Medina River Watershed Protection Plan

Chapter 4

Potential Sources

This chapter provides the foundation for identifying appropriate management measures to reach pollutant reduction targets and restore water quality in the watershed. The sources of bacteria and nutrients described here will be analyzed in the following chapters to determine their potential pollutant load, identify priority subbasins, and inform development of appropriate management measures. The sources identified here do not include all potential causes of pollutants but focus on those for which regulations are in place, and for which economically feasible and effective management measures are known.

Pollutants originate from a variety of sources and can have differing effects on water quality. Pollutants enter the environment from either a *point source*, such as a pipe or channel, or from a *nonpoint source* with widespread origins. Both types of sources often reach a water body, such as a stream, river, lake, aquifer, or estuary, and contribute both pollutants and water to the natural system.

Point sources are regulated and require a permit to discharge to land and waterways. Point sources in Texas are regulated and managed through the Texas Pollutant Discharge Elimination Systems (TPDES), administered by the TCEQ. Permits issued under the program identify and limit the amount of water and specific pollutants each facility may discharge directly to the landscape or to a particular waterbody. Examples of point sources include municipal or industrial wastewater treatment facilities (WWTF), sanitary sewer overflows (SSO), construction site runoff, and municipal separate storm sewer systems (MS4) of urbanized areas.

Pollutants that enter the environment from a source that does not have a single point of origin are referred to as nonpoint source (NPS) pollution. These pollutants are eventually carried across the landscape and into water bodies by rainfall runoff. Nonpoint sources are not regulated and are controlled primarily through responsible land stewardship and voluntary land management practices. Examples of nonpoint sources include on-site sewage facilities (OSSF), pet waste, livestock, wildlife, and feral hogs.

The sections below describe the potential sources of bacteria and nutrients that may be contributing to water quality concerns or impairments in the Medina River watershed. These sources were identified and estimated using publicly available databases, as well as local knowledge and input by stakeholders and project partners. Details of the methods used to quantify identified sources are located in Appendix A. Identified sources of bacteria and nutrients, along with their potential causes and impacts to water quality are summarized in Table 4-1.

Table 4- 1. Summary of potential pollutant sources in the Medina River watershed

Source	Potential Causes	Pollutant Impact
WWTF and SSO	System overflow during storm events Systemic failure due to age, lack of routine maintenance, etc.	Bacteria and nutrients from un-treated wastewater may enter water bodies
OSSF (Septic Systems)	Poor functioning due to site design, age, lack of maintenance (e.g., routine pumping) Incorrect treatment of waste (e.g., not chlorinating system properly, pouring household chemicals down drain)	Bacteria and nutrients may enter water bodies through rainfall runoff or subsurface migration, especially from households close to rivers and creeks
Urban Stormwater Runoff	Rainfall washes pollutants from impervious surfaces (e.g., parking lots, roadways) Dumping chemicals in storm drains. Excessive application of fertilizers and pesticides to lawns and public areas	Bacteria, litter, oils, and nutrients, washed into water bodies during rain events
Livestock, Wildlife, Feral Hogs	Direct deposit of feces into water or riparian area. Soil disturbance from foot traffic, wallowing and rooting in channels and riparian areas	Introduction of bacteria and nutrients from waste to water bodies Soil erosion and sediment input to stream
Pets	Improper disposal of waste in public areas and at home Lack of education regarding proper disposal of pet waste	Introduction of bacteria and nutrients from waste to water bodies
Illegal Dumping	Litter and animal carcasses dumped in or near water bodies Trashed areas tend to stay trashed	Bacteria, nutrients, chemicals, and other pollutants from trash and decaying carcasses

Wastewater Treatment Facilities (WWTF)

Wastewater treatment facilities treat municipal wastewater before applying the effluent to land or discharging directly to a water body. These facilities and their discharges are regulated by TCEQ under the Texas Pollutant Discharge Elimination System (TPDES). TPDES permits contain limits on the concentration, timing, and loading of pollutants discharged, including bacteria and nutrients. Facilities are required to monitor and report on the quality of their effluent, including those that exceed or violate their permit conditions.

Wastewater treatment is a complex process, and a variety of factors may cause occasional exceedances, such as excessive rainfall runoff entering the collection system, grease and other collection system blockages, mechanical failures, deferred maintenance, or illicit substances entering the collection system. In some cases, facilities may require infrastructure or process improvements to meet their regulatory requirements or to accommodate growth and inflows to their collection system.

Most wastewater treatment facilities in the watershed meet their permit limits with few, periodic exceptions. However, because human waste is associated with a variety of pathogens, identifying permit exceedances for indicator bacteria, such as *E. coli*, is important in understanding overall impacts to waterbodies. While wastewater treatment can be highly effective at removing bacteria and pathogens, it is less effective in nutrient removal and advanced treatment may be needed for discharges to sensitive waterbodies or drinking water supplies.

The TCEQ online database of wastewater permits was searched to determine the number of wastewater treatment facilities in the watershed and their permit limits (Table 4- 2). The EPA Environmental Compliance History Online database was used to document reported exceedances of permit limits during the October 2020 to March 2024 timeframe, for parameters of concern to the Medina River watershed.

There are currently seven WWTFs discharging effluent to the Medina River watershed, including one major (> 1 MGD permitted discharge) and six minor facilities (Figure 4-1; Table 4- 2). The Medio Creek Recycling Center, owned by the San Antonio River Authority, is permitted to release up to 16 million gallons per day (MGD) and reports discharging just over half that amount, on average. Daily average flow is calculated as the average of the daily flows within one calendar month. Daily average concentrations of pollutants are calculated as the average of all samples within a calendar month. Over the most recent five years, the Medio Creek facility reported two instances of ammonia nitrogen exceeding the daily maximum concentration limit of 7.0 mg/L at the discharge monitoring location. The La Coste facility discharges approximately 73% of its permitted flow and reported two exceedances of the daily average concentration limit for ammonia nitrogen during the most recent five years. The Portranco Ranch Subdivision facility reports a daily average discharge of approximately 73% of its permitted amount and has experienced exceedances for *E. coli*, biochemical oxygen demand (BOD), and total suspended solids (TSS) for both daily average and daily maximum limits. No exceedances were reported for the remaining facilities.

Two facilities, Forest Glen Utility's WRRF2 and Portranco Ranch Subdivision, are phased permits, meaning that permit values for flow and some pollutant concentrations would change during the five-year permit period as facilities are constructed or upgraded. The Forest Glen WRRF2 and Portranco Ranch Subdivision permits will increase permitted average daily flow to 0.23 MGD and 0.24 MGD, respectively, over the course of the current permit. Forest Glen WRRF2 daily average concentration limit for ammonia nitrogen decreases from 2.0 mg/L to 1.0 mg/L with no change in permitted total phosphorus concentration during the current permit cycle. The Portranco Ranch Subdivision permit does not include limits for nitrogen or phosphorus. At the time of this report, the Forest Glen WRRF3 facility is under construction. A 2022 Public Utilities Commission filing indicates construction is estimated to be completed January 2026 and a phased permit for a 0.06MGD/0.15MGD discharge is anticipated. As of the date of this report, a TPDES permit has not been issued for the facility.

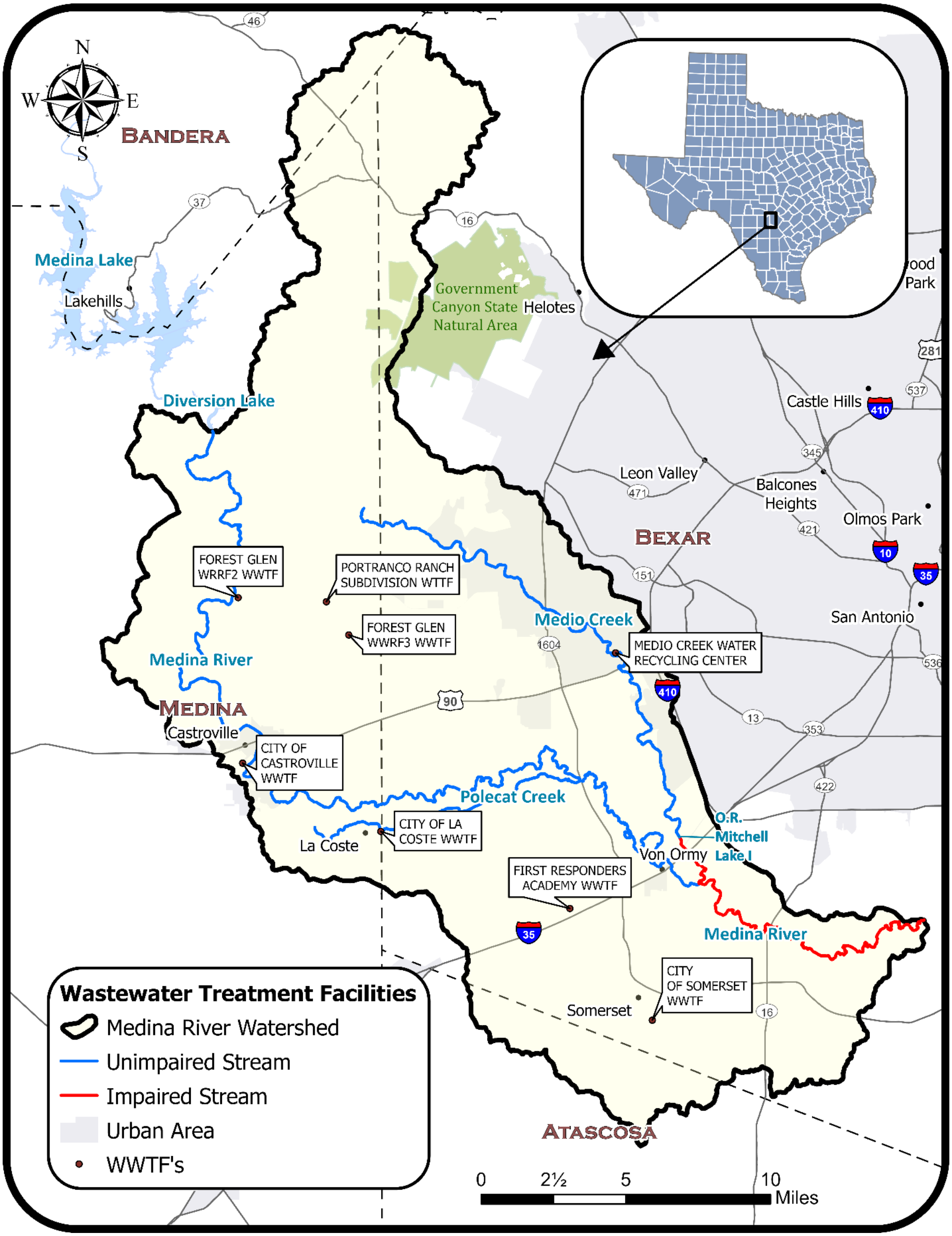

Figure 4-1. TCEQ permitted wastewater treatment facilities.

Table 4- 2. Daily average flow and pollutant concentrations from wastewater treatment facilities between October 2020 and March 2024.

Facility Name	Stream Segment	Flow Daily Average (MGD)		*E. coli* Daily Average (cfu/100mL)		Nitrogen-NH3 Daily Average (mg/L)		Total-P Daily Average (mg/L)		Instances of Discharge Limit Exceedances
		Permit Limit	Reported	Permit Limit	Reported	Permit Limit	Reported	Permit Limit	Reported	
City of Castroville	1903	0.70	*	126	*	2.0	*	1.0	*	
City of La Coste	1903	0.20	0.146	126	1.1	3.0	0.805	n/a	n/a	N-NH3 (2 daily avg)
City of Somerset	1903	0.32	0.094	126	1.0	n/a	n/a	n/a	n/a	
First Responders Academy	1903	0.025	0.003	126	1.0	3.0	0.12	n/a	n/a	
Forest Glen WRRF2[1]	1903	0.06 (0.23)	*	126	*	2.0 (1.0)	*	0.15	*	
Medio Creek WRC	1912	16.0	9.189	126	2.6	2.0	0.389	n/a	n/a	N-NH3 (2 daily avg)
Portranco Ranch Subdivision[1]	1903	0.108 (0.24)	0.079	126	32.8	n/a	n/a	n/a	n/a	*E. coli* (1 daily avg, 3 daily max) BOD (4 daily avg, 4 daily max) Total Suspended Solids (7 daily avg)

Daily Average = the arithmetic average of all determinations within a period of one calendar month.
cfu = colony forming units; mL = milliliter; E. coli = Escherichia coli; TSS – total suspended solids
[1]Facility under construction; no discharge.
*Not Reported
n/a = not applicable

Sanitary Sewer Overflows (SSO)

Sanitary sewer overflows (SSOs) can occur when sewer lines lose functionality due to age, lack of maintenance, inappropriate connections, or overload during storm events. Inflow and infiltration (I&I) of stormwater are common issues to all sanitary sewer systems. Inflow most often coincides with large runoff events and can occur through uncapped cleanouts and gutter connections to the sewer system or through cross connections with storm sewers and faulty manhole covers. Infiltration happens slowly because it generally occurs through cracks and breaks in lateral lines on private property or sewer mains, through bad connections between laterals and sewer mains, and in deteriorated manholes.

This contaminated stormwater can reach water bodies during an SSO event, resulting in substantial periodic bacteria and nutrient loading. Wastewater permit holders are required by TCEQ to report known overflows that occur in their system. According to the TCEQ regional office database, 20 SSO events were reported in the Medina River watershed between October 2018, and October 2023 (Table 4- 3). Reported causes vary, though most were the result of lift station or manhole overflows during heavy rain, power failures, or sewer lines clogged by materials not recommended for flushing or pouring down drains. Pollutant loads associated with individual events vary widely depending on the amount and makeup of the discharge.

Table 4- 3. SSO events documented by TCEQ, October 2018 and October 2023

Facility Name	Number of Spills	Year(s)	Total Spilled (gallons)	Causes
City of Castroville	1	2023	7,500	Equipment/Electrical Failure
City of Somerset	1	2021	50	Equipment Failure
Medio Creek WRC	14	2019-2023	240,079	Infiltration & Inflow (1) Grease Blockage (7) Line Blockage (non-grease) (3) Line Break (2) Human Error (1)
Portranco Ranch Subdivision	1	2023	7,500	Equipment/Electrical Failure

On-Site Sewage Facilities (OSSF)

On-site sewage facilities, also known as septic systems, are the typical wastewater treatment system for households, businesses, and other establishments outside the service area or collection system of a WWTF. In Texas, TCEQ or local government entities with OSSF regulations approved by TCEQ are authorized to administer state OSSF rules (30 TAC 285), including permitting, planning, construction, operation, and maintenance. Additional requirements also apply to systems installed in the Edwards Aquifer Recharge zone, such as minimum lot size and distance to recharge features. In the Medina River watershed, counties are the primary authorized agents, although some cities have ordinances governing OSSFs within their jurisdictional limits.

Typical OSSF designs include anaerobic systems, composed of septic tank(s) and an associated drainage field, or aerobic systems with aerated holding tanks and typically a sprinkler system to distribute effluent above ground. Multiple factors affect OSSF performance, such as deterioration of pipes and materials, improper design for site conditions, and lack of maintenance or sludge removal. When properly designed, installed, and maintained, these systems can function properly for many years.

When not functioning properly, OSSFs may contribute *E. coli,* nutrients, and waste solids to the landscape and water bodies. Improperly functioning systems can result in untreated or partially treated wastewater percolating to the surface and migrating to lower elevations. Inadequately treated wastewater can transmit waterborne diseases such as cholera, cryptosporidiosis and giardiasis, and can lead to contamination of agricultural crops and nearby water bodies. Proximity to streams is important for determining an OSSF's potential impact on water quality. The closer a potentially failing system is to a stream, the more likely it is to impact instream water quality.

Soil characteristics, such as topography, saturated hydraulic conductivity, depth to the water table, ponding, and flooding tendency, are important factors in a system's ability to completely treat waste. Soil suitability ratings developed by the USDA Natural Resources Conservation Service (NRCS 2023) inform the design of individual OSSFs and are used to evaluate its ability to accommodate the projected flow from the system. Soil suitability ratings are categorized as Not Limited, Somewhat Limited, and Very Limited. Those located in Somewhat or Very Limited soils pose an increased risk of failure, especially if not properly designed, installed, or maintained.

Locations of OSSFs in the Bexar County portion of the watershed were provided by the county. To estimate locations of OSSFs in the Medina, Bandera, and Atascosa County portion of the watershed, a method associating 911 addresses with household structures by reviewing satellite imagery and cross-referencing estimated location with census household data was used (Gregory et al. 2013). This process utilized the 2021 map of 911 addresses, 2020 U.S. Census data, and 2022 satellite imagery. Addresses located outside of the city limit boundaries and urban land uses are presumed to use OSSFs as the primary method to treat wastewater. Based on these methods, an estimated 13,733 OSSFs are located within the Medina River watershed (Figure 4-2).

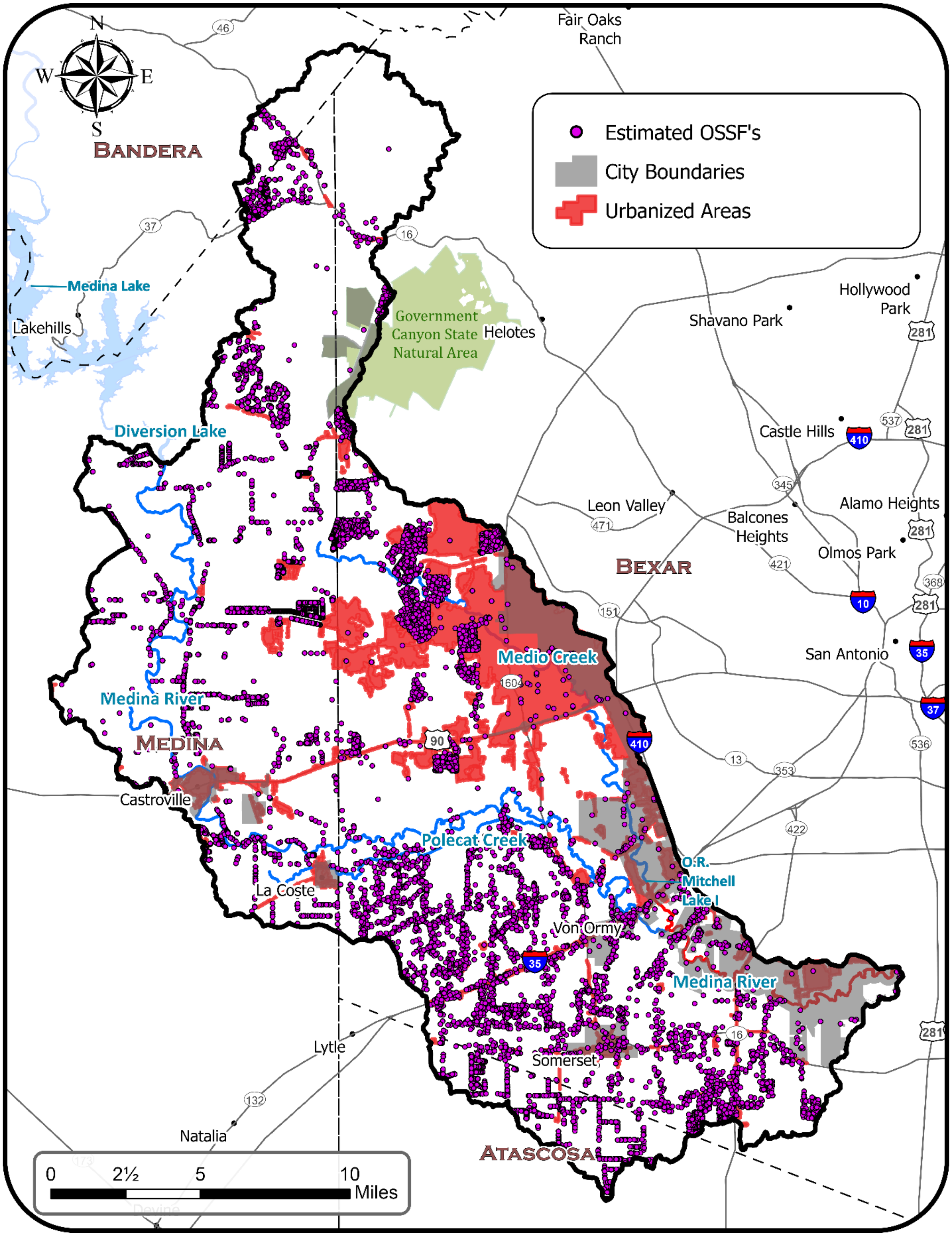

Figure 4-2 Estimated locations of OSSFs.

Essentially the entire watershed contains soils considered limited for OSSF functionality (Figure 4-3), according to the NRCS suitability ratings. It's estimated that Somewhat Limited soils comprise about 13% of the watershed and contain about 1,444, or 10.5% of OSSFs in the watershed. These soils occur primarily at lower elevations and along stream valley corridors. Very Limited soils are estimated to cover about 87% of the watershed and contain approximately 12,289, or 89.5% of the OSSFs in the watershed. Soils classified as Not Rated comprise only 0.5% of the watershed and do not contain any OSSFs. Additionally, it's estimated that approximately 588 OSSFs are located within 100 yards of a stream.

In addition to streams and other surface water, groundwater can also be impacted by underperforming or failing OSSFs. The Edwards Aquifer is a significant and sensitive source of drinking water for the region (Figure 4-4), as well as habitat for several endemic and endangered species, and the source of many local springs and streams. The Contributing and Recharge zones, located in the northern portion of the watershed, receive water into the formation from streams passing through the area and rain falling directly on the Recharge zone. Water flows deeper through the formation to the Artesian Zone, roughly located in the mid-section of the watershed, where it's accessible by domestic and municipal wells. Through its Abandoned Well Program, the Edwards Aquifer Authority has identified approximately 300 abandoned wells within its jurisdiction, with 50 in in the Medina River WPP watershed. These open wells are capable of delivering surface or near-surface pollutants directly to the aquifer. As the program continues, additional abandoned wells could be identified. Analysis for this report indicates that approximately 69% of the OSSFs in the Medina River watershed are located over the Edwards Aquifer.

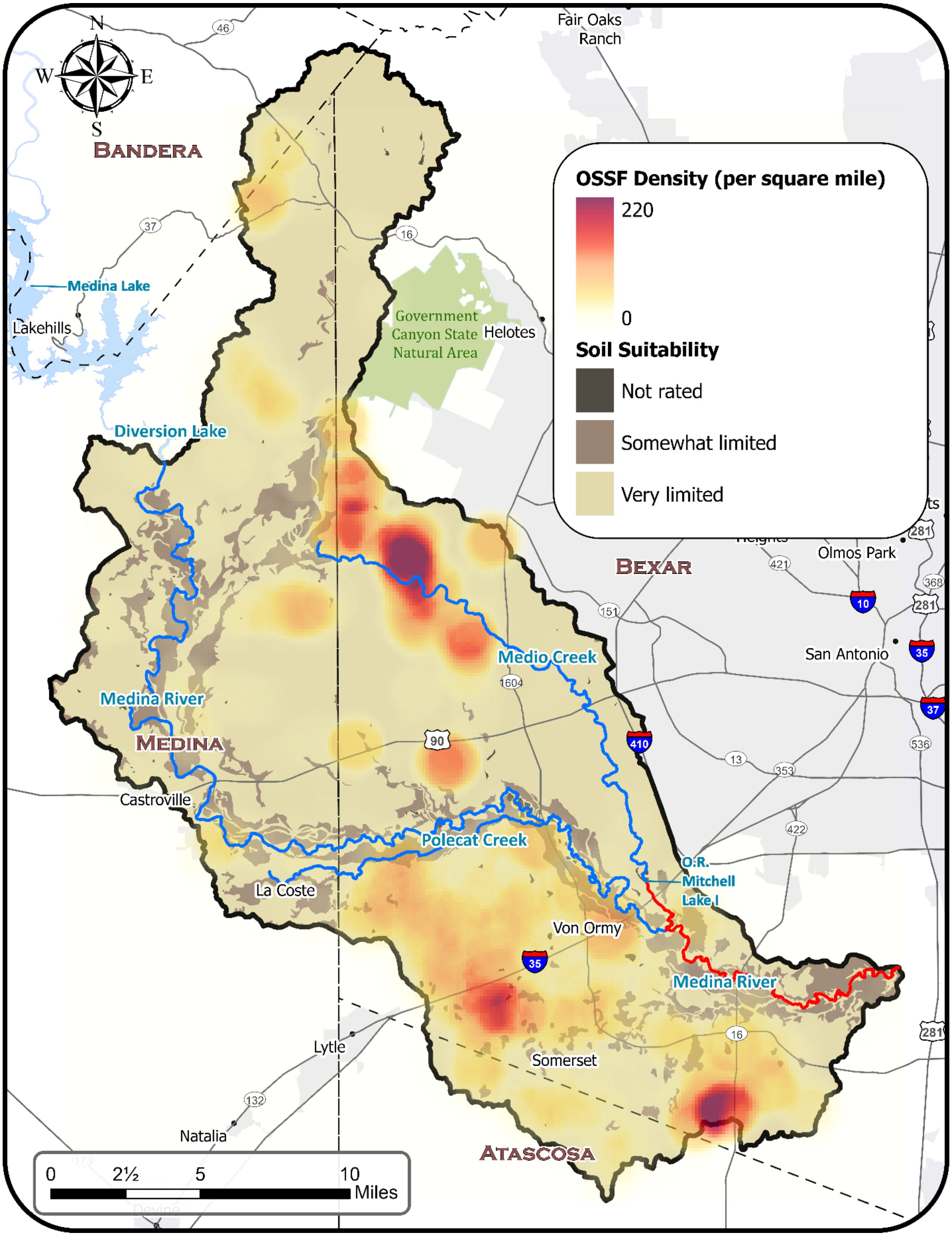

Figure 4-3. Figure 4-3. Soil suitability and OSSF density.

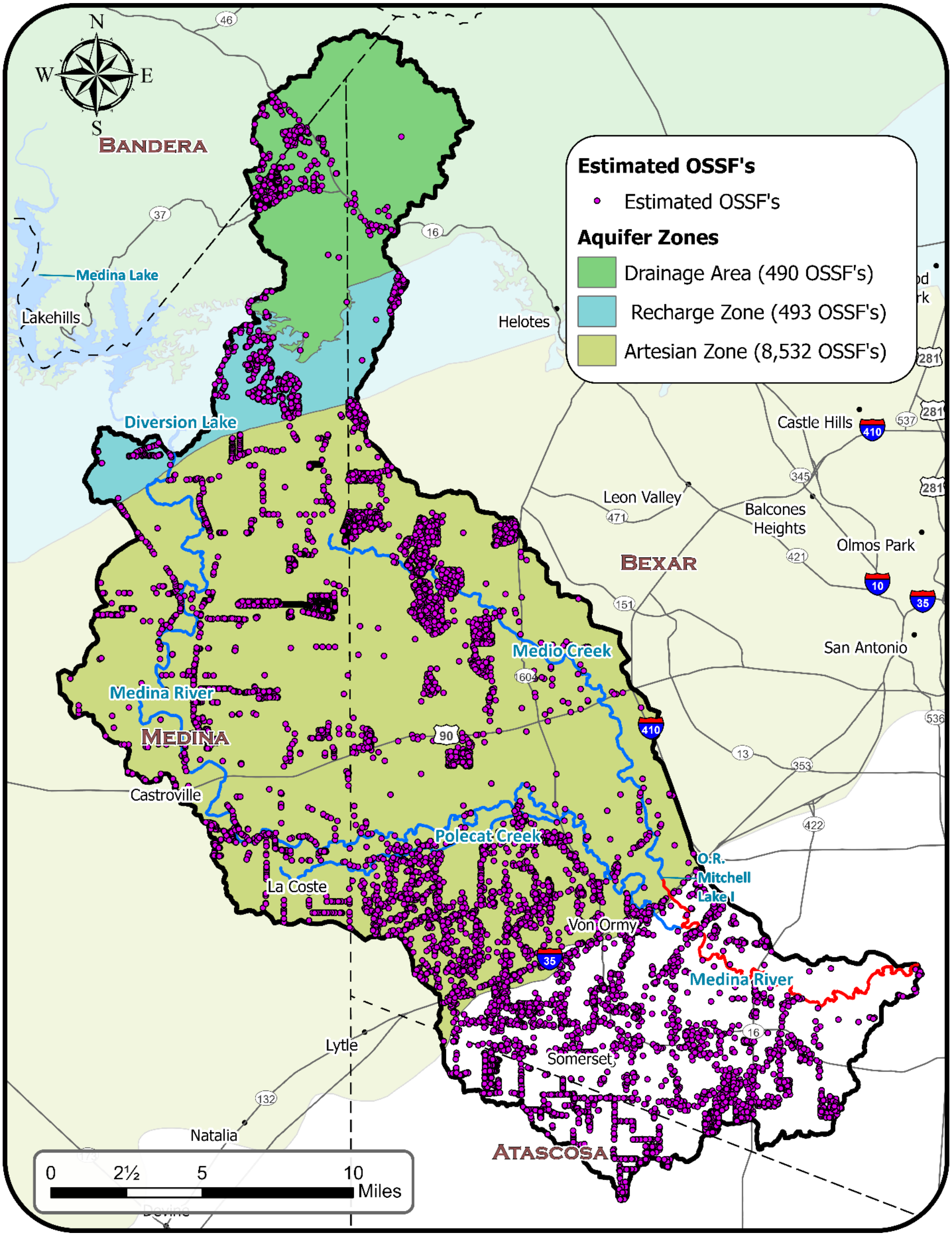

Figure 4-4. Edwards Aquifer zones and estimated locations of OSSFs.

Pet Waste

Domestic pets can contribute to fecal bacteria and nutrient loading in water bodies when waste is carried by runoff from lawns, parks, and other surfaces. In rural areas, dogs tend to roam so proper waste disposal may not be practical. In urban areas, pet owners' behavior may be influenced through education and conveniently placed waste bins, especially since those areas are more densely populated. Bacteria loading from pets can be reduced if pet owners properly dispose of waste in the garbage. According to the American Veterinary Medical Association (AVMA), approximately 60% of U.S. households owns at least one dog, at an average rate of 1.46 dogs/household (AVMA 2023). Based on stakeholder knowledge, the dog population was estimated using 60% ownership and an average rate of 1.46 dogs/household. The number of domestic dogs in the watershed was estimated based on the number of households represented in the U.S. Census block data (Table 4-4).

Table 4-4. Estimated population of dogs

Households	Dogs
77,375	**50,384**

Urban Stormwater

Stormwater runoff occurs from all land cover and soil types when rainfall exceeds soil infiltration capacity. Impervious surfaces such as rooftops and parking lots increase runoff above what would occur naturally. Stormwater is a vehicle for almost all pollutant types that impact water bodies. Debris, bacteria, nutrients (nitrogen, phosphorus, etc.), sediment, and other pollutants are transported into water bodies by stormwater. Stormwater from more developed areas also reaches streams faster and often leads to flooding and erosion. Unmanaged stormwater can result in degradation of riparian areas and stream channels, destabilized stream banks, increased erosion, and release of nutrients and other pollutants from sediment and bank materials.

Stormwater in urban areas with populations over 50,000 is regulated by the TCEQ under the Texas Pollutant Discharge Elimination System (TPDES). The program applies to stormwater runoff from municipal separate storm sewer systems (MS4), industrial activities, and construction activities. An MS4 includes ditches, curbs, gutters, storm sewers, and similar infrastructure for carrying runoff and does not connect with a wastewater collection system or treatment plant. An MS4 system must be owned or operated by a public agency such as a city, utility district, county, or government agency.

Regulated entities must develop, implement, and enforce a stormwater management program (SWMP) to describe how the program will reduce pollutants leaving it's system. The SWMP contains measures that address the impacts of urban stormwater, including public education and involvement, illicit discharges, construction and post-construction site runoff, pollution prevention, and industrial stormwater. Entities that own or operate systems serving a population of 100,000 or greater fall under a Phase I MS4 permit with additional requirements and responsibilities specific to their stormwater system. Entities that serve populations between 50,000 and 100,000 may operate under a more simplified Phase II General permit.

There are four entities in the Medina River watershed permitted under the TCEQ urban stormwater rules (Table 4-5; Figure 4-5). The City of San Antonio (CoSA) and San Antonio Water System (SAWS) are co-permittees under a Phase I permit, with each entity responsible for discharges from the portion of the stormwater system they own or operate. Bexar County and Joint Base San Antonio – Lackland (JBSA-LAK) operate under the Phase II General permit. The Texas Department of Transportation (TxDOT) operates under a statewide Phase II permit that covers all stormwater infrastructure located within, or discharging to, the jurisdiction of other MS4s. In the Medina watershed, this includes stormwater infrastructure within the TxDOT right-of-way within or discharging to any of the other three MS4s. TxDOT also manages stormwater runoff in all areas of the state under the TCEQ's Construction General Permit, designed to decrease erosion and sediment generated by roadway and other construction projects.

Urbanization is increasing rapidly in the watershed, particularly in Bexar County and eastern Medina County. Commercial development is extending westward along major highways and large scale residential developments are growing throughout the central portion of the watershed. Stakeholders have identified new development and the associated challenges of land use conversion and population increases as a challenge in watershed planning and protecting water quality. Pollutant contributions from urban stormwater are expected to increase over time. Additional analysis may be needed to fully assess the impact of urbanization on *E. coli* loading in the watershed.

Table 4-5. Municipal separate sewer stormwater permits.

Permittee	Type	Permit #	Regulated Area
City of San Antonio, San Antonio Water System	MS4 - Phase I	TXS001901	Corporate boundary of the City of San Antonio
Bexar County	MS4 - Phase II General	TXR040000	Bexar County
Joint Base San Antonio – Lackland	MS4 - Phase II General	TXR040000	Main Base Lackland, Kelly Field Annex, and Lackland Training Annex
Texas Department of Transportation	Construction General	WQ0005011000	Statewide, TxDOT projects disturbing 1 acre or more
	MS4 - Phase II	TXR150000	Statewide, within TxDOT right-of-way in urbanized areas

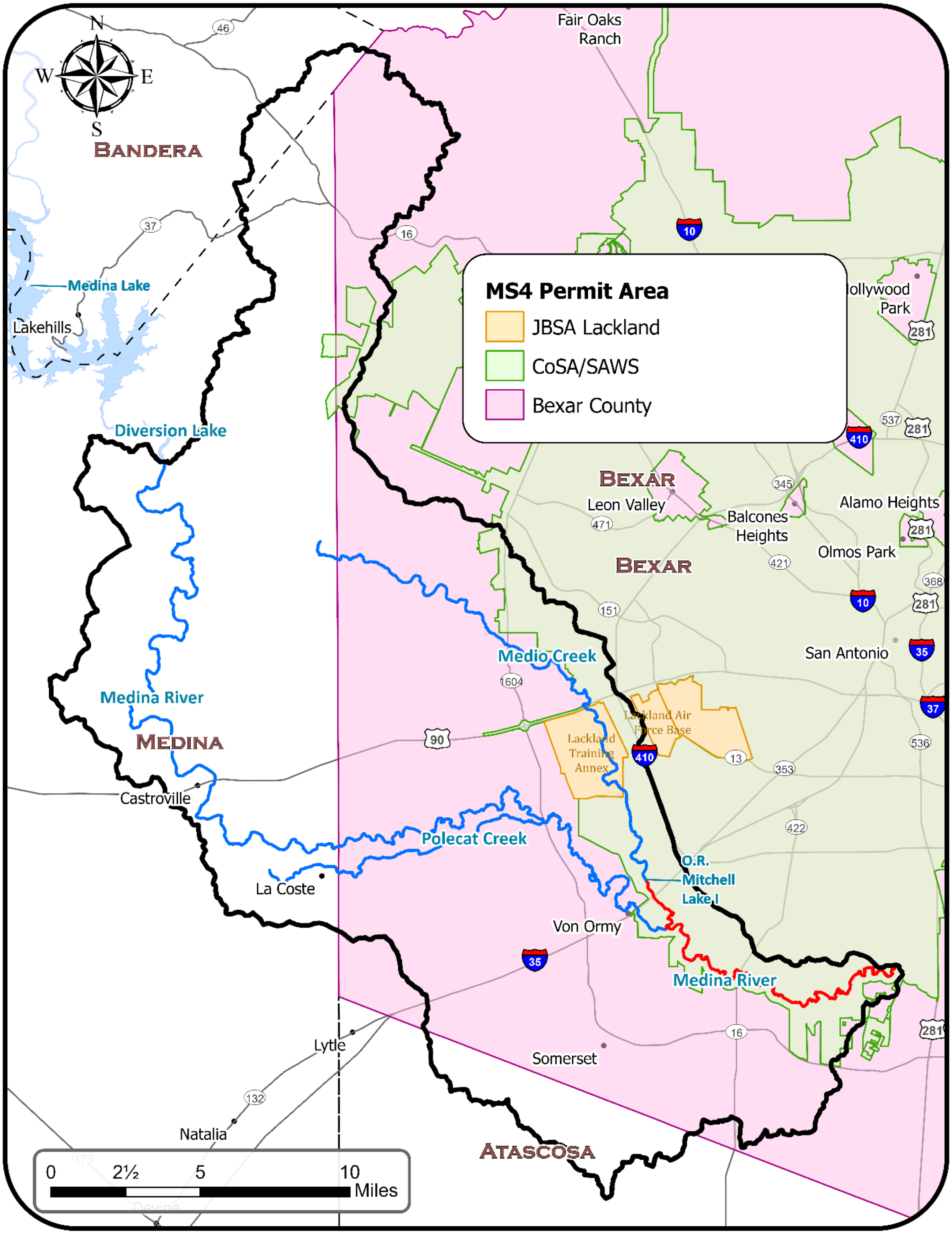

Figure 4-5. Entities regulated under TCEQ MS4 permits.

Livestock

Livestock, including cattle, horses, goats, sheep, pigs, and chickens occur throughout the watershed, primarily on pasture/hay, grassland, rangeland, and deciduous-mixed forest land cover types. These animals serve as a potential source of bacteria and nutrients to the watershed and water bodies by depositing urine and fecal matter as they move across the landscape. Fecal matter can be transported to nearby creeks during rainfall events, which would contribute to increased bacteria in the water body. Determining the exact number of livestock at a point in time is impossible due to birth, death, purchase, sale, and transport. However, county-level population estimates are available from the USDA National Agricultural Statistics Service (NASS) that help estimate the number of livestock in the watershed. Recommended stocking rates available from the USDA Farm Service Agency (FSA) can also be used to generate these estimates.

Stakeholders considered estimates developed using both data sources and determined that an average number of cattle calculated using the two methods would be most appropriate for the watershed. Estimates for other livestock were derived from NASS county statistics. All livestock are considered to exist on pasture/hay, grassland, rangeland, and deciduous-mixed forest land cover types. Table 4-6 contains the estimated population of livestock in the Medina River watershed.

Table 4-6. Estimated population of livestock

Estimated Population in Watershed			
Cattle	**Horses**	**Goats**	**Sheep**
9,505	591	2,358	2,357

Deer

Many species of wild animals call the watersheds home, including a variety of birds and mammals that can contribute significantly to bacteria loading in the watersheds. The lack of information regarding population estimates for many of these animals and their fecal production rates prevent their impacts from being quantified. Additionally, reducing bacteria loading from certain wild animal populations is impossible due to wildlife management and preservation laws. Bacteria from wildlife not specifically identified here contribute to bacteria in the creeks, but their impacts are not assessed and no management recommendations to address these sources are discussed.

Riparian areas provide ideal habitat for wildlife, which leads to their congregation in these areas. Therefore, wildlife feces can be a source of pollution in close proximity to waterbodies.

White-tailed deer and feral hogs are two species that density estimates are available for, even though they do not constitute the total wildlife population. The Texas Parks and Wildlife Department (TPWD) conducts periodic deer population surveys at the deer management unit (DMU) level. DMUs are landscapes indexed by similar ecological characteristics within a defined area. The Medina River watershed is situated within four DMUs: DMU 8 East, DMU 8 West, Urban San Antonio all of which are considered South Texas Plains ecoregions and DMU 7 North which is considered the Edwards Plateau ecoregion. For this project, the most recent five years of density estimates were averaged and applied to appropriate land uses (TPWD 2020). The density average for DMU 8 East is 25.6 deer/1,000 ac, DMU 8 West is 30.5 deer/1,000 ac, and DMU 7 North is 156.6 deer/1,000 ac. Deer densities were applied to all LULC classes in the watersheds except for open water, barren land, and developed land yielding an estimate of 17,280 deer in the watershed.

Feral Hogs

Feral hogs tend to live within riparian corridors that are not barren or developed, and forage in almost all land use types. Bacteria from wild animals enters the water body through direct deposition when wading and through runoff during a storm event. Feral hogs tend to be particularly destructive to riparian vegetation which also reduces the riparian area's capacity to filter bacteria and other pollutants from other sources. Estimates of most wildlife including raccoons, opossums, and birds are difficult to ascertain; therefore, management measures commonly focus on two species with practical management options: white-tailed deer and feral hogs. Both species prefer similar land cover classes: forest, pasture, shrub, and wetlands. While they mostly travel through riparian corridors, they can also be found in the pastures, croplands, and rangelands, especially at night. Feral hogs are significant contributors of fecal bacteria to water bodies as they spend much of their time wallowing in and around the water. These non-native, invasive hogs also cause erosion and soil loss issues due to their rooting and wallowing habits.

Statewide feral hog density estimates have ranged from 32 ac/hog to 72 ac/hog (Wagner and Moench 2009; Timmons et al. 2012). Based on stakeholder input, a feral hog density of 32 ac/hog was applied to all land uses except barren, developed, and open water (Table 4-7).

Table 4-7. Estimated population of deer and feral hogs

Estimated Population in Watershed	
Deer	**Feral Hogs**
17,280	6,146

Illegal Dumping

Watershed stakeholders identified illegal dumping as a problem across the watershed. While most items dumped are not considered major bacteria or nutrients sources, trash accumulation leads to additional dumping. Some items dumped, including animal carcasses and household waste, contain bacteria, while other discarded trash, such as electronic or automotive waste, contain harmful chemicals, metals, and more. Improper waste disposal is bad for the environment, and local stakeholders strongly desire to address this pollution source.

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Chapter 5
Pollutant Source Assessment

Water quality monitoring data presented and analyzed in Chapter 3 establishes that the lower portions of the Medina River and Medio Creek are not supporting primary contact recreation due to elevated *E. coli* concentrations. To meet water quality standards, the overall geometric mean of *E. coli* concentrations within an assessment unit or segment must be no greater than 126 cfu/100mL.

To calculate load reductions needed to meet the *E. coli* criterion, the load capacity of each waterbody was estimated using the Load Duration Curve (LDC) method. The load capacity represents the load of *E. coli* a waterbody could receive and still meet the water quality criterion. Comparison of the load capacity to the current *E. coli* load results in a reliable estimate of the needed load reduction. The needed load reduction estimate will serve as a numeric target for management measures and activities to reduce bacteria loading and meet water quality standards. Analysis of flow conditions can also assist stakeholders in prioritizing management measures, since land management activities and measures to mitigate pollutant loads to waterbodies are most effective for mid-range and low flow conditions, and least effective for high flow conditions.

The relative *E. coli* load contributions from identified sources in the watershed were calculated using a Geographic Information System (GIS) method which incorporates the best available data about the watershed and potential sources with local stakeholder knowledge. By estimating the location and relative contributions of each identified source, the location of management measures can be prioritized, and the number and types of needed management measures can be estimated.

Load Duration Curve Analysis

The relationship between flow and *E. coli* concentration in the Medina River watershed was established using LDCs, a widely accepted methodology used to characterize *E. coli* loads across different flows. The LDC provides a visual display between streamflow, load capacity, and water quality data. This approach allows existing bacteria loads to be calculated and compared to allowable loads. Details of the LDC methodology are presented in Appendix B.

Generally, loads observed during high flow conditions are due to significant rainfall runoff transporting pollutants from the landscape to the waterbody. At high flows, contributions from sources such as wastewater discharges and failing OSSFs are largely diluted by the excessive amount of water in the stream, and sources washing in from the landscape dominate bacteria contributions. These loads are not readily managed and are not the focus of this WPP. Loads delivered during average or mid-range conditions may include a combination of point and nonpoint sources of *E. coli*. Examples include sources in close proximity to a waterbody where bacteria is transported from the landscape during smaller rainfall-runoff events, from nearby failing OSSFs discharging directly to the waterbody, or by direct deposition from animals. Elevated loads detected during low flow conditions are generally attributed to point sources such as WWTFs, failing OSSFs, and/or direct deposition or disturbance animals. In some cases, elevated *E. coli* detected during mid-range or low flow conditions may be caused by dumping of animal carcasses immediately upstream of sampling locations.

The relatively complex interactions of streams with groundwater in the Medina watershed may complicate these assumptions about the relationships between flow condition and bacteria sources, particularly at mid-range and low flows. In the Edwards Aquifer contributing and recharge zones, it could be possible for instream *E. coli* loads to be transported to the aquifer through karst formations, or diluted by spring flows, before stream flows reach downstream monitoring stations. Analyses conducted for the WPP did not attempt to identify or quantify these potential interactions.

The following LDC graphs show individual samples as points as well as the Allowable Load and Existing Load (lines). Load points above the Allowable Load line represent samples where the concentration exceeds the water quality criterion. The difference between the Allowable and Existing lines are an estimation of the reduction needed.

Station 12814

For this station, located on the Medina River at Applewhite Road, analysis of flow data indicates high flow conditions are represented by the highest 10% of stream flows occurring an average of 36 days per year, while low flow conditions are observed during the lowest 10% of stream flows, also occurring an average of 36 days per year. Mid-range flow conditions are observed approximately 80% of the time, or approximately 292 days per year (Figure 5-1, Table 5-1).

The LDC profile indicates that *E. coli* exceeds allowable loads under all flow conditions at least part of the time. Analysis shows flow categories with the highest geomeans of *E. coli* concentrations were observed in the high flow and low flow categories, with needed load reductions of 77% and 48%, respectively. The lowest median geomean was observed in the mid-range flow category, with a load reduction target of 26%.

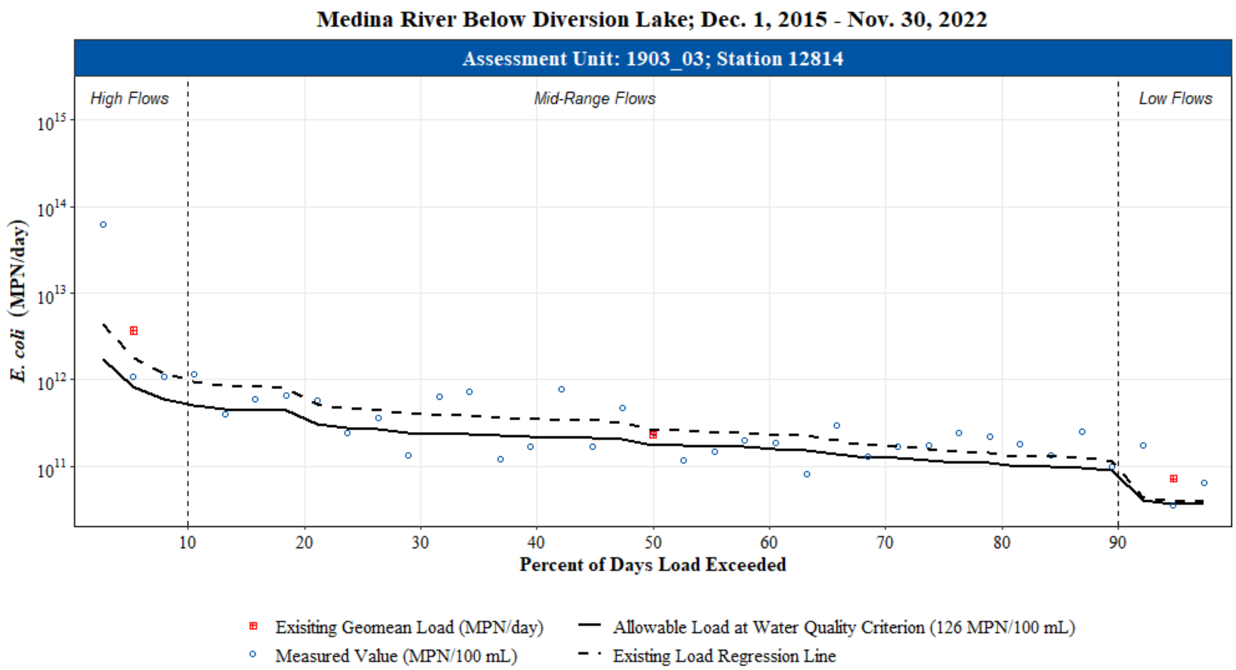

Figure 5-1. LDC profile for station 12814 .

Table 5-1. E. coli loads and reductions needed for station 12814.

Medina River Below Diversion Lake	**Flow Condition**		
Station: 12814	**High Flows**	**Mid-Range Flows**	**Low Flows**
Days per year represented by flow category	36.5	292	36.5
Median Flow (cfs)	273	56	12
Existing *E. coli* Geomean Concentration (MPN/100 mL)	553.18	169.69	243.96
Daily Allowable Load (MPN/day)	8.42E+11	1.73E+11	3.70E+10
Daily Existing Load (MPN/day)	3.69E+12	2.32E+11	7.16E+10
Annual Allowable Load (MPN/year)	3.07E+14	6.30E+13	1.35E+13
Annual Existing Load (MPN/year)	1.35E+15	8.49E+13	2.61E+13
Annual Load Reduction Needed (MPN/year)	1.04E+15	2.19E+13	1.26E+13
Percent Reduction Needed	77%	26%	48%
Total Annual Load (MPN/year)	1.46E+15		
Total Annual Load Reduction (MPN/year)	1.08E+15		
Total Percent Reduction	74%		

Station 12916

Analysis of flow data collected at Station 12916, located on Medio Creek at the Hidden Valley Campground, indicates that high flow conditions are represented by the highest 8% of stream flows occurring an average of 29 days per year, while low flow conditions are observed during the lowest 25% of stream flows, occurring an average of 91 days per year. Mid-range flow conditions are observed approximately 67% of the time, or approximately 245 days per year (Figure 5-2, Table 5-2).

The LDC profile indicates that *E. coli* exceeds allowable loads under all flow conditions at least part of the time. Analysis shows the highest median geomeans of *E. coli* concentrations were observed in the high flow and low flow categories, with needed load reductions of 36% and 29%, respectively. The lowest median geomean was observed in the mid-range flow category, with a load reduction target of 12%.

The station is located approximately 1.7 stream miles downstream of the O.R. Mitchell Lake 1 dam. This earthen dam impounds Medio Creek north of Interstate 10 and was constructed in the 1960's for irrigation purposes. Flows may pass through a vertical primary spillway pipe or over an earthen spillway, and satellite imagery indicates relatively permanent seepage through or under the dam. The dam is significant to the LDC analysis in that the impoundment serves to dampen or reduce stream flows from the upper portion of the Medio Creek watershed, as evidenced by the relatively low median flow of 40 cfs observed in the high flow category. Also, because *E. coli* is subject to degradation by ultraviolet light, waters exposed to sunlight in the lake prior to being captured at the downstream monitoring may no longer be representative of the potential sources of *E. coli* located upstream of the dam.

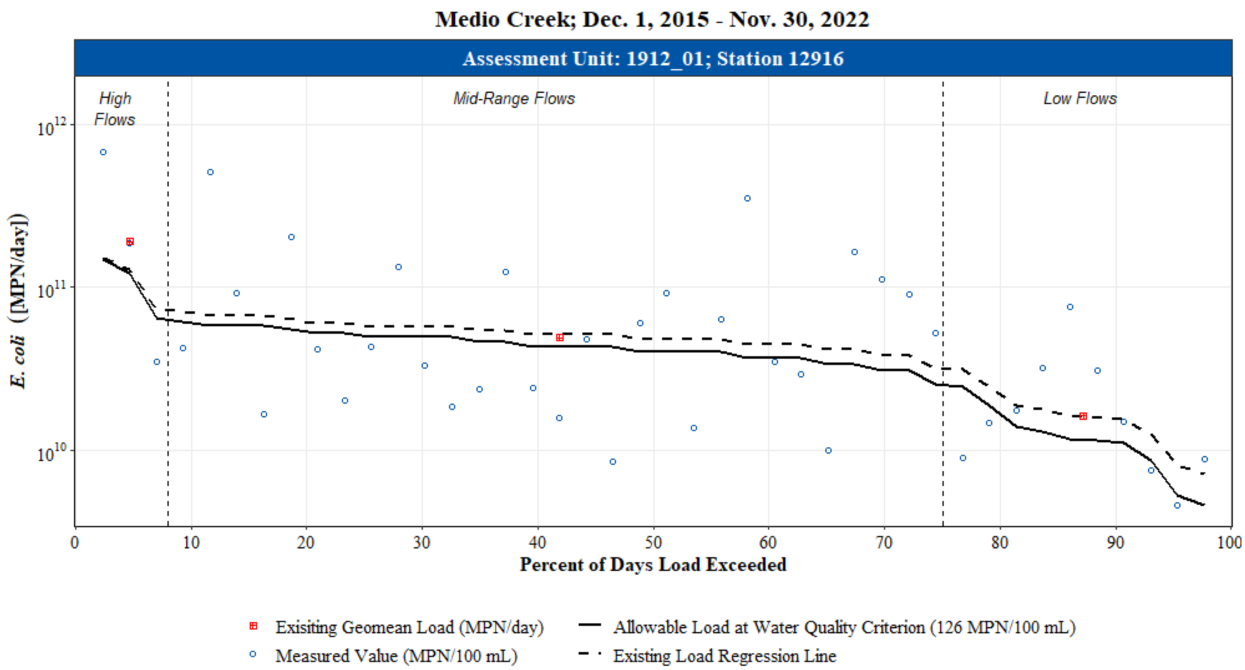

Figure 5-2. LDC for station 12916 Medio Creek.

Table 5-2. Annualized reductions using the LDC for station 12916.

Medio Creek	Flow Condition		
Station: 12916	**High Flows**	**Mid-Range Flows**	**Low Flows**
Days per year represented by flow category	29	245	91
Median Flow (cfs)	40	14	4
Existing *E. coli* Geomean Concentration (MPN/100 mL)	195.69	143.84	177.35
Daily Allowable Load (MPN/day)	1.23E+11	4.32E+10	1.16E+10
Daily Existing Load (MPN/day)	1.92E+11	4.93E+10	1.63E+10
Annual Allowable Load (MPN/year)	4.50E+13	1.58E+13	4.22E+12
Annual Existing Load (MPN/year)	6.99E+13	1.80E+13	5.94E+12
Annual Load Reduction Needed (MPN/year)	2.49E+13	2.23E+12	1.72E+12
Percent Reduction Needed	36%	12%	29%
Total Annual Load (MPN/year)	9.38E+13		
Total Annual Load Reduction (MPN/year)	2.88E+13		
Total Percent Reduction	31%		

Spatial Analysis of Potential E. coli Loading

The distribution of potential pollutant loadings from identified sources across the watershed was evaluated using a GIS-based approach similar to the Spatially Explicit Load Enrichment Calculation Tool (SELECT) (Teague et al., 2009) methodology. By estimating relative potential contributions of various *E. coli* sources across the watershed, critical source areas can be prioritized for management measures.

To assist in prioritizing and geographically targeting management measures, the watershed was divided into smaller units, or subbasins, based on 12-digit hydrologic unit codes (HUCs). The area within each subbasin is generally similar with respect to topography and hydrological features. Details of the methodology are presented in Appendix C.

Publicly available information such as land use/land cover, soil characteristics, U.S. Census data, and discharge points was used along with stakeholder knowledge to identify a variety of sources of bacteria and their estimated potential *E. coli* contributions to the watershed. These data were used to evaluate potential loadings from livestock, deer, feral hogs, domestic pets, OSSF, and WWTFs at the subbasin level. Contributions from SSOs, urban stormwater, illicit dumping, and populations of other wildlife were not quantified.

E. coli loading estimates are presented on the following maps to allow easy comparison of potential loading between subbasins and to facilitate targeting of management measure prioritizations. Depicted are potential loading estimates depicted that do not consider naturally occurring bacteria fate and transport processes that occur between the points where they originate and if or where they may enter the waterbody. Therefore, this analysis presents a worst-case scenario that does not represent the actual bacteria loading expected to enter waterbodies.

Analyses indicate that subbasins 7, 6, 10, and 9 have the highest potential loads from identified sources (Figures 5-3 through 5-9), and that domestic dogs and livestock have the highest potential for *E. coli* loads across the watershed, followed by OSSFs, deer, and feral hogs (Figure 5-9).

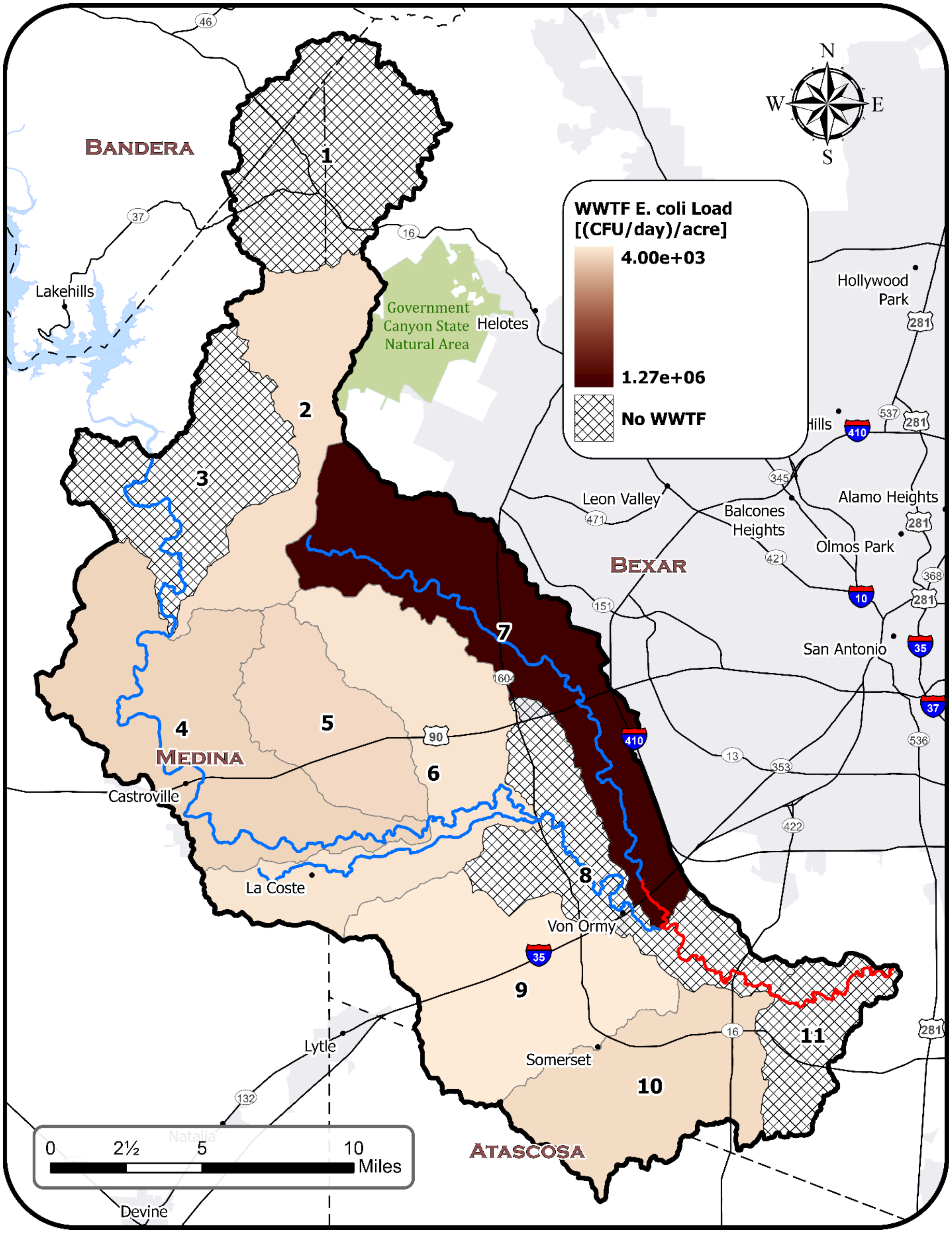

Figure 5-3. Distribution of potential loads from WWTFs

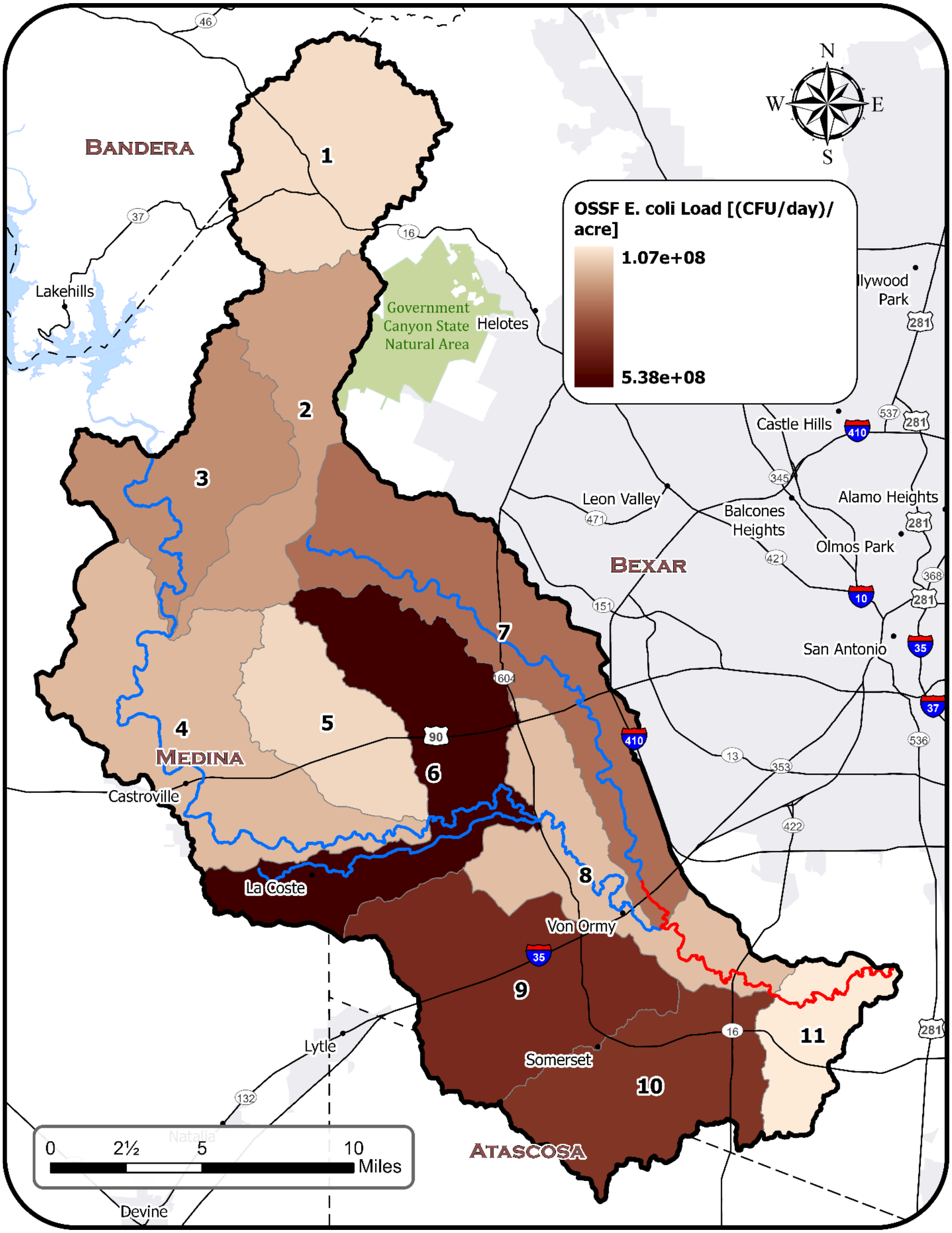

Figure 5-4. Distribution of potential loads from OSSFs

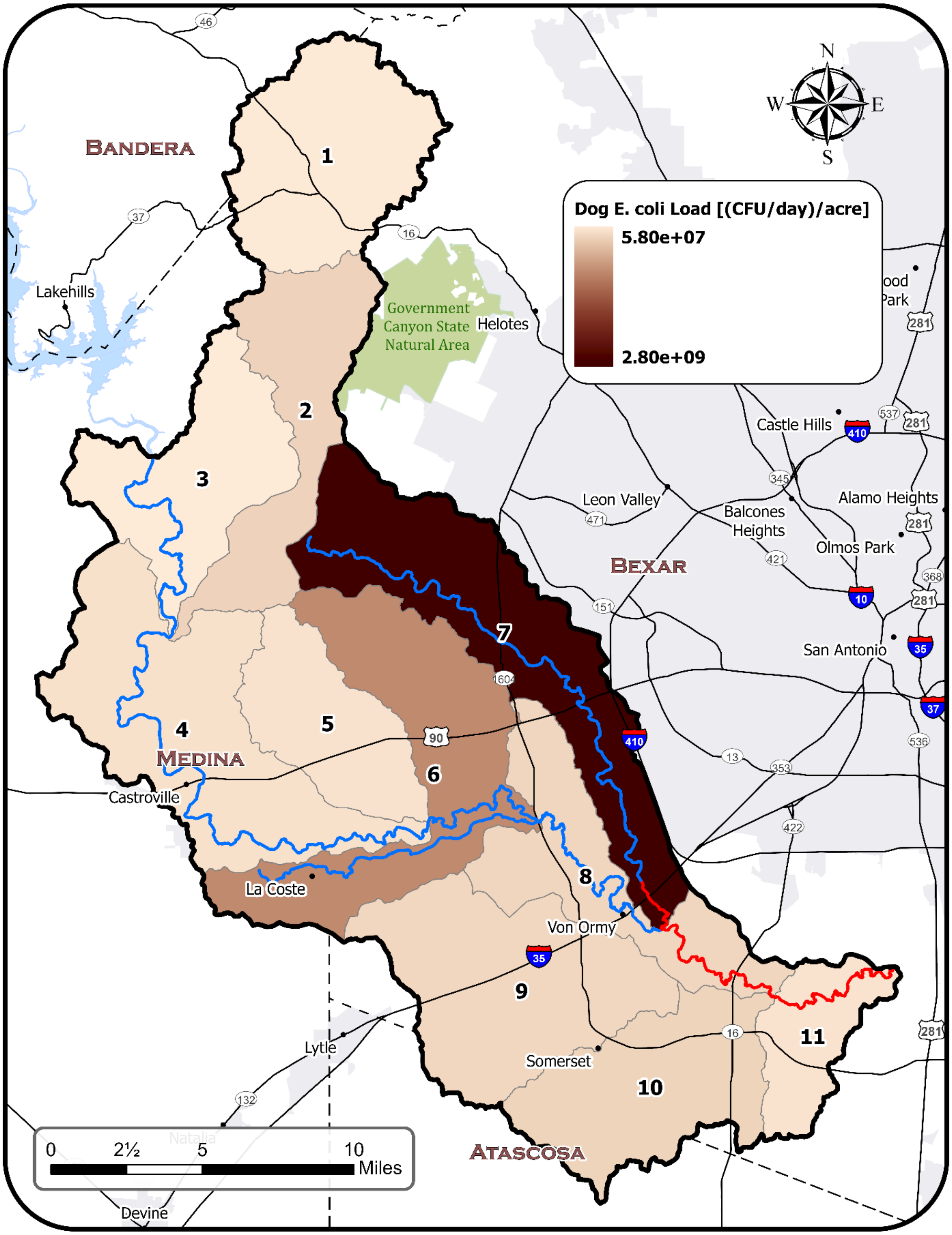

Figure 5-5. Distribution of potential loads from dogs

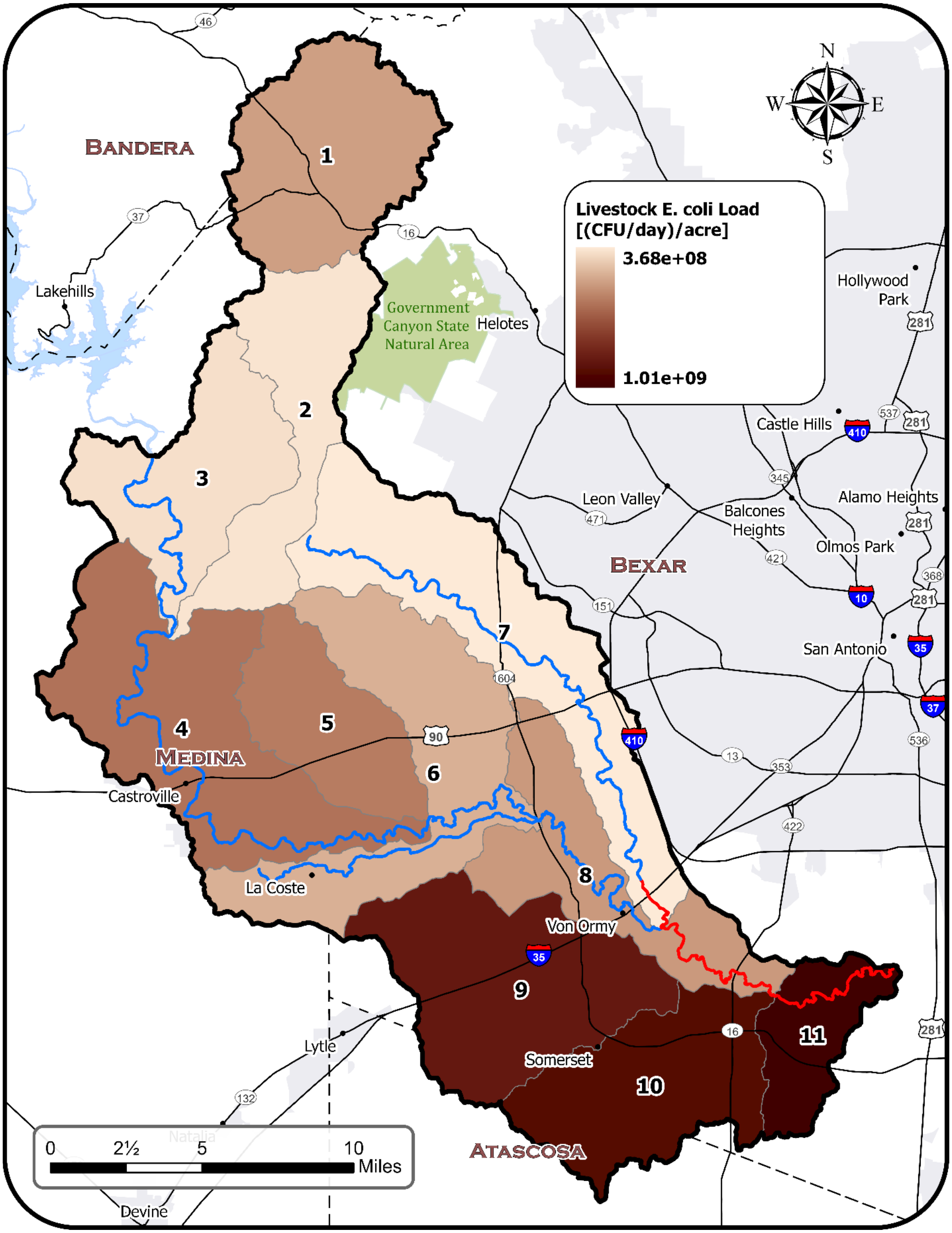

Figure 5-6. Distribution of potential loads from livestock

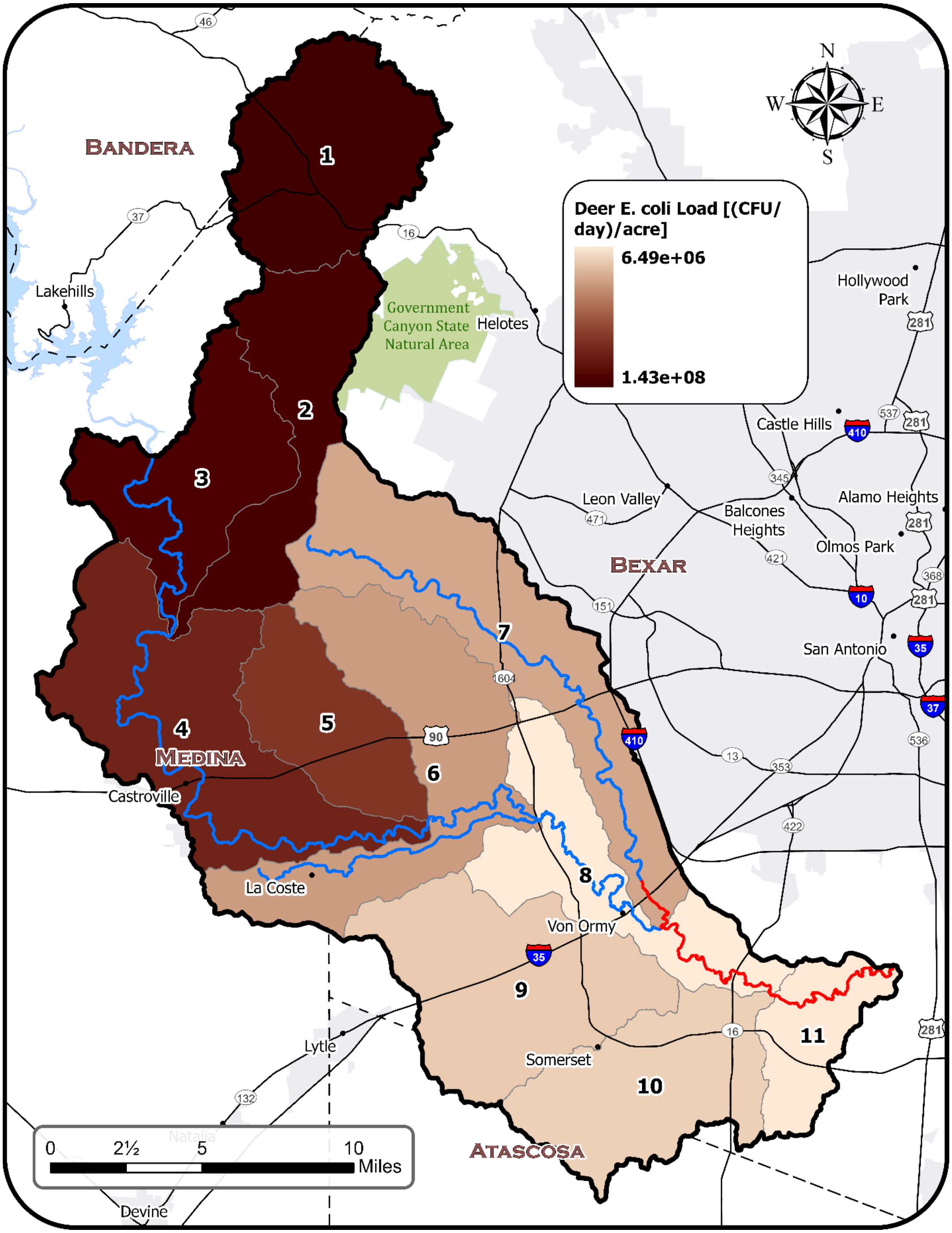

Figure 5-7. Distribution of potential loads from deer

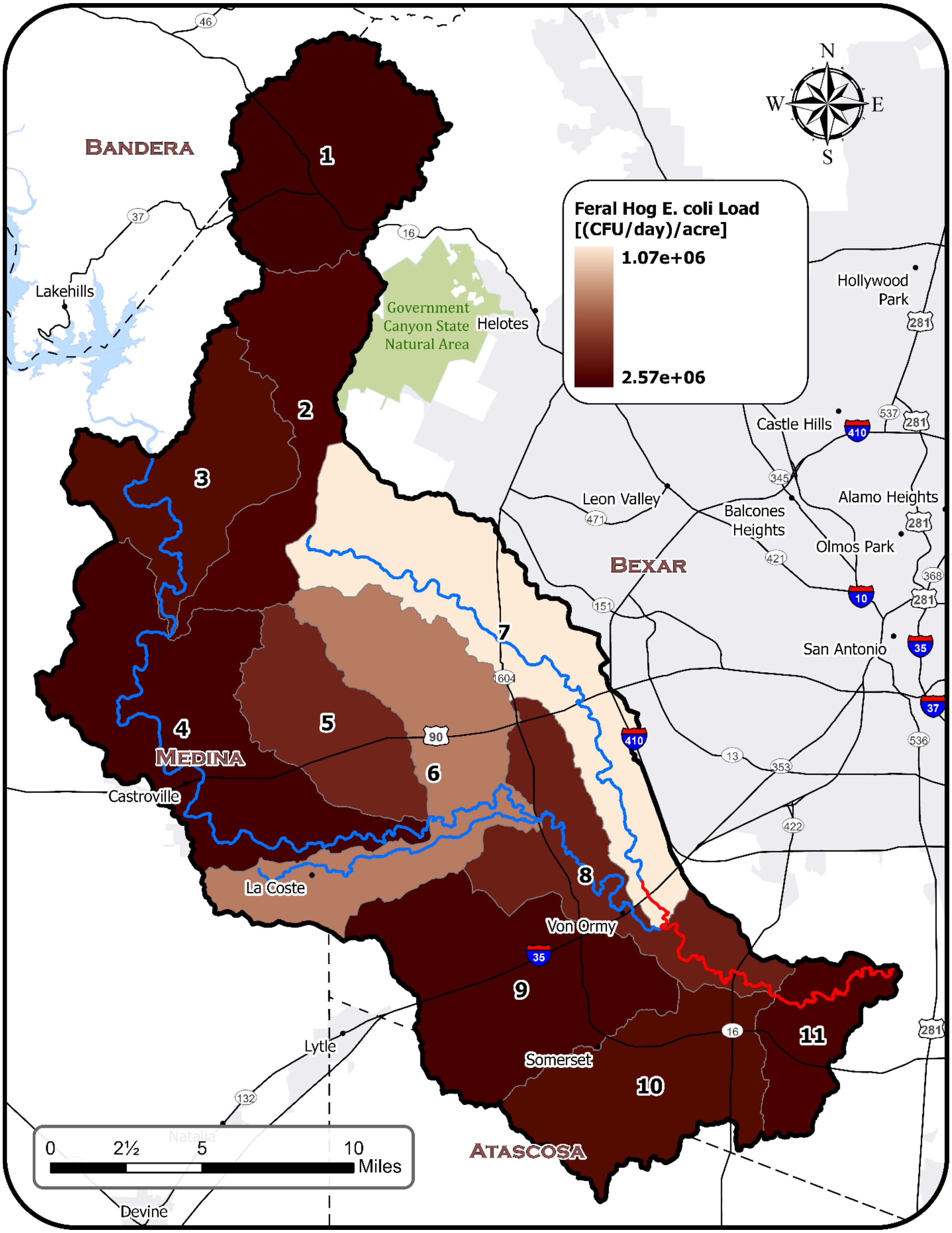

Figure 5-8. Distribution of potential loads from feral hogs

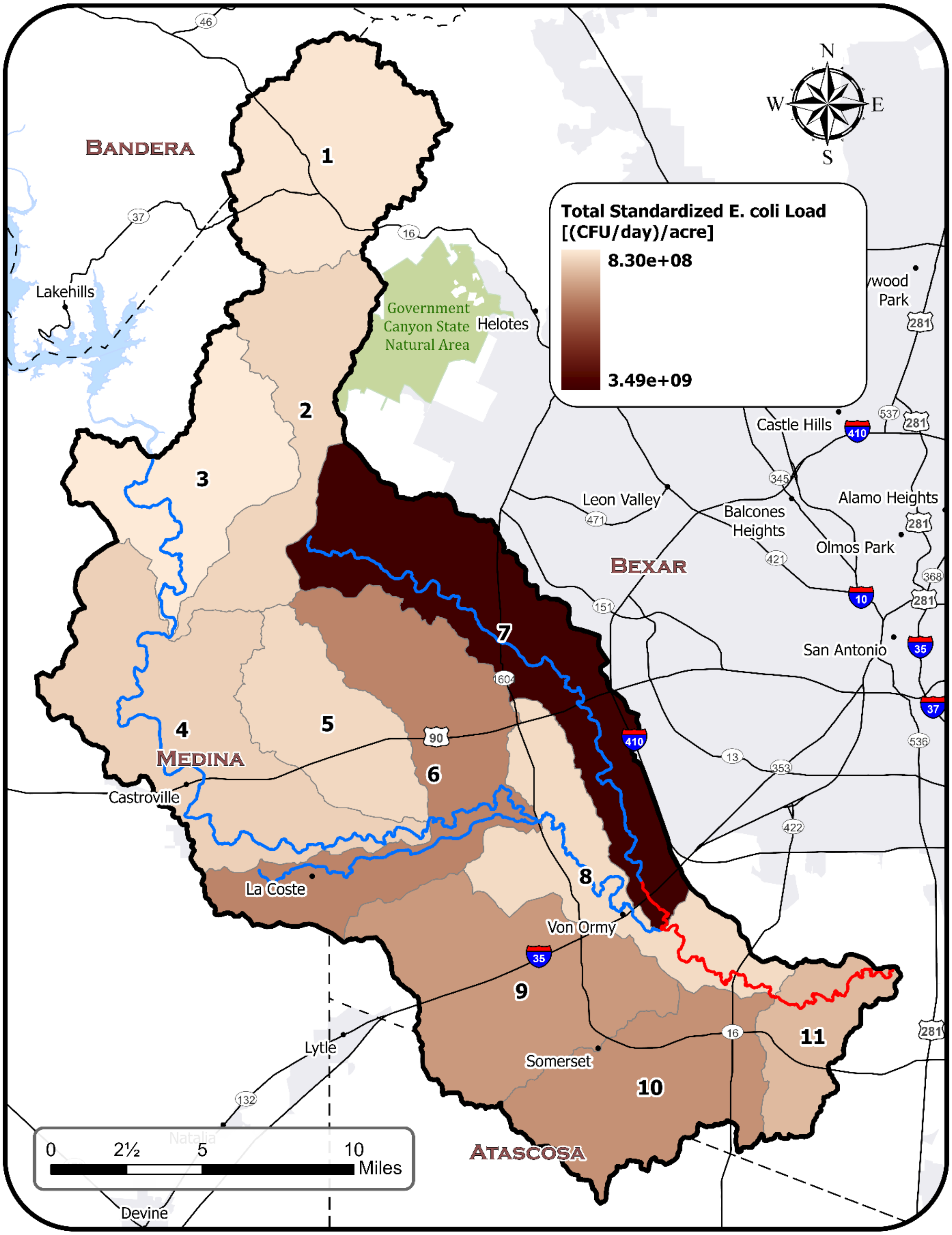

Figure 5-9. Distribution of total potential loads from all identified sources

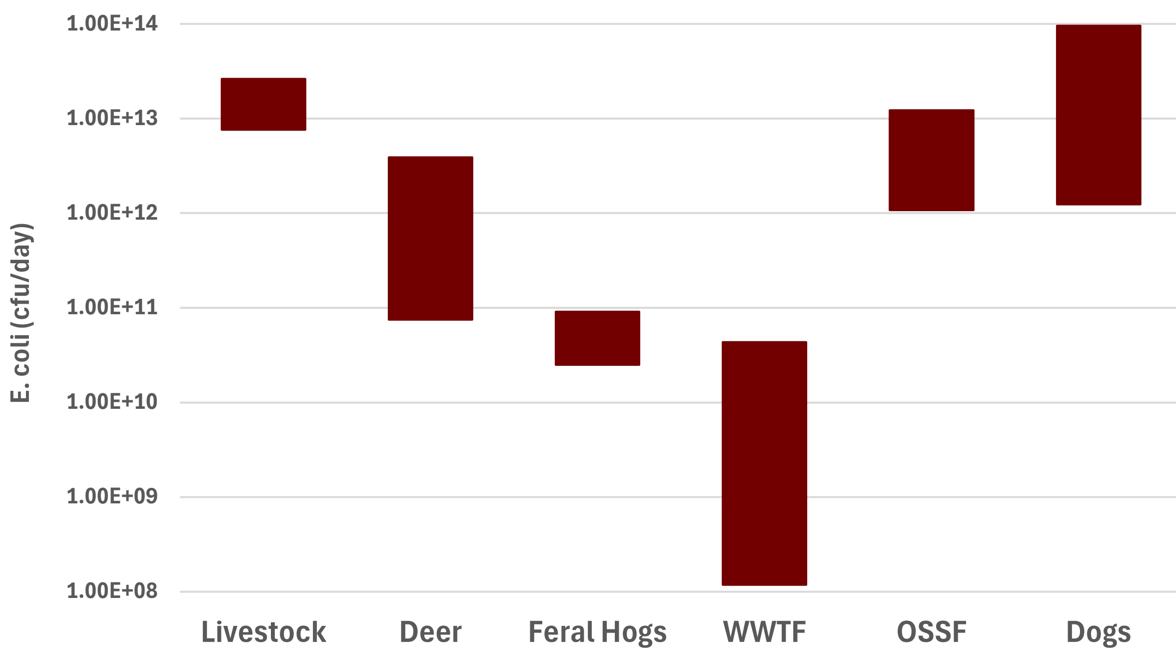

Figure 5-10. Range of total potential E. coli loads from identified sources

References

Teague, A., Karthikeyan, R., Babar-Sebens, M., Srinivasan, R., Persyn, R. 2009. Spatially explicit load enrichment calculation tool to identify E. coli sources in watersheds. Transactions of ASABE. 52(4): 1109-1120. http://doi.org/10.13031/2013.27788.