Technical Support Document for a Total Maximum Daily Load for Indicator Bacteria in Martinez Creek

Segment 1911I

Assessment Unit 1911I _01

Martínez Creek – Westside Creeks Restoration Project. (2019). Retrieved July 18, 2019, from https://www.westsidecreeks.com/about-the-creeks/martinez-creek/

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Segment: 1911I

Assessment Unit: 1911I _01

Prepared for
Total Maximum Daily Load Program
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List of Acronyms and Abbreviations

AU	assessment unit
BCPW	Bexar County Public Works
cfs	cubic feet per second
cfu	colony forming units
DAR	drainage-area ratio
E. coli	Escherichia coli
EPA	U.S. Environmental Protection Agency
FDC	flow duration curve
FG	future growth
FIB	fecal indicator bacteria
GIS	Geographic Information System
I&I	inflow and infiltration
I-Plan	implementation plan
LA	load allocation
LDC	load duration curve
MCM	minimum control measure
MGD	million gallons per day
mL	milliliter
MOS	margin of safety
MRLC	Multi-Resolution Land Characteristics (consortium)
MS4	municipal separate storm sewer system
NEIWPCC	New England Interstate Water Pollution Control Commission
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
OSSF	on-site sewage facility
SAWS	San Antonio Water System
SSO	sanitary sewer overflow
SWMP	stormwater management program
SWQM	surface water quality monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TIAER	Texas Institute for Applied Environmental Research
TMDL	total maximum daily load
TPDES	Texas Pollutant Discharge Elimination System
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
USCB	U.S. Census Bureau
USGS	U.S. Geological Survey
WLA	wasteload allocation
WUG	water user group
WWTF	wastewater treatment facility

Section 1
INTRODUCTION

1.1 Background

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

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

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

The TCEQ identified the bacteria impairment within Martinez Creek in the 2014 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d) (TCEQ, 2015a) and also in the Draft 2016 Texas Integrated Report for the Clean Water Act Sections 305(b) and 303(d) (TCEQ, 2018), which in this document will be referred to as the 2014 Integrated Report and Draft 2016 Integrated Report.

This document will consider a bacteria impairment in the downstream assessment unit (AU) within the segment: 1911I_01.

1.2 Water Quality Standards

To protect public health, aquatic life, and development of industries and economies throughout Texas, water quality standards were established by the TCEQ. The water quality standards describe the limits for indicators which are monitored in an effort to assess the quality of available water for specific users. The TCEQ is charged with monitoring and assessing water bodies based on these water quality standards, and publishes the Texas Water Quality Integrated Report list biennially.

The Texas Surface Water Quality Standards (TCEQ, 2010) are rules that:

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

Standards are established to protect designated uses assigned to water bodies of which the primary uses assigned in the Texas Surface Water Quality Standards to water bodies are:

- aquatic life use
- contact recreation
- domestic water supply
- general use

Fecal indicator bacteria (FIB) are used to assess the risk of illness during contact recreation (e.g., swimming) from ingestion of water. FIB are present in the intestinal tracts of humans and other warm-blooded animals. The presence of these bacteria in water indicates that associated pathogens from the wastes that may be reaching water bodies as a result of such sources as inadequately treated sewage, improperly managed animal waste from livestock, pets, aquatic birds, wildlife, and failing septic systems (TCEQ, 2006b). *Escherichia coli* (*E. coli*) is a member of the fecal coliform bacteria group and is used in the State of Texas as the FIB in freshwater.

On June 30, 2010, the TCEQ adopted revisions to the Texas Surface Water Quality Standards (TCEQ, 2010) and on June 29, 2011, the U.S. Environmental Protection Agency (USEPA) approved the categorical levels of recreational use and their associated criteria. Recreational use consists of four categories:

- Primary contact recreation is that with a significant risk of ingestion of water (such as swimming), and has a geometric mean criterion for *E. coli* of 126 colony forming units(cfu) per 100 milliliter (mL) and an additional single sample criterion of 399 cfu per 100 mL;
- Secondary contact recreation 1 covers activities with limited body contact and a less significant risk of ingestion of water (such as fishing), and has a geometric mean criterion for *E. coli* of 630 cfu per 100 mL;
- Secondary contact recreation 2 is similar to secondary contact 1, but activities occur less frequently. It has a geometric mean criterion for *E. coli* of 1,030 cfu per 100 mL; and
- Noncontact recreation is that with no significant risk of ingestion of water, where contact recreation should not occur due to unsafe conditions. It has a geometric mean criterion for *E. coli* of 2,060 cfu per 100 mL (TCEQ, 2010).

Martinez Creek is presumed for primary contact recreation and has the associated *E. coli* geometric mean criterion of a 126 cfu per 100 mL and single sample criterion of 399 cfu per 100 mL.

1.3 Report Purpose and Organization

The Martinez Creek TMDL project was initiated through a contract between the TCEQ and Texas Institute for Applied Environmental Research (TIAER). This project is considered to be an addendum to the existing bacteria TMDL (*Three TMDLs for Indicator Bacteria in the San Antonio Area)* (TCEQ, 2007). The existing TMDL was adopted by the TCEQ on July 25, 2007, and approved by EPA on September 25, 2007. Addendum One to these three TMDLs was completed April 2016 and was approved by EPA on August 9, 2016 (TCEQ, 2016a) through a Water Quality Management Plan update. Therefore, this will be the second TMDL addendum.

Figure 1 shows the Martinez Creek watershed within the area of the Upper San Antonio River watershed from the original TMDL project . The tasks of this project were to (1) develop, have approved, and adhere to a quality assurance project plan; (2) develop a technical support document for the impaired watershed; and (3) assist the TCEQ with public participation. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDL for the impaired watershed of Martinez Creek. This report contains:

- information on historical data,
- watershed properties and characteristics,
- summary of historical bacteria data that confirm the State of Texas 303(d) listings of impairment due to the presence of indicator bacteria (*E. coli*),
- development of a load duration curve (LDC), and
- application of the LDC approach for the pollutant load allocation process.

Whenever it was feasible, the data development and computations for developing the LDC and pollutant load allocation were performed in a manner to remain consistent with Addendum One to the *Three TMDLs for Indicator Bacteria in the San Antonio Area*.

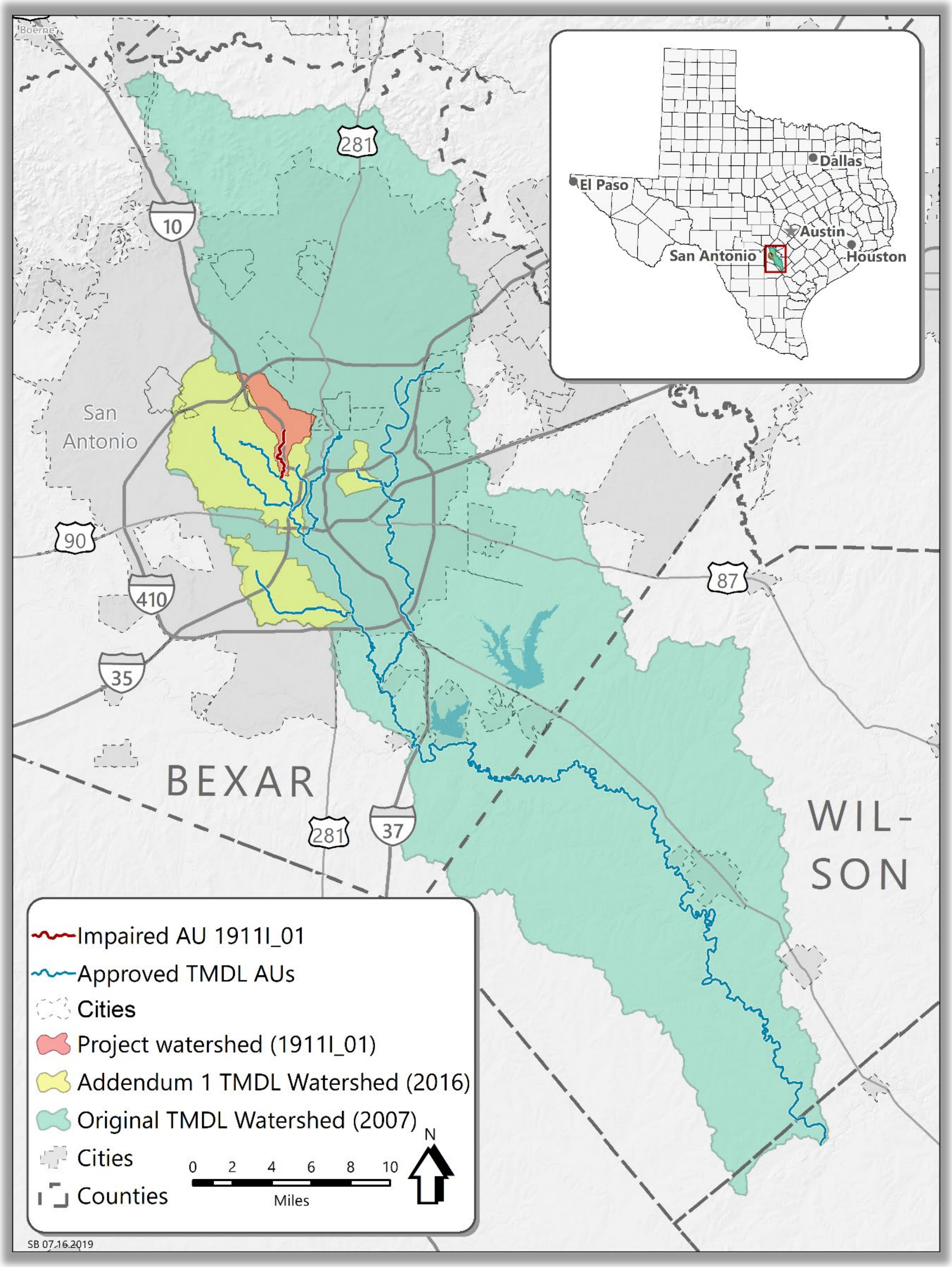

Figure 1. Map showing the TMDL and addendum watersheds.

Section 2
HISTORICAL DATA REVIEW AND WATERSHED PROPERTIES

2.1 Description of the Study Area

Martinez Creek (Segment 1911I) is a tributary of the Upper San Antonio River (Segment 1911). Martinez Creek is an unclassified, freshwater stream composed of two AUs – the downstream AU (1911I_01) has a flow type of "Intermittent with pools"; the upstream AU (1911I_02) has a flow type of "Intermittent" (TCEQ, 2018). Martinez Creek (Segment 1911I) flows into Alazan Creek (1911C) in San Antonio and is approximately 6 miles in length. At its mouth, Martinez Creek drains an area of 7.29 square miles in Bexar County. Martinez Creek is located within the San Antonio city limits and is largely channelized within concrete banks.

The Draft 2016 Texas Integrated Report (TCEQ, 2018) provides the following segment and AU descriptions for Martinez Creek:

- Segment 1911I (Martinez Creek) – Martinez Creek from the confluence of Alazan Creek in central San Antonio upstream to the terminus at Vance Jackson Rd in north San Antonio
  - 1911I_01 – Martinez Creek from the confluence of Alazon Creek in central San Antonio upstream to the concrete channel portion at San Francisco St in north San Antonio
  - 1911I_02 – Martinez Creek from the concrete channel portion at San Fransico St upstream to the terminus at Vance Jackson Rd in north San Antonio

Using a watershed based approach and because the impaired AU 1911I_01 is downstream of non-impaired AU 1911I_02, the entire watershed of Martinez Creek will be considered in this report.

2.2 Watershed Climate

The Martinez Creek watershed is located within the central portion of Texas, classified as the Subtropical Subhumid climate region(Larkin & Bomar, 1983). As in much of the state, the region's subtropical climate is caused by the "predominant onshore flow of tropical maritime air from the Gulf of Mexico," while the increasing moisture content (from west to east) reflects variations in "intermittent seasonal intrusions of continental air" (Larkin & Bomar, 1983).

Climate data from 2004 through 2018 for the San Antonio International Airport weather station (USW00012921) indicate a bimodal precipitation pattern (Figure 3) (NOAA, 2019a). Annual rainfall in the San Antonio area averages 32.4 inches. The wettest months are typically May and September (4.5 and 4.6 inches) while February and August (1.6 and 2.0 inches) are normally the driest months (NOAA, 2019b). Average high temperatures generally reach their peak of 96° F in August, while the average low temperature bottoms out at 41° F in January.

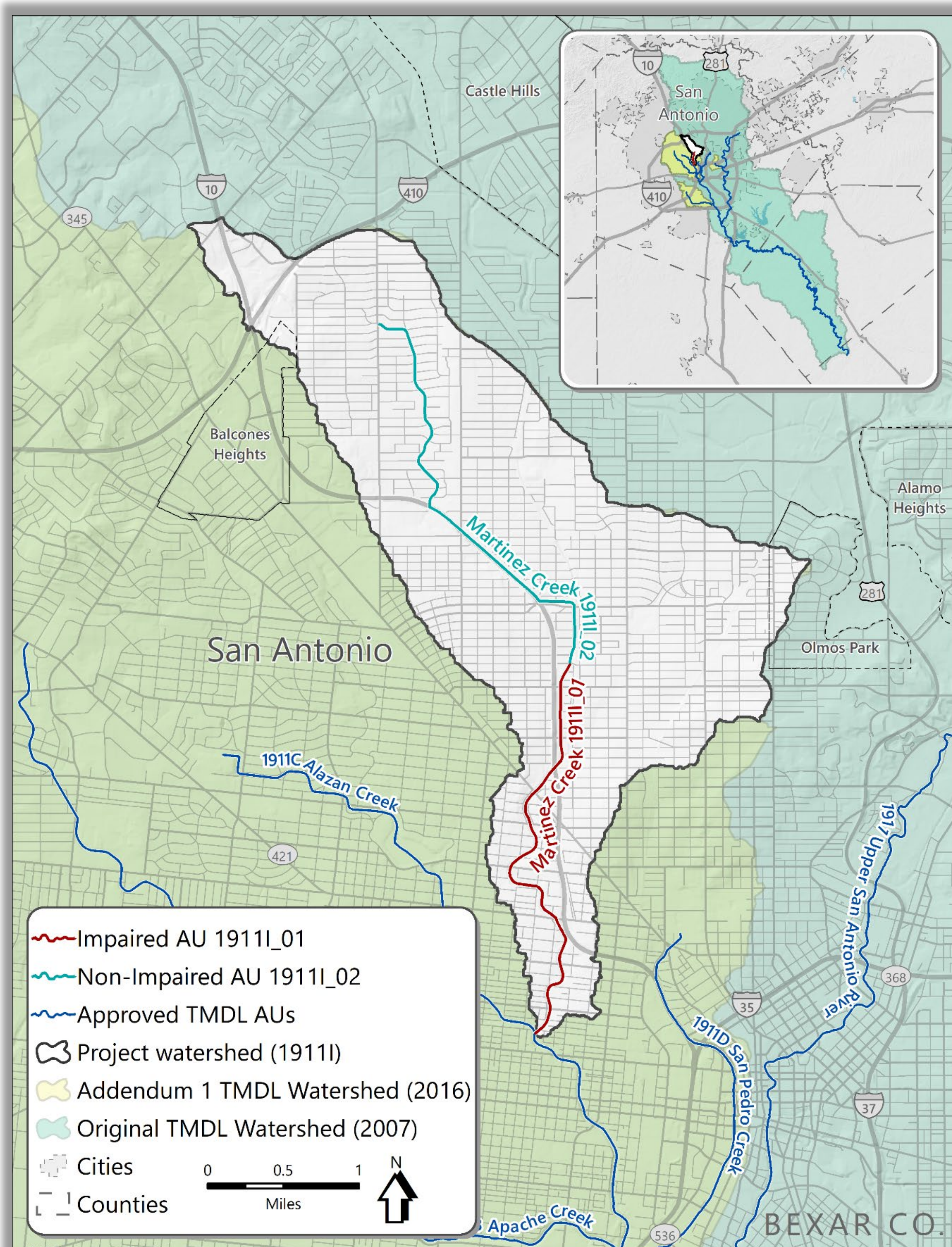

Figure 2. Overview map showing the subject watershed for Martinez Creek (1911I_01).

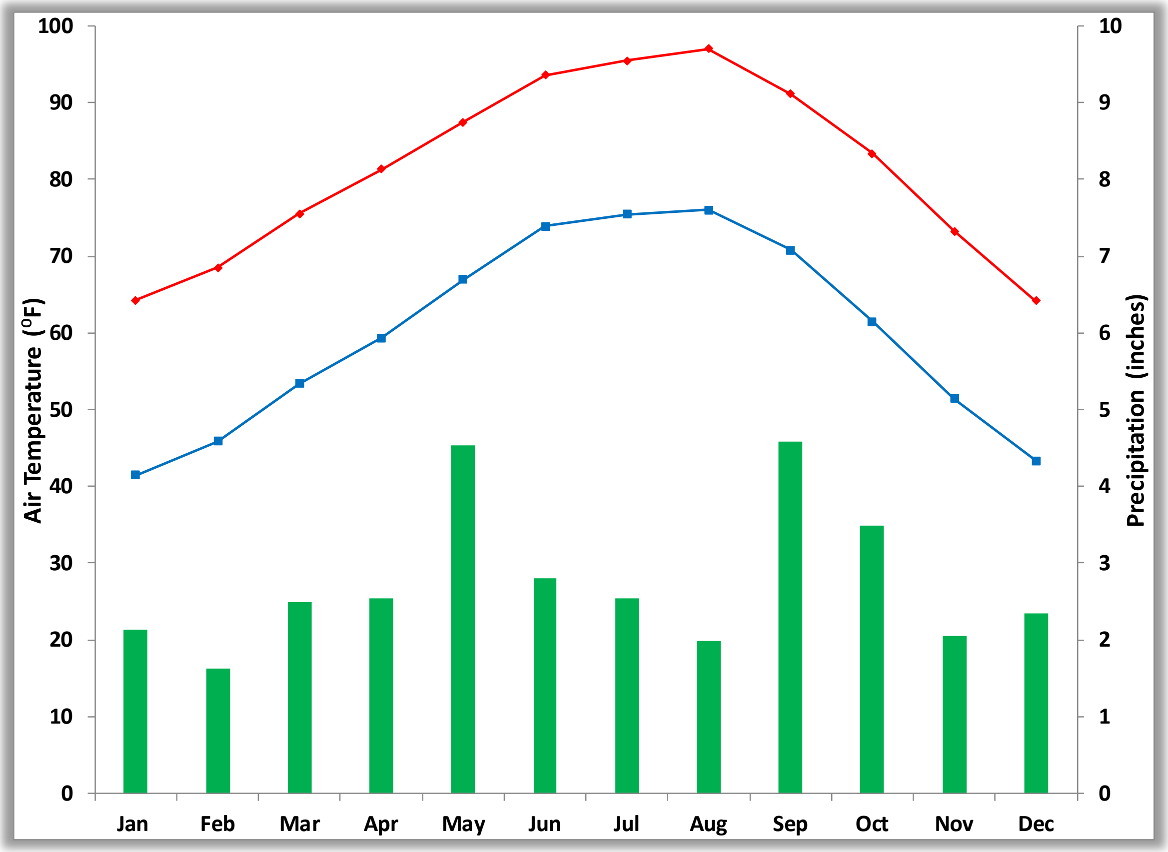

Figure 3. Chart showing the average minimum and maximum air temperature and total precipitation by month from 2004-2018 for the San Antonio International Airport weather station.

2.3 Watershed Population and Population Projections

According to the United States Census Bureau (USCB) 2010 Census (USCB, 2011), there are an estimated 47,010 people in the Martinez Creek watershed, indicating a population density of 6,449 people/ square mile. The majority of the population (46,657 people, or 99.25 percent) live within the San Antonio city limits (Figure 4). The entire watershed is included within the San Antonio Water System (SAWS) service area.

Geospatial analysis based on water user groups (WUGs), which allows a refinement of county and city-level projections developed by the Office of the State Demographer and the Texas Water Development Board (TWDB, 2018), reveals that populations are predicted to increase 82.6 percent in the Martinez Creek watershed between 2010 and 2070 (Table 1).

Table 1. 2010 Population and 2070 Population Projections for the Martinez Creek watershed.

Water Body	Segment	2010 U.S. Census Population	2070 Projected Population	Projected Population Increase	Percent change (2010 - 2070)
Martinez Creek	1911I	47,010	85,858	38,848	82.64%

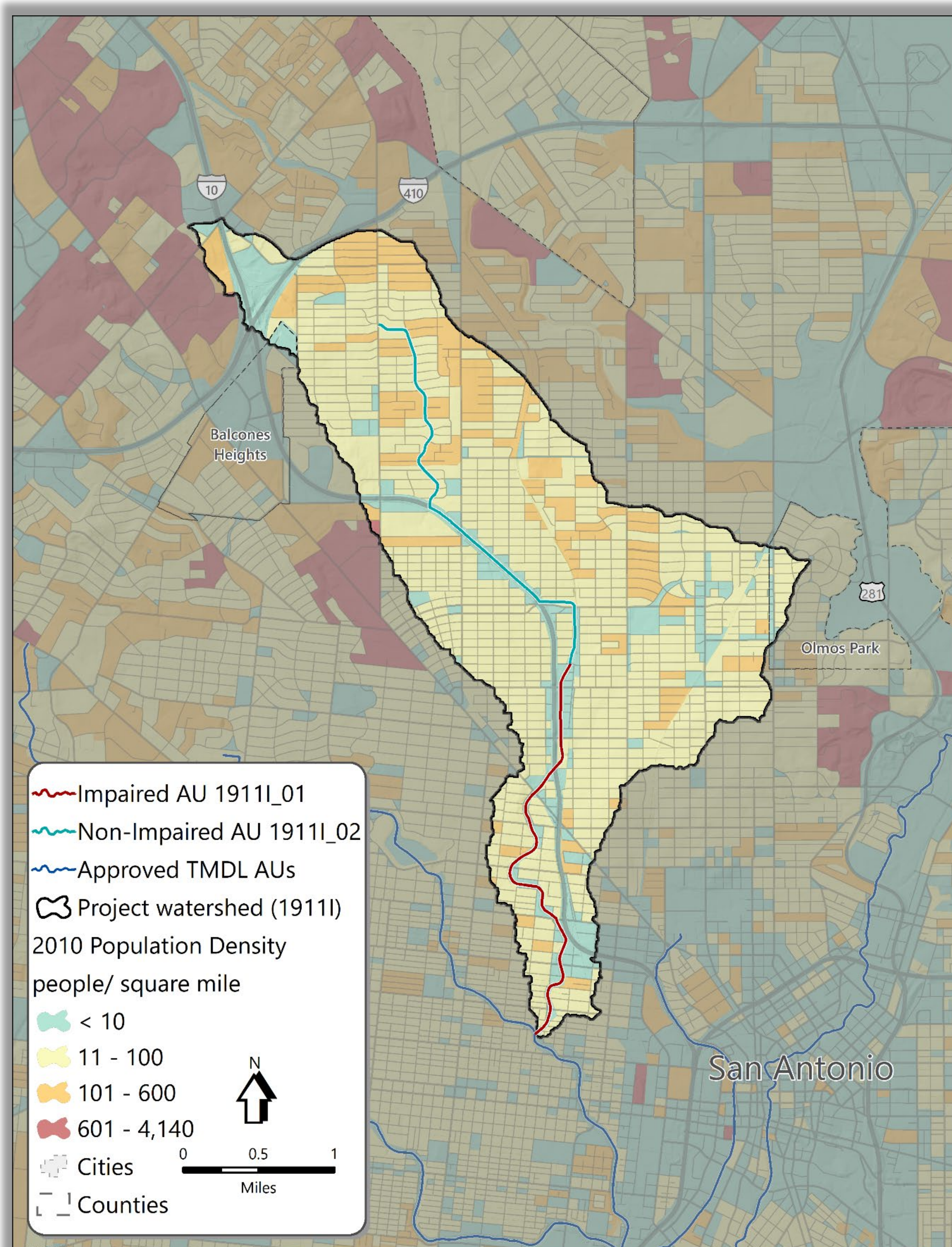

Figure 4. Population density map showing 2010 population by census block.

2.4 Land Use

The land use/land cover data for the Martinez Creek watershed was obtained from the 2016 National Land Cover Database (NLCD) (MRLC, 2019) and are displayed in Figure 5.

The land use/land cover is represented by the following categories and definitions:

- Open Water - areas of open water, generally with less than 25% cover of vegetation or soil.
- Developed, Open Space - areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- Developed, Low Intensity - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20 percent to 49 percent of total cover. These areas most commonly include single-family housing units.
- Developed, Medium Intensity - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 percent to 79 percent of the total cover. These areas most commonly include single-family housing units.
- Developed, High Intensity - highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 percent to 100 percent of the total cover.
- Barren Land (Rock/Sand/Clay) - areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover.
- Deciduous Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
- Evergreen Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
- Mixed Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
- Shrub/Scrub - areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
- Grassland/Herbaceous - areas dominated by graminoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

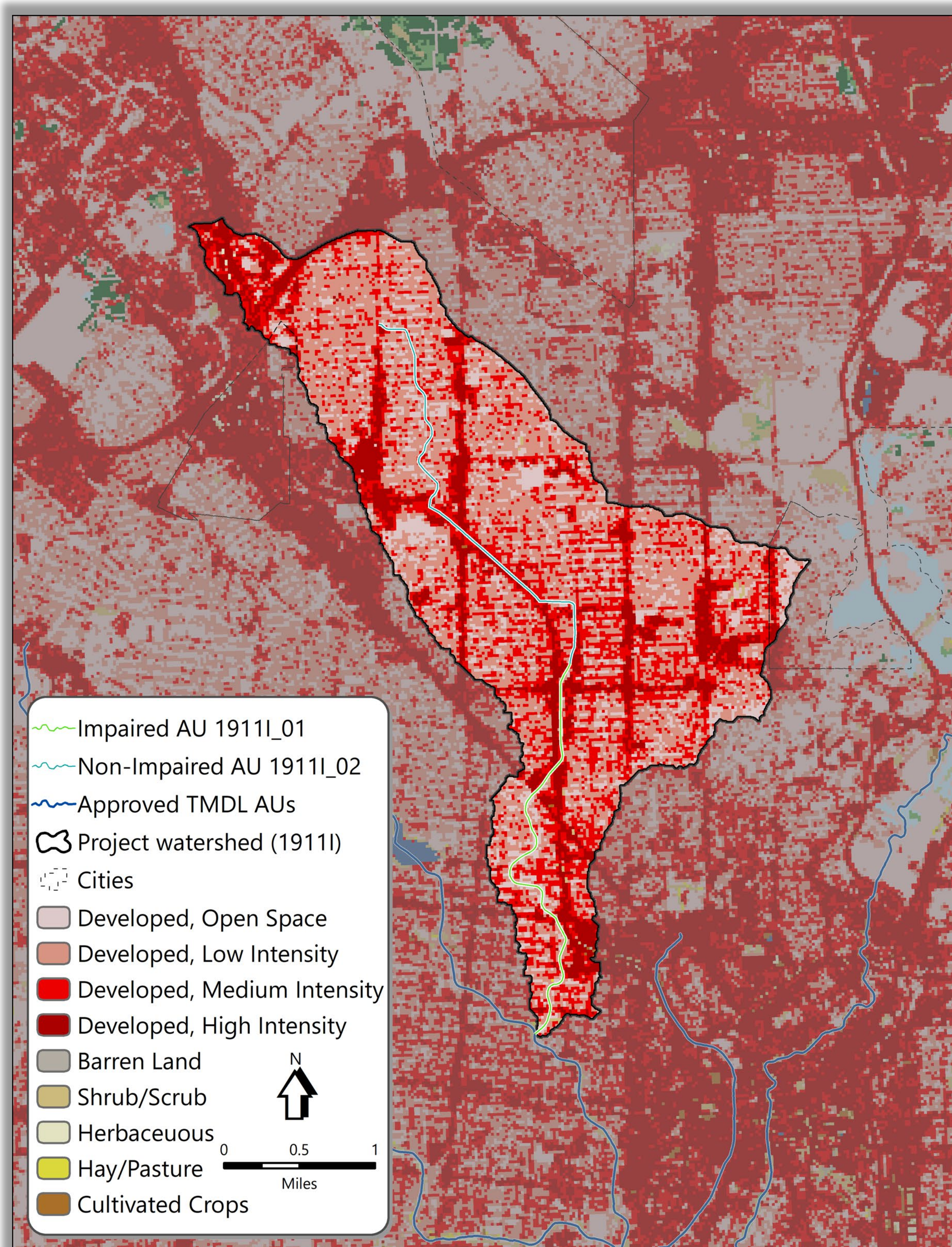

Figure 5. Land use/ land cover map showing categories within the Martinez Creek watershed.

- Pasture/Hay- areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
- Cultivated Crops - areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
- Woody Wetlands - areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

As shown in Table 2, the watershed area encompassing Segment 1911I (Martinez Creek watershed) is approximately 4,665.5 acres. The Martinez Creek watershed is almost completely developed; at 44.2%, the dominant classification is “Developed, Low Intensity”.

Table 2. 2016 Land/Use Land Cover within the Martinez Creek watershed.

Classification	Acres	% of Total
Developed, Open Space	636.8	13.7%
Developed, Low Intensity	2065.2	44.3%
Developed, Medium Intensity	1307	28.0%
Developed High Intensity	643.6	13.8%
Barren Land	0.4	0.01%
Shrub/Scrub	8.7	0.19%
Grassland/Herbaceous	1.8	0.04%
Pasture/Hay	0.2	0.004%
Cultivated Crops	1.8	0.04%
Total	**4,665.5**	**100.0%**

2.5 Soils

Soils within the Martinez Creek watershed were categorized by their Hydrologic Soil Group as shown in Figure 6. The Hydrologic Soil Groups are represented by the following categories and definitions:

- Group A soils consist of deep, well-drained sands or gravelly sands with high infiltration and low runoff rates.
- Group B soils consist of deep, well-drained soils with a moderately fine to moderately coarse texture and a moderate rate of infiltration and runoff.

- Group C consists of soils with a layer that impedes the downward movement of water or fine-textured soils and a slow rate of infiltration.
- Group D consists of soils with a very slow infiltration rate and high runoff potential. This group is composed of clays that have a high shrink-swell potential, soils with a high water table, soils that have a clay pan or clay layer at or near the surface.

Geospatial analysis reveals that the project watershed is primarily comprised of Group C and Group D soils, indicating that the watershed soils, generally, have high runoff potential. In the Martinez Creek watershed, Group C and Group D soils comprise 40.5 percent and 59.0 percent of the area of the watershed, respectively.

2.6 Review of Routine Monitoring Data

2.6.1.Data Acquisition

Ambient *E. coli* data were obtained from the TCEQ Surface Water Quality Web Reporting Tool on January 13, 2019 (TCEQ, 2019a). The data represented all the historical routine ambient *E.coli* and other water quality data collected in the project area, and included routine *E. coli* data collected from September 2008 through November 2018. Ambient *E. coli* data were available for one surface water quality monitoring station (SWQM) in Segment 1911I (Table 3).

The monitoring station at which *E. coli* data were collected is shown in Figure 7.

Table 3. Summary of historical data set of *E. coli* concentrations from the Surface Water Quality Web Reporting Tool.

Water Body	Segment	Station	Station Location	No. of E. coli Samples	Geometric Mean (cfu/100 mL)	Data Date Range
Martinez Creek	1911I	12751	Martinez Creek at Ruiz Street in San Antonio	74	257	2008-2018

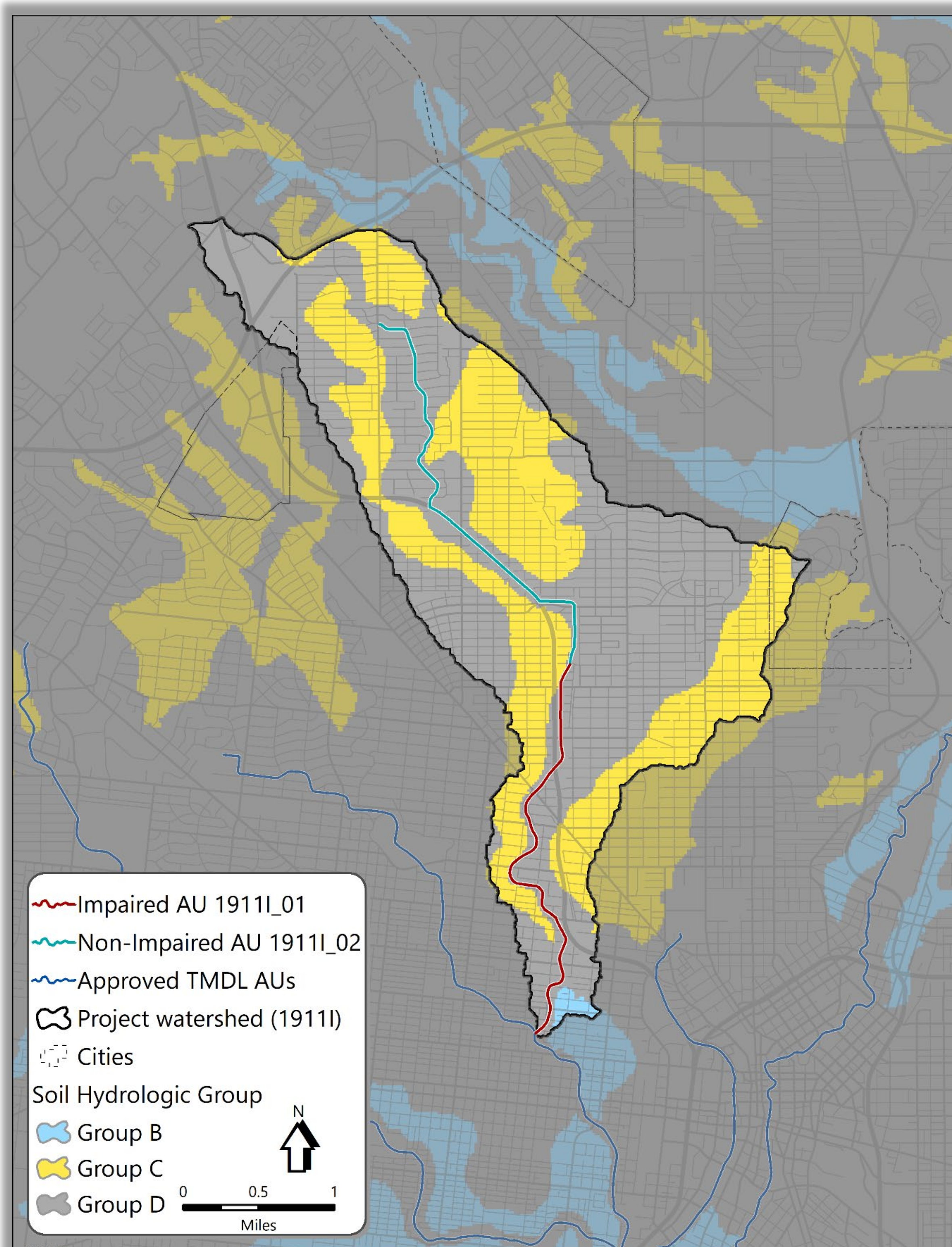

Figure 6. Soil Hydrologic Group categories within the Martinez Creek watershed.

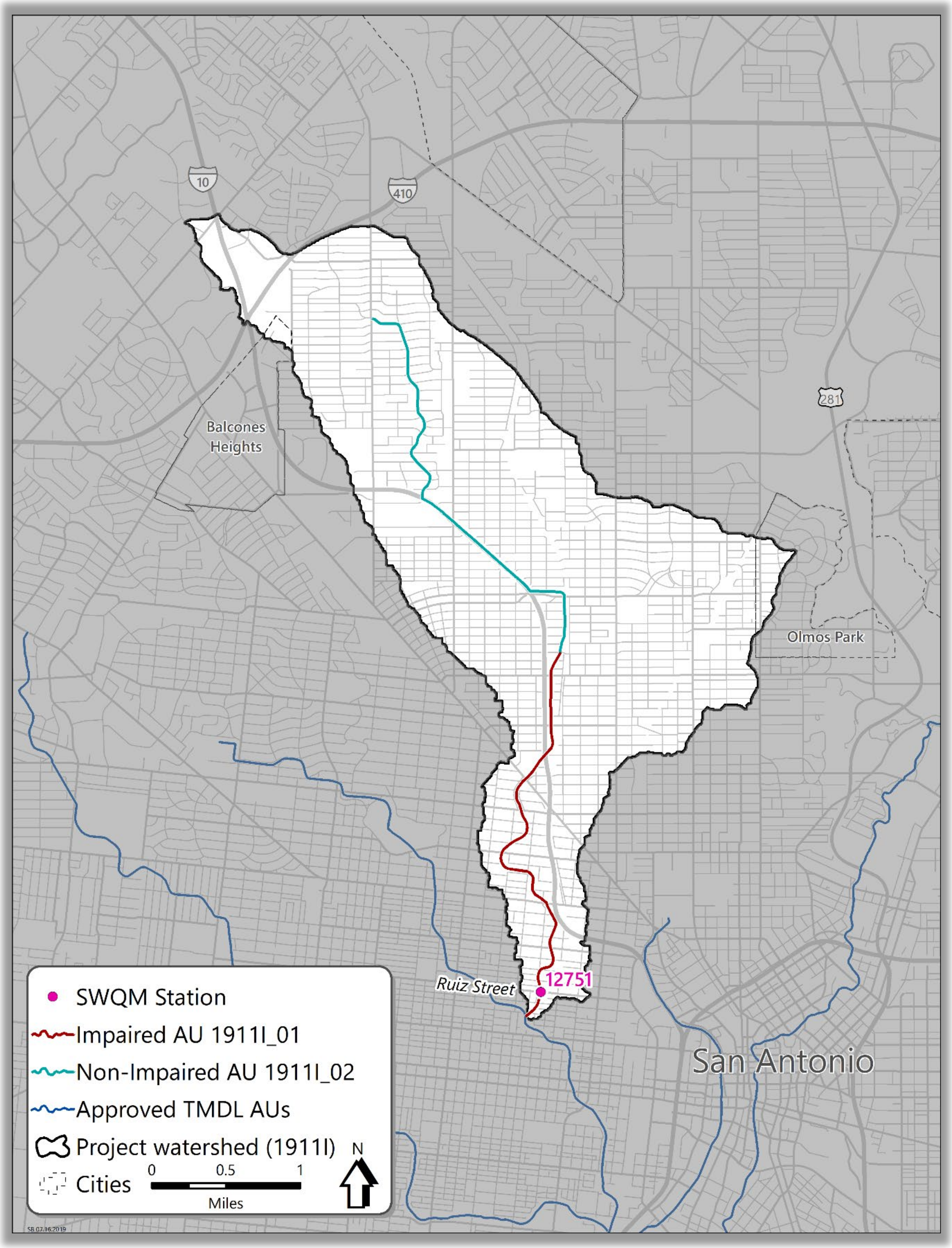

Figure 7. Map showing the monitoring station within the Martinez Creek watershed.

2.6.2 Analysis of Bacteria Data

E. coli data collected at station 12751 over the seven year period of December 1, 2005 through November 30, 2012, were used in assessing attainment of the primary contact recreation use as reported in the 2014 Texas Integrated Report (TCEQ, 2015a) and are summarized in Table 4. The 2014 assessment data for the Martinez Creek watershed indicate non-support of the primary contact recreation use because the geometric mean concentrations exceed the *E. coli* geometric mean criterion of 126 cfu/100 mL. The Draft 2016 Integrated Report (TCEQ, 2018) is available for public review at the time of development of this document. The 2016 assessment data also indicate non-support of the primary geometric mean concentration, and for completeness the draft assessment results are included in Table 4.

Table 4. 2014 and Draft 2016 Integrated Report Summaries for Martinez Creek.

Integrated Report Year	Water Body	Segment Number	AU	Parameter	Station	No. of Samples	Data Date Range	Station Geometric Mean (cfu/100 mL)
2014	Martinez Creek	1911I	1911I_01	*E. coli*	12751	41	2005-2012	268
2016 (draft)	Martinez Creek	1911I	1911I_01	*E. coli*	12751	50	2007-2014	238

2.7 Potential Sources of Fecal Indicator Bacteria

Potential sources of indicator bacteria pollution can be divided into two primary categories: *regulated* and *unregulated*. Pollution sources that are regulated have permits under the Texas Pollutant Discharge Elimination System (TPDES) and National Pollutant Discharge Elimination System (NPDES) programs. Examples of regulated sources are wastewater treatment facility (WWTF) discharges and stormwater discharges from industries, construction, and municipal separate storm sewer systems (MS4s) of cities.

Unregulated sources are typically nonpoint source in nature, meaning the pollution originates from multiple locations and is usually carried to surface waters by rainfall runoff. Nonpoint sources are not regulated by permit.

With the exception of WWTFs, which receive individual wasteload allocations or WLAs (see report Section 4.7.3, Wasteload Allocation), the regulated and unregulated sources in this section are presented to give a general account of the potential sources of bacteria in the watershed.

2.7.1 Permitted Sources

Permitted sources are regulated by permit under the TPDES and the NPDES programs. Stormwater discharges from MS4s represent the potential permitted sources in the Martinez Creek watershed.

2.7.1.1 Domestic Wastewater Treatment Facility Discharges

Currently, no WWTFs exist within the Martinez Creek watershed.

2.7.1.2 Sanitary Sewer Overflows

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

The TCEQ Region 13 Office maintains a database of SSO data reported by municipalities. These SSO data typically contain estimates of the total gallons spilled, responsible entity and a general location of the spill. A summary of the reports of SSO events that were determined to have occurred within the Martinez Creek watershed between January 2012 and December 2017 are shown in Table 5, as well as in Figure 8.

Table 5. Summary of SSO incidences reported in the Martinez Creek watershed from 2012 - 2017.

Source: TCEQ Region 13

Segment	No. of Incidents	Total Volume (gallons)	Average Volume (gallons)	Minimum Volume (gallons)	Maximum Volume (gallons)
1911I	69	196,037	2,841	5	75,600

2.7.1.3 TPDES-Regulated Stormwater

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

1. Stormwater subject to regulation, which is any stormwater originating from TPDES/NPDES regulated Municipal Separate Storm Sewer System (MS4) entities, industrial facilities, and construction activities; and
2. stormwater runoff not subject to regulation.

The TPDES/NPDES MS4 Phase I and II rules require municipalities and certain other entities in urban areas to obtain permit coverage for their stormwater systems. A regulated MS4 is a publicly owned system of conveyances and includes ditches, curbs, gutters, and storm sewers that do not connect to a wastewater collection system or treatment facility. Phase I permits are individual permits for large and medium-sized communities with populations of 100,000 or more based on the 1990 U.S. Census, whereas the Phase II general permit regulates smaller communities within a U.S. Census Bureau defined urbanized area.

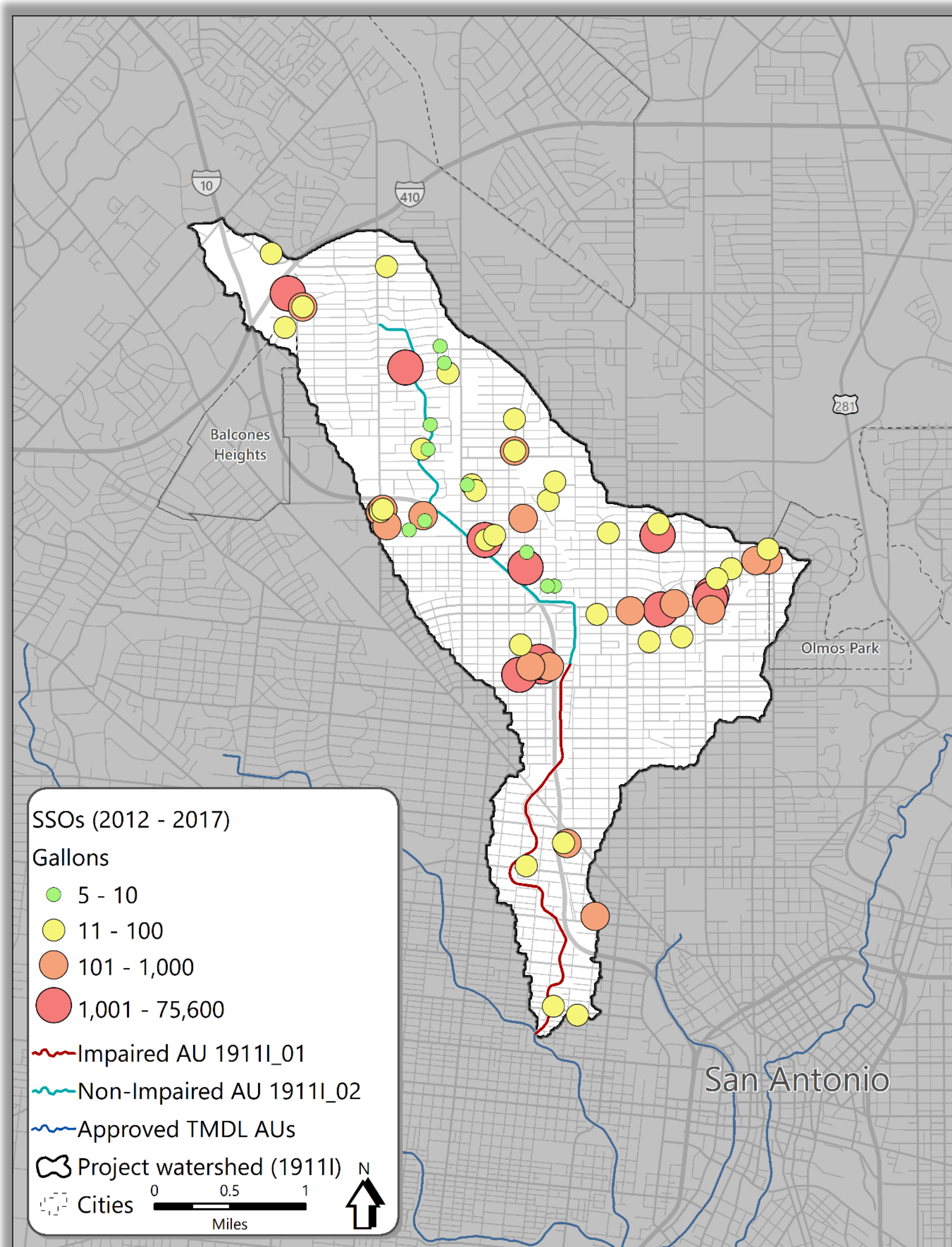

Figure 8. Map showing SSO incidences reported in the Martinez Creek watershed and surrounding areas from 2012 - 2017.

The purpose of an MS4 permit is to reduce discharges of pollutants in stormwater to the "maximum extent practicable" by developing and implementing a Stormwater Management Program (SWMP). The SWMP describes the stormwater control practices that will be implemented consistent with permit requirements to minimize the discharge of pollutants from the MS4. The permits require that the SWMPs specify the best management practices to meet several minimum control measures (MCMs) that, when implemented in concert, are expected to result in significant reductions of pollutants discharged into receiving waterbodies. Phase II MS4 MCMs include:

- Public education, outreach, and involvement;
- Illicit discharge detection and elimination;
- Construction site stormwater runoff control;
- Post-construction stormwater management in new development and redevelopment;
- Pollution prevention and good housekeeping for municipal operations; and
- Industrial stormwater sources.

Phase I MS4 individual permits have similar MCMs organized a little differently and are further required to perform water quality monitoring.

The area of the project watershed (1911I) is covered by both Phase I and II MS4 permits; the associated permits match the jurisdictional boundaries of the regulated entity. For Phase I permits the jurisdictional area is defined by the city limits and for Phase II permits the jurisdictional area is defined as the intersection or overlapping areas of the city limits and the 2010 Census Urbanized Area (USCB, 2012).

For the Martinez Creek project watershed entities with Phase I individual permits and Phase II general permits, the areas included under these MS4 permits were used to estimate the regulated stormwater areas for construction, industrial and MS4 permits. For the project watershed (1911I), there is 100% coverage by the urbanized area (Figure 9). However even in highly urbanized areas such as this one, there remain small areas that are not strictly regulated stormwater and which may receive bacteria loadings from unregulated sources such as wildlife and feral hogs. To account for these small unregulated areas in each impaired watershed, the surface area within the channel of the creek is excluded from the urbanized area and represents an area of unregulated stormwater contribution. This estimation of an area subject to unregulated direct deposition was performed in a Geographic Information System (GIS), where the average channel width was determined based on recent aerial imagery (51.2 feet) and multiplied by the entire length of Martinez Creek, resulting in an area of 37.6 acres, or 0.81% of the watershed (Figure 9).

A review of Phase I permits and a review of the TCEQ central registry for Phase II MS4 permit coverage in the entire Martinez Creek watershed revealed two Phase I permits and two Phase II permits (TCEQ, 2019b). For the Martinez Creek watershed, the total area under MS4 permits is 4,627.9 acres, or 99.19% of the watershed.

Table 6. TPDES and NPDES MS4 permits associated with the Martinez Creek watershed.

Entity/ Permittee	Permitted Area	TPDES Permit	NPDES Permit
City of San Antonio/ San Antonio Water System/ Texas Dept. of Transportation	San Antonio	WQ0004284-000	TXS001901
Texas Dept. of Transportation	Statewide	WQ0005011-000	TXS002101
City of Balcones Heights	Balcones Heights	TX040000	TXR040156
City of Olmos Park	Olmos Park	TX040000	TXR040026

2.7.1.4 Dry Weather Discharges/Illicit Discharges

Bacteria loads from regulated stormwater can enter the streams from permitted outfalls and illicit discharges under both dry and wet weather conditions. The term "illicit discharge" is defined in TPDES General Permit No. TXR040000 for Phase II (Small) MS4 as "Any discharge to a municipal separate storm sewer that is not entirely composed of stormwater, except discharges pursuant to this general permit or a separate authorization and discharges resulting from emergency firefighting activities." Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges identified in the Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities (NEIWPCC, 2003) includes:

Direct illicit discharges:

- sanitary wastewater piping that is directly connected from a home to the storm sewer;
- materials (e.g., used motor oil) that have been dumped illegally into a storm drain catch basin;
- a shop floor drain that is connected to the storm sewer; and
- a cross-connection between the municipal sewer and storm sewer systems.

Indirect illicit discharges:

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

2.7.1.5 TPDES General Wastewater Permits

In addition to individual wastewater discharge permits, discharges of processed wastewater from certain types of facilities are required to be covered by one of several TPDES general permits:

- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production facilities
- TXG340000 – petroleum bulk stations and terminals
- TXG500000 – quarries in John Grabes Scenic Riverway
- TXG670000 – hydrostatic test water discharges
- TXG830000 – petroleum fuel or petroleum substances
- TXG870000 – pesticides
- TXG100000 – wastewater evaporation
- TXG830000 – water contaminated by petroleum fuel or petroleum substances

- TXG920000 – concentrated animal feeding operations
- WQG20000 – livestock manure compost operations (irrigation only)

A review of active general permit coverage (TCEQ, 2019b) in the Martinez Creek watershed as of 14 June 2019, found no operations or facilities of the type described above.

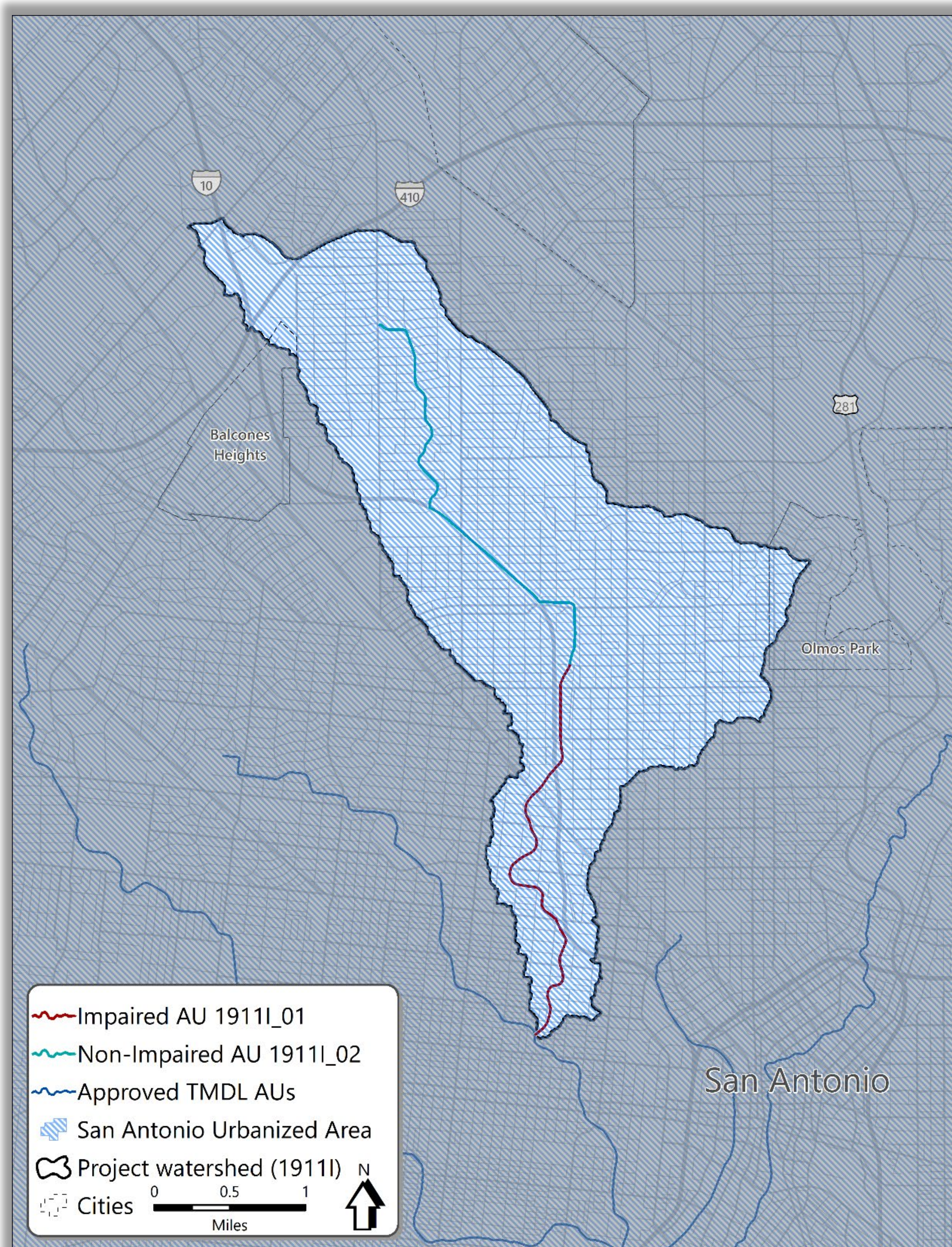

Figure 9. Map showing the regulated stormwater area based on Phase I and Phase II MS4 permits within the Martinez Creek Watershed.

2.7.2 Unregulated Sources

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

2.7.2.1 Wildlife and Unmanaged Animal Contributions

E. coli bacteria are common inhabitants of the intestines of all warm-blooded animals, including feral hogs and wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife and feral hogs. Wildlife and feral hogs are naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife and feral hog waste can be a concentrated source of bacteria loading to a water body. Fecal bacteria from wildlife and feral hogs are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. The *E. coli* contribution from feral hogs and wildlife in Martinez Creek cannot be determined based on existing information, however due to the urbanized nature of the watershed it is assumed that the contribution would be minimal.

2.7.2.2 On-Site Sewage Facilities

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

Several pathways of the liquid waste in OSSFs afford opportunities for bacteria to enter ground and surface waters, if the systems are not properly operating. Properly designed and operated, however, OSSFs would be expected to contribute virtually no fecal bacteria to surface waters. For example, it has been reported that less than 0.01% of fecal coliforms originating in household wastes move further than 6.5 feet down gradient of the drainfield of a septic system (Weiskel, Howes, & Heufelder, 1996).

Reed, Stowe, and Yanke LLC (2001) provide information on estimated failure rates of OSSFs for different regions of Texas. The TMDL watershed is located within Region II (covering parts west and central Texas), a region having a reported failure rate of about 12 percent, which provides insights into expected failure rates for the area. Failing OSSFs are a source of fecal pathogens and indicator bacteria loading to streams. Loading from failing OSSFs can be transported to streams in a variety of ways, including runoff from surface discharge or from transport by stormwater runoff.

Estimates of the number of OSSFs in the Martinez Creek watershed were determined using spatial data supplied by the Bexar County Public Works Department (BCPW). The BCPW data indicate that there are 14 OSSFs located within the project watershed (Table 7 and Figure 10).

Table 7. OSSF permits for the Martinez Creek watershed.

Watershed	Segment/ AU Number	Permitted OSSFs
Martinez Creek	1911I	14

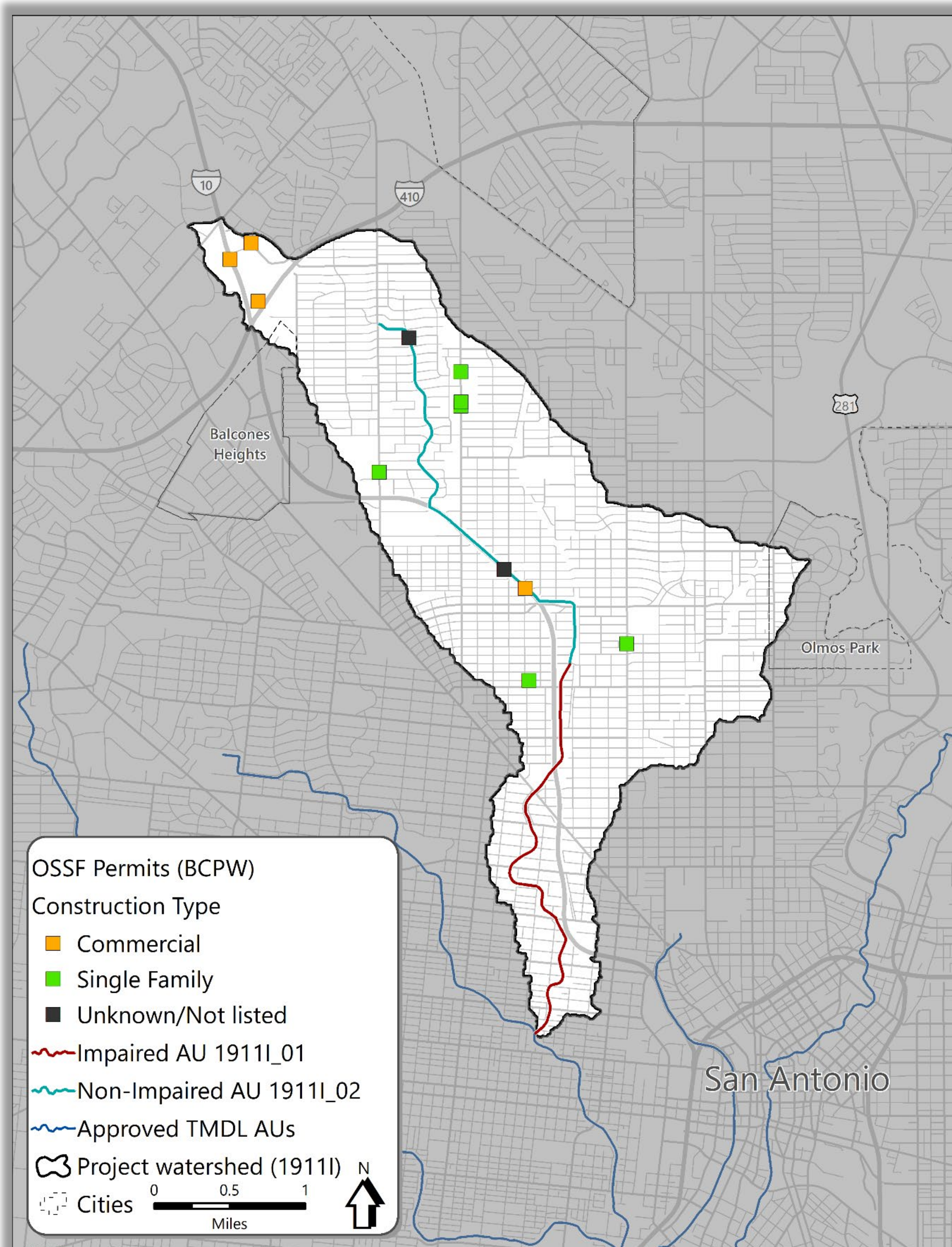

Figure 10. Map showing OSSFs located within the Martinez Creek watershed.

2.7.2.3 Unregulated Agricultural Activities and Domesticated Animals

Activities, such as livestock grazing close to water bodies and farmers' use of manure as fertilizer, can contribute fecal indicator bacteria such as *E. coli* to nearby water bodies. Due to the highly urbanized nature of the TMDL study area, livestock were not considered a major source of bacteria loading.

Fecal matter from dogs and cats is transported to streams by runoff in both urban and rural areas and can be a potential source of bacteria loading. Table 8 summarizes the estimated number of dogs and cats for the TMDL watershed. Pet population estimates were calculated as the estimated number of dogs (0.584) and cats (0.638) per household (AVMA, 2012). The number of households in the watershed was estimated using 2010 USCB data (USCB, 2011). The actual contribution and significance of fecal bacteria loads from pets reaching the water bodies of the Martinez Creek watershed is unknown.

Table 8. Estimated Households and Pet Populations for the Martinez Creek watershed.

Estimated Number of Households	Estimated Dog Population	Estimated Cat Population
17,620	10,290	11,242

2.7.2.4 Bacteria Survival and Die-off

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

SECTION 3
BACTERIA TOOL DEVELOPMENT

This section describes the rationale for choosing the LDC method to develop the pollutant load allocations for Martinez Creek and then details the procedures and results of LDC development.

3.1 Tool Selection

Previous to this report, there have been two main TDML efforts in this Upper San Antonio River watershed. The original TMDL (*Three Total Maximum Daily Loads for Bacteria in the San Antonio Area*) was approved by the EPA in 2007, and it is described in the TSD *Modeling Report for Bacteria TMDL (Total Maximum Daily Load) Development: Salado Creek, Segment 1910 Walzem Creek, Segment 1910A Upper San Antonio River, Segment 1911* (TCEQ, 2006a) An addition to the original TDML (*Addendum One to Three Total Maximum Daily Loads for the Upper San Antonio Watershed*) was approved by the EPA in 2016; it is described in the TSD *Technical Support Document for Additions to the Upper San Antonio Watershed Bacteria TMDLs* (TCEQ, 2015b).

For consistency between this TMDL the most recent of the previously completed San Antonio River TMDLs, the pollutant load allocation activities for Martinez Creek used the LDC method. The LDC method has been previously used on TCEQ-adopted and USEPA-approved TMDLs for *Addendum One to Three Total Maximum Daily Loads for the Upper San Antonio Watershed* (TCEQ, 2016a).

The LDC method allows for estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003) . In addition to estimating stream loads, the LDC method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment. The LDC method has found relatively broad acceptance among the regulatory community, primarily due to the simplicity of the approach and ease of application. The regulatory community recognizes the frequent information limitations, often associated with bacteria TMDLs that constrain the use of more powerful mechanistic models. Further, the bacteria task force appointed by the TCEQ and the Texas State Soil and Water Conservation Board (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 nonpoint source.

3.2 Martinez Creek Data Resources

Successful application of the LDC method requires two basic types of data: continuous daily streamflow data and historical bacteria data for the relevant indicator bacteria, which in this case is *E. coli*.

Hydrologic data in the form of daily streamflow records were unavailable for the Martinez Creek watershed; however, streamflow records were available for the nearby Olmos Creek watershed (Figure 11).

Streamflow records for the Olmos Creek watershed are collected and made readily available by the U.S. Geological Survey (USGS), which operates the Olmos Creek streamflow gauge (Table 9) (USGS, 2019). USGS streamflow gauge 08177700 is located along the mainstem of Olmos Creek within Segment 1911A and serves as the primary source for streamflow records used in this document. The Olmos Creek streamflow gage served as the source of streamflow records for *Addendum One to Three Total Maximum Daily Loads for the Upper San Antonio Watershed* (TCEQ, 2016a).

Table 9. Basic information on the Olmos Creek USGS streamflow gauge.

Gauge No.	Site Description	Segment	Drainage Area (sq. miles)	Daily Streamflow Record (beginning & end date)
08177700	Olmos Creek at Dresden Drive, San Antonio, TX	1911A	21.2	June 1968 – present

Ambient *E. coli* data were available through the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) for one station located along Martinez Creek, as described previously in Table 3.

3.3 Methodology for Flow Duration & Load Duration Curve Development

To develop the flow duration curve (FDC) and LDC, the previously discussed data resources were used in the following series of sequential steps.

- **Step 1**: Determine the hydrologic period of record to be used in developing the FDC.
- **Step 2**: Determine stream location for which FDC and LDC development is desired.
- **Step 3**: Develop daily streamflow records at the desired stream location using the daily gauged streamflow records and drainage area ratio (DAR).
- **Step 4**: Develop an FDC at the desired stream location, segmented into discrete flow regimes.
- **Step 5**: Develop the allowable bacteria LDC at the same stream locations based on the relevant criteria and the data from the FDC.
- **Step 6**: Superpose historical bacteria data on the allowable bacteria LDC.

Additional information explaining the LDC method may be found in (Cleland, 2003) and (NDEP, 2003).

3.3.1 Step 1: Determine Hydrologic Period

A 51-year period of continuous daily streamflow was available for USGS gauge 08177700 located on nearby Olmos Creek (Table 9 and Figure 11). The period of record is more than adequate to capture a reasonable variation in meteorological patterns of high and low rainfall periods.

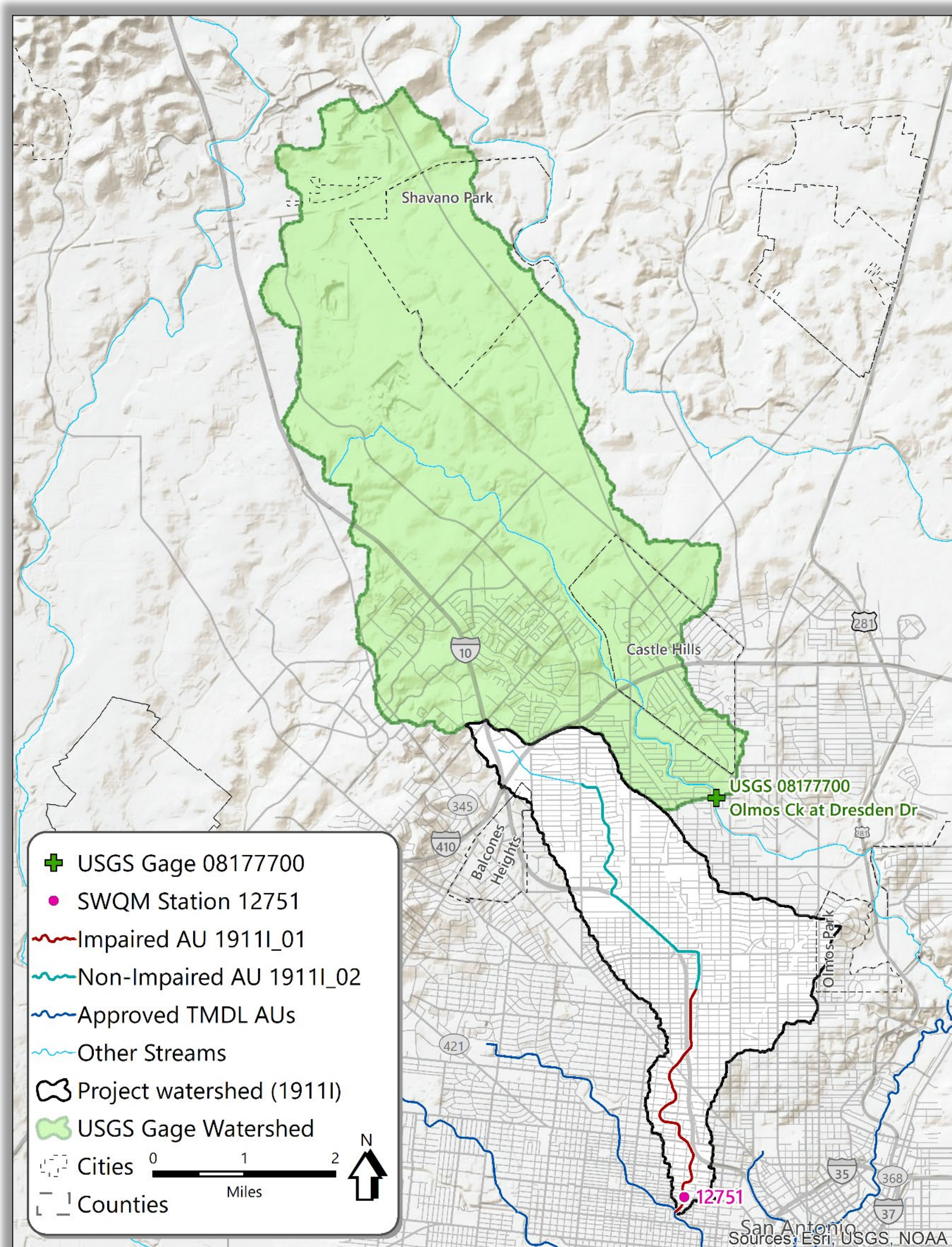

Figure 11. Martinez Creek watershed, Olmos Creek watershed and USGS Station 08177700 location in San Antonio, Texas.

Optimally, the period of record to develop FDCs should include as much data as possible in order to capture extremes of high and low streamflow and hydrologic variability from high to low precipitation years, but the flow during the period of record selected should also be representative of recent conditions experienced within the watershed and when the *E. coli* data were collected. A 15-year record of daily streamflow from September 1, 2003, through September 1, 2018, was selected to develop the FDC at the sampling station. A 15-year period is of sufficient duration to contain a reasonable variation of dry and wet periods and, at the same time, is short enough in duration to reflect recent and current conditions in the watershed. This time period is five years longer than the 10-year period (2002-2012) that was used in the previously completed *Addendum One to Three Total Maximum Daily Loads for the Upper San Antonio Watershed* (TCEQ, 2016a).

3.3.2 Step 2: Determine Desired Stream Locations

When using the LDC method, the optimal location for developing the pollutant load allocation is a currently monitored SWQM station located near the outlet of the watershed with an abundance of historical bacteria data. The SWQM station on Martinez Creek was selected because it was the only station for which *E. coli* data were available. A total of 72 *E. coli* measurements were recorded within the 15-year period selected for streamflow record development. Station 12751 on Martinez Creek is located near the confluence with Alazan Creek (Figure 7) and has an abundance of *E. coli* data that are found in SWQMIS (Table 3).

3.3.3 Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and station location were determined, the next step was to develop the 15-year daily streamflow record for each monitoring station. The daily streamflow records were developed from extant USGS records (Table 9).

The method to develop the necessary streamflow record for the FDC/LDC location (i.e., SWQM station location) involved a DAR approach. The DAR approach involves multiplying a USGS gaging station daily streamflow value by a factor to estimate the flow at a desired monitoring station location. The factor is determined by dividing the drainage area above the desired monitoring station by the drainage area above the USGS gauge (Table 10).

Table 10. DARs for the TMDL watershed based on the drainage area of the Olmos Creek USGS gauge.

Water Body	Segment	Gauge/Station	Drainage Area (acres)	DAR
Olmos Creek	1911A	USGS Gauge 8166000	13,633.42	1.00
Martinez Creek	1911I	SWQM Station 12751	4638.01	0.3402

Because an assumption of the DAR approach is similarity of hydrologic response based on commonality of landscape features such as geology, soils, and land use/land cover, point source derived flows should first be considered for removal from the flow record of the Olmos Creek gauge prior to application of the ratio. A search for NPDES/TPDES permitted facilities within the Olmos Creek watershed returned zero active permits upstream of the gauge (TCEQ, 2014a). Therefore, no adjustments for discharges were made to the Olmos Creek USGS gauge record prior to application of the DAR.

Additionally, a sqatial query of water rights features (diversions, withdrawals, return flows) was conducted for the Olmos Creek watershed, and none were found (TCEQ, 2014b). This was also true for the Martinez Creek watershed.

The DARs for locations within the TMDL study area are presented in Table 10. The computation of the daily streamflow record at each station was performed by multiplying each daily streamflow in the 15-year Olmos Creek gauged record by the DAR at station 12751.

3.3.4 Steps 4-6: Flow Duration Curve and Load Duration Curve Methods

FDCs and LDCs are graphs indicating the percentage of time during which a certain value of flow or load is equaled or exceeded. To develop a FDC for a location the following steps were undertaken:

- order the daily streamflow data for the location from highest to lowest and assign a rank to each data point (1 for the highest flow, 2 for the second highest flow, and so on);
- compute the percent of days each flow was exceeded by dividing each rank by the total number of data point plus 1; and
- plot the corresponding flow data against exceedance percentages.

Further, when developing a LDC:

- multiply the streamflow in cubic feet per second (cfs) by the appropriate water quality criterion for *E. coli* (geometric mean of 126 cfu/100 mL) and by a conversion factor ($2.44658x10^{7}$), which gives a loading in units of cfu/day; and
- plot the exceedance percentages, which are identical to the value for the streamflow data points, against geometric mean criterion of *E. coli*.

The resulting curve represents the maximum allowable daily loadings for the geometric mean criterion. The next step was to plot the sampled *E. coli* data, when such data existed at the LDC locations, on the developed LDC using the following two steps:

- using the unique data for each monitoring station, compute the daily loads for each sample by multiplying the measured *E. coli* concentrations on a particular day by the corresponding streamflow on that day and the conversion factor ($2.44658x10^{7}$), which gives a loading in units of cfu/day; and
- plot on the LDC the load for each measurement at the exceedance percentage for its corresponding streamflow.

The plots of the LDC with the measured loads (*E. coli* concentration multiplied by the daily streamflow) display the frequency and magnitude that measured loads exceed the maximum allowable loadings for the geometric mean criterion. Measured loads that are above a maximum allowable loading curve indicate an exceedance of the water quality criterion, while those below a curve show compliance.

3.4 Flow Duration Curve for Sampling Station within the Martinez Creek Watershed

An FDC was developed for the most downstream monitoring station within the Martinez Creek watershed (Figure 12). For this report, an FDC was developed by applying the DAR method and using the Olmos Creek USGS gauge and 15-year period (2003-2018) described in the previous sections.

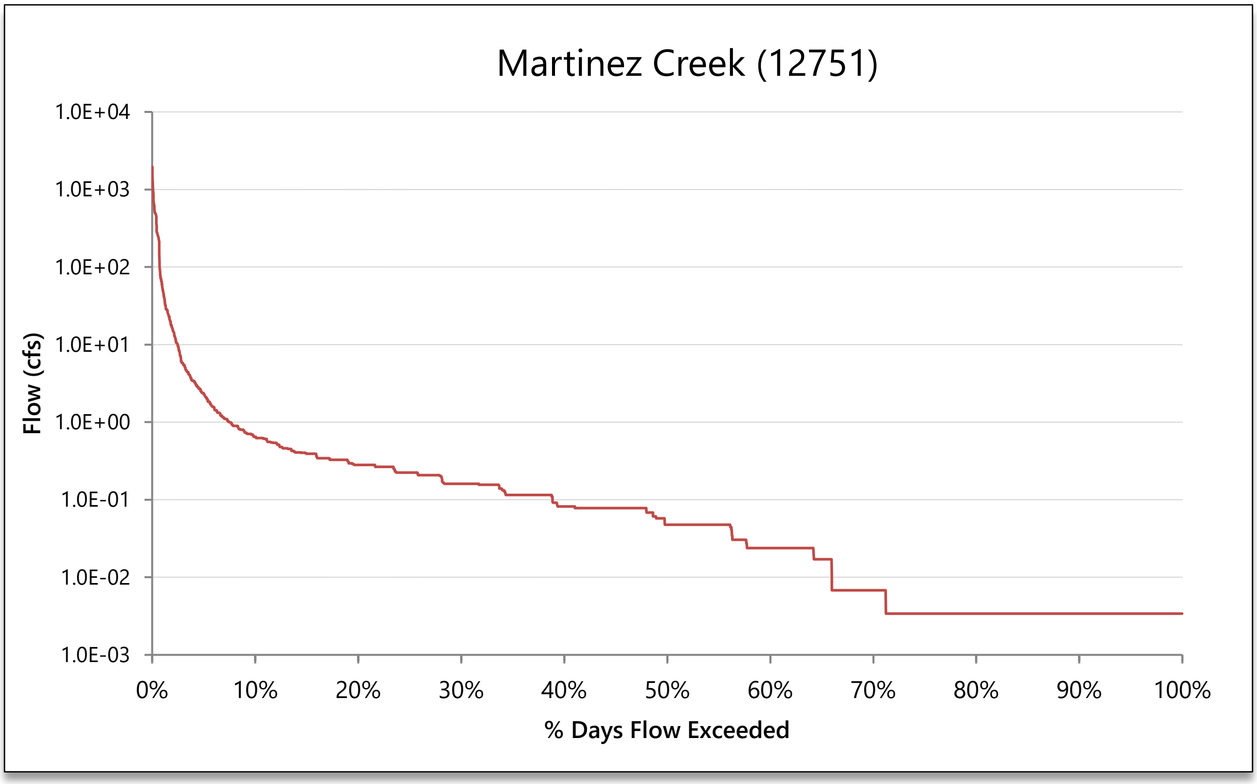

Figure 12. Flow duration curve for Martinez Creek (Station 12751).

Flow exceedances less than 10 percent typically represent streamflows influenced by storm runoff, while higher flow exceedances represent receding hydrographs after a runoff event and base flow conditions. The stair-step pattern in the LDC between the 20th and 70th percentiles of flow exceedance is an artifact of the way in which the flows in the gauged watershed are reported (generally flows are reported to three significant digits, so flows above 100 cfs are reported to the nearest cfs, while flows of less than 10 are reported to two decimal places). Another feature of the Olmos Creek streamflow record is that the condition of no flow exists almost 30 percent of the time, which is anticipated to be reflective of actual conditions in Martinez Creek.

3.5 Load Duration Curve for Sampling Station within theTMDL Watershed

A LDC was developed for Martinez Creek using data obtained from Station 12751 (Figure 13). A useful refinement of the LDC approach is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curves. This approach can assist in determining streamflow conditions under which exceedances are occurring. A commonly used set of regimes that is provided in Cleland (2003) is based on the following five intervals along the x-axis of the FDCs and LDCs: (1) 0-10 percent (high flows); (2) 10-40 percent (upper/mid-range flows); (3) 40-60 percent (mid-range flows); (4) 60-90 percent (lower/mid-range conditions); and (5) 90-100 percent (low flows).

For the Martinez Creek watershed, a three-interval division was selected:

- High flow regime: 0-20% range, related to flood conditions and non-point source loading
- Mid-range flow regime: 20-80% range, intermediate conditions of receding hydrographs after storm runoff and base line conditions
- Low flow regime: 80-100% range, related to dry conditions

The selection of the flow regime intervals was based on general observations of the monitoring station LDC. The selected flow regime intervals also provide consistency with the previously completed *Addendum One to Three Total Maximum Daily Loads for the Upper San Antonio Watershed* (TCEQ, 2016a).

The LDC for Martinez Creek, showing the three flow regimes, is provided in Figure 13. This LDC was constructed for developing the TMDL allocation for Martinez Creek. Geometric mean loadings for the data points within each flow regime have also been distinguished on each figure to aid interpretation. The LDC depicts the allowable loadings at the station under the geometric mean criterion (126 cfu/100 mL) and shows that existing loadings often exceed the criterion. In addition, the LDC presents the allowable loading at the station under the single sample criterion (399 cfu/100 mL).

Additionally, historical bacteria measurements (*E. coli*) were aligned with the streamflow on the day of measurement. The historical bacteria measurements were then multiplied by the streamflow value and the conversion factor, as described in Section 3.3.4, to calculate a loading associated with each measured bacteria concentration. Of note, short gaps in the USGS flow record for the Olmos Creek station coincided with the dates of two of the *E. coli* sampling events; those samples were dropped out, resulting in 70 total *E. coli* samples used for loading calculations. On each graph the measured *E. coli* data are presented as associated with a "wet weather event" or a "non-wet weather event." Due to the variability in available data, this determination was made based on satisfying one of the following criteria:

- the total rainfall for that day and the preceding two days exceeded 0.05 inches (daily PRISM dataset for a location 1000 feet upstream of Station 12751 (PRISM, 2019); or
- the "days since last precipitation" value (if available) was less than or equal to 3 days ($\leq$ 3);

For the Martinez Creek LDC (Figure 13), the wet weather data points occurred, as expected, predominately under the higher flow regimes and consistently exceeded the geometric mean criterion. Wet weather data points in the lowest flow regime typically represent bacteria data collected after a small rainfall-runoff event when conditions up to the event were very dry. Often the non-wet weather event data points also exceed the geometric mean criterion for Martinez Creek. The geometric mean of existing data shown by flow regime further substantiate the elevated *E. coli* levels as they are consistently greater than the geometric mean criterion for the waterbody.

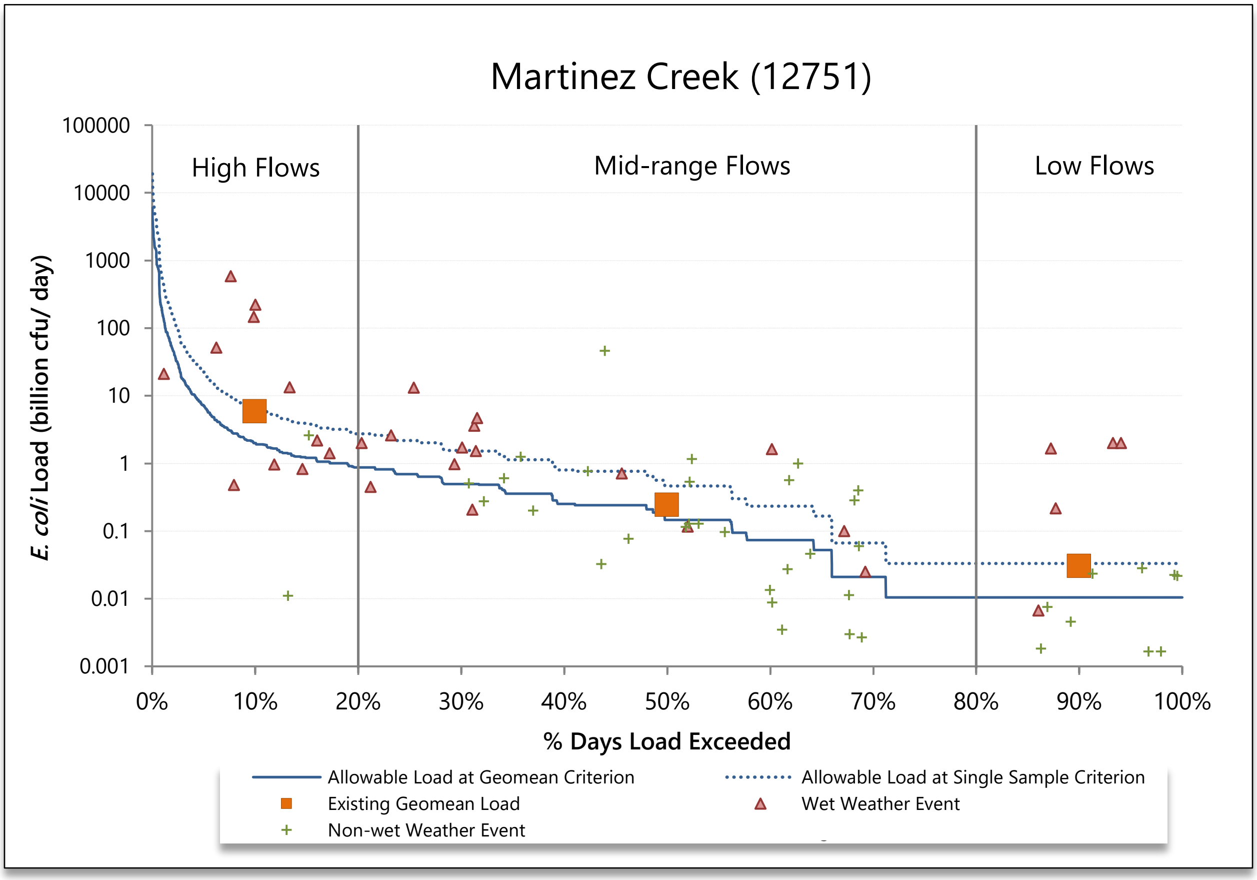

Figure 13. Load duration curve for Martinez Creek (Station 12751).

SECTION 4
TMDL ALLOCATION ANALYSIS

Presented in this report section is the development of the bacteria TMDL allocation for the Martinez Creek watershed. The tool used for developing each TMDL allocation was the LDC method previously described in Section 3 – Bacteria Tool Development. Endpoint identification, margin of safety, load reduction analysis, TMDL allocations, and other TMDL components are described herein.

The LDC method provided a flow-based approach to determine necessary reductions in bacteria loadings and allowable loadings within the Martinez Creek watershed. As developed previously in this report, the modified LDC method uses frequency distributions to assess a bacteria criterion over the historical range of flows, providing a means to determine maximum allowable loadings and the load reduction necessary to achieve support of the primary contact recreation use.

For the purposes of this TMDL study, the TMDL watershed is considered to be the entire Martinez Creek (AU 1911I_01) watershed as shown in the overview map (Figure 1). SWQM Station 12571 was selected based on the criteria mentioned in Section 3.3.2: downstream location, extensive historical *E. coli* dataset, and current monitoring status.

4.1 Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions. The Martinez Creek watershed has a use of primary contact recreation, which is measured against a numeric criterion for the indicator bacteria *E. coli*. Indicator bacteria are not generally pathogenic and are indicative of potential viral, bacterial, and protozoan contamination originating from the feces of warm-blooded animals. The *E. coli* criterion to protect contact recreation in freshwater streams consists of a geometric mean concentration not to exceed 126 cfu/100 mL, as stated in the 2010 Surface Water Quality Standards (TCEQ, 2010).

The endpoint for this TMDL is to maintain concentrations of *E. coli* below the geometric mean criterion of 126 cfu/100 mL. This endpoint is identical to the geometric mean criterion in the 2010 Surface Water Quality Standards (TCEQ, 2010).

4.2 Seasonality

Seasonal variations or seasonality occur(s) when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents. Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Analysis of the seasonal differences in indicator bacteria concentrations were assessed by comparing *E. coli* concentrations obtained from 10 years (2008 – 2018) of routine monitoring collected in the warmer months (May – September) against those collected during the cooler months (October – April). Differences in *E. coli* concentrations obtained in warmer versus cooler months were then evaluated by performing a t-test on the natural log-transformed dataset. This analysis of *E. coli* data indicated that there was no significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for Martinez Creek at station 12751.

4.3 Linkage Analysis

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

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

Bacteria load contributions from permitted and non-permitted stormwater sources are greatest during runoff events. Rainfall runoff, depending on the severity of the storm, has the capacity to carry indicator bacteria from the land surface into the receiving stream. Generally, this loading follows a pattern of lower concentrations in the water body just before the rain event, followed by a rapid increase in bacteria concentrations in the water body as the first flush of storm runoff enters the receiving stream. Over time, the concentrations decline because the sources of indicator bacteria are attenuated as runoff washes them from the land surface and the volume of runoff decreases following the rain event.

An LDC was used to examine the relationship between instream water quality and the source of indicator bacteria loads. Inherent to the use of LDCs as the mechanism of linkage analysis is the assumption of a one-to-one relationship between instream loadings and loadings originating from point sources and the landscape as regulated and non-regulated sources. Further, this one-to-one relationship was also inherently assumed when using an LDC to define the TMDL pollutant load allocation (Section 4.7).

4.4 Load Duration Curve Analysis

The LDC method was used to examine the relationship between instream water quality, the broad sources of indicator bacteria loads, and are the basis of the TMDL allocations. The strength of this TMDL is the use of the LDC method to determine the TMDL allocations. LDCs are a simple statistical method that provides a basic description of the water quality problem. This tool is easily developed and explained to stakeholders, and uses available water quality and flow data. The LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed. The USEPA supports the use of the basic LDC approach to characterize pollutant sources. In addition, many other states are using this basic method to develop TMDLs. As discussed in more detail in Section 4.7 (Pollutant Load Allocation), TMDL loads were based on the median flow within the High Flows regime (or 10 percent flow), where exceedances to the primary contact recreation criteria are most pronounced.

The LDC method allows for estimation of existing and TMDL loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, this method allows for the determination of the hydrologic conditions under which impairments are typically occurring, can give indications of the broad origins of the bacteria (i.e., point source and stormwater) and provides a means to allocate allowable loadings.

Based on the LDCs to be used in the pollutant load allocation process with historical *E. coli* data added to the graph (Figure 13) and Section 2.7 (Potential Sources of Fecal Indicator Bacteria), the following broad linkage statements can be made. For the Martinez Creek watershed, the historical *E. coli* data indicate that elevated bacteria loadings occur under all flow conditions. Elevated loadings also appear to be associated with samples collected during wet weather conditions within all three flow regimes.

4.5 Margin of Safety

The margin of safety (MOS) is used to account for uncertainty in the analysis performed to develop the TMDL and thus provides a higher level of assurance that the goal of the TMDL will be met. According to EPA guidance (USEPA, 1999), the MOS can be incorporated into the TMDL using two methods:

1) Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or

2) Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS is designed to account for any uncertainty that may arise in specifying water quality control strategies for the complex environmental processes that affect water quality. Quantification of this uncertainty, to the extent possible, is the basis for assigning a MOS. The TMDL in this report incorporates an explicit MOS of five percent.

4.6 Load Reduction Analysis

While the TMDL for the Martinez Creek watershed was developed using the LDC method and associated load allocations, additional insight may, in certain situations, be gained through a load reduction analysis. A single percent load reduction required to meet the allowable loading for each of the three flow regimes was determined using the historical *E. coli* data obtained from station 12751.

For each flow regime, the percent reduction required to achieve the geometric mean criterion was determined by calculating the difference in the existing (or measured) geometric mean concentration and the 126 cfu/100 mL criterion and dividing that difference by the existing geometric mean concentration (Table 11).

Table 11. Percent reduction calculations for station 12751 (AU 1911I_01).

Flow Regime	Number of Samples	Geometric Mean by Flow Regime (cfu/100 mL)	Percent Reduction by Flow Regime
High Flows (0-20%)	13	367	66%
Mid-range Flows (20-80%)	43	208	39%
Low Flows (80-100%)	14	364	65%

4.7 Pollutant Load Allocation

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

TMDL = WLA + LA + FG + MOS (Eq. 1)

Where:

TMDL = total maximum daily load

WLA = wasteload allocation, the amount of pollutant allowed by existing regulated or permitted dischargers

LA = load allocation, the amount of pollutant allowed by non-regulated or non-permitted sources

FG = loadings associated with future growth from potential permitted facilities

MOS = margin of safety load

As stated in 40 CFR, §130.2(1), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For *E. coli*, TMDLs are expressed as cfu/day, and represent the maximum one-day load the stream can assimilate while still attaining the standards for surface water quality.

4.7.1 AU-Level TMDL Computations

The bacteria TMDL for Martinez Creek was developed as pollutant load allocations based on information from the LDC (Figure 13). As discussed in more detail in Section 3, the bacteria LDC was developed by multiplying each flow value along the flow duration curves by the *E. coli* geometric mean criterion (126 cfu/100 mL) and by the conversion factor used to represent the allowable loading in cfu/day. Effectively, the "Allowable Load" displayed in the LDC at 10 percent exceedance (the median value of the high flow regime) is the TMDL:

TMDL (cfu/day) = Criterion * Flow (cfs) * Conversion factor (Eq. 2)

Where:

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

Conversion factor (to billion cfu/day) = (283.168 100 mL/ft3 * 86,400 sec/day)/1.0E+9

At 10 percent load duration exceedance, the TMDL values are provided in Table 12.

Table 12. Summary of allowable loading calculations for AU within the TMDL watershed.

Watershed (Station)	AU	10% Exceedance Flow (cfs)	10% Exceedance Load (cfu/ day)	Indicator Bacteria	TMDL (Billion cfu/ day)
Martinez Creek (12571)	1911I_01	0.64978	2.003E+09	*E. coli*	2.0031

4.7.2 Margin of Safety

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

MOS = 0.05 * TMDL (Eq. 3)

Where:

MOS = margin of safety load

TMDL = total maximum daily load

Since the MOS is based solely on the TMDL term, the calculation is straightforward (Table 13).

Table 13. MOS calculations for downstream station within the TMDL watershed.

Watershed	AU	TMDL[a] (Billion cfu/day)	MOS (Billion cfu/day)
Martinez Creek	1911I_01	2.0031	0.1002

[a] TMDL from Table 12

4.7.3 Wasteload Allocation

The WLA consists of two parts – the wasteload that is allocated to TPDES-regulated wastewater treatment facilities (WLA_{WWTF}) and the wasteload that is allocated to regulated stormwater dischargers (WLA_{SW}).

$WLA = WLA_{WWTF} + WLA_{SW}$ (Eq. 4)

TPDES-permitted WWTFs are allocated a daily wasteload (WLA_{WWTF}) calculated as their full permitted discharge flow rate multiplied by the instream geometric criterion. One-half the freshwater *E. coli* criterion (126 cfu/100mL) is used as the WWTF target. This is expressed in the following equation:

WLA_{WWTF} = Criterion/2 * Flow * Conversion Factor (Eq. 5)

Where:

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

Flow = full permitted flow in million gallons per day (MGD)

Conversion Factor (to billion cfu/day) = (1.54723 cfs/MGD *283.168 100 mL/ft3 * 86,400 s/d)/1.0E+9

Due to the absence of any permitted dischargers in the Martinez Creek watershed the WLA_{WWTF} component is zero.

Stormwater discharges from MS4, industrial, and construction areas are also considered permitted or regulated point sources. Therefore, the WLA calculations must also include an allocation for permitted stormwater discharges (WLA_{SW}). A simplified approach for estimating the WLA for these areas was used in the development of these TMDLs due to the limited amount of data available, the complexities associated with simulating rainfall runoff, and the variability of stormwater loading. The percentage of the land area included in the Martinez Creek watershed that is under the jurisdiction of stormwater permits is used to estimate the amount of the overall runoff load that should be allocated as the permitted stormwater contribution in the WLA_{SW} component of the TMDL.

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

$$WLA_{SW} = (TMDL - WLA_{WWTF} - FG - MOS) * FDA_{SWP} \quad \text{(Eq. 6)}$$

Where:

WLA_{SW} = sum of all regulated stormwater loads

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

FG = sum of future growth loads from potential permitted facilities

MOS = margin of safety load

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

The fractional proportion of the drainage area under the jurisdiction of stormwater permits (FDA_{SWP}) must be determined in order to estimate the amount of overall runoff load that should be allocated to WLA_{SW}. The term FDA_{SWP} was calculated based on the combined area under regulated stormwater permits. As described in Section 2.7.1.3, the Martinez Creek watershed is covered 100 percent by MS4 Phase I and MS4 Phase II permits. However, even in highly urbanized areas such as the Martinez Creek watershed, there remain small areas of streams within each watershed that are not strictly regulated and which may receive bacteria loadings from unregulated sources such as wildlife. To account for these small unregulated areas, the stream length (TCEQ, 2016b) was multiplied by the average channel width as calculated based on recent aerial imagery, and the results were used to compute an area of unregulated stormwater contribution (Table 14).

Table 14. Basis of unregulated stormwater area and computation of FDA_{SWP} term.

Watershed	AU	Total Area (acres)	Stream Length (feet)	Estimated Average Channel Width (feet)	Estimated Stream Area (acres)	Fraction Unregulated Area	FDA_{SWP}
Martinez Creek	1911I_01	4,665.5	31,975.7	51.2	37.6	0.0081	0.9919

In order to calculate WLA_{SW} (Eq. 6), the Future Growth (FG) term must be known. The calculation for the FG term is presented in the next section, but the results will be included here for continuity. Table 15 provides the information needed to compute WLA_{SW}.

Table 15. Regulated stormwater calculations for the TMDL watershed.

Load units expressed as billion cfu/day *E. coli*

Watershed	AU	Indicator	TMDL [a]	WLA_{WWTF}	FG	MOS [b]	FDA_{SWP} [c]	WLA_{SW}
Martinez Creek	1911I_01	*E. coli*	2.0031	0	0	0.1002	0.9919	1.8875

[a] TMDL from Table 12
[b] MOS from Table 13
[c] FDA_{SWP} from Table 14

4.7.4 Future Growth

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

The FG term is calcuated as follows:

$$FG = Criterion * WWTF_{FP} * Conversion\ Factor \quad \text{(Eq. 7)}$$

Where:

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

$WWTF_{FP}$ = full permitted discharge (MGD) of potential future WWTF

Conversion Factor (to billion cfu/day) = (1.54723 cfs/MGD *283.168 100 mL/ft3 * 86,400 s/d)/1.0E+9

As noted previously in sections 2.3 and 2.7.1.1 the Martinez Creek watershed is entirely within the collection system area of the SAWS. Additionally there are no WWTFs located within the Martinez Creek watershed and there are no plans to build a new WWTF within the watershed (SAWS, 2019). Due to 100 percent coverage of wastewater collection by the SAWS and the absence of WWTFs in the Martinez Creek watershed, the FG component for impaired segment 1911I is zero.

4.7.5 Load Allocation

The load allocation (LA) is the loads from unregulated sources, and is calculated as:

$$LA = TMDL - WLA_{WWTF} - WLA_{SW} - FG - MOS \quad \text{(Eq. 8)}$$

Where:

LA = allowable loads from unregulated sources within the AU

TMDL = total maximum daily load

WLA_{WWTF} = sum of all WWTF loads

WLA_{SW} = sum of all regulated stormwater loads

FG = sum of future growth loads from potential permitted facilities

MOS = margin of safety load

The calculation results are shown in Table 16.

Table 16. Load allocation calculations for the TMDL watershed.

Units expressed as billion cfu/day *E. coli*.

Watershed	AU	Indicator	TMDL[a]	WLA_{WWTF}	WLA_{SW}[b]	FG	MOS[c]	LA
Martinez Creek	1911I_01	*E. coli*	2.0031	0	1.8875	0	0.1002	0.0154

[a] TMDL from Table 12
[b] WLA_{SW} from Table 15
[c] MOS from Table 13

4.8 Summary of TMDL Calculations

Table 17 summarizes the TMDL calculations for the Martinez Creek (11911I_01) watershed. The TMDL was calculated based on the median flow in the 0-20 percentile range (10 percent exceedance, high flow regime) for flow exceedance from the LDC developed for the downstream SWQM station in the watershed (12751). Allocations are based on the current geometric mean criterion for *E. coli* of 126 cfu/100 mL for each component of the TMDL.

Table 17. TMDL allocation summary for the Martinez Creek watershed.

Units expressed as billion cfu/day *E. coli*.

AU	Stream Name	Indicator	TMDL [a]	WLA_{WWTF} [b]	WLA_{SW} [c]	LA [d]	FG [e]	MOS [f]
1911I_01	Martinez Creek	*E. coli*	2.0031	0	1.8875	0.0154	0	0.1002

[a] TMDL from Table 12
[b] WLA_{WWTF} 0 cfu/100 mL due to an absence of any WWTFs within the Martinez Creek watershed
[c] WLA_{SW} from Table 15
[d] LA from Table 16
[e] FG 0 cfu/100 mL since the establishment of WWTFs within the Martinez Creek watershed is highly unlikely
[f] MOS from Table 13

The final TMDL allocations (Table 18) needed to comply with the requirements of 40 CFR §130.7 include the future growth component within the WLA_{WWTF}.

In the event that the criterion changes due to future revisions in the state's surface water quality standards, Appendix B provides guidance for recalculating the allocations in Table 18. Figure A-1 was developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of proposed water quality criteria for *E. coli*. The equations provided, along with Figure A-1, allow calculation of a new TMDL and pollutant load allocation based on any potential new water quality criterion for *E. coli*.

Table 18. Final TMDL allocations for the impaired Martinez Creek watershed.

Units expressed as billion cfu/day *E. coli*.

AU	TMDL	WLA_{WWTF} [a]	WLA_{SW}	LA	MOS
1911I_01	2.0031	0	1.8875	0.0154	0.1002

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

SECTION 5
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Appendix A.
Equations for Calculating TMDL Allocations for Changed Contact Recreation Standard

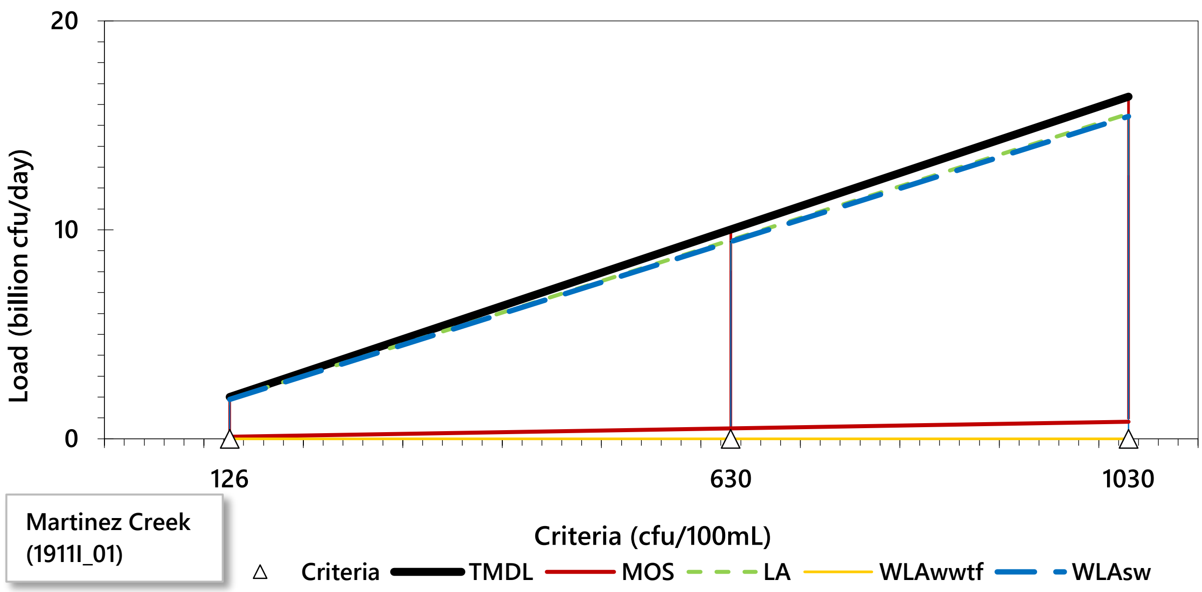

Figure A-1. Allocation loads for Martinez Creek (1911I_01) as a function of water quality criteria.

All loads below are in billion cfu/day

Term	Criterion 126 cfu/100 mL	Criterion 630 cfu/100 mL	Criterion 1030 cfu/100 mL
TMDL	2.0031	10.0154	16.3743
MOS	0.1002	0.5008	0.8187
LA	0.0154	0.0771	0.1260
WLA_{WWTF}	0.0000	0.0000	0.0000
WLA_{SW}	1.8875	9.4375	15.4296

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

TMDL =(0.01589735 * Std) + 0.00004528

MOS =(0.00079480 * Std) + 0.00006085

LA =(0.00012235 * Std) - 0.00000472

WLA_{WWTF} =0.0

WLA_{SW} =(0.01498020 * Std) - 0.00001085

Where:

Std = Revised Contact Recreation Standard

MOS = Margin of Safety

LA = Total load allocation (non-permitted source contributions)

WLA_{WWTF} = Wasteload allocation (permitted WWTF load + future growth)

WLA_{SW} = Wasteload allocation (permitted stormwater)