Upper San Antonio River: Bacteria in Waters Used for Contact Recreation

- **Three TMDLs Adopted July 25, 2007**
  Approved by EPA September 25, 2007
- **Seven TMDLs Added by Addendum April 2016**
  Approved by EPA August 9, 2016 (scroll to view or print this addendum)

Water Quality Planning Division, Office of Water
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Addendum One to Three Total Maximum Daily Loads for the Upper San Antonio Watershed

Seven Total Maximum Daily Loads for Bacteria in the Upper San Antonio Watershed

For Segments 1910D, 1911B, 1911C, 1911D, and 1911E
Assessment Units 1910D_01, 1911B_01, 1911C_01, 1911C_02, 1911D_01, 1911D_02, and 1911E_01

Introduction

The Texas Commission on Environmental Quality (TCEQ) adopted the total maximum daily loads (TMDLs) *Three Total Maximum Daily Loads for Bacteria in the Upper San Antonio Watershed: Segments 1910, 1910A, and 1911* (TCEQ 2007) on 7/25/2007. The TMDLs were approved by the United States Environmental Protection Agency (EPA) on 9/25/2007. This document is an addendum to add seven additional assessment units (AUs) in five segments to the original TMDL document, and will be submitted to the EPA through a Water Quality Management Plan (WQMP) update. The public comment period for this addendum will be from May 13, 2016 through June 13, 2016.

This addendum includes new information specific to seven additional AUs located within the watershed of the approved TMDL project for bacteria in the Upper San Antonio River watershed. Concentrations of indicator bacteria in these seven AUs exceed the criteria used to evaluate attainment of the contact recreation standard. For background or other information for the five segments, please refer to the *Technical Support Document for Additions to the Upper San Antonio Watershed, San Antonio, Texas* (University of Houston 2015), which has additional details related to all aspects of this addendum. The document was completed in January, 2015 and is available on the TCEQ Web page for the Upper San Antonio River <www.tceq.state.tx.us/assets/public/waterquality/tmdl/34uppersa/34-TSD-UpperSanAntonio-2015-01.pdf>

Refer to the original, approved TMDL document for details related to the overall project watershed as well as the methods and assumptions used in developing this TMDL addendum. This addendum focuses on the subwatersheds of the additional AUs, and it offers the details related to developing the TMDL allocations for the additional AUs, which were not addressed individually in the original document. These additional AUs are also covered by an implementation plan developed by stakeholders in the San Antonio area. The implementation plan addresses multiple watersheds in the Upper San Antonio River area.

Problem Definition

The TCEQ identified the bacteria impairment to the AUs included in this addendum in the 2010 and 2012 Texas Water Quality Inventory and 303(d) Lists (Table 1). The impaired AUs include 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). See Figure 1 for a map of these subwatersheds.

The Texas surface water quality standards (TSWQS) give numeric and narrative criteria to evaluate attainment of designated uses (TCEQ 2010). The basis for water quality targets for the TMDL developed in this report will be the numeric criteria for bacterial indicators from the 2010 TSWQS. *Escherichia coli* (*E. coli)* is the preferred indicator bacteria for assessing contact recreation use in freshwater.

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, as well as the period of record to use for the data, include:

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

As a result of these evolving factors, the historical data used to support the TMDLs in this report have been narrowed, wherever possible, to use only *E. coli* data from 2007 through 2010.

Table 2 summarizes the ambient water quality data for the TCEQ SWQM stations on the impaired water bodies, and Figure 2 shows the station locations within the watershed.

For Menger Creek (Segment 1010D), the geometric mean criterion for *E. coli* was exceeded in 45 percent of the samples at the only SWQM station location at which *E. coli* data were collected within this subwatershed. The criterion was exceeded in the samples an average of 61 percent for Apache Creek (Segment 1911B), 48 percent for Alazan Creek (Segment 1911C), 53 percent for San Pedro Creek (Segment 1911D), and 46 percent for Sixmile Creek (Segment 1911E) in each subwatersheds' monitoring stations.

Watershed Overview

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 in the city of San

Antonio. The Upper San Antonio River watershed drains approximately one third of both Bexar and Wilson counties, as well as a small portion of Karnes County, however the impaired portion for the watershed lies entirely within Bexar County. Based on data from 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 (PRISM 2006) in this portion of Texas range between 30.4 and 31.7 inches per year, as shown in Table 3.

The central portion of the Upper San Antonio River watershed is heavily developed, since it encompasses the city of San Antonio. The much smaller northern portion is sparsely developed and largely evergreen forest and shrub. A small southeastern portion is predominantly low intensity developed land, pasture/hay, and shrub with sparse cultivated cropland and open water, including Calaveras Lake and Victor Braunig Lake. Table 4 summarizes the percentages of the land cover categories for the contributing subwatershed associated with each impaired AU in the Upper San Antonio watershed. The land cover data were retrieved from the U.S. Geological Survey (USGS) land cover database obtained from the USGS National Map Viewer (USGS 2006). The total acreage of each AU in Table 4 corresponds to the watershed delineation shown in Figure 3. The predominant land cover category in the subwatersheds is developed land (between 92 percent and 100 percent), followed by shrub/scrub (between 0 percent and 4 percent), evergreen forest (between 0 percent and 1 percent), and pasture/hay (between 0 percent and 0.2 percent). Open water and barren land account for less than 1 percent of the assessment units. The land cover for each subwatershed is shown in Figure 3.

Population estimates and future population projections were examined for counties and cities in the project area. These are discussed in the original TMDL document as well as the Technical Support Document for this addendum.

Table 1. Synopsis of Texas 2012 303(d) List for Water Bodies in the Upper San Antonio Watershed

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

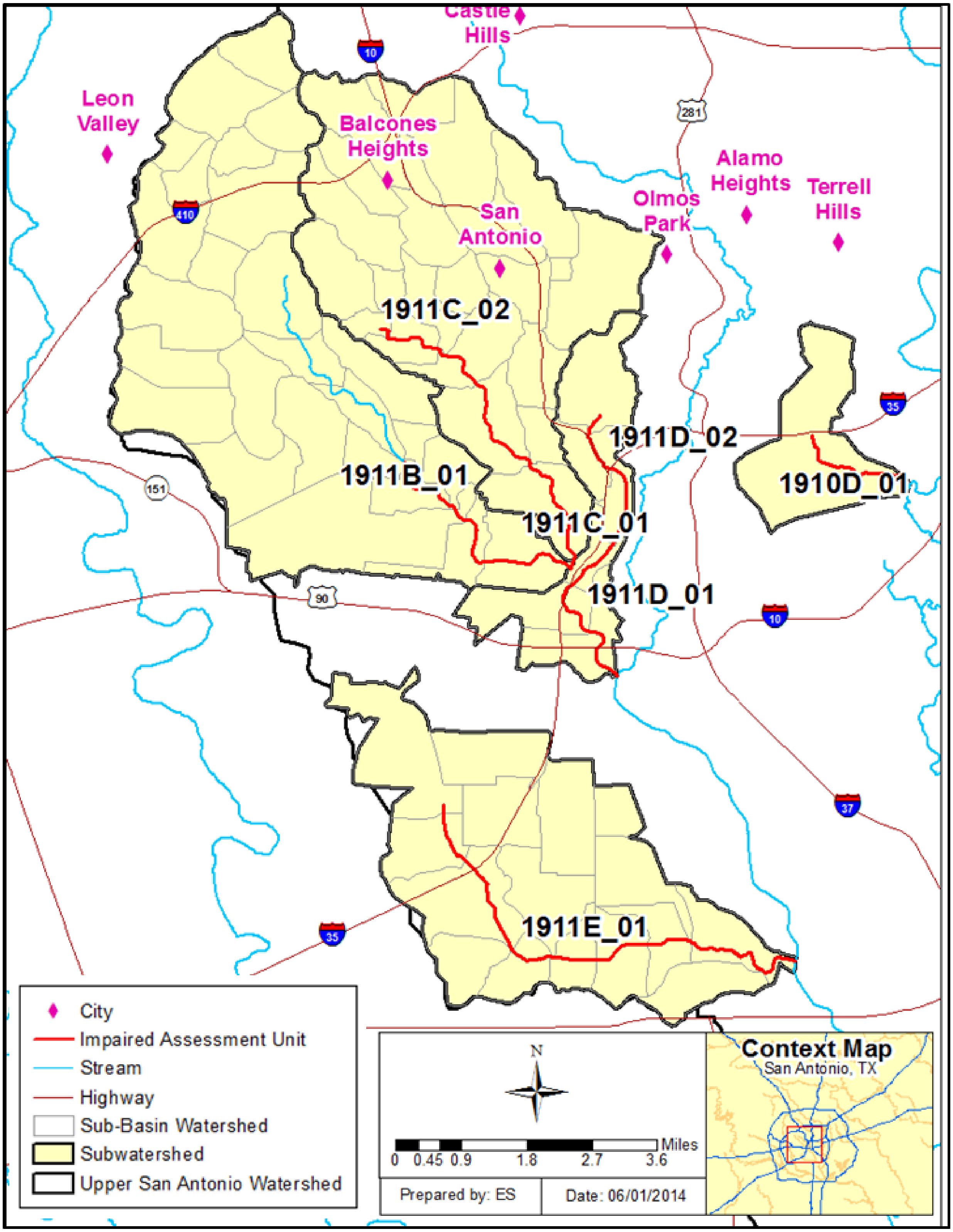

Figure 1. Location Map for Impaired Regions of the Upper San Antonio Watershed Region

Table 2. Historical Water Quality Data for the TCEQ Stations from 2007 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.
**MPN: most probable number*

Table 3. 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

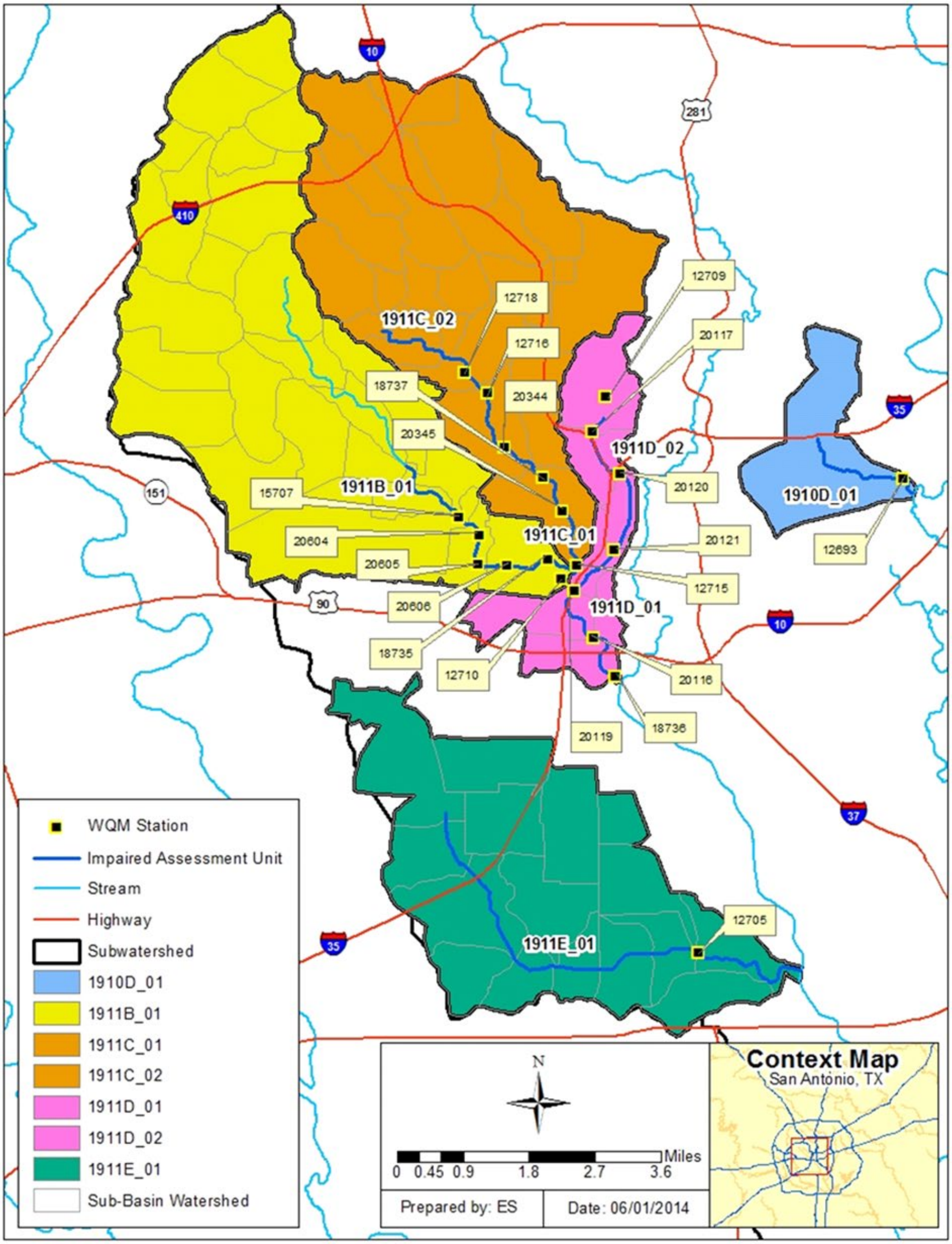

Figure 2. SWQM Station Locations

Table 4.	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**
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/>

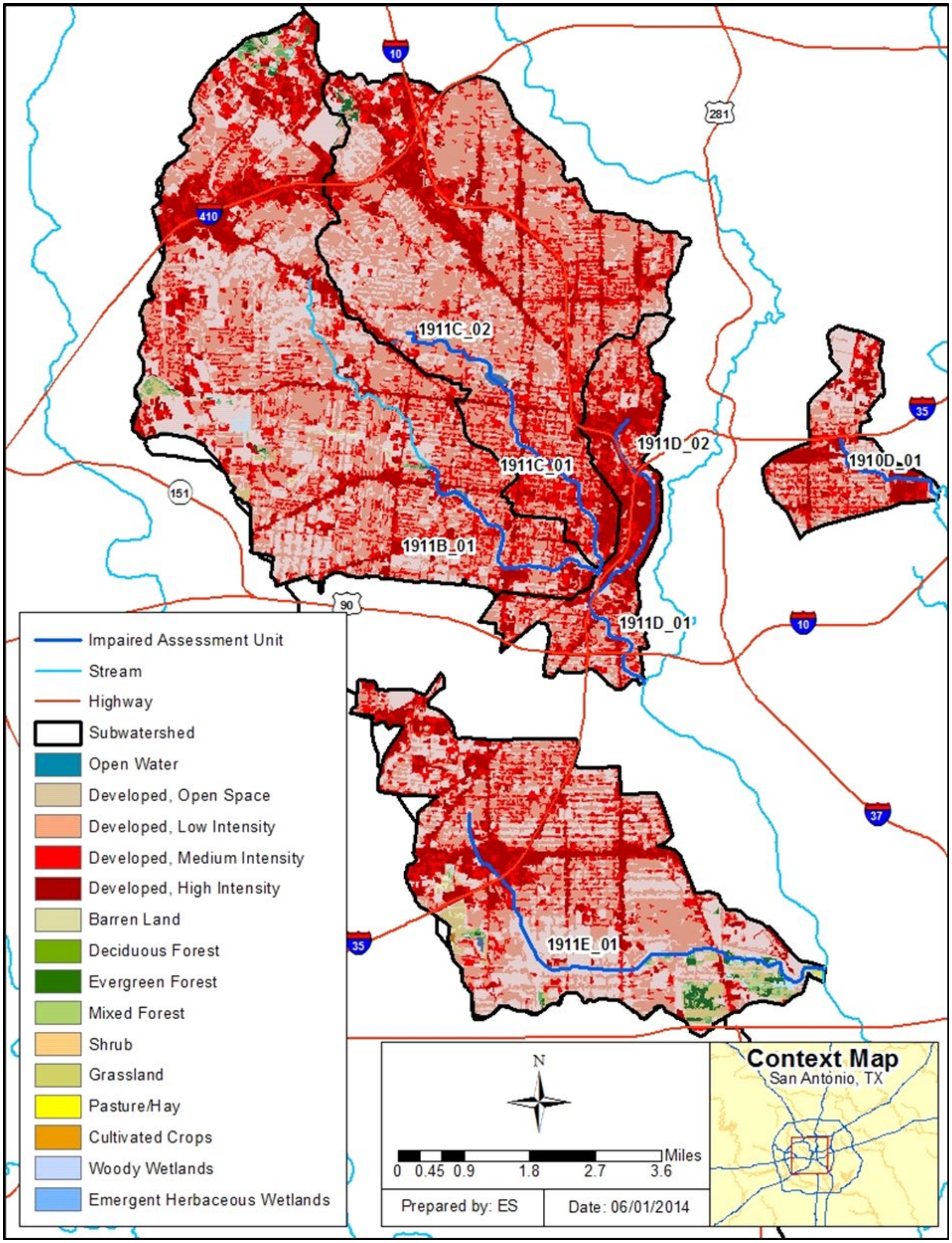

Figure 3. Land Cover Map

Endpoint Identification

The water quality target for the TMDLs for these seven freshwater AUs is to maintain concentrations below the geometric mean criterion of 126 MPN/100 mL for *E. coli*. The TMDL will be based on bacteria allocations required to meet this geometric mean criterion.

Source Analysis

Regulated Sources

One subwatershed in the area, Sixmile Creek (1911E_01) has two National Pollution Discharge Elimination System (NPDES)/TPDES-permitted sources, as shown in Figure 4. The entire 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 concentrated animal feeding operations within the area. As shown in Table 5, the permitted flow associated with the continuously discharging facility Kelly Air Force Base was 1.0 million gallons per day (MGD) (TCEQ 2014). The regulated San Antonio Equipment Repair and Maintenance Yard facility in the watershed does not have large continuous discharges.

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 Kelly Air Force Base facility is shown in Table 6.

Table 5. TPDES-Permitted Facilities in the subwatershed

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	0.11
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
**This is not a WWTF, so there is no discharging effluent for the WLA. The facility holds a stormwater permit only.*

Sanitary Sewer Overflows

The TCEQ maintains a database of sanitary sewer overflow (SSO) data collected from wastewater operators in the Upper San Antonio River watershed. TCEQ Region 13 (San Antonio) provided SSO data for the Upper San Antonio River watershed, which are shown in Table 7 for 2010 through 2012.

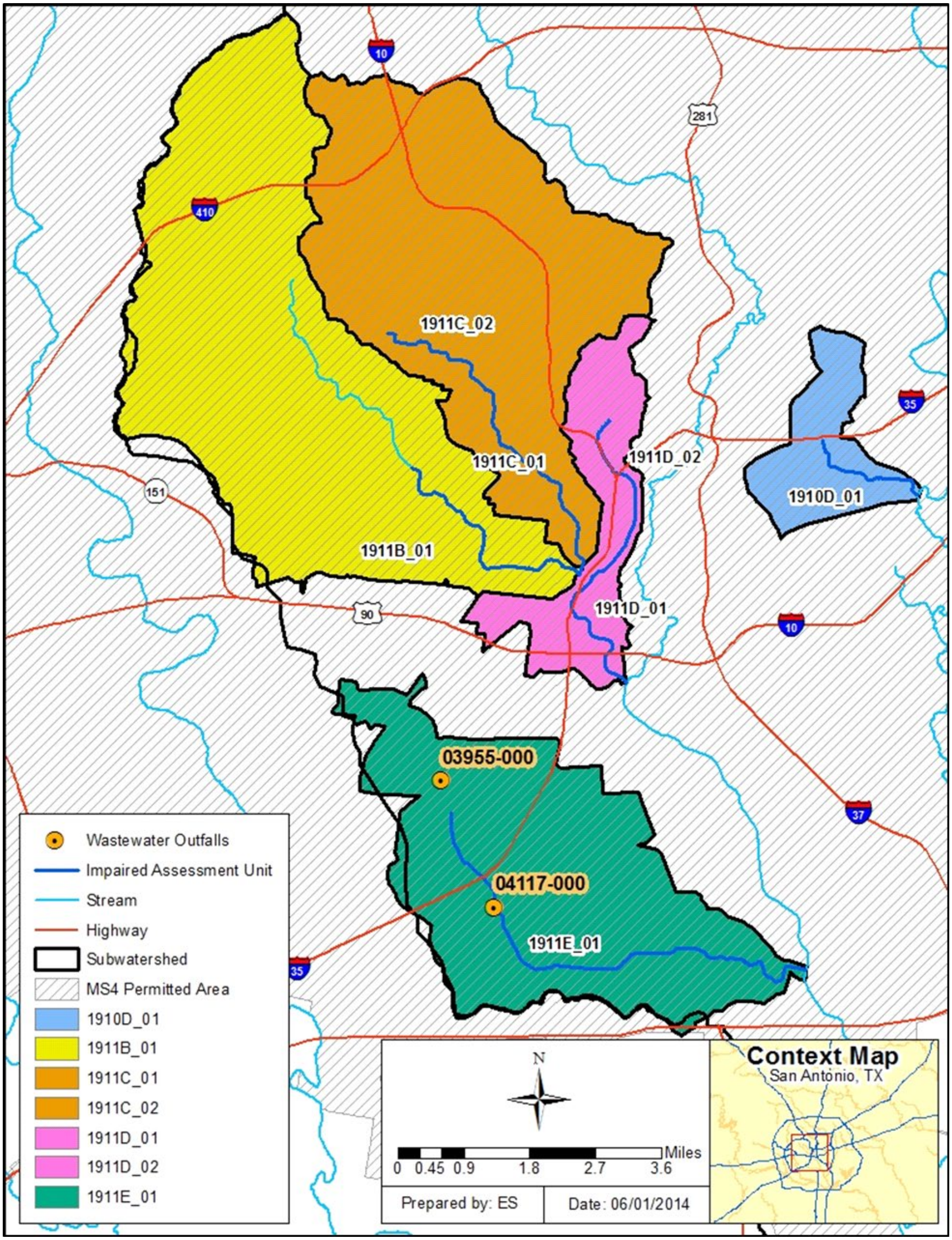

Figure 4: TPDES-Permitted Facilities that discharge into the Upper San Antonio Watershed

Table 6. 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	0.11	1

Source: DM) 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.*

The Leon Creek and Dos Rios facilities provide wastewater services within the subwatershed areas. However the facilities discharge into other watersheds and are not included in the regulated facilities calculation for this TMDL. Information on sanitary sewer overflow is considered as a potential for impacting water quality.

The locations and magnitudes of all reported SSOs within the Upper San Antonio River watershed region are displayed, along with wastewater treatment facilities (WWTF) service area boundaries, in Figure 5. These numbers represent only a potential for compromising water quality, since not all overflows actually reach the water body.

As shown in Table 7, there have been approximately 207 sanitary sewer overflows reported in the Upper San Antonio River watershed since January 2010. The reported SSOs averaged 39,773 gallons per event.

Table 7. 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

TPDES-Regulated Stormwater

Within this area of the Upper San Antonio River watershed, there is one individual Phase I municipal separate storm sewer system (MS4) permit that is currently regulated by the TCEQ. This MS4 is operated by the City of San Antonio, SAWS, and TxDOT (Phase I permit).

The coverage area for this permit is displayed in Figure 4, which shows that the entire area for these subwatersheds is covered under the City of San Antonio/SAWS/TxDOT MS4 permit (TPDES Permit No. WQ0004284000, NPDES Permit No. TXS001901).

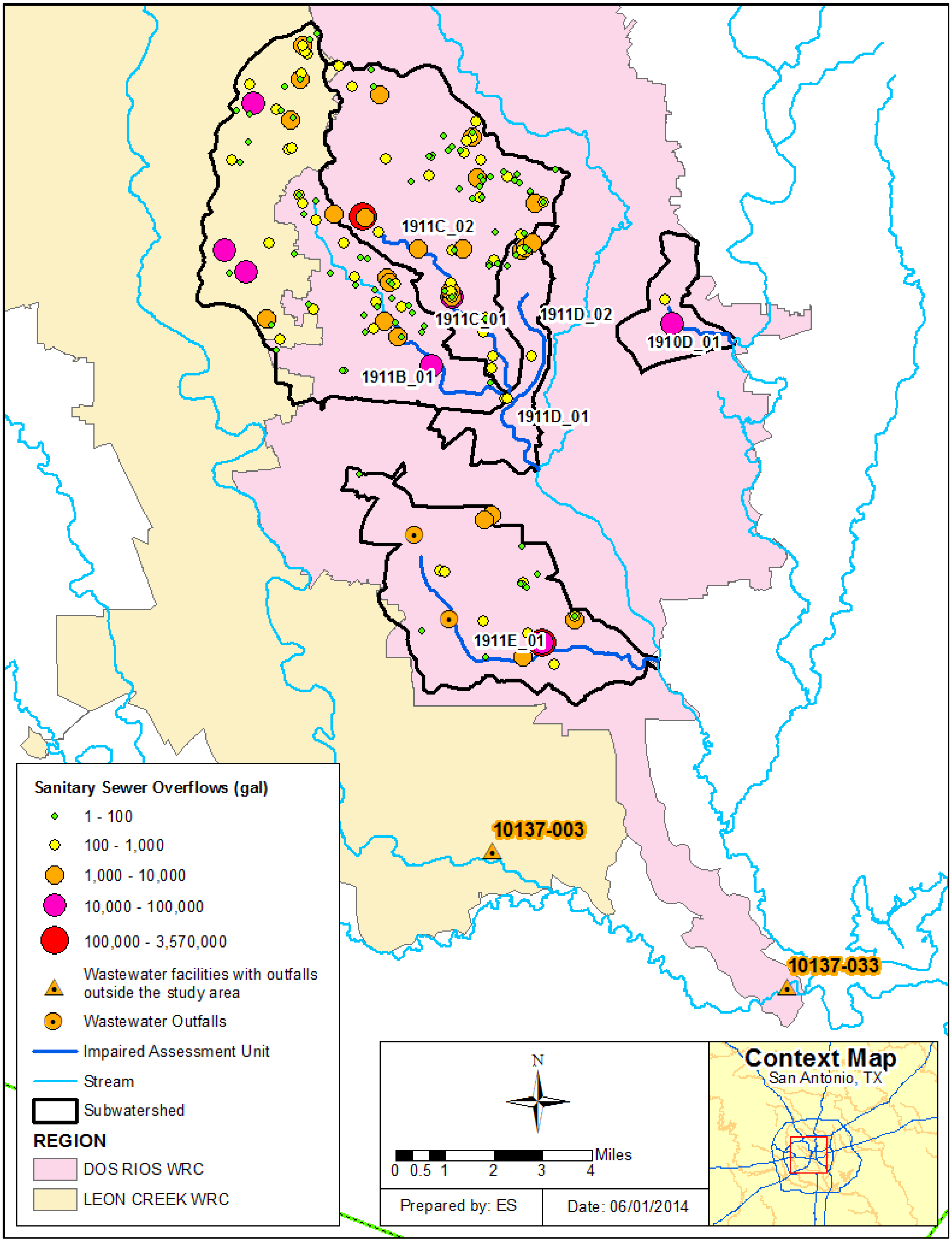

Figure 5. Locations of Sanitary Sewer Overflows

Unregulated Sources

Pollutants from unregulated sources enter the impaired AUs through distributed, nonspecific locations, which may include urban runoff not covered by a permit, wildlife, various agricultural activities and animals, land application fields, failing onsite sewage facilities (OSSFs), and domestic pets.

Wildlife and Unmanaged Animal Contributions

The portions of shrub and evergreen forest and sources of water in the area are a habitat for many species of wildlife such as mammals and birds, which are sources of bacteria. There are currently insufficient data available to estimate populations and spatial distribution of wildlife and avian species by subwatershed. Consequently, it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category.

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 estimated numbers of selected livestock by watershed were calculated based on the 2007 United States Department of Agriculture county agricultural census data (USDA 2007). The county-level estimated livestock populations were distributed throughout the subwatershed based on Geographic Information System (GIS) calculations of pasture land per watershed, based on the National Land Cover Database (National Oceanic and Atmospheric Administration 2011). It should be noted that these are planning-level livestock numbers and are not evenly distributed across counties or constant with time.

Cattle are estimated to be the most abundant species of livestock in the 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 River watershed. Using the estimated livestock populations and the fecal coliform production rates from the American Society of Agricultural Engineers, an estimate of fecal coliform production from each group of livestock was calculated for each subwatershed of the 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. The remaining subwatersheds are in highly urbanized areas, so livestock are likely to be an insignificant source of bacteria loading.

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. 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). A statewide study conducted by Reed, Stowe & Yanke, LLC (2001) reported that approximately 12 percent of the OSSFs in Bexar County were chronically malfunctioning. 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 regulated 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 subwatersheds. Table 8 lists the OSSF totals based on GIS data given by the Bexar County Public Works Department. Figure 6 displays all regulated OSSF systems. It should be noted that any unsewered areas fall under the purview of wastewater service areas in the subwatersheds.

To estimate fecal coliform loading in watersheds, the OSSF failure rate of 12 percent from the Reed, Stowe & Yanke, LLC (2001) report for Texas On-Site Wastewater 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 percent, 3 percent, and 12 percent for those regions, respectively. The land cover in the area is most similar to Texas Regions 2 and 4, so the 12 percent 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. (EPA 2001):

$$\#\frac{counts}{day} = \left(\#Failing\_systems\right)\times\left(\frac{10^6\,counts}{100ml}\right)\times\left(\frac{60gal}{personday}\right)\times\left(\#\frac{person}{household}\right)\times\left(3785.2\frac{ml}{gal}\right)$$

The average number of people per household was calculated to be 2.66 for the subwatersheds' area based on an average household density for the census blocks within the area (U.S. Census Bureau 2010). Sixty 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 8. Based on this data, it was determined that the estimated fecal coliform loading from OSSFs in the area was found to be negligible.

Table 8. Estimated Number of OSSFs per Watershed and Fecal Coliform Load

Segment	Stream Name	Number of authorized OSSFs in the area	# of Failing OSSFs	Estimated Loads from OSSFs (billion counts/day)
1910D	Menger Creek	0	0	0
1911B	Apache Creek	95	11.4	68.87
1911C	Alazan Creek	34	4.08	24.65
1911D	San Pedro Creek	2	0.24	1.45
1911E	Sixmile Creek	29	3.48	21.02

Data from Bexar County Public Works Department

Domestic Pets

Fecal matter from dogs and cats is transported to streams by runoff from urban and suburban areas and can be a 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 subwatershed. Table 9 summarizes the estimated number of dogs and cats for each of the subwatersheds.

Table 9. Estimated Numbers 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

Since many pet owners dispose of their cat's waste indoors and clean up after their dogs outside, only a small portion of these loads is expected to reach water bodies, through wash-off of land surfaces and conveyance in runoff.

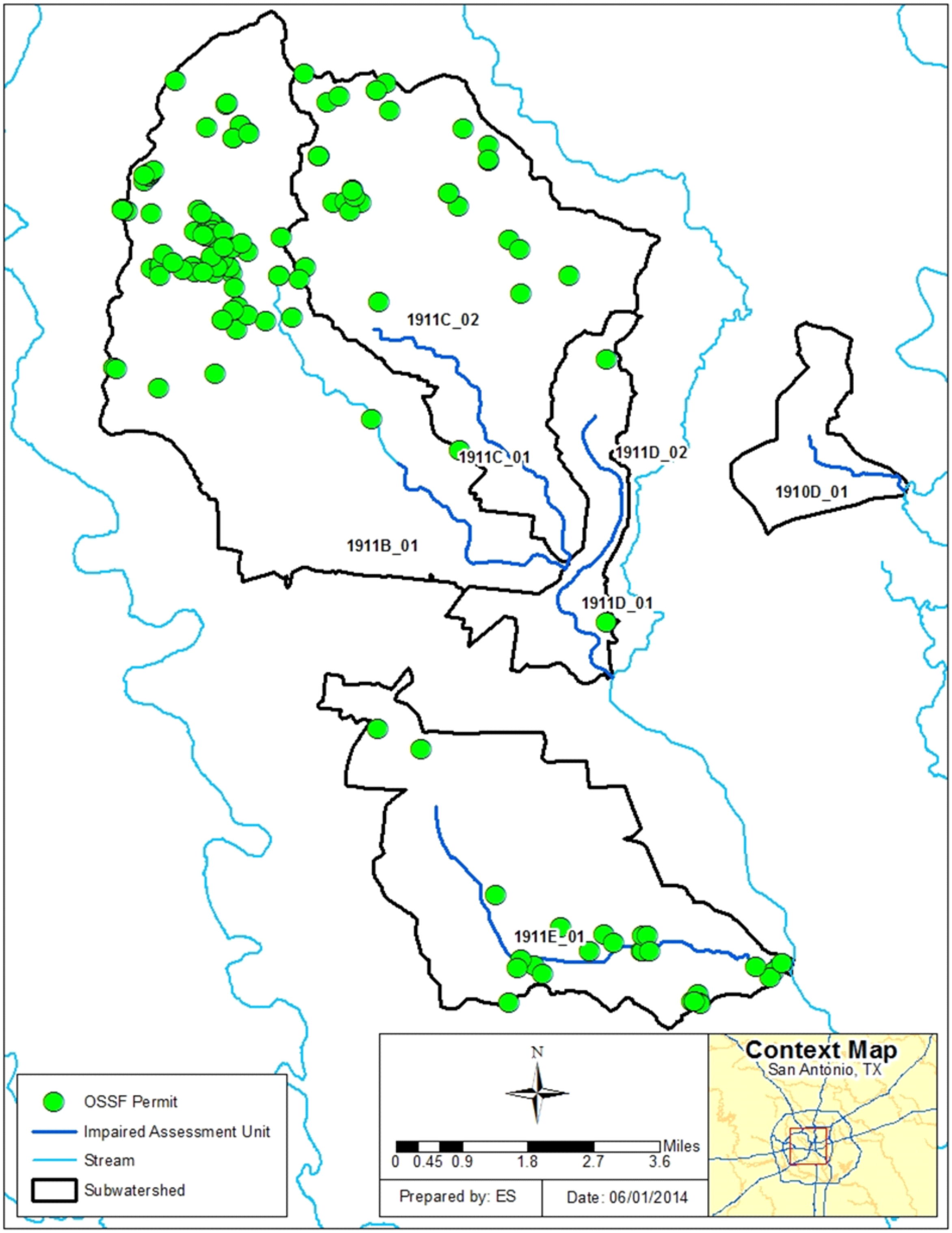

Figure 6. Unsewered Areas and Subdivisions with OSSFs

Linkage Analysis

Load duration curve (LDC) analysis (including flow duration curve (FDC) analysis) was used for analyzing indicator bacteria load and instream water quality for the segments in this project (EPA 2007). The Technical Support Document has details about this analysis.

Margin of Safety

The TMDL covered by this report incorporates an explicit margin of safety (MOS) by setting a target for indicator bacteria loads that is 5 percent lower than the single sample criterion. For contact recreation, using this MOS 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 the MOS is that the assimilative capacity or allowable pollutant loading of the water body is slightly reduced. The TMDL covered by this report incorporates an explicit MOS in each LDC by using 95 percent of the single sample criterion.

Pollutant Load Allocation

Pollutant load allocations were developed using FDC and LDC methods. To establish the subwatershed targets, TMDL calculations and associated allocations were developed for the most-downstream sampling location in each subwatershed. This establishes a distinct TMDL for each 303(d)-listed water body.

To calculate the bacteria load at the criterion for the segment, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*24,465,755 dL/ft3 * seconds/day*) and the *E. coli* criterion. This calculation produces the maximum bacteria load in the stream without exceeding the instantaneous standard over the range of flow conditions. *E. coli* loads are plotted versus flow exceedance percentiles as an LDC. The x-axis represents the flow exceedance percentile, while the y-axis represents bacteria load.

Two USGS gages outside the subwatersheds, Olmos Creek at Dresden Drive and San Antonio River at Loop 410 were chosen to conduct flow projections. The period of record for flow data used from these stations was 2002 through 2012. Pollutant loads were then calculated by multiplying the measured bacteria concentration by the flow rate and the unit conversion factor of *24,465,755 dL/ft3 * seconds/day*. The associated flow exceedance percentile is then matched with the measured flow. The observed bacteria loads are added to the LDC plots as points, and these points represent individual ambient water quality samples of bacteria. Points above the LDC show the bacteria instantaneous standard was exceeded at the time of sampling. Conversely, points under the LDC show the sample met the criterion.

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

The load allocation goal for each subwatershed's area is based on data analysis using the geometric mean criterion since it is expected that achieving the geometric mean over an extended period of time will likely ensure that the single sample criterion will also be achieved.

Figure 7 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 shows that the geometric mean of observed *E. coli* loading exceeds the instantaneous and geometric mean water quality targets under all three flow conditions.

Figure 8 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 shows that *E. coli* levels exceed the instantaneous and geometric mean water quality targets under all three flow conditions.

Figure 9 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). The LDC shows that *E. coli* levels exceed the instantaneous and geometric mean water quality targets under all three flow conditions.

Figure 10 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 shows that *E. coli* levels exceed the instantaneous and geometric mean water quality targets under all three flow conditions.

Figure 11 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). The LDC shows that *E. coli* levels exceed the instantaneous and geometric mean water quality targets under all three flow conditions.

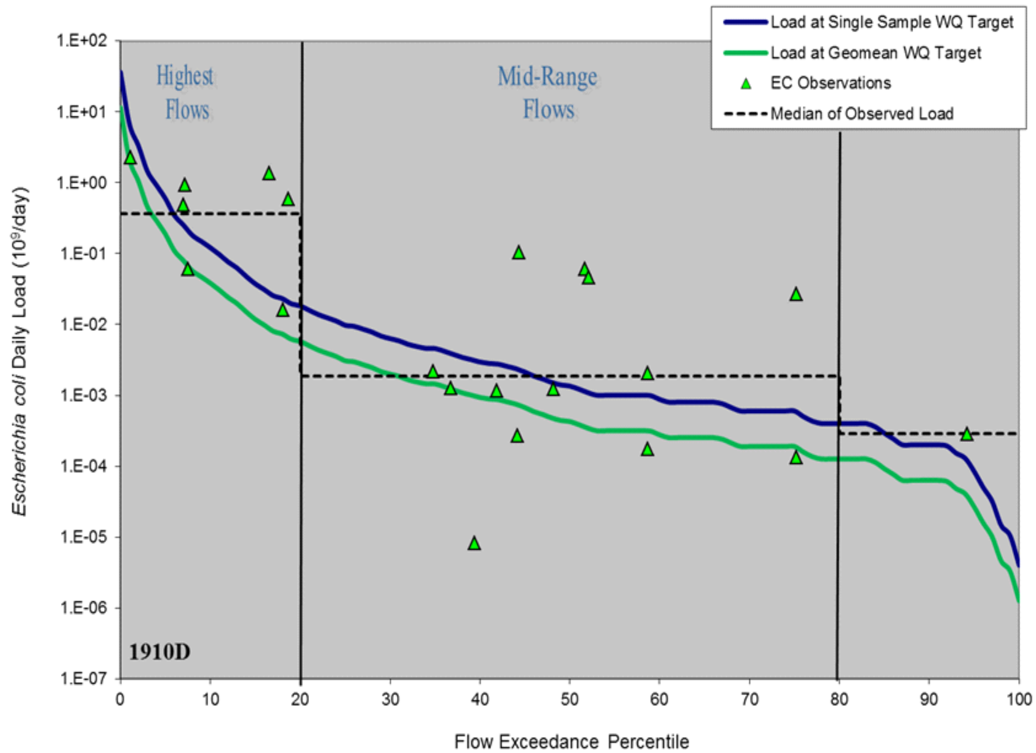

Figure 7. Load Duration Curve for Menger Creek (1910D_01)

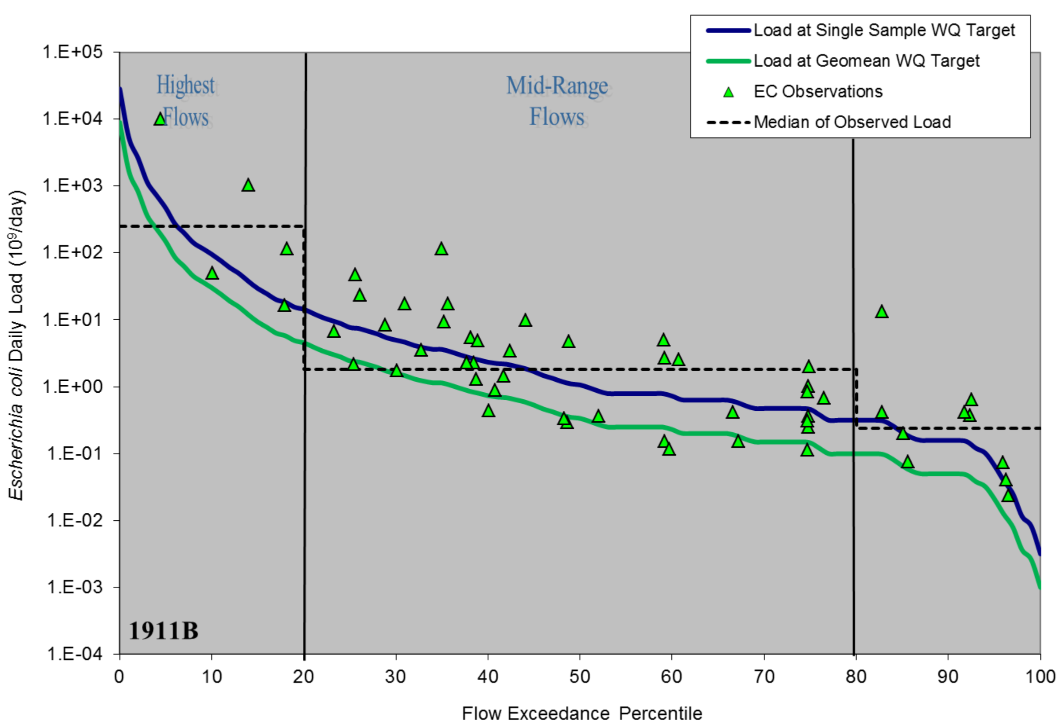

Figure 8. Load Duration Curve for Apache Creek (1911B_01)

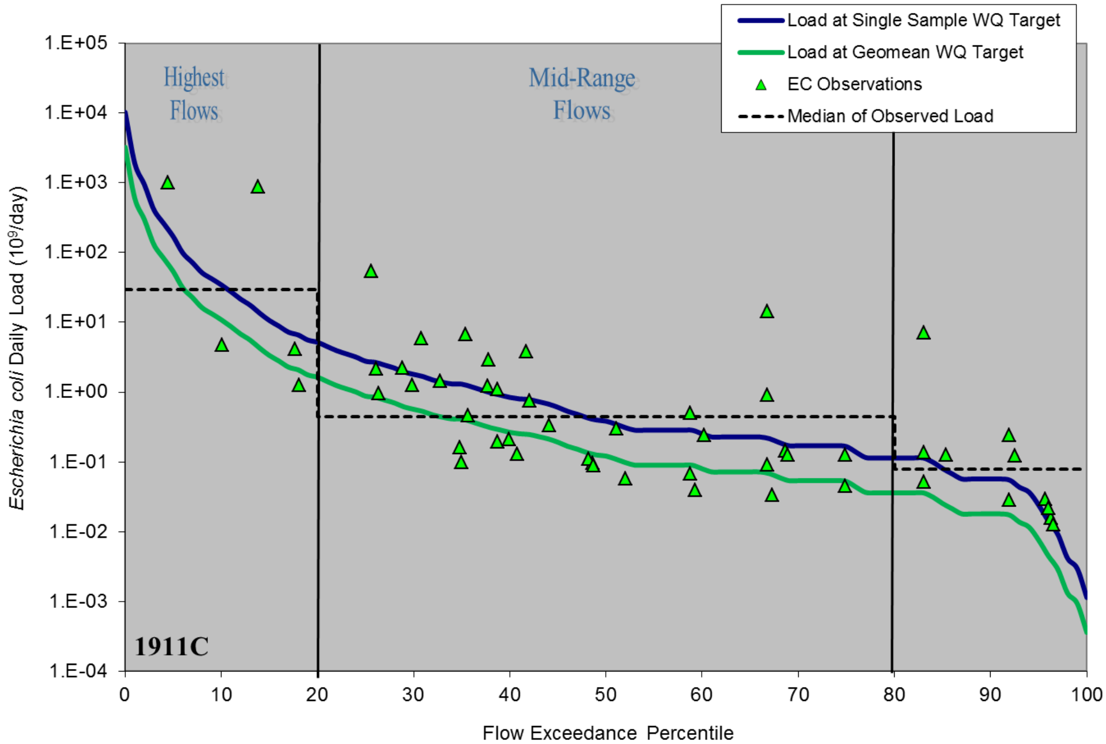

Figure 9. Load Duration Curve for Alazan Creek (1911C_01 & 1911C_02)

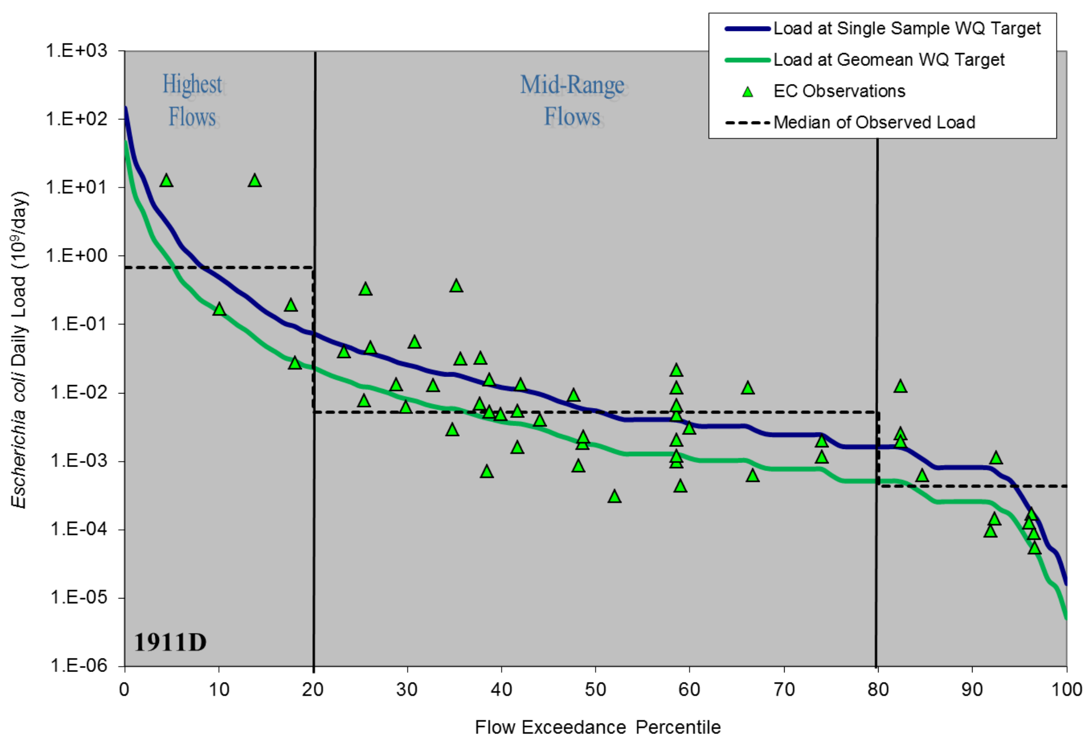

Figure 10. Load Duration Curve for San Pedro Creek (1911D_01 & 1911D_02)

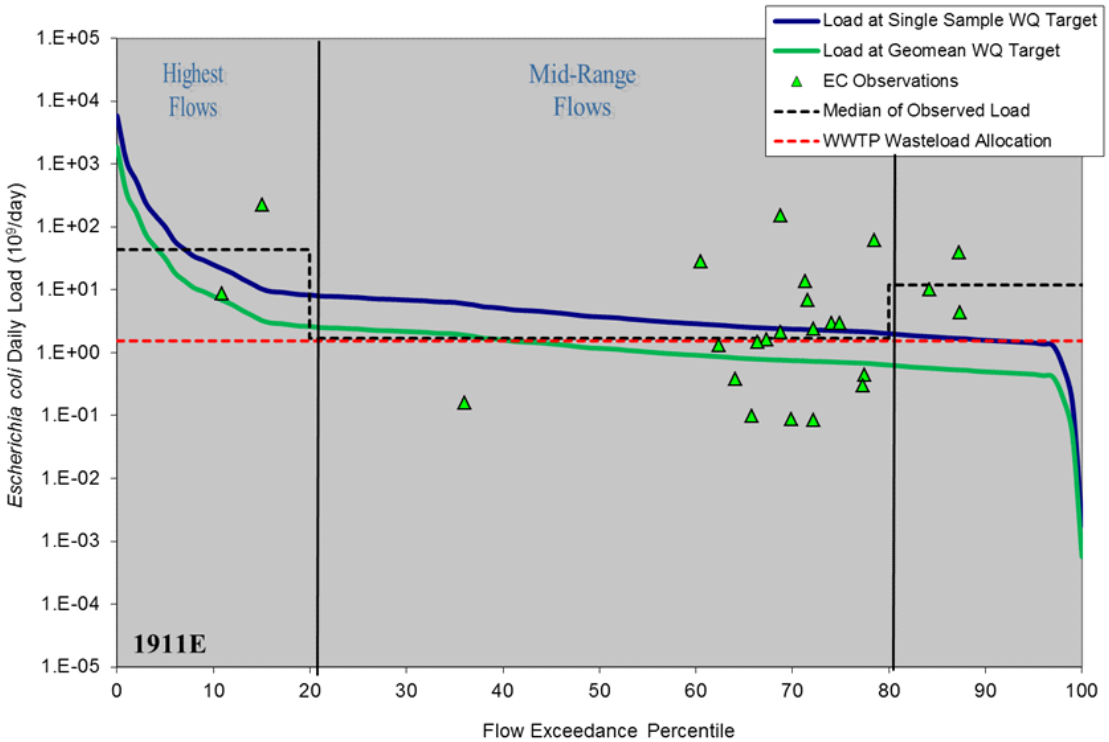

Figure 11. Load Duration Curve for Sixmile Creek (1911E_01)

Wasteload Allocation

TPDES-permitted facilities are allocated a daily waste load calculated as their permitted discharge flow rate multiplied by one half of the instream geometric mean water quality criterion. Only Sixmile Creek subwatershed has TPDES facilities which discharge into the segment. Table 10 summarizes the wasteload allocation (WLA) for the TPDES-permitted facilities within the subwatershed. The WLA for each facility (WLA_{WWTF}) is derived from the following equation:

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

Where:

criterion = 126 counts/dL for E. coli

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

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

There are no TPDES-permitted facilities which discharge into the watersheds of segments 1910D, 1911B, 1911C, and 1911D. When there are no TPDES WWTFs discharging into the contributing watershed of a SWQM station, then the WLA_{WWTF} is zero (EPA 2007).

Compliance with the WLA_{WWTF} will be achieved by adhering to the discharge limits and disinfection requirements of TPDES permits.

Table 10. Wasteload Allocations for TPDES-Permitted Facilities

TPDES Number	NPDES NUMBER	Facility Name	Final Permitted Flow (MGD)	WLA_{WWTF} (Billion MPN/day)
03955-000	TX0116114	Kelly Air Force Base	1	2.38
04117-000	TX0069931	San Antonio Equipment Repair and Maintenance Yard	n/a	n/a

Stormwater

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

The percentage of the subwatersheds that are under the jurisdiction of stormwater permits (i.e., defined as the area designated as urbanized area in the 2010 US Census) was used to estimate the amount of the overall runoff load to be allocated as the regulated stormwater contribution in the $WLA_{Stormwater}$ component of the TMDL. The watershed area is 100 percent covered by the MS4 permit. The load allocation (LA) component of the TMDL corresponds to direct nonpoint source runoff and is the difference between the total load from stormwater runoff and the portion allocated to $WLA_{Stormwater}$. These allocation values are found in Table 11.

Load Allocation

The LA is the sum of loads from unregulated sources. Since the entirety of the subwatershed is within the urbanized area, a negligible LA was incorporated into the TMDL equation, to account for potential wildlife contributions, and other minor sources that are difficult to measure.

Allowance for Future Growth

As described in the original TMDL document, future growth of existing or new point sources is not limited by this TMDL 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. Consequently, increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation standard. New or amended permits for wastewater discharge facilities will be evaluated case by case.

To account for the high probability that new additional flows from WWTFs may occur in this segment, a provision for future growth was included in the TMDL calculations by estimating regulated flows to year 2050 using population projections completed by the Texas Water Development Board (TWDB 2013). A summary of the methods used to predict wastewater flow capacity based on population growth is included in the Technical Support Document for reference.

TMDL Calculations

Table 11 summarizes the estimated maximum allowable load of *E. coli* for the AUs in this project.

The final TMDL allocation required to comply with the requirements of 40 Code of Federal Regulations (CFR) 130.7 is summarized in Table 12. The future capacity for WWTFs has a non-zero value for the Sixmile Creek watershed that contains a TPDES permitted facility. The other segments have their entire drainage area serviced by WWTFs that discharge outside the watershed boundary. TMDL values and allocations in Table 12 are derived from calculations using the existing water quality criteria for *E. coli*. Figures 12 through 18 show these allocations graphically. Designated uses and water quality criteria for these water bodies are subject to change through TSWQS revisions. Figures 12 through 18 were developed to show how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of hypothetical water quality criteria. The equations from these figures allow the calculation of new TMDLs and pollutant load allocations based on any potential new water quality criteria for *E. coli*.

Table 11. *E. coli* TMDL Summary Calculations for Subwatershed 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	0.0374	0.001	0.0020	0.0
1911B_01	Apache Creek	*E. coli*	31.78	0.0	30.19	0.001	1.59	0.0
1911C_01	Alazan Creek	*E. coli*	3.99	0.0	3.79	0.00035	0.2	0.0
1911C_02	Alazan Creek	*E. coli*	7.49	0.0	7.12	0.00065	0.37	0.0
1911D_01	San Pedro Creek	*E. coli*	0.061	0.0	0.058	0.00037	0.003	0.0
1911D_02	San Pedro Creek	*E. coli*	0.104	0.0	0.098	0.00063	0.005	0.0
1911E_01	Sixmile Creek	*E. coli*	9.66	2.38	5.44	0.001	0.48	1.36

[a] *Maximum allowable load for the highest flow range (0 to 30th percentile flows)*
[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*
[c] $WLA_{Stormwater}$ *= (TMDL – MOS - WLA_{WWTF})*(percent of drainage area covered by stormwater permits)*
[d] *LA= TMDL – MOS – WLA_{WWTF} – $WLA_{Stormwater}$ – Future Growth*
[e] *MOS= TMDL x 0.05*
[f] *Projected increase in WWTF permitted flows*126/2*conversion factor*

Table 12. Final TMDL Allocations

Assessment Unit	TMDL[a]	WLA_{WWTF}[b]	$WLA_{Stormwater}$	LA	MOS
	(Billion MPN/day)				
1910D_01	0.0404	0.0	0.0374	0.001	0.0020
1911B_01	31.78	0.0	30.19	0.001	1.59
1911C_01	3.99	0.0	3.79	0.001	0.2
1911C_02	7.49	0.0	7.12	0.001	0.37
1911D_01	0.061	0.0	0.058	0.001	0.003
1911D_02	0.103	0.0	0.098	0.001	0.005
1911E_01	9.67	3.74	5.44	0.001	0.48

[a] *TMDL=* $WLA_{WWTF} + WLA_{Stormwater} + LA + MOS$

[b] $WLA_{WWTF} = WLA_{WWTF}$ *+ Future Growth*

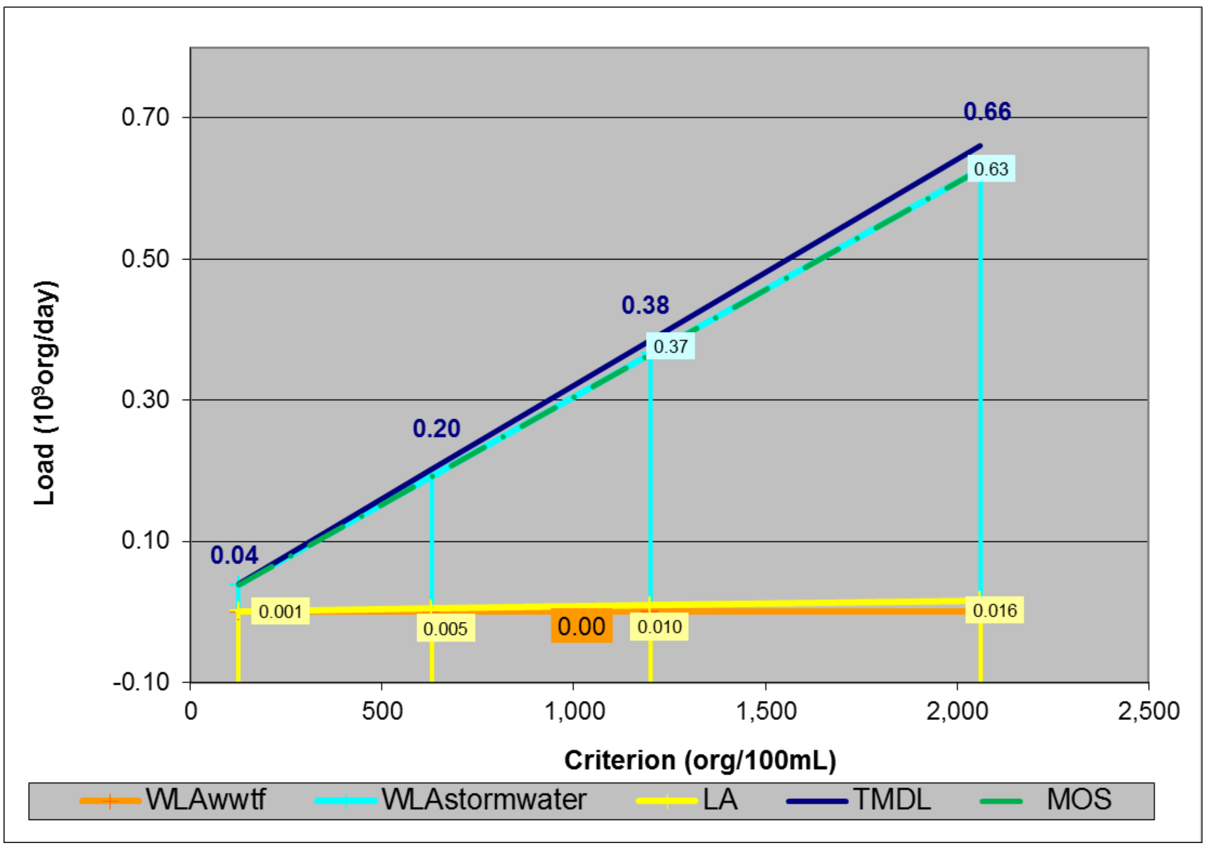

Figure 12. Allocation Loads for AU 1910D_01 as a Function of Water Quality Criteria

Equations for Calculating New TMDL and Allocations

$$TMDL = 0.000321 * Std - 0.0$$
$$MOS = 0.05 * TMDL$$
$$LA = 0.000008 * Std + 0.0$$
$$WLA_{Stormwater} = 0.000305 * Std - 0.0$$
$$WLA_{WWTF} = 0.0$$

Where:

Std= Revised Contact Recreation criteria
LA= load allocation (unregulated source contributions)
$WLA_{Stormwater}$= wasteload allocation (regulated stormwater);
WLA_{WWTF}= wasteload allocation (regulated WWTF)

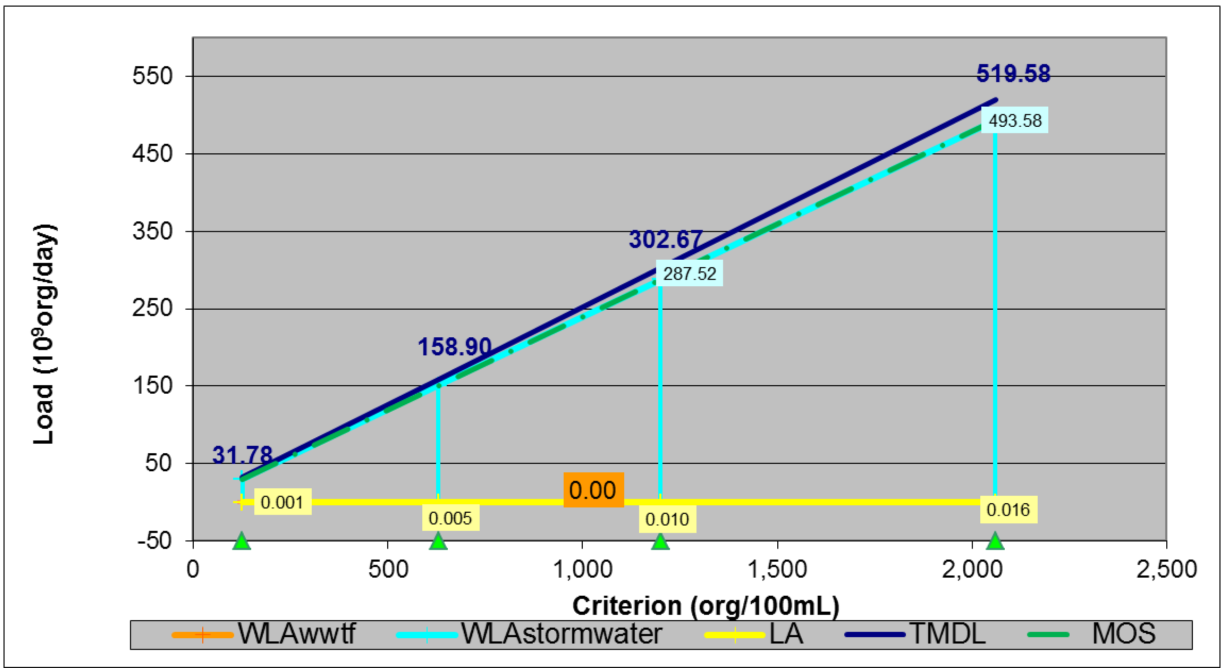

Figure 13. Allocation Loads for AU 1911B_01 as a Function of Water Quality Criteria

Equations for Calculating New TMDL and Allocations

$$TMDL = 0.252 * Std - 0.0$$
$$MOS = 0.05 * TMDL$$
$$LA = 0.000008 * Std + 0.0$$
$$WLA_{Stormwater} = 0.2396 * Std - 0.0$$
$$WLA_{WWTF} = 0.0$$

Where:

Std= Revised Contact Recreation criteria

LA= load allocation (unregulated source contributions)
$WLA_{Stormwater}$= wasteload allocation (regulated stormwater);
WLA_{WWTF}= wasteload allocation (regulated WWTF)

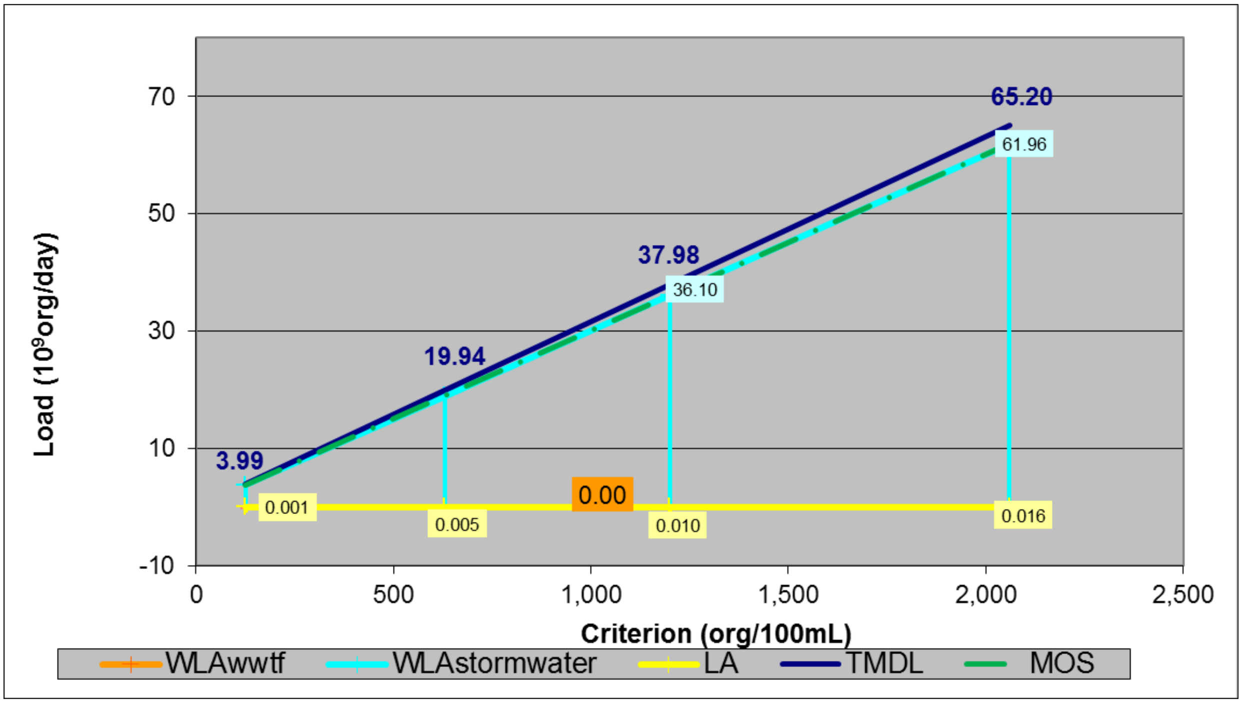

Figure 14. Allocation Loads for AU 1911C_01 as a Function of Water Quality Criteria

Equations for Calculating New TMDL and Allocations

$$TMDL = 0.031652 * Std - 0.00$$
$$MOS = 0.05 * TMDL$$
$$LA = 0.000008 * Std + 0.0$$
$$WLA_{Stormwater} = 0.03008 * Std - 0.0$$
$$WLA_{WWTF} = 0.0$$

Where:

Std= Revised Contact Recreation criteria
LA= load allocation (unregulated source contributions)
$WLA_{Stormwater}$= wasteload allocation (regulated stormwater);
WLA_{WWTF}= wasteload allocation (regulated WWTF)

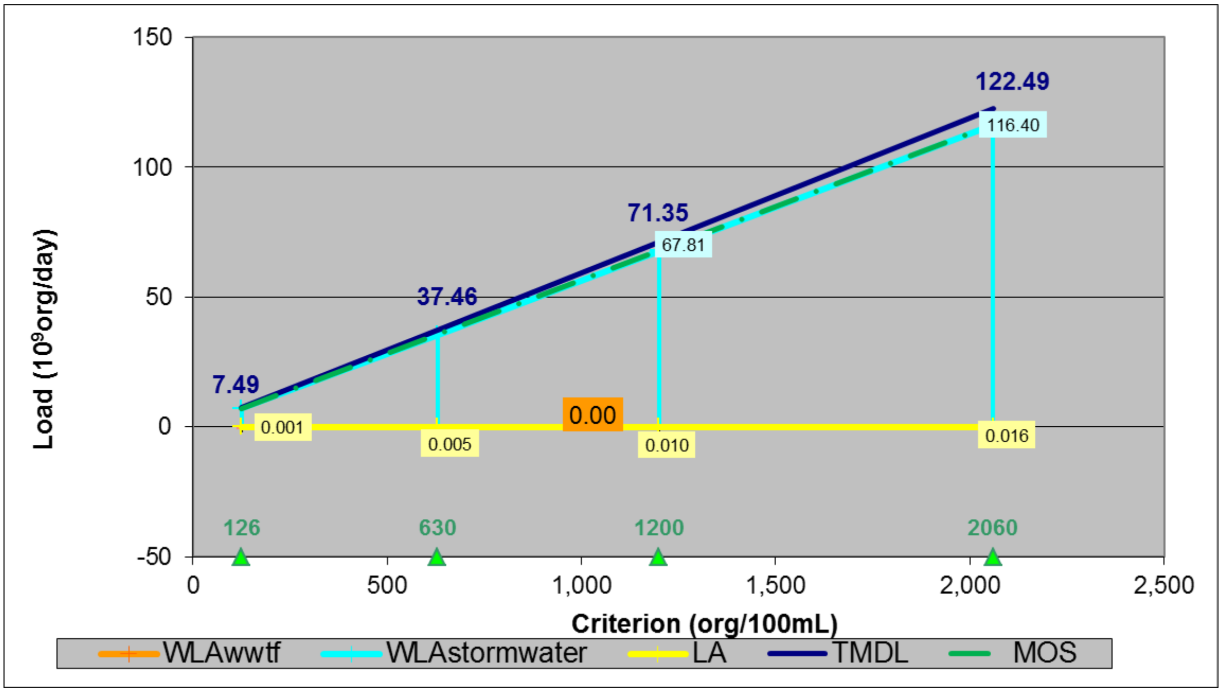

Figure 15. Allocation Loads for AU 1911C_02 as a Function of Water Quality Criteria

Equations for Calculating New TMDL and Allocations

$$\text{TMDL} = 0.05946 * \text{Std} - 0.0$$
$$\text{MOS} = 0.05 * \text{TMDL}$$
$$\text{LA} = 0.000008 * \text{Std} + 0.0$$
$$\text{WLA}_{\text{Stormwater}} = 0.0565 * \text{Std} - 0.00$$
$$\text{WLA}_{\text{WWTF}} = 0.0$$

Where:

Std= Revised Contact Recreation criteria

LA= load allocation (unregulated source contributions)

$\text{WLA}_{\text{Stormwater}}$= wasteload allocation (regulated stormwater);

WLA_{WWTF}= wasteload allocation (regulated WWTF)

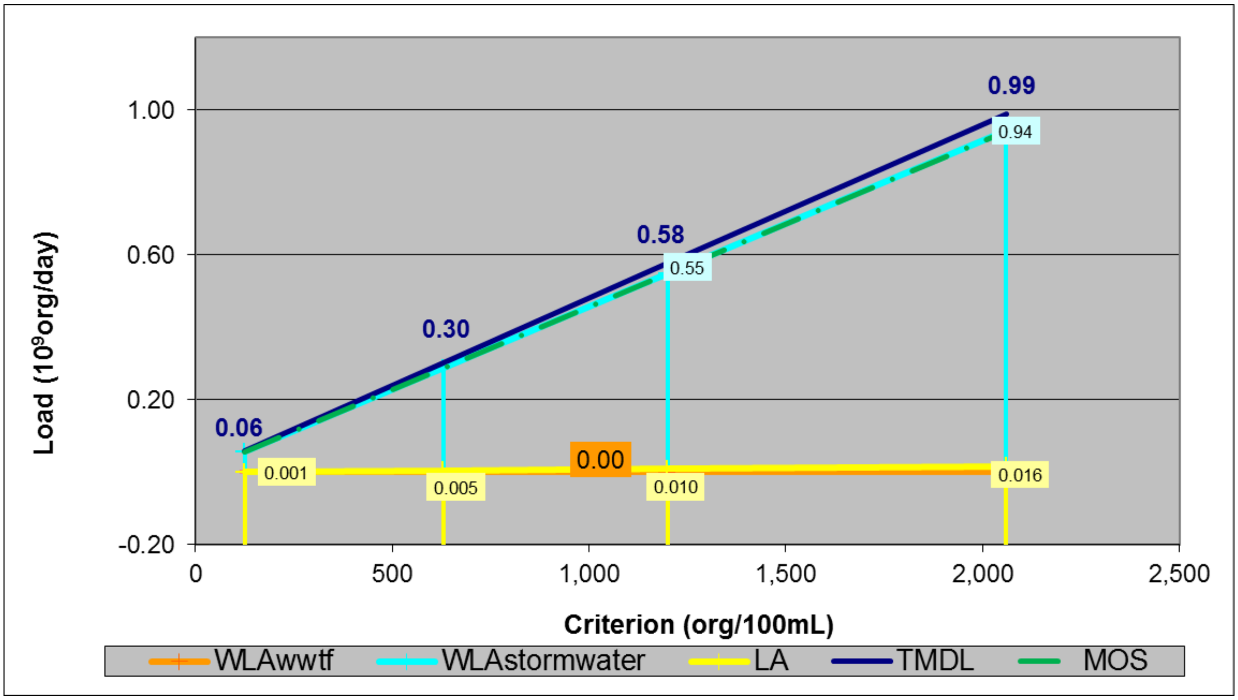

Figure 16. Allocation Loads for AU 1911D_01 as a Function of Water Quality Criteria

Equations for Calculating New TMDL and Allocations

$$\text{TMDL} = 0.000481 * \text{Std} - 0.0$$
$$\text{MOS} = 0.05 * \text{TMDL}$$
$$\text{LA} = 0.000008 * \text{Std} + 0.0$$
$$\text{WLA}_{\text{Stormwater}} = 0.000458 * \text{Std} - 0.0$$
$$\text{WLA}_{\text{WWTF}} = 0.0$$

Where:

Std= Revised Contact Recreation criteria
LA= load allocation (unregulated source contributions)
$\text{WLA}_{\text{Stormwater}}$= wasteload allocation (regulated stormwater);
WLA_{WWTF}= wasteload allocation (regulated WWTF)

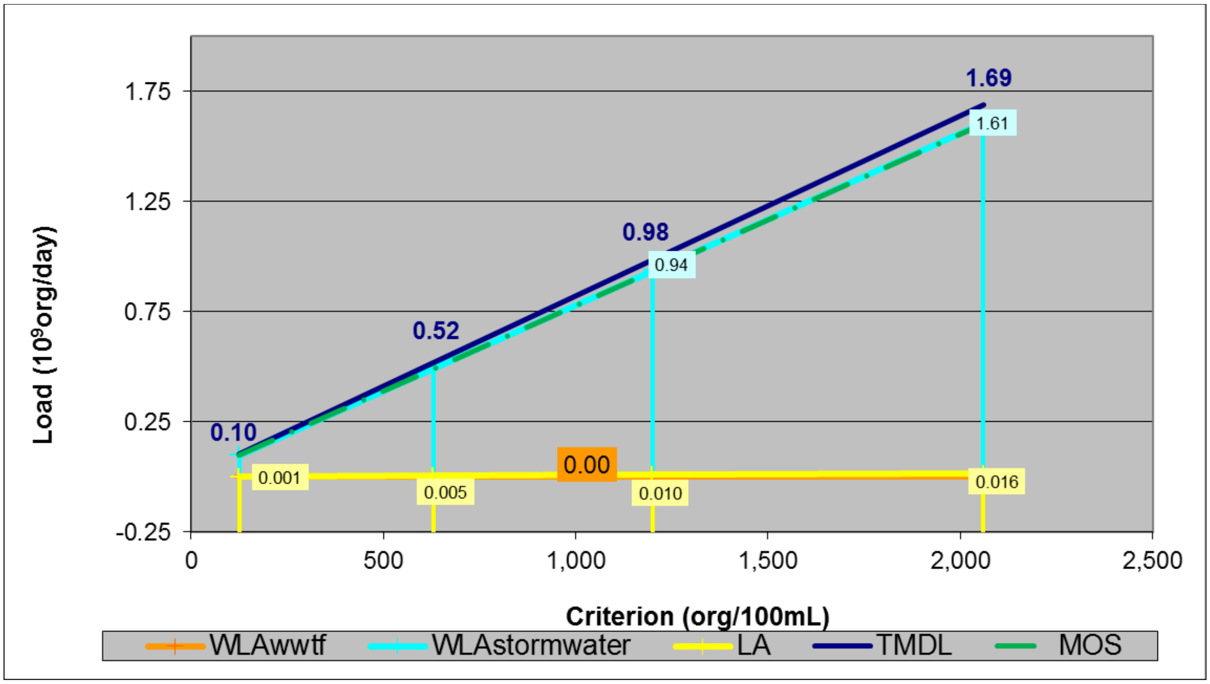

Figure 17. Allocation Loads for AU 1911D_02 as a Function of Water Quality Criteria

Equations for Calculating New TMDL and Allocations

$$\text{TMDL} = 0.000821 * \text{Std} - 0.0$$
$$\text{MOS} = 0.05 * \text{TMDL}$$
$$\text{LA} = 0.000008 * \text{Std} + 0.0$$
$$\text{WLA}_{\text{Stormwater}} = 0.000781 * \text{Std} - 0.0$$
$$\text{WLA}_{\text{WWTF}} = 0.0$$

Where:

Std= Revised Contact Recreation criteria

LA= load allocation (unregulated source contributions)

$\text{WLA}_{\text{Stormwater}}$= wasteload allocation (regulated stormwater);

WLA_{WWTF}= wasteload allocation (regulated WWTF)

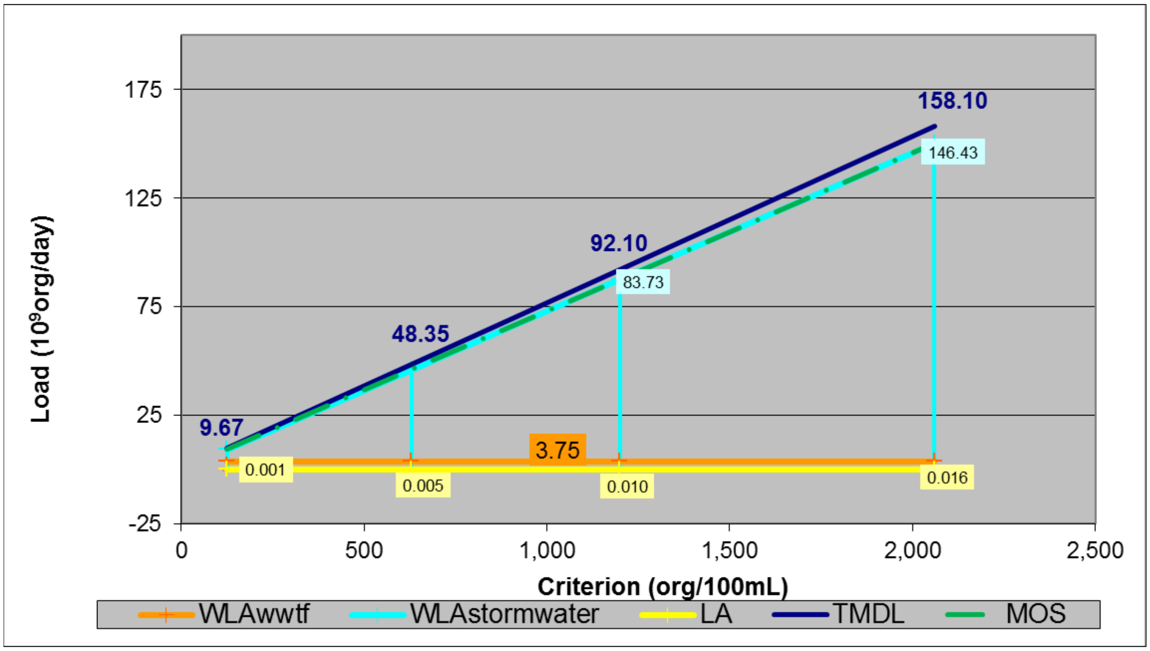

Figure 18. Allocation Loads for AU 1911E_01 as a Function of Water Quality Criteria

Equations for Calculating New TMDL and Allocations

$$\text{MDL} = 0.0767 * \text{Std} - 0.00029\text{MOS} = 0.05 * \text{TMDL}$$
$$\text{LA} = 0.000008 * \text{Std} + 0.0$$
$$\text{WLA}_{\text{Stormwater}} = 0.0729 * \text{Std} - 3.7488$$
$$\text{WLA}_{\text{WWTF}} = 3.75$$

Where:

Std= Revised Contact Recreation criteria
LA= load allocation (unregulated source contributions)
$\text{WLA}_{\text{Stormwater}}$= wasteload allocation (regulated stormwater);
WLA_{WWTF}= wasteload allocation (regulated WWTF)

Seasonal Variation

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 four years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

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 percent confidence interval between the warmer and cooler months, as shown in Table 13.

Table 13. 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.
<www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/climate-normals/1981-2010-normals-data>

Public Participation

The TCEQ maintains an inclusive public participation process. From the start of the investigation, the project team sought to ensure that stakeholders were informed and involved. Communication and comments from the stakeholders in the watershed strengthen TMDL projects and their implementation.

Regular stakeholder meetings have been held and TCEQ solicited stakeholder comments at each project milestone, while assisting stakeholders with communications. Texas AgriLife Research and the San Antonio River Authority are key partners in this project. As contractors to TCEQ, the University of Houston provides technical support and presentations at stakeholder meetings. Five coordination committee meetings were held between August 2013 and June 2014. Technical Subcommittee meetings were held on a monthly to bi-monthly bases between October 2013 and August 2014.

A stakeholder committee called the San Antonio Bacteria TMDL Advisory Group helped the TCEQ in developing the original TMDLs for the Upper San Antonio River. The responsibility of each stakeholder on the committee is to communicate project information and provide their personal/organization's perspective on all issues, knowledge of the watershed, comments and suggestions during the project, and solicit input from others. The group includes volunteer members who represent government, regulated facilities, agriculture, business, environmental, and community interests. This Advisory Group was consulted on the additions to these TMDLs through a public meeting June 11, 2015, where the results of the study were presented by the University of Houston project manager. The information was also presented to the Bexar Regional Watershed Management Group's Water Quality Focus Group June 26, 2015, and questions and comments were addressed during the meeting and in a follow up e-mail. A 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 Web page for the Upper San Antonio River.

The TCEQ held a public comment meeting for the original TMDL document April 20, 2007, with a comment period from March 23, 2007 to April 23, 2007. Thirteen comments came in from the public, a majority of which came from SAWS. TCEQ project managers addressed all comments and questions, and made a few minor changes based on suggestions from SAWS. The EPA also submitted 13 questions and comments about the document. These were addressed, with minor errors being corrected.

Implementation and Reasonable Assurance

The segments covered by this addendum are within the existing Upper San Antonio River Bacteria TMDL project watershed. The San Antonio Bacteria TMDL Advisory Group and other stakeholders, with support from the TCEQ and Texas A&M AgriLife Research, have developed a plan to implement TMDLs with measures that reduce pollution. The implementation plan identifies the management measures needed to reduce bacteria, as well as a timeline for implementation.

Please refer to the original TMDL document for additional information on implementation and reasonable assurance.

References

American Veterinary Medical Association. 2002. U.S. Pet Ownership and Demographics Sourcebook (2002 Edition). Schaumberg, IL.

ASAE. 1998. American Society of Agricultural Engineers Standards, 45th edition: Standards, Engineering Practices Data. St. Joseph, MI.

Canter, L.W. and R.C. Knox. 1985. Septic tank system effects on ground water quality. Lewis Publishers, Boca Raton, FL.

Cogger, C.G. and B.L. Carlile. 1984. Field performance of conventional and alternative septic systems in wet soils. *J. Environ. Qual.* 13 (1).

Drapcho, C.M. and A.K.B. Hubbs. 2002. Fecal Coliform Concentration in Runoff from Fields with Applied Dairy Manure. < http://water.usgs.gov/wrri/01grants/prog-compl-reports/2001LA2621B.pdf >.

Hall, S. 2002. Washington State Department of Health, Wastewater Management Program Rule Development Committee, Issue Research Report - Failing Systems, June 2002.

Metcalf and Eddy. 1991. Wastewater Engineering: Treatment, Disposal, Reuse: 2nd Edition.

NOAA. 2001. San Antonio Climate Summary. (PDF). National Weather Service, San Antonio International Airport. Retrieved May 28, 2014.

NOAA. 2011. National Oceanic and Atmospheric Administration, Coastal Services Center. National Land Cover Database 2011. Accessed October 2014 <www.h-gac.com/rds/gis_data/clearinghouse/>.

PRISM Group 2006. Oregon State University, <www.prismclimate.org>, created 12 June 2006.

Reed, Stowe &Yanke, LLC. 2001. Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-Site Sewage Facility Systems in Texas. September 2001.

San Antonio River Authority. 2008. San Antonio River Basin Summary Report. Texas Clean Rivers Program.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at <http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>. Accessed October 2014.

TCEQ. 2010. Texas Surface Water Quality Standards. §307.1-307.10. Adopted by the Commission: June 30, 2010; Effective July 22, 2010 as the state rule. Austin, Texas.

TCEQ. 2012. Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) & 303(d) <www.tceq.texas.gov/waterquality/assessment/waterquality/assessment/12twqi/twqi12>.

TCEQ. 2010. Draft 2010 Guidance for Assessing and Reporting Surface Water Quality in Texas.

TWDB. 2013. Region I - Draft Population and Municipal Demand Projections for 2016 Regional and 2017 State Water Plan <www.twdb.state.tx.us/waterplanning/data/projections/2017/demandproj.asp>.

University of Florida. 1987. Institute of Food and Agricultural Sciences, University Of Florida, Florida Cooperative Extension Service, No. 31, December, 1987.

U.S. Census Bureau. 1995. Supplement to the American Housing Survey for the United States. <www.census.gov/prod/2001pubs/h151-95-1.pdf>.

U.S. Census Bureau. 2010. <www.census.gov>.

USEPA. 2000. Bacterial Indicator Tool User's Guide. Washington, D.C., US EPA: EPA-823-B-01-003.

USEPA. 2001. Protocol for Developing Pathogen TMDLs. First Edition. Office of Water, USEPA 841-R-00-002.

USEPA. 2007. U.S. Environmental Protection Agency, Office of Water. An approach for using Load Duration Curves in the Development of TMDLs. EPA841-B-07-006. August 2007.

USGS 2014. U.S. Geological Survey, National Land Cover Database 2006. <http://www.mrlc.gov/>.