TECHNICAL SUPPORT DOCUMENT FOR ADDITIONS TO THE UPPER SAN ANTONIO WATERSHED, SAN ANTONIO, TEXAS (1910D, 1911B, 1911C, 1911D, AND 1911E)

Photo of Alazan Creek - © San Antonio River Authority (SARA)
http://westsidecreeks.com/aboutcreeks/alazan.html

Prepared for:

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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ACRONYMS AND ABBREVIATIONS

ASAE	American Society of Agricultural Engineers
C-CAP	Coastal Change Analysis Program
CAFO	concentrated animal feeding operation
CFR	Code of Federal Regulations
cfs	cubic feet per second
counts	colony forming unit
CN	curve number
CWA	Clean Water Act
dL	Deciliter
DMR	discharge monitoring report
E coli	Escherichia coli
FDC	flow duration curve
GIS	geographic information system
LA	load allocation
LDC	load duration curve
mL	Milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NRCS	National Resources Conservation Service
OSSF	on-site sewage facility
RMSE	root mean square error
SARA	San Antonio River Authority
SAWS	San Antonio Water System
SSO	sanitary sewer overflow
SWQS	surface water quality standards
SWQMIS	Surface Water Quality Monitoring Information System
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TCOON	Texas Coastal Ocean Observation Network
TMDL	Total Maximum Daily Loads
TPDES	Texas Pollution Discharge Elimination System
TWDB	Texas Water Development Board
TxDOT	Texas Department of Transportation
USDA	U.S. Department of Agriculture

USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	waste load allocation
WQM	water quality monitoring
WQS	water quality standard
WWTF	wastewater treatment facility

CHAPTER 1
INTRODUCTION

1.1 Watershed Description

The Upper San Antonio Watershed is part of the San Antonio River Basin which encompasses most of the greater San Antonio area and the upstream and downstream areas that drain into the San Antonio River and its confluences. The San Antonio River Basin drains over 4,194 square miles of land, a large portion of which is the city of San Antonio. The San Antonio River Basin is composed of Medina River Watershed, Leon Creek Watershed, Salado Creek Watershed, Cibolo Creek Watershed, Upper San Antonio River Watershed, and Lower San Antonio River Watershed. These watersheds drain into the 85 mile long San Antonio River which empties into the Gulf of Mexico. The main segment of the San Antonio River Basin is the San Antonio River, which flows for 240 miles from San Antonio in Bexar County, to its confluence with the Guadalupe River in Refugio County, and then flows for another 11 miles before draining into the San Antonio Bay and the Gulf of Mexico. The San Antonio River Basin contains a network comprised of more than 8,800 miles of streams.

The San Antonio River Basin begins in the northeast at Kerr County and continues southwest to its confluence with the Guadalupe River in Refugio County. Approximately 11 miles downriver of the confluence, the Guadalupe drains into the San Antonio Bay and the Gulf of Mexico. The San Antonio River Basin drains the majority of Bandera, Bexar, Wilson, and Karnes counties as well as approximately one third of Goliad County and small portions of Kerr, Kendall, Medina, Comal, Atascosa, Guadalupe, Victoria, and Refugio Aransas Counties. The Upper San Antonio River Watershed drains approximately one third of Bexar and Wilson Counties, as well as a small portion of Karnes County. The Upper San Antonio River Watershed drains much of the central San Antonio area.

The Upper San Antonio River Watershed contains Apache Creek, San Pedro Creek, Alazan Creek, and Martinez Creek subwatersheds. The Apache Creek Watershed spans approximately 23.4 square miles, and the Alazan Creek Watershed spans approximately 17.5 square miles. The San Pedro Creek Watershed spans approximately 45.6 square miles and was historically a focal point for human and animal settlement, having been occupied by Native Americans, Paleo-Indians, Mastodons, and giant tigers. The Martinez Creek Watershed spans approximately 7.3 square miles; however, a large eastern section of houses in this watershed are vacant due to flooding in 1998 and 2002.

The San Antonio River Basin is home to diverse wildlife and contains five ecoregions, and the Upper San Antonio River Watershed spans two of the regions: the Texas Blackland Prairies and the East Central Texas Plains. The Texas Blackland Prairies ecoregion is temperate grassland of oaklands and savannahs, shaped by frequent wildfire and named for its dark, fertile soil. The East Central Texas Plains is a temperate broadleaf and mixed forest ecoregion with small pockets of prairies; however, the natural environment has changed greatly as a result of cattle ranching and forest clearance for agriculture. Both these ecoregions are complex and diverse ecosystems full of many different species of wildlife and plants.

There are three nature parks within the San Antonio River Basin, and one within the Upper San Antonio River Watershed. The Helton-San Antonio Nature Park is with the Upper

San Antonio Watershed spanning 98 acres and is operated by the San Antonio River Authority.

Subwatershed List

This report focuses on the following waterbodies that TCEQ placed in Category 5 [303(d) list] of the 2012 Integrated Report for nonsupport of contact recreation use:

§ 1910D - Menger Creek (1910D_01)

§ 1911B - Apache Creek (1911B_01) listed 2010

§ 1911C - Alazan Creek (1911C_01) & (1911C_02) listed 2010

§ 1911D - San Pedro Creek (1911D_01) & (1911D_02) listed 2010

§ 1911E - Sixmile Creek (1911E_01)

Figure 1-1 is a location map showing these Texas waterbodies and their contributing watersheds. The delineation of each subwatershed is derived from 2007 geographic information system (GIS) subbasin files for Bexar County acquired through the San Antonio River Authority (SARA). These waterbodies and their surrounding watersheds are hereinafter referred to as the Study Area.

The climate of the region is subtropical humid, with very hot and humid summers and mild winters. The average monthly temperature is 26.7 degrees Celsius (80 degrees Fahrenheit) while the temperature averages between 10 degrees Celsius (50 degrees Fahrenheit) during the winter. While summer rainfall is limited in July and August due to semi-arid conditions, when heavy rainfall does occurs it is dominated by the remnants of tropical storms or stalled frontal systems. Winter rainfall typically occurs due to cold frontal storms, though rainfall is highly variable for this region. (NOAA 2014)

Table 1-1, derived from the 2000 and 2010 U.S. Census, demonstrates that the county in which the watershed is located is very densely populated. Table 1-1 also shows population growth for Bexar County (U.S. Census Bureau 2010).

Table 1-1: County Population and Density

County Name	2000 U.S. Census	2000 Population Density (per square mile)	2010 U.S. Census	2010 Population Density (per square mile)
Bexar	1,392,931	1,124	1,714,773	1,384

Source: U.S. Census 2000 and 2010

The five largest cities within the Upper San Antonio Watershed are expected to increase in population by an average of 20 percent from 2010 to 2030, according to the Texas Water Development Board (TWDB) (TWDB 2013). Table 1-2 lists TWDB population growth estimates for these five cities from 2010 to 2030. City of San Antonio is the largest City in the watershed and is anticipated to grow by 30% while Windcrest is the smallest city and is anticipated to grow a small amount, just 8% between 2010 and 2030.

Table 1-2: Upper San Antonio Watershed Population Increases by City, 2010 to 2030

City	2010 Census Population	2020 Population Estimate	2030 Population Estimate	Growth Rate (2010-2030)
KIRBY	8,000	9,210	10,411	30%
LEON VALLEY	10,151	10,886	11,616	14%
SAN ANTONIO	1,327,407	1,528,129	1,727,491	30%
WINDCREST	5,364	5,573	5,781	8%
ALAMO HEIGHTS	7,031	8,095	8,423	20%

Source: Region I - Draft Population and Municipal Demand Projections for 2016 Regional and 2017 State Water Plan
http://www.twdb.state.tx.us/waterplanning/data/projections/2017/demandproj.asp

Population estimates for each Assessment Unit drainage area were derived from the 2010 Census and are provided in Table 1-3.

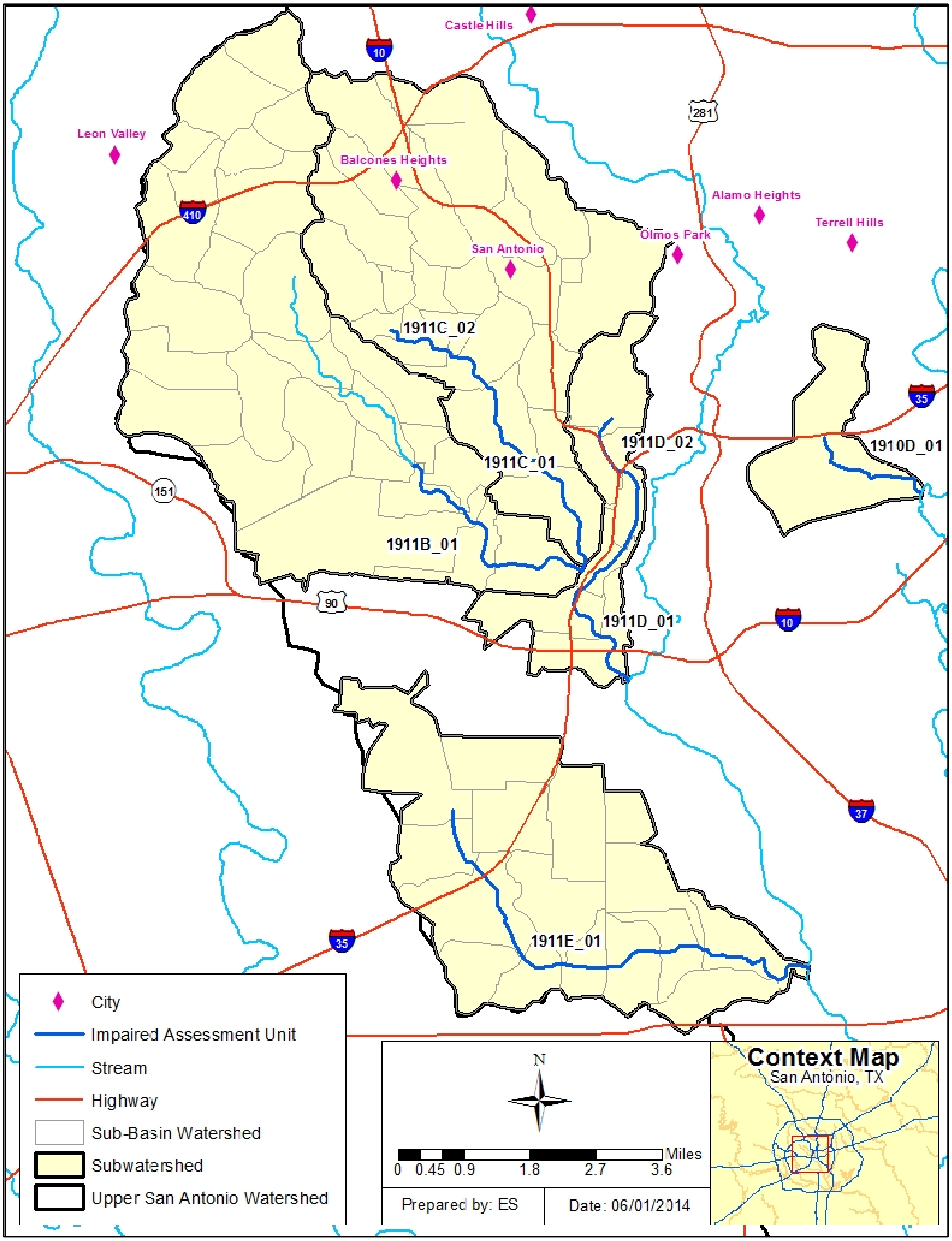

Figure 1-1: Location Map for Upper San Antonio Watershed Region

Table 1-3: Population Estimate by Assessment Unit

Segment Name	Assessment Unit	2010 Census Population Estimate	2010 Census Household Count
Menger Creek	1910D	11,157	4,113
Apache Creek	1911B	125,978	46,364
Alazan Creek	1911C	108,503	42,609
San Pedro Creek	1911D	24,734	10,323
Sixmile Creek	1911E	58,927	20,197

1.2 Summary of Existing Data

The following subsections summarize existing data relevant to soil, land cover, and precipitation throughout the watershed as well as the chemical and physical characteristics of the waterbodies using ambient water quality, stream flow, and conductivity data.

1.2.1 Soil

The geology of this portion of the Upper San Antonio Watershed is comprised of well-draining to moderately well-draining clayey soils with low available water storage. The Soil Survey Geographic (SSURGO) Database National Resources Conservation Service (NRCS) 2012 information was used to characterize the soil in the Study Area. As shown in Figure 1-2, the soil types that dominate the watershed are the Houston, Branyon, and Lewisville soil series. Table 1-4 lists the attributes of the soil series found in the Study Area and Table 1-5 provides the soil distribution in the Study Area.

Table 1-4: Characteristics of Soil Types in the Subwatersheds within the Upper San Antonio Watershed

NRCS Soil Type	Surface Texture	Soil Series Name	Hydro-logic Soil Group	Soil Drainage Class	Average Available Water Storage (cm)
TX029	Silty Clay	Austin silty clay, 1 to 3 percent slopes	C	Well Drained	19.3
TX029	Silty Clay	Austin silty clay, 3 to 5 percent slopes	C	Well Drained	13.7
TX029	Clay Loam	Whitewright clay loam 1 to 5 percent slopes	D	Well Drained	6.6
TX029	Gravelly Clay Loam	Brackett gravelly clay loam, 3 to 12 percent slopes	D	Well Drained	4.8
TX029	Silty Clay	Whitewright-Austin complex, 1 to 5 percent slopes	C/D	Well Drained	19.3
TX029	Clay	Heiden-Ferris complex, 5 to 10 percent slopes, severely eroded	D	Well Drained	30.2
TX029	Clay	Houston Black clay, 0 to 1 percent slopes	D	Moderately Well Drained	22.9
TX029	Clay	Houston Black clay, 1 to 3 percent slopes	D	Moderately Well Drained	22.9
TX029	Clay	Houston Black clay, 3 to 5 percent slopes	D	Moderately Well Drained	22.9
TX029	Clay	Branyon clay, 0 to 1 percent slopes	D	Moderately Well Drained	23.6
TX029	Clay	Branyon clay, 1 to 3 percent slopes	D	Moderately Well Drained	23.6
TX029	Gravelly Clay	Houston Black gravelly clay, 1 to 3 percent slopes	D	Moderately Well Drained	22.1
TX029	Gravelly Clay	Houston Black gravelly clay, 3 to 5 percent slopes	D	Moderately Well Drained	22.1
TX029	Silty Clay	Lewisville silty clay, 0 to 1 percent slopes	B	Well Drained	25.4
TX029	Silty Clay	Lewisville silty clay, 1 to 3 percent slopes	B	Well Drained	25.4
TX029	Silty Clay	Stephen silty clay, 1 to 3 percent slopes	D	Well Drained	6.1
TX029	Cobbly Clay	Eckrant cobbly clay, 1 to 5 percent slopes	D	Well Drained	4.1
TX029	Gravelly Clay Loam	Eddy gravelly clay loam, 1 to 8 percent slopes	D	Well Drained	1.3
TX029	Clay	Tinn and Frio soils, 0 to 1 percent slopes, frequently flooded	C/D	Moderately Well Drained	32.8
TX029	Clay Loam	Loire clay loam, 0 to 2 percent slopes, occasionally flooded	B	Well Drained	35.3
TX029	Clay Loam	Patrick soils, 1 to 3 percent slopes, rarely flooded	B	Well Drained	11.9
TX029	Gravelly Clay Loam	Patrick soils, 3 to 5 percent slopes, rarely flooded	B	Well Drained	10.2
TX029	Fine Sandy Loam	Miguel fine sandy loam, 1 to 3 percent slopes	C	Well Drained	23.4
TX029	Clay Loam	San Antonio clay loam, 1 to 3 percent slopes	C	Well Drained	25.1

All information derived from SSURGO data: http://datagateway.nrcs.usda.gov/

Table 1-5: Soil Type Distribution in the Subwatersheds within the Upper San Antonio Watershed

	Segments				
Soil Series Name	**1910D**	**1911B**	**1911C**	**1911D**	**1911E**
Austin silty clay, 1 to 3 percent slopes	1.40%	0.00%	12.00%	7.40%	0.00%
Austin silty clay, 3 to 5 percent slopes	1.90%	0.00%	15.80%	7.10%	0.00%
Whitewright clay loam 1 to 5 percent slopes	1.61%	0.00%	6.78%	0.00%	0.00%
Brackett gravelly clay loam, 3 to 12 percent slopes	0.00%	0.00%	3.00%	0.00%	0.00%
Whitewright-Austin complex, 1 to 5 percent slopes	11.20%	4.10%	4.36%	0.00%	0.00%
Heiden clay, 1 to 3 percent slopes	0.50%	0.00%	0.00%	0.00%	0.00%
Heiden-Ferris complex, 5 to 10 percent slopes, severely eroded	0.12%	13.00%	0.00%	0.00%	0.00%
Houston Black clay, 0 to 1 percent slopes	1.24%	0.00%	0.00%	0.00%	1.75%
Houston Black clay, 1 to 3 percent slopes	13.00%	9.60%	34.00%	0.00%	7.07%
Houston Black clay, 3 to 5 percent slopes	0.92%	0.00%	4.00%	0.00%	0.00%
Branyon clay, 0 to 1 percent slopes	15.60%	0.00%	1.68%	26.70%	40.39%
Branyon clay, 1 to 3 percent slopes	3.80%	0.00%	4.70%	23.40%	4.20%
Houston Black gravelly clay, 1 to 3 percent slopes	12.40%	43.30%	0.60%	0.00%	3.37%
Houston Black gravelly clay, 3 to 5 percent slopes	6.70%	25.80%	2.30%	0.00%	0.80%
Lewisville silty clay, 0 to 1 percent slopes	6.70%	0.10%	2.65%	11.60%	27.86%
Lewisville silty clay, 1 to 3 percent slopes	0.72%	1.70%	0.00%	13.40%	4.60%
Pits and Quarries, 1 to 90 percent slopes	0.10%	0.00%	0.00%	0.00%	0.30%
Stephen silty clay, 1 to 3 percent slopes	1.00%	0.00%	0.00%	0.00%	0.00%
Stephen silty clay, 3 to 5 percent slopes	0.20%	0.00%	0.00%	0.00%	0.00%
Eckrant cobbly clay, 1 to 5 percent slopes	0.35%	0.00%	0.10%	5.40%	0.00%
Eddy gravelly clay loam, 1 to 8 percent slopes	14.00%	0.10%	5.65%	0.00%	0.00%
Tinn and Frio soils, 0 to 1 percent slopes, frequently flooded	6.10%	0.00%	2.10%	2.80%	1.80%
Sunev clay loam, 1 to 3 percent slopes	0.34%	0.00%	0.00%	0.00%	0.00%
Water	0.10%	0.00%	0.28%	0.00%	0.00%

Rock outcrop-Olmos complex, 5 to 25 percent slopes	0.00%	0.30%	0.00%	0.00%	0.44%
Loire clay loam, 0 to 2 percent slopes, occasionally flooded	0.00%	2.00%	0.00%	0.00%	0.35%
Patrick soils, 1 to 3 percent slopes, rarely flooded	0.00%	0.00%	0.00%	0.60%	0.00%
Patrick soils, 3 to 5 percent slopes, rarely flooded	0.00%	0.00%	0.00%	1.60%	0.68%
Miguel fine sandy loam, 1 to 3 percent slopes	0.00%	0.00%	0.00%	0.00%	1.92%
San Antonio clay loam, 1 to 3 percent slopes	0.00%	0.00%	0.00%	0.00%	4.00%
Floresville fine sandy loam, 1 to 3 percent slopes	0.00%	0.00%	0.00%	0.00%	0.47%

All information derived from SSURGO data: http://datagateway.nrcs.usda.gov/

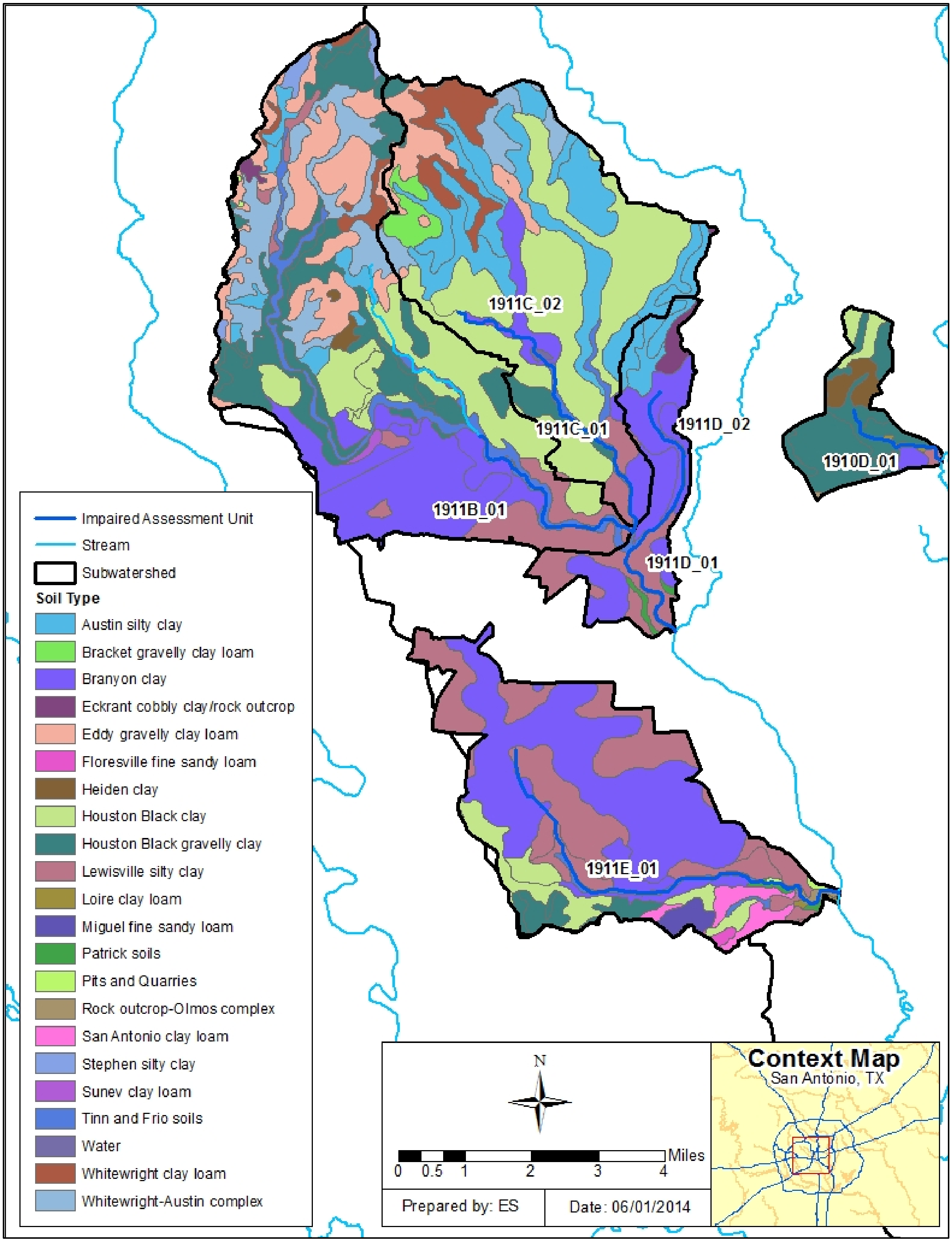

Figure 1-2: Upper San Antonio Watershed Region Soil Types

1.2.2 Land Cover

As previously noted, the central portion of the Upper San Antonio watershed is heavily developed as it encompasses the major city of San Antonio. The northern portion is sparsely developed and largely evergreen forest and shrub. The southeastern portion is predominantly low intensity developed land, pasture/hay, and shrub with sparse cultivated cropland and open water: Calaveras Lake and Victor Braunig Lake. Table 1-6 summarizes the acreages and the corresponding percentages of the land cover categories for the contributing subwatershed associated with each impaired assessment unit in the Upper San Antonio Watershed. The land cover data was retrieved from the U.S. Geological Survey (2006) land cover database obtained from USGS National Map Viewer. The total acreage of each segment in Table 1-6 corresponds to the watershed delineation shown in Figure 1-3. The predominant land cover category in the Upper San Antonio Watershed is developed land (between 8% and 69%), followed by shrub/scrub (between 0% and 19%), evergreen forest (between 0% and 11%), and pasture/hay (between 0% and 10%). Open water and barren land account for less than 10 percent of the assessment units. The land cover for each subwatershed is shown in Figure 1-3.

Table 1-6: Aggregated Land Cover Summaries by Assessment Unit

Aggregated Land Cover Category	Segment Name and Assessment Unit ID						
	Menger Creek	Apache Creek	Alazan Creek		San Pedro Creek		Sixmile Creek
Assessment Unit	1910D_01	1911B_01	1911C_01	1911C_02	1911D_01	1911D_02	1911E_01
Watershed Area (acres)	1959	14559	11231		2993		9532
Acres of Open Water	0	31	34		0		8
Acres of Developed, Open Space	506	3684	1610		318		2686
Acres of Developed, Low Intensity	618	5674	5398		875		3275
Acres of Developed, Medium Intensity	473	2979	2423		778		1573
Acres of Developed, High Intensity	361	1819	1698		993		1298
Acres of Barren Land (Rock/sand/clay)	0	1	0		1		0
Acres of Deciduous Forest	0	105	0		0		76
Acres of Evergreen Forest	0	40	30		0		118
Acres of Mixed Forest	0	0	0		0		29
Acres of Shrub/Scrub	0	125	12		13		349
Acres of Grassland/Herbaceous	0	49	25		16		26
Acres of Pasture/Hay	0	0	0		0		18
Acres of Cultivated Crops	0	3	0		0		8
Acres of Woody Wetlands	0	48	2		0		68
Acres of Emergent Herbaceous Wetlands	0	0	0		0		0

Aggregated Land Cover Category	Segment Name and Assessment Unit ID						
	Menger Creek	Apache Creek	Alazan Creek		San Pedro Creek		Sixmile Creek
Assessment Unit	**1910D_01**	**1911B_01**	**1911C_01**	**1911C_02**	**1911D_01**	**1911D_02**	**1911E_01**
Watershed Area (acres)	**1959**	**14559**	**11231**		**2993**		**9532**
Percent Open Water	0%	0.2%	0.3%		0%		0.08%
Percent Developed, Open Space	25.8%	25.3%	14.3%		10.6%		28.18%
Percent Developed, Low Intensity	31.6%	39%	48.1%		29.2%		34.36%
Percent Developed, Medium Intensity	24.2%	20.5%	21.6%		26%		16.5%
Percent Developed, High Intensity	18.4%	12.5%	15.1%		33.2%		13.61%
Percent Barren Land (Rock/sand/clay)	0%	0%	0%		0%		0%
Percent Deciduous Forest	0%	0.7%	0%		0%		0.8%
Percent Evergreen Forest	0%	0.3%	0.3%		0%		1.2%
Percent Mixed Forest	0%	0%	0%		0%		0.3%
Percent Shrub/Scrub	0%	0.9%	0.1%		0.44%		3.7%
Percent Grassland/Herbaceous	0%	0.3%	0.2%		0.53%		0.27%
Percent Pasture/Hay	0%	0%	0%		0%		0.2%
Percent Cultivated Crops	0%	0%	0%		0%		0.08%
Percent Woody Wetlands	0%	0.3%	0%		0%		0.72%
Percent Emergent Herbaceous Wetlands	0%	0%	0%		0%		0%

All information derived from USGS data: http://viewer.nationalmap.gov/viewer/

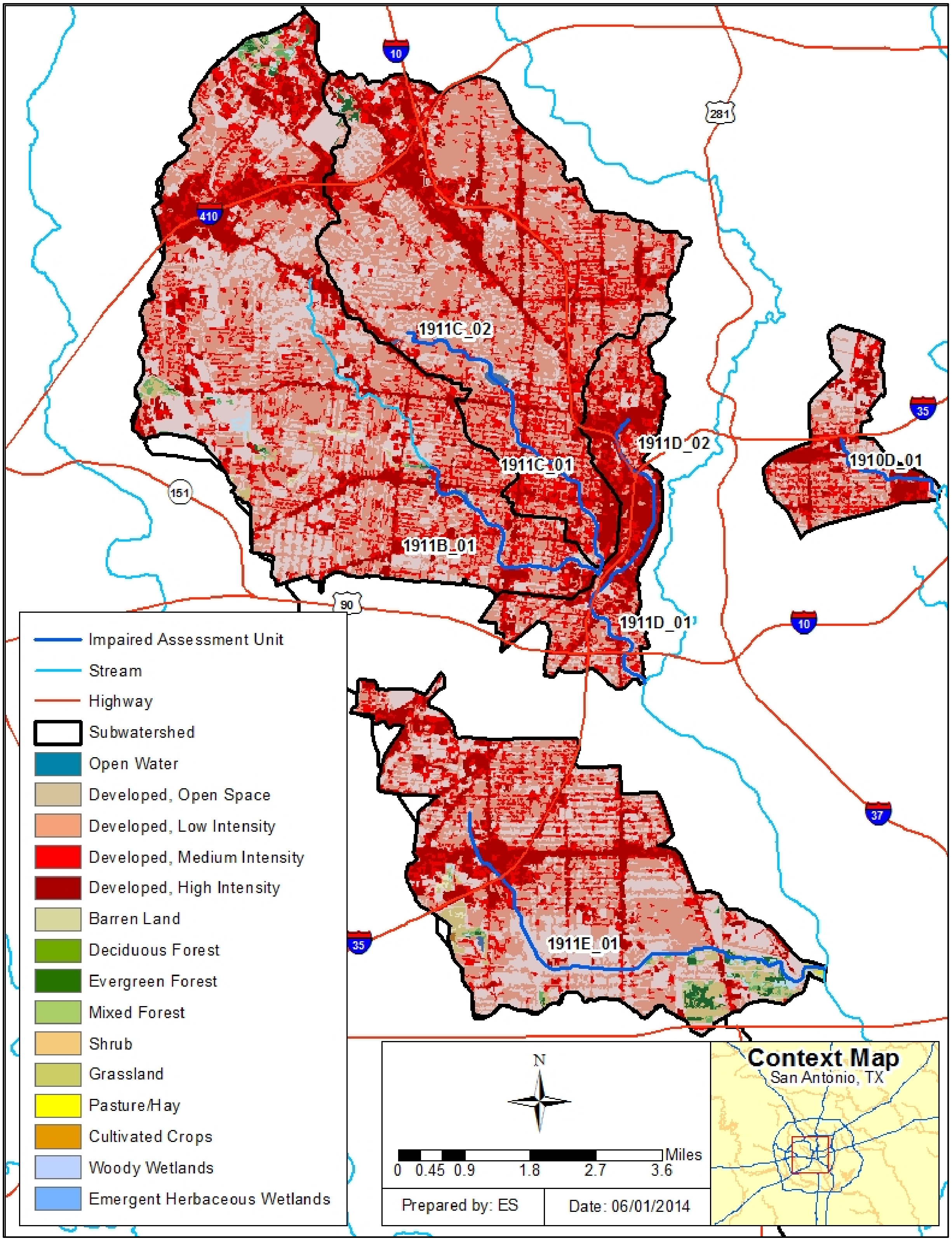

Figure 1-3: Upper San Antonio Watershed Land Cover

1.2.3 Precipitation

As shown in Figure 1-4, there are approximately 16 rain gages in the surrounding area for these segments, but only three gages had data available for an extended time period. None of the three gages were within the subwatershed for any of the segments of interest. These three gages are maintained by the National Oceanic and Atmospheric Administration (NOAA) as part of the National Climate Data Center. The total annual rainfall for the three gages for a 13-year period was obtained. It should be noted that one gage, San Antonio SeaWorld, did not have data for 2012. The region has low levels of humidity and receives annual precipitation ranging between 28.7 and 34.4 inches per year. Based on data for the period 2000 to 2012, this region of the Upper San Antonio Watershed has an annual rainfall average of 31.7 inches per year.

The annual average precipitation values for each subwatershed derived from PRISM data in this portion of Texas range between 30.2 and 32.4 inches per year (Table 1-7). The average determined through the PRISM data is within the range of rainfall for the three gages near the region of interest. Since the number and spread of the gages is not acceptable for the segments of interest, the Thiessen polygons were not determined and the PRISM average values will be used in load duration curve development.

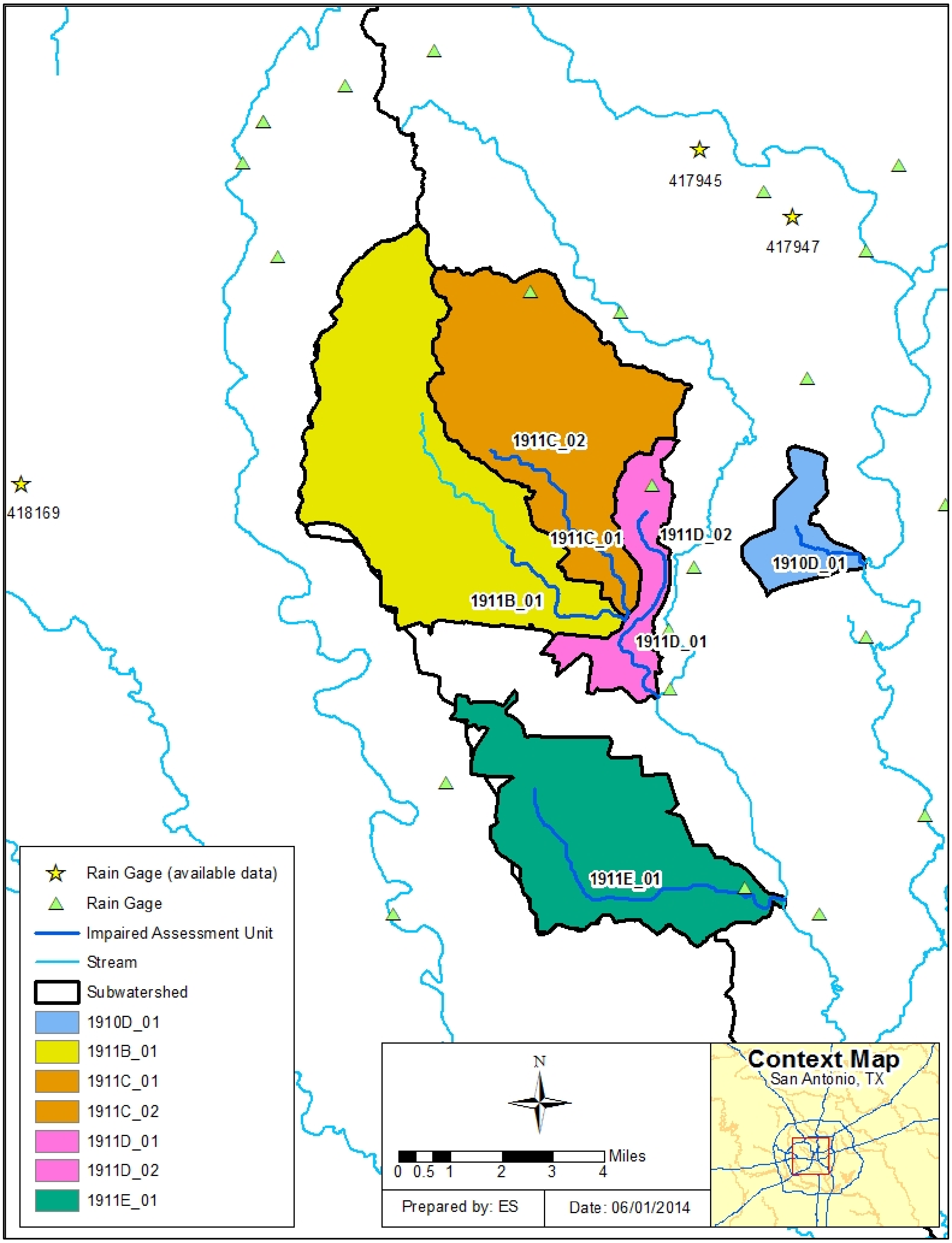

Figure 1-4: Rain Gages within the Upper San Antonio Watershed

Table 1-7: PRISM Annual Average Precipitation, 1981-2010

Segment Name	Segment	Average Annual (Inches)
Menger Creek	1910D	31.6
Apache Creek	1911B	31.1
Alazan Creek	1911C	31.7
San Pedro Creek	1911D	31.1
Sixmile Creek	1911E	30.4

Source: PRISM Group 2006

1.2.4 Ambient Water Quality

Considerable amounts of ambient water quality data are available to support water quality assessment and development of TMDLs for segments in the Upper San Antonio Watershed. Historical indicator bacteria data for the period 2000 to 2012 were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) database. All of the data corresponds to *Escherichia coli* samples (608 samples).

Table 1-8 summarizes the historical ambient water quality data for indicator bacteria (2000-2012) for select TCEQ Water Quality Monitoring (WQM) stations in the Upper San Antonio Watershed. Figure 1-5 shows the locations of the WQM locations with indicator bacteria data. Table 1-8 presents the number of indicator bacteria samples, as well as the geometric mean of the concentrations for each indicator, and the number and percentage of single sample exceedances of the Texas Surface Water Quality Standards (SWQS). A more in-depth discussion of the analysis of this data set is provided in Sections 2.3 and 2.4.

Table 1-8: Historical Water Quality Data for the TCEQ Stations from 2000 to 2012

Segment	Station ID	Indicator Bacteria	Geometric Mean Concentration (MPN/100ml)	Number of Samples	Number of Samples Exceeding Single Sample Criterion	% of Samples Exceeding
1910D	12693	EC	485.23	22	10	45%
1911B	12710	EC	521.06	6	4	67%
	15707	EC	1199.74	6	4	67%
	18735	EC	522.96	46	23	50%
	20604	EC	1193.71	6	3	50%
	20605	EC	894.34	6	4	67%
	20606	EC	935.03	6	4	67%
1911C	12715	EC	316.64	43	17	40%
	12716	EC	159.68	6	3	50%
	12718	EC	344.47	6	2	33%
	18737	EC	321.30	6	3	50%
	20344	EC	646.24	6	3	50%
	20345	EC	740.68	6	4	67%
1911D	12709	EC	77.64	23	4	17%
	18736	EC	327.25	45	19	42%
	20116	EC	446.44	6	2	33%
	20117	EC	539.80	28	15	54%
	20119	EC	504.27	31	15	48%
	20120	EC	1406.59	6	6	100%
	20121	EC	908.12	6	5	83%
1911E	12705	EC	385.10	24	11	46%

EC: E coli.
Geometric Mean Criteria: 126 MPN/100 ml for EC.
Single Sample Criteria: 399 MPN/100 ml for EC.
Geometric mean concentrations were calculated assuming one-half the value of any concentration reported as less than the detection limit

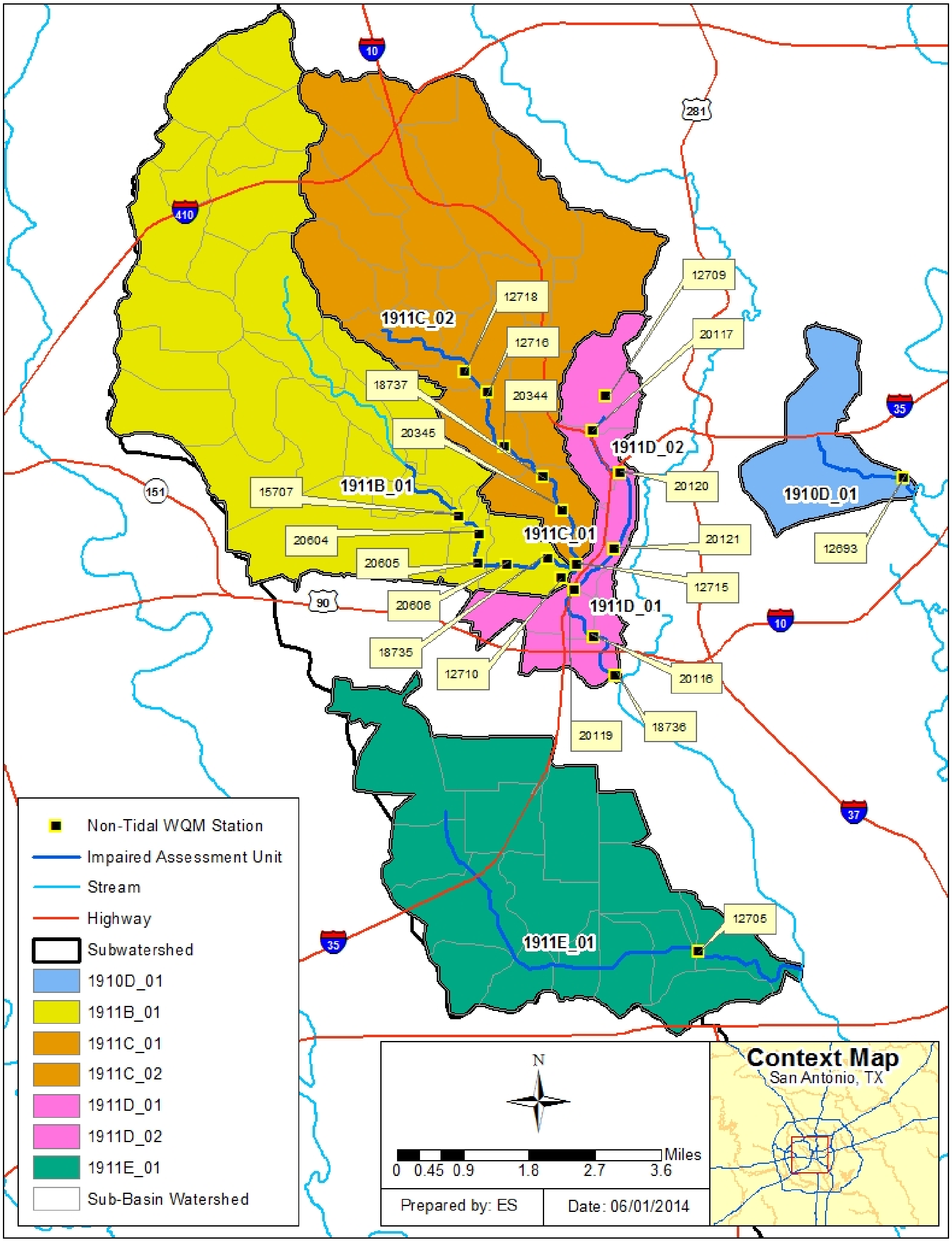

Figure 1-5: WQM Station Locations

1.2.5 Stream Flow Data

Stream flow data is key information when conducting water quality assessments such as TMDLs. The U.S. Geological Survey (USGS) does not maintain any current flow gages in the Study Area.

1.3 Upper San Antonio Watershed Seasonality

Seasonal differences in indicator bacteria concentrations were assessed by comparing historical bacteria concentrations collected in the warmer months versus those collected during the cooler months. The monthly average temperatures for San Antonio shown in Table 1-9 were obtained from NOAA and were used to divide the data sets into warmer (25 – 29°C) and cooler months (11 – 21°C). Based on these temperature ranges, November, December, January, February, and March were considered the cooler months; May, June, July, August, and September were warmer months.

Table 1-9: Average Monthly Temperatures for San Antonio International Airport (1981-2010)

Month	Daily Max (°C)	Daily Min (°C)	Daily Mean (°C)	Classification
Jan	30.0	-8.9	11.6	Cool
Feb	33.3	-8.3	13.4	Cool
March	35.6	-7.2	17.5	Cool
April	37.8	1.7	21.6	n/a
May	40.0	8.3	25.4	Warm
June	41.1	17.2	28.5	Warm
July	40.0	19.4	29.2	Warm
August	43.3	17.2	30.1	Warm
Sept	43.9	8.9	26.6	Warm
Oct	35.0	2.8	21.9	n/a
Nov	32.2	-2.2	16.7	Cool
Dec	30.0	-5.0	11.8	Cool

Note: Temperature values from NOAA San Antonio International AP Station (degrees Fahrenheit) have been converted to degrees Celsius.
http://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/climate-normals/1981-2010-normals-data

To determine if there was a statistically significant difference between cool and warm months, a *t*-test was conducted on the log transformed data between the warmer months and cooler months for WQM stations with six or more bacteria samples. Geometric means were also calculated for the warmer and cooler months.

Table 1-10 shows seasonal variation for all stations for *E coli*.

For *E coli*, six of the eight stations with six or more samples exhibited higher geometric mean concentrations for the warmer months than the colder months. Two stations, Station 12709 on segment 1911D and Station 12705 on segment 1911E, showed a statistically significant difference at the 95% confidence interval between the warmer and cooler months.

Table 1-10: Seasonal Differences for *E coli* Concentrations

Segment	Station ID	Indicator	Warm Months		Cold Months		p-value
			n	Geomean (MPN/100 ml)	n	Geomean (MPN/100 ml)	
1910D	12693	EC	9	613.55	9	1246.93	0.55
1911B	12710	EC	3	324.08	3	837.77	0.23
	15707	EC	3	1099.03	3	1309.67	0.92
	18735	EC	22	623.17	20	474.32	0.52
	20604	EC	3	477.98	3	2981.22	0.48
	20605	EC	3	358.82	3	2229.09	0.45
	20606	EC	3	371.05	3	2356.24	0.25
1911C	12715	EC	20	354.76	20	281.01	0.60
	12716	EC	3	300.68	3	84.80	0.31
	12718	EC	3	473.38	3	250.66	0.77
	18737	EC	3	321.16	3	321.45	1.00
	20344	EC	3	505.02	3	826.95	0.75
	20345	EC	3	1402.72	3	391.11	0.12
1911D	12709	EC	8	235.33	10	18.13	0.01
	18736	EC	21	424.35	20	262.16	0.30
	20116	EC	3	353.09	3	564.48	0.70
	20117	EC	11	736.03	13	423.31	0.18
	20119	EC	13	389.91	13	399.72	0.97
1911E	12705	EC	10	2324.67	10	99.87	0.00

EC: E coli, n = number of samples
Highlighted rows correspond to stations for which the warm and cold datasets are significantly different at a 95% confidence interval.
p-value is based on a t-test conducted at each station using the log of the single sample concentrations.
All concentrations are in counts/dL; values less than the detection limit were treated in calculations as one-half the detection limit.

CHAPTER 2
PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Pollutant of Concern: Characteristics of Bacterial Indicators

The contact recreation use is assigned to almost every designated water body in the State of Texas, although full support of the contact recreation use is not a guarantee that the water is completely safe of disease-causing organisms. The evolution of the contact recreation criteria currently used by Texas began with criteria first published in 1968 based on general studies done on lakes in the Midwest and New York using fecal coliform bacteria as an indicator of the potential presence of fecal contamination (USEPA 1986). The USEPA-recommended criteria for recreational waters in 1976 included a geometric mean criterion: no more than 200 counts/dL based on five samples collected over a 30-day period; and an instantaneous criterion: no more than 10 percent of the individual grab samples could exceed 400 counts/dL (USEPA 1986). Shortly thereafter, these recommended criteria were adopted by the State of Texas in its SWQSs. The fecal coliform criteria, and the studies on which they were based, were heavily criticized by the USEPA in 1986 (USEPA 1986) following an extensive program of epidemiology testing. During that decade, USEPA studies found that fecal coliform was not a good predictor of the risk of disease and recommended new tests and criteria. The USEPA recommended new criteria for swimming areas, using *E coli* and enterococci as new fecal indicator organisms, and incorporating the idea of varying criteria with the level of swimming use.

In Texas, three indicator bacteria have been analyzed in water samples collected to determine support of the contact recreation use: fecal coliform and *E coli* in freshwater and fecal coliform and enterococci in marine waters. Currently, *E coli* and enterococci bacteria are measured to determine the relative risk of contact recreation, depending on whether the water body is fresh or marine. The presence of these bacteria indicates that associated pathogens from the fecal waste of warm-blooded species (human or animal) may be reaching a body of water. High concentrations of certain bacteria in water indicate there may be an increased risk of becoming ill from recreational activities.

Texas water quality standards (WQS) for contact recreation allow exemptions for waterbodies where elevated bacteria concentrations frequently occur due to sources of pollution that cannot be reasonably controlled by the existing regulations, or where recreation is considered unsafe for other reasons, such as barge or ship traffic (e.g., the Houston Ship Channel), unrelated to water quality. This exemption and reclassification to less strict "noncontact recreation" standards has been applied to only a few waterbodies in Texas.

2.2 TCEQ Water Quality Standards for Contact Recreation

The TCEQ is responsible for administering provisions of the constitution and laws of the State of Texas to promote judicious use of and protection of the quality of waters in the state. Included in this responsibility is the continuous monitoring and assessment of water quality to evaluate compliance with SWQSs established within Texas Water Code, §26.023 and Title 30 Texas Administrative Code (TAC), §§307.1-307.10. Texas SWQS, 30 TAC 307.4, specify the designated uses and general criteria for all surface waters in the state.

This report focuses on five waterbodies within the Upper San Antonio Watershed that are on the federal Clean Water Act §303(d) list because they do not support contact recreation use. Table 2-1 lists all the assessment units within the Upper San Antonio Watershed that are on the 2012 303(d) list, provides a description of those assessment units, identifies the year each waterbody was placed on the Texas' Clean Water Act §303(d) List for nonsupport of contact recreation use, the stream length of each assessment unit in miles, and other designated uses for each waterbody Table 2-2 summarizes the designated uses and the applicable bacteria indicators used to assess the contact recreation use of each waterbody addressed in this report. The TMDLs in this report only address the contact recreation use.

Table 2-1: Synopsis of Texas 2012 303(d) List

Assessment Unit	Segment Name	Description	Category	Year First Listed
1910D_01	Menger Creek	From the confluence with segment 1910 to the upper end of the water body	5c	2012
1911B_01	Apache Creek	From the confluence with San Pedro Creek up to just upstream of the confluence with Zarzamora Creek	5a	2010
1911C_01	Alazan Creek	From the confluence with Apache Creek up to the confluence with Martinez Creek	5a	2010
1911C_02	Alazan Creek	From just upstream of the confluence with Martinez Creek to the upper end of the segment.	5a	2010
1911D_01	San Pedro Creek	From the confluence with segment 1911 up to the confluence with Apache Creek	5a	2010
1911D_02	San Pedro Creek	From the confluence with Apache Creek to the upper end of the segment, NHD RC 12100301000867	5a	2010
1911E_01	Sixmile Creek	From the confluence with 1911 to the upper end of the water body at NHD RC 12100301000061	5c	2012

Table 2-2: Synopsis of Texas Integrated Report for the Upper San Antonio Watershed

Assessment Unit	Segment Name	Parameter	Designated Use*				Year Impaired	Stream Length (miles)
			CR	AL	GU	FC		
1910D_01	Menger Creek	Dissolved Oxygen Grab, *E coli*	NS	NS	NA	NA	2012	1.81
1911B_01	Apache Creek	Dissolved Oxygen Grab, *E coli*, Nutrient Screening	NS	CS	FS	NA	2010	3.49
1911C_01	Alazan Creek	Dissolved Oxygen Grab, *E coli*, Nutrient Screening	NS	FS	FS	NA	2010	1.78
1911C_02	Alazan Creek	Dissolved Oxygen Grab, *E coli*, Nutrient Screening	NS	FS	CS	NA	2010	1.35
1911D_01	San Pedro Creek	Dissolved Oxygen Grab, *E coli*, Nutrient Screening	NS	FS	FS	NA	2010	1.77
1911D_02	San Pedro Creek	Dissolved Oxygen Grab, *E coli*, Nutrient Screening	NS	CS	CS	NA	2010	3.02
1911E_01	Sixmile Creek	Dissolved Oxygen Grab, *E coli*	NS	FS	NA	NA	2012	6.84

** CR: Contact recreation; AL: Aquatic Life; GU: General Use; FC: Fish Consumption; ENT: enterococci, NS = Not Supporting; FS = Fully Supporting; CS = Concern for Screening Level; NA= Not Assessed*

The excerpts below from Chapter 307, Texas SWQS stipulate how water quality data were assessed to determine support of contact recreation use as well as how the water quality targets are defined for each bacterial indicator. In addition to the specific requirements of §307.7

outlined below, the TMDLs for the Upper San Antonio Watershed will also adhere to §307.5 of the SWQS which defines the antidegradation policy and procedures that apply to authorized wastewater discharges, TMDLs, waste load evaluations, and any other miscellaneous actions, such as those related to man-induced nonpoint sources of pollution, which may impact the water in the state.

Excerpted from 30 Texas Administrative Code (TAC) §307.7. Site-specific Uses and Criteria.

(a) Uses and numerical criteria are established on a site-specific basis in Appendices A,B,D,E,F and G of §307.10 of this title (relating to Appendices A - G). Site-specific uses and numerical criteria may also be applied to unclassified waters in accordance with §307.4(h) of this title (relating to General Criteria) and §307.5(c) of this title (relating to Antidegradation). Site-specific criteria apply specifically to substances attributed to waste discharges or human activities. Site-specific criteria do not apply to those instances in which surface waters exceed criteria due to natural phenomena. The application of site-specific uses and criteria is described in §307.8 of this title (relating to the Application of Standards) and §307.9 of this title (relating to the Determination of Standards Attainment).

(b) Appropriate uses and criteria for site-specific standards are defined as follows.

(1) Recreation. Recreational use consists of four categories – primary contact recreation, secondary contact recreation 1, secondary contact recreation 2, and noncontact recreation waters. Classified segments are designated for primary contact recreation unless sufficient site-specific information demonstrates that elevated concentrations of indicator bacteria frequently occur due to sources of pollution which cannot be reasonably controlled by existing regulations, wildlife sources of bacteria are unavoidably high and there is limited aquatic recreational potential, or primary or secondary contact recreation is considered unsafe for other reasons such as ship or barge traffic. In a classified segment where contact recreation is considered unsafe for reasons unrelated to water quality, a designated use of noncontact recreation may be assigned criteria normally associated with contact recreation. A designation of primary or secondary contact recreation is not a guarantee that the water so designated is completely free of disease-causing organisms. Indicator bacteria, although not generally pathogenic, are indicative of potential contamination by feces of warm blooded animals. The criteria for contact recreation are based on these indicator bacteria, rather than direct measurements of pathogens. Criteria are expressed as the number of bacteria per 100 milliliters (ml) of water (in terms of colony forming units, most probable number, or other applicable reporting measures). Even where the concentration of indicator bacteria is less than the criteria for primary or secondary contact recreation, there is still some risk of contracting waterborne diseases. Additional guidelines on minimum data requirements and procedures for evaluating standards attainment are specified in the TCEQ Guidance for Assessing and Reporting Surface Water Quality Data in Texas, as amended.

(A) Freshwater

- *(i) Primary contact recreation. The geometric mean criterion for E coli is 126 per 100 mL. In addition, the single samples criterion for E coli is 399 per 100 mL.*
- *(ii) Secondary contact recreation 1. The geometric mean criterion for E coli is 630 per 100 mL.*
- *(iii) Secondary contact recreation 2. The geometric mean criterion for E coli is 1,030 per 100 mL.*

(iv) Noncontact recreation. The geometric mean criterion for E coli is 2,060 per 100 mL.

(v) For high saline inland water bodies where enterococci is the recreational indicator for instream bacteria sampling at all times for the classified water body and for the unclassified water bodies that are within the watershed of that classified segment, unless it is demonstrated that an unclassified water body is not high saline. E coli is the applicable recreational indicator for instream bacteria sampling at all times for unclassified water bodies where conductivity values indicate that the water bodies are not high saline. For high saline water bodies with primary contact recreation, the geometric mean criterion for enterococci is 33 per 100 ml and the single sample criterion is 78 per 100 ml. For high saline inland waters with secondary contact recreation 1, the geometric mean criterion for enterococci is 165 per 100 ml. For high saline inland waters with secondary contact recreation 2, the geometric mean criterion for enterococci is 270 per 100 ml. For high saline inland water bodies with noncontact recreation, the geometric mean criterion for enterococci is 540 per 100 ml.

(B) Saltwater

(i) Primary contact recreation. The geometric mean criterion for enterococci is 35 per 100 mL. In addition, the single sample criterion for enterococci is 104 per 100 mL.

(ii) Secondary contact recreation 1. A secondary contact recreation 1 use for tidal streams and rivers can be established on a site-specific basis in §307.10 of this title if justified by a use-attainability analysis and the water body is not a coastal recreation water as defined in the Beaches Environmental Assessment and Coastal Health Act of 2000 (BEACH Act). The geometric mean criterion for enterococci is 175 per 100 mL.

(iii) Noncontact recreation. A noncontact recreation use for tidal streams and rivers can be established on a site-specific basis in §307.10 of this title if justified by a use-attainability analysis and the water body is not a coastal recreation water as defined in the BEACH Act. The geometric mean criterion for enterococci is 350 per 100 mL.

(C) Fecal coliform bacteria. Fecal coliform bacteria can be used as an alternative instream indicator of recreational suitability in high saline inland water bodies where enterococci is the designated recreational indicator in Appendix A of §307.10 of this title for two years after the adoption of this title to allow time to collect sufficient data for enterococci. Fecal coliform criteria for high saline inland water bodies are as follows:

(i) Primary contact recreation. The geometric mean criterion for fecal coliform is 200 per 100 mL. In addition, single sample criterion for fecal coliform is 400 per 100 mL.

(ii) Secondary contact recreation 1 and 2. The geometric mean criterion for fecal coliform is 1,000 per 100 mL.

(iii) Noncontact recreation. The geometric mean criterion for fecal coliform is 2,000 per 100 mL.

(D) Swimming advisory programs. For areas where local jurisdictions or private property owners voluntarily provide public notice or closure based on water quality, the use of any single sample or short-term indicators of recreational suitability are selected at the discretion of the local managers of aquatic recreation. Guidance for single-sample bacterial indicators is available in the USEPA document entitled Ambient Water Quality Criteria for Bacteria - 1986. Other short-term indicators to assess water quality suitability for recreation -- such as measures of streamflow, turbidity, or rainfall -- may also be appropriate.

A minimum of 10 samples from the last seven years or the most recently collected 10 samples for up to ten years are used to determine use support

As stipulated in 2010 *Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ 2010), utilization of the geometric mean to determine compliance for any of the bacterial indicators depends on the collection of a *minimum of 10 samples from the last seven years or the most recently collected 10 samples for up to ten years are used to determine use support*. The 2010 *Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ 2010) specifically states the following*:*

- *Ten samples will also be required for listing and delisting water bodies for which the assessment method is based on an average. Larger sample sizes increase the state's confidence that impairments are not missed. Although we will use more than 10 samples, if available, it is not reasonable at this time to require more than 10 samples for a minimum data set, given the monitoring resources and currently available data.*
- *The 2010 assessment period of record for the last seven years is December 1, 2001 through November 30, 2008. Samples from these seven years are evaluated when available, and if necessary, the most recent samples collected in the preceding three years (December 1, 1998 through November 30, 2000) can also be included to meet the requirements for minimum sample*

2.3 Problem Identification

Pursuant to §303(d) of the federal Clean Water Act, states must establish TMDLs for pollutants contributing to violations of WQSs. Table 2-3 identifies the waterbodies requiring TMDLs identified in Category 5 of the 2012 Texas Water Quality Inventory and §303(d) List (TCEQ 2012). Between 1996 and 2010 as the TCEQ WQSs and water quality assessment method were modified and additional water quality data were collected throughout the Upper San Antonio Watershed, areas of impairment were added to the §303(d) List. Table 2-3 lists the TCEQ WQM stations from which ambient water quality data were summarized to support the decision to place these waterbodies on the TCEQ 303(d) List. The waterbodies requiring the TMDLs were first listed in 1998. The locations of these WQM stations are displayed in Figure 1-5.

A number of changes have occurred in the past 10 years that warrant refinements in how indicator bacteria data are used to support water quality assessments and TMDL development in Texas. Some key factors that influence which indicator bacteria to use for water quality assessment and TMDL development and the period of record to use include:

- Changes in land cover and locations of Texas Pollution Discharge Elimination System (TPDES)-permitted facilities
- Changing the indicator bacteria in the 2000 TCEQ SWQS from fecal coliform to *E coli* for fresh water, and enterococci for marine waters
- Refinements in the TCEQ SWQM monitoring procedures
- Changes in the TCEQ guidance, *Assessing and Reporting Surface Water Quality in Texas*

As a result of these evolving factors in the water quality management arena associated with the protection and maintenance of contact recreation use, the historical data set used to support the TMDLs in this report have been narrowed, wherever possible, to utilize only *E coli* data from 2007 through 2010.

Table 2-3: Water Quality Monitoring Stations Used for 303(d) Listing Decision

Assessment Unit	Water Body	Description	Monitoring Station IDs	Year
1910D_01	Menger Creek	Menger Creek immediately upstream of Coliseum Road	12693	2012
1911B_01	Apache Creek	Apache Creek at Laredo Street	12710	2010
		Apache Creek at Elmendorf Lake, 13 meters downstream from 24th Street at Shoal Area on South Bank	12712	
		Apache Creek at San Luis St immediately downstream of Elmendorf Lake Footbridge	15707	
		Apache Creek at Brazos Street approximately 0.7 km upstream of the confluence with Alazan Creek	18735	
		Apache Creek/Elmendorf Lake immediately upstream of West Commerce Street 412 m upstream of Southwest 24th Street	18814	
		Apache Creek at Guadalupe Street in West San Antonio	20604	
		Apache Creek 200 meters west and 55 meters south from the intersection of South Zarzamora Street and Potosi Street in West San Antonio	20605	
		Apache Creek at South Navidad Street in West San Antonio	20606	
1911C_01	Alazan Creek	Alazan Creek at Tampico Street in San Antonio	12715	2010
		Alazan Creek at Martin Street 337 meters downstream of Martinez Creek confluence near west side of San Antonio, Texas	18737	
		Alazan Creek immediately downstream of Colorado Street in San Antonio	20345	
1911C_02	Alazan Creek	Alazan Creek at Waverly Street in San Antonio	12716	2010
		Woodlawn Lake at Boat Dock	12718	
		Woodlawn Lake upstream end immediately upstream of S Josephine Tobin Drive crossing 400 m downstream of W Woodlawn Avenue	18813	
		Alazan Creek at Arbor Place 130 meters downstream of Zarzamora Street in San Antonio	20344	
1911D_01	San Pedro	San Pedro Creek at Furnish Street in San Antonio permit 0000968 union stock yards	12707	2010

	Creek	San Pedro Creek at Probandt Street 195 m upstream of the San Antonio River confluence	18736	
		San Pedro Creek immediately upstream of Flores Street approximately 0.74 km downstream of Nogalitos Street	20116	
1911D_02	San Pedro Creek	San Pedro Creek at Alamo Street in San Antonio	12708	2010
		San Pedro Creek at Croft Trace Street 304 m downstream of W Laurel Street	20117	
		San Pedro Creek 107 m upstream of confluence with Alazan Creek and immediately upstream of IH 10	20119	
		San Pedro Creek tunnel inlet approximately 121 m downstream of IH35	20120	
		San Pedro Creek tunnel outlet access point 45 m upstream of Guadalupe Street	20121	
1911E_01	Sixmile Creek	Six Mile Creek at Roosevelt Avenue in San Antonio	12705	2012

2.4 Water Quality Targets for Contact Recreation

The Code of Federal Regulations (40 CFR §130.7(c)(1)) states that, "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards." The Texas SWQSs (TCEQ 2010) provide numeric and narrative criteria to evaluate attainment of designated uses. The basis for water quality targets for all TMDLs developed in this report will be the numeric criteria for bacterial indicators from the 2010 Texas SWQSs as described in Subsection 2.2 above. *E coli* is the preferred indicator bacteria for assessing contact recreation use in freshwater, and enterococci is the preferred indicator bacteria in saltwater.

Several studies have been performed by the USEPA that show a stronger link between the concentrations of *E coli* and enterococci and the concentrations of fecal pathogens than the previous standard, fecal coliform. The USEPA studies found that in freshwater streams, *E coli* concentrations were the strongest predictor of illness following contact recreation. The TCEQ adopted the limit of 399 per dL for single samples of *E coli* and a geometric mean limit of 126 per dL for waterbodies that have been designated for contact recreation use. Within tidal streams and saltwater bodies, the USEPA determined that enterococci concentrations were the strongest predictor of illness. The TCEQ adopted a limit of 104 per dL for enterococci in any single sample, and a limit of 35 per dL for the geomean of all samples at any location for enterococci concentrations within a tidal stream designated for contact recreation uses (TCEQ 2010).

The water quality target for the TMDLs for freshwater segments is to maintain concentrations below the geometric mean criterion of 126 counts per dL for *E coli*. The water quality target for the TMDLs for tidal (saltwater) segments is to achieve concentrations of enterococci below the geometric mean criterion of 35 counts per dL. There are no tidal segments located within the Study Area. Maintaining the geometric mean criterion for each indicator bacteria is expected to be protective of the single sample criterion also and therefore will ultimately result in the attainment of the contact recreation use. TMDLs will be based on a percent reduction goal required to meet the geometric mean criterion.

The water quality target for each waterbody will incorporate an explicit 5 percent margin of safety (MOS). For example, if *E coli* is utilized to establish the TMDL, then the water quality target would be 379 counts/dL, 5 percent lower than the single sample water quality criterion (399 counts/dL) and the geometric mean water quality target would be 120 counts/dL, 5 percent lower than the criterion value (126 counts/dL). For enterococci, the single sample water quality target would be 74 counts/dL and the geometric mean water quality target would be 31 counts/dL, both 5 percent lower than the criterion values.

For non-tidal segments, each water quality target will be used to determine the allowable bacteria load that is derived by using the actual or estimated flow record multiplied by the instream criteria minus a 5 percent MOS. For tidal segments, a mass-balance model will be used to determine the maximum amount of loading discharged to the water bodies that result in meeting the geometric mean criteria throughout the length of the segment.

CHAPTER 3
POLLUTANT SOURCE ASSESSMENT

To support TMDL development, a pollutant source assessment attempts to characterize known and suspected sources of pollutant loading to impaired waterbodies. Pollutant sources within a watershed are categorized and quantified to the extent that information is available. Fecal bacteria such as *E coli* and Enterococcus originate in the intestines of warm-blooded species (human and animal), and sources of bacteria may be point (permitted) or nonpoint (unregulated) in nature.

Point sources are permitted through the National Pollution Discharge Elimination System (NPDES) program. Some stormwater runoff may be permitted through NPDES as municipal separate storm sewer systems (MS4). Other unregulated sources of stormwater runoff that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location are often referred to as nonpoint sources. For example, unregulated sources include land activities that contribute bacteria to surface water as a result of rainfall runoff or on-site sewage system facilities. For the TMDLs presented in this report, all sources of pollutant loading not regulated by a NPDES/TPDES permit are considered nonpoint sources. The following discussion describes what is known regarding permitted and unregulated sources of bacteria in the impaired watersheds.

3.1 Point Sources: NPDES/TPDES-Permitted Sources

Under 40 CFR, §122.2, a point source is described as a discernible, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Under the Texas Water Code, the TCEQ has adopted rules and procedures to issue permits to control the quantity and quality of discharges into, or adjacent to, waters of the state through the TPDES program. NPDES/TPDES-permitted facilities classified as point sources that may contribute bacteria loading to surface waters include:

- TPDES municipal wastewater treatment facilities (WWTF)
- TPDES industrial WWTF (stormwater and/or wastewater)
- TPDES municipal no-discharge WWTF
- TPDES regulated stormwater (municipal separate storm sewer systems)
- TPDES Concentrated Animal Feeding Operation (CAFO)

Point source discharges such as WWTFs could result in discharge of elevated concentrations of fecal bacteria if the plant is not properly maintained, is of poor design, or if flow rates exceed the treatment capability of the plant. Industrial WWTFs may contain fecal bacteria in their effluent. While no-discharge facilities do not discharge wastewater directly to a waterbody, it is possible that collection systems associated with these types of facilities may be a source of bacteria loading to surface waters. Permitted stormwater runoff from TPDES regulated discharge areas, called municipal separate storm sewer systems (MS4), may also contain high fecal bacteria concentrations. Finally, CAFOs are recognized by USEPA as a significant potential source of pollution, and may have the potential to cause serious impacts to water quality if not properly managed.

One watershed in the Study Area, Sixmile Creek (1911E_01), has two NPDES/TPDES-permitted sources as shown in Figure 3-1. The entire Study Area is regulated under the TPDES stormwater discharge permit jointly held by the City of San Antonio, San Antonio Water System (SAWS), and the Texas Department of Transportation (TxDOT). There are no NPDES-permitted CAFOs within the Study Area.

3.1.1 Permitted Sources: NPDES/TPDES Wastewater Facility Point Source Discharges

There are two TPDES-permitted facilities within the Study Area, and these facilities along with the MS4s are shown in Figure 3-1. Additional details on each permitted facility are provided in Table 3-1. In addition to these two TPDES-permitted facilities, there are two active TPDES-permitted facilities outside the Study Area. These three facilities are wastewater treatment facilities and their location and service areas are shown in Figure 3-2

TPDES-permitted facilities that discharge treated wastewater are required by their permit to monitor their effluent for certain parameters. A summary of the discharge monitoring report (DMR) data for the two domestic facilities in the watershed will be shown in Table 3-2 once received from the TCEQ regional office.

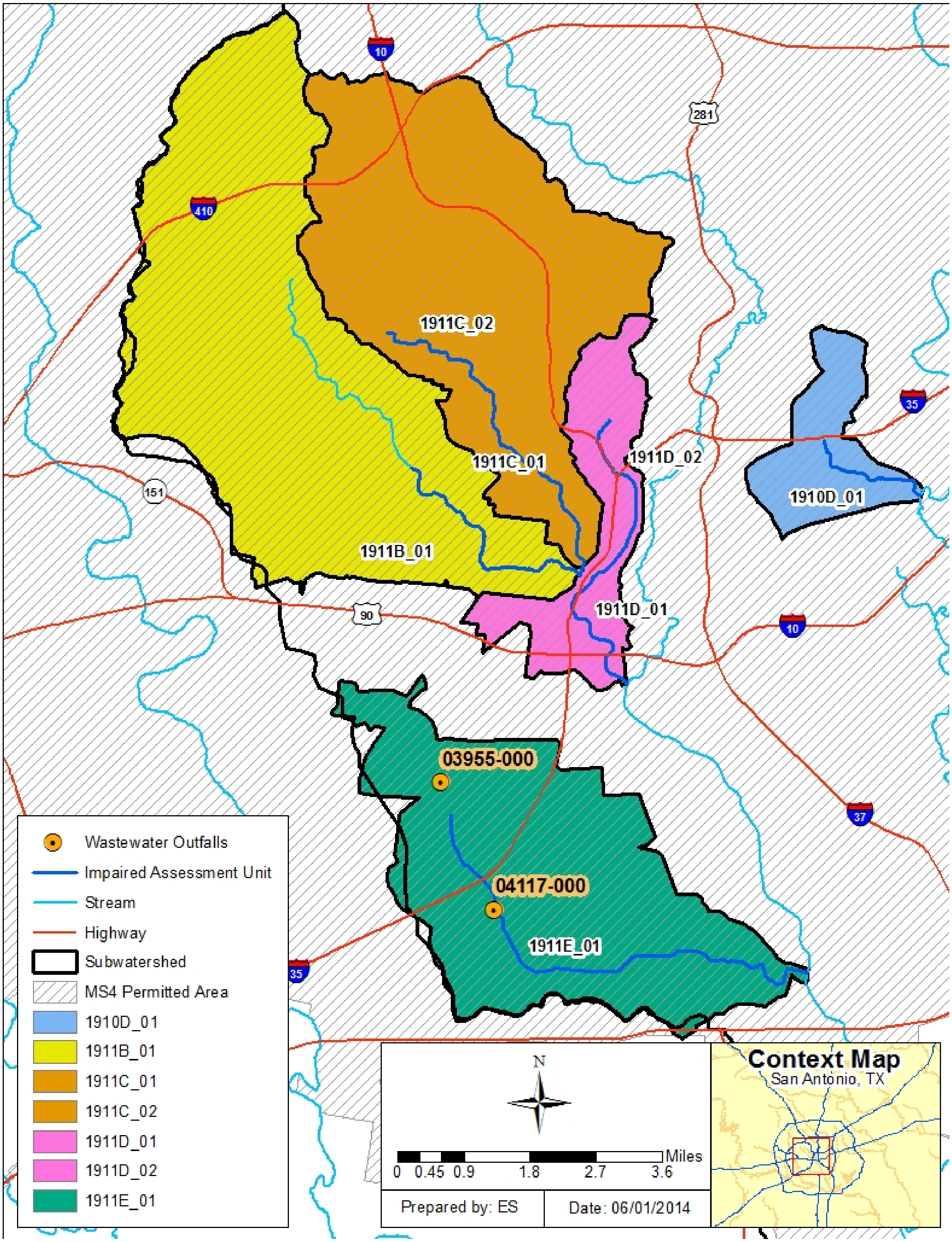

Figure 3-1: TPDES-Permitted Facilities in the Upper San Antonio Watershed

Table 3-1: TPDES-Permitted Facilities in the Study Area

Assessment Unit	Receiving Water	TPDES Number	NPDES Number	Facility Name	Facility Type	DTYPE	Permitted Flow (MGD)	Average Monthly Flow (MGD)
1911E	Sixmile Creek	03955-000	TX0116114	Kelly Air Force Base	Sewerage System	W	1	3.15
1911E	Sixmile Creek	04117-000	TX0069931	San Antonio Equipment repair and Maintenance yard	Industrial Stormwater	n/a	n/a	n/a

Source: TCEQ Wastewater Outfall Shapefile, May 2014, EPA, TCEQ monitoring data search May 2014
MGD = Millions of Gallons per Day; n/a = Not Applicable
TYPE: D = Domestic < 1 MGD; W=Domestic >= 1 MGD

Table 3-2: DMR Data for Permitted Wastewater Discharges

TPDES Number	NPDES Number	Facility Name	Assessment Unit	Stream Name	Dates Monitored		# of Records	Monthly Average Flow (MGD)*	Permitted Flow (MGD)
					Start	End			
03955-000	TX0116114	Kelly Air Force Base	1911E	Sixmile Creek	n/a	n/a	n/a	3.15	1

Source: Discharge Monitoring Report (DMR) Pollutant Loading Tool (http://cfpub.epa.gov/dmr/facility_detail.cfm)
*Notes: n/a = Not Available, MGD = Millions of Gallons per Day, cfu = Colony Forming Unit; *there were several missing monthly flow data points; these gaps were filled by taking average of flows for the previous and subsequent months.*

3.1.2 Permitted Sources: Sanitary Sewer Overflows

Sanitary sewer overflows (SSO) are overflows from sanitary sewers that most often result from blockages in the sewer collection pipes caused by tree roots, grease and other debris. Occurrences of SSOs are permit violations that must be addressed by the responsible TPDES permittee.

The TCEQ maintains a database of SSO data collected from wastewater operators in the Upper San Antonio Watershed. TCEQ Region 13 – San Antonio will be providing SSO data in the Upper San Antonio Watershed. These data are provided in Table 3-3 for the years 2010 – 2012.

The locations and magnitudes of the all reported SSOs within the Upper San Antonio Watershed region are displayed, along with WWTF service area boundaries, in Figure 3-2.

Table 3-3: Sanitary Sewer Overflow (SSO) Summary

Facility Name	NPDES Permit No.	Facility ID	Number of Occurrences	Date Range		Amount (Gallons)	
				From	To	Min	Max
Leon Creek WRC	TX0077801	10137-033	36	1/1/2010	8/31/2012	10	54,000
Dos Rios WRC	TX0052639	10137-003	171	1/1/2010	8/26/2012	1	3,570,000

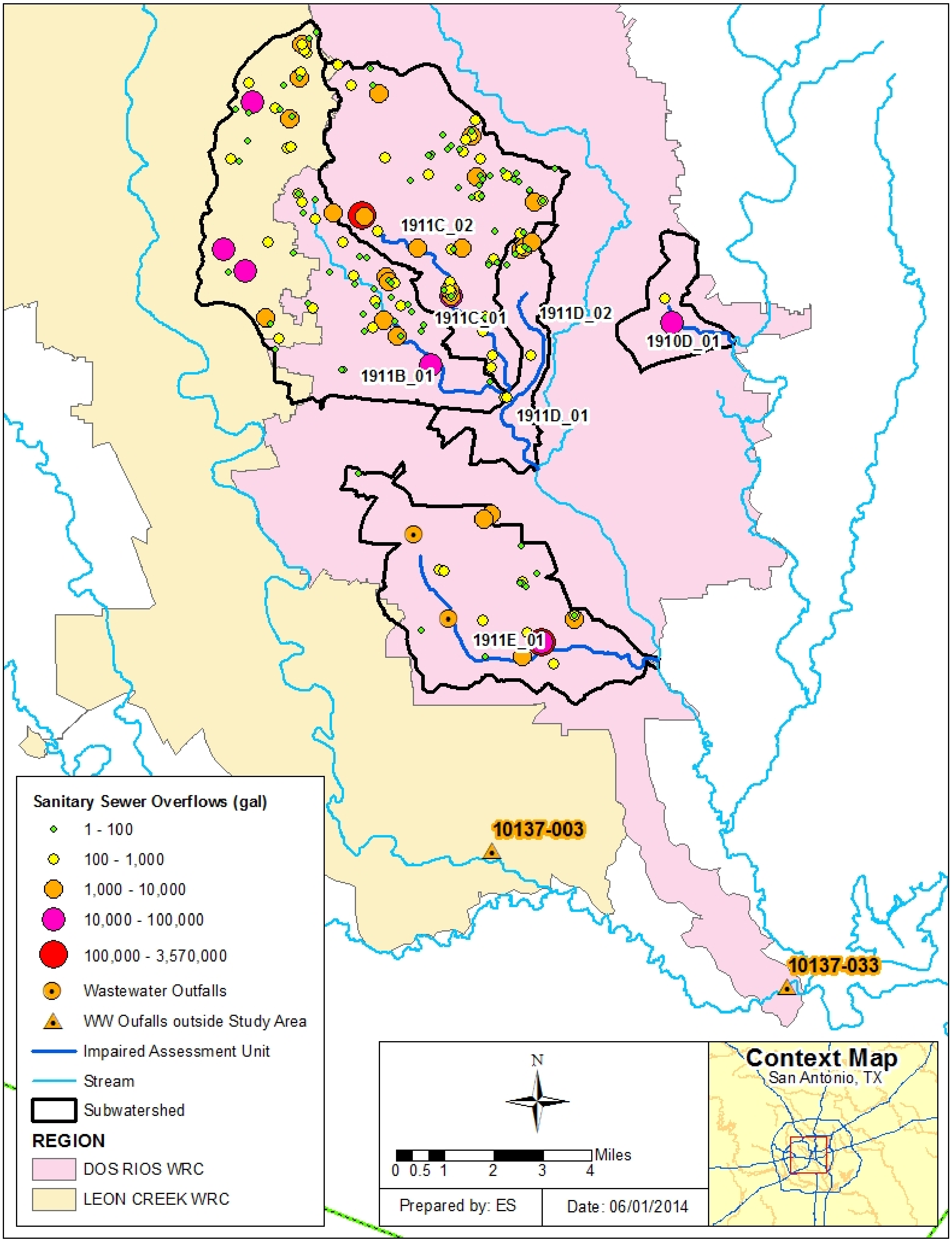

Figure 3-2: Sanitary Sewer Overflow Locations

3.1.3 Permitted Sources: TPDES Regulated Stormwater

In 1990, the USEPA developed rules establishing Phase I of the NPDES Stormwater Program, designed to prevent nonpoint source pollutants from being washed by stormwater runoff into municipal separate storm sewer systems and then discharged into local waterbodies (USEPA 2005). Phase I of the program required medium and large permitted dischargers (those generally serving populations of 100,000 or greater) to implement a stormwater management program as a means to control polluted discharges. Approved stormwater management programs for medium and large permitted discharges are required to address a variety of water quality-related issues, including roadway runoff management, municipal-owned operations, and hazardous waste treatment.

Phase II of the rule extended coverage of the NPDES Stormwater program in 2000 to certain small MS4s. Small MS4s are defined as any MS4 in an urbanized area as defined by the U.S. Census Bureau that was not already covered by a Phase I NPDES Stormwater Permit. The Phase II MS4 program requires operators of regulated small MS4s to obtain NPDES permits and develop a stormwater management program. Programs are designed to reduce discharges of pollutants to the "maximum extent practicable," to protect water quality, and satisfy appropriate water quality requirements of the CWA. Small MS4 stormwater programs must address the following minimum control measures including Public Education and Outreach; Public Participation/Involvement; Illicit Discharge Detection and Elimination; Construction Site Runoff Control; Post – Construction Runoff Control; and Pollution Prevention/Good Housekeeping.

When evaluating pollutant loads originating from stormwater runoff, a critical distinction must be made between stormwater originating from an area under an NPDES/TPDES regulated discharge permit and stormwater originating from areas not under an NPDES/TPDES regulated discharge permit. To characterize pollutant loads from stormwater runoff, it is necessary to segregate stormwater into two categories:

1) permitted stormwater, which is stormwater originating from an NPDES/TPDES-permitted Phase I or Phase II urbanized area; and
2) unregulated stormwater, which is stormwater originating from any area outside an NPDES/TPDES-permitted Phase I or Phase II urbanized area.

Within this area of the Upper San Antonio Watershed, there is one individual Phase I MS4 program that is currently permitted by the TCEQ. This program is operated by:

- § City of San Antonio/SAWS/TxDOT (Phase I permit)

The coverage area for this permit is shown in Figure 3-1. As shown in the figure, the entire Study Area is covered under the City of San Antonio/SAWS/TxDOT MS4 permit (TPDES Permit No. WQ0004284000). The jurisdictional boundary of the San Antonio MS4 permit is derived from *Urbanized Area Map Results for Texas* which is based on the 2010 U.S. Census and can be found at the USEPA website http://cfpub.epa.gov/npdes/stormwater/urbanmapresult.cfm?state=TX.

Table 3-4 is a summary of the individual watersheds of interest and the percentage of each watershed that is covered by one or more MS4 permits. This table shows that all watersheds are covered by MS4 permit.

Table 3-4: Percentage of Permitted Stormwater in Each Watershed

Segment	Receiving Stream	Regulated Entity Name	TPDES Number	Total Area (acres)	Area under MS4 Permit (Acres)	Percent of Watershed under MS4 Jurisdiction
1910D	Menger Creek	City of San Antonio/ SAWS/TxDOT	WQ0004284000	1959	1959	100
1911B	Apache Creek	City of San Antonio/ SAWS/TxDOT	WQ0004284000	13951	13951	100
1911C	Alazan Creek	City of San Antonio/ SAWS/TxDOT	WQ0004284000	11837	11837	100
1911D	San Pedro Creek	City of San Antonio/ SAWS/TxDOT	WQ0004284000	2993	2993	100
1911E	Sixmile Creek	City of San Antonio/ SAWS/TxDOT	WQ0004284000	9532	9532	100

3.1.4 Concentrated Animal Feeding Operations

There are no CAFOs located within the Study Area.

3.2 Unregulated Sources: Stormwater, On-site Sewage Facilities, and Direct Deposition

Unregulated sources (nonpoint sources) include those sources that cannot be identified as entering the waterbody at a specific location. The following section describes possible major unregulated sources contributing bacteria loading within the Study Area.

Nonpoint sources of bacteria can emanate from wildlife, various agricultural activities, domesticated animals, land application fields, urban runoff, failing on-site sewage facilities (OSSF), and domestic pets. Bacteria associated with urban runoff can emanate from humans, wildlife, livestock, and domestic pets. Based on the ability of warm-blooded animals to harbor and shed human pathogens, the current USEPA policy establishes the position that it is inappropriate to conclude that livestock and wildlife sources present no risk to human health from waterborne pathogens. Consequently, states and authorized tribes should not use broad exemptions from the bacteriological criteria for waters designated for primary contact recreation based on the presumption that high levels of bacteria resulting from non-human fecal contamination present no risk to human health (USEPA 2002). Water quality data collected from streams draining urban communities often show existing concentrations of fecal coliform bacteria at levels greater than a state's instantaneous standards. A study under USEPA's National Urban Runoff Project indicated that the average fecal coliform concentration from 14 watersheds in different areas within the United States was approximately 15,000 /dL in stormwater runoff (USEPA 1983). Based on data such as these, unregulated stormwater have the potential to be a significant source of fecal bacteria.

3.2.1 Wildlife and Unmanaged Animal Contributions

E coli and enterococci bacteria are common inhabitants of the intestines of all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify the potential for bacteria contributions from wildlife by watershed. Wildlife can be naturally attracted to 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 loading to a waterbody. *E coli* and enterococci bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff.

The portions of shrub and evergreen forest and sources of water in the Study Area provide a habitat for many species of mammals, reptiles, and amphibians. For example, large populations of feral hogs, javelin, deer, rabbits, coyotes, raccoons, opossums, turkey, quail, dove, heron, martins, song birds, duck, and geese are of specific concern in many parts of the watershed (San Antonio River Authority 2008).

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

3.2.2 Unregulated Agricultural Activities and Domesticated Animals

There are a number of unregulated agricultural activities that can also be sources of fecal bacteria loading. Agricultural activities of greatest concern are typically those associated with livestock operations (Drapcho and Hubbs 2002). The following are examples of livestock activities that can contribute to bacteria sources:

§ Processed livestock manure is often applied to fields as fertilizer, and can contribute to fecal bacteria loading to waterbodies if washed into streams by runoff before incorporation.

§ Livestock grazing in pastures deposit manure containing fecal bacteria onto land surfaces. These bacteria may be washed into waterbodies by runoff if inadequate buffers exist between pastures and waterbodies.

§ Livestock may have direct access to waterbodies and can provide a concentrated source of fecal bacteria loading directly into streams.

The estimated numbers of selected livestock by watershed were calculated based on the 2007 USDA county agricultural census data (USDA 2007). The county-level estimated livestock populations were distributed among watersheds based on GIS calculations of pasture land per subwatershed, based on the National Land Cover Database (NOAA 2011). It should be noted that these are planning level livestock and are not evenly distributed across counties or constant with time.

As shown in Table 3-5, cattle are estimated to be the most abundant species of livestock in the Study Area. Livestock numbers and their associated bacteria loading are expected to decrease over time as more land is converted from grazing to developed urban uses in the Upper San Antonio Watershed.

Table 3-5: Livestock and Manure Estimates by Subwatershed

Type of Animal	1910D	1911B	1911C	1911D	1911E	Total Animals
Cattle and Calves	0	0	0	0	7	**7**
Horses and Ponies	0	0	0	0	1	**1**
Goats	0	0	0	0	1	**1**
Hogs and Pigs	0	0	0	0	0	**0**
Sheep and Lambs	0	0	0	0	1	**1**
Bison	0	0	0	0	0	**0**
Captive Deer	0	0	0	0	0	**0**
Donkey	0	0	0	0	0	**0**
Rabbits	0	0	0	0	0	**0**
Llamas	0	0	0	0	0	**0**
Pullets	0	0	0	0	0	**0**
Broilers	0	0	0	0	0	**0**
Layers	0	0	0	0	1	**1**
Turkeys	0	0	0	0	0	**0**
Ducks	0	0	0	0	0	**0**
Geese	0	0	0	0	0	**0**
Other Poultry	0	0	0	0	0	**0**
Total Animals	**0**	**0**	**0**	**0**	**11**	**11**

According to a livestock study conducted by the American Society of Agricultural Engineers (ASAE) and referenced by the USEPA (2000) in their Bacteria Indicator Tool, the daily fecal coliform production rates by livestock species were estimated as follows (ASAE 1998):

- Beef cattle release approximately 104 billion units per animal per day
- Dairy cattle release approximately 101 billion units per animal per day
- Swine release approximately 10.8 billion units per animal per day
- Chickens release approximately 0.136 billion units per animal per day
- Sheep release approximately 12.0 billion units per animal per day
- Horses release approximately 0.42 billion units per animal per day

- Turkey release approximately 0.093 billion units per animal per day
- Ducks release approximately 2.43 billion units per animal per day
- Geese release approximately 49.0 billion units per animal per day

Using the estimated livestock populations and the fecal coliform production rates from ASAE, an estimate of fecal coliform production from each group of livestock was calculated in Table 3-6 for each watershed of the Study Area. It should be noted that only a fraction of these fecal coliform loading estimates are expected to reach the receiving water, either washed into streams by runoff or by direct deposition from wading animals. Cattle appear to represent the most significant livestock source of fecal bacteria based on overall loading estimates for Sixmile Creek.

Table 3-6: Fecal Coliform Production Estimates for Selected Livestock (x billion cfu/day)

Stream Name	Cattle & Calves	Horses & Ponies	Sheep & Lambs	Hogs & Pigs	Ducks	Geese	Chickens	Total
Menger Creek	0	0	0	0	0	0	0	0
Apache Creek	0	0	0	0	0	0	0	0
Alazan Creek	0	0	0	0	0	0	0	0
San Pedro Creek	0	0	0	0	0	0	0	0
Sixmile Creek	728	0.4	1.2	0	0	0	0	730

3.2.3 Failing On-site Sewage Facilities

OSSFs can be a source of bacteria loading to streams and rivers. Bacteria loading from failing OSSFs can be transported to streams in a variety of ways, including runoff from surface ponding or through groundwater. Indicator bacteria-contaminated groundwater can also be discharged to creeks through springs and seeps.

Over time, most OSSFs operating at full capacity will fail if not properly maintained. OSSF failures are proportional to the adequacy of a state's minimum design criteria (Hall 2002). The 1995 American Housing Survey conducted by the U.S. Census Bureau estimates that, nationwide, 10 percent of occupied homes with OSSFs experience malfunctions during the year (U.S. Census Bureau 1995). Most studies estimate that the minimum lot size necessary to ensure against contamination is roughly one-half to one acre (Hall 2002). Some studies, however, found that lot sizes in this range, or even larger, could still cause contamination of ground or surface water (University of Florida 1987). It is estimated that areas with more than 40 OSSFs per square mile (6.25 septic systems per 100 acres) can be considered to have potential contamination problems (Canter and Knox 1985).

Only permitted OSSF systems are recorded by authorized county or city agents; therefore, it is difficult to estimate the exact number of OSSFs in use in the Study Area. Table 3-7 lists the OSSF totals based on GIS data information provided by Bexar County Public Works Department. Figure 3-3 displays all permitted OSSF systems and it should be noted that there are no unsewered areas that do not fall under the wastewater service areas in the Study Area.

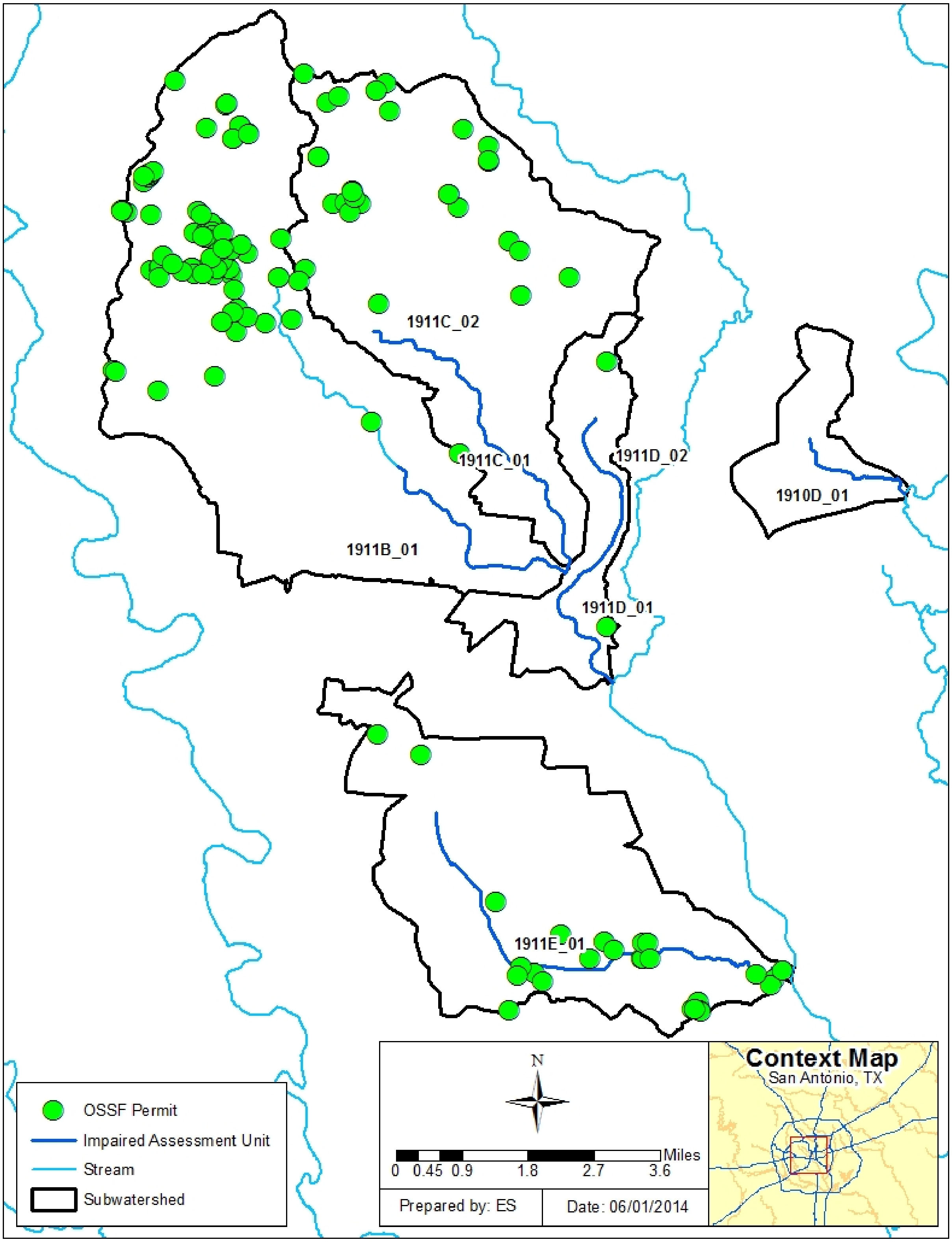

Figure 3-3: Unsewered Areas and Subdivisions with OSSF

For the purpose of estimating fecal coliform loading in watersheds, the OSSF failure rate of 12 percent from the Reed, Stowe & Yanke, LLC (2001) report was used. Bexar County is located at the tripoint between Texas Regions 2, 3, and 4, and the report states that the failure rates are 12%, 3%, and 12% for those regions, respectively. Texas Region 2 includes west Texas and stretches eastward into south central Texas. Texas Region 3 includes the very southern tip of Texas and is typically referred to as the Lower Rio Grande Valley. Texas Region 4 covers part of north, central, and coastal Texas. The land cover in the Study Area is most similar to Texas Regions 2 and 4, so the 12% failure rate was used for this study. Using this 12 percent failure rate, calculations were made to characterize fecal coliform loads in each watershed.

Fecal coliform loads were estimated using the following equation (USEPA 2001):

$$\#\frac{counts}{day} = \left(\#\,Failing\_systems\right) \times \left(\frac{10^6\,counts}{100ml}\right) \times \left(\frac{70gal}{personday}\right) \times \left(\#\frac{person}{household}\right) \times \left(3785.2\frac{ml}{gal}\right)$$

The average number of people per household was calculated to be 2.66 for the Study Area (U.S. Census Bureau 2010) based on an average household density for the census blocks within the Study Area. Approximately 70 gallons of wastewater were estimated to be produced on average per person per day as the flow rate for a residential home in the United States (Metcalf and Eddy 1991). The fecal coliform concentration in failing septic tank effluent was estimated to be 10^6 per 100 mL of effluent based on reported concentrations from a number of published reports (Metcalf and Eddy 1991; Canter and Knox 1985; Cogger and Carlile 1984). Using this information, the estimated load from failing septic systems within each subwatershed was calculated and is summarized in Table 3-7. Based on this data, it was determined that the estimated fecal coliform loading from OSSFs in the Study Area were found to be negligible.

Table 3-7: Estimated Number of OSSFs per Watershed and Fecal Coliform Load

Segment	Stream Name	OSSF data from Bexar County Public Works Dept.	# of Failing OSSFs	Estimated Loads from OSSFs (billion counts/day)
1910D	Menger Creek	0	0	0
1911B	Apache Creek	95	11.4	80.35
1911C	Alazan Creek	34	4.08	28.76
1911D	San Pedro Creek	2	0.24	1.69
1911E	Sixmile Creek	29	3.48	24.53

3.2.4 Domestic Pets

Fecal matter from dogs and cats is transported to streams by runoff from urban and suburban areas and can be a potential source of bacteria loading. On average nationally, there are 0.58 dogs per household and 0.66 cats per household (American Veterinary Medical Association 2002). Using the U.S. Census data at the block level (U.S. Census Bureau 2010), dog and cat populations can be estimated for each watershed.

Table 3-8 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-8: Estimated Number of Pets

Segment	Stream Name	Dogs	Cats
1910D	Menger Creek	2,386	2,715
1911B	Apache Creek	26,891	30,601
1911C	Alazan Creek	24,713	28,122
1911D	San Pedro Creek	5,987	6,813
1911E	Sixmile Creek	11,714	13,330

Table 3-9 provides an estimate of the fecal coliform load from pets. These estimates are based on estimated fecal coliform production rates of $5.4 x 10^8$ per day for cats and $3.3 x 10^9$ per day for dogs (Schueler 2000). Only a small portion of these loads is expected to reach waterbodies, through wash-off of land surfaces and conveyance in runoff.

Table 3-9: Fecal Coliform Daily Production by Pets (x billion)

Segment	Stream Name	Dogs	Cats	Total Load (Billion cfu/day)
1910D	Menger Creek	7,872	1,466	9,338
1911B	Apache Creek	88,742	16,524	105,266
1911C	Alazan Creek	81,553	15,186	96,739
1911D	San Pedro Creek	19,759	3,679	23,438
1911E	Sixmile Creek	38,657	7,198	45,855

3.2.5 Bacteria Re-growth and Die-off

Bacteria are living organisms that grow and die. Certain enteric bacteria can regrow in organic materials if appropriate conditions prevail (*e.g.*, warm temperature). It has been shown that fecal organisms can regrow from improperly treated effluent during their transport in pipe networks, and they can regrow in organic rich materials such as compost and sludges. 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 regrowth is less well understood. Both processes (regrowth and die-off) are in-stream processes and are not considered in the bacteria source loading estimates of each water body.

CHAPTER 4
TECHNICAL APPROACH AND METHODS

The TMDL represents the maximum amount of a pollutant that the stream can receive in a single day without exceeding the water quality standard. A TMDL is expressed as the sum of three elements as described in the following mathematical equation:

TMDL = Σ WLA + Σ LA + MOS

The wasteload allocation (WLA) is the portion of the TMDL allocated to existing and future permitted (point) sources. The load allocation (LA) is the portion of the TMDL allocated to non-permitted (nonpoint) sources, including natural background sources. The MOS is intended to account for uncertainty and ensure that the standard for contact recreation will be met. Thus, the allowable pollutant load that can be allocated to point and nonpoint sources can then be defined as the TMDL minus the MOS.

40 CFR §130.2(1), states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For *E coli* or enterococci bacteria, TMDLs are expressed as numbers per day, where possible, or as a percent reduction goal, and represent the maximum one day load the stream can assimilate while still attaining the standard for contact recreation. For the Upper San Antonio Watershed, to quantify allowable pollutant loads, percent reduction goals to achieve standard for contact recreation, and specific TMDL allocations for point and nonpoint sources, the following method is used: the load duration curve method for non-tidal streams.

4.1 Using Load Duration Curves to Develop TMDLs

The TMDL calculations for freshwater streams presented in this report are derived from load duration curves (LDCs). LDCs facilitate development of TMDLs, and as a TMDL development tool, can be effective at identifying whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the four following steps described in Subsections 4.2 through 4.4 below:

1. Preparing flow duration curves (FDC) for gaged and ungaged WQM stations;
2. Estimating existing bacteria loading in the receiving water using ambient water quality data;
3. Using LDCs to identify the critical condition that will dictate loading reductions necessary to attain the contact recreation standard; and
4. Interpreting LDCs to derive TMDL elements – WLA, LA, MOS, and percent reduction goal.

Historically, in developing WLAs for pollutants from point sources, it was customary to designate a critical low flow condition (*e.g.*, 7Q2) at which the maximum permissible loading was calculated. As water quality management efforts expanded in scope to quantitatively address nonpoint sources of pollution and types of pollutants, it became clear that this single critical low flow condition was inadequate to ensure suitable water quality across a range of flow conditions. Because the LDC covers a range of flow conditions, use of the LDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. For waterbodies impacted by both point and nonpoint sources, the "nonpoint source critical condition" would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the "point source critical condition" would typically occur during low flows, when WWTF effluent would dominate the base flow of the impaired water.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by the water quality criterion. Using LDCs, a TMDL can be expressed as a continuous function of flow, or as a discrete value derived from a specific flow condition.

4.2 Development of Flow Duration Curves

FDCs serve as the foundation of LDCs and are graphical representations of the flow characteristics of a stream at a given site. When historical flow data are available, FDCs utilize the hydrologic record from stream gages to forecast future recurrence frequencies. While many WQM stations throughout Texas do not have long term flow data, there are various methods that can be used to estimate flow frequencies at ungaged stations or gaged stations missing flow data.

The most basic method to estimate flows at an ungaged site involves 1) identifying an upstream or downstream flow gage; 2) calculating the contributing drainage areas of the ungaged sites and the flow gage; and 3) calculating daily flows at the ungaged site by using the flow from an acceptable nearby gaged site multiplied by the drainage area ratio. Because no upstream/downstream gages were located on the segments of interest for the Upper San Antonio Watershed, a more complex approach was used that correlates nearby gages and also considers watershed differences in pervious and impervious cover, land cover, WWTF discharges, and the hydrologic properties of the watershed. A more detailed explanation of the methods for estimating flow at ungaged WQM stations is provided in Appendix F.

FDCs are a type of cumulative distribution function. The curve represents the fraction of flow observations that exceed a given flow at the site of interest. The observed flow values are first ranked from highest to lowest then, for each observation, the percentage of observations exceeding that flow is calculated. The flow value is read from the y-axis, which is typically on a logarithmic scale since the high flows would otherwise overwhelm the low flows. The flow exceedance frequency is read from the x-axis, which is numbered from 0 to 100 percent, and may or may not be logarithmic. The lowest measured flow occurs at an exceedance frequency of 100 percent indicating that flow has equaled or exceeded this value 100 percent of the time, while the highest measured flow is found at an exceedance frequency of 0 percent. The median flow occurs at a flow exceedance frequency of 50 percent.

While the number of observations required to develop a flow duration curve is not rigorously specified, a flow duration curve is usually based on more than 5-years of observations, and encompasses inter-annual and seasonal variation. Ideally, the drought of record and flood of record are included in the observations. For this purpose, the long-term flow gaging stations operated by the USGS are utilized. As previously mentioned, there are no long-term flow data from within the Study Area and therefore, flows were estimated for all WQM stations/watersheds in the Upper San Antonio Watershed using the gage correlation approach described in Appendix F. Two USGS gages outside the watershed, Sims Bayou at Hiram Clarke Street and Vince Bayou at Pasadena, TX, were chosen to conduct flow projections. The period of record for flow data used from this station was 2000 through 2013.

A typical semi-log FDC exhibits a sigmoidal shape, bending upward near a flow exceedance frequency value of 0 percent and downward at a frequency near 100 percent, often with a relatively constant slope in between. For sites that on occasion exhibit no flow, the curve will intersect the abscissa at a frequency less than 100 percent. As the number of observations at a site increases, the line of the FDC tends to appear smoother. However, at extreme low and high flow values, these curves may exhibit a "stair step" effect due to the USGS flow data rounding conventions near the limits of quantitation.

FDCs can be subdivided into hydrologic condition classes to facilitate the diagnostic and analytical uses of flow and LDCs. The hydrologic classification scheme utilized in this application is described in Table 4-1.

Table 4-1: Hydrologic Classification Scheme

Flow Exceedance Percentile	Hydrologic Condition Class
0-20	Highest flows
20-80	Mid-range flows
80-100	Lowest flows

Figures 4-1 through 4-5 presents the FDC developed for the downstream WQM station in Menger Creek (Figure 4-1); Apache Creek (Figure 4-2); Alazan Creek (Figure 4-3); San Pedro Creek (Figure 4-4); and Sixmile Creek (Figure 4-5) for calculating the TMDL of the 303(d) listed freshwater stream using the gage correlation method outlined above and further described in Appendix F. The flow exceedance percentiles for these segments are presented in tabular form in Appendix F.

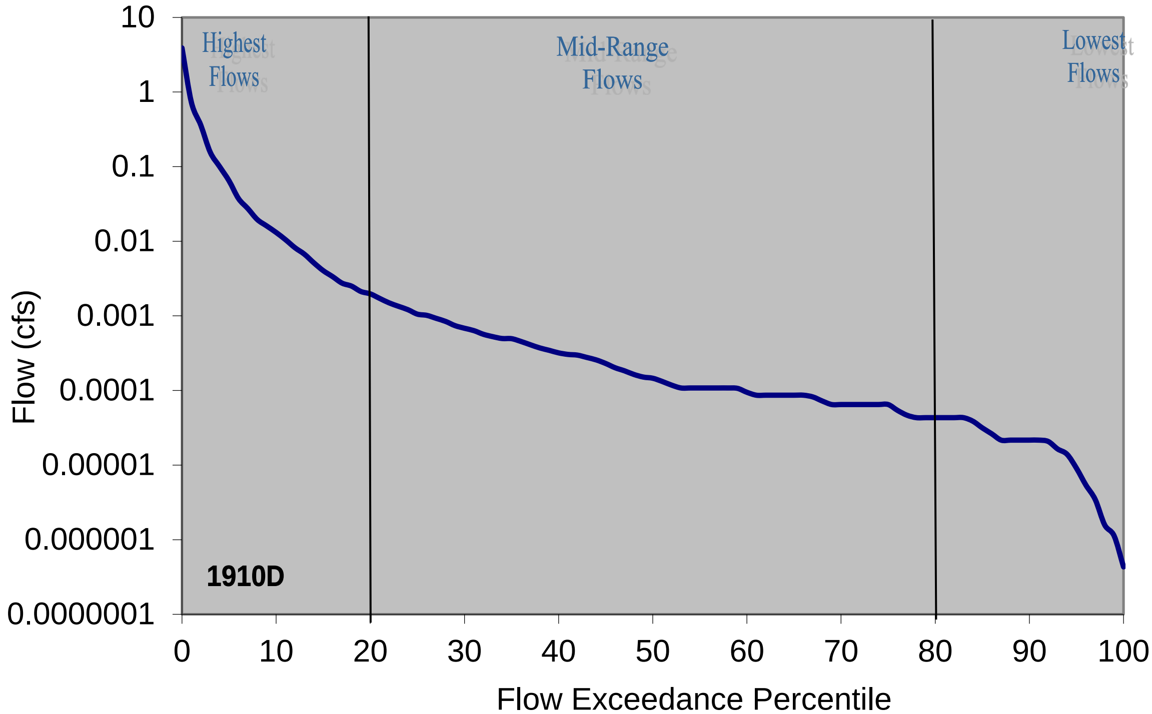

Figure 4-1: Flow Duration Curve for Menger Creek (1910D_01)

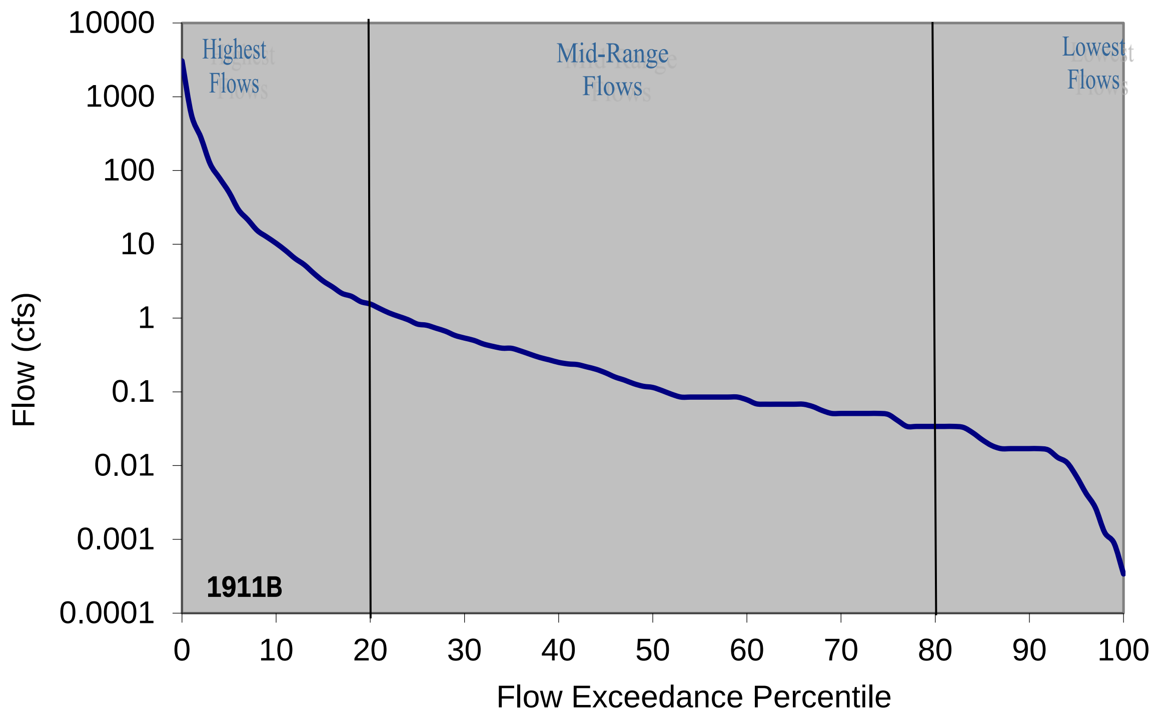

Figure 4-2: Flow Duration Curve for Apache Creek (1911B_01)

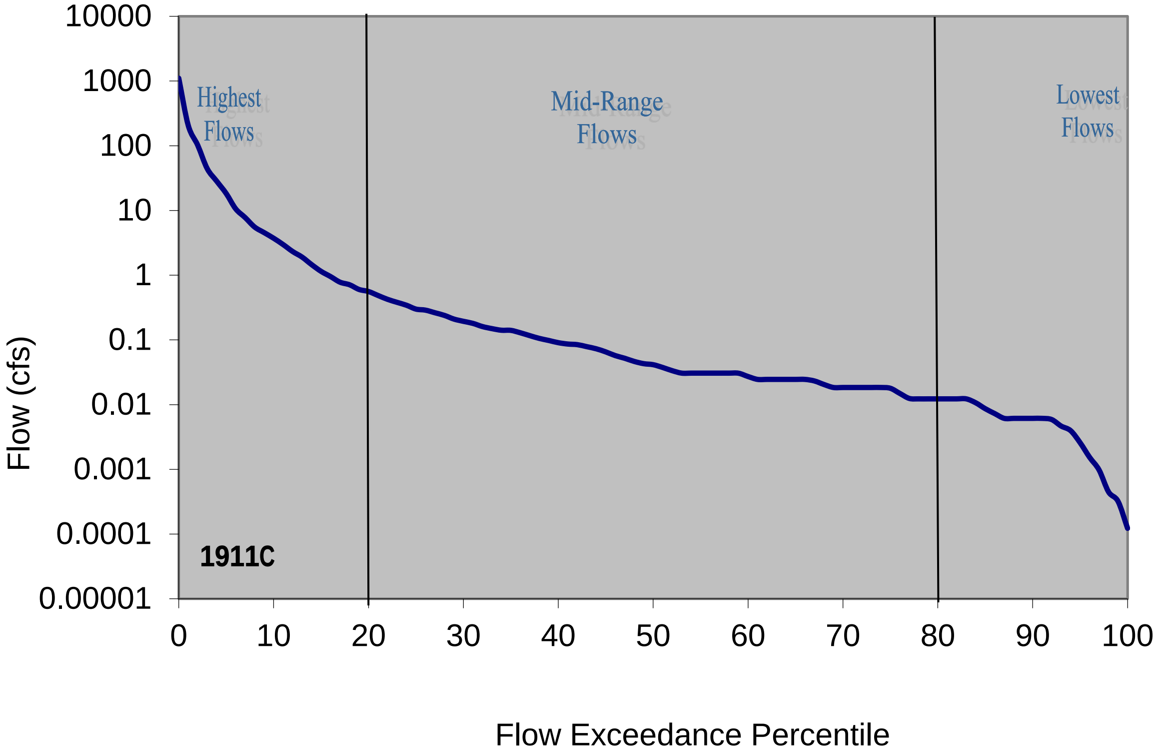

Figure 4-3: Flow Duration Curve for Alazan Creek (1911C_01 & 1911C_02)

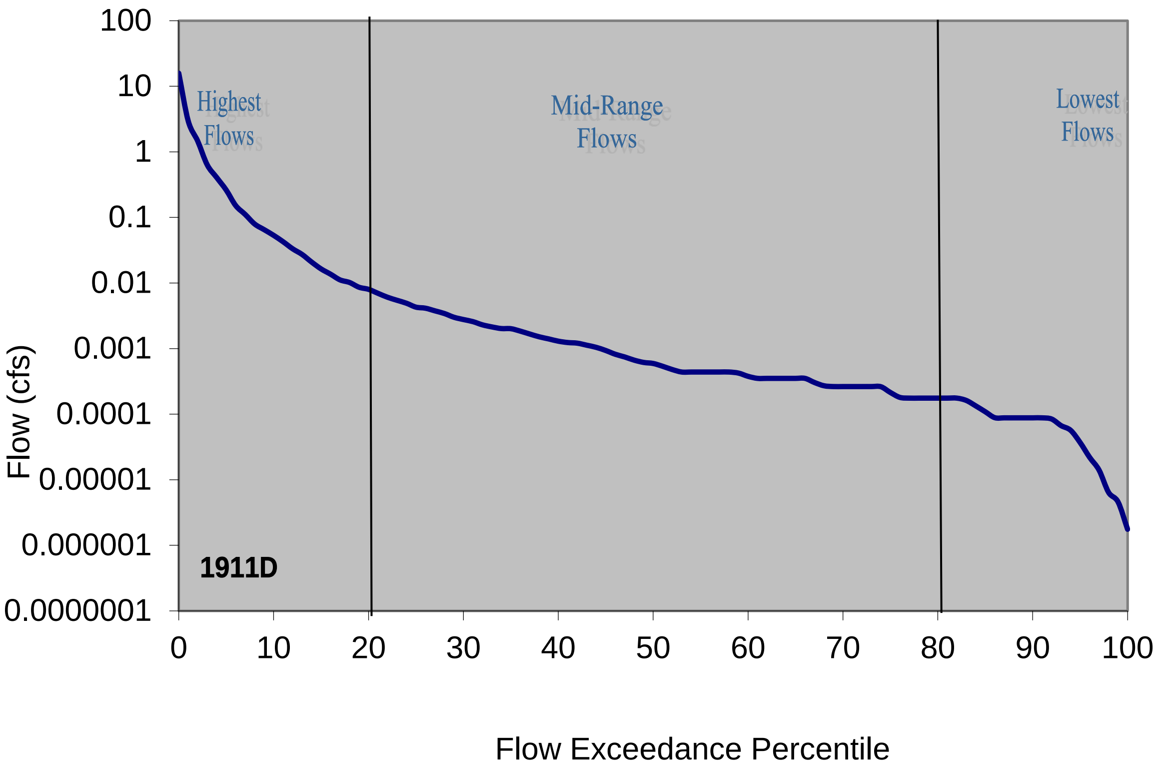

Figure 4-4: Flow Duration Curve for San Pedro Creek (1911D_01 & 1911D_02)

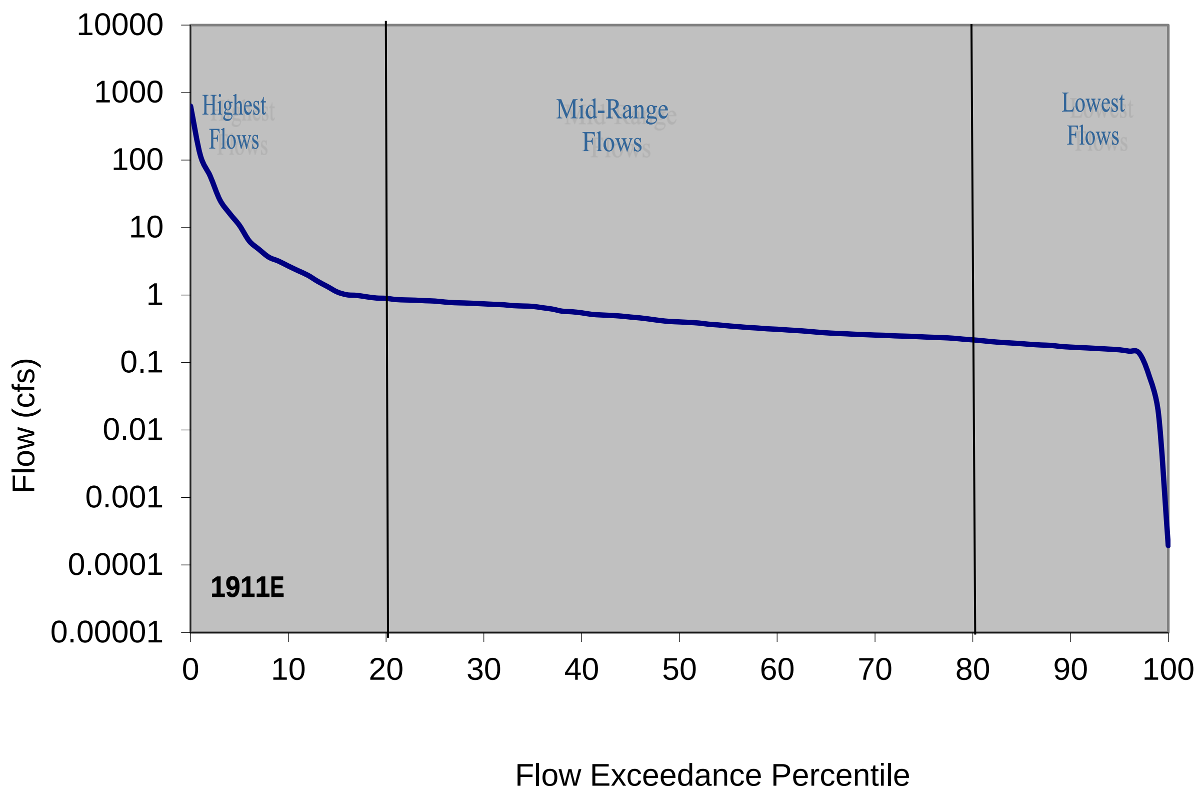

Figure 4-5: Flow Duration Curve for Sixmile Creek (1911E_01)

4.3 Estimating Current Point and Nonpoint Loading and Identifying Critical Conditions from Load Duration Curves

Another key step in the use of LDCs for TMDL development is the estimation of existing bacteria loading from point and nonpoint sources and the display of this loading in relation to the TMDL. There is one domestic or otherwise continuously discharging point source (i.e., WWTFs) in the Sixmile Creek watershed. In Texas, WWTFs that discharge treated sanitary wastewater must meet the criteria for indicator bacteria at the point of discharge. However, for TMDL analysis it is necessary to understand the relative contribution of WWTFs to the overall pollutant load and its general compliance with required effluent limits.

The critical condition for the LDC is considered the flow regime that requires the most significant bacteria reduction to meet water quality standards. For all watersheds of interest, this was the high flow (0-20th percentile flow) conditions.

4.4 Development of Bacteria TMDLs for Freshwater Streams Using Load Duration Curves

The final step of the process involves developing calculations to support development of the TMDL allocations.

Step 1: Generate Bacteria LDCs. LDCs are similar in appearance to FDCs; however, the ordinate is expressed in terms of a bacteria load in counts/day. The curve represents the water quality criteria for *E coli* (either single sample criteria of 394 MPN/dL or geometric mean criteria of 126 MPN/dL), expressed in terms of a load through multiplication by the continuum of flows at the site determined using the gage correlation approach. The basic steps to generating an LDC involve:

- develop flow estimates using the gage correlation approach described in Appendix F and develop FDC as described in previous sections;
- obtaining the water quality data for the WQM station;
- matching the water quality observations with the flow estimates from the same date;
- display a curve on a plot that represents the allowable load multiply the actual or estimated flow by the surface water quality standard for each respective indicator;
- multiplying the flow by the water quality parameter concentration to calculate daily loads; then
- plotting the flow exceedance percentiles and the daily observed bacteria load .

The culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

*TMDL (counts/day) = criterion * flow (cfs) * unit conversion factor*

Where: criterion = 399 counts/dL (E coli) and

*unit conversion factor = 24,465,755 dL/ft3 * seconds/day*

The flow exceedance frequency (x-value of each point) is obtained by looking up the historical exceedance frequency of the measured or estimated flow; in other words, the percent of historical observations that equal or exceed the measured or estimated flow. Historical observations of bacteria concentration are paired with flow data and are plotted on the LDC. The indicator bacteria load (or the y-value of each point) is calculated by multiplying the indicator bacteria concentration (counts/dL) by the instantaneous flow (cubic feet per second [cfs]) at the same site and time, with appropriate volumetric and time unit conversions. Indicator bacteria loads representing exceedance of water quality criterion fall above the water quality criterion line.

Figure 4-6 provides a schematic representation of where permitted and non-permitted sources of pollution occur throughout the entire hydrograph for a typical stream. This figure shows that runoff typically contributes pollutant loads during high flow to mid-ranged flow conditions. However, flows do not always correspond directly to runoff events. For instance, high flows may occur in dry weather and runoff influence may be observed with low or moderate flows.

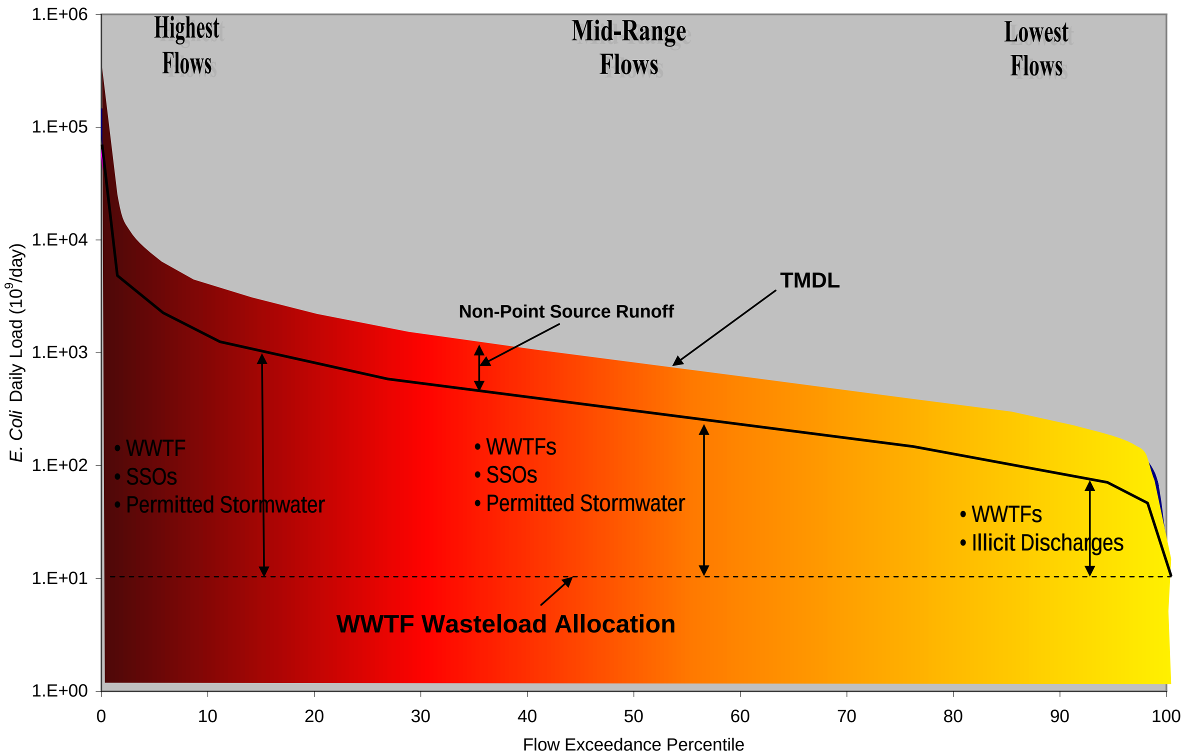

Figure 4-6: Schematic Diagram – Interpreting Sources and Loads

Step 2: Develop LDCs with MOS. The MOS may be defined explicitly or implicitly. An LDC depicting slightly lower estimates than the TMDL is typically developed to incorporate an MOS into the TMDL calculations. A typical explicit approach would reserve some fraction of the TMDL (*e.g.*, 5%) as the MOS. For the TMDLs for freshwater streams in this report, an explicit MOS of 5 percent of the TMDL value (5% of the geometric mean water quality criterion) has been selected. The MOS at any given percent flow exceedance, therefore, is defined as the difference in loading between the TMDL and the TMDL with MOS.

Step 3: Calculate WLA. As previously stated, the pollutant load allocation for permitted (point) sources is defined by the WLA. A point source can be either a wastewater or storm water permitted discharge. Storm water point sources are typically associated with urban and industrialized areas, and recent USEPA guidance includes NPDES-permitted storm water discharges as point source discharges and, therefore, part of the WLA.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading will vary with flow condition. TMDLs can be expressed in terms of maximum allowable concentrations, or as different maximum loads allowable under different flow conditions, rather than single maximum load values. This concentration-based approach meets the requirements of 40 CFR, 130.2(i) for expressing TMDLs “in terms of mass per time, toxicity, or other appropriate measures” and is consistent with USEPA’s Protocol for Developing Pathogen TMDLs (USEPA 2001).

WLA for WWTF. WLAs may be set to zero for watersheds with no existing or planned permitted point sources. For watersheds with permitted point sources, WLAs may be derived from TPDES permit limits. A WLA may be calculated for each active TPDES wastewater discharger using a mass balance approach as shown in the equation below. The permitted average flow rate used for each point source discharge and the water quality criterion concentration are used to estimate the WLA for each wastewater facility. Through TPDES permits WLAs for WWTFs are constant across all flow conditions and ensure that WQS will be attained (USEPA 2007). All WLA values for each TPDES wastewater discharger are then summed to represent the total WLA for the watershed.

*WLA = criterion * flow * unit conversion factor (#/day)*

Where: criterion = 126/dL (E. coli) or 35/dL (Enterococci); flow (mgd) = permitted flow;

unit conversion factor = 37,854,120-dL/ mgd

WLA for NPDES/TPDES MS4s. Given the lack of data and the complexity of quantifying bacteria concentrations or loads associated with wet weather events, the percentage of a watershed that is under MS4 jurisdiction is used to estimate the load that should be allocated as the permitted storm water load. For example, the area of the City of San Antonio/SAWS/TxDOT permitted MS4 discharges in the project area is estimated to be 1,959 acres, 100 percent of the Menger Creek (Segment 1910D_01) watershed. Therefore, 100 percent of the wasteload allocation will be designated as the WLA for stormwater.

Step 4: Calculate LA. LAs for non-permitted sources (nonpoint sources) can be calculated under different flow conditions as the water quality target load minus the sum of WLA for WWTFs (if any) and permitted storm water (or MS4). The LA at any particular flow exceedance is calculated as shown in the equation below.

$$LA = TMDL - MOS - \Sigma WLA_{WWTF} - \Sigma WLA_{MS4}$$

Where:

LA = allowable load from non-permitted sources
TMDL= total allowable load
ΣWLA_{WWTF} = sum of all WWTF loads
ΣWLA_{MS4} = sum of all MS4 loads
MOS = margin of safety

Step 5: Estimate WLA Load Reduction. If there were WWTFs in the segments of interest for this report, the WLA load reduction for TPDES-permitted WWTFs would not be calculated. Instead, it would be assumed that continuous dischargers are adequately regulated under existing permits and, therefore, no WLA reduction would be required. However, for permitted stormwater the load reduction will be the same as the percent reduction goal established for the LA (nonpoint sources).

Step 6: Estimate LA Load Reduction. A percent reduction goal is derived for each WQM station on each segment for the geometric mean criterion After existing loading estimates are computed for the applicable indicator bacteria (fecal coliform or *E. coli*), nonpoint load reduction estimates for each sampling location are calculated by using the difference between estimated existing loading and the allowable load expressed by the LDC (TMDL-MOS). Existing loads were determined by using the median flow (10^{th}, $50^{th,}$ and 90^{th} flow exceedance percentile) of each of the three flow regimes multiplied by the geometric mean concentration of the historical bacteria data. For example, for the 0-20th percentile flow range, the flow corresponding to the 10th percentile was used. The geometric mean of the indicator bacteria samples within the 0-20th flow percentile range was then multiplied by the 10th flow exceedance percentile to determine the existing load. Overall, percent reduction goals were also calculated for the most-downstream station of each segment. The highest reduction determined for each segment is then applied as the percent reduction goal. In this case, all indicator bacteria data from flow exceedance percentiles of 0 through 100 were used to calculate the geometric mean and the percent reduction goal was derived using the formula of:

Percent Reduction Goal = ABS(Geometric Mean of Indicator Bacteria Load – TMDL) / Geometric Mean of Indicator Bacteria Load

4.5 Development of Bacteria TMDLs for Tidal Streams Using a Mass Balance Approach

There are no tidal streams with in the Study Area.

CHAPTER 5
TMDL CALCULATIONS

5.1 Results of TMDL Calculations

The calculations and results of the TMDLs for the 303(d)-listed water bodies in the Study Area are provided in Section 5. The bacteria load allocations derived from the technical approach for freshwater is discussed in the subsections of Section 5 below.

5.2 Estimated Loading and Critical Conditions

USEPA regulations at 40 CFR 130.7(c) (1) require TMDLs to take into account critical conditions for stream flow, loading, and all applicable water quality standards. To accomplish this, available instream WQM data were evaluated with respect to stream flows and the magnitude of water quality criteria exceedance. TMDLs are derived for specific indicator bacteria in 303(d) listed water bodies at specific WQM stations based on LDCs for Menger Creek (1910D_01), Apache Creek (1911B_01), Alazan Creek (1911C_01 & 1911C_02), San Pedro Creek (1911D_01 & 1911D_02), and Sixmile Creek (1911E_01).

As previously described in Chapter 4, an LDC was used to calculate the bacteria load at the criterion for the freshwater segment over a range of flow conditions. This calculation produces the maximum bacteria load in the stream without exceeding the instantaneous standard over the range of flow conditions.

The pollutant load allocations and percent reduction goals for each flow regime are summarized in Section 5.8. The highest percent reduction goals for the segment was found to occur in the flow regime with the highest flows (0–20th percentile) and consequently, this was the flow regime used to estimate the TMDL.

Figure 5-1 represents the LDC for Menger Creek (1910D_01) which is based on *E coli* bacteria measurements at sampling location 12693 (Menger Creek immediately upstream of Coliseum Road). The LDC indicates that geometric mean observed *E coli* loading exceeds the TMDL, established using the geometric mean water quality target, under all three flow conditions. Load reductions ranging from 77 to 89.3% are required to meet the TMDL across the flow conditions.

Figure 5-2 represents the LDC for Apache Creek (1911B_01) which is based on *E coli* bacteria measurements at sampling location 18735 (Apache Creek at Brazos Street). The LDC indicates that *E coli* levels exceed the geometric mean water quality target under all three flow conditions. Load reductions ranging from 79.2 to 88% are required to meet the TMDL across the flow conditions.

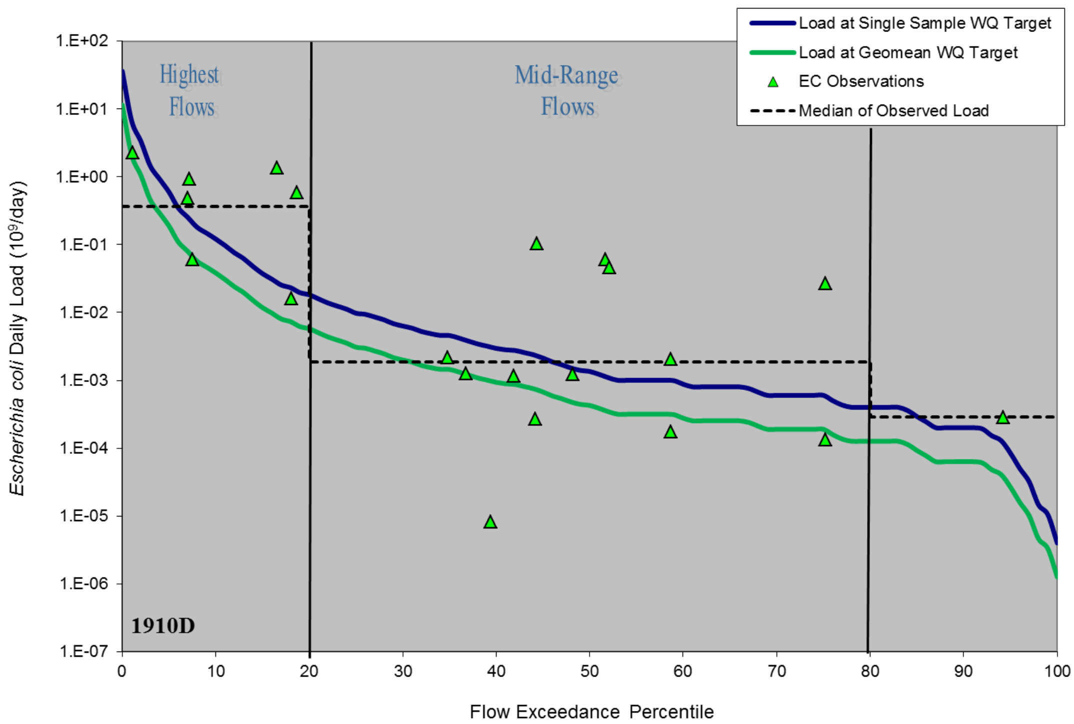

Figure 5-1: Load Duration Curve for Menger Creek (1910D_01)

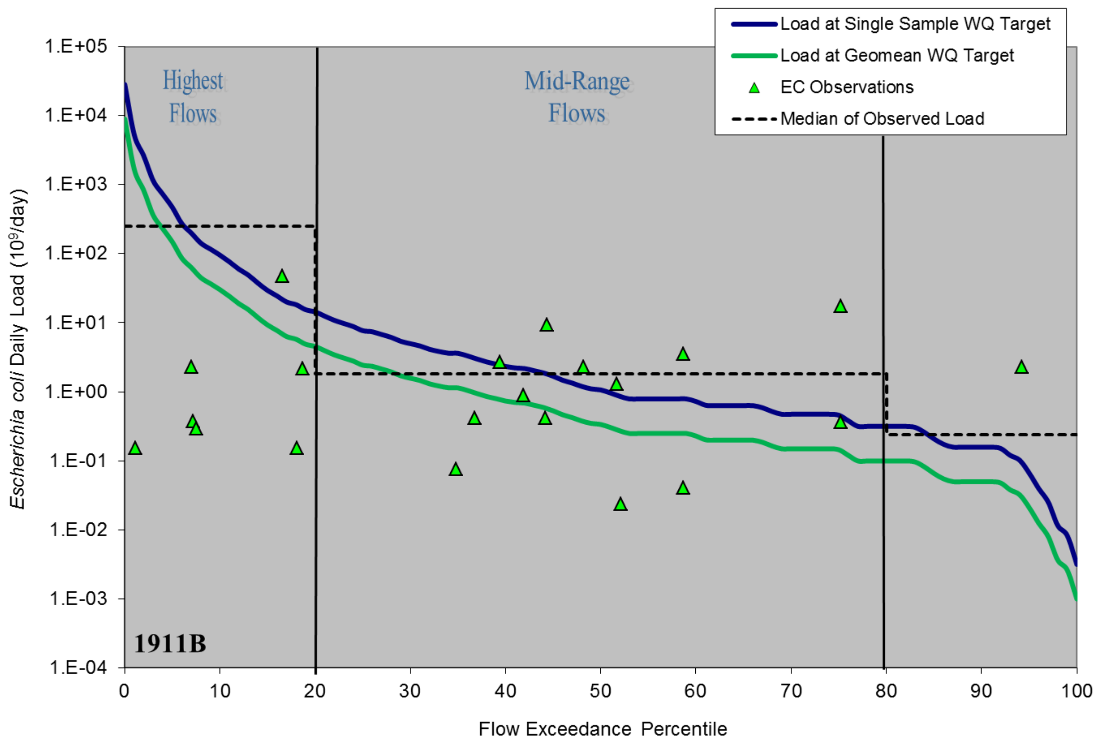

Figure 5-2: Load Duration Curve for Apache Creek (1911B_01)

Figure 5-3 represents the LDC for Alazan Creek (1911C_01 & 1911C_02) which is based on *E coli* bacteria measurements at sampling location 12715 (Alazan Creek at Tampico Street in San Antonio). The LDC indicates that *E coli* levels exceed the instantaneous and geometric mean water quality criteria under all three flow conditions. Load reductions ranging from 62.9 to 77.1% are required to meet the TMDL across the flow conditions.

Figure 5-4 represents the LDC for San Pedro Creek (1911D_01 & 1911D_02) which is based on *E coli* bacteria measurements at sampling location 18736 (San Pedro Creek at Probandt Street). The LDC indicates that *E coli* levels exceed the instantaneous and geometric mean water quality criteria under all three flow conditions. Load reductions ranging from 40.9 to 77.1% are required to meet the TMDL across the flow conditions.

Figure 5-5 represents the LDC for Sixmile Creek (1911E_01) which is based on *E coli* bacteria measurements at sampling location 12705 (Six Mile Creek at Roosevelt Avenue in San Antonio). The LDC indicates that *E coli* levels exceed the instantaneous and geometric mean water quality criteria under all three flow conditions. Load reductions ranging from 30.3 to 95.8% are required to meet the TMDL across the flow conditions.

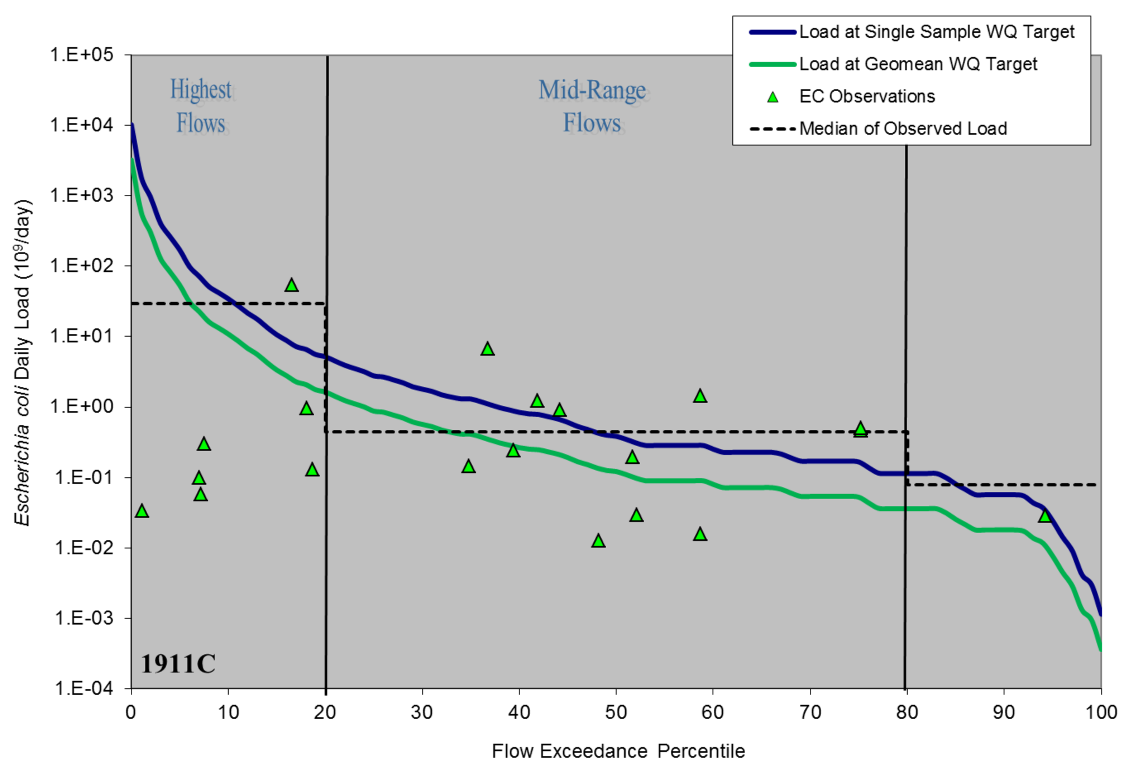

Figure 5-3: Load Duration Curve for Alazan Creek (1911C_01 & 1911C_02)

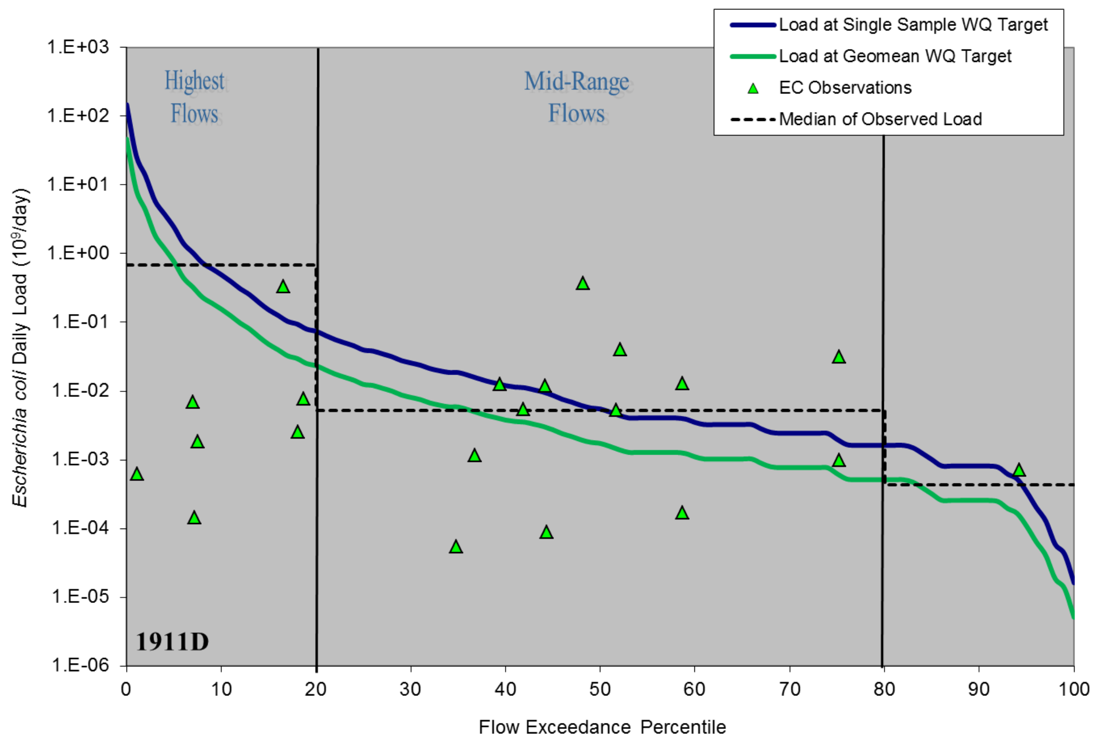

Figure 5-4: Load Duration Curve for San Pedro Creek (1911D_01 & 1911D_02)

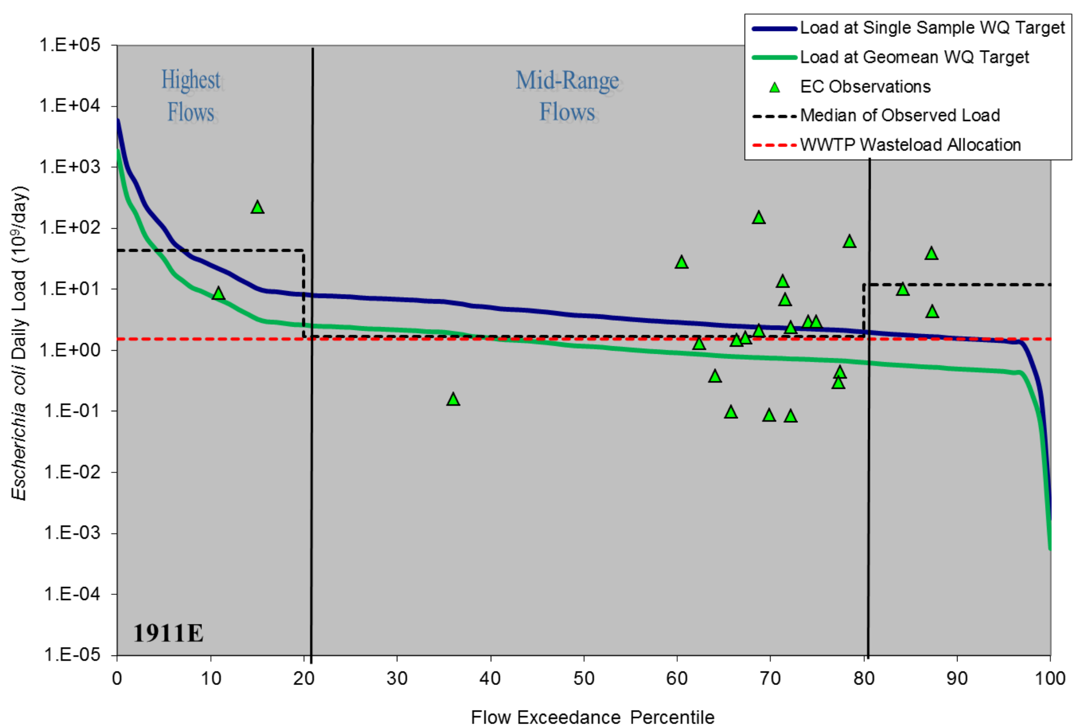

Figure 5-5: Load Duration Curve for Sixmile Creek (1911E_01)

5.3 Wasteload Allocation

TPDES-permitted facilities are allocated a daily wasteload calculated as their permitted discharge flow rate multiplied by one half of the instream geometric mean water quality criterion. Table 5-1 summarizes the WLA for the TPDES-permitted facilities within the Study Area. The WWTFs will not be subject to all listed indicator bacteria. The WLA for each facility (WLA_{WWTF}) is derived from the following equation:

*WLA_{WWTF} = criterion/2 * flow * unit conversion factor (#/day)*

Where:

criterion = 53 and 126 counts/dL for enterococci and E coli, respectively

flow (10^6 gal/day) = permitted flow

unit conversion factor = 37,854,120-10^6gal/day

When multiple TPDES facilities occur within a watershed, loads from individual WWTFs are summed and the total load for continuous point sources is included as part of the WLA_{WWTF} component of the TMDL calculation for the corresponding segment. When there are no TPDES WWTFs discharging into the contributing watershed of a WQM station, then WWTF WLA is zero. Compliance with the WLA_{WWTF} will be achieved by adhering to the fecal coliform discharge limits and disinfection requirements of TPDES permits.

Stormwater discharges from MS4 areas are considered permitted point sources. Therefore, the WLA calculations must also include an allocation for permitted stormwater discharges. Given the limited amount of data available and the complexities associated with simulating rainfall runoff and the variability of stormwater loading a simplified approach for estimating the WLA_{MS4} areas was used in the development of these TMDLs. For the LDC method the percentage of each watershed that is under a TPDES MS4 permit is used to estimate the amount of the overall runoff load that should be dedicated as the permitted stormwater contribution in the $WLA_{STORMWATER}$ component of the TMDL. The difference between the total stormwater runoff load and the portion allocated to $WLA_{STORMWATER}$ constitutes the LA component of the TMDL (direct nonpoint runoff).

Table 5-1: Wasteload Allocations for TPDES-Permitted Facilities

TPDES Number	NPDES NUMBER	Facility Name	Final Permitted Flow (MGD)	Enterococci (counts/day)
03955-000	TX0116114	Kelly Air Force Base	1	n/a
04117-000	TX0069931	San Antonio Equipment repair and Maintenance yard	n/a	n/a

Notes: n/a = Not Available, MGD = Millions of Gallons per Day

For the freshwater stream, the flow dependent calculations for the MS4 portion of the WLA are derived using LDC and the MS4 percentages provided in Table 3-5

5.4 Load Allocation

As discussed in Section 3, non-permitted sources of bacteria loading to the receiving streams of each waterbody emanate from a number of different sources. The data analyses demonstrate that exceedances at the WQM stations are the result of a variety of nonpoint source loading. The LAs for each stream segment are calculated as the difference between the TMDL, MOS, WLA, and WLA for MS4 as follows:

$$LA = TMDL - \sum WLA_{WWTF} - \sum WLA_{STORMWATER} - MOS$$

Where:

LA = allowable load from non-permitted sources
TMDL= total allowable load
ΣWLA_{WWTF} = sum of all WWTF loads
$\sum WLA_{STORMWATER}$ = sum of all stormwater loads
MOS = margin of safety

5.5 Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Seasonal variation was accounted for in these TMDLs by using more than 5 years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

Analysis of the available data for *E coli* and enterococci in Table 1-13 showed no consistent trend among all evaluated stations for warmer and/or cooler months.

5.6 Allowance for Future Growth

Compliance with these TMDLs is based on keeping the indicator bacteria concentrations in the selected waters below the limits that were set as criteria for the individual sites. Future growth of existing or new point sources is not limited by these TMDLs as long as the sources do not cause indicator bacteria to exceed the limits. The assimilative capacity of streams increases as the amount of flow increases. Increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation criterion. The addition of any future wastewater discharge facilities will be evaluated on a case-by-case basis.

To account for the high probability that new additional flows from WWTF may occur in any of the segments, a provision for future growth was included in the TMDL calculations by estimating permitted flows to year 2050 using population projections completed by the Texas Water Development Board. A summary of the methodology used to predict waste water flow capacity based on population growth is included in Appendix E. For the freshwater segment, the projected WWTF permitted flows were added to the flows from runoff to build the $TMDL_{future}$ for various flows.

5.7 Margin of Safety

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include an MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the uncertainty associated with calculating the allowable pollutant loading to ensure geometric mean criterion are attained. USEPA guidance allows for use of implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for uncertainty, then the MOS is considered explicit.

The TMDL for the freshwater segments incorporates an explicit MOS by setting a more stringent target for indicator bacteria loads that is 5 percent lower than the single sample criterion. The explicit margin of safety was used because of the limited amount of data. For contact recreation, this equates to a single sample target of 379 MPN/100mL for *E coli* and a geometric mean target of 120 MPN/100mL. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each waterbody is slightly reduced. The TMDL for the freshwater stream in this report incorporate an explicit MOS in the LDC by using 95 percent of the single sample criterion.

5.8 TMDL Calculations

The bacteria TMDLs for the 303(d)-listed WQM stations covered in this report were derived using LDCs. A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for uncertainty concerning the relationship between effluent limitations and water quality.

This definition can be expressed by the following equation:

$$TMDL = \Sigma\, WLA + \Sigma\, LA + MOS + Future\ Growth$$

Tables 5-2 through 5-6 summarize the pollutant load allocations and percent reduction goals at current flows, for each flow regime, for the freshwater segment. Table 5-7 summarizes the estimated maximum allowable load of *E coli* for the freshwater assessment unit included in this project.

Table 5-2: E coli TMDL Calculations for Menger Creek (1910D_01)

Station 12693			
Flow Regime %	**0%-20%**	**20%-80%**	**80%-100%**
Median Flow, Q (cfs)	**0%-20%**	**20%-80%**	**80%-100%**
Observed Geomean Load (10^9 org/day)	0.013119	0.000146	0.000022
TMDL (Q*C) (10^9 org/day)	0.360562	0.001860	0.000286
MOS (Q*C*0.05) (10^9 org/day)	0.040441	0.000450	0.000067
Allowable Load at Water Quality Target,	0.002022	0.000022	0.000003
Load Reduction (10^9 org/day)	0.038419	0.000427	0.000063
Load Reduction (%)	89.3%	77.0%	77.8%
TMDL (Qfuture*WQS) (10^9 org/day)	0.0		

Table 5-3: E coli TMDL Calculations for Apache Creek (1911B_01)

Station 18735			
Flow Regime %	**0%-20%**	**20%-80%**	**80%-100%**
Median Flow, Q (cfs)	10.308	0.115	0.017
Observed Geomean Load (10^9 org/day)	250.531	1.824	0.239
TMDL (Q*C) (10^9 org/day)	31.778	0.353	0.052
MOS (Q*C*0.05) (10^9 org/day)	1.589	0.018	0.003
Allowable Load at Water Quality Target,	30.189	0.336	0.050
Load Reduction (10^9 org/day)	220.342	1.488	0.189
Load Reduction (%)	88.0%	81.6%	79.2%
TMDL (Qfuture*WQS) (10^9 org/day)	0.0		

Table 5-4: E coli TMDL Calculations for Alazan Creek (1911C_01 & 1911C_02)

Station 12715			
Flow Regime %	**0%-20%**	**20%-80%**	**80%-100%**
Median Flow, Q (cfs)	3.7247	0.0414	0.0061
Observed Geomean Load (10^9 org/day)	29.3988	0.4386	0.0784
TMDL (Q*C) (10^9 org/day)	11.4819	0.1277	0.0189
MOS (Q*C*0.05) (10^9 org/day)	0.5741	0.0064	0.0009
Allowable Load at Water Quality Target,	10.9078	0.1213	0.0180
Load Reduction (10^9 org/day)	18.4909	0.3172	0.0604
Load Reduction (%)	62.9%	72.3%	77.1%
TMDL (Qfuture*WQS) (10^9 org/day)	0.0		

Table 5-5: E coli TMDL Calculations for San Pedro Creek (1911D_01 & 1911D_02)

Station 18736			
Flow Regime %	**0%-20%**	**20%-80%**	**80%-100%**
Median Flow, Q (cfs)	0.05330	0.00059	0.00009
Observed Geomean Load (10^9 org/day)	0.68041	0.00519	0.00044
TMDL (Q*C) (10^9 org/day)	0.16429	0.00183	0.00027
MOS (Q*C*0.05) (10^9 org/day)	0.00821	0.00009	0.00001
Allowable Load at Water Quality Target,	0.15608	0.00174	0.00026
Load Reduction (10^9 org/day)	0.52433	0.00345	0.00018
Load Reduction (%)	77.1%	66.5%	40.9%
TMDL (Qfuture*WQS) (10^9 org/day)	0.0		

Table 5-6: E coli TMDL Calculations for Sixmile Creek (1911E_01)

Station 12705			
Flow Regime %	**0%-20%**	**20%-80%**	**80%-100%**
Median Flow, Q (cfs)	2.69	0.40	0.17
Observed Geomean Load (10^9 org/day)	43.73	1.68	11.92
TMDL (Q*C) (10^9 org/day)	8.31	1.23	0.52
MOS (Q*C*0.05) (10^9 org/day)	0.42	0.06	0.03
Allowable Load at Water Quality Target,	7.89	1.17	0.50
Load Reduction (10^9 org/day)	35.84	0.51	11.42
Load Reduction (%)	82.0%	30.3%	95.8%
TMDL (Qfuture*WQS) (10^9 org/day)	1.36E+00		

Table 5-7: E coli TMDL Summary Calculations for Non-tidal Segments

Assess-ment Unit	Stream Name	Indicator Bacteria	TMDL[a] (Billion MPN/day)	WLA_{WWTF}[b] (Billion MPN/day)	$WLA_{STORM\ WATER}$[c] (Billion MPN/day)	LA[d] (Billion MPN/day)	MOS[e] (Billion MPN/day)	Future Growth[f] (Billion MPN/day)
1910D_01	Menger Creek	*E coli*	0.0404	0.0	0.0384	0.0	0.0020	0.0
1911B_01	Apache Creek	*E coli*	31.78	0.0	30.19	0.0	1.59	0.0
1911C_01 & 1911C_02	Alazan Creek	*E coli*	11.48	0.0	10.91	0.0	0.57	0.0
1911D_01 & 1911D_02	San Pedro Creek	*E coli*	0.164	0.0	0.156	0.0	0.008	0.00
1911E_01	Sixmile Creek	*E coli*	9.67	2.38	5.44	0.0	0.48	1.36

[a] *Maximum allowable load for the flow range requiring the highest percent reduction (Tables 5-2 to 5-6)*

[b] *Sum of loads from the WWTF discharging upstream of the TMDL station. Individual loads are calculated as permitted flow * 126/2 (E coli) MPN/100mL*conversion factor (Table 5-1)*

[c] *$WLA_{STORM\ WATER}$ = (TMDL – MOS –WLA_{WWTF})*(percent of drainage area covered by storm water permits)*

[d] *LA = TMDL – MOS –WLA_{WWTF} –$WLA_{STORM\ WATER}$-Future growth*

[e] *MOS = TMDL x 0.05*

[f] *Projected increase in WWTF permitted flows*126/2*conversion factor*

CHAPTER 6
PUBLIC PARTICIPATION

A stakeholder committee called the San Antonio Bacteria TMDL Advisory Group is assisting the TCEQ in developing the original TMDLs for the Upper San Antonio River. The group includes volunteer members who represent government, permitted facilities, agriculture, business, environmental, and community interests. This Advisory Group will be consulted on the additions to these TMDLs through a public meeting where the results of the study are presented by the University of Houston project manager. A Water Quality Management Plan (WQMP) update tool will also be prepared and distributed to the Advisory Group as well as the general public through web-based notifications. This update can be found on the TCEQ project webpage for the Upper San Antonio River, and the 30-day public comment period will begin once the proper notifications have been made.

CHAPTER 7
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APPENDIX A
AMBIENT WATER QUALITY BACTERIA DATA*

**** See attached CD***

APPENDIX B
USGS FLOW DATA*

**** See attached CD***

APPENDIX C
DISCHARGE MONITORING REPORTS

***Note: At the time of writing, no reliable data were available for the discharge monitoring reports.**

APPENDIX D
METHODOLOGY FOR ESTIMATING FLOW AT WQM STATIONS

Appendix D
Methodology for Estimating Flow at WQM Stations

Because there are no USGS flow gages located in the Upper San Antonio Watershed, a procedure was developed for estimating historical flows at multiple locations in The San Antonio River. There are no gage records available for the River other than a handful of individual flow measurements. To support LDC development, ten years of daily flow estimates are recommended at the five impaired locations in the River. Ten years of daily flow were not available in this area, so seven to three years of data are provided, which is representative of present-day flow conditions as a result of recent land development.

Approach

A statistical model based on historical flows from adjacent streams will be used to estimate flows. The flow records for several adjacent streams appear to be reliable, complete, and are highly correlated among one another. These flow time series will be used to derive candidate flow prediction models. Both linear and nonlinear models were tested but ultimately the nonlinear model was selected as the preferred option for developing flow estimates for the River.

Data

Extended periods of daily flow records are available on Olmos Creek and the San Antonio River. Olmos Creek and the San Antonio River are adjacent to the Upper San Antonio River and are similar in size and land use. A comparison of the two gages is provided in Table D-1, and a summary of land cover for each of the gage drainage areas is presented in Table D-2 and compared with the land cover for the Upper San Antonio River. In addition, a graphical comparison of land cover and gage locations is shown in Figure D-1.

Table D-1: USGS Gages in the area with a Continuous Period of Record from 2002-2012

Gage Number	Name	Percent		Drainage Area (acres)	Mean Flow (cfs)	Number of Continuous Data Points
		Developed Land	Forest/Wetland			
08177700	Olmos Creek at Dresden Dr., San Antonio, TX	83%	14%	13,435	12.51	3777
08178565	San Antonio River at Loop 410,San Antonio, TX	93%	4%	81,710	152	3777

Table D-2: Land Cover Summary

	Menger Creek		Apache Creek		Alazan Creek		San Pedro Creek		Sixmile Creek		Olmos Creek		San Antonio	
	1910D_01		1911B_01		1911C_01 &1911C_02		1911D_01 &1911D_02		1911E_01		08177700		08178565	
Land cover class	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Open Water	0	0%	31	0.2%	34	0.3%	0	0%	8	0.08%	5	0%	102	0%
Developed, Open Space	506	25.8%	3684	25.3%	1610	14.3%	318	10.6%	2686	28.18%	3870	29%	19941	24%
Developed, Low Intensity	618	31.6%	5674	39%	5398	48.1%	875	29.2%	3275	34.36%	3922	29%	29134	36%
Developed, Medium Intensity	473	24.2%	2979	20.5%	2423	21.6%	778	26%	1573	16.5%	2068	15%	14966	18%
Developed, High Intensity	361	18.4%	1819	12.5%	1698	15.1%	993	33.2%	1298	13.61%	1308	10%	11670	14%
Barren Land	0	0%	1	0%	0	0%	1	0%	0	0%	91	1%	320	0%
Deciduous Forest	0	0%	105	0.7%	0	0%	0	0%	76	0.8%	394	3%	696	1%
Evergreen Forest	0	0%	40	0.3%	30	0.3%	0	0%	118	1.2%	1440	11%	1785	2%
Mixed Forest	0	0%	0	0%	0	0%	0	0%	29	0.3%	0	0%	82	0%
Shrub/Scrub	0	0%	125	0.9%	12	0.1%	13	0.44%	349	3.7%	229	2%	1536	2%
Grassland/ Herbaceous	0	0%	49	0.3%	25	0.2%	16	0.53%	26	0.27%	106	1%	346	0%
Pasture/Hay	0	0%	0	0%	0	0%	0	0%	18	0.2%	0	0%	235	0%
Cultivated Crops	0	0%	3	0%	0	0%	0	0%	8	0.08%	0	0%	37	0%
Woody Wetlands	0	0%	48	0.3%	2	0%	0	0%	68	0.72%	2	0%	860	1%
Emergent Herbaceous	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%

Wetlands														
Total	**1959**	**100%**	**14559**	**100%**	**11231**	**100%**	**2993**	**100%**	**9532**	**100%**	**13435**	**100%**	**81709**	**100%**
Total Developed	**1959**	**100%**	**14157**	**97%**	**11128**	**99%**	**2963**	**99%**	**8832**	**93%**	**11169**	**83%**	**75712**	**93%**
Total Forest / Wetland	**0**	**0%**	**193**	**1%**	**32**	**0%**	**0**	**0%**	**291**	**3%**	**1836**	**14%**	**3423**	**4%**

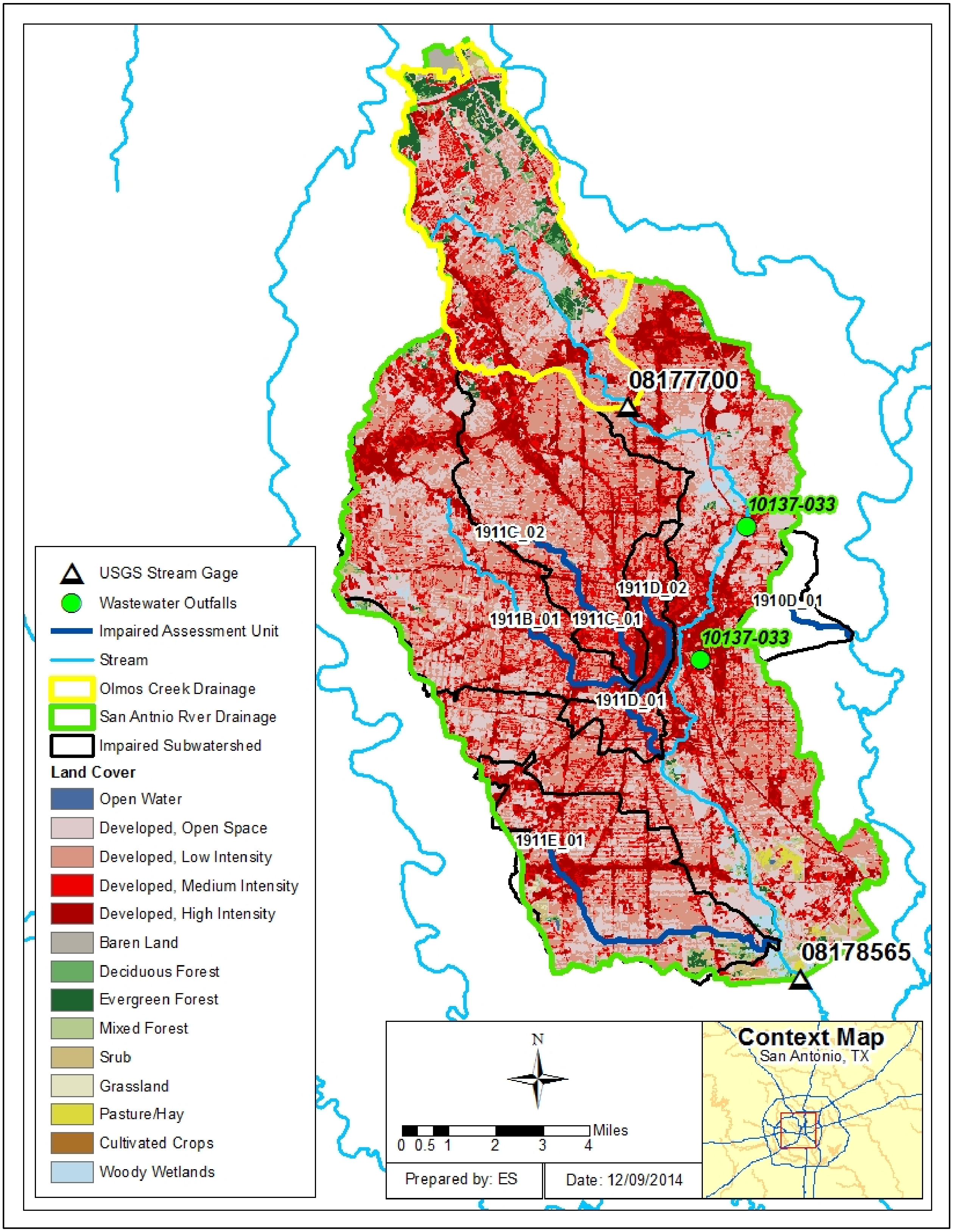

Figure D-1: USGS Gage locations

Model Development

Model form

A model is desired that will reliably predict an unknown flow in one location as a function of known flows from other locations with similar weather and land use. Such models can be linear, nonlinear or autoregressive (Linsley, Kohler and Paulhus 1982). In general, they take the form:

$$Q_{u,t}= f(Q_{k,t}\ Q_{k,t\ -1\ldots})$$

Where:

$Q_{u,t}$= unknown flow time series
$Q_{k,t}$= known flow time series;
f(x) = linear or exponential function)

In general, the time interval of the data is not important so long as the measurements are contemporaneous and equivalently averaged as there is no such thing as a truly instantaneous flow rate. In this case the input and output of the model are average daily flows. An initial investigation of gage correlation revealed a significant correlation (0.806) between the contemporaneous daily values of Olmos Creek and the San Antonio River and much lower values for flows lagged by one day. An analysis in log space produced significant but lower correlations thus a contemporaneous liner model was selected. Next, the model coefficients were selected based on the following model form:

$$Q_u=Q_kA^xD^yW^z$$

Where:

Q_u= unknown flow
Q_k= known flow;

A= Drainage area ratio

D= Developed area ratio

W= Wetland/Forest area ratio

x, y, z = parameters

Note there is no constant term because it is assumed that the unknown flow is zero anytime the known flow is zero. This isn't the case because of treatment plant discharges in the San Antonio River but as discussed below, the gauge data were adjusted to remove their effect.

Parameter Selection

The model parameters were selected using the following process:

- Reasonable model parameters were selected.
- The San Antonio River gage was used as input to the model, and used to compare to the known flows at Olmos Creek.

- Similarly, the Olmos Creek gage was used as input to the model, and used to compare to the known flows at San Antonio River.
- Through an iterative process, the model parameters were refined to improve the fit for both San Antonio River and Olmos Creek.

A total of two wastewater treatment plant outfalls are located in the San Antonio River watershed. In order to properly use the USGS gage flows for the gage correlation approach, it was necessary to establish base flows without the plants. This was accomplished as follows:

- The monthly WWTP flows were obtained for each of the plants.
- These flows were totaled to come up with a single WWTP flow for each month.
- These flows were subtracted from the Sims Bayou USGS gage flow as shown in equation below.

$$Q_{baseflow} = Q_{USGSgage} - \sum_{\#wwtf}^{1} Q_{Avg.MonthlyWWTF}$$

- When $Q_{baseflow}$ resulted in a negative value, 30% of the USGS flow was used as a representative baseflow. This assumption is based on goodness of fit, best professional judgement and previous studies that showed baseflow is typically 20-40% of bayou flows.

Final Model

The final model parameters used to estimate flows in the Upper San Antonio watershed were as follows:

- $X = 1.682$
- $Y = 1.665$
- $Z = 0.045$

Goodness of Fit

A combination of visual evaluation, minimization of daily mean residuals and root mean square error were used to arrive at the model parameters that provided the best fit across a range of flow conditions.

To demonstrate the fit that was achieved using the above model, an example of the FDC developed based on the USGS gage flow for Olmos Creek compared with the projected flows is presented in Figure D-3. As shown in the Figure, the fit over the entire range of flow conditions is quite good. The model underpredicts a small amount at the high flow conditions (i.e., less than the 20th percentile), which may inflate the root mean squared error.

The mean residuals achieved for this comparison and root mean square error is presented in Table D-3.

Figure D-3: Olmos Creek Gage Correlation Model Comparison

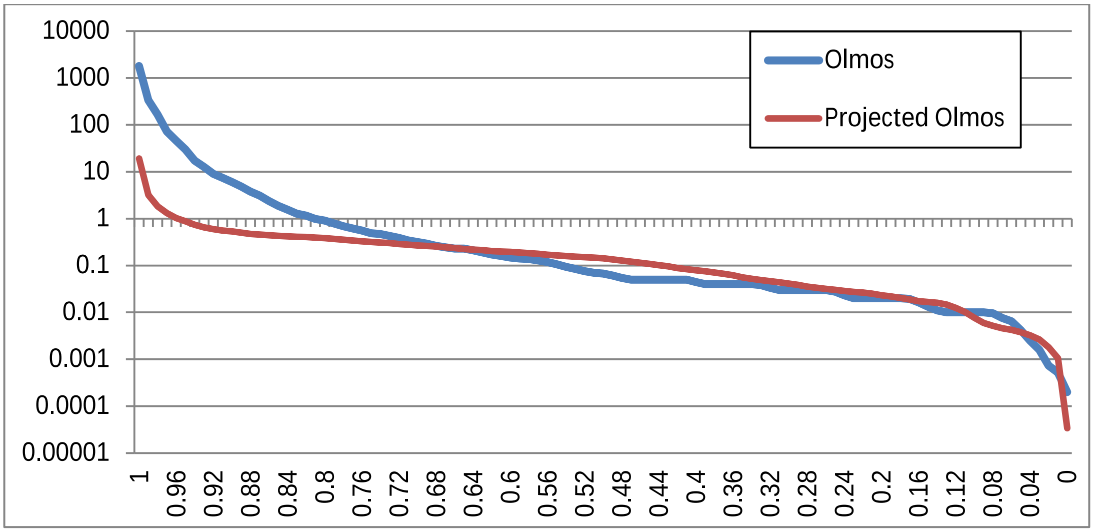

Table D-3: Gage Correlation Model Fit

Gage Number	Name	Mean Daily Residuals (cfs)	Root Mean Square Error (cfs)	No. Data Points
08177700	Olmos Creek at Dresden Dr., San Antonio, TX	12.24	83.25	3,777

Model application

This approach was used to develop FDCs for the Study Area. The flow exceedance tables developed using the gage correlation model are presented in Table D-4. Note that for impaired segments with no forested or wetland land cover, only parameters X and Y were employed.

Table D-4: Flow Exceedance Percentiles (cfs)

Percentile	1910D	1911B	1911C	1911D	1911E
10	0.0000216	0.017	0.0061	0.0000878	0.17
20	0.0000432	0.034	0.012	0.00018	0.217
30	0.0000649	0.051	0.018	0.0002	0.256
40	0.0000946	0.078	0.0272	0.0004	0.311
50	0.00015	0.11	0.041	0.0006	0.40
60	0.0003	0.25	0.091	0.0012	0.55
70	0.0007	0.54	0.194	0.003	0.74
80	0.002	1.55	0.568	0.008	0.89
90	0.013	10.3	3.72	0.053	2.69
100	3.896	3061	1106	15.8	631

APPENDIX E

METHOD FOR ESTIMATING FUTURE WWTF PERMITTED FLOWS

Appendix E - Methodology to Project Permitted Flows for WWTFs Discharging to the Upper San Antonio Bayou Watershed

The methodology used to predict future growth to 2050 is based on the approach used in the Clear Creek TMDL report. This appendix describes the procedure used for the growth prediction.

Municipal Wastewater Projections

Municipal wastewater flow projections are based on the population difference between the 2010 census population and the 2050 population estimate from the Texas Water Development Board Region H Population/Demand Estimates (2013). If a WWTF was located within a city, the population growth for that city was used to project future WWTF flows; otherwise, county population projections were used. Table E-1 presents the population estimates for cities and counties in the Upper San Antonio watershed. In the case of the two WWTFs in the Upper San Antonio watershed, the only city of interest is the City of San Antonio.

Table E-1 Summary of Population Estimates for Upper San Antonio Bayou Watershed

City	2010 U. S. Census Population	2020 Population Estimate	2050 Population Estimate	Percent Increase (2000-2050)
KIRBY	8,000	9,210	10,495	31%
LEON VALLEY	10,151	10,886	12,932	27%
SAN ANTONIO	1,327,407	1,528,129	2,086,803	57%
WINDCREST	5,364	5,573	6,156	15%
ALAMO HEIGHTS	7,031	8,095	8,423	20%

Next, the per capita permitted flow for each city in the watershed was determined for 2010. To do this, permitted flows were obtained for all WWTFs within the cities. According to the TCEQ, the City of San Antonio is permitted to discharge a total of 1463 MGD (2013). This value was used to calculate the per capita flow for the City as shown in Table E-2. Using the calculated per capita flow, the future permitted flow for 2050 was projected and is also included in Table E-3. It should be noted that this estimate is lower than would be expected based on typical wastewater generation estimates per person which is expected since portions of the City are served by non-City of San Antonio WWTFs. However, this estimate was determined to be acceptable for use in this analysis.

Table E-2 Per Capita Flow by City

City	Wastewater generated Per Capita (gallons per day)	Total permitted flow (MGD) - 2010	Total permitted flow (MGD) - 2050
San Antonio	0.00112	1493	2347.1

For WWTFs within city limits, the amount of the city's flow made up by the facility was determined. In both cases for the WWTFs in the Upper San Antonio watershed, the entire WWTF contributing area was within the boundaries of the City of San Antonio. Therefore, the calculated future permitted flow for each plant is determined as follows:

- The percentage of City flow is calculated by taking the permitted flow for each plant divided by the current total City permitted flow.
- The estimated 2050 Permitted flow is then the percentage of City Flow multiplied by the Total permitted flow for the City of San Antonio provided in Table E-2.

The results of this analysis are shown in Table E-3.

Table E-3 Summary of Future Permitted Flows by WWTF

TCEQ Permit	Permittee	Location of Outfall	2010 Permitted Flow (MGD)	% of City Flow	Estimated 2050 Permitted Flow (MGD)
03955-000	Kelly Air Force Base	City of San Antonio	1	0.1%	1.572

Industrial Wastewater Projections

There is one NPDES/TPDES industrial permit within the Upper San Antonio watershed, TCEQ permit 04117-000 which is issued to San Antonio Equipment Repair and Maintenance Yard. This facility is permitted to discharge industrial stormwater only and therefore, is not included in this analysis for wastewater projections.

Summary

A summary of the future growth calculations and resulting value is presented in Table E-4.

Table E-4 Flow Projections

Permit #	Facility	Permitted Flow (MGD)	Receiving Segment	Use Pop Projection from	GPCD[a]	Pop 2050[b]	% Flow In City[c]	Flow 2050[d] (MGD)	Adj Flow 2050[e] (MGD)
03955-000	Kelly Air Force Base	1	1911E_01	City of San Antonio	1.12E-03	2,086,803	0.1%	1.572	0.572

[a] *From Table E-2*
[b] *From Table E-1*
[c] *Permitted flow for facility/total permitted flow for the city in which the facility is located*
[d] *GPCD*Population 2050*%flow in city*

Table E-5 Projected Flows by Watershed

Segment	Stream Name	Projected Permitted Flow (MGD)
1910D_01	Menger Creek	NA
1911B_01	Apache Creek	NA
1911C_01 & 1911C_02	Alazan Creek	NA
1911D_01 & 1911D_02	San Pedro Creek	NA
1911E_01	Sixmile Creek	1.572

NA = Allocation not applicable at this time. There are no WWTFs discharging to the Assessment Unit.