develop annual load reduction estimates.

Nutrients

The modified LDC approach was also applied to total phosphorus samples collected in Carancahua Bay (Figure 19) using the estimated flows derived in the modified LDC approach detailed in Appendix B. The LDC indicates total phosphorus loads typically exceed the allowable load at the current 0.21 mg/L screening criterion across most of the flow range. The load estimate during the highest flow events is based on a single sample and must be interpreted with caution; more samples are required to properly characterize the highest flow regime. Table 19 provides the estimated load reductions to meet screening level criteria for total phosphorus.

Table 19. Total phosphorus load reductions required to meet nutrient screening levels in Carancahua Bay.

	Flow Conditions				
	High	**Moist**	**Mid-Range**	**Dry**	**Low**
Days per year	36.5	109.5	73	109.5	36.5
Median Flow (ft^3/s)[1]	1,106.373	85.056	30.417	6.33	0.612
Existing Average Concentration (mg/L)	0.31	0.42	0.26	0.30	0.21
Allowable Daily Load (lbs/day)	1,253.18	96.34	34.45	7.17	0.69
Allowable Annual Load (lbs/year)	45,740.97	10,549.46	2,515.07	785.11	25.30
Existing Daily Load (lbs/day)	1,849.93	194.77	42.81	10.09	0.70
Existing Annual Load (lbs/year)	67,522.39	21,327.25	3,124.79	1,104.61	25.54
Annual Load Reduction Needed (lbs)	21,781.42	10,777.80	609.71	319.51	0.24
Percent Reduction Needed	32.26%	50.54%	19.51%	28.92%	<1%
Possible sources	Overland flow Sanitary Sewer Overflows Resuspension				
	Failing or non-existent OSSFs				
		Direct deposition from wildlife, feral hogs, livestock, pets. Illegal dumping			
Total Annual Load (lbs)	93,104.58				
Total Annual Load Reduction (lbs)	33,488.68				
Total Percent Reduction	35.97				

Cubic feet per second, ft3/s; milligram, mg; liter, L; pounds, lbs; on-site sewage facilities, OSSFs

[1] Median flow based on data used in Adams and Hauck (2017).

Spatially Explicit Load Enrichment Calculation Tool (SELECT)

To aid in identifying potential areas of bacteria contributions within the watershed, we employed the Spatially Explicit Load Enrichment Calculation Tool (SELECT) (Borel et al. 2012). SELECT utilizes the best available information combined with stakeholder input to estimate potential pollutant loadings based on livestock population estimates, land cover, housing and population density, OSSF locations and other available data. SELECT can be thought of as depicting the worst-case pollutant loading scenarios that can be used to identify areas to prioritize pollution prevention efforts and management.

SELECT was applied to cattle (Figure 20), horses (Figure 21), goats (Figure 22), feral hogs (Figure 23), deer (Figure 24), dogs (Figure 25), cats (Figure 26), OSSFs (Figure 27) and the maximum permitted WWTP discharges (Figure 28). Total potential bacteria loads in subwatersheds ranged from 2.58×1012 colony forming units (cfu) per day to 9.65×1012 cfu/day (Figure 29). Subwatersheds 1, 2 and 6 have the highest potential for bacteria loads when accounting for all sources.

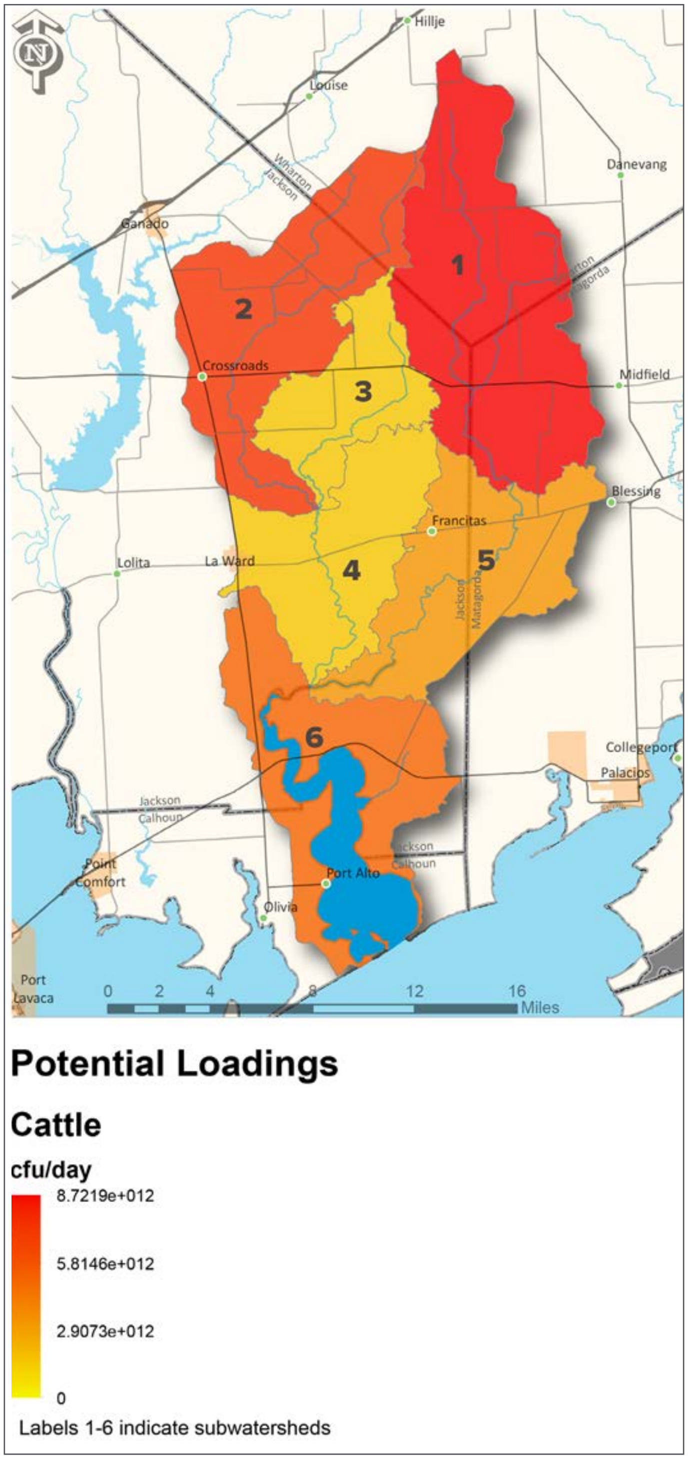


Figure 20. Total potential loading attributed to cattle estimated by SELECT.

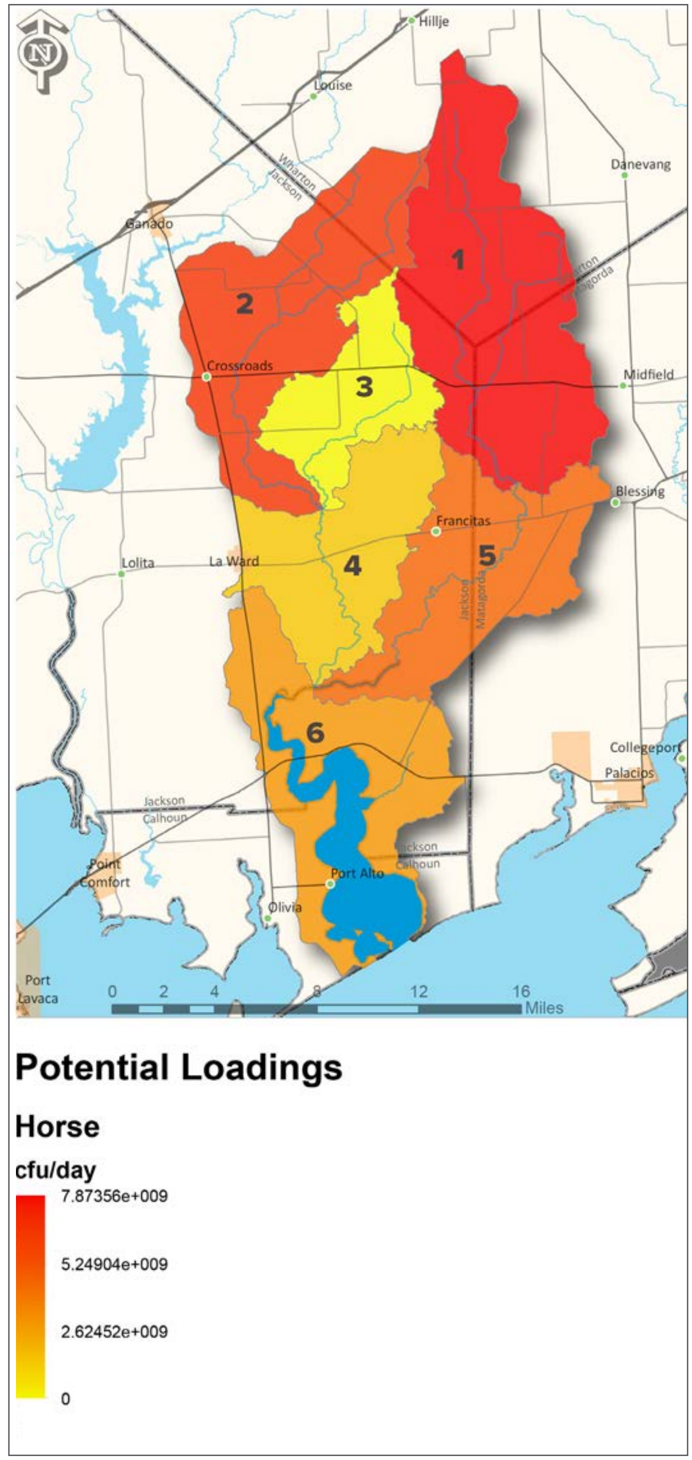


Figure 21. Total potential loading attributed to horses estimated by SELECT.

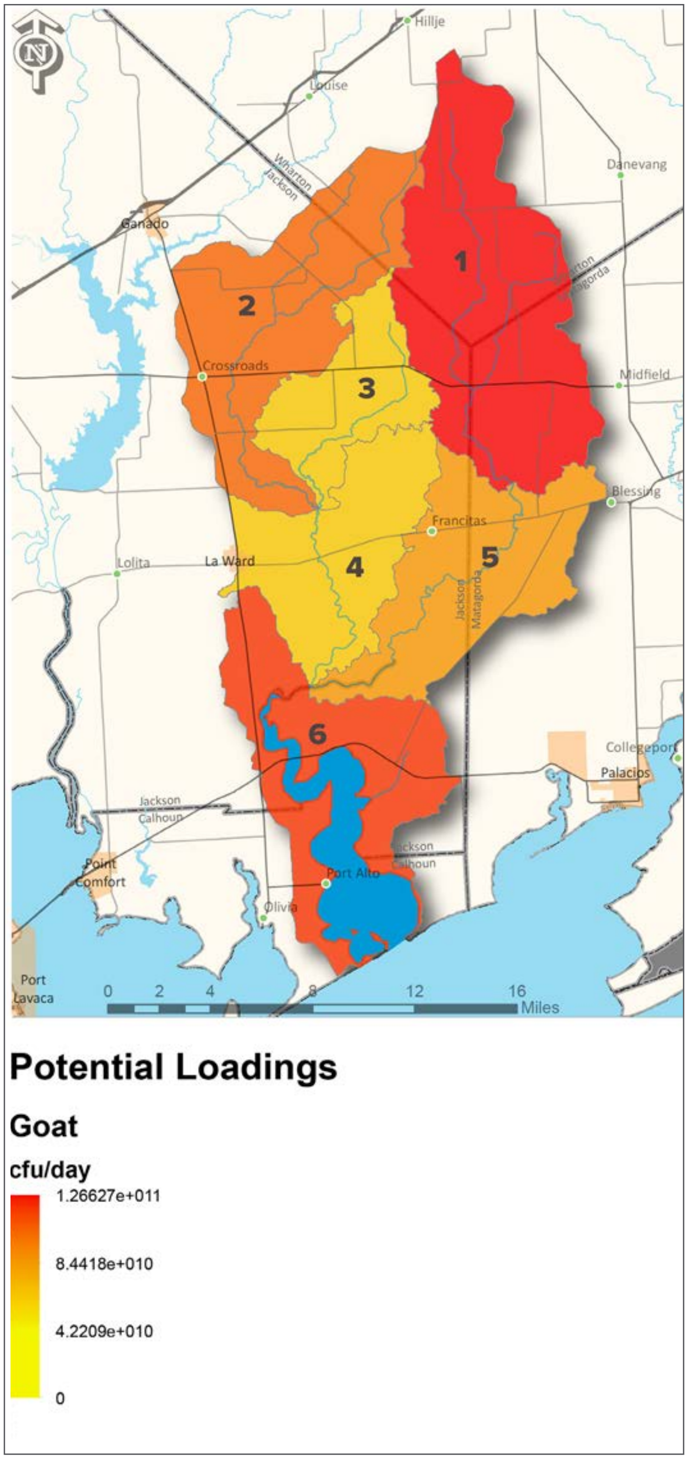


Figure 22. Total potential loading attributed to goats estimated by SELECT.

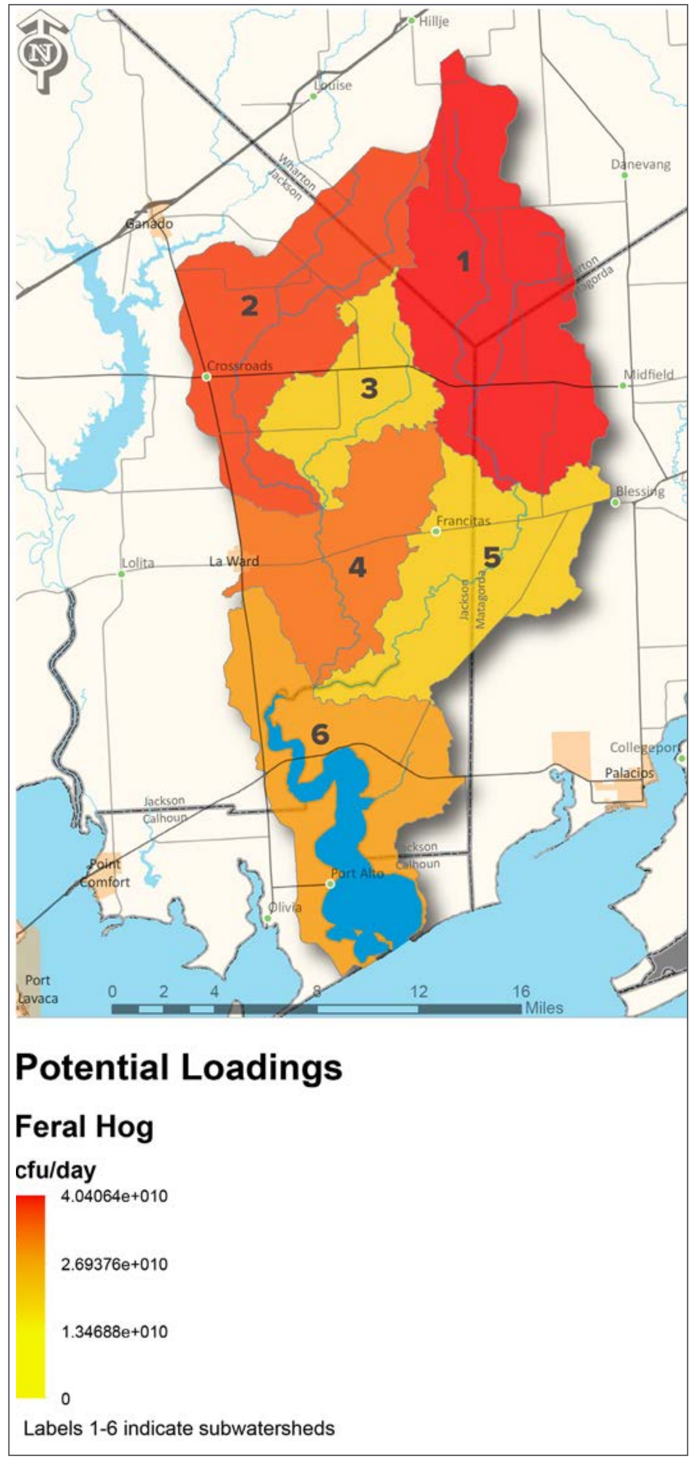


Figure 23. Total potential loading attributed to feral hogs estimated by SELECT.

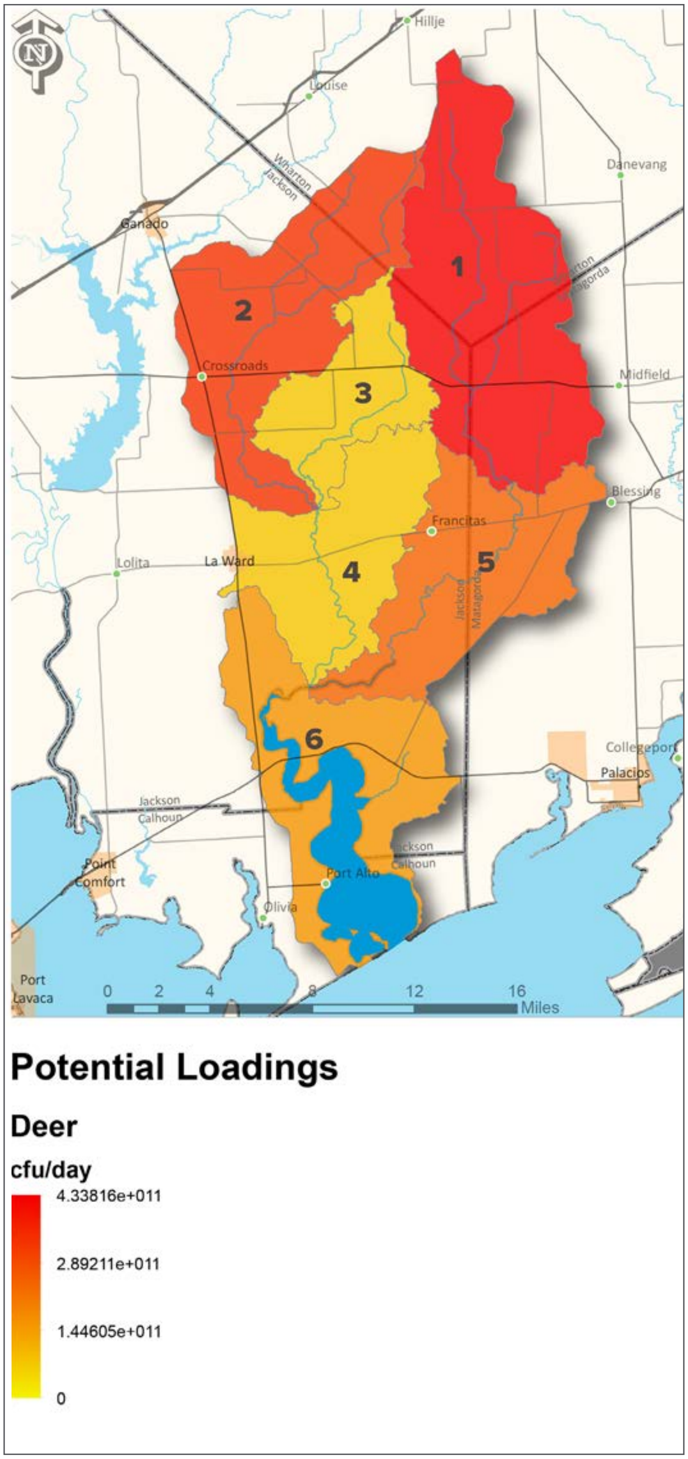


Figure 24. Total potential loading attributed to deer estimated by SELECT.

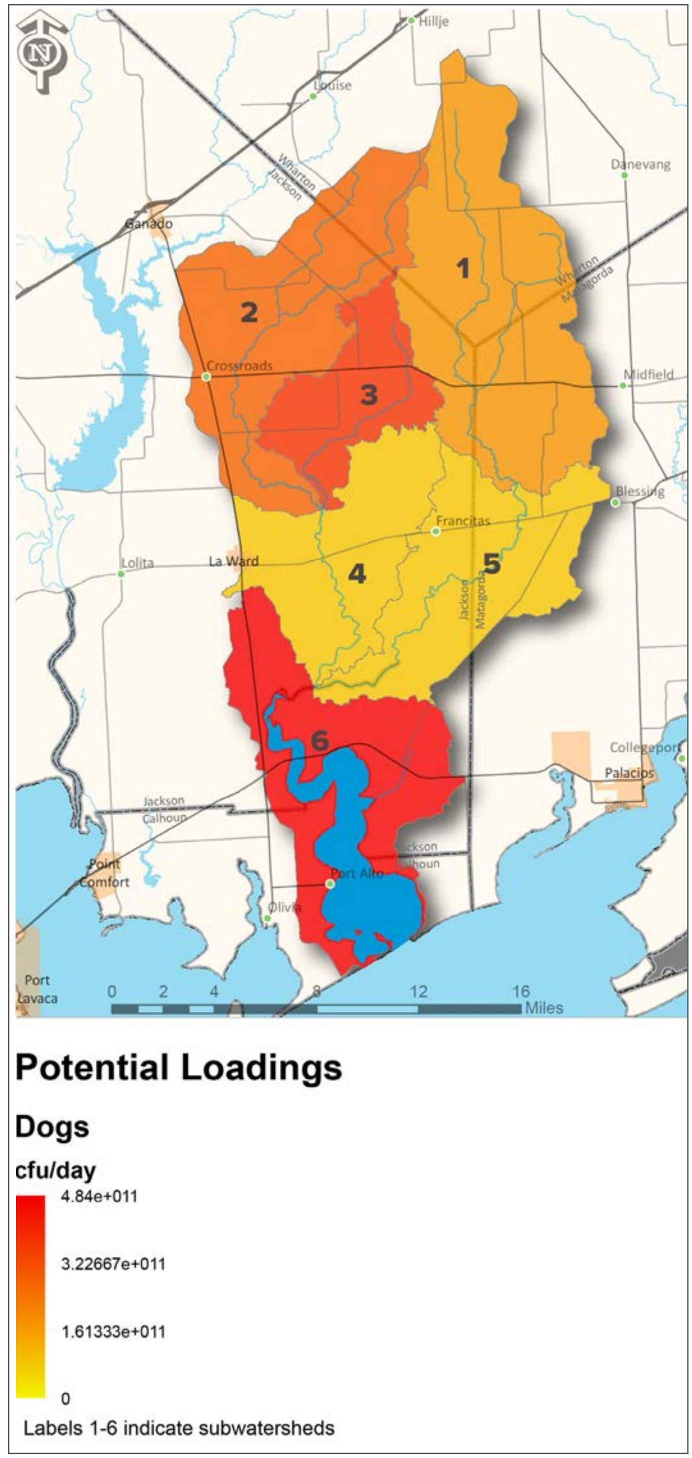


Figure 25. Total potential loading attributed to dogs estimated by SELECT.

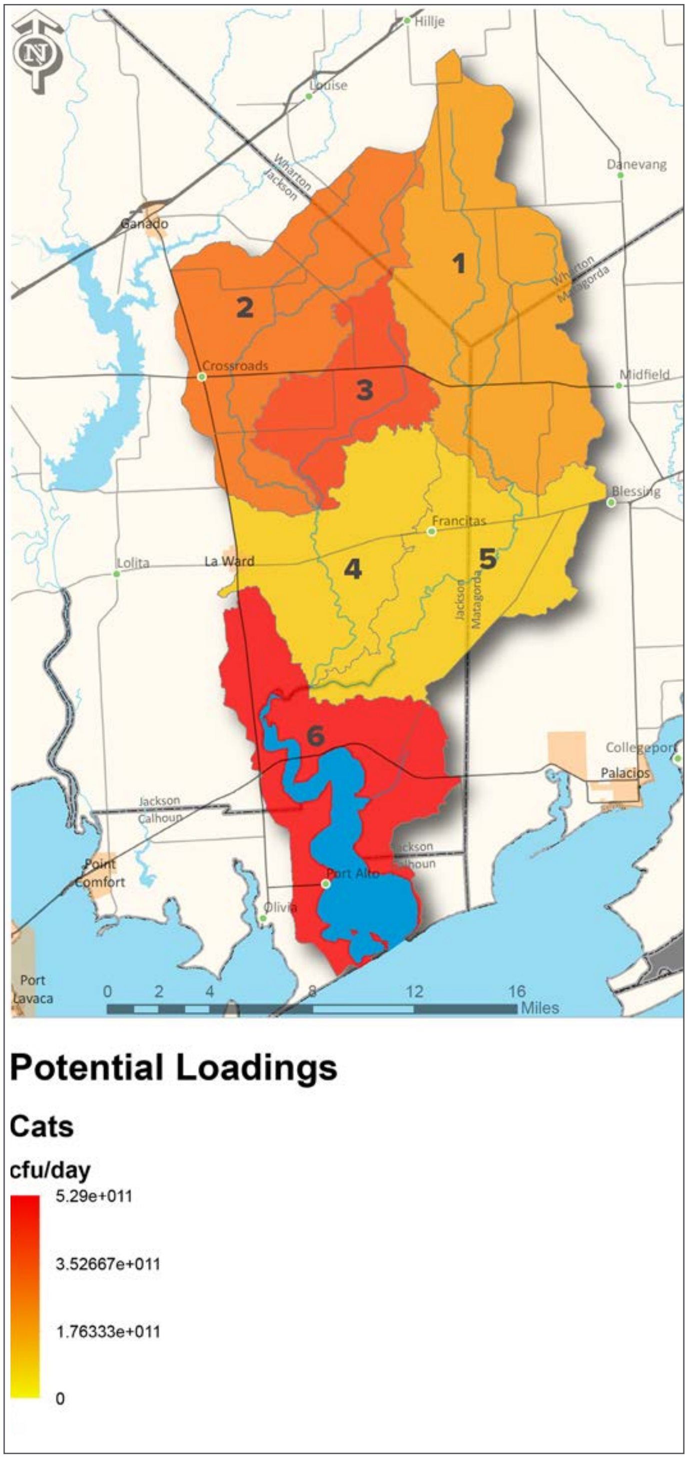


Figure 26. Total potential loading attributed to cats estimated by SELECT.

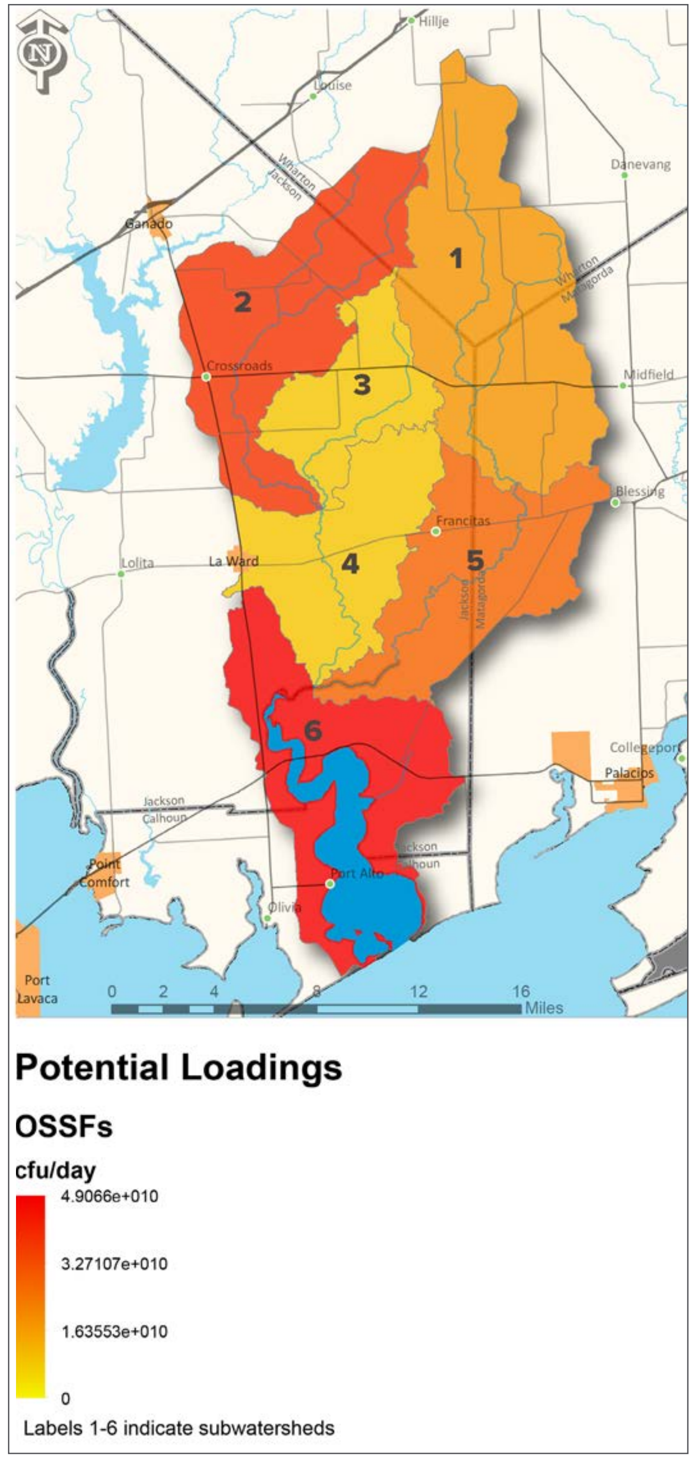


Figure 27. Total potential loading attributed to OSSFs estimated by SELECT.

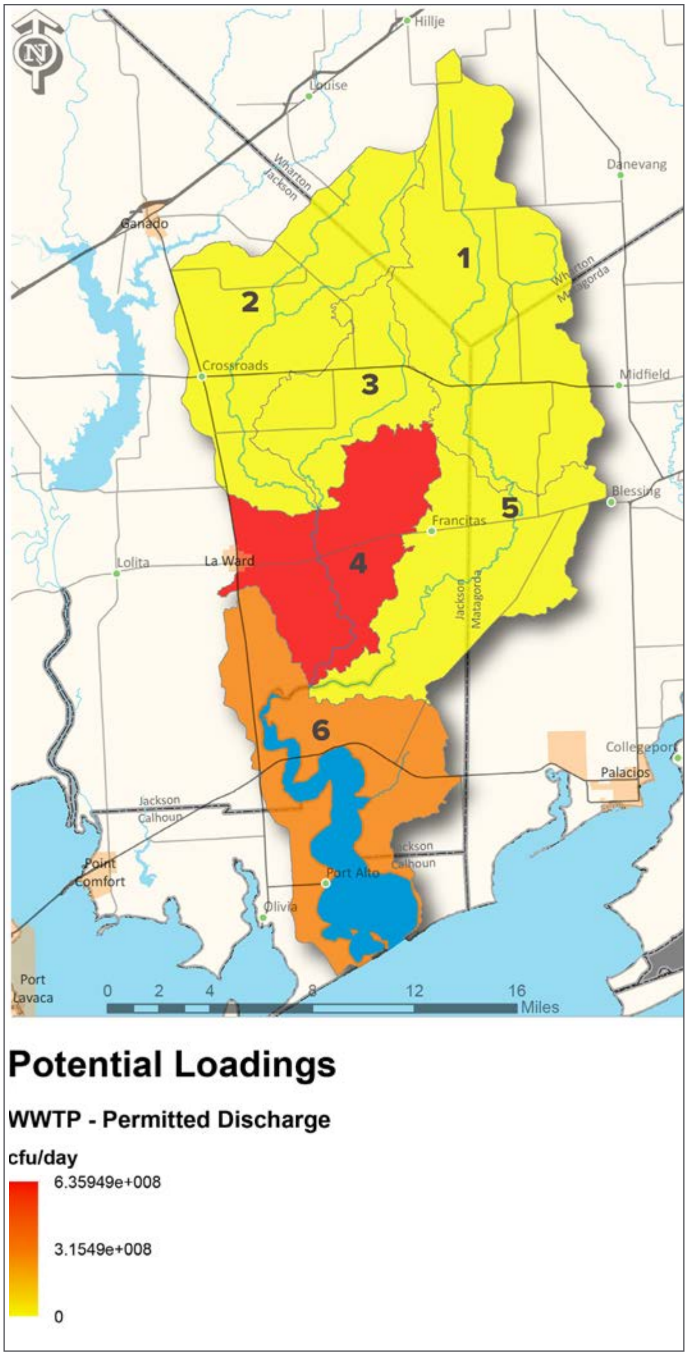


Figure 28. Total potential loading attributed to maximum permitted WWTP discharges estimated by SELECT.

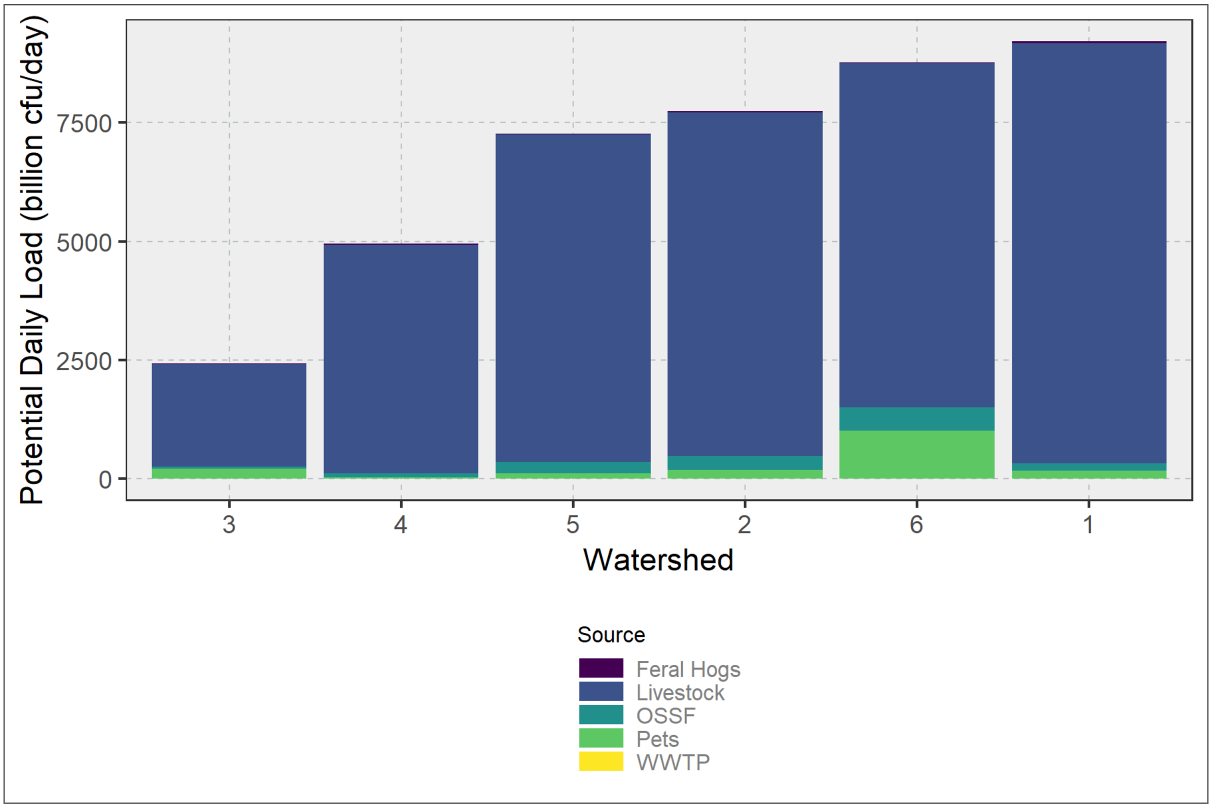
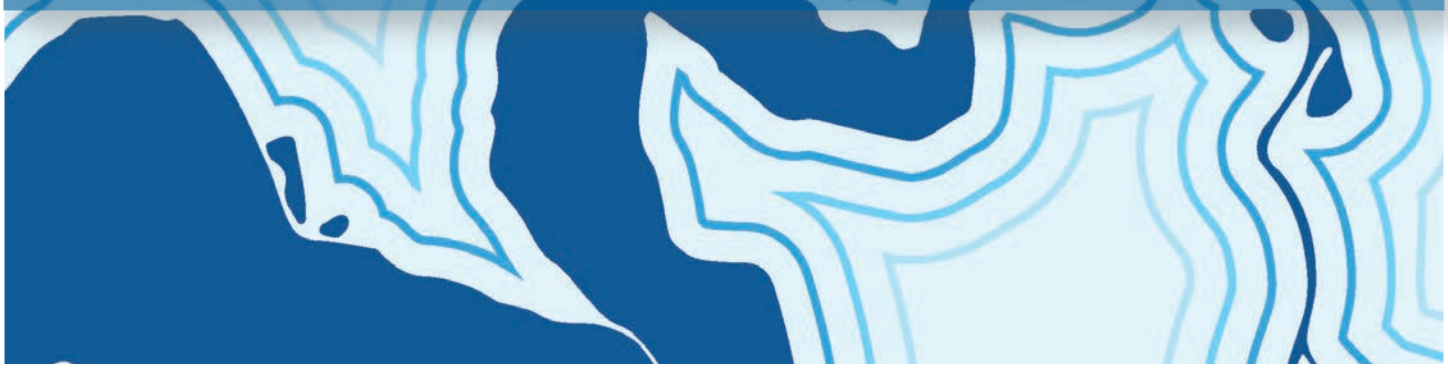


Figure 29. Total potential bacteria loadings by source and subwatershed.

Chapter 5
Implementation Strategies



Introduction

Stakeholders identified and recommended management measures to achieve *Enterococci* bacteria and nutrient reductions. These management measures are based on the current understanding and knowledge of management effectiveness, feasibility and local acceptance. We anticipate that managing sources of fecal bacteria will result in direct reductions of bacteria loads reaching local water bodies. We also anticipate that managing nutrient sources will contribute to potential increases in DO. However, we note that the linkage between decreased nutrient loadings and increased DO is more tenuous. Many other factors influence DO concentration (for example, temperature, salinity and flow). Much more data and resources are required to understand the DO dynamics specific to this tidal system. However, it is likely that the management measures outlined in this chapter include benefits to both bacteria and DO in most cases.

A variety of sources contribute bacteria and nutrients to Carancahua Bay. Therefore, an approach that addresses the diversity of sources is recommended to addresses pollutant loads. The approach outlined in the CBWPP focuses on the contributions that are most feasibly managed, have a chance to be locally accepted and are most likely to reduce instream pollutant loads. Because stakeholders are ultimately responsible for the deployment of these voluntary management measures, stakeholder recommendations were critical and indicate a greater degree of feasibility and willingness to implement.

Priority areas for each management measure were identified using the SELECT results (Chapter 4). By focusing efforts in priority areas, the effectiveness and efficiency of deployed resources will be maximized. Load reductions resulting from each management measure were calculated where possible to guide stakeholders in the understanding of the number of management measures and length of time it may take to see quantifiable improvements in water quality.

Chapter 5 Highlights

1. **The CBWPP identifies seven management measure that will achieve pollutant reductions needed to meet water quality standards.**
2. **These voluntary management measures will address bacteria and nutrient loading by reducing runoff from agricultural land, reducing septic system failure, controlling feral hog populations, reducing unmanaged pet waste and restoring oyster populations.**

Table 20. Available best management practices for producers to improve water quality.

Practice	NRCS Code	Focus Area or Benefit
Brush Management	314	Livestock, water quality, water quantity, wildlife
Fencing	382	Livestock, water quality
Filter Strips	393	Livestock, water quality, wildlife
Grade Stabilization Structures	410	Water quality
Grazing Land Mechanical Treatment	548	Livestock, water quality, wildlife
Heavy Use Area Protection	562	Livestock, water quantity, water quality
Pond	378	Livestock, water quantity, water quality, wildlife
Prescribed Burning	338	Livestock, water quality, wildlife
Prescribed Grazing	528	Livestock, water quality, wildlife
Range/Pasture Planting	550/512	Livestock, water quality, wildlife
Shade Structure	N/A	Livestock, water quality, wildlife
Stream Crossing	578	Livestock, water quality
Supplemental Feed Location	N/A	Livestock, water quality
Water Well	642	Livestock, water quantity, wildlife
Watering Facility	614	Livestock, water quantity

Management Measures

Management Measure 1: Promote and implement water quality management plans (WQMPs) or conservation plans

Bacteria loadings from grazed lands in the Carancahua Bay watershed are likely to be relatively high compared to other evaluated sources. While the fate and transport of fecal bacteria deposited on upland surfaces is not always certain, livestock may spend substantial time in and around water bodies resulting in direct impacts on water quality. Importantly, livestock grazing behavior can be modified through food, shelter, fencing and water availability. Modifying the time spent by livestock in riparian pastures through rotational grazing, alternative water supplies, shade structures and supplemental feeding can directly reduce potential bacteria loads reaching nearby water bodies. Additionally, these practices can improve livestock health and productivity.

NRCS and TSSWCB give technical and financial assistance to producers for planning and implementing best management practices (BMPs) that protect and improve water quality. NRCS offers a variety of programs to implement operation specific conservation plans that will meet producer goals and outline how BMPs will be implemented. TSSWCB, through local soil and water conservation districts (SWCDs), gives technical and financial assistance to develop and implement water quality management plans (WQMPs) through planning, implementation and maintenance of each practice.

Promoting and implementing WQMPs and conservation plans is anticipated to provide direct benefits to water quality and can provide benefits to producers. A variety of BMPs are available to achieve goals of improving forage quality, distributing livestock across a property and making water available to livestock. Table 20 provides a list of common practices available to producers. However, the practices available to producers are not limited to those in the table. The actual practices will vary by operation and should be determined through assistance from NRCS, TSSWCB and local SWCDs as appropriate.

This management measure will develop and implement 70 conservation plans or WQMPs that include practices that benefit water quality. To support this management measure, a field technician will be hired to assist producers with developing plans. Furthermore, the CBWPP recommends the development and delivery of outreach materials to inform landowners and promote participation.

There is reasonable support by stakeholders in the benefits and effectiveness of this management measure. Currently, 24 operations in the watershed, covering 5,277 ac, have WQMPs. However, the costs of implementing practices and committing to maintain practices are anticipated barriers that might prevent producers from participating in these programs. Fortunately, several programs are available to provide cost share and other assistance for participation. Increasing awareness of availability and the benefits of these programs will be critical to increase adoption. Table 21 provides a summary of the management measure.

Table 21. Summary of management measure 1: Promote and implement water quality management plans or conservation plans.

Source: Livestock and agricultural runoff			
Problem: Fecal bacteria and nutrient loading from livestock (direct and indirect loading) and agricultural runoff.			
Objectives: • Develop and implement property specific conservation plans or WQMPs that include conservation practices to reduce bacteria and nutrient loadings in the watershed. • Provide technical and financial support to producers to develop and implement plans. • Develop and provide education and outreach materials and programs to landowners and producers.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
TSSWCB, NRCS, SWCD	Fund and hire field technician to develop conservation plans or WQMPs.	2020–2030	$75,000 per year
Landowners, TSSWCB, NRCS, SWCD	Develop and implement 70 conservation plans or WQMPs.	2020–2030	$15,000 per plan
Watershed coordinator, AgriLife Extension	Provide outreach materials and agricultural education for landowners.	2020–2030	N/A
Priority Areas: Subwatersheds 1 and 2; All riparian properties			
Estimated Load Reduction			
3.75×10^{14} MPN/year *Enterococcus*† 6.80×10^{4} lbs of nitrogen per year† 3.58×10^{4} lbs of phosphorous per year†			
Effectiveness	Medium/High: Conservation practices result in substantial reductions in edge-of-field bacteria and nutrient reductions. These edge-of-field reductions can, but do not always, translate to watershed-wide load reductions.		
Certainty	Medium: Stakeholders acknowledge the importance of land stewardship practices. However, producers can be reluctant to implement new practices for many reasons (examples: costs, reluctance to enter into contracts with agencies, hesitancy about trying new practices).		
Commitment	Medium: Landowners are willing to implement stewardship practices shown to improve productivity; however, because costs are often prohibitive, financial incentives are needed to increase implementation rates.		
Resource Needs	High: Implementation will not occur without financial assistance programs. Educating landowners about conservation practices, available programs and the benefits of conservation practices is required to increase adoption of needed practices.		
Potential Funding Sources	EPA Clean Water Act §319 grant program; NRCS Environmental Quality Incentives Program; Conservation Innovation Grants; Conservation Stewardship Program; Regional Conservation Partnership Program‡		

Texas State Soil and Water Conservation Board, TSSWCB; Natural Resources Conservation Service, NRCS; soil and water conservation district, SWCD; most probable number, MPN; pounds, lbs; United States Environmental Protection Agency, EPA

† Load reduction calculations described in Appendix E and Appendix F.

‡ Funding sources described in Chapter 7.

Management Measure 2: Increase soil testing on agricultural lands

AgriLife Extension offers soil testing services to producers and property owners to encourage proper nutrient management in both agricultural and urban areas. Nutrient management ensures proper volumes and ratios of fertilizers and nutrients are applied to fields and yards. When excess nutrients are applied, rainfall events and runoff can load water bodies with nutrients causing excess plant growth, algal blooms organic material accumulation and ultimately contribute to depressed DO levels.

The Soil Testing Lab at Texas A&M offers soil tests for $10 per sample, with bags and forms available at AgriLife Extension offices. The CBWPP will promote and recommend that all producers use nutrient management and take advantage of soil testing to ensure proper amounts and ratios of nutrients are applied. To increase landowner participation, the

Table 22. Summary of management measure 2: Increase soil testing on agricultural lands.

Source: Pastures and row crop fields			
Problem: Nutrient loadings pastures and row crop fields.			
Objectives: • Increase the number of producers testing fields for nutrients. • Reduce the amount of excess nitrogen and phosphorus applied to fields. • Develop and initiate a soil testing campaign.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
Landowners, producers, lessees	Soil-testing	2020–2030	$10 per sample (each sample covers 20 acres)
AgriLife Extension, NRCS, TSSWCB, SWCDs, watershed coordinator	Develop soil testing campaign	2019–2029	$78,252 (covers 156,505 acres of pasture and row crops)
Priority Areas: Subwatersheds 1 and 2; all riparian properties			
Estimated Load Reduction			
Load reductions were not calculated for this management measure.			
Effectiveness	Medium/High: Producers provided with detailed information about soil conditions can directly reduce the amount of nutrients applied before the growing season. This translates to direct nutrient load reductions in catchments.		
Certainty	Medium: Participation in programs can be uncertain and producers will take convincing. However, because testing can result in direct costs savings, participation is more likely than some other practices.		
Commitment	Medium: Landowners are generally willing to commit to practices that save money and maintain productivity.		
Resource Needs	Medium: Cost to landowners can range from low to high, depending on operation size and the number of soil samples they need to submit. Costs associated with a watershed-wide campaign can be substantial and more than local entities are able to pick up alone.		
Potential Funding Sources	EPA Clean Water Act §319(h) grant program; NRCS Environmental Quality Incentives Program; Conservation Innovation Grants; Conservation Stewardship Program; Regional Conservation Partnership Program‡.		

Texas State Soil and Water Conservation Board, TSSWCB; Natural Resources Conservation Service, NRCS; soil and water conservation district, SWCD; most probable number, MPN; pounds, lbs; United States Environmental Protection Agency, EPA

‡ Funding sources described in Chapter 7.

CBWPP also recommends a soil testing campaign that offers free soil tests and educates participants about results.

Load reductions from this management measure are highly dependent on how and when producers apply fertilizers. This information is not currently available and potential nutrient load reductions were not estimated. However, stakeholders agreed that this is an important management measure for all producers to participate in. Table 22 provides a summary of the management measure.

Management Measure 3: Repair and replace failing OSSFs

Analysis indicted that OSSFs are likely a moderate contributor to potential bacterial loadings across the watershed. Nearly all the soils in the watershed are classified as "very limited" for OSSF suitability. This indicates that conventional septic tank systems are not suitable for proper treatment of household wastewater. In these areas, advanced treatment systems, most commonly aerobic treatment units, are suitable alternative options for wastewater treatment. While advanced treatment systems are highly effective, the operation and maintenance needs for these systems are rigorous compared to conventional OSSFs. Limited awareness and lack of maintenance can lead to system failures.

Failing or non-existent OSSFs were a concern raised by stakeholders. The exact number of failing systems is unknown, but literature rates estimate that approximately

Table 23. Summary of management measure 3: Repair and replace failing OSSFs.

Source: Failing OSSFs			
Problem: Pollutant loading from failing or nonexistent OSSFs.			
Objectives: • Secure funding to promote OSSF repairs/replacements. • Repair or replace 42 OSSFs as funding allows.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
County staff, designated representatives, AgriLife Extension	Administer OSSF repair/replacement program to address deficient systems identified during inspections.	2019–2029	Repair $5,000/OSSF Replace $10,000/OSSF
Homeowners and contractors	Repair/replace OSSFs as funding allows.	2019–2029	$7,500 per system (est.)
Priority Areas: Subwatersheds 6 and 2.			
Estimated Load Reduction			
9.67×10^{12} MPN/year *Enterococcus* 4.87×10^{2} lbs of nitrogen per year 1.22×10^{2} lbs of phosphorous per year			
Effectiveness	High: Replacement or repair of failing OSSFs will yield direct bacteria and nutrient load reductions to the waterways and near waterway areas of the watershed.		
Certainty	Low: Funding available to identify, inspect and repair or replace OSSFs is limited; thus, the actual level of implementation attainable is uncertain.		
Commitment	Moderate: Watershed stakeholders acknowledge failing OSSFs as a potential source of pollutant loading. However, lack of resources to address the issue prevents high levels of commitment.		
Resource Needs	High: Funding to identify, inspect and repair/replace OSSFs is limited. Costs to administer a program, identify, inspect and repair or replace OSSFs are considerable. Many homeowners may not realize that their OSSF is failing, so delivering educational resources to them is critical. Some homeowners may know they need a new OSSF but may not have the funds available to acquire one.		
Potential Funding Sources	EPA Clean Water Act §319(h) grant program; Texas Supplemental Environmental Projects; local funds, property owners‡		

On-site sewage facility, OSSF; most probable number, MPN; pounds, lbs; United States Environmental Protection Agency, EPA

† Load reduction calculations described in Appendix E and Appendix F.
‡ Funding sources described in Chapter 7.

15% of systems are expected to be in failing condition. Improper system design or selection, improper maintenance and lack of education are likely reasons contributing to OSSF failure. In some cases, systems can be treated and repaired while in other cases, systems need to be redesigned and replaced; however, homeowners must have the awareness and resources to address OSSF problems when they arise.

In addition to the management measure geared at educating stakeholders about their OSSF system (Management Measure 4), this management measure recommends the replacement of 42 systems by acquiring programmatic resources and funding to replace high priority systems (Table 23).

Management Measure 4: Develop voluntary OSSF inspection program

There are an estimated 1,389 OSSFs in the watershed, with an estimated 15% failure rate. Proactive inspection and maintenance of systems is needed to ensure they do not discharge fecal waste to surface water bodies. While newer systems are required to have a permit and maintenance contract on file with the county, an unknown number of older systems operate without routine inspection. A voluntary OSSF inspection program will be implemented to encourage inspection and maintenance of systems (Table 24). These inspections should be free or reduced cost for homeowners and include recommendations to homeowners on repairs, maintenance or other actions that can be taken. We plan to

Table 24. Summary of management measure 4: Develop voluntary OSSF inspection program.

Source: Failing OSSFs			
Problem: Pollutant loading from failing or nonexistent OSSFs.			
Objectives: • Increase the number of inspected OSSFs in the watershed. • Encourage people to properly maintain working OSSFs or repair problems as needed.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
AgriLife Extension, county staff, designated representatives, watershed coordinator	Develop a voluntary OSSF inspection program to provide OSSF health assessment for homeowners.	2020–2030	$278,000 ($400 per inspection×695 systems)
Priority Areas: Subwatersheds 6 and 2.			
Estimated Load Reduction			
Load reductions were not calculated for this management measure. Loads reductions resulting from this management measure are highly dependent on actual failure rates determined by inspections and the actions taken by property owners after inspections.			
Effectiveness	Uncertain: Participation in the program is very uncertain. The effectiveness of reducing loads will largely depend on actions taken after identification of failing systems.		
Certainty	Low: Relatively little information is available about unpermitted systems that most likely need to be inspected. Furthermore, participation rates are unknown.		
Commitment	Moderate: Watershed stakeholders acknowledge failing OSSFs as a potential source of loadings. However, gaining commitment from property owners is challenging due to associated costs and hesitancy to be permitted.		
Resource Needs	High: The need for financial resources to inspect OSSFs at scale is high, and there are no local authoritative bodies available to take on the financial and operational burden.		
Potential Funding Sources	EPA Clean Water Act §319(h) grant program; Texas Supplemental Environmental Projects; local funds, property owners‡		

On-site sewage facility, OSSF; United States Environmental Protection Agency, EPA

‡ Funding sources described in Chapter 7.

target the program at half the OSSFs (695) in the watershed since not all homeowners need to (newer construction, for example) or will be willing to participate in such a program.

Management Measure 5: Promote feral hog removal

Spatial analysis indicated that potential bacteria loadings from feral hogs were moderate compared to other sources. While other sources of potential bacteria loadings were higher, feral hogs demonstrate a preference for the dense habitat, water and shade provided by riparian areas. Feral hog behavior and habitat preferences suggest a high likelihood for negative impacts on riparian habitat and water quality.

While the complete eradication of feral hogs from the watershed is not feasible, a variety of methods are available to manage or reduce populations. Trapping animals is likely the most effective method available to landowners for removing large numbers of feral hogs. Shooting feral hogs removes comparatively fewer individuals before they begin to move to other parts of the watershed. Trapping requires some amount of effort and proper planning to maximize effectiveness, but it also gives landowners a means to recoup costs associated with trapping efforts through the sale of live hogs. Specifically, the State of Texas allows transport of live feral hogs to approved holding facilities for sale. The purchase price will vary by facility and comparative market prices. Furthermore, costs of purchasing or building live traps can also be split amongst landowners.

Additionally, given the opportunistic feeding nature of feral hogs, minimizing available food from deer feeders is important. Feeders can help support the survival of local feral hog populations while also lowering trapping success by reducing the likelihood of feral hogs entering traps. Feeders located in or near riparian zones may also help maintain populations in areas that maximize their potential impact on water quality. Therefore, constructing exclusion fences around feeders and locating feeders away from riparian areas are other important strategies for minimizing feral hog impacts on water quality.

Table 25. Summary of management measure 5: Promote feral hog removal.

Source: Feral hogs			
Problem: Direct and indirect fecal loading, riparian habitat destruction, forest and pasture damage from feral hogs.			
Objectives: • Reduce fecal contaminant loading from feral hogs. • Reduce and control feral hog populations by 15% per year. • Provide technical support to landowners to implement feral hog control practices.			
Implementation Strategy			
Responsible Parties	**Recommendations**	**Period**	**Capital Costs**
Landowners, land managers, lessees	Voluntarily construct fencing around deer feeders to prevent feral hog use.	2020–2030	$200 per feeder exclusion
	Voluntarily identify travel corridors and employ trapping and hunting in these areas to reduce hog numbers.	2020–2030	N/A
	Voluntarily shoot all hogs on site; ensure that lessees shoot all hogs on site.	2020–2030	N/A
AgriLife Extension	Deliver feral hog workshops.	2020–2030	$2,500 ea.
Priority Areas: Subwatersheds 1 and 2.			
Estimated Load Reduction			
1.72×1013 MPN/year *Enterococcus*† 5.68×103 lbs of nitrogen per year† 2.03×103 lbs of phosphorous per year†			
Effectiveness	Moderate: Reducing feral hog population will result in a direct decrease in bacteria and nutrient loading in streams; however, removing enough hogs to decrease their population is difficult.		
Certainty	Low: Feral hogs are transient, intelligent and adapt to changes in environmental conditions. Population reductions require diligence on the part of landowners to reduce food availability and maintain trapping pressure.		
Commitment	Moderate: Many landowners already engage in feral hog control to reduce damage to pastures and crops.		
Resource Needs	Moderate: Landowners benefit from technical and educational resources to inform them about feral hog management options. Funds are needed to deliver these workshops.		
Potential Funding Sources	EPA Clean Water Act §319(h) grant program, local funds‡		

Most probable number, MPN; pounds, lbs; United States Environmental Protection Agency, EPA

† Load reduction calculations described in Appendix E and Appendix F.

‡ Funding sources described in Chapter 7 (note that §319(h) funds cannot be used for direct feral hog control activities, funds are limited to workshops).

Education programs and workshops will be used to improve feral hog removal effectiveness. Currently, AgriLife Extension offers a variety of educational resources for landowners: http://feralhogs.tamu.edu. Delivering up-to-date information and resources to landowners through workshops and demonstrations is critical to maximizing landowner success in removing feral hogs. Table 25 summarizes the management measure.

Management Measure 6: Promote effective pet waste management

Pet waste, compared to other sources of fecal bacteria, contains extremely high concentrations of fecal bacteria. Although population densities are low in the watershed, pets can contribute an outsized amount of fecal loadings due to the high density of fecal loads in their waste. Typical methods used to reduce the amount of dog and cat fecal material

Table 26. Summary of management measure 6: Promote effective pet waste management.

Source: Household pets			
Problem: Direct and indirect fecal loading from household pet waste.			
Objectives: • Reduce fecal contaminant loading from cats and dogs. • Increase resident and visitor knowledge about fecal bacteria loading from pet waste and impacts on water quality.			
Implementation Strategy			
Responsible Parties	**Recommendations**	**Period**	**Capital Costs**
Watershed coordinator	Develop and deliver education and outreach materials about pet waste.	2020–2030	$1,700
Priority Areas: Subwatersheds 6 and 3.			
Estimated Load Reduction			
2.69×10^{13} MPN/year *Enterococcus*† 88.2 lbs of nitrogen per year† 20.4 lbs of phosphorous per year†			
Effectiveness	High: Collecting and properly disposing of dog waste is a direct method of preventing bacteria and nutrients from entering water bodies, directly reducing potential loading in water bodies.		
Certainty	Low: Some pet owners in the watershed likely already collect and properly dispose of dog waste. Those that do not properly dispose of pet waste are likely difficult to reach or convince. The number of additional people that will properly dispose of waste is difficult to anticipate.		
Commitment	Low: Uptake of behavior change is often very low.		
Resource Needs	Low: Resources required to create and distribute materials are relatively low compared to other measures.		
Potential Funding Sources	EPA Clean Water Act §319(h) grant program, Texas General Land Office Coastal Management Program, local funds.‡		

Most probable number, MPN; pounds, lbs; United States Environmental Protection Agency, EPA

† Load reduction calculations described in Appendix E and Appendix F.
‡ Funding sources described in Chapter 7.

include education programs to residents and pet waste stations. Due to the low residential density and lack of public parks and other recreation areas in the watershed, deploying pet waste stations is neither feasible nor anticipated to be effective. Therefore, increasing resident and visitor knowledge about the impacts of pet waste on water quality and human health is recommended as the primary method to reduce pet waste loadings.

To increase knowledge and desired behavior, education and outreach materials will be delivered to watershed residents, as resources are made available (Table 26). Resources will include flyers, factsheets, signage and other outreach materials that are determined to be most effective at reaching area residents. Anticipating behavior change resulting from education and outreach is inherently difficult. Based on previous survey results we assumed that approximately 12% of dog owners will adjust behavior based on outreach efforts (Center for Watershed Protection 1999) and that those actions would be approximately 75% effective at reducing loads (an assumption that people do not pick up pet waste all the time).

Management Measure 7: Restore oyster and coastal wetland habitat

As oysters grow, they form rock-like reefs that provide valuable ecosystem services. These structures provide valuable habitat for small fish and invertebrates. Oyster reefs are areas of high biodiversity and support recreational and commercially important fish species. These reefs also help stabilize shoreline, marsh and bottom habitats in the bay against erosive impacts from wave action, tides and storm surges. Finally, oysters provide water quality benefits through their natural filtering behavior. A single oyster filters up to 50 gallons (gal) per day, removing suspended sediment, particle bound nutrients and chlorophyll-a (Beseres Pollack et al. 2013; Dame et al. 1984; Nelson et al. 2004).

Table 27. Summary of management measure 7: Restore oyster habitat.

Source: Degraded oyster and wetland habitat			
Problem: Decreased ecosystem resilience resulting from reduced oyster populations and reduced wetland services.			
Objectives: • Restore oyster habitat and populations. • Restore coastal wetland habitats.			
Implementation Strategy			
Participation	**Recommendations**	**Period**	**Capital Costs**
Watershed coordinator, Sea Grant Agents, Matagorda Bay Foundation, Bayfront property owners	Work with property owners to create community oyster gardens.	2020–2030	$250 per participant
Watershed coordinator, Sea Grant Agents, Matagorda Bay Foundation, Bayfront property owners	Support living shoreline, habitat restoration and oyster reef restoration efforts in Carancahua Bay.	2020–2030	N/A
Priority Areas: Communities and properties along Carancahua Bay shoreline.			
Estimated Load Reduction			
Load reductions were not estimated for this management measure.			
Effectiveness	Moderate: Oyster reefs and wetlands provide natural filtering that can reduce sediment, nutrients and bacteria. They provide numerous ancillary benefits for fish, wildlife and shoreline protection.		
Certainty	Moderate: Property owners along Carancahua Bay often have a direct interest in the fish and wildlife of Carancahua Bay and understand the important of oysters and oyster reefs for the Bay system. These property owners are often willing to participate and support programs once educated and provided with needed materials.		
Commitment	Moderate: Participation in similar programs in nearby bay and estuary systems has been successful. We anticipate similar commitment levels from Carancahua Bay residents given the appropriate resources.		
Resource Needs	Low: Resources required to create and distribute materials are relatively low compared to other measures.		
Potential Funding Sources	Texas General Land Office Coastal Management Program; National Fish and Wildlife Foundation (NFWF) Gulf Environmental Benefit Fund; local funds.‡		

‡ Funding sources described in Chapter 7.

Numerous factors have combined to decrease oyster populations, size and habitat in Carancahua Bay. Notably, recent periods of extreme low and high freshwater inflow created periods of prolonged high and low salinity in the bay, reducing oyster resistance to disease and predators and reducing recruitment of spat (free floating larval oysters) in the bay (State of Texas 2017). Oyster spat require hard-bottomed habitat to attach and grow. Example structures include oyster shells, calcareous rocks, piers and pilings. To increase available habitat and populations of oysters in the bay, the CBWPP recommends working with Bayfront property owners to build community oyster gardens and supporting living shoreline and reef restoration projects in Carancahua Bay (Table 27).

Coastal wetlands provide similar services, estimated to value in the billions of dollars nationally (Pendleton 2010). Coastal wetlands provide flood protection, erosion control, wildlife habitat and support commercial fisheries (Costanza et al. 2008; Engle 2011; Gedan et al. 2011). Coastal wetlands also provide an important role in improving water quality by reducing nitrogen and phosphorus loads (Ardón et al. 2010; Verhoeven et al. 2006). Currently, a project is underway to begin restoration and protection of 2 mi of Carancahua Bay shorelines and 1,000 ac of habitat in Carancahua Bay. The watershed coordinator will work with stakeholders to support this project and other restoration projects as opportunities are identified.

Table 28. Estimated potential load reductions expected from full management measure implementation.

Management Measure	Source	Potential *Enterococcus* Reduction (MPN/ year)	Potential Nitrogen Reduction (Pounds/Year)	Potential Phosphorus Reduction (Pounds/Year)
Promote and implement water quality management plans or conservation plans.	Livestock	6.26×10^{14}	6.80×10^{4}	3.58×10^{4}
Increase soil testing on agricultural lands.	Pasture and cropland	N/A	N/A	N/A
Repair and replace failing OSSFs.	OSSFs	9.60×10^{12}	4.87×10^{2}	1.22×10^{2}
Develop voluntary OSSF inspection program.	OSSFs	N/A	N/A	N/A
Promote feral hog removal.	Wildlife	8.58×10^{12}	5.68×10^{3}	2.03×10^{3}
Promote effective pet waste management.	Household pets	2.69×10^{13}	88.2	20.4
Restore oyster and coastal wetland habitat.	Degraded oyster and wetland habitat	N/A	N/A	N/A
	Total potential reduction:	6.71×10^{14}	6.80×10^{4}	3.80×10^{4}
	Reduction required:	2.86×10^{14}	N/A	3.35×10^{4}

Most probable number, MPN

Estimated Load Reductions

Implementation of the management measures outlined at the beginning of Chapter 5 will provide direct and indirect reduction in bacteria and nutrient loads. Some management measures, such as implementing conservation plans and WQMPs on farms, will result in direct load reductions by reducing pollutant loads reaching water bodies. Other management measures, such as pet waste education, will result in reductions not easily quantified because they depend on human behavior. We used the best available information to estimate likely reductions in bacteria and nutrient loads if the management measures are fully implemented. Appendix E and Appendix F provide the calculations used to estimate load reductions outlined in Table 28.

Summary

The CBWPP outlines the implementation of seven management measures expected to reduce bacteria and nutrient loads in the watershed. The estimated potential bacteria load reductions will reduce bacteria loads to levels that meet the 35 MPN/100 mL water quality criteria. The estimated potential phosphorus reductions will reduce total phosphorus loads to levels that meet the 0.21 mg/L screen criteria.

DO and chlorophyll-a levels cannot be calculated as direct load reductions. Both parameters are reflective of complex physical and biological stream and estuarine processes. We do anticipate the reductions in nitrogen and phosphorus will have positive impacts on these two parameters. Chapter 8 will discuss how these parameters will be monitored to gauge effectiveness and how the plan will be adapted if progress toward water quality goals are not met.

Chapter 6
Plan Implementation

Introduction

Effective implementation will take concerted efforts by many stakeholders. However, they will need additional support in many cases. Coordinating actual implementation efforts, working to secure funding, tracking progress and water quality monitoring are all activities beyond the responsibility of a single stakeholder. This chapter outlines additional activities required to support implementation and outlines an implementation schedule.

Watershed Coordinator

Implementing the WPP will require significant time and effort. Therefore, we recommend a dedicated, funded watershed coordinator to support plan implementation. This position will be responsible for working with stakeholders to identify funding opportunities, develop and file funding applications, administer projects, keep stakeholders engaged, coordinate and organize educational programming, track implementation progress and document changes in water quality condition. With the proximity of the Tres Palacios and Lavaca River watersheds and overlapping stakeholder groups common to these watersheds, it might be cost effective to share watershed coordinator resources with those watersheds. A full-time watershed coordinator is estimated at $95,000 per year for salary, benefits, travel and supplies required for the position. Without municipalities, local non-government organizations and other potential organizations that could fund this position, grant funding will be critical.

Water Quality Monitoring

Currently, one station in Carancahua Bay is routinely sampled for water quality data. Station 13388 (at the Highway 35 Bridge near Cape Carancahua) has the most data available for bacteria and other routinely monitored parameters. The TCEQ Region 14 office is responsible for conducting monitoring at this station and usually schedules semiannual or quarterly monitoring at the site. Water quality monitoring is conducted under quality assurance project plans approved by TCEQ and EPA to ensure the quality of data used in assessments and data reviews.

West Carancahua Creek has only been periodically monitored, with most of the water quality data on the segment from special studies occurring in the early 2000s. Tracking progress toward water quality goals will require additional monitoring on this segment. Station 13293 (at County Road 440) offers the most historic (albeit limited) data to track progress against.

Chapter 6 Highlights

1. **The CBWPP will be implemented over a 10-year period.**
2. **A watershed coordinator, increased education and outreach and increased water quality monitoring are needed to fully implement the CBWPP.**

Table 29. Water quality monitoring needed to track improvements in water quality.

Station	Parameters	Frequency
13388	Bacteria, Field, Conventional†	Quarterly
13293	Bacteria, Field, Conventional†, 24-hour‡	Quarterly

† Bacteria parameter is *Enterococci* (at tidal stations) or *E. coli* (freshwater stations); field parameters are instantaneous dissolved oxygen, temperature, pH, salinity (at tidal stations), transparency and specific conductance; conventional parameters are ammonia-nitrogen, nitrate-nitrogen or nitrite+nitrate-nitrogen, Kjeldahl nitrogen, total nitrogen, total phosphorus and chlorophyll-a. Parameters might change based on lab capabilities.
‡ Monitoring 24-hr parameters will begin after adequate instantaneous measurements have been collected.

The frequency of routine monitoring at Carancahua Bay is suitable for assessment purposes, although more frequent monitoring would be useful for trend assessments. West Carancahua Creek is not monitored on a routine basis. Additional monitoring, including 24-hr monitoring, will be required for assessment purposes and measuring progress toward water quality goals and targets. Because of the limited existing data, routine monitoring of field and conventional parameters should occur to substantiate current listings before 24-hr sampling is conducted. Based on available data and known data gaps, quarterly monitoring for bacteria, field and conventional parameters at both stations in the watershed will be used to track changes in water quality (Table 29). The watershed coordinator and TWRI will work with TCEQ and regional Clean Rivers Program (CRP) partners to initiate additional monitoring as recommended.

Education and Outreach

Successful progress toward water quality goals requires stakeholders who are knowledgeable about water quality conditions, their impacts and how to improve them. Increased education and outreach efforts are required to positively change behavior and start water quality improvements. Targeted audiences include watershed residents and visitors, landowners, agricultural producers, county officials, SWCDs, OSSF authorized agents and nonprofit groups.

In addition to the feral hog management workshops and pet waste education material outlined in the Chapter 5 management measures, other existing programs will be targeted to watershed stakeholders. These include but are not limited to:

- Texas Watershed Stewards
- Texas Riparian and Stream Ecosystem Education
- Texas Well Owner Network
- Lone Star Healthy Streams

In addition to traditional workshops, interested stakeholders can participate in volunteer water quality monitoring opportunities through the Texas Stream Team. Although the data is not used for regulatory purposes, long-term routine data from citizen scientists can be used to inform other stakeholders of ongoing water quality trends or acute water quality problems that occur in between routine sampling events. Furthermore, landowners can participate and provide context to water quality conditions that otherwise wouldn't be available because of limited river access. To initiate volunteer water quality monitoring, a Texas Stream Team training will be held, and resources will be secured to offer monitoring kits to interested groups.

Electronic and physical newsletters provide a periodic overview of the state of the watershed. Newsletters will communicate water quality and available assistance programs and promote best management practices.

Websites provide a centralized source of information and resources for watershed stakeholders. TWRI updates and maintains the Carancahua Bay watershed website. The website contains information about the watershed, upcoming meetings and previous meeting presentations. The website will continue to be maintained and improved to best serve project needs.

Implementation Schedule

Implementing the CBWPP will occur over a 10-year period. Additional time and management actions may be required and will be addressed through adaptive management (see Chapter 8, page 61). A complete schedule of management measures, educational activities and estimated costs are included in Table 30.

Operation and Maintenance

Almost all of the physical BMPs covered in Chapter 5 will be implemented on private property by property owners. Therefore, upkeep and maintenance of practices is largely up to the owner.

Practices installed under WQMP or conservation plan agreements funded by TSSWCB or NRCS are required to be maintained by the operator. During the planning, installa-

Table 30. Implementation Schedule.

Management Measures and Activities	Responsible Party	Number implemented in year:										Unit Cost	Total
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029		
WQMP, Conservation Plans	TSSWCB, SWCD, NRCS	7	7	7	7	7	7	7	7	7	7	$15,000[a]	$1,050,000
WQMP Technician	TSSWCB, SWCD			1	1	1	1	1	1	1	1	$75,000	$675,000
Soil Tests	Landowners, Lessees	-b	-b	-b	-b	-b	-b	-b	-b	-b		$10	N/A
Soil Test Campaign	AgriLife Extension, TSSWCB, SWCD, Others						1	1	1	1	1	$15,000	$90,000
OSSF Repair/Replacement	Homeowner				6	6	6	6	6	6	6	$7,500	$315,000
OSSF Inspection Program	Counties, AgriLife Extension, TWRI, Others					1						$400 per system	$278,000
OSSF Education Workshop	AgriLife Extension			1				1			1	$3,000	$9,000
Feral Hog Exclusions	Landowner, Lessees	-b	-b	-b	-b	-b	-b	-b	-b	-b	-b	$200	NA
Feral Hog Removal	Landowner, Lessees	-b	-b	-b	-b	-b	-b	-b	-b	-b	-b	N/A	-
Feral Hog Workshop	AgriLife Extension			1			1			1		$3,000	$9,000
Pet Waste Education Material	AgriLife Extension, TWRI, Others				1	1	1	1	1	1	1	$1,200[c] $0.50 postage	$1,700
Oyster Gardens	Homeowners, Texas Sea Grant	-b	-b	-b	-b	-b	-b	-b	-b	-b	-b		
Watershed coordinator	AgriLife Extension, TWRI		1	1	1	1	1	1	1	1	1	$95,000	$950,000
Water Quality Monitoring	TCEQ, TWRI, CRP			4	4	4	4	4	4	4	4	$2,000[d]	$72,000
Texas Watershed Stewards	AgriLife Extension		1				1					N/A[e]	-
Texas Riparian and Stream Ecosystem Training	AgriLife Extension			1				1				N/A[e]	-
Texas Well Owner Network	AgriLife Extension		1				1					N/A[e]	-
Lone Star Healthy Streams	AgriLife Extension			1				1				N/A[e]	-
Texas Stream Team	Meadows Center			1					1			N/A[f]	-
Newsletter	Watershed coordinator, TWRI	2	2	2	2	2	2	2	2	2	2	$500	$11,000
Website	Watershed coordinator, TWRI	1	1	1	1	1	1	1	1	1	1	N/A[g]	-

Water Quality Management Plan, WQMP; Texas State Soil and Water Conservation Board, TSSWCB; soil and water conservation district, SWCD; Natural Resources Conservation Service, NRCS; on-site sewage facility, OSSF; Texas Water Resources Institute, TWRI; Texas Commission on Environmental Quality, TCEQ; Clean Rivers Program, CRP

[a] WQMPs typically involve funding from TSSWCB and the landowner. The TSSWCB contribution is a maximum of $15,000 per plan. Landowner costs can vary depending on the nature, scale, acreage and other operation specific factors.
[b] Indicates as many as possible
[c] Initial material development is estimated at $1,200 but is likely a one-time cost unless materials need a major update. Postage is per delivery.
[d] Existing monitoring is funded under the CRP; however, additional monitoring will require outside funding. Actual costs will vary by suite of test parameters and other factors (for example, 24-hr monitoring requires more time than grab samples).
[e] Additional funding not required, currently funded through existing programs
[f] Training is funded under existing programs. However, test kits are approximately $500. The number of test kits needed will depend on the number of stakeholders interested in participating.
[g] Website is already provided through TWRI; costs may vary substantially if a different website is desired.

tion and reimbursement process, field staff will work with operators to ensure that practices are properly designed, installed and maintained.

Homeowners with new OSSFs will require a permit from their respective county office, in addition to proof of annual service agreements. This ensures systems are adequately designed and maintained.

Technical assistance with design, operation and maintenance of feeder exclosures, traps and other practices for managing feral hogs is available and covered in Chapter 7 on page 55. Landowners will be responsible for operations and maintenance of feral hog maintenance practices.

Technical assistance is also available for design, installation and maintenance of oyster gardens and covered in Chapter 7 on page 56. Texas Sea Grant will work with property owners to install and maintain these oyster gardens, but the property owner is responsible for respective oyster garden over the course of each growing season.

Chapter 7
Implementation Resources

Introduction

The Carancahua Bay watershed is largely rural with limited resources available for implementation of the management measures desired by stakeholders. This chapter identifies the potential sources of technical and financial assistance available to implement management measures. Grant funding will likely be a substantial source of implementation funding given the availability of resources identified so far.

Technical Assistance

Designing, planning and implementing some of the management recommendations in the plan will require technical expertise. Numerous agencies and organizations are available to provide technical guidance in implementation (Table 31).

Chapter 7 Highlights

1. **Federal, state and local agencies can provide technical assistance to stakeholders implementing management measures.**
2. **There are at least 15 sources of financial assistance available to stakeholders to assist with implementation.**

Promote and implement water quality management plans or conservation plans

Developing and implementing practices to reduce runoff from agricultural lands will require substantial technical expertise. Technical assistance can be obtained by contacting local SWCDs, local NRCS offices, TSSWCB and local AgriLife Extension offices. Producers requesting planning assistance will work with the local SWCD and local NRCS office to define operation-specific management goals and objectives and develop a management plan that prescribes effective practices to achieve stated goals while also improving water quality.

Increase soil testing on agricultural lands

Producers looking to incorporate soil testing should work with NRCS and SWCDs to discuss nutrient management and soil testing. Soil testing and nutrient management may fall within the scope of the conservation plan or WQMP developed with the producer. AgriLife Extension offers soil testing services through the Soil, Water and Forage Testing Laboratory[3] at a minimal cost.

Repair and replace failing OSSFs

The repair and replacement of OSSFs requires licensed personnel and permits through respective county offices. The Jackson County Office of Permitting[4] and the Matagorda

[3] http://soiltesting.tamu.edu/

[4] http://www.co.jackson.tx.us/default.aspx?Jackson_County/Permitting-FloodPlain

Table 31. Summary of potential sources of technical assistance.

Management Measure	Technical Assistance Sources
Promote and implement water quality management plans or conservation plans.	• AgriLife Extension • Local SWCDs • NRCS • TSSWCB
Increase soil testing on agricultural lands.	• AgriLife Extension • Local SWCDs • NRCS • TSSWCB
Repair and replace failing OSSFs.	• AgriLife Extension • Jackson County Office of Permitting • OSSF service providers • Matagorda County Environmental Health Department • Victoria County Public Health Department (for permitting issues in Calhoun County) • Wharton County Permits and Inspections
Develop voluntary OSSF inspection program.	• AgriLife Extension • Jackson County Office of Permitting • Matagorda County Environmental Health Department • Victoria County Public Health Department (for permitting issues in Calhoun County) • Wharton County Permits and Inspections
Promote feral hog removal.	• AgriLife Extension • TPWD
Promote effective pet waste management.	• EPA • TCEQ • TWRI
Restore oyster and wetland habitat.	• AgriLife Extension • Texas Sea Grant • Texas A&M AgriLife Research

Soil and Water Conservation District, SWCD; Natural Resources Conservation Service, NRCS; Texas State Soil and Water Conservation Board, TSSWCB; on-site sewage facility, OSSF; Texas Parks and Wildlife Department, TPWD; United States Environmental Protection Agency, EPA; Texas Commission on Environmental Quality, TCEQ; Texas Water Resources Institute, TWRI

County Health Department[5] can assist with the permitting process within their respective jurisdictions. AgriLife Extension offers education, programs and training associated with OSSF maintenance, operations and services.[6] The design, construction and installation of new systems should be coordinated with local service providers. Wharton County maintains a list of licensed installers.[7]

Develop voluntary OSSF inspection program

OSSFs should be inspected by licensed and knowledgeable personnel. The Jackson County Office of Permitting and Wharton County Health Department can assist property owners with inspection and licensing needs. AgriLife Extension provides resources for homeowners and service providers. AgriLife Extension also has experience in developing and implementing inspection programs.

Promote feral hog removal

Numerous resources are available to assist landowners and managers to control feral hog populations. AgriLife Extension offers technical materials and workshops on feral hog identification, impacts and control methods. Similar resources are available through USDA Animal and Plant Health Inspection Services. TPWD offers general information about identification, trapping, hunting and regulations regarding removal of feral hogs that all stakeholders involved in feral hog control should be aware of.

[5] http://www.co.matagorda.tx.us/default.aspx?Matagorda_County/EnvironmentalHealth

[6] https://ossf.tamu.edu/

[7] http://tools.cira.state.tx.us/users/0160/docs/Permits%20and%20Inspections/septic%20contractors.pdf

Table 32. Summary of potential sources of financial assistance.

Management Measure	Technical Assistance Sources
Promote and implement water quality management plans or conservation plans.	• Clean Water Act §319(h) Nonpoint Source Grant Program • Natural Resources Conservation Service (NRCS) Conservation Innovation Grants (CIG) • NRCS Conservation Stewardship Program (CSP) • NRCS Environmental Quality Incentives Program (EQIP) • NRCS Regional Conservation Partnership Program (RCPP) • Texas State Soil and Water Conservation Board (TSSWCB) Water Quality Management Plan (WQMP) Program
Increase soil testing on agricultural lands.	• Clean Water Act §319(h) Nonpoint Source Grant Program • NRCS CIG • NRCS CSP • NRCS EQIP • NRCS RCPP • TSSWCB WQMP Program
Repair and replace failing OSSFs.	• Clean Water Act §319(h) Nonpoint Source Grant Program • Texas Commission on Environmental Quality (TCEQ) Supplemental Environmental Projects (SEP)
Develop voluntary OSSF inspection program.	• Clean Water Act §319(h) Nonpoint Source Grant Program, • TCEQ SEP
Promote feral hog removal.	• Clean Water Act §319(h) Nonpoint Source Grant Program (for education)
Promote effective pet waste management.	• U.S. Environmental Protection Agency Urban Waters Small Grants Program, • Clean Water Act §319(h) Nonpoint Source Grant Program • Coastal Management Program (CMP)
Restore oyster and wetland habitat.	• Coastal Conservation Association (CCA) • CMP • National Fish and Wildlife Foundation (NFWF) Gulf Environmental Benefit Fund • Texas Trustee Implementation Group (TIG) Natural Resource Damage Assessment (NRDA) • NRCS RCPP

Promote effective pet waste management

EPA[8] and TCEQ[9] have materials available for local jurisdictions and organizations to develop education and outreach materials to promote proper pet waste management. TWRI can provide technical expertise in outreach material creation, design and distribution.

Restore oyster and wetland habitat

Bayfront property owners participating in oyster garden projects can get technical expertise and assistance from Texas Sea Grant. The Texas Sea Grant agent will assist with obtaining the required materials, educate owners on installation, maintenance and monitoring and ultimately assist with spat transplant. Texas A&M AgriLife Research and AgriLife Extension Service can provide technical resources and expertise related to wetland restoration efforts and projects.

[8] https://cfpub.epa.gov/npstbx/

[9] https://www.tceq.texas.gov/p2/Education/nps.html

Financial Assistance

Successful implementation of the CBWPP, as written, will require substantial fiscal resources. Diverse funding will be sought to meet these needs. Resources will be leveraged where possible to extend the impacts of acquired and contributed implementation funds. While this section outlines potential financial resource to assist with implementation, funding sources can change substantially year to year (Table 32). Therefore, other sources of funding should be sought out as appropriate.

Financial Resource Descriptions

Clean Water Act §319(h) Nonpoint Source Grant Program

The EPA gives grant funding to the State of Texas to implement projects that reduce NPS pollution through the §319(h) Nonpoint Source Grant Program. In Texas, TCEQ and TSSWCB administer these grants. Watershed protection plans that satisfy the nine key elements of successful watershed-based plans are eligible for funding through this program. To be eligible for funding, implementation measures must be included in the accepted watershed protection plan and meet other program rules. Some commonly funded items include:

- Development and delivery of educational programs
- Water quality monitoring
- OSSF repairs and replacements, land BMPs
- Water body clean-up events and others

Coastal Conservation Association (CCA)

The CCA is a nonprofit organization that advises and educates the public on marine resource conservation with a goal to conserve, promote and enhance coastal resources for use by the public. CCA supports restoration projects with funding programs such as the Habitat Today for Fish Tomorrow program, which has provided over $6 million in habitat restoration funding. CCA also provides funding for education, research and coastal enforcement.

Coastal Management Program (CMP)

The CMP, administered by NOAA and TGLO, is a voluntary partnership between the federal government and U.S. coastal and Great Lake states and territories and is authorized by the Coastal Zone Management Act of 1972 to address national coastal issues. The Act provides funding for protecting, restoring and responsibly developing the nation's diverse coastal communities and resources. To meet the goals of the Coastal Zone Management Act, the National Coastal Zone Management Program takes a comprehensive approach to coastal resource management, balancing the often competing and occasionally conflicting demands of coastal resource use, economic development and resource conservation. Some of the key elements of the National Coastal Zone Management Program include:

- Protecting natural resources
- Managing development in high hazard areas
- Giving development priority to coastal-dependent uses
- Providing public access for recreation
- Coordinating state and federal actions

The Coastal Zone Management Program provides pass-through funding to TGLO, which, in turn, uses the funding to finance coastal restoration, conservation and protection projects under TGLO's CMP.

EPA Urban Waters Small Grants Program

The objective of the Urban Waters Small Grants Program, administered by EPA, is to fund projects that will foster a comprehensive understanding of local urban water issues, identify and address these issues at the local level and educate and empower the community. In particular, the Urban Waters Small Grants Program seeks to help restore and protect urban water quality and revitalize adjacent neighborhoods by engaging communities in activities that increase their connection to, understanding of and stewardship of local urban waterways.

National Fish and Wildlife Foundation (NFWF) Gulf Environmental Benefit Fund

The Gulf Environmental Benefit Fund was established as a result of the BP and Transocean court cases for the Deepwater Horizon oil spill. The plea agreements directed $2.544 billion to NFWF to fund natural resource project on the Gulf Coast. The Gulf Environmental Benefit Fund will direct $203 million for project on the Texas Gulf Coast.

NRCS Conservation Innovation Grants (CIG)

The USDA NRCS administers the CIG Program, which is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, EQIP funds are used to award competitive grants to non-federal governmental or nongovernmental organizations, tribes or individuals.

NRCS Conservation Stewardship Program (CSP)

The CSP is a voluntary conservation program administered by USDA NRCS that encourages producers to address resource concerns in a comprehensive manner by undertaking additional conservation activities as well as improving, maintaining and managing existing conservation activities. The program is available for private agricultural lands including cropland, grassland, prairie land, improved pasture and rangeland. CSP encourages landowners and stewards to improve conservation activities on their land by installing and adopting additional conservation practices. Practices may include, but are not limited to, prescribed grazing, nutrient management planning, precision nutrient application, manure application and integrated pest management.

NRCS Environmental Quality Incentives Program (EQIP)

Operated by USDA NRCS, EQIP is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of 10 years. These contracts offer financial assistance to help plan and implement conservation practices that address natural resource concerns in addition to opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland. People engaged in livestock or agricultural production on eligible land are permitted to participate in EQIP. Selected practices address natural resource concerns and are subject to the NRCS technical standards adapted for local conditions. They also must be approved by the local SWCD. Local work groups are formed to give recommendations to USDA NRCS that advise the agency on allocations of EQIP county-based funds and to identify local resource concerns. Watershed stakeholders are strongly encouraged to participate in their local work group to promote the objectives of this CBWPP with the resource concerns and conservation priorities of EQIP.

NRCS Regional Conservation Partnership Program (RCPP)

The RCPP is a flexible program that uses partnerships to stretch and multiply conservation investments and reach conservation goals on a regional or watershed scale. Through the RCPP and NRCS, state, local and regional partners coordinate resources to help producers install and maintain conservation activities in selected project areas. Partners leverage RCPP funding in project areas and report on the benefits achieved.

Currently, Ducks Unlimited and NRCS have partnered on an RCPP project to help rice producers in Calhoun, Jackson and Matagorda counties implement conservation practices that improve irrigation management, control sediment and nutrient runoff and provide waterfowl habitat on rice production lands. Interested producers can find more information at: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/.

TCEQ Supplemental Environmental Projects (SEP)

The SEP program, administered by TCEQ, directs fines, fees and penalties for environmental violations toward environmentally beneficial uses. Through this program, a respondent in an enforcement matter can choose to invest penalty dollars in improving the environment, rather than paying into the Texas General Revenue Fund. Program dollars may be directed to OSSF repair, trash dump clean up and wildlife habitat restoration or improvement, among other things. Program dollars may be directed to entities for single, one-time projects that require special approval from TCEQ or directed entities (such as Resource Conservation and Development Councils) with pre-approved "umbrella" projects.

Texas Trustee Implementation Group (TIG) Natural Resource Damage Assessment (NRDA)

The TIG administers funding for restoration projects designed to compensate for injuries to natural resources caused by the Deepwater Horizon oil spill. The TIG will allocate $175 million in funding from projected selected to be part of the TIG developed restoration plan.

TSSWCB WQMP Program

WQMPs are management plans developed and implemented to improve land and water quality. TSSWCB and local SWDCs offer technical assistance to develop plans that meet producer and state goals. Once the plan is developed, TSSWCB may financially assist implementing a portion of prescribed BMPs. As of 2018, TSSWCB has developed and certified 24 WQMPs in the watershed. Through these plans, over 5,277 ac are currently enrolled in the Carancahua Bay watershed and include practices such as conservation cover, prescribed grazing, fencing, heavy use area protection, water facilities, wells and upland wildlife management.

Other Sources of Financial Assistance

Private foundations, nonprofit organizations, land trusts and individuals can potentially assist with implementation funding of some aspects of the CBWPP. Funding eligibility requirements for each program should be reviewed before applying to ensure applicability. Some groups that may be able to provide funding include but are not limited to:

- Cynthia and George Mitchell Foundation: Provides grants for water and land conservation programs to support sustainable protection and conservation of Texas' land and water resources
- Dixon Water Foundation: Provides grants to nonprofit organizations to assist in improving/maintaining watershed health through sustainable land management
- Meadows Foundation: Provides grants to nonprofit organizations, agencies and universities engaged in protecting water quality and promoting land conservation practices to maintain water quality and water availability on private lands
- Texas Agricultural Land Trust: Funding provided by the trust assists in establishing conservation easements for enrolled lands

Chapter 8 Measuring Success

Introduction

Measuring the impacts of management measures on water quality is a critical but complicated process. Ongoing water quality monitoring at locations with existing data will help provide the data needed to evaluate progress toward water quality goals. The watershed coordinator is also responsible for working with stakeholders to track implementation progress, so we can link implementation with water quality goals.

Progress toward water quality improvements is the ultimate measure of success. Progress can be slow due to delays in implementation or lag effects between implementation and water quality response. Therefore, establishing milestones that evaluate progress in implementation success is also important. By periodically evaluating progress toward milestones along with progress toward improvements in water quality we can assess what is working and adapt the plan as needed to maximize effectiveness. This approach is called *adaptive management* and is a crucial component of all watershed protection plans.

Water Quality Goals and Targets

The goal of the CBWPP is to achieve water quality standards established by the state of Texas for Carancahua Bay and West Carancahua Creek. To achieve this goal, the geometric mean *Enterococcus* bacteria concentrations in Carancahua Bay must decrease to a concentration of 35 MPN/100mL, 10% of minimum and average DO measurements in West Carancahua Creek must exceed 3 mg/L and 4 mg/L respectively. While the overall goal will take at least 10 years to achieve, we expect incremental progress as implementation takes place. Therefore, incremental water quality targets are established to evaluate progress every few years.

Indicator Bacteria Goals and Targets

The 2014 Texas Integrated Report indicates Carancahua Bay had a geometric mean of 123.8 MPN/100mL for samples collected during the seven-year assessment period (December 1, 2005 through November 30, 2012). If we look at the seven-year geometric mean for assessment data collected through November 2016, the geometric mean decreased to 67.3 MPN/100mL (Figure 30). Based on the more recent water quality data, we established a goal of achieving a seven-year geometric mean concentration 35 MPN/100 mL *Enterococcus* in 2030. An interim target is established to achieve seven-year geometric mean concentration of 57 MPN/100 mL *Enterococcus* in 2025.

Chapter 8 Highlights

1. **The CBWPP establishes water quality goals for bacteria, dissolved oxygen and nutrient water quality parameters.**
2. **Implementation milestones are established to track progress made.**
3. **The CBWPP is a living document and will be reviewed and adapted in light of new information, lack of progress or negative changes in water quality.**

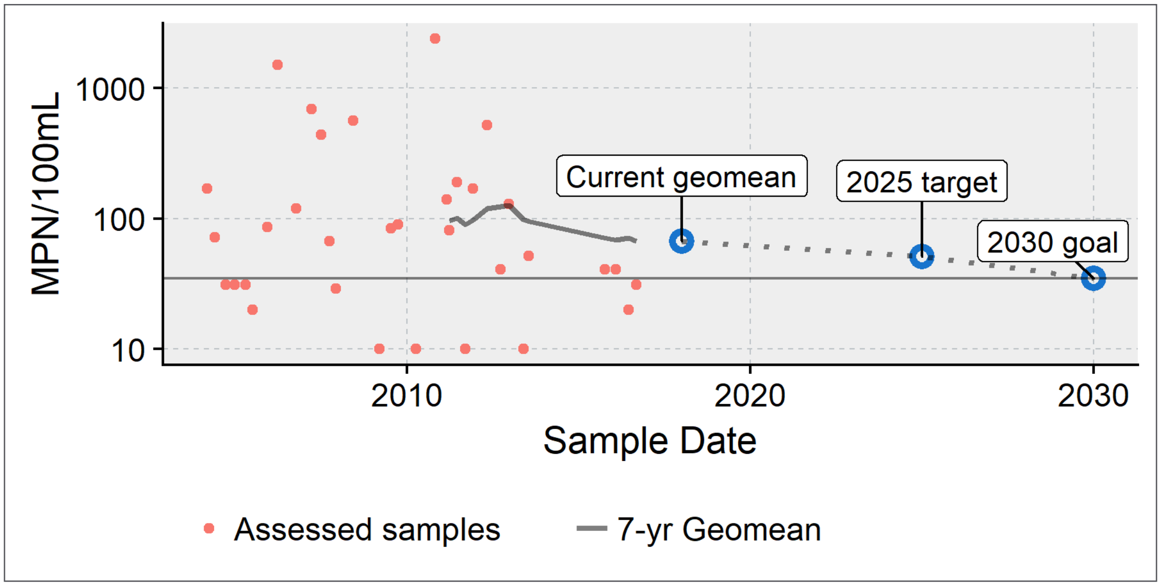


Figure 30. Bacteria concentrations and targets for Carancahua Bay.

Dissolved Oxygen Goals and Targets

The 2014 Texas Integrated Report includes West Carancahua Creek as impaired due to depressed DO. This listing was caused by at least 10% of the 24-hr minimum and average DO samples falling below a threshold of 3 and 4 mg/L respectively. Although recent data has not been collected, past data indicated that 75% of the 24-hr minimum DO samples and 50% of the 24-hr DO samples failed to meet standards. The DO goal is to reduce DO exceedances to fewer than 10% of samples by 2030. The interim target is to reduce DO exceedances to fewer than 30% of samples by 2025.

Nutrient Goals and Targets

The 2014 Texas Integrated Report includes a screening concern for total phosphorus in Carancahua Bay and screening concerns for chlorophyll-a in both Carancahua Bay and West Carancahua Creek. The goal for both water bodies is to reduce chlorophyll-a and total phosphorus exceedances to less than 20% of assessed samples in both water bodies. The most recent assessments indicate that approximately 88% of total phosphorus and chlorophyll-a samples in Carancahua Bay exceed the water quality standard. The interim target will be to reduce exceedances to 54% by 2025 in both water bodies. The goal will be to reduce exceedances to fewer than 20% by 2030.

Data Review

Progress toward water quality targets and goals will be measured using three methods. First, TCEQ's Texas Integrated Report on Surface Water Quality is made available every two years and includes updates on current water quality impairments that are reported to EPA. The Integrated Report serves as the official regulatory document indicating the impairment status of a water body. However, the report is only made available every two years and includes a two-year data lag, so often the most recent data might be three or four years old by the time the report is made available.

The second method will be to independently calculate the seven-year geometric mean for *Enterococcus* and percent exceedances for DO and nutrient parameters based on water quality made available through the state's Surface Water Quality Monitoring Information System (SWQMIS) database. These assessments will serve to update stakeholders on an annual basis but do not serve as official assessments for listing purposes.

Third; statistical trend analysis of water quality constituent concentrations and loads will be used. By reporting statistical trends in concentrations, stakeholders will be made aware of significant progress (or degradation) of instream water quality conditions. Trend analysis of constituent loads can also indicate progress toward instream conditions. Importantly, constituent load analysis can control for changes in flow, so stakeholders can be made aware of impacts of land management on the amount of NPS pollutant reaching water bodies.

Project Milestones

The successful implementation of management measures over the next 10 years will drive progress toward the accomplishing water quality goals outlined above. Interim milestones have been established for each management measure to evaluate progress. These milestones are established to evaluate if progress is being made slower or faster than anticipated. By breaking up management measures into smaller achievable milestones, we can focus on implementing achievable actions and visualize real progress from year to year. The following list shows current project milestones.

Agriculture

- 2022 – Hire a field technician to develop WQMPs and conservation plans
- 2025 – 35 WQMPs or conservation plans developed; soil test campaign initiated
- 2030 – 35 additional WQMPs or conservation plans developed (70 WQMPs or conservation plans total)

OSSFs

- 2023 – Deliver at least one OSSF workshop
- 2025 – Develop a voluntary inspection program; 22 failing OSSFs repaired/replaced
- 2030 – 22 additional failing OSSFs repaired/replaced (44 failing OSSFs total)

Household Pets

- 2025 – Develop and deliver pet waste management educational material to 1,000 watershed homes

Wildlife

- 2023 – Deliver one feral hog workshop
- 2027 – Deliver one feral hog workshop
- 2030 – Deliver one feral hog workshop (three over 10 years)

General

- 2022 – Fund a watershed coordinator
- 2025 – Deliver four general water quality education workshops; initiate coordinated volunteer water quality monitoring

Adaptive Management

The CBWPP is a living document and is intended to be reviewed and revised as required. The ultimate measure of success will be the achievement of water quality goals. However, as new data and methods to improve water quality become available, there will be a need to revise the number or types of management measures required to improve water quality in Carancahua Bay.

Adaptive management is a structured, iterative process of decision-making in the face of uncertainty. As we learn what works and does not work for improving water quality in the watershed, stakeholders will give guidance to improve the contents of the plan with a goal of achieving improved water quality outcomes.

Stakeholders will formally review progress at least every five years, as facilitated by the watershed coordinator. Progress will be reviewed using the following assessments:

- Water Quality – Stakeholders will review water quality assessments of Carancahua Bay and West Carancahua Creek. Additional water quality analysis, as available, will also be used. This might include trend analysis of pollutant concentrations and loads. An increase in pollutant concentrations or percent exceedances will be considered a negative outcome.
- Implementation Progress – Stakeholders will review the overall progress of the CBWPP in meeting anticipated interim milestones. Substantial delays or lower than expected achievements in milestones will be considered a negative outcome.
- External factors – Stakeholders will evaluate, as appropriate, available data concerning trends in population growth, land use, economic factors and other available data to evaluate changes to the amount or numbers of potential pollutant sources outlined in the CBWPP. Significant increases in potential pollutant sources or hydrologic changes will be considered a negative outcome.

If negative outcomes are identified by two or more of the above assessments during the formal review, stakeholders will make changes based on adaptive management.

References

Adams, T., Hauck, L. 2017. Technical Support Document for Total Maximum Daily Load for Indicator Bacteria in Carancahua Bay, Stephenville, TX: Texas Commission on Environmental Quality. No. PR 1703. https://www.tceq.texas.gov/assets/public/waterquality/tmdl/108carancahua/108-carancahua-technical-support.pdf.

AVMA (American Veterinary Medical Association). 2012. U.S. Pet Owner Statistics. In U.S. Pet Ownership & Demographics Sourcebook. Schaumburg, IL.

Ardón, M., Morse, J. L., Doyle, M. W., Bernhardt, E. S. 2010. The water quality consequences of restoring wetland hydrology to a large agricultural watershed in the southeastern coastal plain. Ecosystems13: 1060–1078. https://doi.org/10.1007/s10021-010-9374-x.

Arguez, A., Durre, I., Applequist, S., Squires, M., Vose, R., Yin, X., Bilotta, R. 2010. NOAA's U.S. Climate Normals (1981–2010). NOAA National Centers for Environmental Information. https://doi.org/10.7289/V5PN93JP.

Beseres Pollack, J., Yoskowitz, D., Kim, H. C., Montagna, P. A. 2013. Role and value of nitrogen regulation provided by oysters (Crassostrea virginica) in the Mission-Aransas Estuary, Texas, USA. PLoS ONE 8 (6): 6–13. https://doi.org/10.1371/journal.pone.0065314.

Borel, K. E., Karthikeyan, R., Smith, P. K., Gregory, L., Srinivasan, R. 2012. Estimating daily potential *E. coli* loads in rural Texas watersheds using Spatially Explicit Load Enrichment Calculation Tool (SELECT). Texas Water Journal 3 (1): 42–58. https://journals.tdl.org/twj/index.php/twj/article/view/6164.

Borel, K. E., Karthikeyan, R., Berthold, T. A., Wagner, K. 2015. Estimating *E. coli* and *Enterococcus* loads in a coastal Texas watershed. Texas Water Journal 6 (1): 33–44. https://journals.tdl.org/twj/index.php/twj/article/view/7008.

Brenner, F. J., Mondok, J. J., McDonald Jr, R. J. 1996. Watershed restoration through changing agricultural practices. In J. J. McDonnell, J. B. Stribling, L. R. Neville, D. J. Leopold (Eds.), Proceedings of the AWRA Annual Symposium Watershed Restoration Management: Physical, Chemical and Biological Considerations (pp. 397–404). Herndon, VA.

Brown, D. S., Snyder, G. L., Taylor, R. L. 1998. Mercury Concentrations in Estuarine Sediments, Lavaca and Matagorda Bays, Texas, 1992. Austin, TX: U.S. Geological Survey. Water-Resources Investigations Report 98–4038. https://pubs.usgs.gov/wri/wri98-4038/pdf/98-4038.pdf.

Byers, H. L., Cabrera, M. L., Matthews, M. K., Franklin, D. H., Andrae, J. G., Radcliffe, D. E., et al. 2005. Phosphorus, sediment, and loads in unfenced streams of the Georgia Piedmont, USA. Journal of Environment Quality 34 (6): 2293. https://doi.org/10.2134/jeq2004.0335.

Center for Watershed Protection. 1999. A Survey of Residential Nutrient Behavior in the Chesapeake Bay. Ellicott City, MD. https://cfpub.epa.gov/npstbx/files/UNEP_all.pdf.

Chesapeake Bay Program. 2017. Chesapeake Assessment Scenario Tool (CAST) Source Data. https://cast.chesapeakebay.net/Home/SourceData.

Cleland, B. R. 2003. TMDL Development from the "bottom up" – Part III: duration curves and wet-weather assessments. Proceedings of the Water Environment Federation 2003 (4): 1740–1766. https://doi.org/10.2175/193864703784828976.

Cook, M. N. 1998. Impact of Animal Waste Best Management Practices on the Bacteriological Quality of Surface Water. Virginia Tech. https://doi.org/http://hdl.handle.net/10919/36762.

Costanza, R., Pérez-Maqueo, O., Martinez, M. L., Sutton, P., Anderson, S. J., Mulder, K. 2008. The value of coastal wetlands for hurricane protection. AMBIO: A Journal of the Human Environment 37 (4): 241–248. https://doi.org/10.1579/0044-7447(2008)37[241:TVOCWF]2.0.CO;2.

Dame, R. F., Zingmark, R. G., Haskin, E. 1984. Oyster reefs as processors of estuarine materials. Journal of Experimental Marine Biology and Ecology 83 (3): 239–247. https://doi.org/10.1016/S0022-0981(84)80003-9.

Davis, M. L., Cornwell, D. A. 1991. Introduction to Environmental Engineering. New York: McGraw Hill.

Engle, V. D. 2011. Estimating the provision of ecosystem services by Gulf of Mexico coastal wetlands. Wetlands 31 (1): 179–193. https://doi.org/10.1007/s13157-010-0132-9.

Flores-Lopez, F., Easton, Z. M., Steenhuis, T. S. 2010. A multivariate analysis of covariance to determine the effects of near-stream best management practices on nitrogen and phosphorus concentrations on a dairy farm in the New York Conservation Effects Assessment Project watershed. Journal of Soil and Water Conservation 65 (6): 438–449. https://doi.org/10.2489/jswc.65.6.438.

Gedan, K. B., Kirwan, M. L., Wolanski, E., Barbier, E. B., Silliman, B. R. 2011. The present and future role of coastal wetland vegetation in protecting shorelines: Answering recent challenges to the paradigm. Climatic Change 106 (1): 7–29. https://doi.org/10.1007/s10584-010-0003-7.

Gesch, D., Oimoen, M., Greenlee, S., Nelson, C., Steuck, M., Tyler, D. 2002. The National Elevation Dataset. Photogrammetric Engineering and Remote Sensing 68 (1): 5-11.

Gregory, L., Brown, M., Hein, K., Skow, K., Engling, A., Wagner, K., Berthold, A. 2014. Basin Approach to Address Bacterial Impairments in Basins 15, 16, and 17. College Station, TX: Texas Water Resources Institute. Technical Report-462. http://twri.tamu.edu/media/468420/tr-462.pdf.

Griffith, G., Bryce, S., Omernik, J., Rogers, A. 2007. Ecoregions of Texas. ftp://newftp.epa.gov/EPADataCommons/ORD/Ecoregions/tx/TXeco_Jan08_v8_Cmprsd.pdf.

Hagedorn, C., Robinson, S. L., Filtz, J. R., Grubbs, S. M., Angier, T. A., Reneau, R. B. 1999. Determining sources of fecal pollution in a rural Virginia watershed with antibiotic resistance patterns in fecal streptococci. Applied and Environmental Microbiology 65 (12): 5522–5531.

Homer, C. G., Dewitz, J. A., Yang, L., Jin, S., Danielson, P., Xian, G., et al. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing 81 (5): 345–354.

Jones, C. A., Wagner, K., Di Giovanni, G., Hauck, L., Mott, J., Rifai, H., et al. 2009. Bacteria Total Maximum Daily Load Task Force Final Report. College Station, TX: Texas Water Resources Institute. Technical Report-341. http://hdl.handle.net/1969.1/86092.

Kay, P., Edwards, A. C., Foulger, M. 2009. A review of the efficacy of contemporary agricultural stewardship measures for ameliorating water pollution problems of key concern to the UK water industry. Agricultural Systems 99 (2–3): 67–75. https://doi.org/10.1016/j.agsy.2008.10.006.

Larkin, T. J., Bomar, G. W. 1983. Climatic Atlas of Texas. Austin, TX: Texas Department of Water Resources. http://hdl.handle.net/1969.3/20098.

Line, D. E. 2002. Changes in land use/management and water quality in the Long Creek watershed. Journal of the American Water Resources Association 38 (6): 1691–1701. https://doi.org/10.1111/j.1752-1688.2002.tb04374.x.

Line, D. E. 2003. Changes in a stream's physical and biological conditions following livestock exclusion. Transactions of the ASABE 46 (2): 287–293. https://doi.org/10.13031/2013.12979.

Line, D. E., Harman, W. A., Jennings, G. D., Thompson, E. J., Osmond, D. L. 2000. Nonpoint-Source Pollutant Load Reductions Associated with Livestock Exclusion. Journal of Environment Quality 29 (6): 1882. https://doi.org/10.2134/jeq2000.00472425002900060022x.

Line, D. E., Osmond, D. L., Childres, W. 2016. Effectiveness of Livestock Exclusion in a Pasture of Central North Carolina. Journal of Environment Quality 45 (6): 1926. https://doi.org/10.2134/jeq2016.03.0089.

Lombardo, L., Grabow, G., Spooner, J., Line, D., Osmond, D., Jennings, G. 2000. Section 319 Nonpoint Source National Monitoring Program: Successes and Recommendations. Raleigh, NC. https://www.epa.gov/sites/production/files/2015-09/documents/nmp_successes_0.pdf.

Meals, D. W. 2001. Water quality response to riparian restoration in an agricultural watershed in Vermont, USA. Water Science and Technology 43 (5): 175–182. http://wst.iwaponline.com/content/43/5/175.

Metcalf and Eddy Inc. 1991. Wastewater Engineering Treatment, Disposal, and Reuse. (G. Tchobanoglous F. Burton, Eds.) (3rd ed.). McGraw-Hill.

Nelson, K. A., Leonard, L. A., Posey, M. H., Alphin, T. D., Mallin, M. A. 2004. Using transplanted oyster (Crassostrea virginica) beds to improve water quality in small tidal creeks: A pilot study. Journal of Experimental Marine Biology and Ecology 298 (2): 347–368. https://doi.org/10.1016/S0022-0981(03)00367-8.

Olness, A., Rhoades, E., Smith, S., Menzel, R. 1980. Fertilizer nutrient losses from rangeland watersheds in Central Oklahoma. Journal of Environmental Quality, 9(1), 81–86. https://doi.org/10.2134/jeq1980.00472425000900010019x.

Oregon Department of Environmental Quality. 2006. Chapter 2: Umpqua Basin Bacteria TMDL. In: Umpqua Basin TMDL. Medford, Oregon. http://www.oregon.gov/deq/FilterDocs/umpchpt2bac.pdf.

Pendleton, L. 2010. The economic and market value of coasts and estuaries: what's at stake? (L. Pendleton, Ed.). Virginia: Restore America's Estuaries. http://www.cabdirect.org/abstracts/20103283407.html.

Peterson, J. L., Redmon, L., McFarland, M. L. 2011. Reducing Bacteria with Best Management Practices for Livestock: Heavy Use Area Protection. College Station, TX. https://www.agrilifebookstore.org/Heavy-Use-Area-Protection-p/esp-406.htm.

PRISM Climate Group. 2016. Climatological normals, 1981–2010. The PRISM Group, Oregon State University, Oregon, USA. https://prism.oregonstate.edu/normals/.

Schuster, S., Grismer, M. E. 2004. Evaluation of water quality projects in the Lake Tahoe basin. Environmental Monitoring and Assessment 90 (1–3): 225–242. https://doi.org/10.1023/B:EMAS.0000003591.52435.8d.

Sharpley, A. N., Kleinman, P. J. A., Jordan, P., Bergström, L., Allen, A. L. 2009. Evaluating the Success of Phosphorus Management from Field to Watershed. Journal of Environment Quality 38 (5): 1981. https://doi.org/10.2134/jeq2008.0056.

Sheffield, R. E., Mostaghimi, S., Vaughan, D. H., Collins Jr., E. R., Allen, V. G. 1997. Off-stream water sources for grazing cattle as a stream bank stabilization and water quality BMP. Transactions of the ASABE 40 (3): 595–604. https://elibrary.asabe.org/abstract.asp?aid=21318.

State of Texas. Proposed Amendments to 31 TAC §58.21 and §58.22, Statewide Oyster Fishery Proclamation 2017. https://texashistory.unt.edu/ark:/67531/metapth881328/.

Tate, K. W., Pereira, M. D. G. C., Atwill, E. R. 2004. Efficacy of vegetated buffer strips for retaining *Cryptosporidium parvum*. Journal of Environment Quality 33 (6) 2243–2251. https://doi.org/10.2134/jeq2004.2243.

TCEQ (Texas Commission on Environmental Quality). 2017. Central Registry Request. Accessed March 30, 2017. https://www15.tceq.texas.gov/crpub/index.cfm?fuseaction=home.welcome.

TSHA (Texas State Historical Association). 2010a. Carancahua Bay. Accessed November 20, 2017. https://tshaonline.org/handbook/online/articles/rrc02.

TSHA (Texas State Historical Association). 2010b. Ward, Lafayette. Accessed November 20, 2017. https://tshaonline.org/handbook/online/articles/fwa49.

TWDB (Texas Water Development Board). 2017. 2016 Regional Water Plan Population & Water Demand Projections. http://www.twdb.texas.gov/waterplanning/data/projections/2017/popproj.asp.

Tuppad, P., Santhi, C., Wang, X., Williams, J. R., Srinivasan, R., Gowda, P. H. 2010. Simulation of conservation practices using the APEX model. Applied Engineering in Agriculture 26 (5): 779–794. https://doi.org/10.13031/2013.34947.

USCB (U.S. Census Bureau). 2011. 2010 United States Census Summary. https://data.census.gov/cedsci/.

USCB (U.S. Census Bureau). 2016. 2016 American Community Survey. https://data.census.gov/cedsci/.

USDA NASS (U.S. Department of Agriculture National Agricultural Statistics Service). 2012. 2012 USDA National Agricultural Statistics Service Cropland Data Layer. Accessed November 20, 2017. https://nassgeodata.gmu.edu/CropScape/.

USDA NASS (U.S. Department of Agriculture National Agriculture Statistics Service). 2014. 2012 Census of Agriculture. https://www.agcensus.usda.gov/Publications/2012/.

USDA NRCS (U.S. Department of Agriculture Natural Resource Conservation Service). 2009. Agricultural Waste Characteristics. In: Agricultural Waste Management Field Handbook. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?&cid=stelprdb1045935.

USDA NRCS (U.S. Department of Agriculture Natural Resource Conservation Service). 2017a. Official Soil Series Descriptions. Accessed November 20, 2017. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053587.

USDA NRCS (U.S. Department of Agriculture Natural Resource Conservation Service). 2017b. Web Soil Survey. Accessed November 21, 2017. https://websoilsurvey.nrcs.usda.gov/.

USEPA (U.S. Environmental Protection Agency). 2001. Protocol for Developing Pathogen TMDLs First Edition, (January), 132. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20004QSZ.txt.

USEPA (U.S. Environmental Protection Agency). 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. Washington, DC. https://www.epa.gov/sites/production/files/2015-09/documents/2008_04_18_nps_watershed_handbook_handbook-2.pdf.

USEPA (U.S. Environmental Protection Agency). 2010. Section 319 Nonpoint Source Program Success Story Oklahoma Implementing Best Management Practices Improves Water Quality. Washington, DC. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1006RU2.txt.

USEPA (U.S. Environmental Protection Agency). 2012. Recreational Water Quality Criteria. Recreational Water Quality Criteria. Washington. https://www.epa.gov/wqc/2012-recreational-water-quality-criteria-documents.

USEPA (U.S. Environmental Protection Agency). 2017. Enforcement and Compliance History Online (ECHO). Accessed December 30, 2017. https://echo.epa.gov.

Verhoeven, J. T. A., Arheimer, B., Yin, C., Hefting, M. M. 2006. Regional and global concerns over wetlands and water quality. Trends in Ecology and Evolution 21 (2): 96–103. https://doi.org/10.1016/j.tree.2005.11.015.

Wagner, K., Moench, E. 2009. Education Program for Improved Water Quality in Copano Bay: Task Two Report. College Station, TX: Texas Water Resources Institute. http://twri.tamu.edu/reports/2009/tr347.pdf.

Appendix A: EPA's Nine Elements

The Clean Water Act section 319(h) grant funding program requires watershed protection plan development to follow the "Elements of Successful Watershed Plans" in USEPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (2008) and contain sufficient information on these elements in order to be eligible for implementation funding.

A. Identification of Causes and Sources of Impairment

Identify the causes and sources that need to be controlled to achieve load reductions estimated in the watershed protection plan. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed.

B. Expected Load Reductions

Estimate the load reduction expected for the management measures proposed as part of the watershed protection plan.

C. Proposed Management Measures

Describe the management measures that will need to be implemented to achieve the estimated load reductions (element b) and identify the critical areas where measures are needed to implement the plan.

D. Technical and Financial Assistance Needs

Estimate the technical and financial assistance needed, associated costs and/or the sources and authorities that will be relied upon to implement this plan.

E. Information, Education and Public Participation Component

Describe the information/education component to enhance public understanding and encourage early and continued participation in selecting, designing and implementing the appropriate NPS management measures.

F. Schedule

Provide a schedule for implementing the NPS management measures in the watershed protection plan that is reasonable expeditious.

G. Milestones

Provides a description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented.

H. Load Reduction Evaluation Criteria

Provide a criteria to determine if loading reductions are being achieved over time and progress is being made towards attaining water quality standards and, if not, criteria for determining whether the watershed protection plan needs to be revised.

I. Monitoring Component

A monitoring component to evaluate the implementation effectiveness over time. The monitoring component should include required project-specific needs, the evaluation criteria and local monitoring efforts.

Appendix B: Modified Load Duration Curve

Adams and Hauck (2017) utilize a modified LDC to estimate allowable and existing *Enterococci* loads in Carancahua Bay to support the development of the Carancahua Bay TMDL and the CBWPP. This Appendix summarizes Section 3 of the report, detailing the selection and application of the modified LDC approach. For more detail, we refer readers to the original report.

Model Selection

The bacteria load allocation process involves assigning *Enterococci* loads to various sources such that the total loads do no exceed the primary contact recreation standard (35 MPN/100 mL). Selection of the appropriate method for Carancahua Bay required consideration of available data and other information required to support application of various tools and guidance in the Texas bacteria task force report (Jones et al. 2009).

The LDC method estimates existing and allowable load using cumulative frequency distributions of streamflow and pollutant concentration data (Cleland 2003). The State of Oregon has developed and applied modified LDCs to tidal waters (Oregon Department of Environmental Quality 2006). In addition to estimating loads, the LDC method allows for determination of hydrologic conditions under which impairments are occurring. Further, the bacteria task force appointed by TCEQ and TSSWCB supports application of the LDC method within their three-tiered approach to TMDL development (Jones et al. 2009). The LDC method provides a means to estimate the difference in bacteria loads and relevant criterion and can give indications of broad sources of the bacteria, i.e., point source and NPS.

The decision was made to use the LDC method with modifications to include tidal influences as opposed to a mechanistic watershed loading and hydrologic/water quality model. The decision was based on the following factors: good availability of historical daily streamflow records in adjacent watersheds, discharge information for relevant municipal WWTFs, *Enterococci* and salinity data and water rights diversion data, as well as deficiencies in data to describe bacterial landscape and instream processes. A modification of the LDC method (modified LDC method) developed by State of Oregon Department of Environmental Quality for bacteria TMDLs of tidal streams of the Umpqua River Basin (Oregon Department of Environmental Quality 2006) was adapted to Carancahua Bay.

Data Resources

Streamflow, water diversion, salinity and *Enterococci* data availability were used to provide guidance in the allocation tool selection process. (Salinity data provided a measure of the degree of mixing of seawater and freshwater in the tidal segment.) Hydrologic data in the form of daily streamflow records were unavailable for the Carancahua Bay watershed. However, streamflow records were available for two adjacent watersheds (Tres Palacios and East Mustang Creek) of similar demographic characteristics, e.g., urbanized area and agricultural influences. Streamflow records that were collected and made readily available by the USGS for USGS streamflow gauge 08162600, located within the Tres Palacios watershed, were representative of the Carancahua Bay watershed streamflow at high flow conditions based on preliminary analysis. Likewise, streamflow records at USGS streamflow gauge 08164504, located in the East Mustang Creek watershed, were determined to be more representative of moderate and baseflow conditions in the Carancahua Bay watershed. Thus, streamflow records from both USGS streamflow gauges 08162600 and 08164504 were used in streamflow development in the Carancahua Bay watershed (Table 33, Figure 31).

Self-reported data in the form of monthly discharge reports (DMRs) were available from January 2000 to December 2016 and necessary for streamflow development in the adjacent Tres Palacios Creek watershed (El Campo WWTF). DMR data were downloaded as available from two EPA compliance databases — ECHO and the Integrated Compliance Information System.

Enterococci data were available through the TCEQ SWQMIS for the period of October 2001–August 2016 for station 13388 in Carancahua Bay AU 2456_02 (Table 34), which was the only station in Carancahua Bay with more than 10 *Enterococci* data. During the period of October 2001–August 2016, 87 surface measurements of salinity were also made at station 13388.

Table 33. Basic information on the USGS streamflow gages used for streamflow development within Carancahua Bay.

Gauge No.	Site Description	Drainage Area (acres)	Daily Streamflow Record (beginning and end date)
08162600	Tres Palacios Creek near Midfield, TX	92,800	June 1970–present
08164504	East Mustang Creek near Louise, TX	34,496	October 1996–present

(Adams and Hauck 2017)

Table 34. Summary of historical bacteria and salinity data sets for station 13388.

Assessment Unit	Station	Station Location	Indicator Bacteria	No. of Bacteria Samples	Geometric Mean (MPN/100mL)	No. of Salinity Samples	Data Date Range
2456_02	13388	Carancahua Bay at State Highway 35	*Enterococci*	43	129	87a	October 2001 – August 2016

Most probable number, MPN; milliliter, mL

(Adams and Hauck 2017)

Methodology

LDCs display the maximum allowable load over the complete range of flow conditions by a curved line, using the calculation of flow multiplied by the water quality criterion (35 MPN/100 mL).

Step 1: Determine the hydrologic period of record to be used in developing the flow duration curves (FDCs) and LDCs.

Step 2: Determine desired TCEQ Surface Water Quality Monitoring station location(s) for developing FDCs and LDCs.

Step 3: Develop naturalized freshwater flows for each desired location.

Step 4: Develop regression of salinity to streamflow at each desired location.

Step 5: Develop daily flow records at each desired location using naturalized flows from Step 3, full permitted WWTF discharges, actual water rights diversions and daily tidal volumes.

Step 6: Develop FDC at each desired location and divide into discrete flow regimes.

Step 7: Develop the allowable bacteria LDC at each desired location based on the relevant criteria and the data from the FDC.

Step 8: Superpose historical bacteria data on each allowable bacteria LDC (Figure 32).

For more information regarding developing the Carancahua Bay LDC, we refer readers to Adams and Hauck (2017). For more information regarding developing and interpreting LDCs, we refer readers to Cleland (2003) and Oregon Department of Environmental Quality (2006).

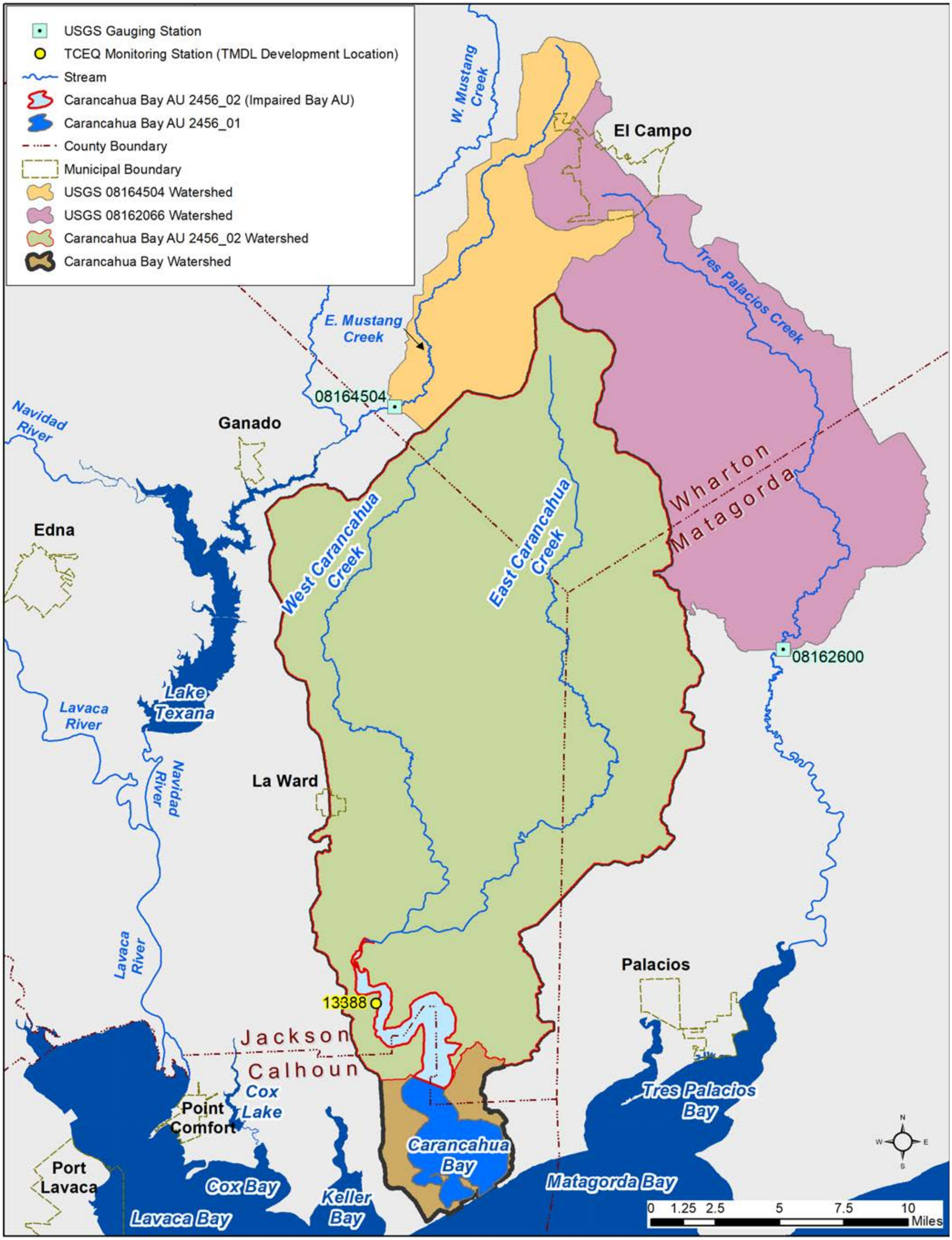


Figure 31. USGS gages used in streamflow development along with LDC development location (station 13388) (Adams and Hauck 2017).

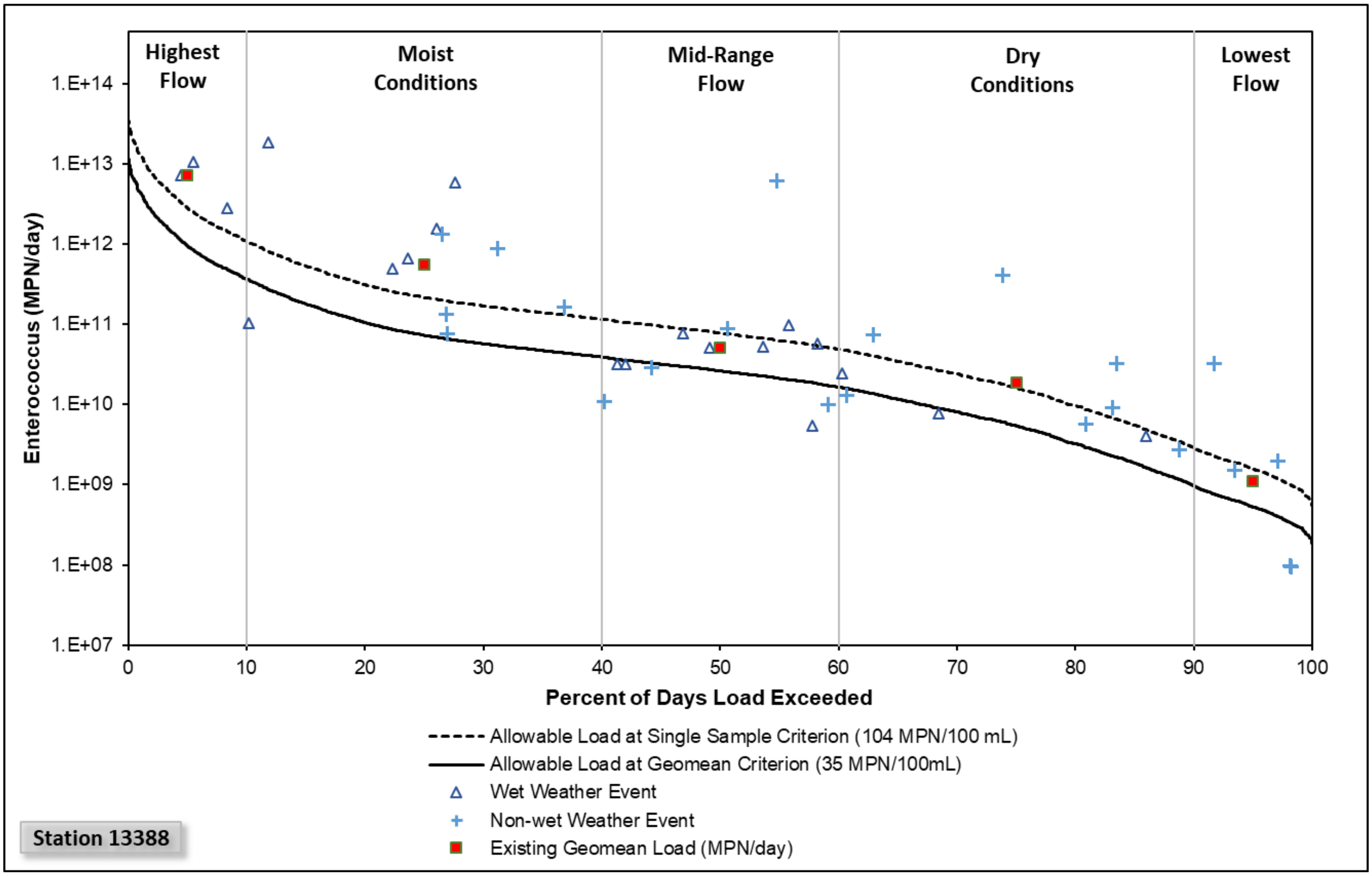


Figure 32. LDC at Station 13388 at Carancahua Bay for January 1, 2002 through December 31, 2016 (Adams and Hauck 2017).

Appendix C: Annual Bacteria Load Reductions

LDCs and measured loads are summarized by range of flows (high, wet, mid-range, dry and low). The generalized loading capacity for each of the five flow categories was computed by using the median daily loading capacity within that flow regime (5%, 25%, 50%, 75% and 95% load exceedances). The required daily load reduction was calculated as the difference between the median loading capacity and the geometric mean of observed *Enterococci* loading within each flow category. To estimate the needed annual bacteria load reductions, the required daily load was multiplied by the number of days per year in each flow condition. Table 35 includes the calculations used to determine annual reductions in each flow condition. The sum of load reductions within each flow condition is the estimated annual load reductions required in the watershed. Table 36 includes the calculated bacteria load reduction values for Carancahua Bay. Different fecal bacteria sources contribute to loadings at different flow regimes. Table 37 provides a generalized flow-based source assessment that indicates the relative importance of potential fecal bacteria sources under different flow conditions.

Table 35. Bacteria load reduction calculations by flow condition.

	Flow Conditions				
	High	**Moist**	**Mid-Range**	**Dry**	**Low**
Days per year	10% × 365	30% × 365	20% × 365	30% × 365	10% × 365
Median Flow (ft^3/s)	Median observed or median estimated flow in each flow category				
Existing Geomean Concentration	Geometric mean of observed *Enterococci* samples in each flow category				
Allowable Daily Load	Median Flow × 35 MPN/100 mL × 283.2 100mL/ft^3 × 86400 s/day				
Allowable Annual Load	Allowable Daily Load × Days/ year				
Existing Daily Load	Median Flow × Existing Geomean Concentration × 283.2 100mL/ ft^3 × 86400 s/day				
Existing Annual Load	Existing Daily Load × Days/year				
Annual Load Reduction Needed	Existing Annual Load – Allowable Annual Load				
Percent Reduction Needed	(Existing Annual Load – Allowable Annual Load)/Allowable Annual Load × 100				
Total Annual Load	Sum of Existing Annual Loads				
Total Annual Load Reduction	Sum of Annual Load Reductions Needed				
Total Percent Reduction	Total Annual Load Reduction/Total Annual Load × 100				

Cubic feet, ft^3; second, s; most probable number, MPN; milliliter, mL

Table 36. Load reduction calculations for Carancahua Bay.

	Flow Conditions				
	High	Moist	Mid-Range	Dry	Low
Days per year	36.5	109.5	73	109.5	36.5
Median Flow (ft^3/s)[1]	1,106.373	85.056	30.417	6.33	0.612
Existing Geomean Concentration (MPN/100 mL)[1]	268	269	68	122	73
Allowable Daily Load (Billion MPN)	947.387	72.83	26.05	5.42	0.52
Allowable Annual Load (Billion MPN)	34,579.626	7,975.26	1,901.36	593.53	19.13
Existing Daily Load (Billion MPN)	7,254.279	559.78	50.60	18.89	1.09
Existing Annual Load (Billion MPN)	264,452.684	61,295.60	3,694.07	2,068.88	39.90
Annual Load Reduction Needed (Billion MPN)	229,873.058	53,320.33	1,792.71	1,475.35	20.77
Percent Reduction Needed	86.94%	86.99%	48.53%	71.31%	52.05%
Total Annual Load (Billion MPN)	331,879.6				
Total Annual Load Reduction (Billion MPN)	286,810.7				
Total Percent Reduction	86.4%				

Cubic feet, ft^3; second, s; most probable number, MPN; milliliter, mL

[1] Median flow and geomean concentrations based on data used in Adams and Hauck (2017).

Table 37. Generalized flow-based source assessment.

Possible Sources	Range of Flow Conditions				
	High	Moist	Mid-Range	Dry	Low
Overland Flow	High	High	Medium		
Sanitary Sewer Overflows	High	Medium	Medium		
Resuspension	High	High	Medium		
Failing/non-existent OSSFs	High	High	Medium	Medium	Medium
Direct Deposition (wildlife, feral hogs, livestock, pets)			Medium	High	High
Illegal Dumping			Medium	Medium	Medium

Appendix D: SELECT and Potential Bacteria Loading Calculations

The SELECT geospatial analysis tool (Borel et al. 2012) was used to estimate potential bacteria loads in the watershed and subwatersheds. This approach estimates potential loads by subwatershed and allows stakeholders to consider results for prioritizing management implementation. This geospatial approach provides an easy method to understand relative contributions and spatial distribution across the watershed without relying on data intense (and expensive) modelling approaches.

The SELECT approach distributes inputs across the watershed based on land use and land cover attributes using Geographic Information Systems. The bacteria loadings are calculated from published bacteria production data. The loadings are then spatially distributed across the watershed based on appropriate land cover.

Agriculture Bacteria Loading Estimates

Cattle populations were estimated across the watershed based on remote-sensed land use data (Homer et al. 2015). Local stakeholders estimate cattle stocking rates at one head per 10 ac of unimproved rangeland and one head per 3 ac on improved pastures.

The assumptions used in this method are documented in Wagner and Moench (2009), Borel et al. (2012) and Borel et al. (2015, Table 38).

Table 38. Bacteria loading assumptions for cattle.

Assumptions	
Acres of unimproved rangeland	34,627.05 ac
Acres of improved pasture	63,100.44 ac
Cattle stocking density on unimproved rangeland	10 ac per animal unit
Cattle stocking density on improved pasture	3 ac per animal unit
Cattle on unimproved range	3,463 animal units
Cattle on improved range	21,033 animal units
Total cattle in the watershed	24,497 animal units
Fecal coliform production rate	8.55×10^{9} cfu/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *Enterococcus* conversion rate	0.175 *Enterococcus* per cfu fecal coliform (Borel et al. 2015)

Acres, ac; colony forming unit, cfu

We then calculate potential daily loadings as:

$$\text{Number of cattle} \times \text{fecal coliform loading rate} \times \text{conversion rate}$$

While cattle are the predominate livestock found throughout the county, some contributions from horses and goats are expected (other livestock are present in the watershed, but population estimates assume these to be extremely minor). The numbers of these livestock were estimated using NASS Agricultural census counts and the ratio of nonurban county land in the watershed to the ratio of nonurban land in the county. Wagner and Moench (2009), Borel et al. (2012) and Borel et al. (2015) document the assumptions used in potential daily load calculations for other livestock (Table 39). Based on these assumptions, potential bacteria load from cattle is 3.67×10^{13} MPN/day *Enterococcus*.

Table 39. Bacteria loading assumptions for other livestock.

Assumptions	
Total number of horses in watershed	380 horses
Total number of goats in watershed	256 goats
Fecal coliform production rate for horses	4.2×10^{8} cfu/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform production rate for goats	1.2×10^{10} cfu/animal-day (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *Enterococcus* conversion rate	0.175 MPN *Enterococcus* per cfu fecal coliform (Borel et al. 2015)

Colony forming unit, cfu; most probable number, MPN

Based on these assumptions and using the same calculation to estimate potential loading used for cattle, the daily potential load from horses is 2.79×10^{10} MPN/day *Enterococcus* and from goats is 5.38×10^{11} MPN/day *Enterococcus*.

Collectively, we estimated the potential loading across the watershed from livestock as 3.72×10^{13} MPN/day *Enterococcus*.

Household Pet Bacteria Loading Estimates

The dog and cat population in the watershed was estimated using American Veterinary Medical Association statistics for average number of dogs and cats per household and an estimate of number of households derived from Census block data. The potential bacteria load from household pets is:

(Number of dogs × dog fecal coliform loading rate) + (Number of cats × cat fecal coliform loading rate) × conversion rate

Using the assumptions listed in Table 40, the daily potential bacteria load from household pets is 1.72×1012 MPN/day *Enterococcus*.

Table 40. Bacteria loadings assumptions for household pets.

Assumptions	
Average dogs per home	0.584 dogs (AVMA 2012)
Average cats per home	0.638 cats (AVMA 2012)
Number of homes	1,605 homes
Estimated number of dogs	937 dogs
Estimated number of cats	1,024 cats
Fecal coliform production rate for dogs	5.00×10^{9} cfu per dog per day (Borel et al. 2012; USEPA 2001)
Fecal coliform production rate for cats	5.00×10^{9} cfu per cat per day (USEPA 2001)
Fecal coliform to *Enterococcus* conversion rate	0.175 *Enterococcus* per cfu fecal coliform

Colony forming unit, cfu

OSSF Bacteria Loading Estimates

OSSF locations in the watershed were estimated with visually validated 911 address data. Nearly all the OSSFs occur on soils with an expected failure rate of 15%. Loadings were calculated using SELECT with the assumptions outlined in Table 41. Different numbers of people per household were assigned to different subwatersheds based on available census block data, stakeholder input and knowledge that absentee homeowners are common in subwatershed 6. The watershed wide calculations are estimated with:

Number of OSSFs × failure rate × average people per household × fecal coliform production rate × conversion rate

Daily potential loads across the watershed from OSSFs were estimated as 1.29×10^{12} MPN/day.

Table 41. Bacteria loadings assumptions for OSSFs.

Assumptions	
Subwatershed 1 Number of OSSFs	102
Subwatershed 2 Number of OSSFs	188
Subwatershed 3 Number of OSSFs	29
Subwatershed 4 Number of OSSFs	50
Subwatershed 5 Number of OSSFs	184
Subwatershed 6 Number of OSSFs	836
Failure rate	15% (USDA NRCS 2017b)
Subwatershed 1 Average number of people per household	2.12 (USCB 2016)
Subwatershed 2 Average number of people per household	2.19 (USCB 2016)
Subwatershed 3 Average number of people per household	2.07 (USCB 2016)
Subwatershed 4 Average number of people per household	2.19 USCB 2016)
Subwatershed 5 Average number of people per household	1.9 (USCB 2016)
Subwatershed 6 Average number of people per household	0.84 (USCB 2016)
Fecal coliform production rate	2.65×10^{10} cfu per person per day (Borel et al. 2012; Metcalf and Eddy Inc. 1991)
Fecal coliform to *Enterococcus* conversion rate	0.175 MPN *Enterococcus* per cfu fecal coliform

On-site sewage facility, OSSF; colony forming unit, cfu; most probable number, MPN

Feral Hog and Wildlife Bacteria Loading Estimates

Feral hog populations were estimated based on an assumed population density of 33.3 ac/hog (Wagner and Moench 2009) and 182,144 ac of available habitat identified in the NLCD. Potential bacteria loadings from feral hogs were estimated using SELECT and the assumptions in Table 42. The potential loading calculation for potential loadings from feral hogs is:

Number of feral hogs × fecal coliform loading rate × conversion rate

The daily potential bacteria load from feral hogs is 1.56×10^{11} MPN/day.

Table 42. Bacteria loading assumptions for feral hogs.

Assumptions	
Number of feral hogs in the watershed	5,936 feral hogs
Fecal coliform production rate for feral hogs	1.51×10^{8} cfu fecal coliform per animal (Borel et al. 2015; Wagner and Moench 2009)
Fecal coliform to *Enterococcus* conversion rate	0.175

Colony forming unit, cfu

White-tailed deer populations were estimated from an assumed population density of 38.4 deer per 1,000 ac of suitable habitat (data provided per communication with TPWD). Potential bacteria loadings were estimated using SELECT and the assumptions in Table 43. The potential bacteria loading calculation for white-tailed deer is:

Number of white-tailed deer × fecal coliform loading rate × conversion rate

The daily potential bacteria load from white-tailed deer is 4.85×10^{11} MPN/day.

Table 43. Bacteria loading assumptions for white-tailed deer.

Assumptions	
Number of white-tailed deer in the watershed	7,924 deer
Fecal coliform production rate for white-tailed deer	3.5×10^8 cfu fecal coliform per animal (Borel et al. 2012; Wagner and Moench 2009)
Fecal coliform to *Enterococcus* conversion rate	0.175

Colony forming unit, cfu

WWTP Bacteria Loading Estimate

Currently, two permitted WWTPs operate in the watershed. Both are permitted to discharge wastewater effluent from treated household sewage and are required to monitor bacteria levels in their discharge. We estimated bacteria loads at a worst-case scenario of full permitted discharge at 35 MPN/100mL *Enterococcus* (Table 44). Potential bacteria loading was estimated as:

$$\text{Maximum permitted discharge} \times \text{bacteria concentration} \times \text{conversion rate}$$

The daily potential bacteria load from WWTPs is 9.67×10^7 MPN/day.

Table 44. Bacteria loading assumptions for WWTFs.

Assumptions	
Treated wastewater effluent discharged per day	49,000 gallons per day (USEPA 2017)
Enterococcus concentration of effluent	35 MPN/100mL
Volumetric conversion	3,785.2 mL/Gallon

Gallon, gal; most probable number, MPN, milliliter, mL

Appendix E: Calculations for Potential Bacteria Load Reductions

Estimates for bacteria load reductions in the CBWPP are based on the best available information regarding the effectiveness of management measures agreed upon by local stakeholders. Real world conditions based on where implementation is completed will ultimately determine the actual load reduction achieved and might differ from estimated values. Local stakeholders determined the types and numbers of management measures to be implemented over a 10-year period based on perceived local acceptability, effectiveness and available resources.

Agricultural Nonpoint Source Load Reductions

The potential load reductions that are achieved through conservation planning will depend on the specific management practices implemented by landowners. The load reduction will vary based on the type of practice, existing land condition, number of cattle in each operation and proximity to water bodies. Substantial research has been conducted on bacteria reduction efficiencies of practices. We reviewed literature to assess the median effectiveness of practices likely to be used in the watershed (Table 45) and used a mean 62.8% load reduction effectiveness rate for conservation planning. Assumptions used in bacteria load reduction calculations are provided in Table 46.

Table 45. Conservation practice effectiveness in reducing bacteria loads.

Effectiveness			
Conservation Practice	**Low**	**High**	**Median**
Exclusionary Fencing[10]	30%	94%	62%
Prescribed Grazing[11]	42%	66%	54%
Watering Facility[12]	51%	94%	73%

[10] Includes the following sources: (Brenner et al. 1996; Cook, 1998; Hagedorn et al. 1999; Line 2002, 2003; Lombardo et al. 2000; Meals 2001; Peterson et al. 2011)

[11] Includes the following sources: (Tate et al. 2004; USEPA 2010)

[12] Includes the following sources: (Byers et al. 2005; Hagedorn et al. 1999; Sheffield et al. 1997)

Table 46. Bacteria load reduction assumptions for livestock.

Assumptions	
Number of operations in the watershed	235
Head of cattle per operation	104
Fecal coliform production rate for cattle	8.55×10^9 cfu per animal unit per day
Fecal coliform to *Enterococcus* conversion rate	0.175
Conservation practice effectiveness rate	62.8%
Proximity factor	25%

Colony forming unit, cfu

Potential bacteria load reductions for livestock management measures were calculated based on the assumed average number of cattle per operation, average fecal coliform production rates, standard conversions, conservation practice effectiveness and proximity factor of practice to water body. The proximity factor is an estimated impact factor that accounts of an assumed stream impact factor based on the location of a practice to the stream. Practices closer to the stream are assumed to have a higher potential load reduction impact while those further away are assumed to have a lower impact. Since actual practices and locations are unknown and proximity factor of 25% was assumed, similar to proximity factors used in nearby watershed protection plans.

Using the above assumptions, the potential daily load reduction was estimated by:

Number of plans × cattle per plan × fecal coliform loading rate × conversion factor × median effectiveness × proximity factor

Based on an assumed 70 plans, we estimate a potential load reduction of 1.72×10^{12} MPN/day or 6.26×10^{14} MPN/year.

OSSF Load Reductions

Table 47. Bacteria load reduction assumptions for OSSFs.

Assumptions	
Persons per household	1.36
Fecal coliform concentration	1×10^{6} cfu/100mL
Gallons of sewage per person per day	70
Milliliters per Gallon	3,785.2 mL/gal
Fecal coliform to *Enterococcus* conversion rate	0.175

Colony forming unit, cfu; milliliter, mL; gallon, gal

Potential load reductions from OSSF replacement assume that replacement of a faulty OSSF will bacteria loadings from the failed system. Therefore, the bacteria load reduction attributed to OSSF repair and replacement is calculated as:

Number of OSSFs replaced × average people per household × fecal coliform concentration × gal of sewage produced per person per day × mL per gal × conversion rate

Table 47 includes the assumption values used in the calculation. The average number of people per household across the watershed was calculated from U.S. Census data (this assumption differs slightly from the load calculation used in SELECT because of different spatial resolutions used).

Based on the replacement of 42 OSSF systems, we estimated a 9.60×10^{12} MPN/year load reduction across the watershed.

Feral Hog Load Reductions

The potential load reduction for feral hog management depends on the direct reduction of feral hog populations within the watershed. The load reduction was calculated based on a goal of reducing and maintaining the population of feral hogs by 15% annually or a reduction of 890 feral hogs in the watershed. Assumptions are listed in Table 48.

The potential load reduction calculation from feral hogs is:

Removed feral hogs × fecal coliform loading rate × conversion rate

The potential load reduction from feral hogs is 2.35×10^{10} MPN/day or 8.58×10^{12} MPN/year.

Table 48. Bacteria loading assumptions for feral hogs.

Assumptions	
Number of feral hogs removed relative to current watershed population	890 feral hogs
Fecal coliform production rate for feral hogs	1.51×10^{8} cfu/animal-day
Fecal coliform to *Enterococcus* conversion rate	0.175

Colony forming unit, cfu

Household Pet Load Reductions

Potential load reductions for pet waste depend on the number of pets that contribute loading and the amount of pet waste that is picked up and disposed of properly. Assessing the number of dog owners who do not pick up waste or who would change behavior based on education or availability of pet waste stations is inherently difficult. It is estimated that 12% of dogs in the watershed will have their waste picked up and disposed of (Center for Watershed Protection 1999). Load reduction assumptions are listed in Table 49.

Dogs in watershed × percent of dogs managed × fecal coliform loading rate × conversion rate × practice efficiency

The potential load reduction from dogs is 7.38×10^{10} MPN/day or 2.69×10^{13} MPN/year

Table 49. Bacteria loading assumptions for dogs.

Assumptions	
Number of dogs in the watershed	937 dogs
Percent of dogs managed	12%
Fecal coliform production rate for feral hogs	5.0×10^9 cfu/animal-day
Fecal coliform to *Enterococcus* conversion rate	0.175
Practice efficiency	75%

Colony forming unit, cfu

Appendix F: Calculations for Potential Nutrient Load Reductions

Agricultural Nonpoint Source Nutrient Load Reductions

The potential load reduction that can be achieved by implementing conservation practices will depend on the specific BMPs implemented by each landowner, the number of cattle in each operation, existing practices and existing land condition.

Table 50. Conservation practice effectiveness.

Conservation Practice	Median Nitrogen Reduction Effectiveness	Median Phosphorus Reduction Effectiveness
Exclusionary Fencing	33% (Line et al. 2000)	49% (Flores-Lopez et al. 2010; Kay et al. 2009; Line et al. 2000, 2016; Sharpley et al. 2009)
Prescribed Grazing	55% (Chesapeake Bay Program 2017; Olness et al. 1980; Tuppad et al. 2010)	41% (Chesapeake Bay Program 2017; Olness et al. 1980; Sharpley et al. 2009; Tuppad et al. 2010)
Watering Facility	5% (Byers et al. 2005; Chesapeake Bay Program 2017)	57% (Byers et al. 2005; Kay et al. 2009; Sheffield et al. 1997)

Table 51. Nutrient load reduction assumptions for livestock.

Assumptions	
Number of operations in the watershed	235
Head of cattle per operation	104
Pounds of nitrogen per day	0.31 lbs nitrogen/animal-day (USDA NRCS 2009)
Pounds of phosphorus per day	0.11 lbs phosphorus/animal-day (USDA NRCS 2009)
Conservation practice effectiveness rate – nitrogen	33%
Conservation practice effectiveness rate – phosphorus	49%
Proximity factor	25%

Pounds, lbs

The total potential load reduction will be strongly influenced by the number of ranchers participating and the number of cattle impacted. Specific load reduction estimates are simply estimates that will strongly depend on the specific management practices implemented. Based on NASS data for all four counties we estimated that there are 235 farms within the watershed (USDA NASS 2014). Using the estimated 24,496 cattle in the watershed, there are an estimated 104 head/farm. Because it is difficult to predict which practices farmers will implement, the average of the Effectiveness Medians was taken to approximate the effectiveness of any management measure taken (Table 50). Daily potential nitrogen load reductions expected from cattle management practices was estimated with:

$$\text{Number of plans} \times \text{cattle per plan} \times \text{lbs of nitrogen per animal per day} \times \text{median effectiveness} \times \text{proximity factor}$$

Daily potential phosphorus load reductions expected from cattle management practices was estimated with:

$$\text{Number of plans} \times \text{cattle per plan} \times \text{lbs of phosphorus per animal per day} \times \text{median effectiveness} \times \text{proximity factor}$$

Based on the above assumptions in listed Table 51 and above equations, the total potential nitrogen load reduction from implementation of 70 conservation plans is estimated at 6.80×10^4 lbs of nitrogen per year. The total potential phosphorus load reduction from implementation of 70 conservation plans is estimated 3.58×10^4 lbs of phosphorus per year.

OSSF Nutrient Load Reductions

Total load reductions from the replacement of failing OSSF systems depend on the amount of effluent discharged by the system and proximity of the system to a water body. Because these actual values are not known before identification and replacement of a failing OSSF, approximate values are used to identify potential load reductions. For load reduction calculations, 1.36 people per household, a discharge rate of 70 gal/person day^{-1} and nutrient concentrations of 40 mg nitrogen/L and 10 mg phosphorus/L were assumed (Table 52, Davis and Cornwell 1991).

Table 52. Nutrient load reduction assumptions for OSSFs.

Assumptions	
Persons per household	1.36
Milligrams of nitrogen per liter	40 mg of nitrogen/L
Milligrams of phosphorus per liter	10 mg of phosphorus/L
Gallons of sewage per person per day	70
Pounds per milligram	2.2×10^{-6} lbs/mg
Liters per gallon	3.79 L/gal

Milligram, mg; liter, L; pounds, lbs; gallon, gal

The potential nitrogen load reductions from OSSFs can be calculated as:

Number of OSSFs replaced × average people per household × mg of nitrogen per L × gallons of sewage produced per person per day × lbs per mg × L per gal

The potential phosphorus load reductions from OSSFs can be calculated as:

Number of OSSFs replaced × average people per household × mg of phosphorus per L × gal of sewage produced per person per day × lbs per mg × L per gal

Assuming 42 failing OSSFs are replaced after 10 years, the potential nitrogen load reduction is 1.33 lbs of nitrogen per day or 4.87×10^{2} lbs of nitrogen per year. The potential phosphorus reduction is 0.33 lbs of phosphorus per day or 1.22×10^{2} lbs of phosphorus per year.

Feral Hog Nutrient Load Reductions

The potential load reductions for feral hog management depend on how much the population can be directly reduced. Load reductions were calculated based on the number of hogs removed annually. Therefore, the same equations to calculate daily loading were used.

The potential nitrogen load reduction calculation from feral hogs is:

Removed feral hogs × pounds of nitrogen per animal per day × animal units per feral hog

The potential phosphorus load reduction calculation from feral hogs is:

Removed feral hogs × pounds of phosphorus per animal per day × animal units per feral hog

Table 53. Nutrient loading assumptions for feral hogs.

Assumptions	
Number of feral hogs removed relative to current watershed population	890 feral hogs
Pounds of nitrogen per animal per day	0.14 lbs of nitrogen/animal-day (USDA NRCS 2009)
Pounds of phosphorus per animal per day	0.05 lbs of phosphorus/animal-day (USDA NRCS 2009)
Animal units per feral hog	0.125

Pounds, lbs

Using the assumptions in Table 53, reducing the feral hog population by approximately 15% would be the equivalent of removing 890 feral hogs from the watershed per year. This equates a nitrogen load reduction of 15.6 lbs of nitrogen per day or 5.68×10^3 lbs of nitrogen per year. The potential phosphorus reduction is 5.56 lbs of phosphorus per day or 2.03×103 lbs of phosphorus per year.

Household Pet Load Reductions

Potential load reductions for household animal waste depends on the number of pets that contribute loading and the amount of pet waste that is picked up and disposed of properly. Assessing the number of pet owners who do not pick up pet waste or who would change behavior based on education or availability of pet waste stations is inherently difficult. It is estimated that 12% of dogs in the watershed will have their waste picked up and disposed of (Center for Watershed Protection 1999).

Table 54. Nutrient loading assumptions for dogs.

Assumptions	
Number of dogs in the watershed	937 dogs
Percent of dogs managed	12%
Grams of nitrogen per day	1.3 grams of nitrogen/day (Schuster and Grismer 2004)
Grams of phosphorus per day	0.3 grams of phosphorus/day (Schuster and Grismer 2004)
Pounds per gram	2.2×10^3 lbs/gram
Practice efficiency	75%

Pounds, lbs

The potential nitrogen load reduction calculation from dogs is:

Dogs in watershed × percent of dogs managed × grams of nitrogen per day × lbs per gram × practice efficiency

The potential phosphorus load reduction calculation from dogs is:

Dogs in watershed × percent of dogs managed × grams of phosphorus per day × lbs per gram × practice efficiency

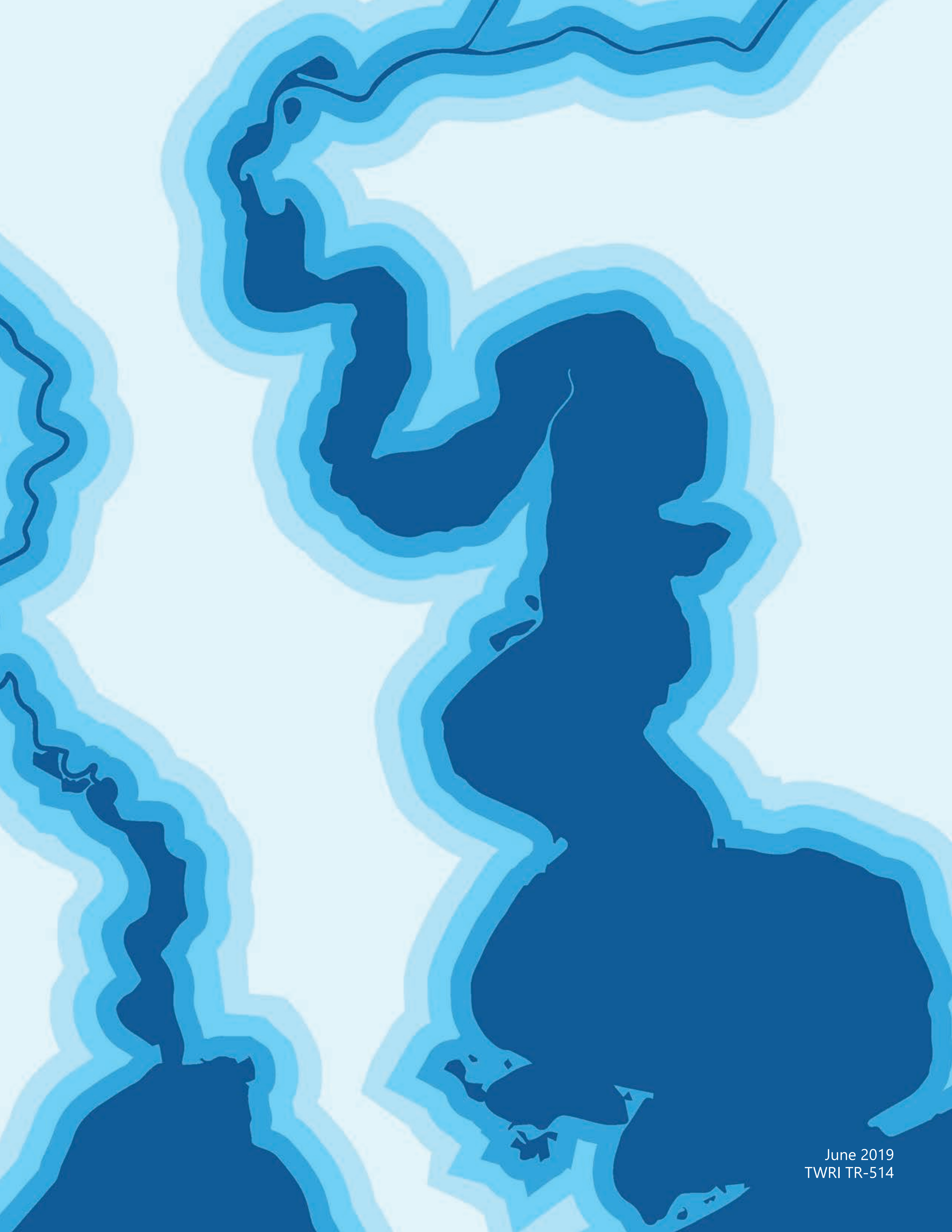
Using the assumptions listed in Table 54, potential nitrogen load reductions are estimated at 0.24 lbs of nitrogen per day or 88.2 lbs of nitrogen per year. Phosphorus load reductions are estimated at 0.06 lbs of phosphorus per day or 20.4 lbs of phosphorus per year.

Appendix G: EPA's Nine Elements Review Checklist

Name of Water Body	Carancahua Bay
Assessment Units	2456_01, 2456_02 and 2456A_01
Impairments Addressed	Indicator Bacteria (2456_02), Dissolved Oxygen (2456A_01)
Concerns Addressed	Total Phosphorus (2456_02), Chlorophyll-a (2456_02, 2456A_01), Dissolved Oxygen Grab (2456A_01)

Element	Report Section(s) and Page Number(s)
Element A: Identification of Causes and Sources	
1. Sources identified, described and mapped	Chapter 2 (Potential Point Sources), page 13; Chapter 2 (Potential Nonpoint Sources), page15; Chapter 4 (Load Duration Curve Analysis) page 30; Chapter 4 (Spatially Explicit Load Enrichment Calculation Tool), page 33
2. Subwatershed sources	Chapter 4 (Spatially Explicit Load Enrichment Calculation Tool), page 33
3. Data sources are accurate and verifiable	Chapter 2 (Potential Point Sources), page 13; Chapter 2 (Potential Nonpoint Sources), page15; Chapter 4 (Spatially Explicit Load Enrichment Calculation Tool), page 33; References, page 62; Appendix B, page 67; Appendix D. page 73
4. Data gaps identified	Chapter 6 (Water Quality Monitoring), page 50
Element B: Expected Load Reductions	
1. Load reductions achieve environmental goal	Chapter 4 (Load Duration Curve Analysis) page 30; Chapter 5 (Estimated Load Reductions), page 49; Appendix C, page 71
2. Load reductions linked to sources	Chapter 4 (Load Duration Curve Analysis) page 30
3. Model complexity is appropriate	Chapter 4 (Load Duration Curve Analysis) page 30; Appendix B – Modified Load Duration Curve, pg. 100
4. Basis of effectiveness estimates explained	Appendix E, page 77; Appendix F, page 80
5. Methods and data cited and verifiable	References, page 62; Appendix B, page 67; Appendix E, page 77; Appendix F, page 80
Element C: Management Measures Identified	
1. Specific management measures are identified	Chapter 5 (Management Measures), page 41
2. Priority areas	Chapter 4 (Spatially Explicit Load Enrichment Calculation Tool), page 33; Chapter 5 (Management Measures), page 41
3. Measure selection rationale documented	Chapter 5 (Introduction), page 40

Element	Report Section(s) and Page Number(s)
4. Technically sound	Chapter 5, page 40; Appendix E, page 77; Appendix F, page 80
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	Chapter 7 (Technical Assistance), page 54
2. Estimate of financial assistance	Chapter 6 (Implementation Schedule), page 51; Chapter 7 (Financial Assistance), page 56
Element E: Education/Outreach	
1. Public education/information	Chapter 6 (Watershed Coordinator), page 50; Chapter 6 (Education and Outreach), page 51
2. All relevant stakeholders are identified in outreach process	Chapter 6 (Education and Outreach), page 51
3. Stakeholder outreach	Chapter 6 (Watershed Coordinator), page 50
4. Public participation in plan development	Chapter 1 (Public Participation), page 5
5. Emphasis on achieving water quality standards	Chapter 8 (Water Quality Goals and Targets), page 59
6. Operation and maintenance of BMPs	Chapter 6 (Operation and Maintenance), page 51
Element F: Implementation Schedule	
1. Includes completion dates	Chapter 6 (Implementation Schedule), page 51
2. Schedule is appropriate	Chapter 6 (Implementation Schedule), page 51
Element G: Milestones	
1. Milestones are measurable and attainable	Chapter 8 (Project Milestones), page 61
2. Milestones include completion dates	Chapter 8 (Project Milestones), page 61
3. Progress evaluation and course correction	Chapter 8 (Adaptive Management), page 61
4. Milestones linked to schedule	Chapter 6 (Implementation Schedule), page 51; Chapter 8 (Project Milestones), page 61
Element H: Load Reduction Criteria	
1. Criteria are measurable and quantifiable	Chapter 8 (Water Quality Goals and Targets), page 59
2. Criteria measure progress toward load reduction goal	Chapter 8 (Water Quality Goals and Targets), page 59
3. Data and models identified	Chapter 8 (Data Review), page 60
4. Target achievement dates for reduction	Chapter 8 (Water Quality Goals and Targets), page 59
5. Review of progress toward goals	Chapter 8 (Data Review), page 60
6. Criteria for revision	Chapter 8 (Adaptive Management), page 61
7. Adaptive management	Chapter 8 (Adaptive Management), page 61
Element I: Monitoring	
1. Description of how monitoring used to evaluate implementation	Chapter 6 (Water Quality Monitoring), page 50); Chapter 8 (Data Review), page 60
2. Monitoring measures evaluation criteria	Chapter 8 (Water Quality Goals and Targets), page 59
3. Routine reporting of progress and methods	Chapter 8 (Data Review), page 60
4. Parameters are appropriate	Chapter 6 (Water Quality Monitoring), page 50
5. Number of sites is adequate	Chapter 6 (Water Quality Monitoring), page 50
6. Frequency of sampling is adequate	Chapter 6 (Water Quality Monitoring), page 50
7. Monitoring tied to quality assurance project plan	Chapter 6 (Water Quality Monitoring), page 50
8. Can link implementation to improved water quality	Chapter 9 (Measuring Success), page 59



June 2019
TWRI TR-514