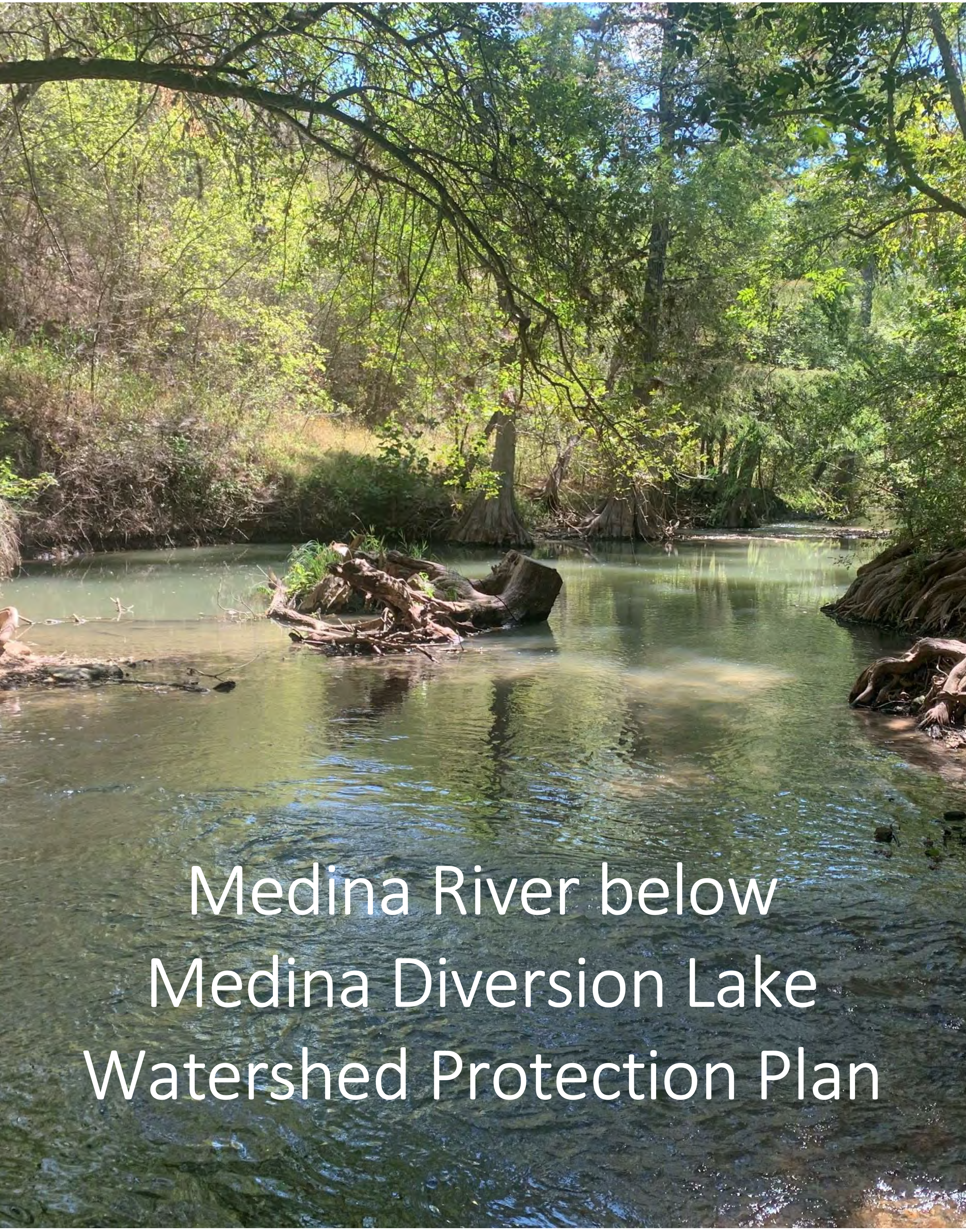

Medina River below Medina Diversion Lake Watershed Protection Plan

A document developed by the stakeholders of the Medina River Watershed to restore and protect water quality in the Medina River (1903_05, 1903_03, 1903_04), Medio Creek (1912A_01, 1912_01), and Polecat Creek (1903A_01).

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List of Acronyms

AU	Assessment Unit
CWA	Clean Water Act
DEM	Digital Elevation Model
DO	Dissolved Oxygen
ECHO	Enforcement and Compliance History Online
EPA	Environmental Protection Agency
GSI	Green Stormwater Infrastructure
HSG	Hydrologic Soil Groups
LULC	Land Use Land Cover
MGD	Million Gallons per Day
MPN	Most Probable Number
MSGP	Multi-Sector General Permit
MSL	Mean Sea Level
NASS	National Agricultural Statistics Service
NLCD	National Land Cover Database
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSSF	On-site Sewage Facilities
PCR	Primary Contact Recreation
RUAA	Recreational Use Attainability Analysis
RMU	Resource Management Unit
SARA	San Antonio River Authority
SSO	Sanitary Sewer Overflow
SNC	Significant Non-Compliance
SSURGO	Soil Survey Geographic Database
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
USDA	United States Department of Agriculture
USGS	United State Geological Survey
WWTF	Wastewater Treatment Facility

Executive Summary

The Watershed

A watershed is a land area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ocean. Any land surface surrounding the water body is considered part of the watershed. Natural processes and human activities affect water quality and quantity within watersheds.

The Medina River below Medina Diversion Lake (Medina River WPP) watershed is approximately 412 square miles of urban, suburban, and agricultural land in parts of Bexar, Medina, Bandera, and Atascosa counties in south-central Texas. (Figure ES-1). The historically rural watershed, containing a mix of small cities and communities, livestock operations, and cropland, is experiencing rapid growth and development from the city of San Antonio. Analysis presented in the following chapters indicate that since 2001, rural land uses have decreased by an average of 986 acres per year, being replaced by commercial, residential, and industrial uses.

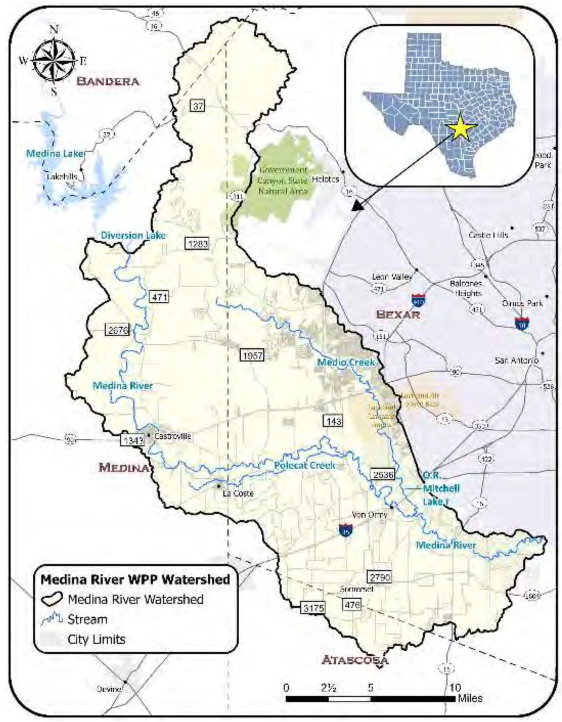

Figure ES-1. Watershed of the Medina River below Medina Diversion Lake.

The region is largely karst in nature, providing efficient conduits between surface water and groundwater through streams, sinkholes, and other features. Portions of three aquifers underlie the watershed - the Trinity, Carrizo-Wilcox, and Edwards Balcones Fault Zone (BFZ) aquifers. The latter, more commonly known as the Edwards Aquifer, is a significant and sensitive source of drinking water for the region, as well as habitat for several endemic and endangered species, and the source of many local springs and streams, including the Medina River.

In 2010, the TCEQ identified bacteria concentrations in portions of Medio Creek and the Medina River that could pose a risk for swimming and wading activities. Since then, elevated nutrient concentrations that could result in excess algae growth and diminished ecosystem health have also been identified as a concern. In 2023, stakeholders came together to develop a locally driven effort to address these issues.

This Watershed Protection Plan (WPP) is the result of a stakeholder process to identify sources of these pollutants and the methods to reduce them. By considering local knowledge and information about the multiple potential pollutant sources in the watershed, this plan describes educational and management measures that, when implemented, will cost-effectively reduce bacteria and nutrient loadings.

Publicly available information and stakeholder knowledge were used to identify a variety of potential sources of bacteria and their estimated contributions to the watershed. Potential sources include livestock, deer, feral hogs, domestic pets, on-site sewage systems (OSSF), and wastewater treatment facilities (WWTF), as well as storm sewer overflows (SSO), urban stormwater, and illicit dumping. Analyses indicate that overall potential load contributions were highest for domestic pets and livestock, followed by on-site sewage systems, deer and feral hogs, and wastewater treatment facilities.

Recommended Management Measures

Due to the number of potential sources contributing to water quality issues, various educational and management measures are recommended to address manageable sources in the watershed. These measures were developed based on stakeholder input, relative pollutant removal efficiencies, likelihood of adoption and applicability to the watershed. While management measures can be implemented throughout the watershed, it’s recommended they be implemented as close to waterways as possible to increase potential instream water quality improvements. This targeted approach will help guide initial implementation.

Recommended educational activities and management measures were developed to address both rural and urban pollutant sources. This comprehensive approach will be critical to the success of the WPP and improving water quality. Stakeholders also recognize that, because of population increases and rapid conversion of rural to urban land uses, increasing emphasis should be placed on management strategies addressing OSSFs, WWTFs, SSOs, pet waste, and urban stormwater, as appropriate.

Wastewater and SSO

In the face of accelerated growth in the region, aging, new, and planned WWTF infrastructure are major concerns for stakeholders. While data indicate that historical WWTF performance is generally good and SSOs are rare, the potential for upsets and overflows would be expected to increase as systems receive more wastewater from a growing population. Conversely, the uptick in purchases of treated effluent for non-potable uses such as irrigation and by commercial or industrial facilities has resulted in the diversion of effluent that would otherwise be discharged into Medio Creek or the Medina River. Operator training, good housekeeping, and planning for future growth are recommended by stakeholders as potential strategies to ensuring that facilities across the watershed prevent discharge of bacteria and other pollutants through SSOs or WWTF failures.

OSSFs are used to treat wastewater where service by WWTFs is not available. Limited awareness and lack of maintenance of both aerobic and conventional OSSFs can lead to system failures. Providing educational workshops to homeowners regarding OSSF operation and maintenance will help address these issues. Repairs and replacements are also needed. It's not possible to know the number that need true repair or replacement versus maintenance, but stakeholders believe that proper maintenance would correct most issues causing failure. Over the next 10 years, it is recommended that 60 failing septic systems in the watershed be addressed annually through repair, replacement, or improved maintenance. Priority should be given to areas with higher density of OSSF systems and those in close proximity to water bodies.

Pet Waste

Pet waste can be a significant source of bacteria in urban and rural residential areas, parks, and other public spaces. Because concentrations of dogs is generally greater in more populated areas, some loading from pet waste may be managed through proper stormwater management. However, additional activities and efforts to remove and properly dispose of pet waste from the landscape will aid in reducing bacteria loads from across the watershed. Recommended management strategies to address pet waste include providing waste bag dispensers and collection stations in areas of high pet density (parks, neighborhoods, etc.) and handing out waste bag carriers for pet owners at events and programs around the watershed. Providing education and outreach materials to pet owners about bacteria contributed by pet waste can increase the number of residents who properly dispose of pet waste.

Urban Stormwater

The objectives of stormwater management measures are to provide educational programs and to work with local entities to identify opportunities to reduce and manage pollutants associated with stormwater runoff, particularly in urban and urbanizing areas. Stakeholders voiced concerns about whether stormwater regulations will be able to keep pace with growth. Discussions included the need for policies, strategies, funding, and decision-maker support for floodplain protection, stormwater detention, design and review criteria for new developments, and interlocal agreements between municipal and county governments to facilitate action. Recommended management measures include implementation of structural and non-structural practices to reduce or delay runoff generated by impervious or highly compacted surfaces such as roofs, roads, and parking lots. Volume reductions from BMPs also have the added benefit of reducing stormwater entering local sewage collection systems and potentially reducing WWTF upsets and SSO events. Anticipated programs and resources by the San Antonio River Authority (SARA), Texas Water Development Board (TWDB), and existing Municipal Separate

Storm Sewer System (MS4) programs in the watershed, will provide a foundation for wider implementation.

Success of this management measure must be supported by educational programs that increase awareness of the impacts of stormwater on water quality. Other recommended educational tools include installation of publicly accessible demonstration projects to promote low impact and green infrastructure practices, training for city and county staff, developers, maintenance providers, homeowners, and the public, as well as existing TAMU AgriLife trainings on lawn/landscape management and riparian areas, flyers, videos, or other outreach materials.

Livestock

The goal of this management measure is to increase the use of conservation planning and practices to reduce time spent in riparian areas by livestock and improve grazing resource management across the property. These sources are also considered manageable since the behavior of cattle and the areas where they spend their time can be modified through changes to food, shelter, water availability, and access. Stakeholders recommend an additional 240 livestock-based Water Quality Management Plans or Conservation Plans be implemented over the next 10 years. This management measure is also supported by targeted educational programs that increase awareness of agricultural practices and measures that can be taken to protect water quality. These programs include educational workshops, demonstration projects, field days, tours, and more.

Feral Hogs

The goal of this management measure is to reduce feral hog populations 8% below current numbers, through a combination of agency technical assistance, education, and landowner implementation of feral hog management techniques. Recommended techniques include those such as live trapping, shooting, hunting, exclusion from deer feeding areas, and habitat management. Educational programs and workshops are recommended to improve feral hog removal efficiency.

Illicit Dumping

Stakeholders indicate that illicit dumping is a problem throughout the watershed. Dumping activities typically occur at or near bridge crossings and access roads near riparian habitats. Items deposited often include animal carcasses, tires, home appliances, household trash, and rubbish. Recommendations include the continued support and enforcement under existing MS4 and other programs, hazardous waste collection events (including agricultural waste), as well as stream clean-up events, education, and outreach.

Restore Degraded Streams and Riparian Areas

Riparian degradation and stream channel erosion, often a result of unmanaged stormwater, can contribute to poor water quality through release of sediment, nutrients, and other pollutants from sediment and stream bank materials. Stakeholders recommend that a preliminary screening effort of riparian function conducted by the Texas A&M Forest Service, be followed up with a more robust assessment to identify needs and support targeted restoration of degraded riparian areas. Stream restoration resources already developed by SARA include design protocols; training for design, construction, and maintenance professionals; research and technical reports; reference reach databases; as well as a stream restoration potential screening tool and database. Given the potential long-term benefits to communities and the environment, stakeholders recommend that both riparian and stream restoration opportunities be further investigated and implemented should funds become available.

Conserve Land

Land conservation occurs when landowners voluntary limit particular land use activities that pose a threat or would be detrimental to the natural resources they wish to protect. Stakeholders recommend that land conservation programs, including those already existing in the watershed such as the joint Edwards Aquifer Authority (EAA)/City of San Antonio Edwards Aquifer Protection Program, Department of Defense conservation programs at Joint Base San Antonio, be supported and continue to protect natural ecosystems in the watershed.

Manage Abandoned Wells

Abandoned wells are capable of delivering contamination from the surface to groundwater, either by direct transport down the well casing or by providing a pathway between upper and lower groundwater layers. Although not identified as a significant source of bacteria, identifying and plugging abandoned or deteriorated wells could prevent bacteria from being transported to water bodies from more remote locations. Stakeholders recommend that programs such as the EAA's abandoned well closure program be supported and continue to protect the integrity of surface and groundwater.

Education and Outreach

Engaging both the general public and specific targeted audiences is a crucial component of ensuring the success of the WPP. In addition to targeted education and outreach associated with each recommended management measure, additional educational programs, outreach efforts, and related strategies will be used to support implementation of this WPP. The purpose of these efforts is to ensure ongoing community involvement in the effort as well as to increase public awareness of water quality and other water resource issues in the watershed.

To ensure the continuity of the effort and a consistent point of coordination, it's recommended that a Watershed Coordinator facilitate implementation of the WPP beginning with existing communication networks, outreach opportunities, and partners to maximize resources and reach a wide array of stakeholders. Public stakeholder meetings were critical to developing this WPP and will continue to provide guidance in implementing management measures and adaptive management strategies going forward.

Tracking Progress and Measuring Success

WPP implementation will occur over a 10-year timeframe. Programmatic milestones such as the number of management measures implemented, events held, people in attendance at events, and other measures will be used to track progress in implementing the plan.

The water quality goal in the Medina River WPP watershed is the existing primary contact recreation standard for E. coli of 126 cfu/100 mL (Table 10-1). TCEQ's biennial water quality assessment will be the primary means of gauging water quality improvement and ultimate success of the WPP.

Adaptive management is the ongoing process of accumulating knowledge regarding impairment causes and water quality response as implementation efforts progress and adjusting management efforts as needed. As implementation activities are instituted, water quality will be tracked to assess impacts. This information can be used to guide adjustments to future implementation activities. This ongoing, cyclical implementation and evaluation process can focus project efforts and optimize its impacts. If stakeholders determine inadequate progress toward water quality improvement or milestones is being made, efforts will be made to increase BMP adoption and adjust strategies or focus areas as appropriate.

Restoring and protecting water quality throughout the watershed is critical to maintaining its value to area communities, including recreational opportunities such as swimming, fishing, and kayaking; agricultural uses; and protection of sensitive recharge features to the Edwards aquifer - a significant water source for millions of people in the region.

The Medina River WPP provides a comprehensive framework for addressing water quality issues through stakeholder collaboration, adaptive management, and targeted implementation of management measures. By leveraging local, state, and federal resources, the plan aims to achieve long-term improvements in water quality and watershed health.

Chapter 1 Introduction to Watershed Management

A watershed is a land area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ocean. Any land surface surrounding the water body is considered part of the watershed. These land surfaces, ranging in size from small geological features to large portions of the country, contribute to the water system during runoff and rainfall events. For example, several sub-watersheds combine to form the Medina River Watershed, which is part of the larger San Antonio River Basin. These sub-watersheds include Medio and Polecat Creek, along with the Medina River.

Natural processes and human activities affect water quality and quantity within watersheds. Pollutants may enter a water body from a "point source," a fixed location such as a pipe or channel, or a "nonpoint source" where they're washed off the landscape by rainfall. Point sources are regulated by the Texas Commission on Environmental Quality (TCEQ) and require a permit to discharge to waterways. Nonpoint sources are not regulated in Texas and are controlled primarily through responsible land stewardship and voluntary land management practices.

The Watershed Approach

State and federal water resource management agencies widely accept the watershed approach to facilitate water resource management. The U.S. Environmental Protection Agency (EPA) describes the watershed approach as "a flexible framework for managing water resource quality and quantity within a specified drainage area or watershed" (USEPA 2008). This process includes engaging stakeholders to make management decisions supported by sound science. One critical aspect of this approach is that it focuses on hydrologic boundaries rather than political boundaries to address potential water resource impacts affecting all potential stakeholders.

These watershed-based plans, called watershed protection plans (WPP) in Texas, are voluntary, locally driven mechanisms that address complex water quality problems across political boundaries within a watershed. They provide a holistic framework to leverage and coordinate private, nonprofit, local, state, and federal agency resources.

The EPA developed guidance, including nine key elements designed to assist in effective watershed-based planning (USEPA 2008). Although the plans vary in methodology, content, and strategy based on local priorities and needs, successful plans contain these nine key elements.

1.) Identification of causes and sources of impairment,

2.) Expected load reductions from management strategies,
3.) Proposed management strategies,
4.) Technical and financial assistance needed to implement management measures,
5.) Information, education, and public participation needed to support implementation,
6.) Schedule for implementing management measures,
7.) Milestones for progress of WPP implementation,
8.) Criteria for determining success of WPP implementation, and
9.) Water quality monitoring

Stakeholders are the foundation and primary decision-making body for watershed planning in Texas. A stakeholder is anyone who lives, works, or recreates in the watershed, or may be affected by efforts to address water resource issues. Stakeholders may include individuals, groups, businesses, organizations, or agencies. Continuous involvement of stakeholders throughout the watershed approach is critical for effectively selecting, designing, and implementing management measures that address water quality and other water resource concerns.

Adaptive management involves developing a natural resource management strategy to facilitate decision-making based on an ongoing, science-based process. Such an approach includes results of continual testing, monitoring, evaluating applied strategies, and revising management approaches to incorporate new information, science, and societal needs (USEPA 2000). Adaptive management promotes flexibility for stakeholders in their decision-making process to account for uncertainty and to improve the performance of specific management measures (William et al. 2009). Using the process of adaptive management will help to implement strategies to address pollutant loadings and to promote efforts to understand further uncertainties in the watershed.

The Medina River below Medina Diversion Lake WPP

A biennial report published by the TCEQ identified water quality issues in portions of Medio Creek and the Medina River between Medina Diversion Lake and its confluence with Leon Creek, south of San Antonio (Figure 1-1). These issues include elevated concentrations of E. coli bacteria that could pose a risk for swimming and wading activities, and nutrient concentrations that could result in excess algae growth and diminished ecosystem health. This watershed protection plan was developed to address these issues.

This WPP identifies and documents potential sources of pollutants contributing to the bacteria and nutrient issues, as well as management measures to address them. Stakeholder recommendations are consistent with those in the 2015 San Antonio River Authority's Holistic Watershed Master Plan, including management measures such as watershed and water quality best management practices, low impact development concepts, and conservation easements to protect areas where development and changes in land use are occurring.

Development of a successful WPP depends on effective education, outreach, and engagement with stakeholders. Educational and outreach events are also the primary platform for delivery of information to stakeholders throughout the implementation process, and are integrated into many of the management measures detailed in this WPP.

Restoring and protecting water quality throughout the watershed is critical to maintaining its value to area communities, including recreational opportunities such as swimming, fishing, and kayaking; agricultural uses; and protection of sensitive recharge features to the Edwards aquifer - a significant water source for millions of people in the region.

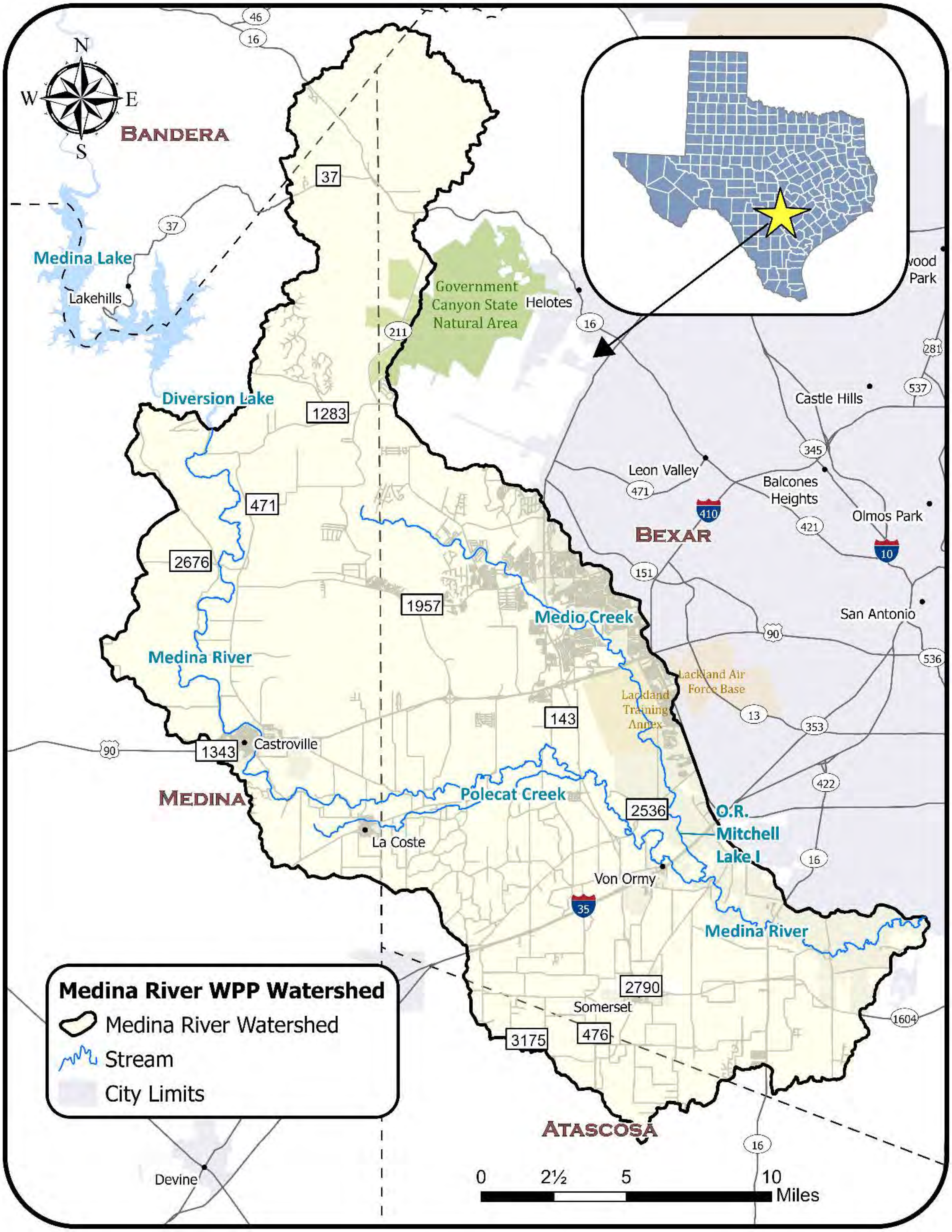

Figure 1-1. Watershed of the Medina River below Medina Diversion Lake.

Chapter 2 Watershed Characterization

This chapter provides an overview of the current and recent condition of the Medina River Below Medina Lake (Medina River WPP) watershed. Information presented here relied heavily on regional, state, and federal data resources, as well as local stakeholder knowledge. Characterization of the watershed as a whole is critical for assessing potential pollutant sources and recommending management measures to address water quality issues.

Physical Characteristics

The watershed is approximately 412 square miles of urban, suburban, and agricultural land in parts of Bexar, Medina, Bandera, and Atascosa counties (Figure 1-1). The watershed includes the cities of Somerset, Lacoste, Von Ormy, and Castroville, a portion of the City of San Antonio, and several smaller communities.

Physical characteristics of a watershed, such as slope, soil type, vegetation cover, and land use, determine how easily rainwater can transport pollutants across the land and into water bodies.

Topography

Watershed topography and soils are important components of watershed hydrology. Topographical properties like slope and elevation define where water will flow to and soil properties influence water infiltration rates, runoff generation, and may limit the types of land development that can occur in some areas.

Watershed elevation ranges for the Medina River Watershed from a maximum elevation of 1,899 feet above sea level in the north to a minimum elevation of 456 feet above sea level in the southeast (Figure 2-1). Elevation was determined using USGS 10-meter 3D Elevation Program. The northeast watershed lies at the edge of the Edwards Plateau and extends to the Texas Blackland Prairie at approximately 980 feet above sea level.

Soils

Hydrologic soil groups add to the understanding of soil within the watershed, and are based on the measure of precipitation, runoff, and infiltration. The primary hydrologic soil groups A, B, C, and D are found in this watershed (Figure 2-2) (USDA NRCS 2023). Group D has a high clay content which results in soil with a high runoff potential and very slow infiltration rates. The most common soil group in the watershed is Group D, making up 46% of the watershed, primarily in the central and northern regions. Group C is the second most common hydrologic soil group, making up approximately 32% of the watershed. Group C consists of finer soils and slow infiltrations rates and is located throughout the watershed but is concentrated in the southernmost region. Approximately 17% of the watershed is composed of Group B. Group B, well-draining silt loam or loam soils. This group is located along stream channels throughout the watershed. Group A is the smallest portion of the watershed by area at about 5%. This group contains sand, loamy sand, or sandy loan and has very low runoff potential and high infiltration rates. There is some Group A soil within water body channels, but the greatest concentration is located at the southernmost tip of the watershed.

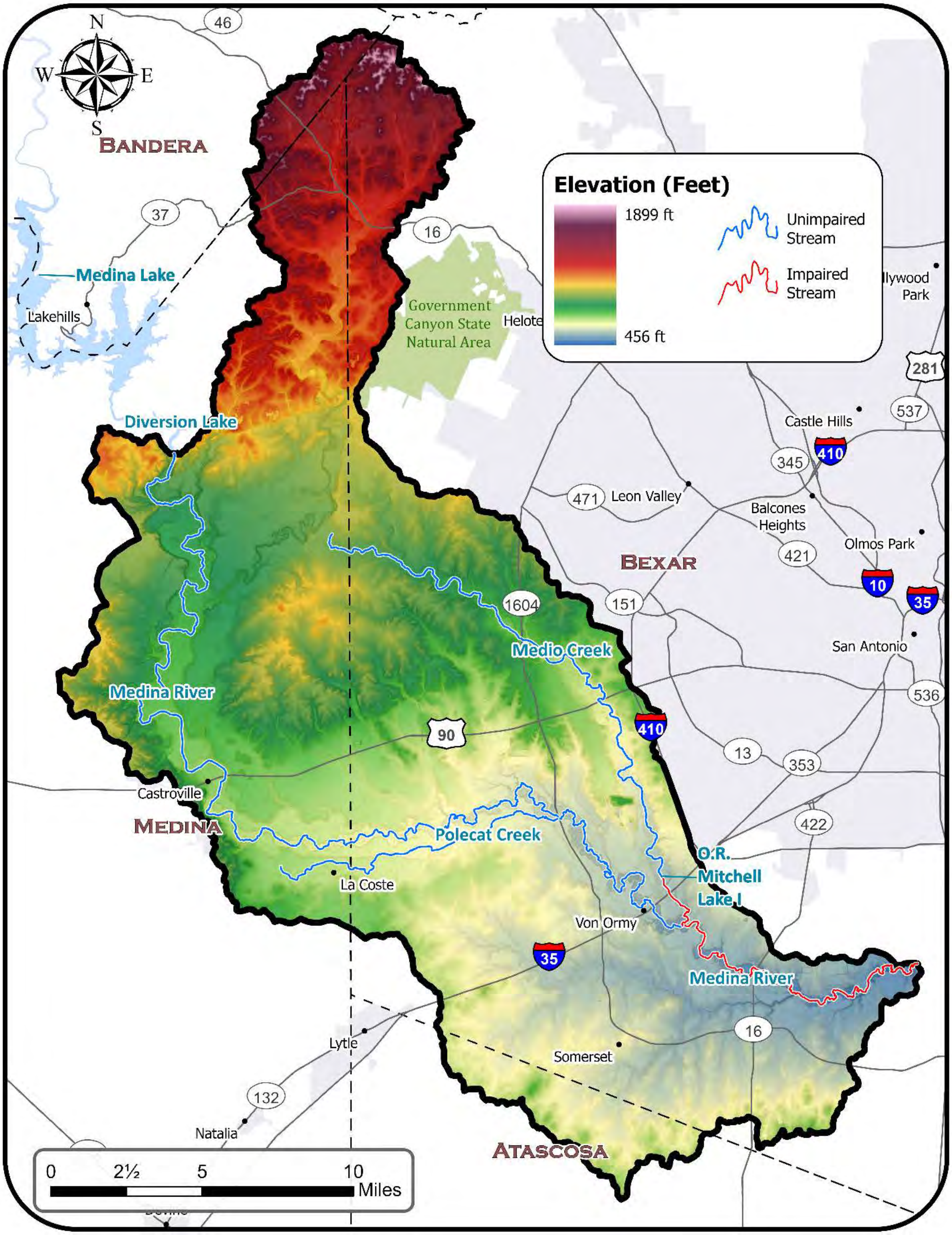

Figure 2-1. Elevation map for the Medina River Watershed. Map data from USGS 3D elevation program.

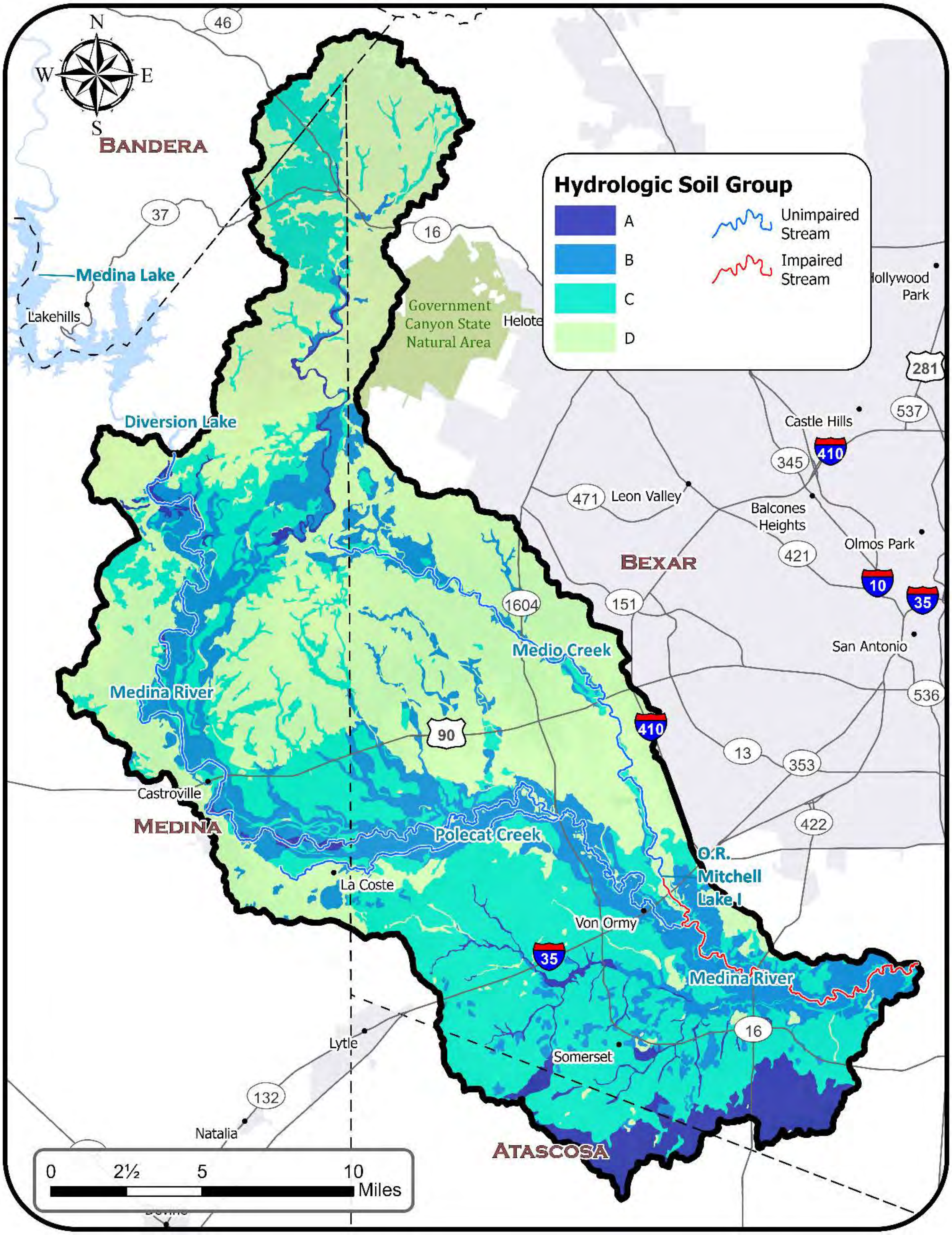

Figure 2-2. Hydrologic Soil Groups, USDA-NRCS.

Land Use and Land Cover

Overall, the Medina River Watershed is predominately rural except for the central-eastern edge of the watershed boundary. According to the 2021 National Land Cover Database (NLCD), the dominant land use and land cover (LULC) categories within the watershed are rangeland, developed, and cultivated crops, and evergreen forest (Figure 2-3; Table 3-1). Rangeland is comprised of shrubs, young trees, or stunted trees under 5 meters tall. Developed land uses include developed open space, as well as low, medium, and high intensity. The evergreen forest class is dominated by trees over 5 meters tall, with most species retaining their leaves year-round. Commonly cultivated crops in the watershed are corn, sorghum, and oats.

Table 2-1. Land use and land cover summary, 2021 NLCD.

	Classification	Square Miles	Percent of Watershed
	Developed, Open Space	20.6	5.0%
	Developed	44.1	10.7%
	Barren	4.5	1.0%
	Deciduous-Mixed Forest	30.2	7.3%
	Evergreen Forest	56	13.6%
	Rangeland	151.1	36.6%
	Grassland	15.2	3.7%
	Pasture/Hay	16	3.9%
	Cropland	63	15.3%
	Wetlands	10.2	2.5%
	Open Water	1.7	0.4%
	Total	**412.6**	**100%**

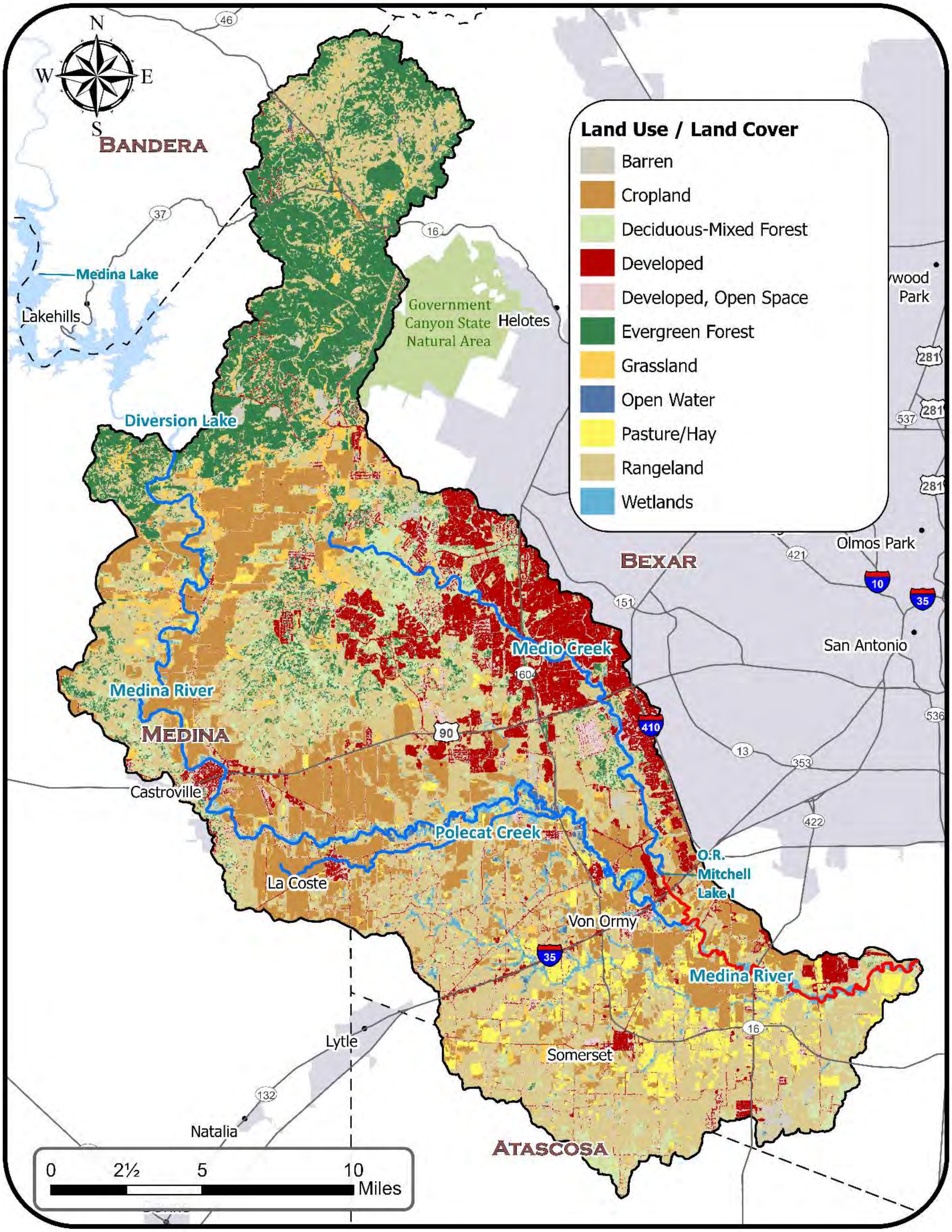

Figure 2-3. Land Use and Land Cover, 2021 National Land Cover Database.

The watershed has experienced rapid development over the last several years, with significant population increases and land use changes readily observed. Analysis of NLCD LULC data between 2001 and 2021 indicates that rangeland, forest and hay/pasture land cover has decreased by an average of 986 acres each year, and developed land use categories have increased an average of 828 acres each year in the same period (Figure 2-4).

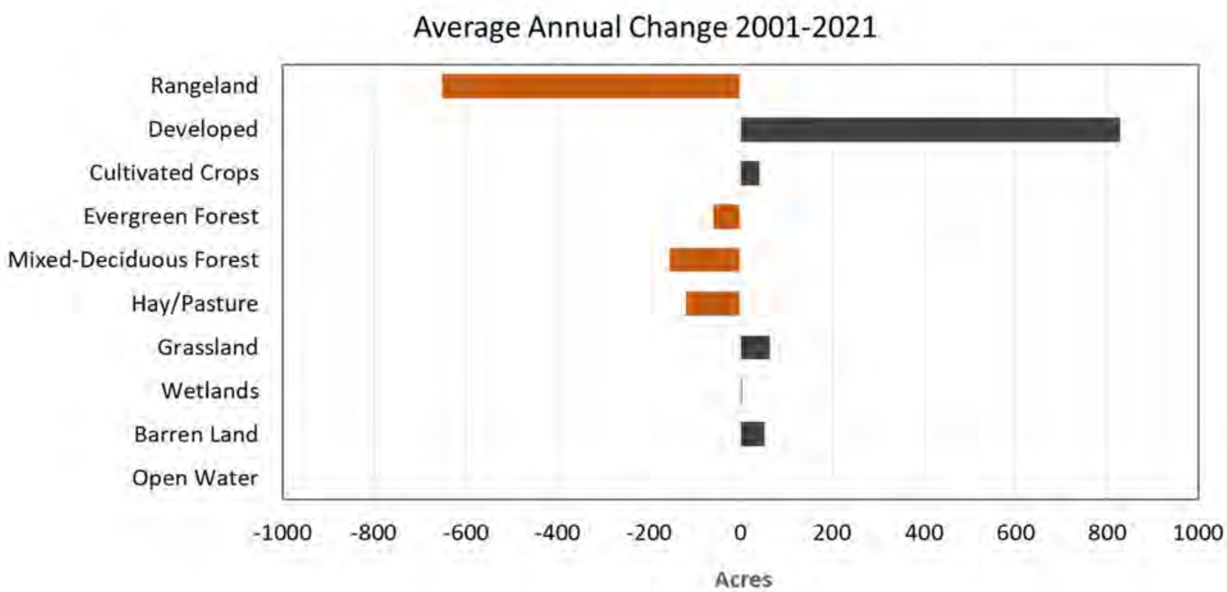

Figure 2-4. Average Annual Change in Land Use and Land Cover, 2001-2021

With population growth and land use changes expected to continue, stakeholders were interested in whether, and how, these changes might affect pollutant sources and the effectiveness of management strategies and measures. To aid in this analysis, the rate of change for each LULC category was projected over the next decade (Table 2-2). Data acquired from Bexar and Medina counties were used to estimate the rate of change for each land use category. Methodology used in this analysis is detailed in Appendix A.

Table 2-2. Projected land use and land cover change 2021 - 2036.

Classification		2021 (ac)	2036 (ac)	Average Annual Change (ac/yr)
	Rangeland	96,725	88,061	-578
	Developed	41,338	53,729	826
	Cultivated Crops	40,321	43,849	235
	Evergreen Forest	35,763	34,359	-94
	Mixed-Deciduous Forest	19,309	16,198	-207
	Hay/Pasture	10,232	8,791	-96
	Grassland	9,745	8,292	-97
	Wetlands	6,514	6,560	3
	Barren Land	2,851	3,039	13
	Open Water	1,058	980	-5

Ecoregions

Ecoregions are land areas with generally similar type, quality, and quantity of natural resources (Griffith et al. 2004). The Medina River WPP watershed is located in four level IV ecoregions: Northern Blackland Prairie, Balcones Canyonlands, Northern Nueces Alluvial Plains, and Southern Post Oak Savanna (Figure 2-4) (USEPA 2013) . The Northern Blackland Prairie dominates the watershed, covering 285 square miles, and consisting of rolling slopes with grasslands underlain by rich soil. The Balcones Canyonlands contains a highly variable landscape and covers around 67 square miles. The Northern Nueces Alluvial Plains covers about 32 square miles of the watershed with vegetation types including mesquite-oak trees, open grasslands, and large areas of rangeland. The Southern Post Oak Savanna covers around 27 sq miles and includes hardwood forests, pastures, and rangeland.

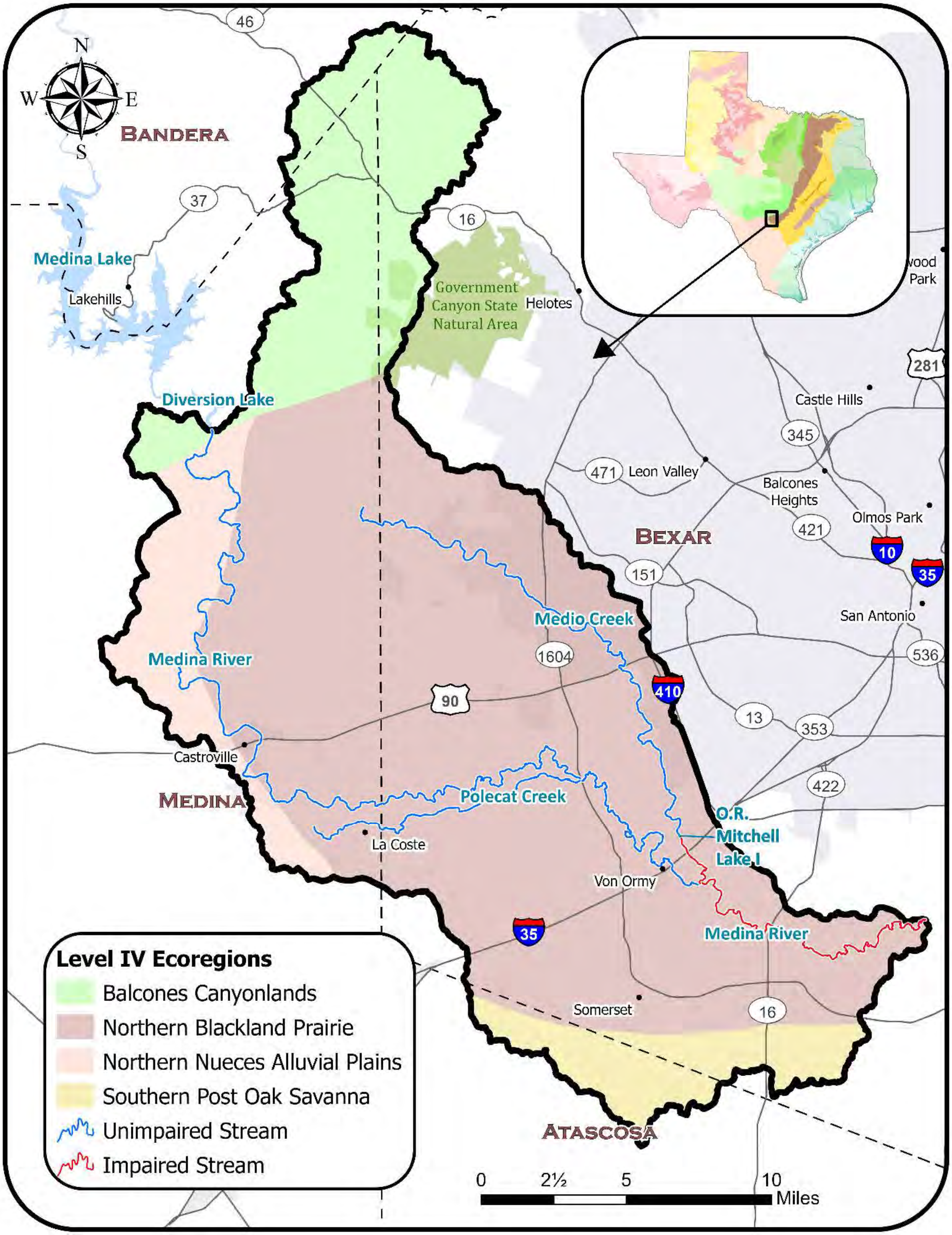

Figure 2-4. US EPA Level IV Ecoregions of the Medina River Watershed.

Climate

The Medina River WPP watershed is a humid subtropical climate with very warm summers and mild winters. According to data from the National Oceanic and Atmospheric Administration National Weather Service at the San Antonio Stinson Municipal Airport, the wettest months are May, September, and October, averaging over 3 inches of precipitation per month, and the driest month is February, averaging 1.1 inches. August is typically the warmest month, with an average maximum temperature of 98 °F, while January is the coldest, with a minimum temperature of 41 °F (Figure 2-5). The average annual precipitation ranges from 29 to 35 inches across the watershed (Figure 2-6).

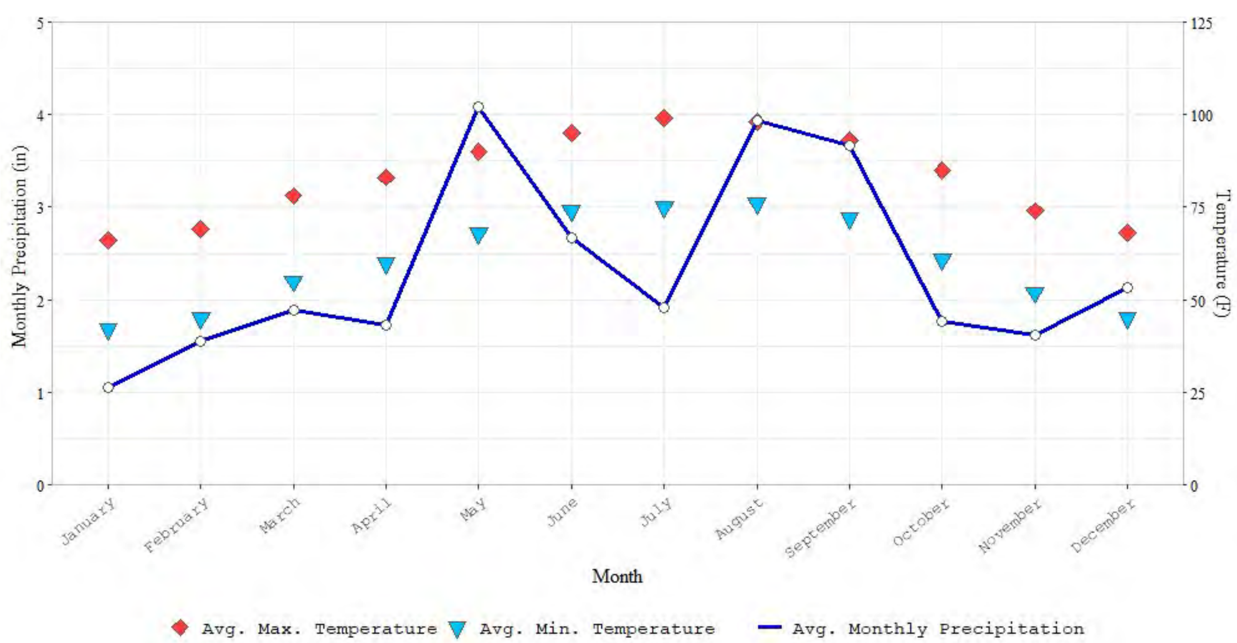

Figure 2-5. Monthly temperature and rainfall at San Antonio Stinson Municipal Airport, December 1, 2015 - November 30, 2022.

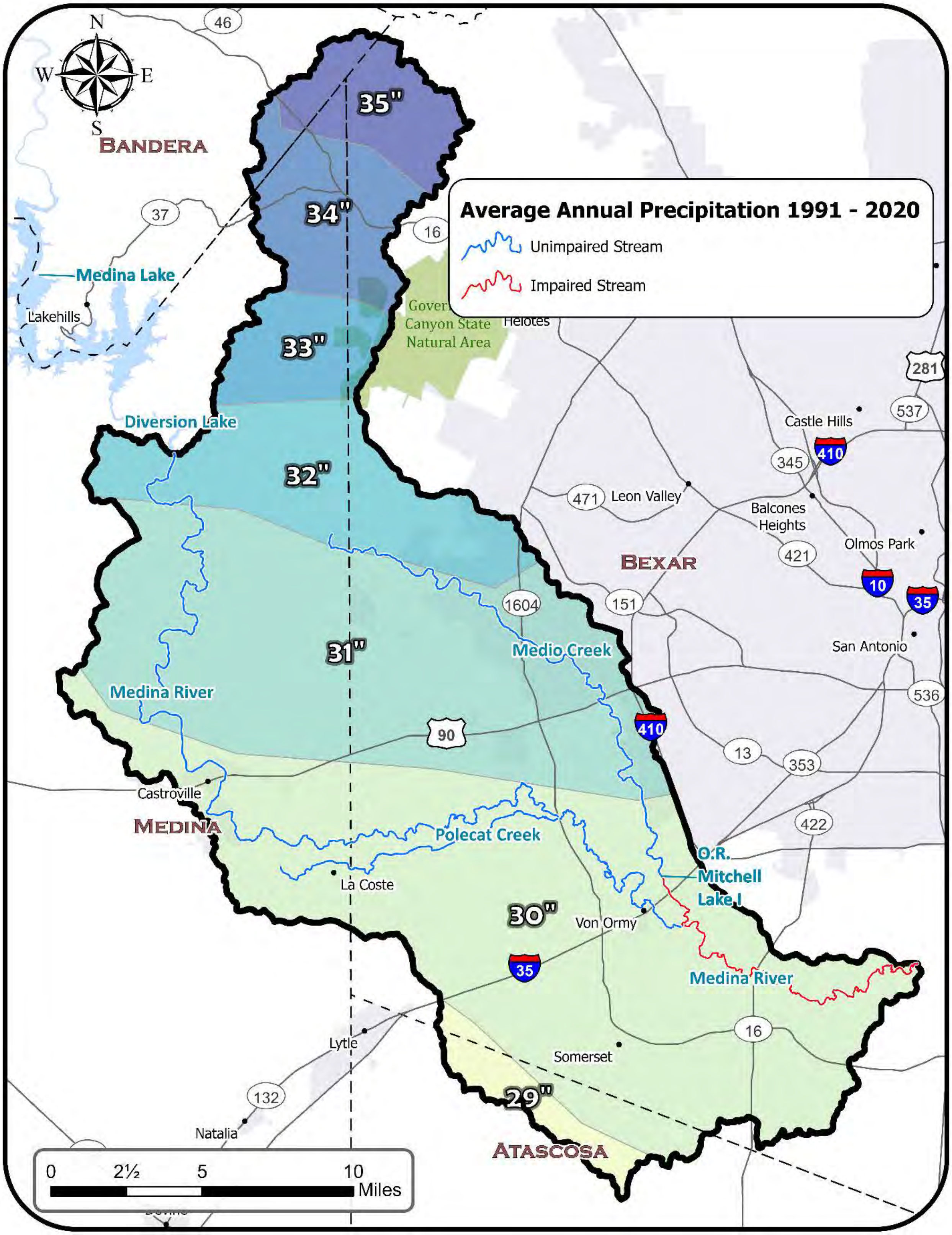

Figure 2-6. Average annual precipitation, 1991-2020.

Surface Water Resources

The Medina River WPP watershed includes the Medina River and its tributaries between Medina Lake and the confluence with Leon Creek in southern Bexar County (Figure 2-7). Major tributaries include Medio and Polecat Creeks. Several small unnamed lakes and ponds occur throughout the watershed. According to the National Hydrography Dataset (NHD), there are approximately 381 miles of perennial and intermittent streams and rivers in the watershed.

Medina River

The Medina River WPP watershed begins just south of Medina Lake at Diversion Lake in Paradise Canyon and flows approximately 69 miles south and eastward to the confluence with Leon Creek. Flow in the upper portions of the river is fed by springs, seepage from Medina Diversion Lake dam, and various small tributaries. Quality is generally high and significant recreation such as swimming, wading, and paddling occurs when sufficient water is available. Flow increases significantly below Castroville and below confluences with Polecat and Medio Creek.

Polecat Creek

Polecat Creek is a smaller tributary near the center of the Medina River watershed. , located upstream of the confluence of Medio Creek and Medina River. It starts just west of the city of La Coste and flows eastwards downstream for 11.7 miles until it meets the Medina River at Texas State Highway Loop 1604.

Medio Creek

Medio Creek flows approximately 26 miles from its headwaters near State Highway 211 at the Bexar-Medina county line, to its confluence with the Medina River south of Interstate 35 in Bexar County. The stream is divided into the Upper Medio Creek and Medio Creek, separated by O.R. Mitchell Lake just north of Interstate 35. The upstream reaches of Upper Medio Creek pass through largely open land and larger subdivisions but the watershed quickly becomes more densely urbanized as it passes through mixed use areas within the city of San Antonio and Joint Base San Antonio – Lackland, as well as forested and agricultural land. The lower portion of Medio Creek receives flow from O.R. Mitchell Lake, small ephemeral tributaries, and various stormwater facilities. It flows approximately 2.5 miles through mixed forested and agricultural land to its confluence with the Medina River in the lower part of the Medina River WPP watershed.

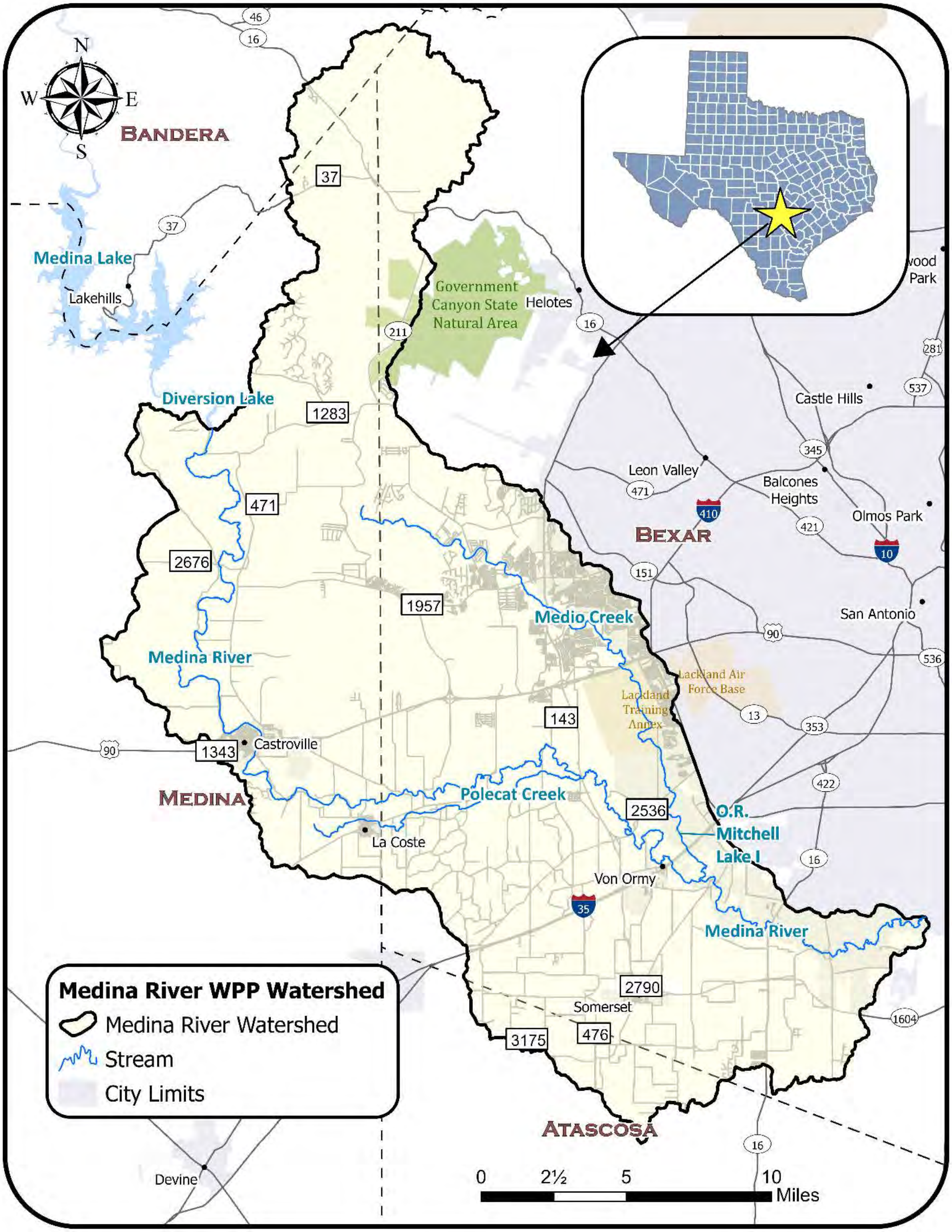

Figure 2-7. Watershed of the Medina River below Medina Diversion Lake.

Flow

Streamflow is dynamic and changes in response to both natural (e.g., precipitation events) and anthropogenic (e.g., changes in land cover or wastewater discharges) factors. Records indicate there are 2 active and 10 inactive USGS stream gaging stations in the watershed. Station 08180700 on the Medina River near Macdona (near the confluence with Polecat Creek) represented the only long-term instantaneous daily streamflow data (Figure 2-8).

For the period between 1981 and 2023, mean monthly streamflow at this gage was typically between 100 and 200 cubic feet per second for nine months out of the year (

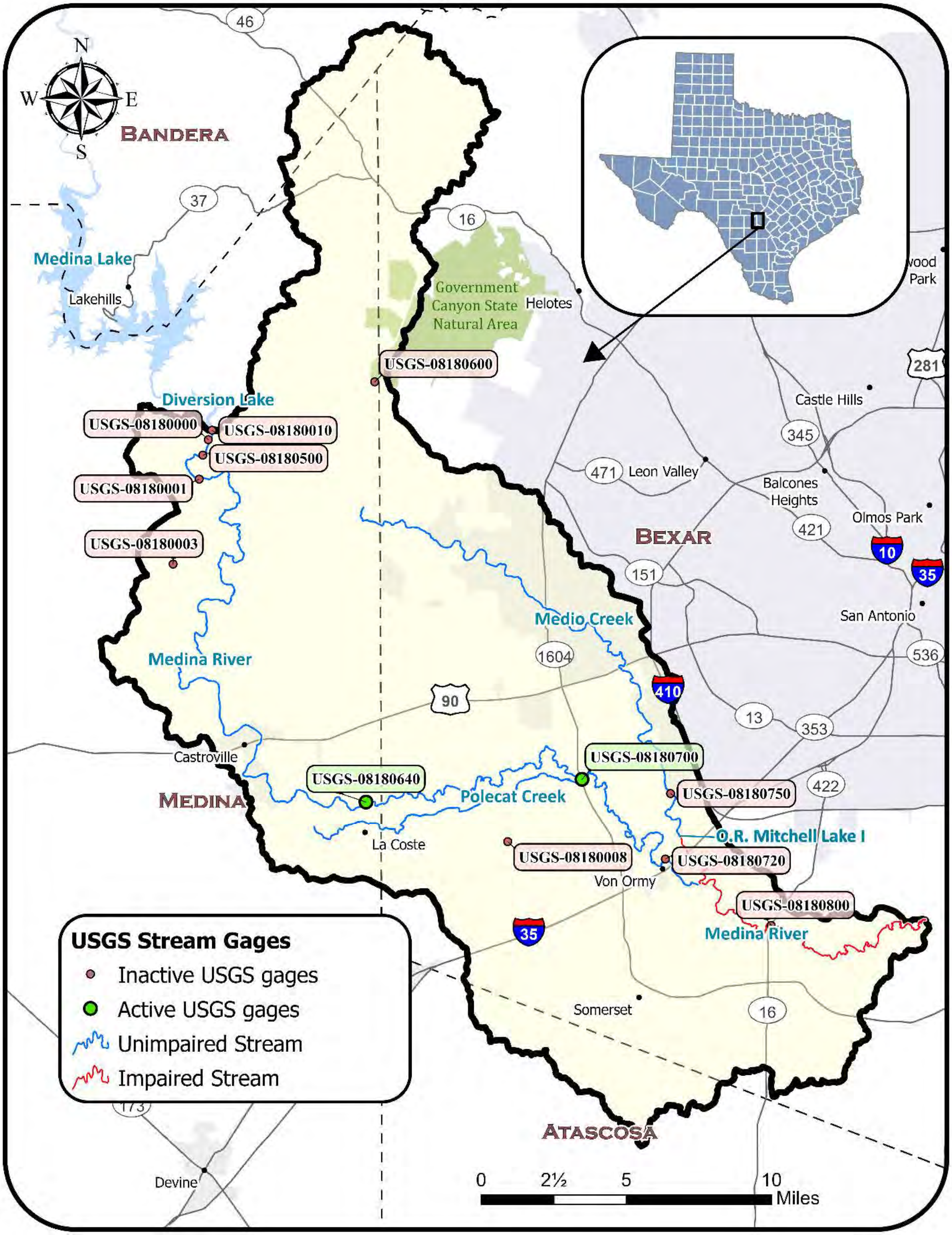

Figure 2-81 2-9a) and typically much higher during May through July. Comparatively, data for the period between 2016 and 2023 indicate lower streamflow during all months of the year, with mean monthly streamflow exceeding 100 cfs only during May and June (Figure 2-9b).

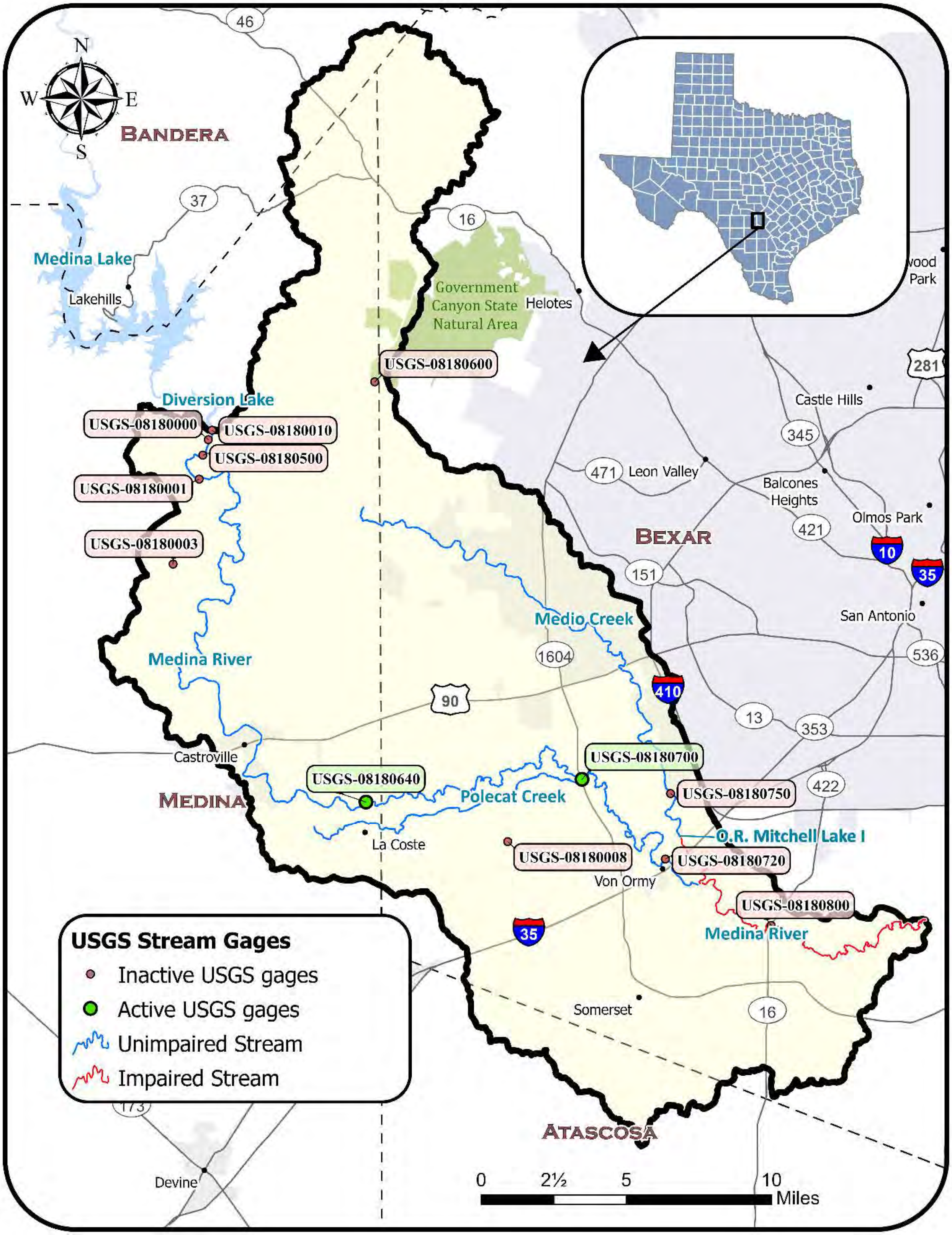

Figure 2-81. U.S. Geological Survey (USGS) active and inactive streamflow gages.

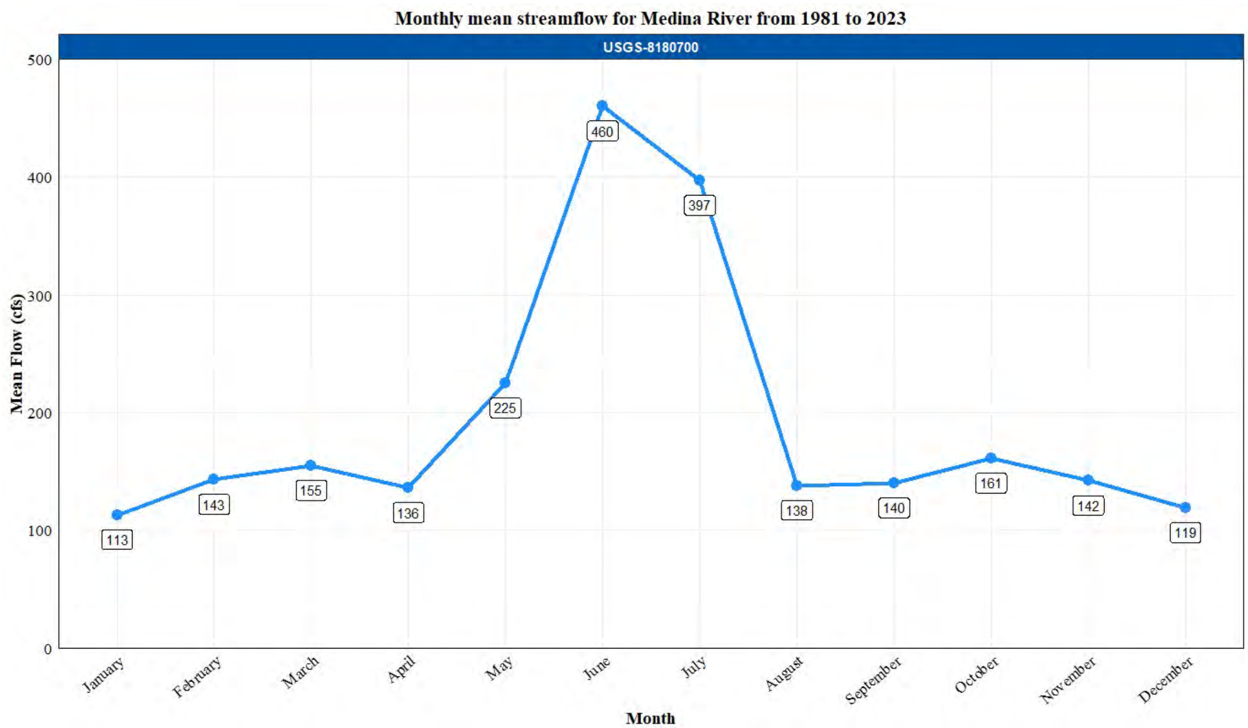

Figure 2-9a. Mean monthly streamflow at USGS Gage 08180700, 1981 - 2023.

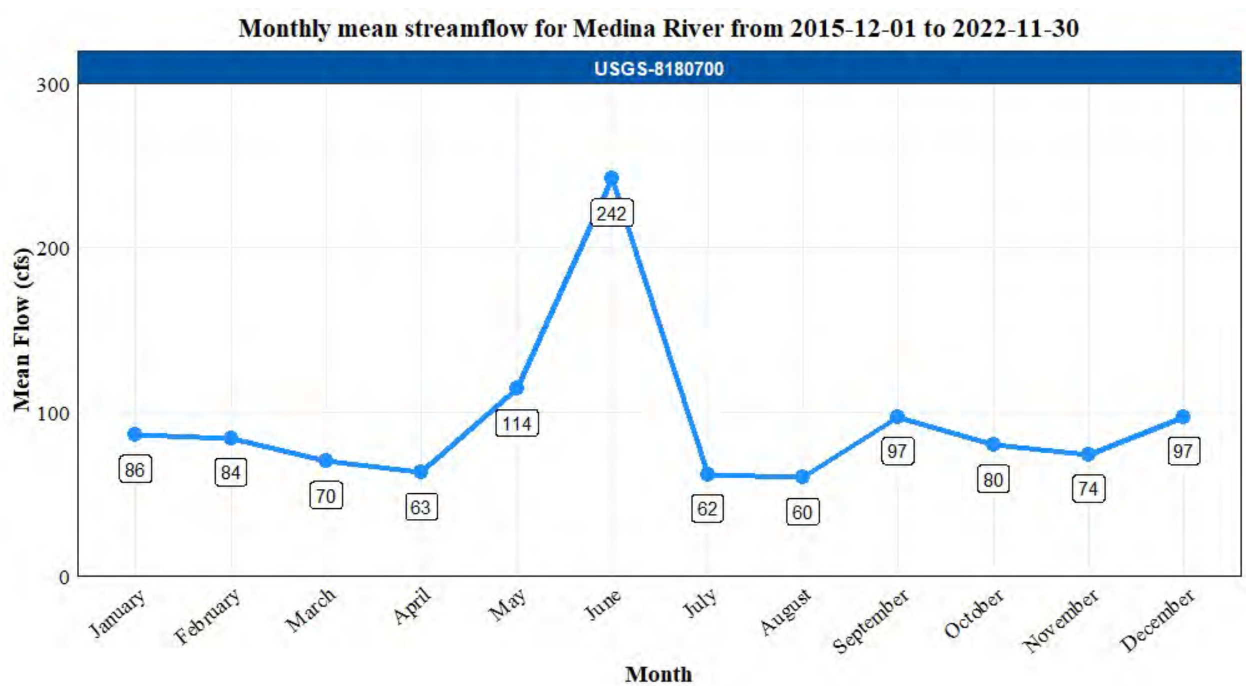

Figure 2-9b. Mean monthly streamflow at USGS Gage 08180700, 2016 - 2023.

Groundwater Resources

The Medina River WPP watershed contains three major aquifers: the Trinity, Carrizo-Wilcox, and Edwards Balcones Fault Zone (BFZ) aquifers (Figure 2-8).

The Trinity Aquifer outcrop is found in the northern tip of the watershed, encompassing 45 square miles. This aquifer also contains several productive water-bearing formations, such as the Glen Rose, and Antlers, all covered within the Trinity Group. These formations are composed of limestone, clay, gravel, and conglomerates, and when combined, they have a saturated thickness ranging from 600 to 1,900 ft. The water within this aquifer is hard, with total dissolved solids ranging from under 1,000 to 5,000 as depth increases. This aquifer is highly utilized by municipalities and for agricultural purposes, and sees some of the largest water level declines of the three aquifers.

The Edwards aquifer outcrop covers roughly 24 sq miles within the watershed and contains the highest quality water of the three aquifers. Total dissolved solids values are less than 500 mg/L and a saturated thickness depth ranges from 200 to 600 ft. The Edwards Aquifer is unique among the Texas aquifers because it is primarily composed of partially dissolved limestone, called karst limestone. The karst limestone features large fissures that create flow paths for water, resulting in a highly permeable saturated thickness. This gives the aquifer the ability to recharge rapidly but also making it more vulnerable to contamination by pollutants in surface water runoff.

Located in the southern portion of the watershed, the Carrizo-Wilcox Aquifer has an outcropping area of about 117 square miles. This aquifer is mostly composed of sands with an overall saturated thickness depth of nearly 3,000 ft. However, only the upper 670 ft of this aquifer contains freshwater, with more saline water below that depth. Total dissolved solids range from 1,000 to 7,000 mg/L.

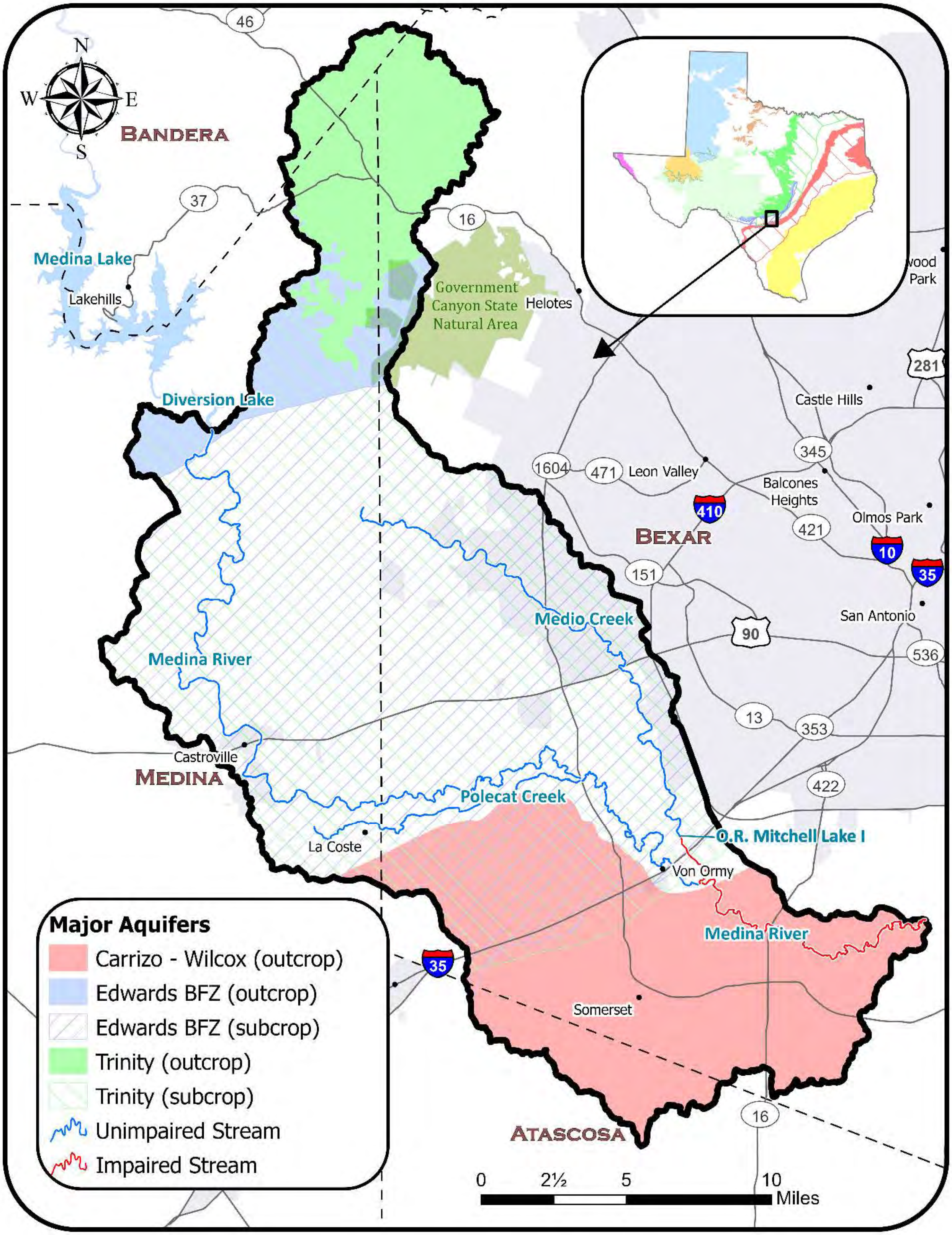

Figure 2-8. Major aquifers of the Medina River Watershed..

Water Resource Management

Surface water in Texas is owned by the state and held in trust for the citizens. The Texas Legislature relies on multiple state agencies and river authorities to manage and distribute surface water resources. The Texas Water Development Board's (TWDB) mission is to lead the state's efforts in ensuring secure future water supplies by collecting and making water-related data public, assisting with regional water supply and flood planning, and administering financial programs. The TCEQ issues water rights permits to individuals, municipalities, and industries for utilizing surface water for purposes other than domestic and livestock use. The agency also regulates the quality of surface water resources by setting and implementing standards for minimum quality thresholds, collecting water-related data, and issuing permits for regulated discharge of pollutants to surface water systems.

Regionally, river authorities work within their river basins to collect data and assess environmental conditions related to water quality, fish and aquatic life population surveys, and aquatic habitat condition. Working under TCEQ authorization, river authorities share this information to assist in assessment of water quality conditions across the state. Some river authorities are also regulated by TCEQ as drinking water providers and wastewater permittees. Although water management activities are associated with river basins and watershed boundaries, their jurisdictional areas assigned by the state legislature often follows county boundaries. The Medina River watershed is located wholly within the San Antonio River basin and partially within SARA's jurisdictional area of Bexar, Wilson, Karnes, and Goliad Counties (Figure 2-9).

Groundwater resources in Texas are primarily managed through groundwater conservation districts (GCD), which are established by the state legislature, or by TCEQ in limited cases, and allow landowners to collectively manage groundwater use within their district boundaries. These districts are the state's preferred method for managing groundwater, with the responsibility to develop and implement plans to conserve, protect, and recharge groundwater within their boundaries. The majority of the Medina River Watershed is managed by the Edwards Aquifer Authority (EAA) and Medina County GCD (Figure 2-10), with smaller areas managed by the Bandera County River Authority and Ground Water District, Evergreen Underground Waer District, and the Trinity Glen Rose GCD. These entities have the authority to either oversee water well production and regulate the spacing of these wells.

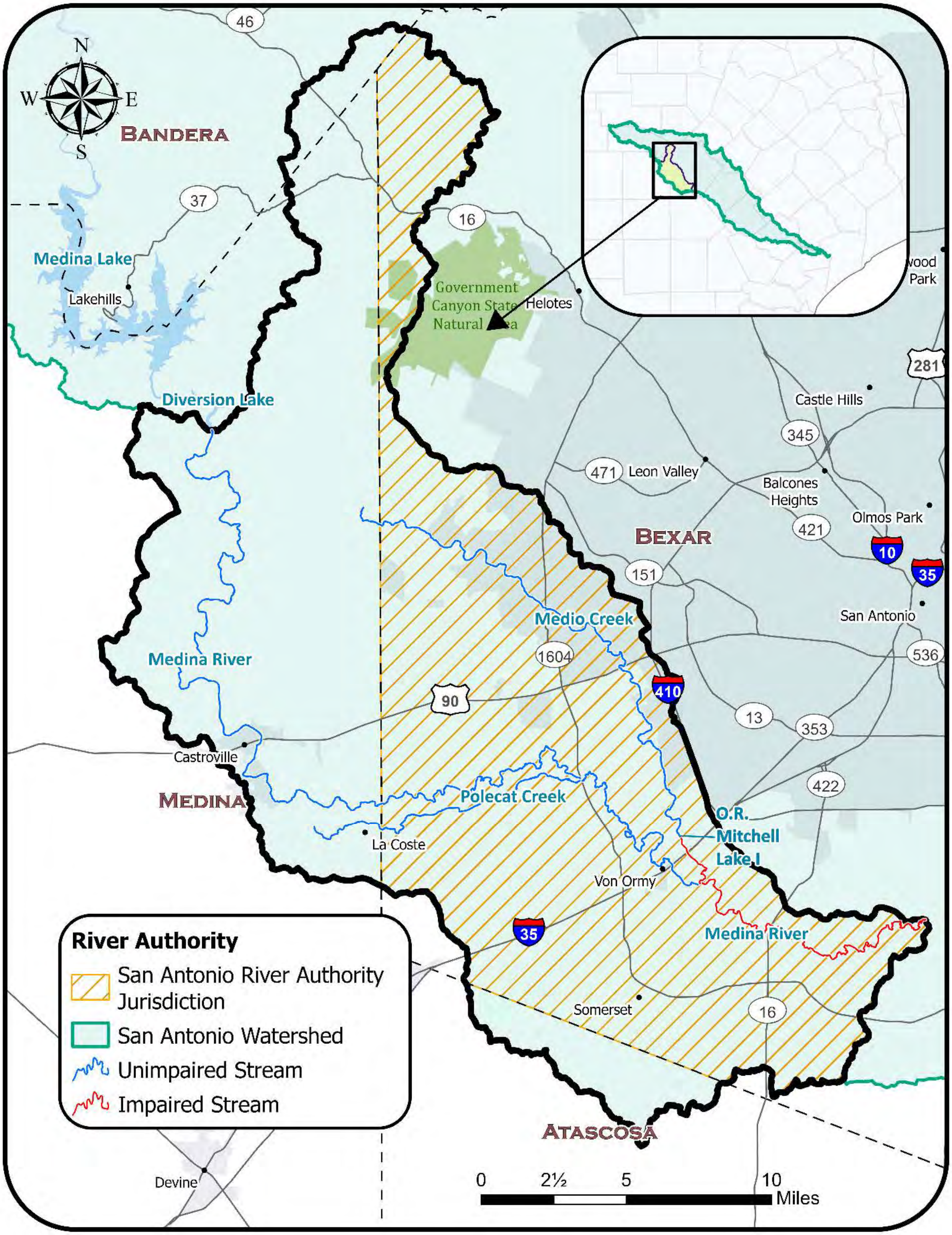

Figure 2-9. River Authority boundaries for the Medina River Watershed.

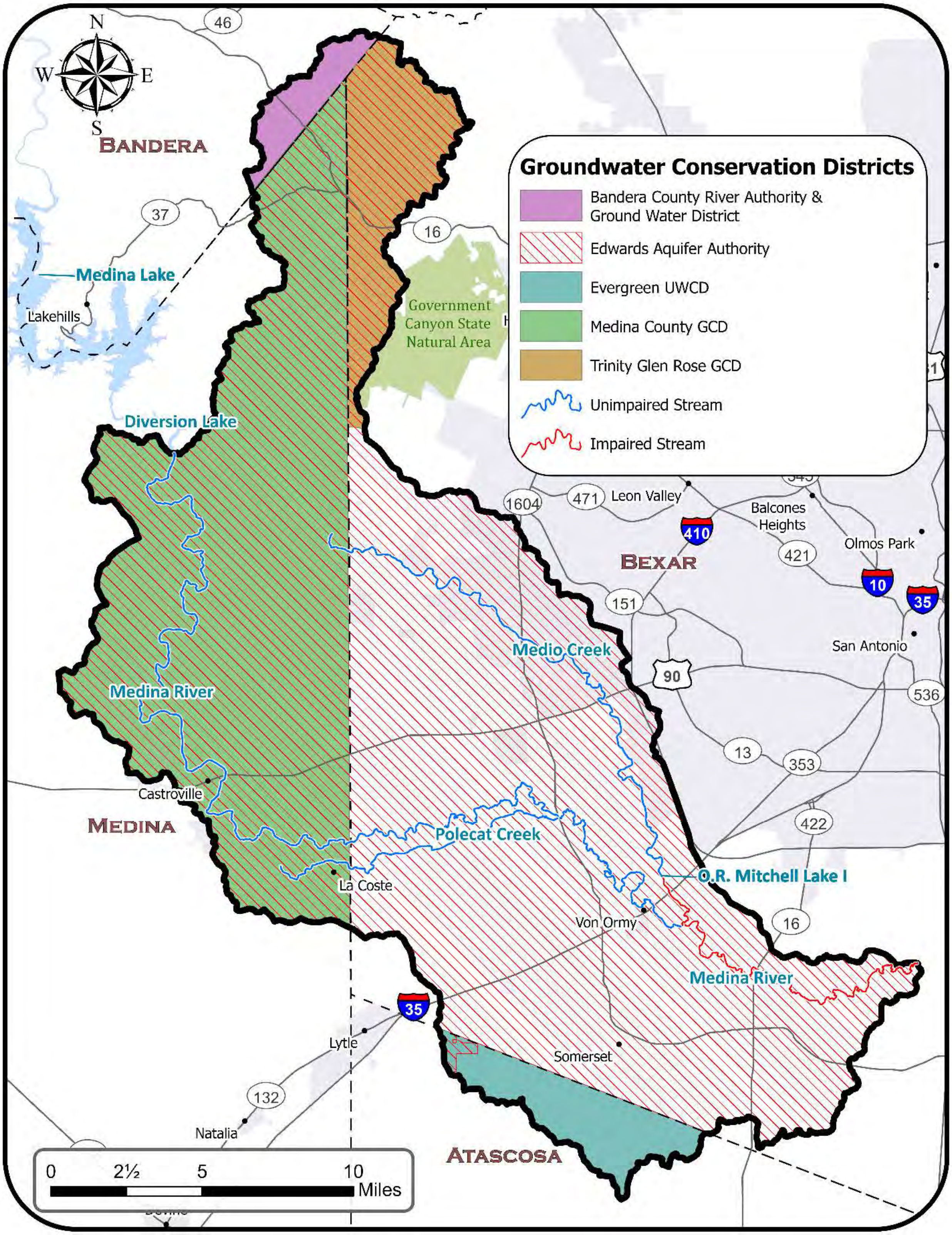

Figure 2-10. Groundwater conservation districts within the Medina River WPP Watershed.

Population and Demographics

According to data from the 2020 U.S. Census Bureau (USCB) data, population of the watershed was approximately 229,830, with greatest density occurring north of US-90 in Bexar County (Figure 2-11). Lowest densities were located in the far northern, western, and southeastern portions of the watershed where agricultural land uses still dominated.

The EPA EJScreen tool was applied to the watershed in June of 2024 and indicates that the watershed contains 32 areas listed as EPA Inflation Reduction Act (IRA) Disadvantaged Communities. These communities make up approximately 22% of the estimated total watershed population. The tool combines socioeconomic and environmental information to identify communities that may be vulnerable to environmental risk factors (USEPA 2024) (Table 2-3).

Table 2-3. EPA EJScreen indices.

EJScreen Indexes	
Particulate Matter 2.5	Superfund Proximity
Ozone	RMP Facility Proximity
Nitrogen Dioxide	Hazardous Waste Proximity
Diesel Particulate Matter	Underground Storage Tanks
Toxic Releases to Air	Wastewater Discharge
Traffic Proximity	Drinking Water Non-Compliance
Lead Paint	

Of the 32 communities, 13 are also "Justice40 (CEJST)" Disadvantaged Communities. These census tracts meet the thresholds for at least one of the Climate and Economic Justice Screening Tool’s categories of burden. The defined categories of burden include climate change, energy, health, housing, legacy pollution, transportation, water & wastewater, and workforce development. The Justice40 tool is designed to identify disadvantaged communities that are marginalized, underserved, and overburdened by pollution (USEPA 2024).

The watershed is undergoing rapid development and significant population growth is expected for most counties within the watershed (TDC, 2024). With population growth, increases in residential and commercial development are expected. This development could adversely affect natural watershed function, further straining existing drainage and wastewater infrastructure, and generally increasing adverse water quality effects across the watershed.

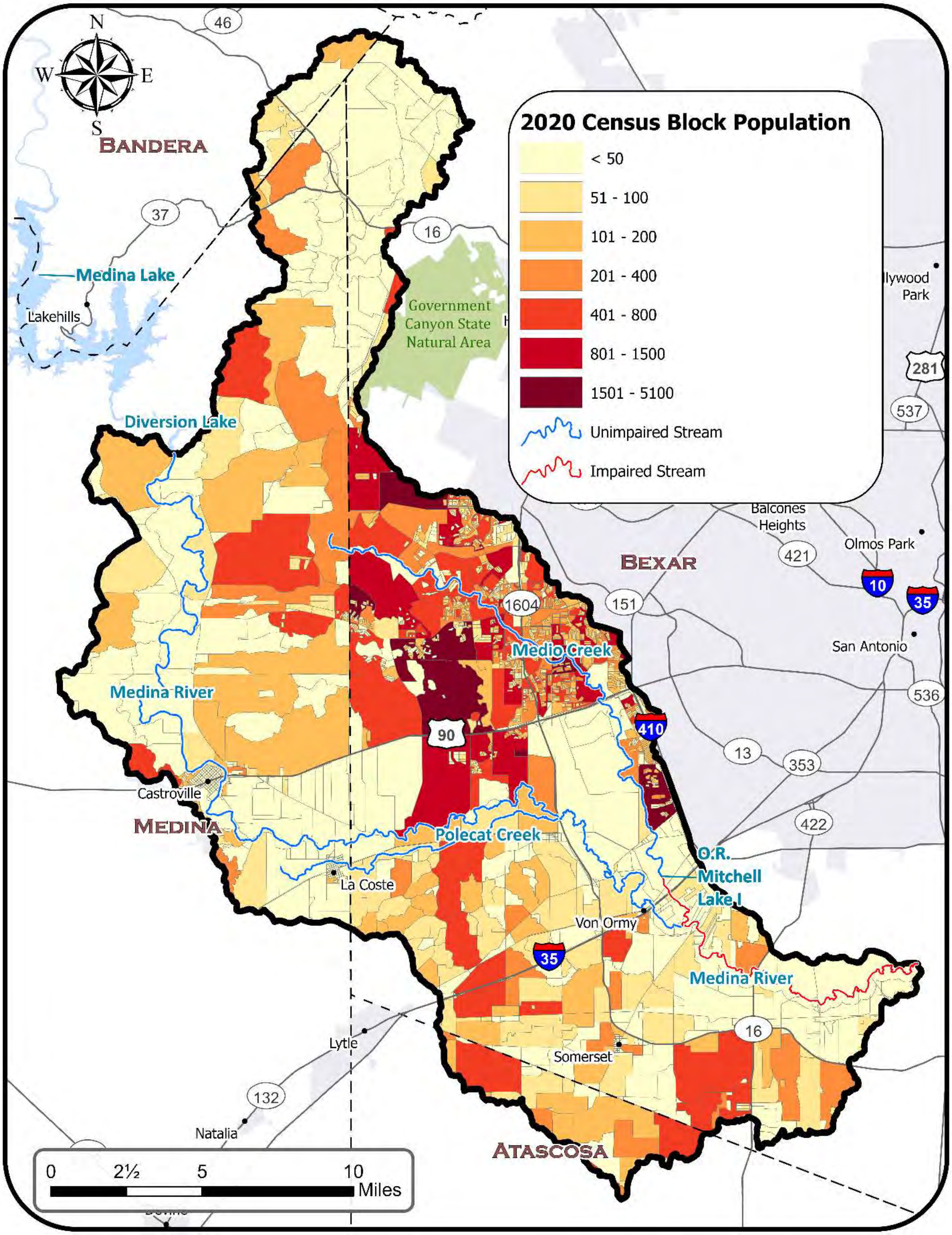

Figure 2-11. Census block population within the Medina River Watershed.

To aid in the watershed planning process, regional analysis of population growth was used to estimate population growth over the next decade (Table 2-4). Census data were combined with student enrollment forecasts by the Medina Valley Independent School District (MVISD). The district covers the vast majority of the watershed, including some of the most rapidly growing areas, and is considered to be a reliable source of information by stakeholders. Reported student enrollment from the 2016 to 2024 school years and projected enrollment for the 2025 to 2034 school years were combined to develop a linear model of population growth. Methodology for this analysis is detailed in Appendix A.

Table 2-4. Estimated watershed population growth 2020 - 2035.

Year	2020	2025	2030	2035
MVISD Total Students	5,852	9,484	14,302	20,020
Estimated Watershed Population	205,118	332,423	501,298	701,737
Estimated Growth Rate	-	62.06%	47.63%	39.98%

Chapter 3 Water Quality

This chapter describes the status of major water bodies in the Medina River WPP watershed and provides the rationale and regulatory basis for TCEQ determinations of water quality concerns and impairments. Information in the following sections also describes the processes of monitoring water bodies and assessing water quality data, the significance of various water quality parameters, and provides historical data and trends of parameters of concern. Conditions described here provide a baseline against which to measure progress in improving and restoring water quality through implementation of strategies and activities described in later chapters.

Texas Surface Water Quality Standards

The Clean Water Act (CWA) §303 requires states to set standards that maintain and restore the chemical, physical, and biological integrity of the nation's waters. This means that state regulations protect fish, wildlife, and recreation in and on the water , and consider the use and value of state waters for public supplies, wildlife, recreation, agricultural, and industrial purposes.

Based on this mandate, TCEQ develops and adopts water quality standards for Texas that are reviewed and approved by EPA. Water quality standards include multiple components. *Designated uses* describe specific goals and expectations for how each water body is used, such as contact recreation, aquatic life, public water supply, and agriculture. *Criteria* specify the desired condition of a water body. Criteria may be numeric or narrative but are most often expressed as a numeric threshold for a specific parameter. In some cases, screening levels are assigned when regulatory criteria have not been established.

For the Medina River and Medio Creek, the designated use of primary contact recreation is supported by a criterion expressed as 126 cfu/100 mL of E. coli bacteria (Table 3-1). If E. coli bacteria concentrations consistently remain below this criterion, the recreation use is met and no action is taken. If concentrations consistently remain above this criterion for a set amount of time, TCEQ is required to take action to address the sources of bacteria and put in place management measures to restore water quality. In the Medina River WPP watershed, regulatory criteria have been approved for most parameters but screening levels are used to assess water quality for nutrients.

Table **3-1**. Designated uses use categories and criteria for water bodies in the Medina River WPP watershed.

Designated Use	Parameter	Criterion or Screening Level
Aquatic Life Use - High	Dissolved Oxygen	5.0/3.0 mg/L*
Aquatic Life Use - Intermediate	Dissolved Oxygen	4.0/3.0 mg/L*
General Use	Nitrate Total Phosphorus	1.95 mg/L 0.69 mg/L
Public Water Supply or Aquifer Protection	N/A	N/A
Recreation - Primary Contact	E. coli	126 cfu/100 mL
*seasonal criteria		

Water Quality Monitoring and Assessments

The CWA §305 requires states to assess water quality data and report the extent to which individual water bodies support their designated uses. To meet this requirement, the TCEQ publishes the Texas Water Quality Inventory every two years to summarize the status of the state's surface waters, including concerns for public health, fitness for use by aquatic species and other wildlife, and specific pollutants and their possible sources. The CWA §303 also requires states to identify water bodies that are not supporting their designated uses, commonly referred to as the 303(d) List, which is reviewed and approved by EPA. The 2022 303(d) List is the most recent version approved by EPA. TCEQ publishes the Texas 303(d) List with the Water Quality Inventory in a single report, referred to as the Texas Integrated Report.

For assigning water quality standards, the TCEQ divides water bodies into smaller units called *segments*. Because these units can be quite large, segments are further divided into smaller *assessment units* (AU) for purposes of evaluating water quality for the Integrated Report. Each AU is intended to contain similar chemical, physical, and hydrological characteristics. The Medina River WPP watershed contains six AUs assessed for the Integrated Report (Table 3-2).

Table 3-2. TCEQ segments and assessment units in the Medina River WPP watershed.

Segment Name	Assessment Unit	Assessment Unit Description
Medina River Below Medina Diversion Lake	1903_03	From the confluence with Lower Leon Creek upstream to the confluence with Medio Creek
	1903_04	From the confluence with Medio Creek upstream to the confluence with Polecat Creek approximately 125 m upstream of FM 1604
	1903_05	From the confluence with Polecat Creek approximately 125 m upstream of FM 1604 upstream to the Medina Diversion Dam
Medio Creek	1912_01	From the confluence with the Medina River in Bexar County to a point 1.0 km (0.6 mi) upstream of IH 35 at San Antonio in Bexar County
	1912A_01	From approximately 1.0 km (0.6 mi) upstream of IH 35 at San Antonio (Bexar County) to approximately 1.0 mi upstream of the Bexar/Medina County Line
Polecat Creek	1903A_01	From 6.4 km above confluence with the Medina River to the spring source 1.3 km above FM 2790 southeast of Lacoste

Water quality, biological, and aquatic habitat data is collected at a network of monitoring sites by TCEQ and various partner agencies and river authorities (Figure 3-1). These data are put into the TCEQ's Surface Water Quality Monitoring Information System, a statewide database that stores, manages, and makes water quality data publicly available. The data undergoes a rigorous quality control and evaluation process before being assessed for the statewide Integrated Report. Based on analysis of the previous seven years of monitoring data, each AU is assigned a category of Fully Supporting (FS), No Concern (NC), Nonsupport (NS), Use Concern (CN), or Screening Level Concern (CS), according to the level of support of its associated water quality standards. Data collected between December 1, 2013 and November 30, 2020 were used to assess water bodies in the 2022 Integrated Report.

According to the 2022 Integrated Report, assessment units 1903_03 of the Medina River and 1912_01 of Medio Creek are classified as impaired due to elevated bacteria, and were first listed as impaired in the 2010 Integrated Report. The criteria for impairment of the primary contact recreation use is 126 colony-forming units (cfu) of *E. coli* per 100 milliliters (mL) of water. Concerns about elevated nitrate and total phosphorus concentrations are also identified for portions of the Medina River and Medio Creek (Table 3-3).

Table 3-3. Water body impairments and concerns in the Medina River WPP watershed.

Water body	AU	Parameter	Criteria	Mean of Data Assessed	Integrated Report Status
Medina River Below Medina Diversion Lake	1903_03	E. coli Nitrate	126 cfu/100 mL 1.95 mg/L	257 cfu/100 Ml n/a	NS CS
	1903_04	Nitrate	1.95 mg/L	n/a	CS
Medio Creek	1912_01	E. coli Nitrate	126 cfu/100 mL 1.95 mg/L	174.67 cfu/100 mL n/a	NS CS
	1912A_01	Nitrate Total Phosphorus	1.95 mg/L 0.69 mg/L	n/a n/a	CS CS

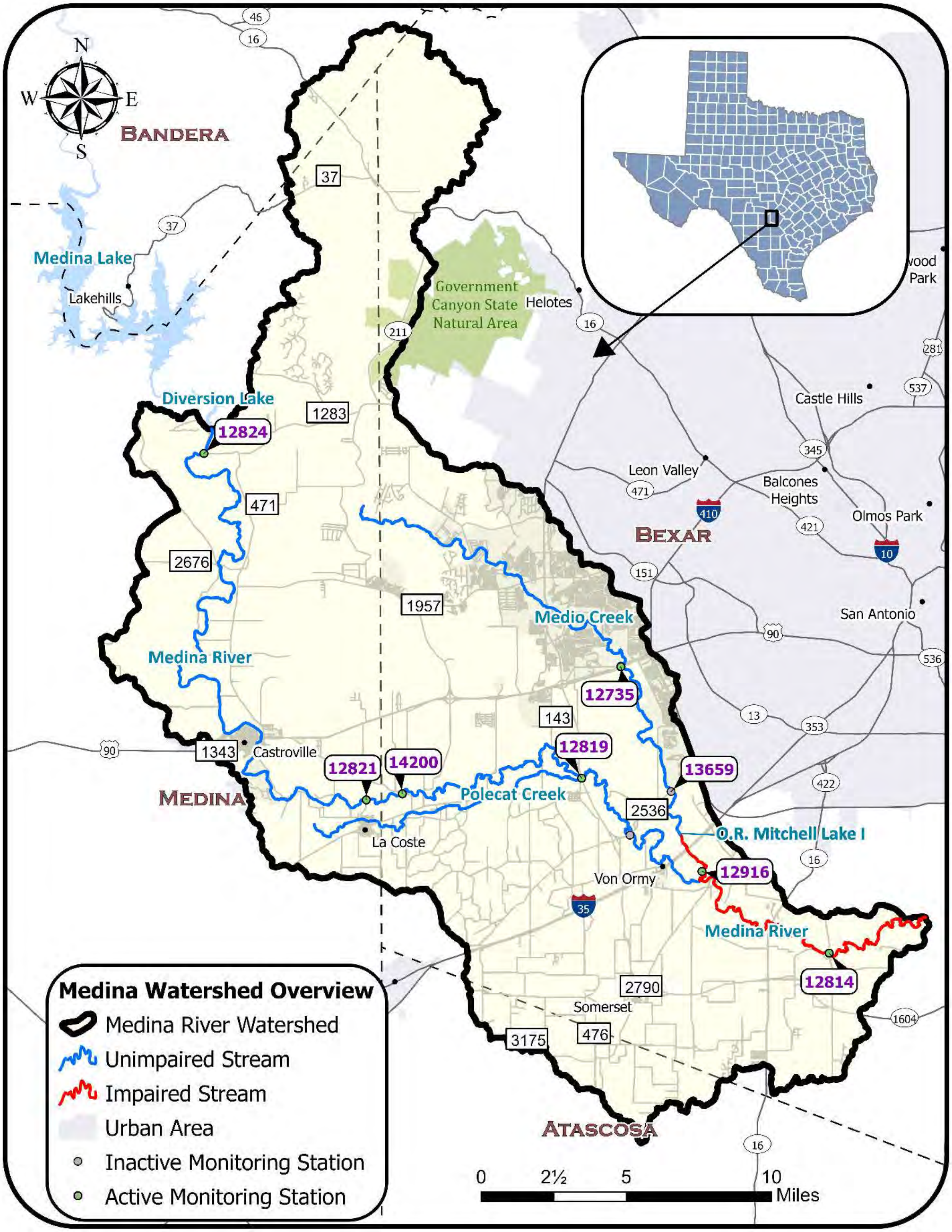

Figure 3-1. TCEQ monitoring stations and USGS gages within the bounds of Medina River Watershed.

Bacteria

Concentrations of E. coli bacteria are evaluated to assess a water body's ability to meet its contact recreation use. The presence of these bacteria may indicate that associated pathogens from the intestinal tracts of warm-blooded animals or other sources could be reaching water bodies and could cause illness in people that recreate in them. This standard must be assessed from at least 20 samples during the 7-year assessment period. Common sources that indicator bacteria can originate from include wildlife, domestic livestock, pets, malfunctioning on-site sewage facilities (OSSFs), urban and agricultural runoff, sewage system overflows, and direct discharges from wastewater treatment facilities (WWTFs). E. coli data from the Medina River and Medio Creek are graphed below, along with the numeric criteria (126 cfu/100mL) as well as the monitoring station numbers where data were collected (Figures 3-2a and 3-2b).

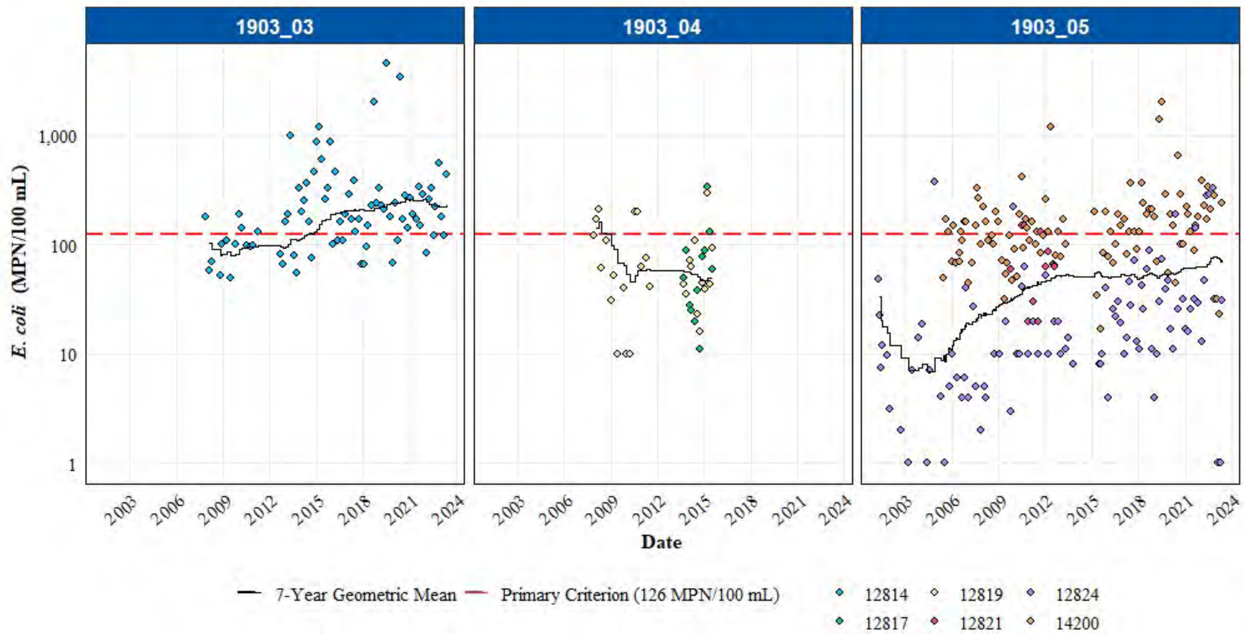

Figure 3-2a. *E. coli* concentrations in the Medina River Below Medina Diversion Lake.

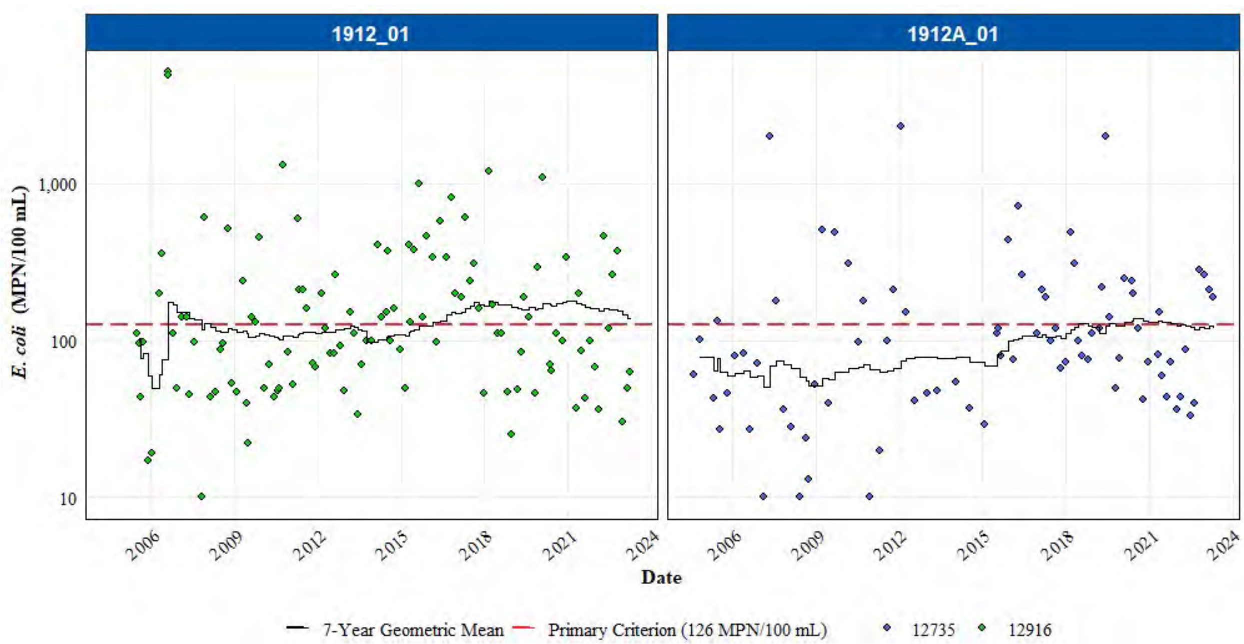

Figure 3-2b. Historical *E. coli* concentrations in Medio Creek.

Dissolved Oxygen

Dissolved oxygen (DO) is the main parameter to determine a water body's ability to support and maintain aquatic life. If DO levels in a water body drop too low, fish and other aquatic species will not survive. Typically, DO levels fluctuate throughout the day, with the highest levels of DO occurring in mid to late afternoon due to plant photosynthesis. DO levels are typically lowest just before dawn as plants and animals in the water continue to consume oxygen while the natural production of DO typically slows overnight. Furthermore, seasonal fluctuations in DO are common because of decreased oxygen solubility in water as temperature increases; therefore, it is common to see lower DO levels during summer than the winter.

While DO can fluctuate naturally, human activities can also cause abnormally low DO levels. Excessive organic matter (vegetative material, untreated wastewater, etc.) can result in depressed DO levels as bacteria break down the materials and consume oxygen. Excessive nutrients from fertilizers and manures can also depress DO as aquatic plant and algae growth increase in response to nutrients. The increased respiration from plants and decay of organic matter as plants die off can also lower DO concentrations.

When evaluating DO levels in a water body, TCEQ considers that monitoring events need to be spaced over an index and critical period. The index period represents the warm-weather season of the year and spans from March 15th to October 15th. The critical period of the year is July 1st to September 30th and is the portion of the year when minimum streamflow, maximum temperatures, and minimum DO levels typically occur across Texas. At least half of the samples used to assess stream DO levels should be collected during the critical period, with one-fourth to one-third of the samples from the index period. DO measurements collected during the cold months are not considered because the flow and DO levels are typically highest during winter (30 TAC § 307.7). DO data from the Medina River and Medio Creek are graphed below, along with their associated numeric criteria and monitoring station numbers where data were collected (Figures 3-3a and 3-3b).

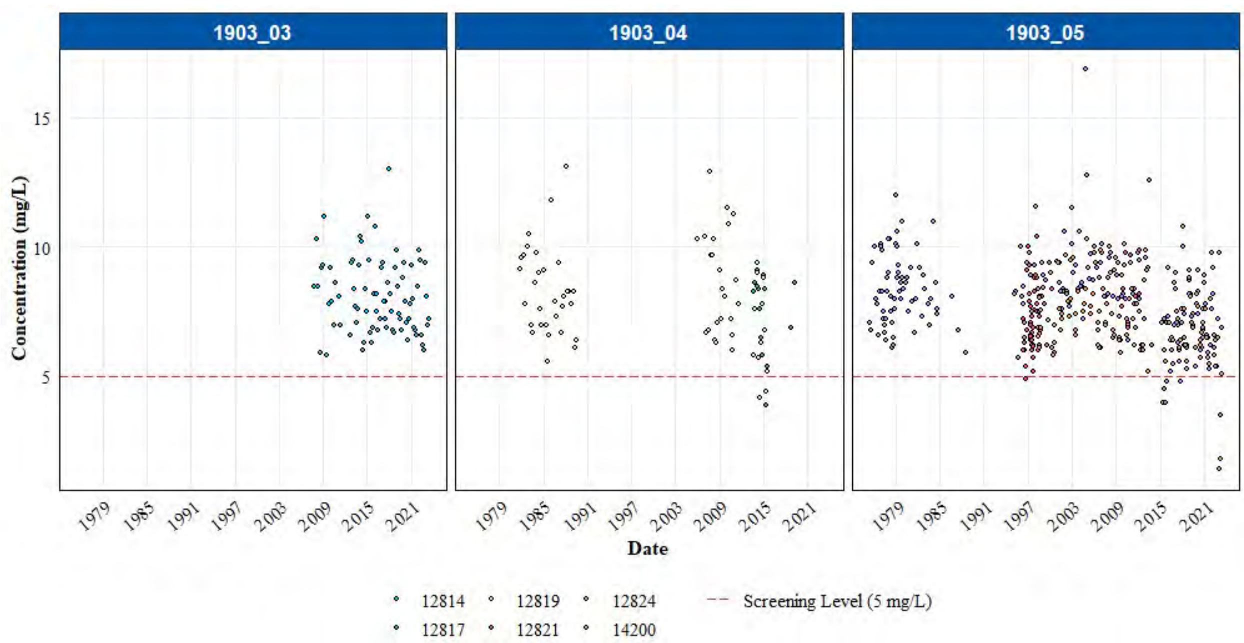

Figure 2-3a. Historical dissolved oxygen concentrations in the Medina River Below Medina Diversion Lake.

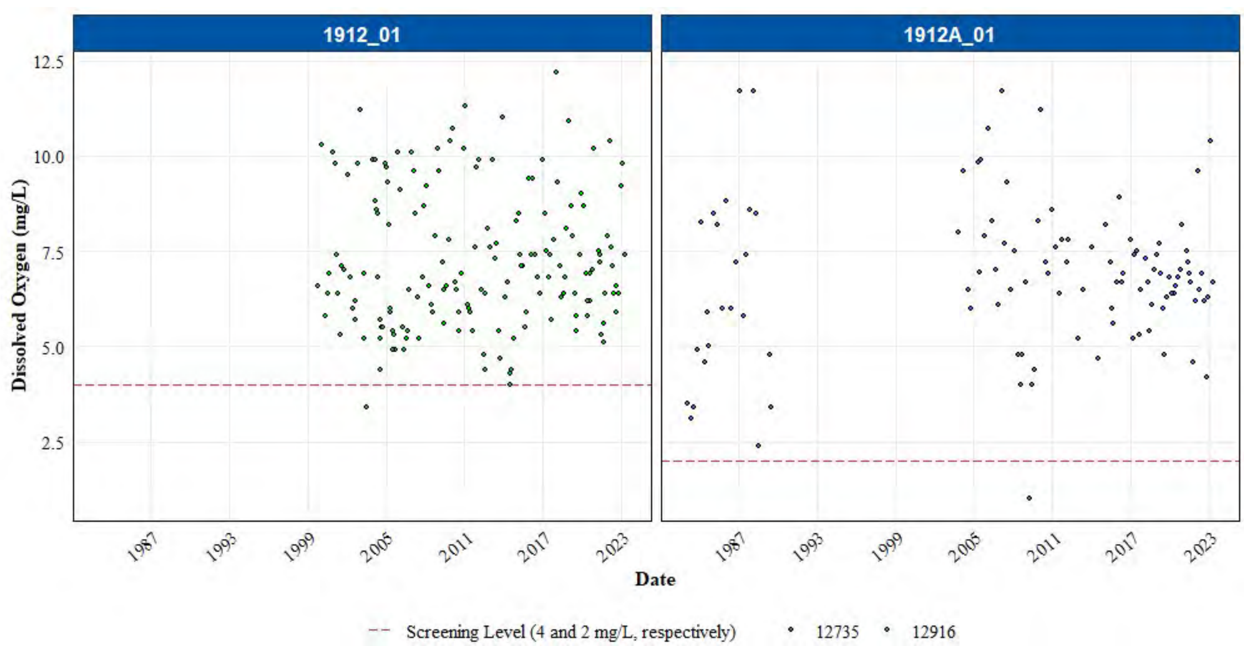

Figure 3-3b. Historical dissolved oxygen concentrations in Medio Creek.

Nutrients

Nutrients, specifically nitrogen and phosphorous, are necessary for plant growth, including aquatic plants and algae. However, excessive nutrients can lead to plant and algae blooms and reduced DO concentrations. High nitrate and nitrite levels can directly affect fish respiration. Nutrient sources can include effluents from WWTFs and OSSFs, direct deposition of animal fecal matter, illegal refuse dumping, groundwater return flows, and fertilizers in runoff from yards and agricultural fields. Additionally, nutrients bind to soil and sediment particles; therefore, runoff and erosion events that result in heavy sediment loads can increase nutrient levels in receiving water bodies.

Numeric criteria have not been adopted in the state's water quality standards, however, nutrient screening levels developed for statewide use were established to evaluate which water bodies may be experiencing excess nutrient loadings. Screening levels are set at the 85th percentile for parameters from similar water bodies. The chlorophyll-a, nitrate, and total phosphorus data from the Medina River and Medio Creek are graphed below, along with their associated screening level and monitoring station numbers where data were collected (Figures 3-4 and 3-6).

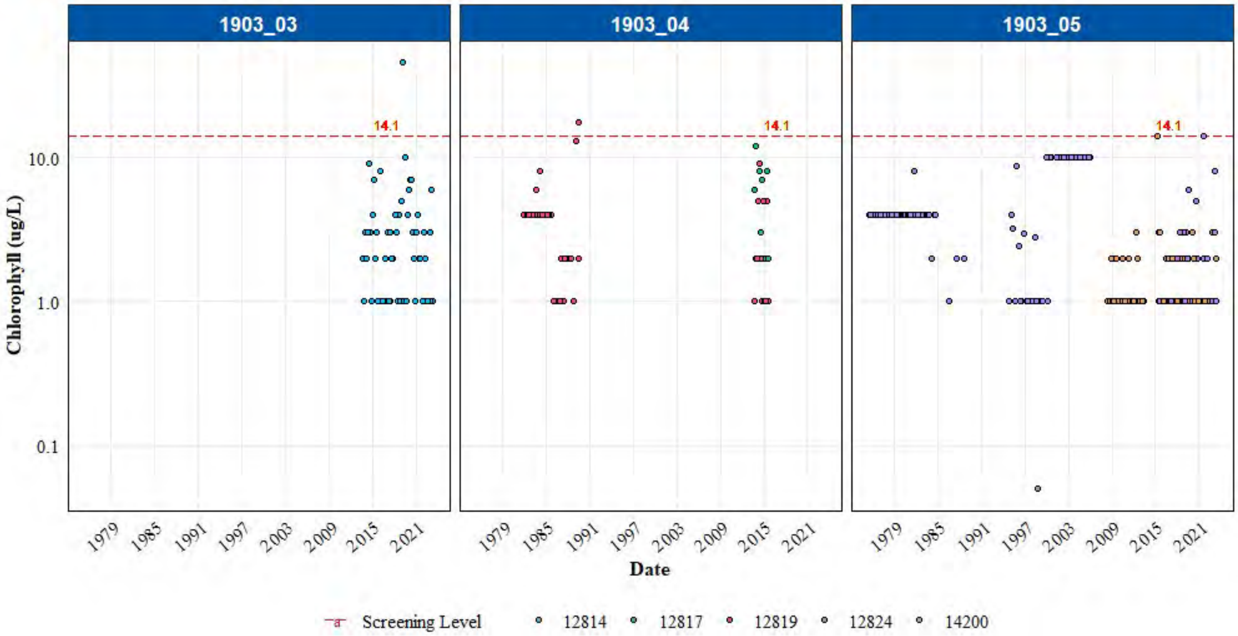

Figure 3-4a. Historical chlorophyll-a concentrations in the Medina River Below Medina Diversion Lake.

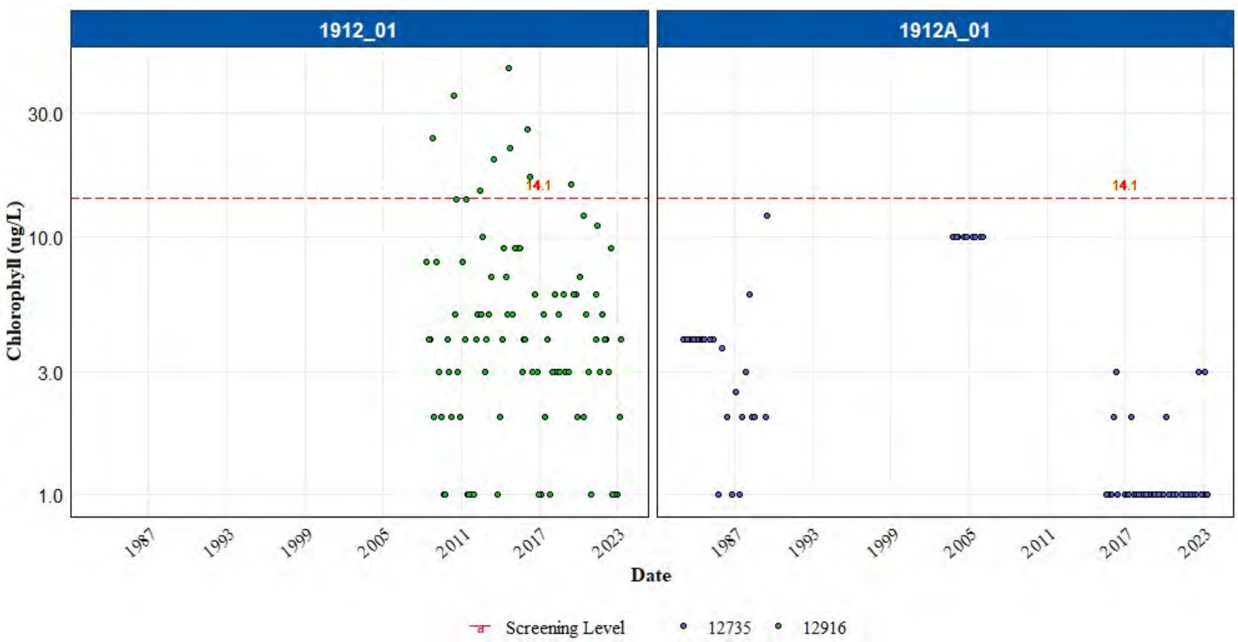

Figure 3-4b. Historical chlorophyll-a concentrations in Medio Creek.

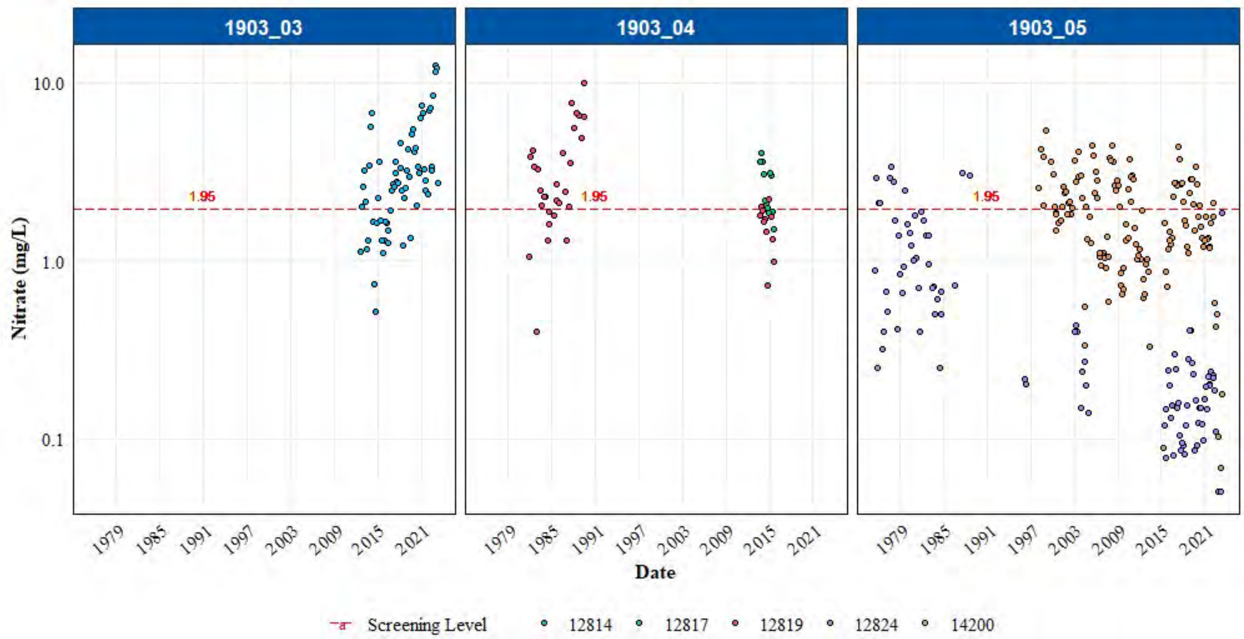

Figure 3-5a. Historical nitrate concentrations in the Medina River Below Medina Diversion Lake.

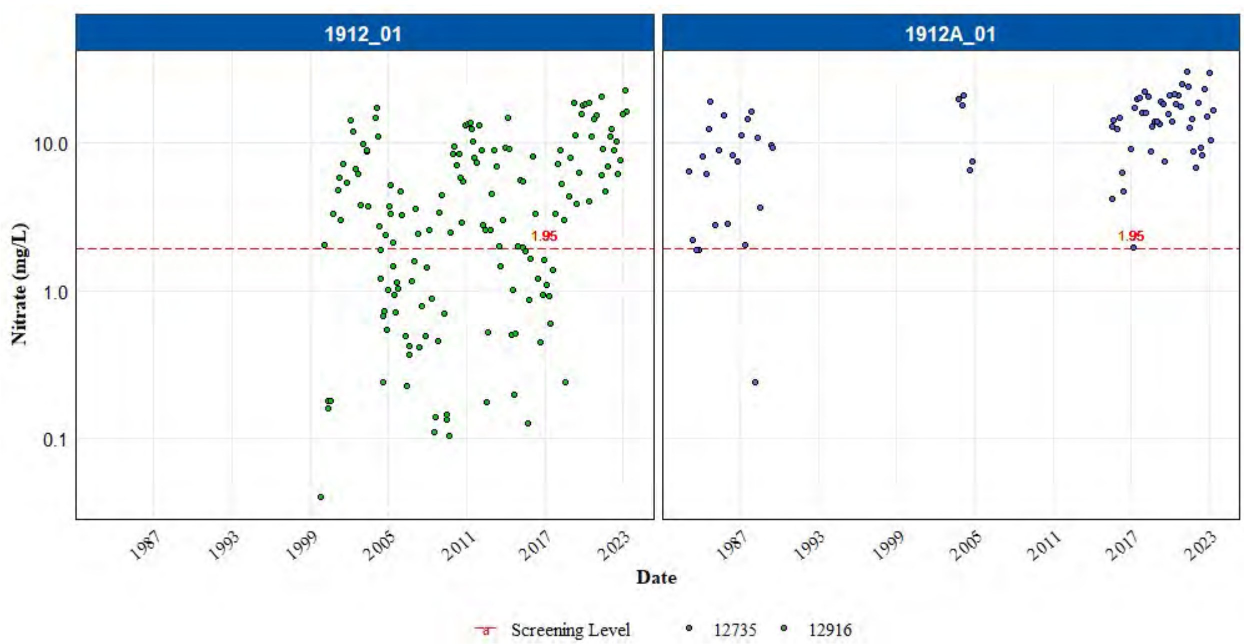

Figure 3-5b. Historical nitrate concentrations in Medio Creek.

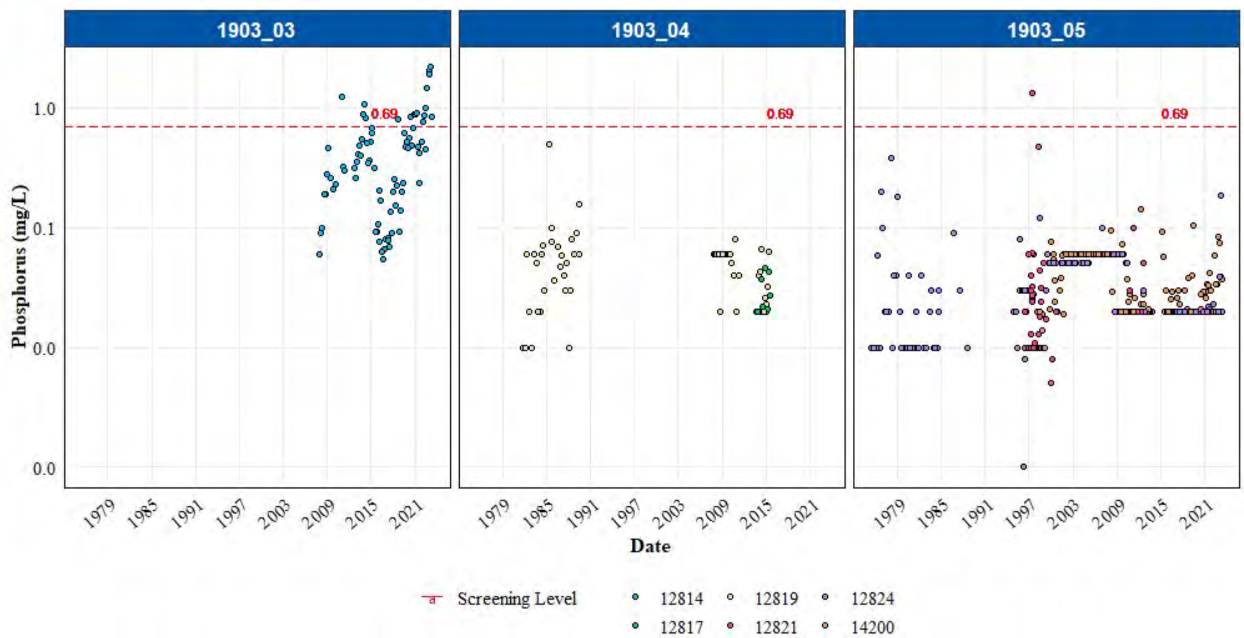

Figure 3-6a. Historical total phosphorus concentrations in the Medina River Below Medina Diversion Lake.

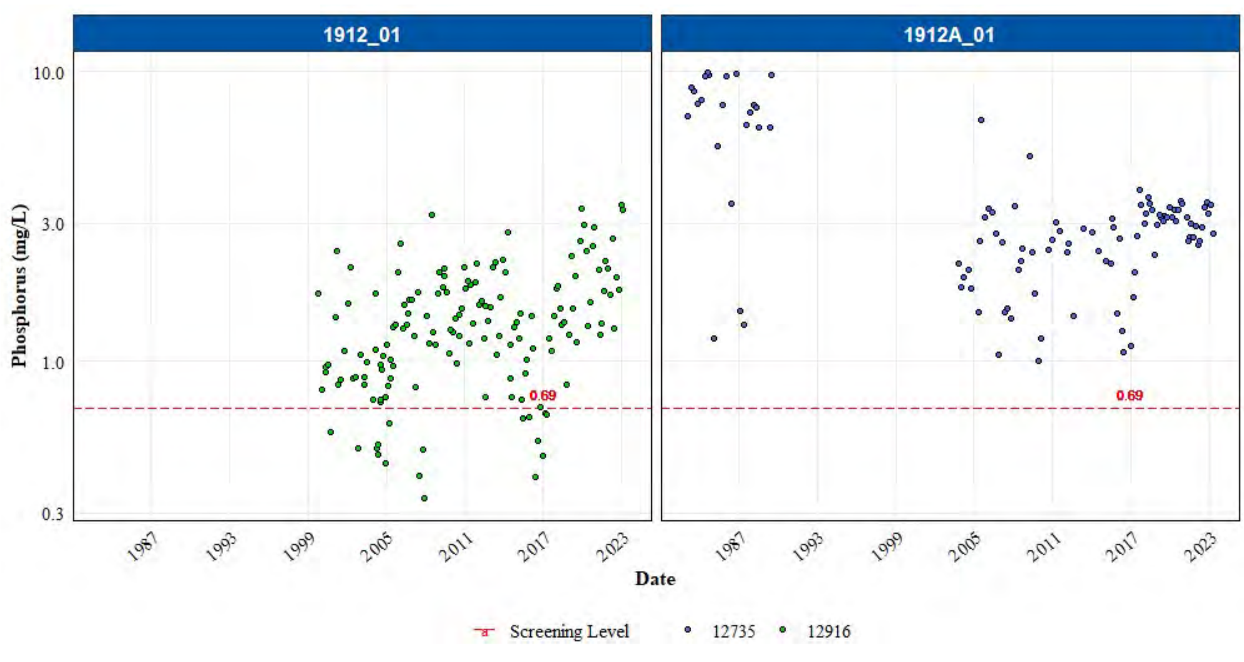

Figure 3-6b. Historical total phosphorus concentrations in Medio Creek.

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. 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 exist, 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 water body. Examples of point sources include municipal or industrial WWTFs, 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 through responsible land stewardship and voluntary land management practices. Examples of nonpoint sources include OSSFs, 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 water bodies. 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 water bodies 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 (ECHO) database (USEPA 2024b) 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 January 2025, a TPDES permit has not been issued for the facility.

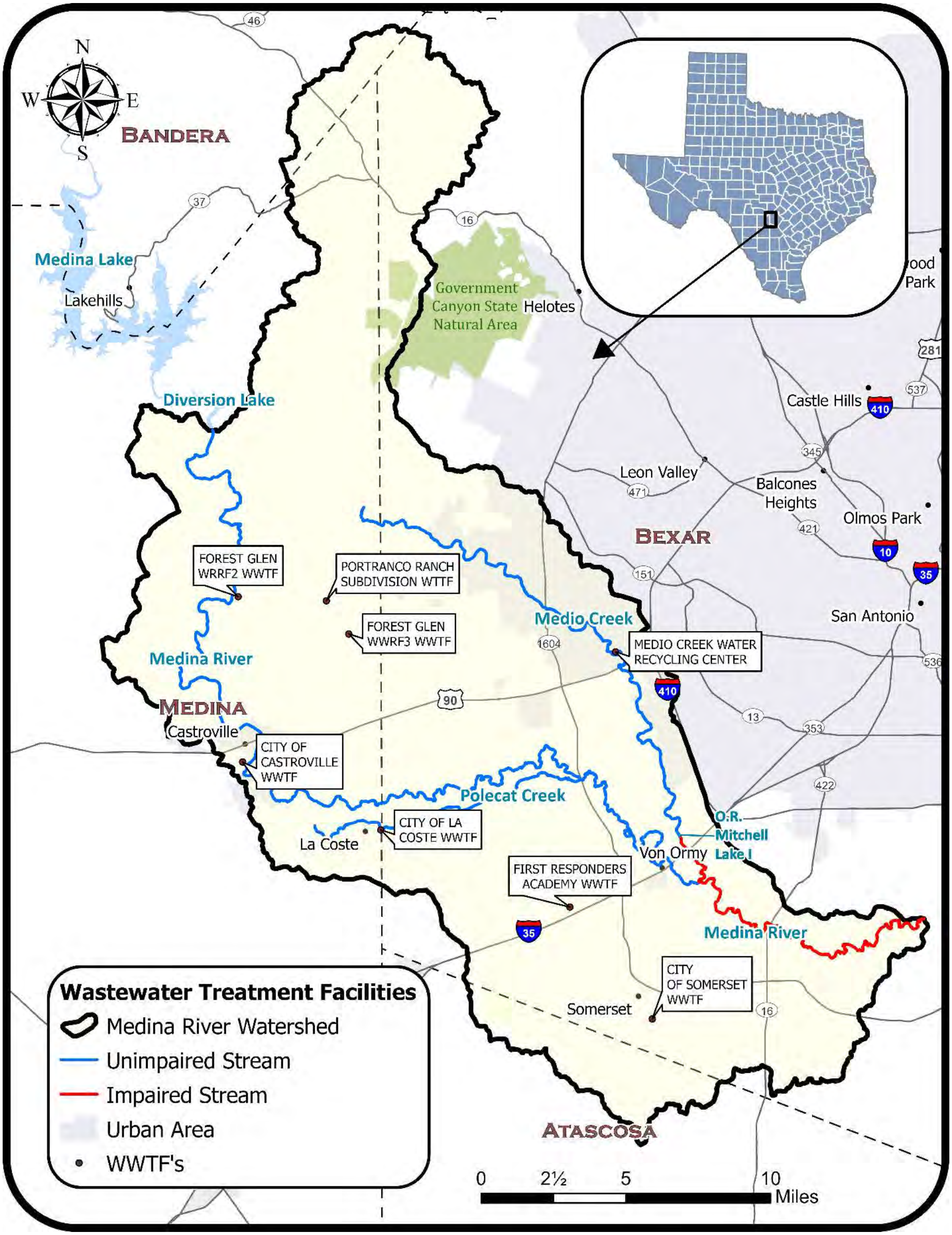

Figure 4-1. TCEQ permitted wastewater treatment facilities.

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 United States Department of Agriculture (USDA) Natural Resources Conservation Service (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).

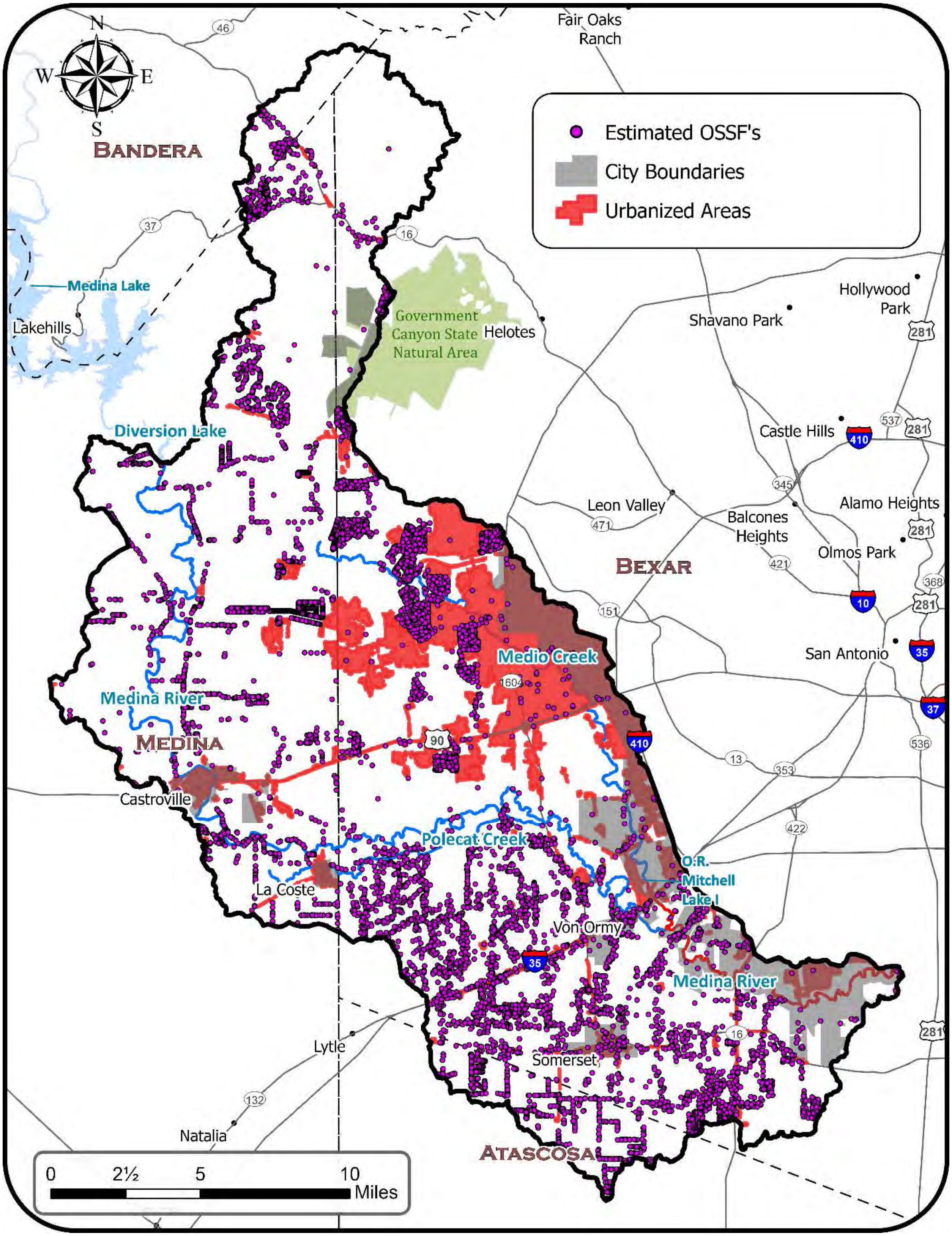

Figure 4-2 Estimated locations of OSSFs.

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.

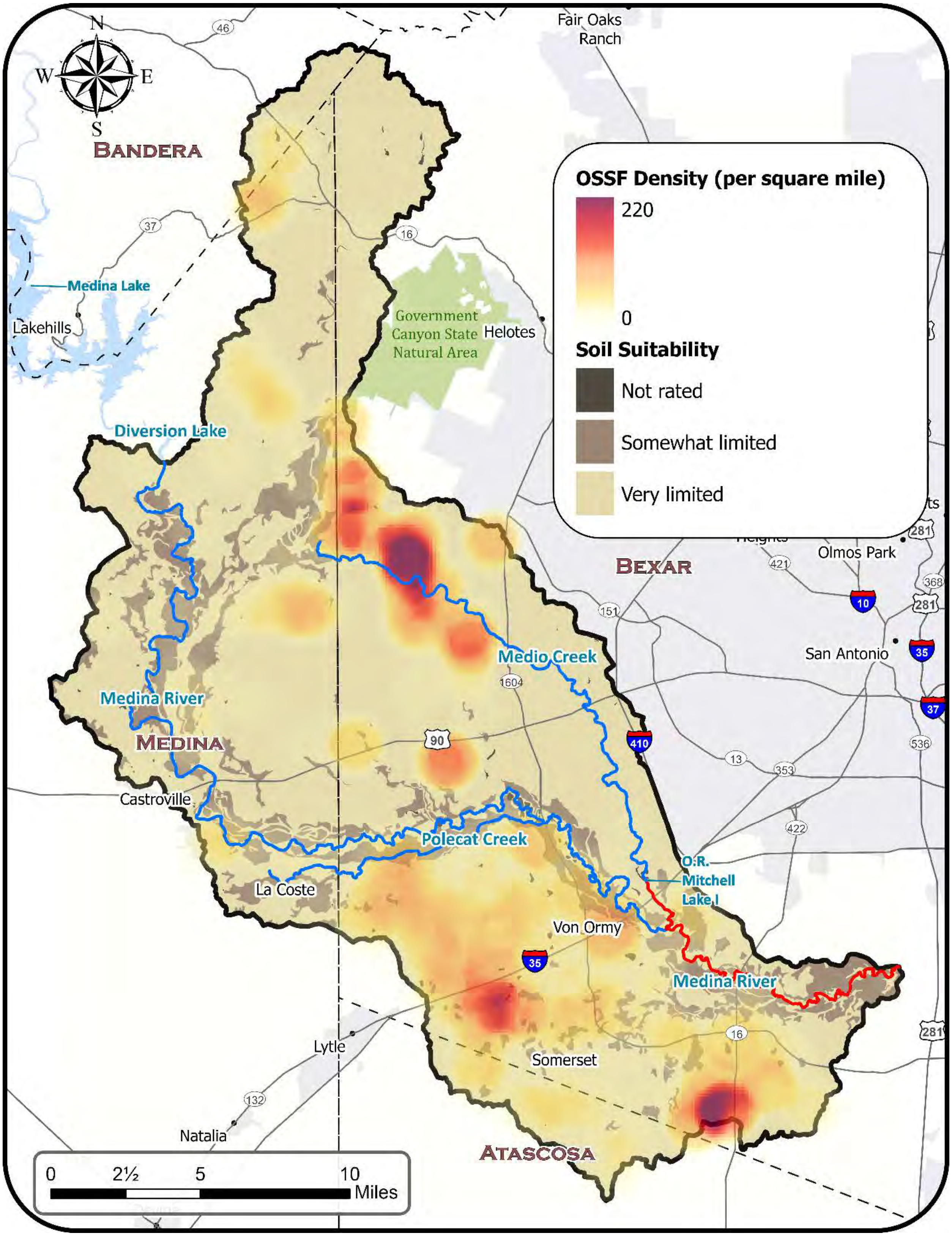

Figure 4-3. Figure 4-3. Soil suitability and OSSF density.

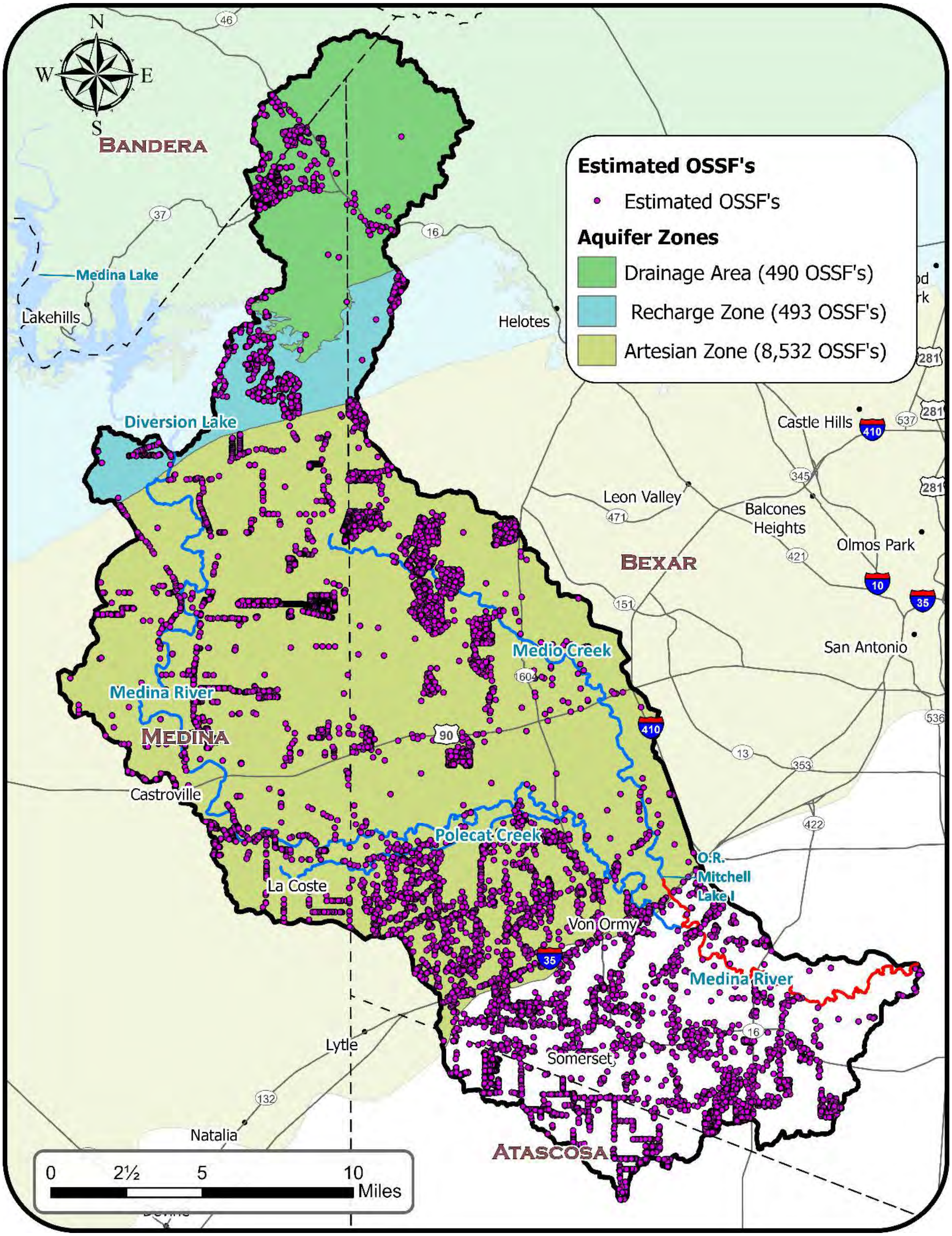

Figure 4-4. Edwards Aquifer zones and estimated locations of OSSFs.

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 2022), 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

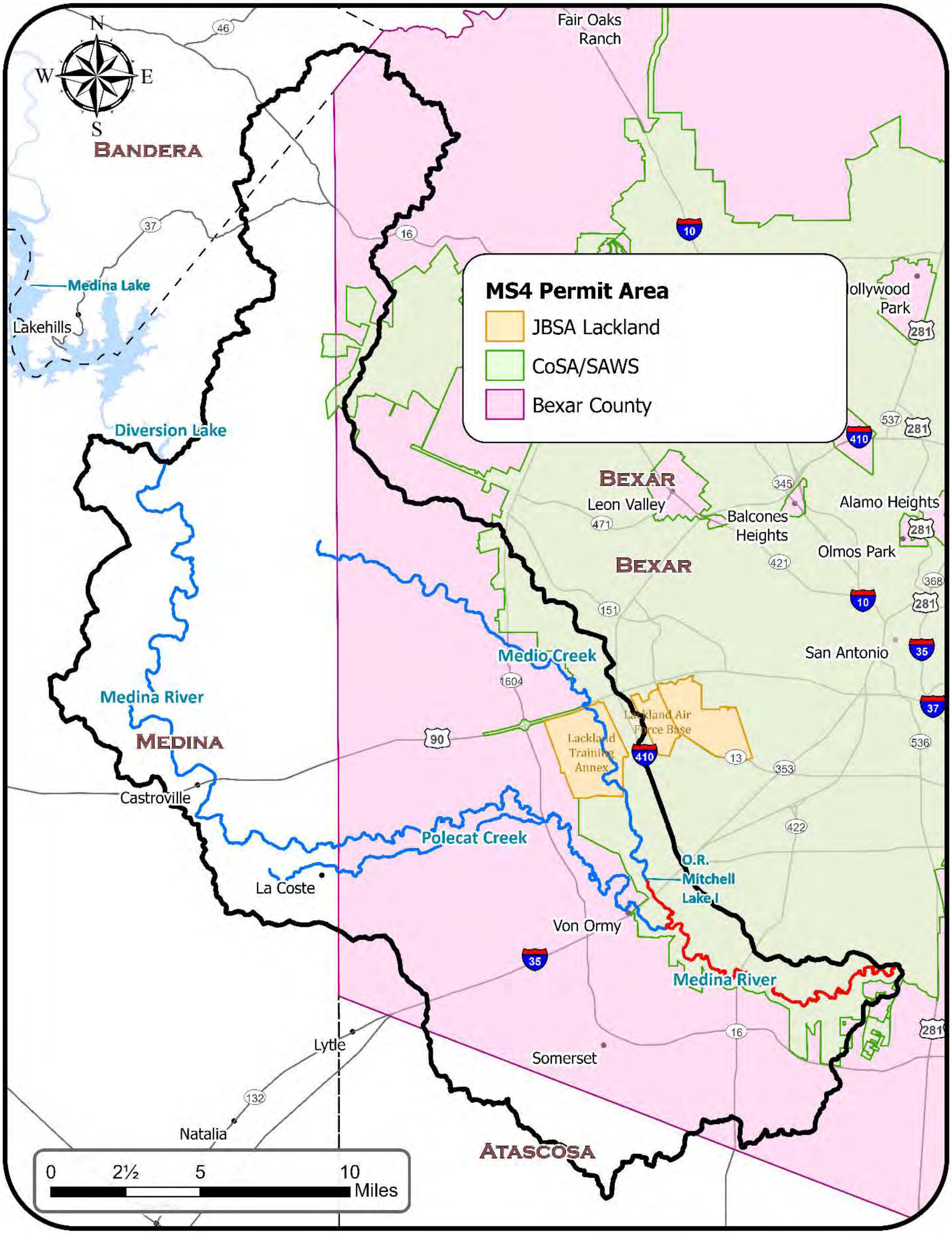

Figure 4-5. Entities regulated under TCEQ MS4 permits.

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 water bodies.

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.

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.

This chapter provides information about the pollutant load reductions required to meet water quality standards, as well as the results from spatial analysis of potential bacteria sources. This information is critical to prioritize the types and locations of management measures intended to improve and protect water quality.

To calculate load reductions needed to meet the *E. coli* criterion, the load capacity of each water body was estimated using the Load Duration Curve (LDC) method. The load capacity represents the load of *E. coli* a water body 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 water bodies 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 water body. 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 water body where bacteria is transported from the landscape during smaller rainfall-runoff events, from nearby failing OSSFs discharging directly to the water body, 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).

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%.

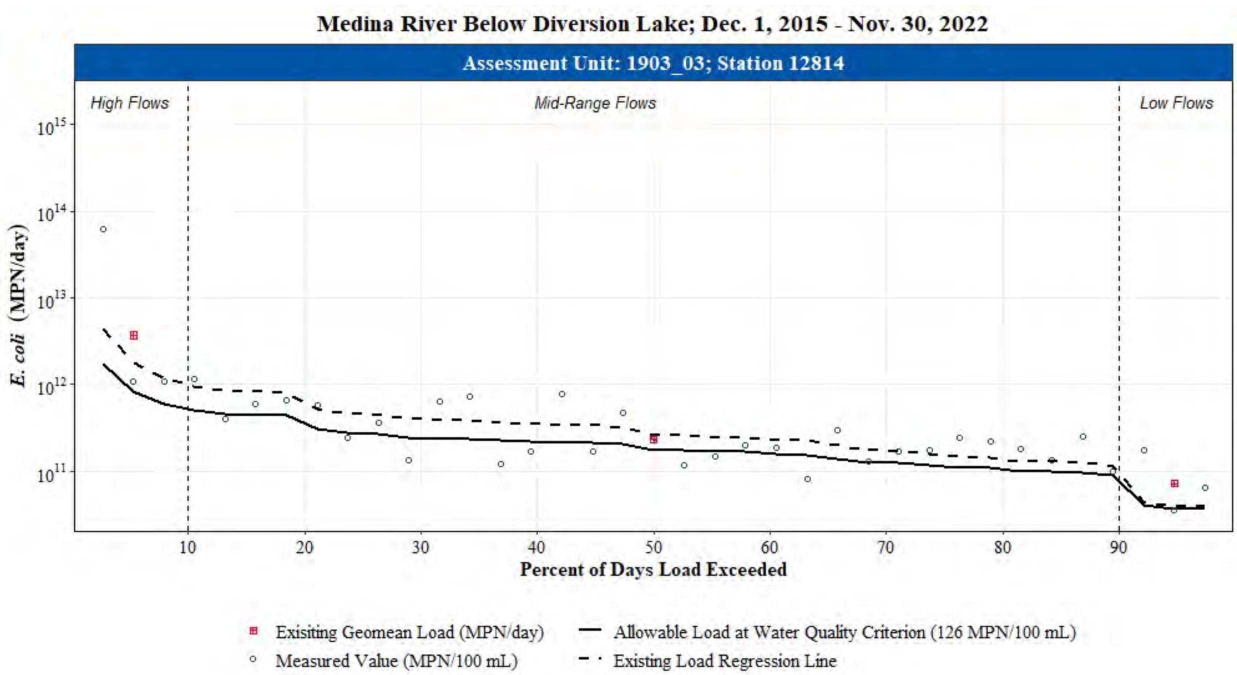

Figure 5-1. LDC profile for station 12814 .

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

Medina River Below Medina 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).

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.

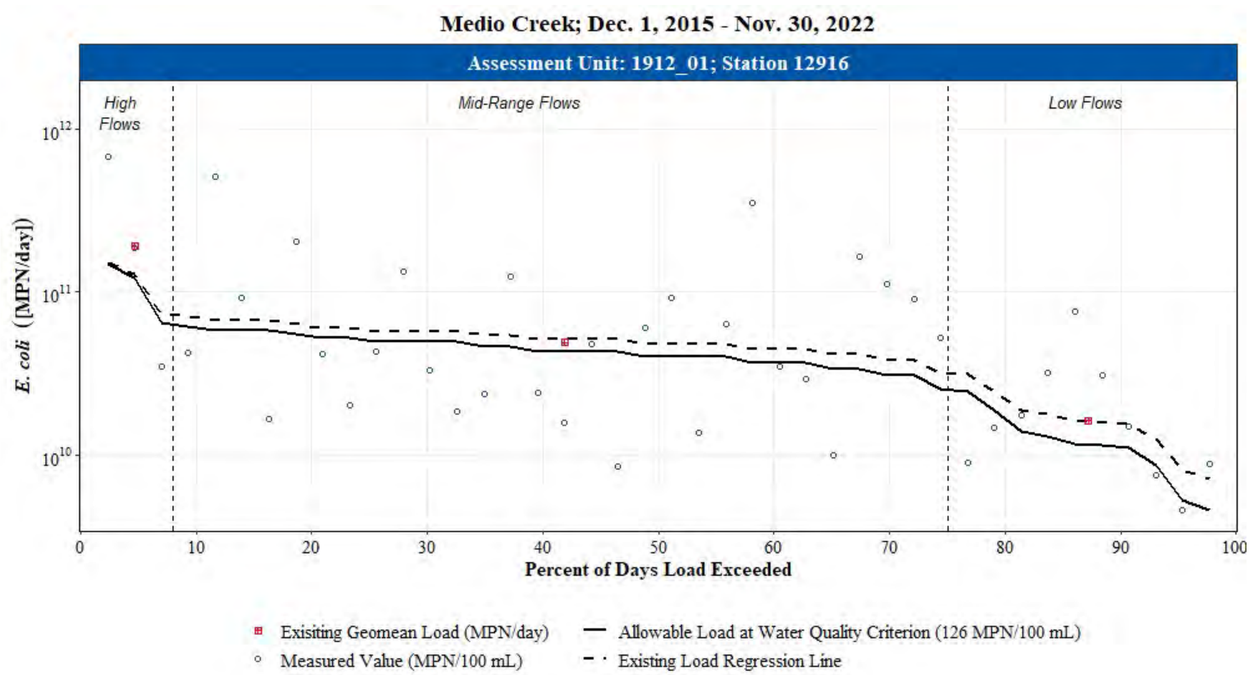

Figure 5-2. LDC for station 12916 Medio Creek.

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 water body. Therefore, this analysis presents a worst-case scenario that does not represent the actual bacteria loading expected to enter water bodies.

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).

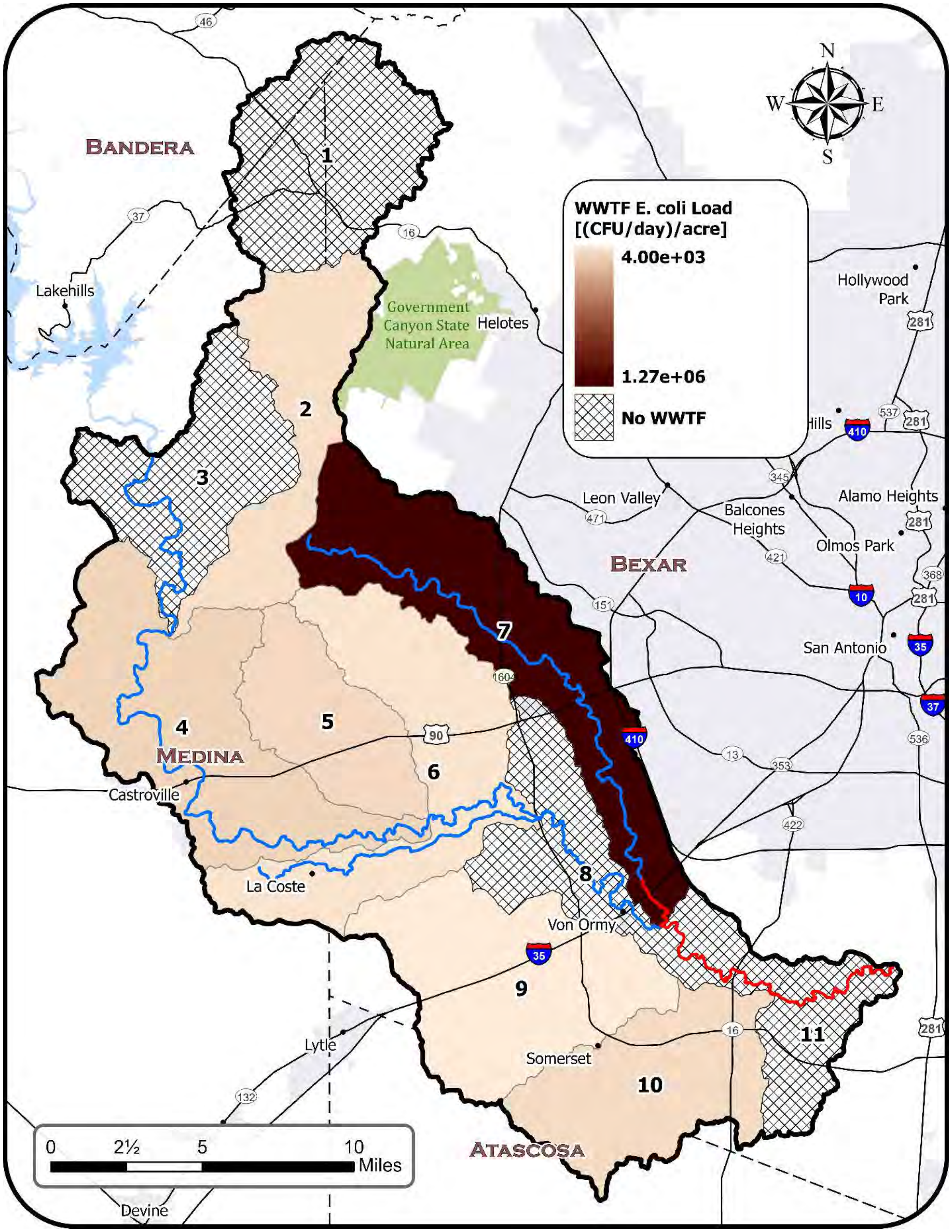

Figure 5-3. Distribution of potential loads from WWTFs

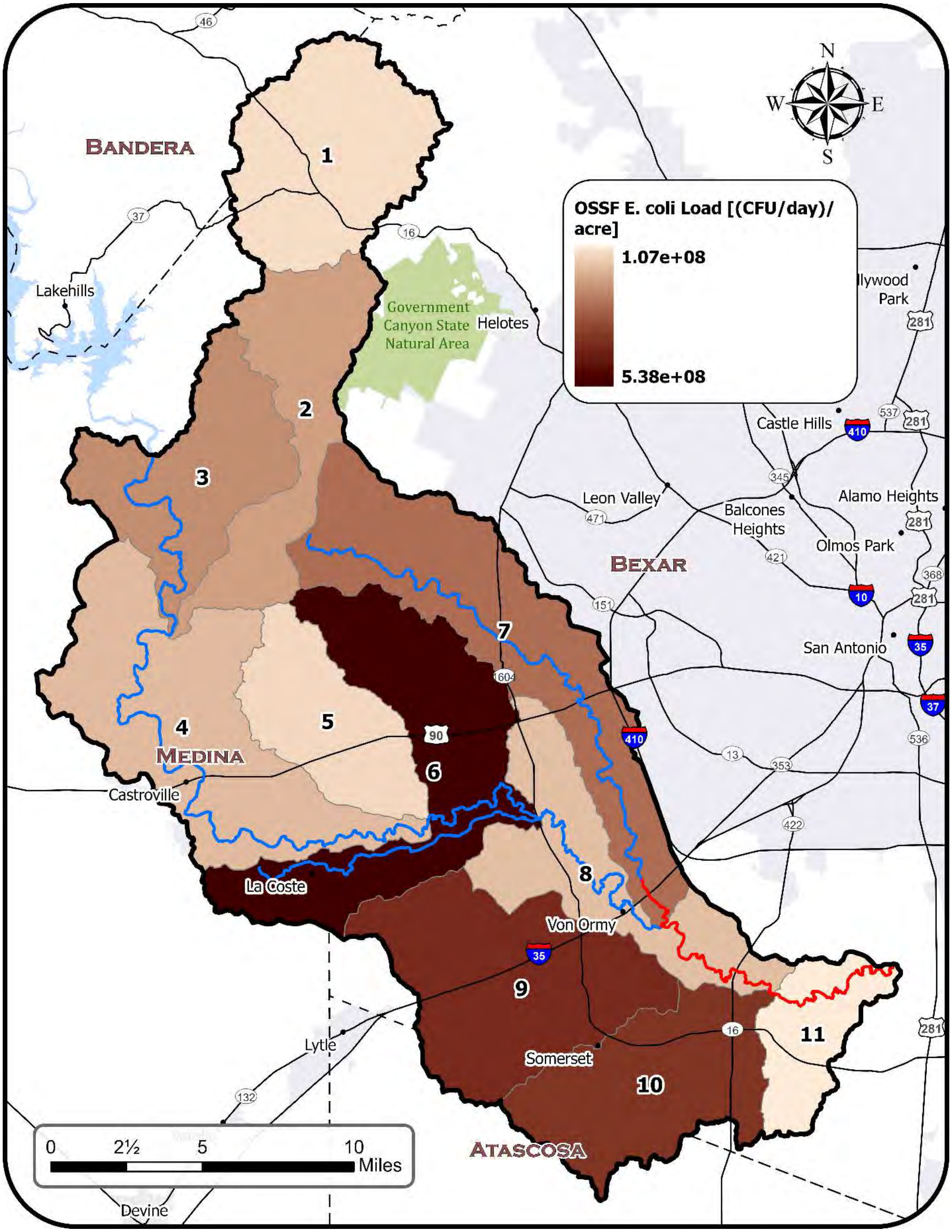

Figure 5-4. Distribution of potential loads from OSSFs

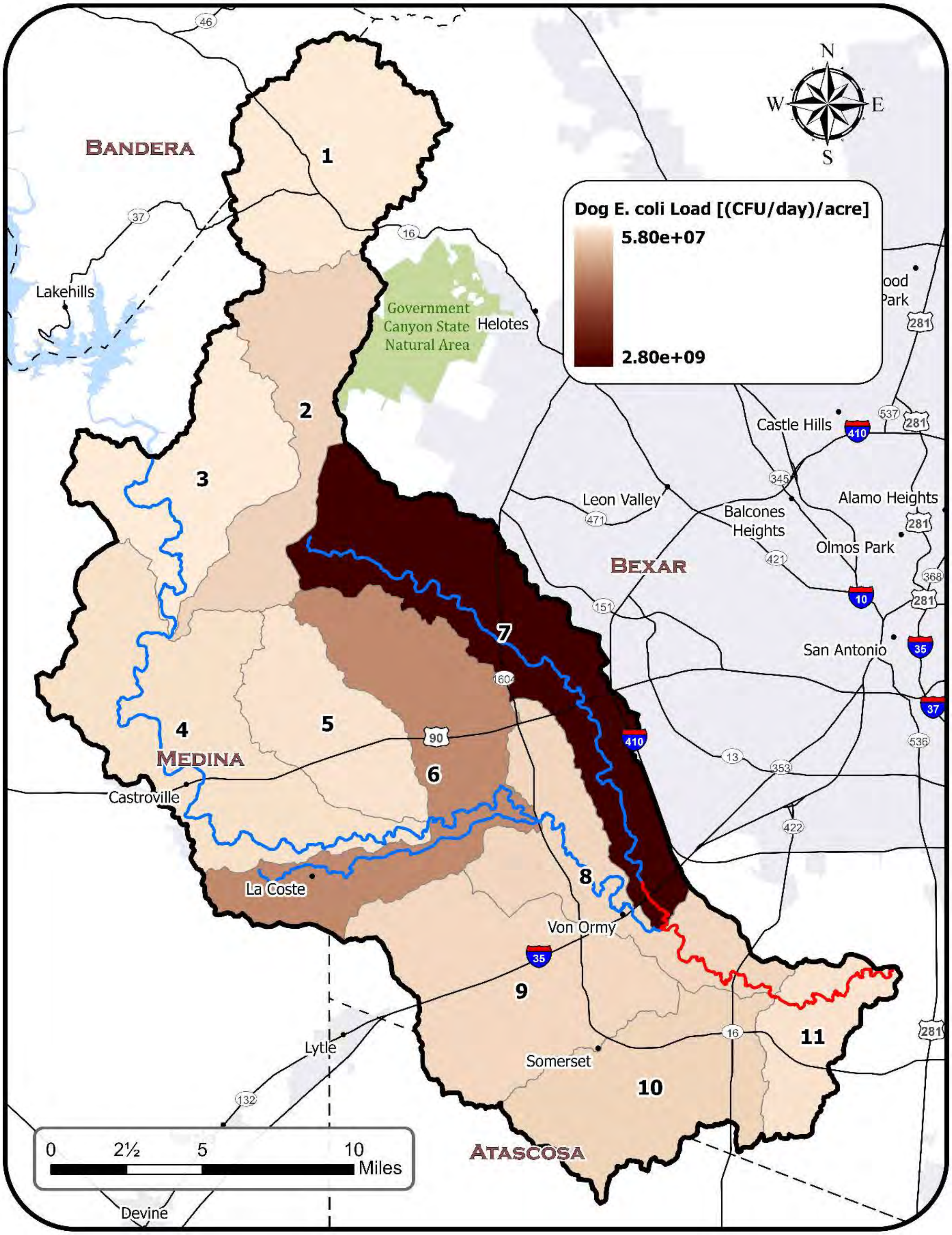

Figure 5-5. Distribution of potential loads from dogs

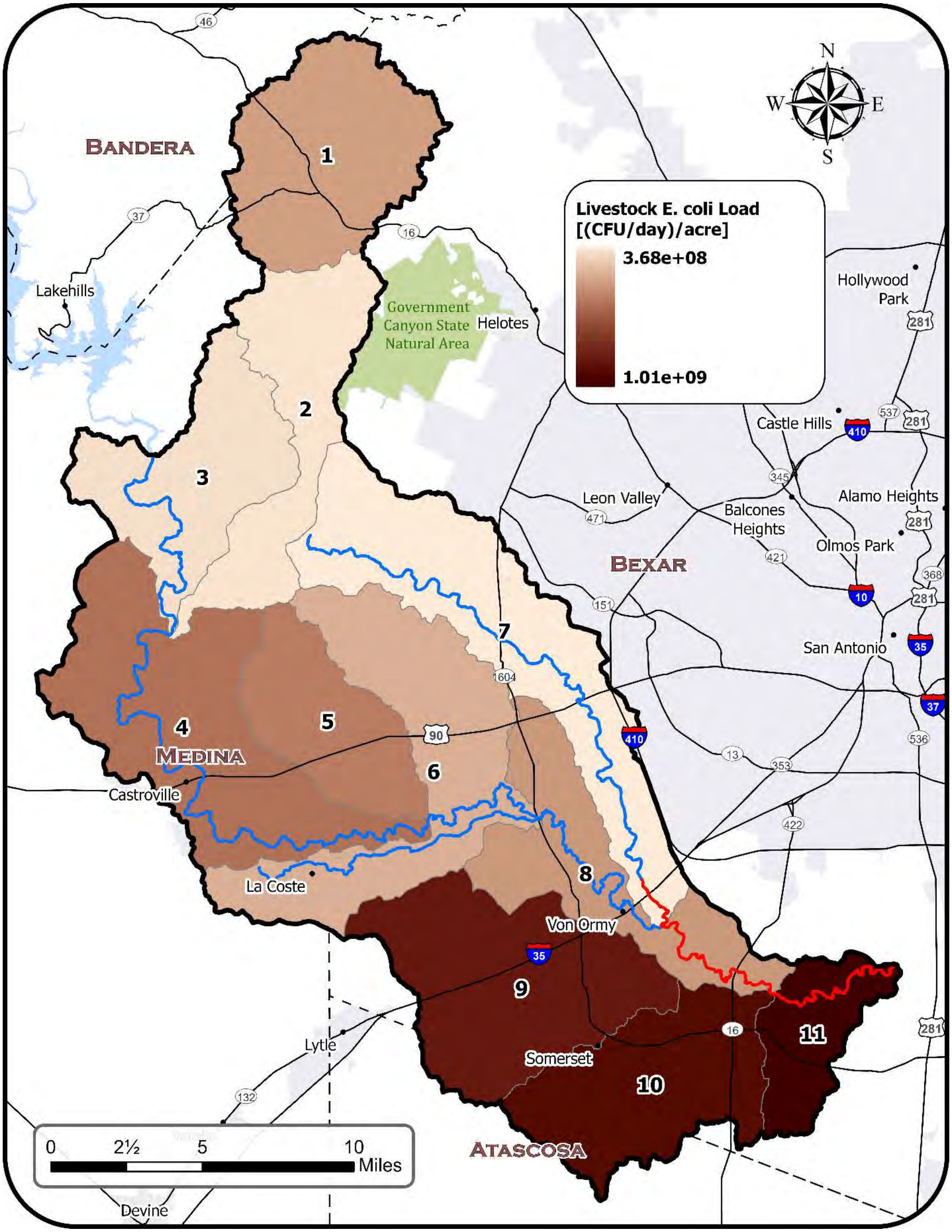

Figure 5-6. Distribution of potential loads from livestock

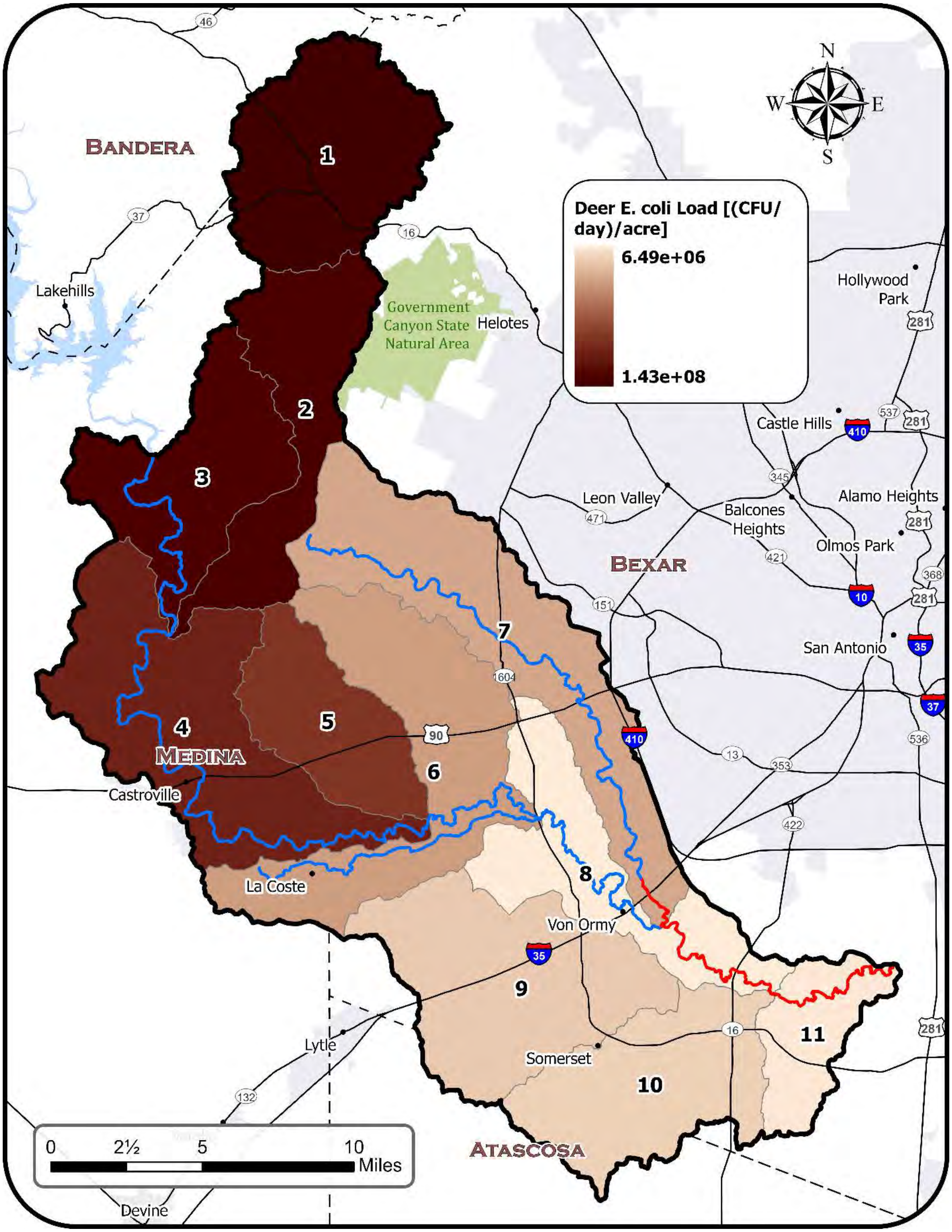

Figure 5-7. Distribution of potential loads from deer

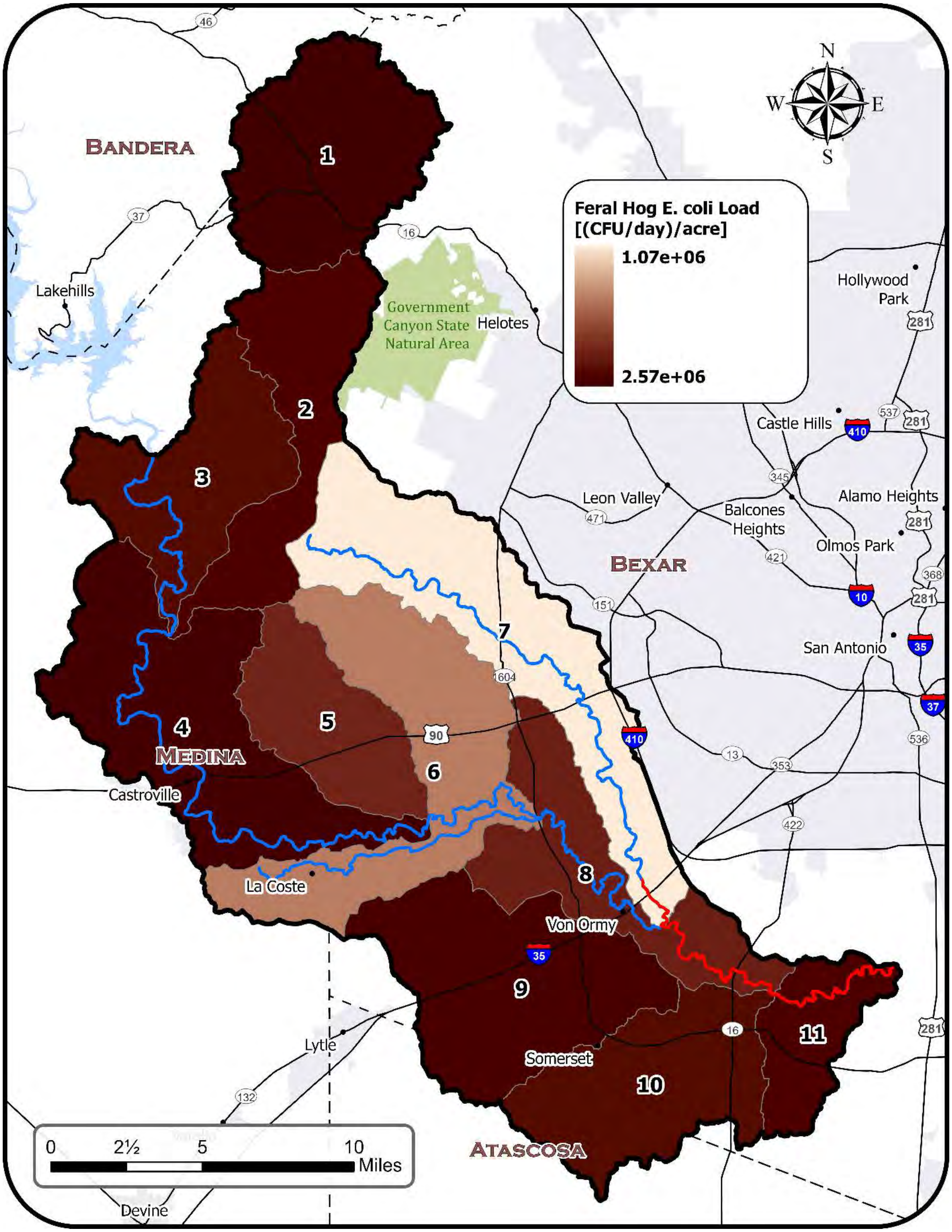

Figure 5-8. Distribution of potential loads from feral hogs

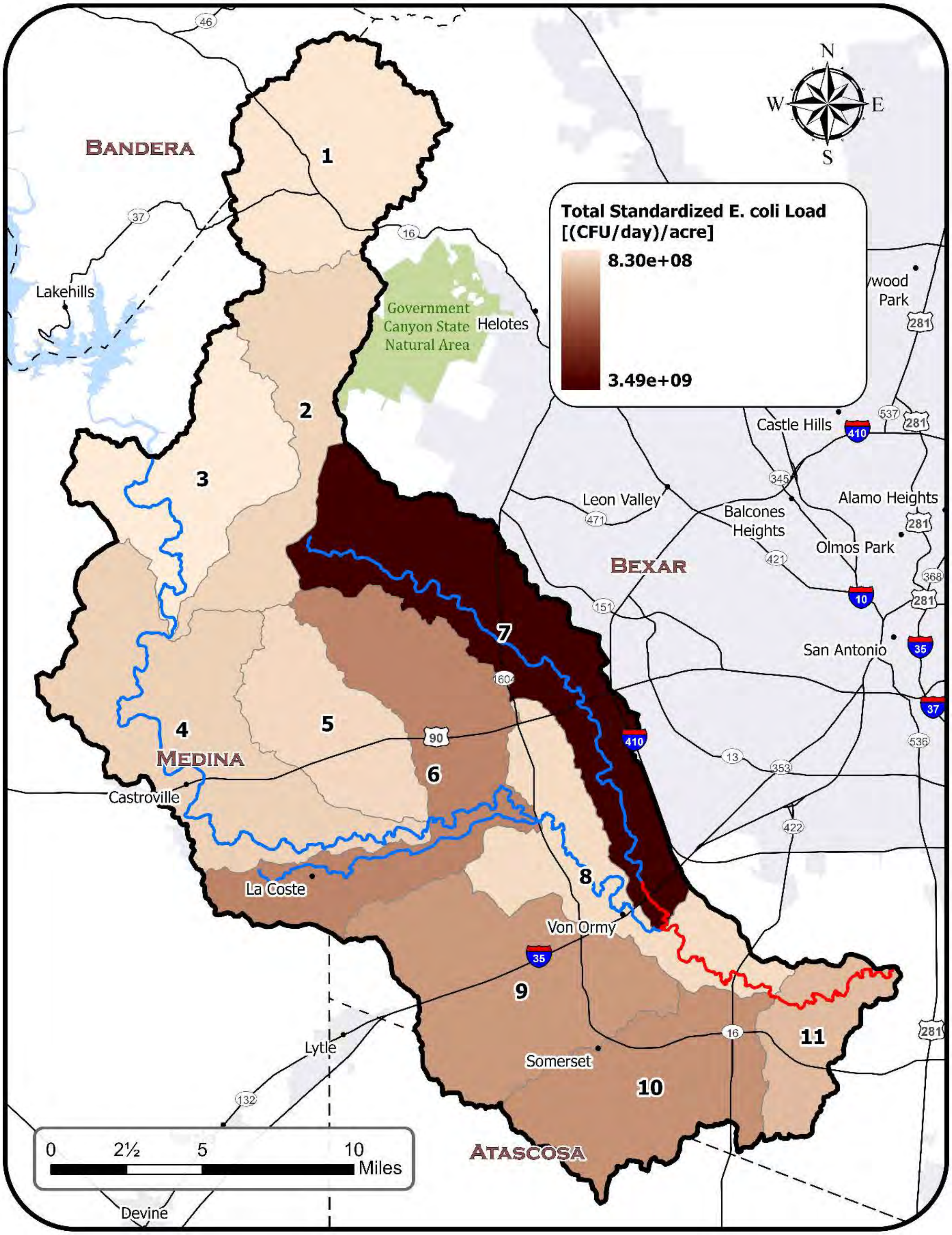

Figure 5-9. Distribution of total potential loads from all identified sources

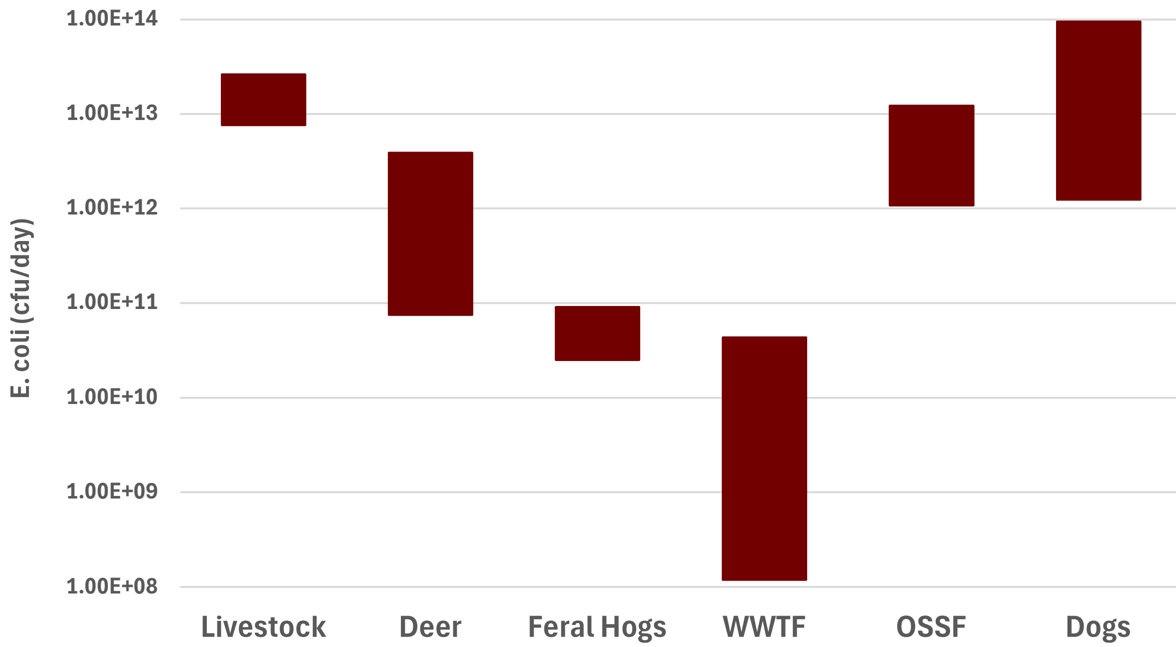

Figure 5-10. Range of total potential E. coli loads from identified sources

Chapter 6 Recommended Implementation Strategies

This WPP is designed to establish a clear link between the causes and sources of contamination, and the solutions identified and scaled to address them. Chapter 4 quantified the sources that contribute to water quality impairments and Chapter 5 identified the bacteria reductions needed to meet water quality standards. This Chapter details the voluntary solutions identified and prioritized by the stakeholders. Chapter 9 discusses the financial and technical resources needed to implement them. Chapter 7 links these activities to corresponding education and outreach elements and Chapter 8 details the timeline and milestones associated with implementation.

No single bacteria source is the primary cause of current water body impairments. According to pollutant loading estimates, OSSFs, dogs, livestock, and deer have the highest potential to contribute *E. coli* across the watersheds; however, all potential sources contribute to overall bacteria loading. Due to potential source diversity, various management strategies are recommended to address manageable *E. coli* sources in the watershed. Recommended management strategies were developed based on stakeholder feedback, relative pollutant removal efficiencies, likelihood of adoption and applicability to the watershed.

Estimated potential bacteria load reductions from each management measure are presented with each recommended action discussed in this chapter and further explained in Appendix C. Load reduction estimates are based on predicted worst-case scenario loading. As a result, these estimates do not accurately predict actual load reductions expected to occur instream. Actual reductions will depend on implementation volume and other changes across the watershed that may trigger the need for adaptive implementation. Comparison of target and potential annual load reductions from management measures discussed in this chapter (Figure 6-1) indicate that reducing bacteria loads to levels that support primary contact recreation use is feasible.

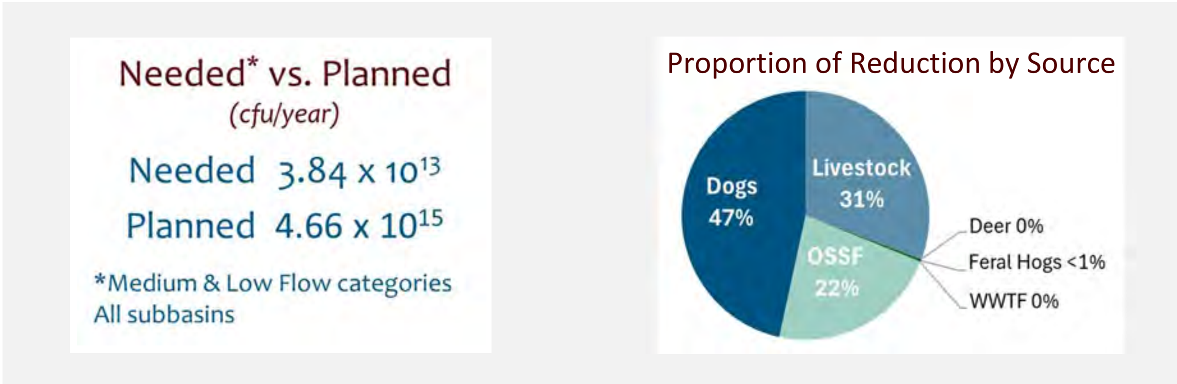

Figure 6-1. Estimated Annual E. coli reduction needed and planned from management measures.

Critical areas for each recommended management strategy were identified based on spatial analysis and stakeholder feedback. While management measures can be implemented throughout the watershed, priority locations were selected where management strategies may most effectively reduce potential loading. In all cases, management activity should be implemented as close to waterways as possible to increase potential instream water quality improvements. This targeted approach will help guide initial implementation in each watershed.

Stakeholder input was crucial throughout the decision-making process for identifying critical areas and management strategies. Stakeholders were engaged throughout the process through in-person workgroup and stakeholder meetings. Management measures suggested in this chapter are voluntary and rely on stakeholder adoption for successful implementation. Therefore, receiving stakeholder input on the feasibility and willingness to adopt these measures is the first step to ensuring successful implementation of the plan. All management measures were discussed with and approved by stakeholders to ensure support and successful implementation.

Reduce SSOs and Unauthorized Discharges

In the face of accelerated growth in the region, aging, new, and planned WWTF infrastructure are major concerns for stakeholders. While data discussed in Chapter 4 indicate that historical WWTF performance is generally good and SSOs are rare, the potential for upsets and overflows would be expected to increase as systems receive more wastewater from a growing population. Conversely, the uptick in purchases of treated effluent for non-potable uses such as irrigation and by commercial or industrial facilities has resulted in the diversion of effluent that would otherwise be discharged into Medio Creek or the Medina River.

The San Antonio Water System (SAWS) continues to make significant investments in upgrading its collection system and other assets for the Medio Creek Water Recycling Center to ensure continued capacity to meet growing demands for treatment and treated recycled water. Much of the treated effluent from the Medio Creek facility leaves the watershed through purchase agreements with a wide range of customers including industrial and commercial users, golf courses, municipal parks, universities, and others. The City of Castroville upgraded and increased treatment capacity of their WWTF in 2019 and utilizes some treated effluent for irrigation purposes. Newer and planned WWTFs are decentralized, serving individual subdivisions or developments in the watershed. While a decentralized approach can provide some flexibility in meeting the needs of rapidly growing areas, there is stakeholder concern that the existing decentralized facilities may not be sufficiently staffed or monitored to reliably comply with permit requirements. Operator training, good housekeeping, and planning for future growth were discussed by stakeholders as potential strategies to ensuring that facilities across the watershed prevent discharge of bacteria and other pollutants through SSOs or WWTF failures.

The TCEQ SSO Initiative is a voluntary program that initiates efforts to address SSOs. These events are often due to aging collection systems and may be the result of I&I issues during storm events caused by line breaks and blockages. Activities in SSO initiatives vary, but commonly include line inspections and testing, routine repairs and replacements, and education and outreach. Fats, oils, grease, non-flushables, and many other substances should not be disposed of through household drains. These items can cause material build up and create blockages in collection systems which lead to system damage and repairs. Several educational programs on proper disposal of fats, oils and grease are available through AgriLife Extension. Education material distribution and other resources on the Medina River below Medina Diversion Lake WPP website will help encourage and inform homeowners of how to properly dispose of fats, oils, grease, and non-flushables.

Table 6-1. Summary of Management Measure: Reduce SSOs and unauthorized discharges.

Source: Municipal Sanitary Sewer Overflow (SSO) or Unauthorized Discharges			
Problem: Fecal bacteria loading from SSO events and malfunctioning sewage infrastructure			
Objectives: • Reduce unauthorized discharges and SSOs. • Replace and repair sewage infrastructure as needed. • Educate residents and homeowners on the need for infrastructure maintenance and what types of waste can be put in the sewer system.			
Critical Areas: Areas serviced by WWTFs in subwatersheds 2, 4, 5, 6, 7, 9, and 10			
Goal: Work with entities operating WWTFs to continue and expand training and inspection efforts. Identify problematic areas and repair or replace problematic infrastructure to reduce I&I issues and minimize WWTF overload occurrences.			
Description: Identify potential locations within municipal sewer systems where I&I occurs using available strategies (e.g., smoke tests, camera inspections, etc.). Prioritize system repairs or replacements based on system impacts (largest impact areas addressed first). Complete repairs or replacements to reduce future I&I issues and WWTF overloading.			
Implementation Strategy			
Participation	Recommendations	Period	Capital Costs
Cities, Permittees, Operators	Identify recurring or high-volume SSOs to target for repair or replacement through capital improvement programs.	2025-2035	TBD
Publicly owned WWTF Permittees	Participate in the TCEQ Sanitary Sewer Overflow Initiative (SSO Initiative).	2025-2035	N/A
Cities, Permittees, Watershed Coordinator	Identify potential resources and develop programs to aid repair or replacement of WWTF collection system infrastructure.	2025-2035	N/A
Cities, Permittees, AgriLife Extension, Watershed Coordinator	Develop and deliver education material to residents and property owners.	2025-2035	N/A
Permittees, Operators	Identify operations and maintenance training needs, develop and deliver resources to appropriate staff.	2025-2035	TBD

Estimated Load Reduction	
Reduction of SSOs and discharges associated with I&I will result in direct reductions in bacteria loads. However, because the response to education efforts and resource acquisition to complete system repairs is uncertain, load reductions were not calculated.	
Effectiveness	Moderate to High: Although infrequent, reduction in SSOs and unauthorized discharges will result in direct reductions to bacteria loading during the highest flow events.
Certainty	Moderate to Low: Costs associated with sewer pipe replacement and treatment plant upgrades are expensive to homeowners and municipalities.
Commitment	Moderate: Municipal public works have incentive to resolve I&I issues to meet discharge requirements. However, limited funding hinders sewage line replacement.
Needs	High: Financial needs are significant.

Address Failing On-Site Sewage Systems

OSSFs are used to treat wastewater where service by WWTFs is not available. Conventional systems use a septic tank and gravity-fed drain field that separates solids from wastewater prior to its distribution into soil where treatment occurs. In the Medina River watershed, approximately 99.5% of the watershed's soils are classified as "limited" or "somewhat limited" and considered unsuitable for proper treatment of household wastewater by conventional systems. In many areas, advanced treatment systems, most commonly aerobic treatment units, are used for wastewater treatment. While advanced treatment systems are highly effective, operation and maintenance needs for these systems are rigorous compared to conventional septic systems. Limited awareness and lack of maintenance can lead to system failures.

Failing or non-existent OSSFs can provide significant bacteria and nutrient loading into the watershed. The exact number of failing OSSFs is unknown; however, it is estimated that 10%, or 1,352, of the estimated number of systems may be malfunctioning across the watershed. Specific locations of failing OSSF are not known and can only be determined through physical inspections. Factors contributing to OSSF failure include improper system design or selection, improper operation and maintenance and lack of financial resources for proper maintenance. The lack of qualified service providers in the watershed was identified as a challenge in addressing failing systems.

Providing educational workshops to homeowners regarding OSSF operation and maintenance will help address these issues. Repairs and replacements are also needed. It's not possible to know the number that need true repair or replacement versus maintenance, but stakeholders believe that proper maintenance would correct most issues causing failure. Over the next 10 years, it is recommended that 60 failing septic systems in the watershed be addressed annually through repair, replacement, or improved maintenance (10 conventional and 20 aerobic in Medina County, 20 in Bexar County, and 10 in Atascosa and Bandera counties). While failing OSSFs should be addressed across the entire watershed, priority subwatersheds include 6, 9, 10, and 7 due to OSSF densities. Additional priority should be given to OSSFs within 100 yds of water bodies. Significant financial resources are needed to support OSSF repairs and replacements, while those addressed through education and proper maintenance would require less.

Table 6-2. Summary of Management Measure: Identify and address failing OSSFs.

<table>
<tr><td colspan="5">Source: Failing On-Site Sewage Facilities (OSSFs)</td></tr>
<tr><td colspan="5">Problem: Pollutant loading reaching streams from untreated or insufficiently treated household sewage</td></tr>
<tr><td colspan="5">Objectives:
Inspect failing OSSFs in the watershed and secure funding to promote OSSF maintenance, repairs or replacement.
Repair or replace OSSFs by working with counties and communities.
Educate homeowners on system operations and maintenance.</td></tr>
<tr><td colspan="5">Critical Areas: Subwatersheds 6, 9, 10, and 7 and systems within 100 yds of perennial waterways.</td></tr>
<tr><td colspan="5">Goal: Identify, inspect, and repair or replace 60 failing OSSFs per year in the watershed (30 in Medina County, 20 in Bexar County, and 10 in Atascosa and Bandera Counties), especially within critical areas.</td></tr>
<tr><td colspan="5">Description: Deliver education programs and workshops on proper maintenance and operation of OSSFs to homeowners. Failing systems should be addressed as needed and appropriate as funding allows. Work with counties to leverage additional resources to address failing OSSFs in the watershed.</td></tr>
<tr><td colspan="5">Implementation Strategy</td></tr>
<tr><td colspan="2">Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td colspan="2">Counties, contractors, homeowners</td><td>Identify, inspect and address through repair or replacement OSSFs as funding allows</td><td>2025–2035</td><td>Est. $8,000-$12,000 per system</td></tr>
<tr><td colspan="2">Counties, municipalities, homeowners</td><td>Inspect and evaluate feasibility of connecting to existing/planned infrastructure</td><td>2025–2035</td><td>N/A</td></tr>
<tr><td colspan="2">Counties, AgriLife Extension, TWRI, watershed coordinator</td><td>Develop and deliver materials (postcards, websites, handouts, etc.) to educate homeowners</td><td>2025–2035</td><td>N/A</td></tr>
<tr><td colspan="2">Counties, AgriLife Extension, TWRI, watershed coordinator</td><td>Operate an OSSF education, outreach, and training program for installers, service providers and homeowners</td><td>2025–2035</td><td>N/A</td></tr>
<tr><td colspan="5">Estimated Load Reduction</td></tr>
<tr><td colspan="5">As planned, 60 OSSFs will be addressed per year across the watershed. Estimated potential E. coli load reductions from these efforts are 1.04×10^{15} per year.</td></tr>
<tr><td>Effectiveness</td><td colspan="4">High: Replacing, repairing, or properly maintaining failing OSSFs yields direct E. coli reductions.</td></tr>
<tr><td>Certainty</td><td colspan="4">Low: Funding available to identify, inspect and repair or replace OSSFs is uncertain; however, funding sources are available for assistance.</td></tr>
<tr><td>Commitment</td><td colspan="4">Moderate: Watershed stakeholders acknowledge failing OSSFs as a bacteria source. Addressing this source has the greatest human health benefit and is a high priority.</td></tr>
<tr><td>Needs</td><td colspan="4">High: Financial resources are needed to identify, repair and replace systems as many homeowners do not have the resources to fund replacement themselves. Education is also critical because many homeowners with failing systems may not realize their system is failing or understand the associated human health or environmental implications.</td></tr>
</table>

Manage Pet Waste

Improper pet waste disposal can be a source of bacteria entering water bodies from urban and rural residential areas, parks, and other public spaces. Because concentrations of dogs is generally greater in more populated areas, much of the *E. coli* loading from pet waste may be managed through proper stormwater management. However, additional activities and efforts to remove and properly dispose of pet waste from the landscape will aid in reducing *E. coli* loads from across the watershed.

Analysis of potential pollutant loading from pet waste was identified as a significant bacteria source in the watershed. Management strategies to address pet waste focus on reducing the transport to streams via stormwater runoff (Table 6-3). Potential strategies include providing waste bag dispensers and collection stations in areas of high pet density (parks, neighborhoods, etc.) and handing out waste bag carriers for pet owners at events and programs around the watershed. These strategies encourage pet owners to pick up waste before it is transported to streams. Several parks in the watershed have pet waste stations, but there are opportunities to expand their numbers. Ongoing pet waste station maintenance should be addressed as new stations are installed.

As part of their MS4 Stormwater program, Bexar County collects stray animals, targeting areas with large numbers of stray dogs. One such area is in the far eastern portion of the Medina River watershed, where new homes and development is expanding. Approximately 17% of all stray animals collected in the county are caught in this area.

Providing education and outreach materials to pet owners about bacteria contributed by pet waste can increase the number of residents who pick up and dispose of pet waste. Recognizing that domestic pets in rural portions of the watershed likely have large areas to roam and that picking up pet waste is likely not feasible for all owners, management measures should target areas of the watershed with public parks and green spaces, and higher housing and pet densities. This management measure is applicable to all subwatersheds, with priority given to areas of higher population.

Table 6-3. Summary of Management Measure: Proper disposal of pet waste.

Source: Dog Waste			
Problem: Direct and indirect fecal bacteria loading from household pets			
Objectives: Furnish education and outreach messaging on disposal of pet waste. Install and maintain pet waste stations in public areas.			
Critical Areas: High pet concentration areas and urbanizing areas; subwatersheds 7, 6, 2, 8, 9, and 10.			
Goal: Reduce the amount of pet waste that may wash into water bodies during rainfall runoff events by providing educational and physical resources to increase stakeholder awareness of water quality and health issues caused by excessive pet waste. Effectively changing behavior of 15% of households with dogs.			
Description: Expand education and outreach regarding the need to properly dispose of pet waste in the watershed. Install and maintain pet waste stations and signage in public areas to facilitate increased collection and proper pet waste disposal.			
Implementation Strategy			
Participation	Recommendations	Period	Capital Costs
Cities, counties, homeowners, homeowner associations	Install and provide needed maintenance supplies for pet waste stations:	2025–2035	Est. $3,500 per station
Cities, Counties, AgriLife Extension and Research, HOAs, MS4s	Develop and provide educational resources to residents	2025–2035	N/A
AgriLife Extension, watershed coordinator	Educational programming for residents	2025–2035	N/A
Estimated Load Reduction			
Estimated *E. coli* load reductions and potential nutrient reductions resulting from pet waste management measures are reliant on changes in people's behavior and are therefore uncertain. Assuming 15% of targeted households respond by properly disposing of pet waste, annual load reduction is: 2.17×10^{15} cfu/year.			

Effectiveness	High: Collecting and properly disposing dog waste is a direct method to immediately prevent *E. coli* from entering water bodies.
Certainty	Low: Some pet owners in the watershed likely already collect and properly dispose of dog waste. Those that do not properly dispose of pet waste may be difficult to reach or convince. The number of additional people that will properly dispose of pet waste is difficult to anticipate.
Commitment	Moderate: Some parks currently have pet waste stations installed; however, maintenance may be less frequent than it needs to be. Meanwhile, little encouragement for owners to pick up after their pets may occur.
Needs	Low: Increasing maintenance on existing pet waste stations could occur. Landscapers may add this to their list of items when mowing parks if resources are provided.

Manage Stormwater Runoff

The objectives of this management measure are to provide educational programs and work with local entities to identify opportunities to reduce and manage stormwater runoff, another potential source of *E. coli* influencing water quality.

As discussed in Chapter 2, the region is experiencing rapid growth and land use changes, particularly in the central portion of the watershed and along major roadways. Stakeholders voiced concerns about the effects of stormwater from rapidly expanding developments and whether stormwater regulations will be able to keep pace with growth. Discussions included the need for policies, strategies, funding, and decision-maker support for floodplain protection, stormwater detention, design and review criteria for new developments, and interlocal agreements between municipal and county governments to facilitate action. While regional flood planning is underway to manage stormwater and reduce flooding potential, water quality is not the focus of these efforts. Significant opportunity exists to combine flooding and water quality management through actions that address both flooding and water quality, including BMPs implemented at the demonstration, property, subdivision or regional scale. The watershed coordinator will work to encourage these activities as appropriate and as funding permits.

Urban stormwater BMPs reduce or delay runoff generated by impervious or highly compacted surfaces such as roofs, roads and parking lots. Potential BMPs include, but are not limited to, rain gardens, rain barrels/cisterns, green roofs, permeable pavement, bioretention, constructed wetlands, swales, and tree box filters. These BMPs vary in ability to reduce stormwater runoff quantity and improve runoff quality based on design and location. Furthermore, volume reductions from BMPs can reduce stormwater entering local sewage collection systems through inflow and infiltration. Well-placed and well-designed stormwater BMPs can substantially decrease and delay runoff and reduce bacteria and nutrient loading. Further implementation of these practices should be encouraged through ordinance development that encourage improved practice use requirements for new development where feasible. Addressing runoff concerns during development can reduce the burden of cost for corrective actions after development.

The TWDB is currently developing guidance on the use of nature-based flood mitigation solutions for Texas communities (TWDB 2024). While the project arose from the state's flood planning effort, the guidance will also help address water quality, groundwater recharge, habitat improvement, and community enhancement goals. The manual will also provide guidance on integrating nature-based features with traditional flood mitigation infrastructure. The public draft release is expected in early 2025 and project completion by spring of 2025.

The San Antonio River Authority's (SARA's) program to promote nature-based solutions for managing stormwater through green infrastructure and low impact development have resulted in the implementation of stormwater BMPs throughout their jurisdiction.

SARA's Green Infrastructure Master Plan guides decision-makers on where and how to apply resources to maximize water quality benefits while addressing local flooding concerns. The SARA Low Impact Development program includes a technical design manual, training program, and modeling tools to identify, plan, design, and construct on-site BMPs to mitigate stormwater pollutants.

There are four regulated Municipal Separate Storm Sewer Systems (MS4) in the watershed – Bexar County, City of San Antonio/San Antonio Water System, Joint Base San Antonio-Lackland, and the Texas Department of Transportation. Under these permits, each entity has developed a stormwater management plan (SWMP) that includes at least the following control actions:

- public education and outreach;
- public involvement or participation;
- detection and elimination of illicit discharges;
- control for stormwater runoff from construction sites;
- post-construction stormwater management in new development and redevelopment zones; and
- pollution prevention and "good housekeeping" measures for municipal operation.

Success of this management measure must be supported by educational programs that increase awareness of the impacts of stormwater on water quality. All MS4 permits in the watershed include outreach and education activities. These include activities such as educational workshops, outreach campaigns, recycling efforts, and more. Other recommended educational tools include installation of publicly accessible demonstration projects to promote low impact and green infrastructure practices, training for city and county staff, developers, maintenance providers, homeowners, and the public, as well as existing TAMU AgriLife trainings on lawn/landscape management and riparian areas, flyers, videos, or other outreach materials.

Table 6-4. Summary of Management Measure: Urban stormwater management.

Source: Stormwater Runoff
Problem: Fecal bacteria loading from stormwater runoff in developed and urbanized areas
Objectives: Educate residents and decision makers about stormwater BMPs. Identify and install stormwater BMPs at all scales feasible. Influence future stormwater manage decisions, requirements, and implementation
Critical Areas: In and near urbanized and urbanizing areas in the watershed
Goal: Reduce *E. coli* loading associated with urban stormwater runoff through implementation of stormwater BMPs as appropriate and to increase local officials and residents' awareness of stormwater pollution and management.
Description: Promote stormwater management BMP projects through education, demonstration and leveraging of other resources. Coordinate with decision makers and property owners.

Implementation Strategy

Participation	Recommendations	Period	Capital Costs
Cities, Counties, SARA, EAA, MS4s, Watershed Coordinator	Identify candidate locations and partners for installing GI/LID BMPs and nature-based solutions for managing stormwater	2025–2035	N/A
Cities, Counties, SARA, EAA, MS4s	Develop plans and install GI/LID BMPs and nature-based solutions as funding becomes available	2025–2035	$40,000 to $100,000 per acre
AgriLife Extension, SARA, MS4s, Watershed Coordinator	Identify and implement opportunities for demonstration projects to encourage use of Green Stormwater/Low Impact Development BMPs	2025–2035	$40,000 to $100,000 per acre
AgriLife Extension and Research, SARA, MS4s, Watershed Coordinator	Deliver education and outreach to landowners and decision makers; encourage stormwater management requirements for future development	2025–2035	N/A

Estimated Load Reduction

Installation of stormwater BMPs that reduce runoff or treat bacteria will result in direct reductions in bacteria loadings in the watershed. Potential load reductions were not calculated because the location, type, and sizes of projects installed will determine the potential load reductions. Nutrient reductions are also commonly realized with many stormwater BMPs; but are not estimated.

Effectiveness	Moderate to High: BMP effectiveness for reducing bacteria loading is dependent on design, site selection and maintenance of the BMP.
Certainty	Moderate: BMP installation requires sustained commitment from local governments. Recent grant funding acquired will help plan and implement specific projects to reduce local flooding which can also have a positive water quality impact if properly designed.
Commitment	Moderate: Flood reduction is a high priority for local cities/counties/drainage districts; financial needs are significant though.
Needs	High: Stormwater management is costly and financial assistance needs are significant yet largely unknown. Information regarding stormwater management alternatives is needed to increase awareness of potential water quality management benefits.

Implement Water Quality Management Plans and Conservation Plans

The goal of this management measure is to increase the use of conservation planning and practices to reduce time spent in riparian areas by livestock and improve grazing resource management across the property.

Bacteria loadings from cattle and other livestock were estimated to be relatively high compared to other evaluated sources. These sources are also considered manageable since the behavior of cattle and the areas where they spend their time can be modified through changes to food, shelter, water availability, and access. Therefore, reducing the amount of time livestock spend in riparian pastures through practices such as rotational grazing, access to alternative watering facilities, or moving supplemental feeding locations can directly reduce loading to water bodies from livestock. This can reduce bacteria volume entering nearby water bodies during runoff by increasing distance between deposition locations and water bodies.

Various BMPs are available to improve forage quality, diversify water resource availability and appropriately distribute livestock across a property. The practices appropriate for implementation vary by operation due to landscape features and landowner goals. Technical assistance is available to landowners upon request to help identify appropriate practices to meet specific property goals. NRCS develops conservation plans while the Texas State Soil and Water Conservation Board (TSSWCB), in partnership with local soil and water conservation districts and NRCS, develops water quality management plans. Stakeholders indicated that developing an additional 240 CPs/WQMPs over the next 10 years is feasible. Bacteria loading from cropland is predominantly from wildlife and is not considered manageable through land conservation practices. Bacteria load reductions on grazing lands achieved from these CPs/WQMPs will vary depending on specific conservation measures implemented.

Implementing CPs/WQMPs is beneficial, regardless of location, as these practices aim to keep water on the landscape by improving forage for livestock and wildlife and maintaining increased ground cover. Increasing vegetation amount and quality on a landscape aids the natural filtration process that can reduce pollutant loading to nearby water bodies. Overall CP/WQMP effectiveness can be maximized on properties with riparian habitat. Therefore, all properties with riparian areas are considered a priority. Properties without riparian habitat are also encouraged to participate in implementation activities because the cooperative effect is still consequential. Priority subwatersheds for livestock related practice implementation are 11, 10, 9, 4, 5, 8, and 1.

This management measure is also supported by targeted educational programs that increase awareness of agricultural practices and measures that can be taken to protect water quality. These programs include educational workshops, demonstration projects, field days, tours, and more. In recent years, a trend toward new and small landowners has been observed, and stakeholders recommend that educational materials and activities also be developed and delivered to meet the needs of these groups. County appraisal districts (CAD) are often a first stop for new landowners in understanding how to optimize their investment. CADs in the Medina WPP watershed take existing WQMPs and CPs into consideration when appraising agricultural property and routinely refer new landowners to AgriLife Extension, SWCDs, and NRCS for technical assistance.

Table 6-5. Summary of Management Measure: Develop and implement WQMPs or CPs.

<table>
<tr><th colspan="5">Source: Cattle and Other Livestock</th></tr>
<tr><td colspan="5">Problem: Direct and indirect fecal bacteria loading due to livestock in streams, riparian degradation, and overgrazing which can increase pollutant loading to water bodies</td></tr>
<tr><td colspan="5">Objectives:
Work with landowners to develop property-specific CPs/WQMPs that improve grazing practices, enhance ground cover, increase pollutant retention, and improve water quality.
Develop funding to hire WQMP technician.
Deliver education and outreach information, programs and workshops to landowners.
Reduce fecal loadings attributed to livestock.</td></tr>
<tr><td colspan="5">Critical Areas: All livestock operations with riparian habitat and subwatersheds 11, 10, 9, 4, 5, 8, and 1.</td></tr>
<tr><td colspan="5">Goal: Develop and implement CPs/WQMPs that reduce time spent in riparian areas by livestock and improve grazing resource management across the property.</td></tr>
<tr><td colspan="5">Description: CPs/WQMPs will be developed upon producer request to implement BMPs that reduce water quality impacts from grazing livestock. Practices will be identified and developed in consultation with NRCS, TSSWCB and local SWCDs as appropriate. Education information, programs and workshops will support and promote the adoption of these practices.</td></tr>
<tr><td colspan="5">Implementation Strategy</td></tr>
<tr><td colspan="2">Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td colspan="2">TSSWCB, SWCDs</td><td>Develop funding to hire WQMP technician</td><td>2025 – 2035</td><td>Estimated $75,000 per year</td></tr>
<tr><td colspan="2">Producers, NRCS, TSSWCB, SWCDs, landowner, lessees</td><td>Develop, implement, and provide financial assistance for livestock CPs and WQMPs</td><td>2025 – 2035</td><td>Est. up to $30,000 per plan) *</td></tr>
<tr><td colspan="2">AgriLife Extension, TWRI, watershed coordinator</td><td>Deliver education and outreach information, programs and workshops to landowners, producers</td><td>2025 – 2035</td><td>N/A</td></tr>
<tr><td colspan="5">Estimated Load Reduction</td></tr>
<tr><td colspan="5">Prescribed management under 24 WQMPs or CPs per year will reduce bacteria loadings associated with livestock by reducing runoff from pastures and rangeland and by reducing direct fecal deposition in water. Nutrient reductions are possible from some implemented practices. Implementation is estimated reduce E.coli loading by 1.43×10^{15} cfu/year.</td></tr>
<tr><td>Effectiveness</td><td colspan="4">High: Decreasing time livestock spend in riparian areas and reducing runoff by managing vegetative cover will reduce NPS contributions of bacteria and other pollutants to creeks.</td></tr>
<tr><td>Certainty</td><td colspan="4">Moderate: Landowners acknowledge the value of good land stewardship practices; however, financial incentives are often needed to encourage CP/WQMP implementation.</td></tr>
<tr><td>Commitment</td><td colspan="4">Moderate: Landowners are willing to implement stewardship practices shown to improve productivity; however, costs are often prohibitive and financial incentives are needed to increase implementation rates.</td></tr>
<tr><td>Needs</td><td colspan="4">High: Financial costs are a major barrier to implementation. Education and outreach are needed to demonstrate benefits of plan development and implementation to producers.</td></tr>
</table>

**Unit costs for Water Quality Management Plans and NRCS Conservation Plans vary widely depending on plan specifics*

Reduce Feral Hog Population

Potential bacteria loading from feral hogs represents a considerable influence on instream water quality. While other sources of bacteria are potentially larger in volume, feral hogs congregate in riparian areas due to the presence of dense habitat, food sources, and water. Common feral hog behavior, such as rooting and wallowing, affects water quality by degrading ground cover which increases erosion. Through a combination of agency technical assistance, education, and landowner implementation of feral hog management techniques, the goal of this management measure is to reduce feral hog populations 8% below current numbers.

Various control efforts are currently employed such as live trapping, shooting, hunting with dogs, exclusion, and habitat management. Aerial hunting is recommended as an additional strategy, but rapidly increasing population density may preclude this from being a feasible option. Trapping has proven to be a common and effective method currently available to landowners. With proper planning and diligence, larger scale trapping can successfully remove large numbers of hogs at once. Comparatively, shooting feral hogs removes fewer than trapping as the animals tend to quickly move away from hunting pressure.

Excluding feral hogs from supplemental feed is also an effective management tool. Given the opportunistic feeding nature of feral hogs, minimizing available food from deer feeders is important. Constructing exclusionary fences around feeders can reduce food ability (Rattan et al., 2010). Locating feeders away from riparian areas can also reduce their impacts on water quality.

The continuation and increased intensity of removal practices, especially in priority areas, along with technical and financial assistance, is needed to reach the overall goal of this plan. Activities will be targeted toward priority areas where landowners should be contacted to discuss the economic savings of removing feral hogs, specific methods to do so, and available programs that assist in feral hog removal.

Educational programs and workshops will be used to improve feral hog removal efficiency. AgriLife Extension provides various online and in-person educational programs and resources for landowners. Delivering up-to-date information and resources to landowners through these workshops can lead to more success removing feral hog populations in the watershed. Landowner-developed wildlife management plans outlining their goals and management practices can also benefit the watershed’s wildlife, habitat, and water quality.

Removing 500 hogs annually would represent approximately 8% of the current feral hog population across the watershed. Based on spatial analysis, subwatersheds 1, 2, 3, 4, 5, 8, 9, 10, and 11 have the highest potential for feral hog loadings based on available habitat. However, given feral hogs’ propensity to travel along riparian corridors in search of food and habitat, priority areas will include all subwatersheds, with high importance placed on properties containing or adjacent to riparian habitat.

Table 6-6. Management Measure: Promote technical and direct operational assistance to landowners for feral hog control.

Source: Feral Hogs			
Problem: Direct and indirect pollutant loading and riparian habitat destruction from feral hogs			
Objectives: Reduce fecal contamination and land disturbance from feral hogs. Work with landowners to reduce feral hog populations. Reduce food availability for feral hogs. Provide education and outreach to stakeholders.			
Critical Areas: All subwatersheds, with high importance placed on riparian properties.			
Goal: Manage feral hog population through all available means to reduce populations by 8% (500 hogs annually).			
Description: Voluntarily implement feral hog population management practices including trapping, reducing access to food supplies and educating landowners and others as they are available.			
Implementation Strategy			
Participation	Recommendations	Period	Capital Costs
Landowners, managers, lessees	Voluntarily construct fencing around deer feeders to prevent feral hog utilization	2025 – 2035	Est $300 per feeder
	Voluntarily trap/remove/shoot feral hogs to reduce numbers	2025 – 2035	TBD
Landowners, producers, TPWD	Develop and implement wildlife management plans and wildlife management practices	2025 – 2035	TBD
AgriLife Extension, Texas Wildlife Services, TPWD	Deliver Feral Hog Education Workshop	2025 – 2035	N/A

Estimated Load Reduction	
Removing and maintaining feral hog populations directly reduces fecal bacteria, nutrient, and sediment loading to water bodies. Reducing the population by 8% would reduce annual E. coli loads by 1.74 x 10^{13} cfu/year.	
Effectiveness	Moderate: Reducing feral hog populations will decrease bacteria and nutrient loading to the streams. However, substantial reduction of the population is difficult.
Certainty	Low: Feral hogs are transient, instinctual, and adapt to changes in environmental conditions. Population reductions require landowner diligence. Combined, there is considerable uncertainty in the ability to remove 8% of the population annually.
Commitment	Moderate: Many landowners are actively battling feral hog populations and will continue to do so if resources remain available. Many other landowners welcome feral hogs as an additional income stream through paid hunting.
Needs	Moderate: Landowners benefit from technical and educational resources to inform them about feral hog management options. Funds are needed to deliver these workshops and to increase removal resources available to landowners.

Reduce Illicit Dumping

Stakeholders indicate that illicit dumping is a problem throughout the watershed. Dumping activities typically occur at or near bridge crossings and access roads near riparian habitats. Items deposited often include animal carcasses, tires, home appliances, household trash, and rubbish. The scope of the problem has not been quantified but it is a potential contributor to the degradation of water and environmental quality. While much of the known trash dumped is not a direct bacteria contributor, it undoubtedly invites additional trash dumping and creates other pollution concerns for habitat, soil and water. Requirements under existing MS4 permits, continued enforcement of local and state regulations, and delivery of educational and outreach materials that focus on the proper disposal of carcasses and other trash should reduce the negative impacts resulting from illicit dumping.

The San Antonio River Authority, as well as all four counties and many cities in the watershed have programs to identify or monitor illegal dumping sites, enforce anti-dumping rules, and conduct public education on anti-littering and illegal dumping. Counties conduct nuisance abatements and routine inspection of known dumping areas, organize clean-up events, and distribute educational materials to engage communities and help prevent illicit dumping. Both SARA and Bexar County conduct annual helicopter surveys to inspect for dumping along stream banks.

While TxDOT relies on the TCEQ or local government for enforcement, the department investigates reports of dumping on its property and right-of-way, and reports problems to the appropriate enforcement agency, as required under its MS4 permit. TxDOT also maintains a hotline and stormwater web page for reporting spills and illegal dumping, and maintains the famous “Don’t Mess With Texas Water” program consisting of billboards placed in sensitive watershed areas that will include a phone number for reporting illicit dumping activities.

Hosting hazardous waste collection events (including agricultural waste) annually in the watershed can reduce improper waste disposal. Stream clean-up events and outreach materials will be scheduled and distributed to help improve current dumping sites and raise public awareness regarding dumping.

Table 6-7. Management Measure: Reduce illicit dumping.

Source: Illicit and Illegal Dumping				
Problem: Illicit and illegal dumping of trash and animal carcasses in and along waterways				
Objectives: Promote and expand education and outreach efforts in the watershed.				
Critical Areas: Entire watershed with focus on bridge crossings and publicly accessible areas				
Goal: Increase awareness of and access to proper disposal techniques and reduce illicit dumping of waste and animal carcasses in or near water bodies throughout the watershed.				
Description: Education and outreach materials will be developed and delivered to residents throughout the watershed on the proper disposal of waste materials.				
Implementation Strategy				
Participation		Recommendations	Period	Capital Costs
Counties, cities, Watershed Coordinator		Organize hazardous waste collection events	2025 – 2035	Est $30,000 per event
Counties, cities, SARA MS4s, Watershed Coordinator		Develop and deliver educational and outreach materials to residents	2025 – 2035	N/A
Estimated Load Reduction				
Load reductions are likely minimal from this management measure and are not estimated.				
Effectiveness	Low: Preventing illicit dumping, especially animal carcasses, is likely to reduce bacteria loads by some amount, although this loading is likely limited to areas with public access.			
Certainty	Low: Anticipating changes in resident behavior due to education and outreach is difficult at best. Reaching residents that illegally dump is likely difficult.			
Commitment	Moderate: Many stakeholders indicate illicit dumping occurs; however, enforcement is difficult. Addressing the issue is not a high priority in all locations and resource availability is low.			
Needs	Moderate: Financial resources are required to develop and distribute educational materials and provide additional events.			

Restore Degraded Streams and Riparian Areas

Stakeholders expressed an interest in identifying areas for riparian restoration and buffers. Many streams in the watershed have been altered through the years by activities such as urban development, encroachment of cropland and pastures, and channelization. Easily identified results of these alterations include degraded riparian vegetation, compacted soils, degraded stream channels, and invasive vegetation. Such changes can alter the natural balance of stream corridors, resulting in flooding, increased erosion and sedimentation, reduced water quality, degraded habitat for aquatic and terrestrial wildlife, and threats to infrastructure such as roads and pipelines.

Maintaining a vegetated buffer (forest, native plantings, etc.) along waterways can slow storm flows, decrease erosion, filter pollutants, and provide other ecosystem services. When maintained in areas appropriate to drainage needs, riparian buffers are a natural, lower cost infrastructure solution. Implementation can take place on public or private land and use a mix of vegetative approaches. A preliminary screening effort was conducted by the Texas A&M Forest Service using the i-Tree Canopy tool to identify riparian areas in the watershed the Medina River with potentially moderate or poor riparian functions. Points representing approximately 6% were identified as moderately functioning and approximately 2% were identified as poorly functioning. These areas are located in all three assessment units of Segment 1912 covered in this WPP. While over 90% of the Medina River riparian areas were identified as potentially properly functioning, the effort demonstrates there are multiple opportunities for establishment or rehabilitation of riparian areas with potential water quality benefits. It's recommended that a more robust assessment be conducted to identify and support targeted restoration of degraded riparian areas.

Stream channel erosion, often a result of unmanaged stormwater, can contribute to poor water quality through release of sediment, nutrients, and other pollutants from sediment and stream bank materials. Restoration of stream channels, especially when paired with riparian and floodplain restoration efforts, can be effective in reducing pollutants and improving water quality. Restoration methods referred to as Natural Channel Design (NCD) focus on the holistic improvement of physical, chemical, and biological functions of a stream system. Physical functions that might be improved are reduction in bank erosion and a self-sustaining water and sediment balance that does not require human intervention (such as dredging). Chemical function improvements can include higher water quality and greater removal of pollutants as water flows through the channel. Biological functions may be improved by expanding habitat for diverse species, such as fish, aquatic insects and other wildlife. The TWDB contracted a study evaluating the potential for use of NCD versus traditional stormwater infrastructure in Texas (TWDB 2013). The report indicated that NCD can be effective in reducing bacteria, nutrient, and sediment in streams.

SARA developed its Stream Restoration program in 2009 in response to recurring channel erosion and stream instability, and has incorporated NCD in both urban and rural locations across their area. Resources developed under this program include design protocols; training for design, construction, and maintenance professionals; research and technical reports; reference reach databases; as well as a stream restoration potential screening tool and database. As part of its watershed master planning efforts, the stream restoration potential screening tool was applied to streams across the San Antonio River basin, including the Medina River WPP watershed. Streams were classified according to the most appropriate method to restore or protect stream corridor functionality using restoration, rehabilitation, or preservation techniques. SARA also conducted feasibility studies for seventeen stream reaches and conceptual designs for three reaches in the watershed (SARA 2024).

The Medina River Beaver Dam Pilot Program is a recently initiated stream restoration effort to pilot test an alternative form of erosion control. SARA's Ecological Engineering Team, in collaboration with the City of San Antonio Parks and Recreation Department, proposed a pilot project involving the River Authority's team of "River Warrior" volunteers. The first project in the pilot program addresses erosion issues at the Medina

River Natural Area, in the lower portion of the watershed. The project includes a series of post-assisted log structures in the erosion valley and miniature dams to reduce erosion, allowing nature to rebuild and stabilize the erosion valleys. The goal is to build 100 of these types of structures and assess the ecological and water quality outcomes.

While much effort has been and continues to be dedicated to identifying and prioritizing areas for potential restoration activities, design and construction costs are often a challenge to completing restoration projects, particularly on private property. Given the potential long-term benefits to communities and the environment, stakeholders recommend that both riparian and stream restoration opportunities be further investigated and implemented should funds become available.

Table 6-8. Summary of Management Measure: Riparian Restoration.

<table>
<tr><th colspan="4">Source: Poorly Functioning Riparian Areas</th></tr>
<tr><td colspan="4">Problem: Degraded riparian areas fail to capture or mitigate pollutant runoff from adjacent areas. Resulting bank instability can promote channel/floodplain erosion and pollutant contributions to water bodies.</td></tr>
<tr><td colspan="4">Objectives:
Promote and expand education and outreach efforts in the watershed.
Identify and implement opportunities for restoration of priority riparian areas.</td></tr>
<tr><td colspan="4">Critical Areas: Entire watershed with focus on poorly functioning riparian areas identified by screening tools.</td></tr>
<tr><td colspan="4">Goal: Increase awareness of properly functioning riparian areas and their benefits to water quality and ecosystem health. Identify and restore degraded systems in priority areas throughout the watershed.</td></tr>
<tr><td colspan="4">Description: Education and outreach programs will be developed and delivered. Screening tools will be used to assist in identifying candidate riparian areas. Restoration activities will be conducted at priority areas.</td></tr>
<tr><td colspan="4">Implementation Strategy</td></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>TFS, Cities, Counties, SARA, EAA, SWCDs, NRCS, MS4s, Watershed Coordinator</td><td>Identify candidate locations and partners for restoration activities</td><td>2025 – 2035</td><td>N/A</td></tr>
<tr><td>TFS, Cities, Counties, SARA, EAA, SWCDs, NRCS, Watershed Coordinator</td><td>Develop plans and conduct riparian restoration activities at priority locations</td><td>2025 – 2035</td><td>TBD</td></tr>
<tr><td>TFS, Cities, Counties, SARA, SWCDs, NRCS, AgriLife Extension, Watershed Coordinator</td><td>Plan and deliver riparian education and outreach programs</td><td>2025 – 2035</td><td>N/A</td></tr>
<tr><td colspan="4">Estimated Load Reduction</td></tr>
<tr><td colspan="4">Enhancement or installation of trees and other vegetation to promote riparian functions will result in direct reductions in bacteria loadings in the watershed by filtering and reducing runoff from adjacent areas. Potential bacteria and nutrient load reductions were not calculated because the location, type, and sizes of projects will determine the potential load reductions.</td></tr>
<tr><td>Effectiveness</td><td colspan="3">Moderate to High: Riparian effectiveness for reducing pollutant loading is known to be high, but will depend on site selection and maintenance of the area. Educational programs have proven effective in knowledge and technology transfer.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Restoration activities and continued maintenance or protection of restored areas require sustained commitment from property owners. Technical and financial assistance is available to help plan and implement specific projects, especially those with additional flood mitigation benefits.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate to Low: Riparian restoration may not be a high priority for local cities or counties. Financial needs may be significant depending on site characteristics.</td></tr>
<tr><td>Needs</td><td colspan="3">Moderate: Technical resources to identify priority sites are available and initial screening has been conducted. Long-term commitment from public property owners is needed. A common understanding by project partners of the expected use, maintenance, and ecosystem benefits of properly functioning riparian areas is needed.</td></tr>
</table>

Table 6-9. Summary of Management Measure: Stream Restoration.

<table>
<tr><td colspan="4">Source: Degraded Stream Channels</td></tr>
<tr><td colspan="4">Problem: Degraded and eroding stream channels impact riparian vegetation, resulting in bank instability, floodplain isolation, sedimentation, and poor water quality.</td></tr>
<tr><td colspan="4">Objectives:
Promote and expand education and outreach efforts in the watershed.
Identify and implement opportunities for restoration of priority areas.</td></tr>
<tr><td colspan="4">Critical Areas: Entire watershed with focus on poorly functioning riparian and publicly accessible areas identified by screening tools.</td></tr>
<tr><td colspan="4">Goal: Increase awareness of properly functioning riparian and stream systems and their benefits to water quality and ecosystem health. Identify and restore degraded stream channels in priority areas throughout the watershed.</td></tr>
<tr><td colspan="4">Description: Education and outreach programs will be developed and delivered. Screening tools will be used to assist in identifying priority areas where restoration activities will be conducted.</td></tr>
<tr><td colspan="4">Implementation Strategy</td></tr>
<tr><td>Participation</td><td>Recommendations</td><td>Period</td><td>Capital Costs</td></tr>
<tr><td>Cities, Counties, SARA, EAA, SWCDs, NRCS, MS4s, Watershed Coordinator</td><td>Identify candidate locations and partners for stream restoration, rehabilitation, or preservation activities.</td><td>2025 – 2035</td><td>N/A</td></tr>
<tr><td>Cities, Counties, SARA, EAA, SWCDs, NRCS, Watershed Coordinator</td><td>Develop plans and conduct activities at priority locations</td><td>2025 – 2035</td><td>TBD</td></tr>
<tr><td>Cities, Counties, SARA, SWCDs, NRCS, AgriLife Extension, Watershed Coordinator</td><td>Plan and deliver riparian education and outreach programs</td><td>2025 – 2035</td><td>N/A</td></tr>
<tr><td colspan="4">Estimated Load Reduction</td></tr>
<tr><td colspan="4">Rehabilitation or restoration of degraded stream systems, including channel, riparian, and floodplain components, will result in direct reductions in bacteria loadings by effectively filtering and reducing runoff from adjacent areas. Reduction in erosion will result in the reduction of bacteria and nutrient loads contained in channel bed and banks. Potential bacteria and nutrient load reductions were not calculated because the location, type, and sizes of projects will determine the potential load reductions.</td></tr>
<tr><td>Effectiveness</td><td colspan="3">Moderate to High: Riparian and floodplain effectiveness for reducing pollutant loading is known to be high, but will depend on site selection and maintenance of the area. Educational programs have proven effective in knowledge and technology transfer.</td></tr>
<tr><td>Certainty</td><td colspan="3">Moderate: Rehabilitation and restoration activities, as well as continued maintenance or protection of restored areas require education and sustained commitment from property owners. Technical and financial assistance is available to help plan and implement specific projects, especially those with additional flood mitigation benefits.</td></tr>
<tr><td>Commitment</td><td colspan="3">Moderate to Low: Rehabilitation or restoration may not be a high priority for local cities or counties. Financial needs are significant and will vary depending on site characteristics.</td></tr>
<tr><td>Needs</td><td colspan="3">Moderate: Technical resources to identify priority sites are available and initial screening has been conducted. Long-term commitment from public property owners is needed. A common understanding by project partners of the expected use, maintenance, and ecosystem benefits of properly functioning stream systems is needed.</td></tr>
</table>

Conserve Land

According to the Texas Land Trust Council (TLTC 2024), over 90,000 acres are protected through conservation easements or fee simple agreements in the four counties partly located in the watershed. Land conservation occurs when landowners voluntary limit particular land use activities that pose a threat or would be detrimental to the natural resources they wish to protect. Depending on the type of easement or agreement, various natural resources may be protected, including water resources, riparian habitat, and native pastures. These voluntary agreements allow deed holders to retain ownership of the property and continue to live on and manage the land. Should the land ever be sold, these easements will typically still apply.

In the Medina River watershed, the Edwards Aquifer Authority joined an interlocal cooperation agreement with the City of San Antonio to support its program to protect land over the environmentally sensitive Recharge and Contributing Zones of the Edwards Aquifer via the Edwards Aquifer Protection Program (EAPP). Most of the properties are protected through conservation easements, legal agreements between the City of San Antonio and local ranch owners that limit development and other activities that may impact the water quality or quantity entering the aquifer. In return for placing a property in a conservation easement, landowners are compensated for a portion of the appraised value of the land. There are currently more than 150,000 acres of land across the aquifer protected under these conservation easements, with over 5,500 in the Medina River WPP watershed. The EAA continues to perform geologic evaluations on prospective properties and conducts the annual monitoring essential to the integrity of the program.

The Department of Defense's Readiness and Environmental Protection Integration (REPI) Program supports land conservation to prevent land use conflicts near military installations. Two REPI program areas are located in the watershed. The JBSA-Lackland REPI project works with local land trust organizations, the San Antonio River Authority, and others on a plan to protect buffer areas around the installation from development pressures. The Camp Bullis Sentinel Landscapes project boundary includes portions of the Contributing and Recharge zones in the upper watershed. Over 60 partner organizations collaborate on this effort to manage and conserve land and natural resources in an area covering portions of six counties. Land conserved under the REPI program could prevent future contributions of pollutants from key tracts along Medio Creek and the lower Medina River, as well as the upper reaches of the watershed.

Management Measure – Manage Abandoned Wells

Abandoned wells are capable of delivering contamination from the surface to groundwater, either by direct transport down the well casing or by providing a pathway between upper and lower groundwater layers. Because of the porous nature of rocks over the Edwards Aquifer, contaminated groundwater could potentially move back to the surface and into water bodies through springs and seeps in the Contributing and

Recharge zones, and via artesian wells or springs in the Artesian zone. Although not identified as a significant source of bacteria, identifying and plugging abandoned or deteriorated wells could prevent bacteria from being transported to water bodies from more remote locations.

The EAA abandoned well closure program was initiated in 2007 and focuses on locating and assessing the condition of Edwards Aquifer water wells within the EAA jurisdiction. Of the over 300 confirmed abandoned wells identified, about 50 are located in the watershed. The EAA works with SAWS to identify and plug abandoned wells, and the EAA funds a needs-based abandoned well closure assistance program to assist well owners with proper plugging of wells.

Chapter 7 Education and Outreach

Engaging both the general public and specific targeted audiences is a crucial component of ensuring the success of the WPP. This Chapter outlines the various educational programs, outreach efforts, and related strategies that will be used to support implementation of this WPP. The purpose of these efforts is to ensure ongoing community involvement in the effort as well as to increase public awareness of water quality and other water resource issues in the watershed.

Long-term commitments from citizens and landowners will be needed to accomplish comprehensive improvements in the Medina WPP watershed. The education and outreach component of implementation must focus on keeping the public, landowners, and agency personnel informed of project activities; provide information about appropriate management practices; and assist in identifying and forming partnerships to lead the effort. Efforts must also be sensitive to stakeholder needs and cultural identities of this urbanizing but historically rural watershed.

To ensure the continuity of the effort and a consistent point of coordination, it's recommended that a Watershed Coordinator facilitate implementation of the WPP. Existing communication networks, outreach opportunities, and partners will be used to maximize resources and reach a wide array of stakeholders. Potential communication and outreach partners will be prioritized to ensure messages meet the needs and concerns of stakeholders from multiple groups. A key focus will be emphasizing the WPP's respect for private property and voluntary solutions.

Watershed Coordinator

The watershed coordinator's role is to lead efforts to establish and maintain working partnerships with stakeholders. In addition to serving as a single point of contact for WPP-related issues, the Watershed Coordinator facilitates stakeholder meetings and coordinates with state and federal agencies to ensure compliance with agreements. The watershed coordinator will be tasked with maintaining stakeholder support, identifying and securing funds to implement the WPP, tracking success of implementation, and working to implement adaptive strategies. A full-time watershed coordinator position in or near the watershed is recommended to effectively support WPP implementation. Texas Water Resources Institute (TWRI) has taken the lead on this role and continues to guide the effort.

General Outreach

The WPP is one of many ongoing efforts toward similar goals of restoring and protecting water and other natural resources for communities in the watershed. These common goals will be leveraged to join forces with, rather than replace, partner organizations. Actively promoting public awareness and interest in the watershed and the WPP is critical to ensuring community support and meeting water quality goals.

Public Stakeholder Meetings

During WPP development, stakeholder engagement was critical. Public meetings to develop the WPP began in October 2023 with local stakeholders. In total, 11 meetings were held to discuss plan development, including general stakeholder meetings and specialized workgroup meetings.

Using stakeholder feedback and data led to the application of planning tools with the WPP as an end goal. This WPP integrates science and stakeholder input to develop a comprehensive watershed-specific plan for restoring and protecting water quality in the Medina River WPP watershed. Public meetings engaging watershed stakeholders have been integral to this effort. Through these meetings, information on new and existing management strategies as well as educational and outreach tools that could be implemented to improve watershed health and water quality was also conveyed.

Maintaining periodic public stakeholder meetings will achieve several WPP implementation goals. Public meetings will provide a platform for the watershed coordinator and project personnel to provide WPP implementation information including implementation progress, near-term implementation goals and projects, information on how to sign-up or participate in active implementation programs, appropriate contact information for specific implementation programs and other information as appropriate. These meetings will keep stakeholders engaged in the WPP process and provide a platform to discuss adaptive management to keep the WPP relevant to watershed and water quality needs. This will be accomplished by reviewing implementation goals and milestones and actively discussing how watershed needs can be better served. Feedback will be incorporated into WPP addendums as appropriate. It's anticipated that public meetings will be held on a quarterly basis during the early years of implementation but may reduce in frequency as the effort advances.

Future Stakeholder Engagement

Watershed stakeholders will continue to be engaged throughout the WPP implementation process. The Watershed Coordinator will play a critical role in this transition by continuing to organize and host periodic public meetings and needed educational events, and by meeting with focused groups of stakeholders to seek out and secure implementation funds. The watershed coordinator will also provide content to maintain and update a project website, track WPP implementation progress, and participate in local events to promote watershed awareness and stewardship. News articles, newsletters, and the project website will be primary tools used to communicate with watershed stakeholders on a regular basis and will be developed to update readers periodically on implementation progress, provide information on new implementation opportunities, available technical or financial assistance, and other items of interest related to the WPP effort.

Texas Watershed Stewards

The Texas Watershed Stewards program is a free educational workshop presented by Texas A&M AgriLife Extension and the TSSWCB. It is designed to help watershed stakeholders improve and protect their water resources by getting involved in local watershed protection and management activities. The program is tailored to address the specific water quality issues within the Medina River WPP watershed.

Events and Opportunities

Many entities working in and around the watershed routinely host educational events that are relevant to the watershed and its stakeholders. These entities include AgriLife Extension, Texas Parks and Wildlife Department, Edwards Aquifer Authority, San Antonio River Authority, City of San Antonio, and various nonprofit organizations such as the Greater Edwards Aquifer Alliance, River Aide San Antonio, Friends of San Antonio Natural Areas, Master Naturalists/Gardeners, Texas Audubon, 4-H, and more. Community and neighborhood events and festivals will provide potential venues for engaging adult and youth through displays, demonstrations, competitions, and print materials. The Watershed Coordinator will identify organizations and events and coordinate as appropriate to increase awareness of the Medina WPP and provide educational materials on various water resource and water quality management strategies.

Volunteer Programs

Active volunteer groups in the watershed that have a focus on water quality and environmental protection include Texas Master Naturalist (TMN) Chapters Brush y Canyons in Medina County, Hill Country in Bandera County, and Alamo Area in Bexar County; as well as the Bexar County Master Gardener Association (TMGA) in Bexar County. These organizations provide training to their members on water quality and environmental protection issues and management strategies, and organize a number of volunteer events each year.

Many TMN, TMGA, and other volunteers engage in various long-term community science efforts such as iNaturalist to map and share observations of plant and animal species, riparian restoration and natural area maintenance, creek cleanups, and water quality monitoring. The Texas Stream Team (TST) is a network of trained volunteers that gather water quality data in lakes, rivers, streams, wetlands, bays, bayous, and estuaries throughout the state. Data collected by TST volunteers is uploaded to a central database and is available for public viewing online. This program is administered through a partnership between Texas State University, the TCEQ, and the EPA, and provides valuable information for local stakeholders and natural resource professionals about water quality.

SARA trains and maintains a group of volunteers, “The River Warriors,” to support the health of the San Antonio River Basin through efforts such as post-storm event litter cleanups, ecosystem restoration plantings and projects, sustainable best management practices, and other workdays. The River Warriors were instrumental in recent construction of the Medina River Beaver Dam Pilot project in the Medina River Natural Area. Efforts will be made to coordinate with these and other volunteer organizations to bolster their activities in the watershed.

Youth Education Programs

Programs delivering knowledge and hands-on experiences to younger stakeholders are an important part of any watershed planning effort. Because youth often share with their parents the information they learn inside and outside the classroom, they can affect adult behavior. Youth educated about water resources may also be better stewards and make lasting behavioral changes in their own lives. Organizations such as the Edwards Aquifer Authority, SARA, and the Greater Edwards Aquifer Alliance, to name a few, conduct and support youth-based educational programs on water resources, healthy watersheds, and water quality. Organizations, such as the Boys and Girls Clubs, that do not provide targeted education on water resources or environmental topics still provide the organizational framework and resources to reach additional stakeholders, and may be engaged to partner in water-related events and activities in the watershed. The Watershed Coordinator will explore interest and promote opportunities for engaging youth programs in the watershed.

The Edwards Aquifer Authority Education Outreach Center (EOC) provides exhibits, self-guided tours, and group learning opportunities. The facility includes a demonstration garden and rainwater harvesting system featuring drought-tolerant landscaping and native vegetation. The program also includes virtual classroom resources and travel scholarships for school groups to visit the facility. The EOC makes significant contributions to improving the environment by educating the community that relies on water from the Edwards Aquifer. EOC presentations are targeted to specific audiences based on age and grade level and include practical steps and calls to action that encourage visitors to do their part in protecting the Edwards Aquifer. SARA conducts an educational program that targets both adults and youth, and includes online presentations, educators toolkits, classroom curriculum, and a K-12 virtual education series. The Greater Edwards Aquifer Alliance (GEAA) also provides online resources, classroom activities and curriculum, as well as resources for managing stormwater, low impact development, and improving water quality.

4-H is the largest youth development program in Texas and is available in every county in the watershed. Programs include art, science, dog training, outdoor education and more. The Texas 4-H Water Ambassadors Program was formed to educate youth about water resources in Texas. Every spring, up to 30 high school youth participate in a summer Leadership Academy. Students travel throughout Texas to learn how water is collected, conveyed, treated, conserved and managed to meet the need of our economy and citizenry. To reinforce knowledge gained during the academy, water ambassadors pass on that information to others as they engage in various education and service activities throughout the year. This program also provides a platform for youth to connect with water industry professionals and educators who represent a wide range of water disciplines.

Emerging research has shown that education programs which include a localized action component like community science can increase knowledge gains and promote behavior change through personal connections to place. To promote these connections, TWRI has developed the Active Community and Citizen Education for Science and Stewardship (ACCESS), a program that connects teachers and students across the state with water educational resources. The goal is to develop watershed specific toolkits with interactive data collection projects leading to increased learning and behavioral impacts. The program engages stakeholders through targeted workshops, introducing a youth education component. This component engages K-12 educators, local universities, and local volunteers to establish a community of practice for ongoing water education efforts in the watershed.

SARA Environmental Advisory Committee

Each year, SARA's 13-member Environmental Advisory Committee (EAC) meets quarterly to review and provide input on SARA's environmental studies and programs. In addition to developing an educated constituent base, the committee advises SARA departments about environmental issues within the basin. The EAC also acts as SARA's Clean Rivers Program Steering Committee, providing guidance and feedback on the River Authority's annual monitoring schedule. These are good meetings for high level issues and concerns and an excellent location to bring up localized water resource concerns and updates on WPP implementation activities.

Newsletters and News Releases

Watershed newsletters will be developed and sent to actively engaged stakeholders at least annually, or more often if warranted. News releases will be developed and distributed through the mass media outlets in the area to highlight significant happenings related to WPP implementation and to continue raising public awareness and support for watershed protection. These means will be used to inform stakeholders of implementation programs, eligibility requirements, and when and where to sign up for specific programs. Public stakeholder meetings and other WPP-related activities will also be advertised through these outlets.

Targeted Educational and Outreach Programs

Delivering applicable and desired educational programming is a critical part of the WPP implementation process. Multiple programs providing information on potential pollutant sources and feasible management strategies will be delivered in and near the watershed and will be advertised to watershed stakeholders. These programs will be coordinated with the efforts of other entities operating in and near the watershed. An approximate program delivery schedule is provided in the management measures described in Chapter 6. As implementation and data collection continues, the adaptive management process will be used to modify this schedule and respective educational needs as appropriate. Potential programs that can meet educational needs are described in subsequent sections.

On-Site Sewage Facilities

OSSF Operation and Maintenance Workshop

A training program that focuses on OSSF rules, regulations, operation and maintenance needs will be delivered in one or more locations in the watershed. This training consists of education and outreach practices to promote proper OSSF management and garners support for efforts to further identify and address failing OSSFs through inspections and remedial actions. AgriLife Extension provides the needed expertise to deliver this training.

Training workshops will be advertised through community newsletters, news releases, the project website, and other appropriate venues. Additionally, an online training module that provides an overview of septic systems, how they operate and what maintenance is required to sustain proper functionality and extend system life will be made available to anyone interested through the project website.

Texas Well Owners Network

Private water wells provide a source of water to many Texas residents. The Texas Well Owners Network (TWON) program provides needed education and outreach regarding private drinking water wells and the impacts on human health and the environment that can be mitigated by using proper management practices. Water quality screenings are conducted through this program and provide useful information to well owners that will benefit them in better managing their water supplies. The “Well Educated” training focuses on informing landowners about groundwater resources, septic system maintenance, well maintenance, water conservation, water quality, and water treatment. As well, TWON has online information and fact sheets about maintaining septic systems to protect well water. Information on this program can be found at: twon.tamu.edu.

Pet Waste

Pet waste is an area in which direct engagement with the public is a necessary component of an effective outreach strategy. Unlike centralized sources like WWTFs, pet waste reduction relies on the individual efforts of thousands of residents. Education may include messaging on pet waste stations or dispensers, general water quality education with a pet waste message included, and amplification of existing educational materials. In addition to website resources and social media, community events and youth engagement opportunities will also be used as outreach tools.

Stormwater Management

Healthy Lawns Healthy Waters Workshop

The Healthy Lawns and Healthy Waters Program aims to improve and protect surface water quality by enhancing awareness, knowledge, and implementation of residential landscape BMPs. This program is most beneficial in urbanized portions of the watershed and can teach homeowners how to care for their lawns appropriately to reduce the risk of NPS pollution entering water bodies.

Urban Riparian and Stream Restoration Workshop

The Urban Riparian and Stream Restoration workshop is available for delivery in the watershed. Although the watershed is predominantly rural at this time, urban stormwater influence on stream health and water quality is growing. This program discusses natural restoration techniques and the unique stressors faced by urban streams.

Regional partners in the WPP, such as the Texas Forest Service, promote urban and riparian forestry or restoration projects for the ecosystem services they provide. The Watershed Coordinator will seek to coordinate with ongoing programs and highlight water quality benefits. As appropriate, funding and technical support for local partners who are doing restoration or new plantings that have a water quality link will be identified. Education and outreach materials will be hosted on the project website to promote riparian restoration projects along the Medina River, Medio Creeks, and tributaries in the watershed.

SARA administers a training program in partnership with Bexar County for the site planning, design, construction inspection and maintenance of LID permanent on-site stormwater Best Management Practices (BMPs). LID is a site assessment and design approach that manages stormwater runoff by mimicking natural hydrologic processes, providing benefits for water quality and mitigating negative impacts of stormwater runoff on downstream resources including streams and rivers. LID practices support stormwater quality improvements within the watershed and can often serve multiple functions in any landscape. The LID training program is comprised of four courses, each offering an optional credentialing component and attendees are eligible for continuing education and professional development hours.

Agricultural Operations and Land Management

Lone Star Healthy Streams Workshop

The watershed coordinator will coordinate with AgriLife Extension personnel to deliver the Lone Star Healthy Streams curriculum. This program is geared to expand knowledge of how to improve grazing lands by beef cattle producers to reduce NPS pollution. This statewide program promotes BMP adoption that is proven to effectively reduce bacterial contamination of streams. This program provides educational support for developing CPs and WQMPs by illustrating the benefits of many practices included in those plans.

Small Acreage and New Landowners

Analysis of historical records shows that small landowners are becoming more prevalent in the Medina River WPP watershed. Small acreage landowners are generally those having between 2 and 100 acres, often using the land for both residential and agricultural purposes. While these acreages are most often located in rural portions of the watershed, they may also be present in or near urban areas. To address stakeholder concerns that these areas are often susceptible to overgrazing, educational opportunities will be provided to small acreage landowners that focus on management of pastures, livestock, and wildlife, as well as proper maintenance of septic systems and water wells.

Field Days and Tours

In addition to printed material and social media, education and outreach methods employed in agricultural and rural areas will include peer-to-peer outreach through workshops, demonstration projects, and field days. Field days are educational events hosted by a producer or an educator and held on a farm or ranch. Events may include demonstrations of specific management practices and highlight economic outcomes or research results. Audiences may include producers, ag professionals, and community members. The field day can include presentations, posters, materials and guided field tours. The Watershed Coordinator will coordinate with NRCS, SWCD, and Extension staff to identify interested landowners and opportunities for hosting field days or tours.

Riparian and Stream Ecosystem Education Training

Healthy watersheds and good water quality go hand in hand with properly managed riparian and stream ecosystems. Delivery of the Riparian and Stream Ecosystem Education program will increase stakeholder awareness, understanding and knowledge about the nature and function of riparian zones and BMPs that can be used to protect them while minimizing NPS pollution. Through this program, riparian landowners will be connected with local technical and financial resources to improve management and promote healthy watersheds and riparian areas on their land. The Watershed Coordinator will work to plan an associated field day to coincide with this event.

Feral Hogs and Wildlife

Feral Hog Workshops

The Watershed Coordinator will coordinate with AgriLife Extension personnel to deliver periodic workshops focusing on feral hog management. This workshop will educate landowners on the negative impacts of feral hogs, effective control methods, and resources to help them control these pests. Workshops will also include significant changes in available means and methods to control feral hogs. Feral hog management is also incorporated into the Lone Star Healthy Streams education program

Wildlife Management Workshops

Periodic wildlife management workshops are warranted to provide information on management strategies and available resources to those interested. The Watershed Coordinator will work with AgriLife Extension wildlife specialists, TPWD and others as appropriate to plan and secure funding to deliver workshops in and near the watershed. Wildlife management workshops will be advertised through newsletters, news releases, the project website, and other avenues as appropriate.

Chapter 8: Plan Implementation

Implementing the WPP is a multi-year commitment that will require active participation from various stakeholders and local entities for a planned 10-year period. This Chapter describes the overall plan for implementing management measures described in Chapter 6, including financial and technical assistance supported by continued education and outreach. The first step to successful implementation is to create a reasonable implementation schedule with interim goals and estimated costs. All management strategies in the WPP are voluntary but have received stakeholder support, which increases the likelihood that they will be implemented.

A complete list of management measures and goals, responsible parties, and estimated costs is included in Table 8-1. Implementation goals are included incrementally to reflect anticipated implementation time frames. In specific cases, funding acquisition, personnel hiring, or program initiation may delay implementation progress. This approach provides incremental implementation targets that can be used as gages to measure implementation progress. If sufficient progress is not made, adjustments will ensue to increase implementation and meet established goals. Adaptive management may also be used to adjust the planned approach if the original strategy is no longer feasible or other measures have proven more effective.

Table 8-1. Implementation Schedule

Management Measure	Participation	Estimated Unit Cost	Number Implemented			Estimated Total Cost
			Years 1-3	Years 4-6	Years 7-10	
SSOs AND UNAUTHORIZED DISCHARGES						
Identify and address recurring or high-volume SSOs for repair or replacement through capital improvement programs	Cities, Permittees, Operators	---	1			n/a[2]
Participate in the TCEQ Sanitary Sewer Overflow Initiative (SSO Initiative)	Publicly owned WWTF Permittees	---	1			n/a[1]
Identify resources to aid repair or replacement of WWTF collection system infrastructure.	Cities, Permittees, Watershed Coordinator	---	1			n/a[1]
Develop and deliver education material to residents and property owners	Cities, Permittees, AgriLife Extension, Watershed Coordinator	$3,000	1	1	1	$9,000
Identify operations and maintenance training needs, develop and deliver resources to appropriate staff as available.	Permittees, Operators	---	As identified, needed, funding available			n/a[1]
OSSF MANAGEMENT						
Identify, inspect, and address 600 failing OSSFs repair, rehabilitation, or replacement	Counties, service providers, homeowners	$8,000 - $12,000	180	180	240	$4,800,000- $72,000,000
Evaluate feasibility of connecting to existing or planned infrastructure	Counties, municipalities, homeowners	---	1			n/a[1]
Develop and deliver materials (postcards, websites, handouts, etc.) to educate homeowners	AgriLife Extension, TWRI, Watershed Coordinator	---	1			n/a[2]
Operate an OSSF education, outreach, and training program for installers, service providers and homeowners	AgriLife Extension, TWRI, Watershed Coordinator, Counties	$4,000	1	1	1	$12,000
PET WASTE MANAGEMENT						
Install and provide maintenance supplies for pet waste stations	Cities, counties, homeowners, HOAs	$3,500	5	10	10	$87,500
Develop and provide educational resources to residents	Cities, Counties, AgriLife Extension and Research, HOAs, Watershed Coordinator	$3,000	1	1	1	$9,000
Develop and deliver educational programs for residents	AgriLife Extension, Watershed Coordinator	$3,000	1	1	1	$9,000

Management Measure	Participation	Estimated Unit Cost	Number Implemented			Estimated Total Cost
			Years 1-3	Years 4-6	Years 7-10	
STORMWATER MANAGEMENT						
Identify candidate locations and partners for installing GI/LID practices and nature-based solutions for managing stormwater	Cities, Counties, SARA, EAA, MS4s, Watershed Coordinator	---	As many as possible			n/a[1]
Develop plans and install GI/LID BMPs and nature-based solutions	Cities, Counties, SARA, EAA, MS4s	$40,000 - $100,000 /acre	As identified, needed, funding available			n/a[2]
Identify and implement opportunities for demonstration projects to encourage use of GI/LID BMPs and nature-based solutions	SARA, MS4s, AgriLife Extension, Watershed Coordinator	$40,000 - $100,000 /acre	As identified, needed, funding available			n/a[2]
Plan and deliver education and outreach programs for landowners, residents, developers, and decision-makers	SARA, MS4s, AgriLife Extension, Watershed Coordinator	$4,000	1	1	1	$12,000
IMPLEMENT WQMPs OR CPs						
Develop funding to hire WQMP technician	TSSWCB, SWCDs	Est $75,000/yr	1			$750,000
Develop, implement, and provide financial assistance for 240 livestock CPs and WQMPs	NRCS, TSSWCB, SWCDs, producers, landowners, lessees	Est. up to $30,000 /plan	72	72	96	$7,200,000
Deliver education and outreach information, programs and workshops to landowners, producers	AgriLife Extension, TWRI, Watershed Coordinator	$4,000	1	1	1	$12,000
FERAL HOG MANAGEMENT						
Voluntarily construct fences around deer feeders to prevent feral hog utilization	Landowners, producers, lessees	Est $300 per feeder	As many as possible			n/a[1]
Voluntarily trap/remove/shoot feral hogs to reduce numbers	Landowners, producers, lessees	---	1,500	1,500	2,000	n/a[2]
Develop and implement wildlife management plans and wildlife management practices	Landowners, producers, TPWD	---	As many as possible			n/a[2]
Deliver Feral Hog Education Workshops	AgriLife Extension, Texas Wildlife Services, TPWD	$4,000	1	1	1	$12,000
REDUCE ILLICIT DUMPING						
Organize hazardous waste collection events	Counties, cities, watershed coordinator	Est $30,000	1	1	1	$90,000
Develop and deliver educational and outreach materials to residents	Counties, cities, SARA MS4 permittees, Watershed Coordinator	$3,000	1	1	1	$9,000

Management Measure	Participation	Estimated Unit Cost	Number Implemented			Estimated Total Cost
			Years 1-3	Years 4-6	Years 7-10	
RIPARIAN RESTORATION						
Identify candidate locations and partners for restoration activities	TFS, Cities, Counties, SARA, EAA, MS4s, TSSWCB, NRCS, Watershed Coordinator	---	As many as possible			n/a[1]
Develop plans and conduct riparian restoration activities at priority locations	TFS, Cities, Counties, SARA, EAA, TSSWCB, NRCS, Watershed Coordinator	---	As identified, needed, funding available			n/a[2]
Plan and deliver riparian education and outreach programs	TFS, Cities, Counties, SARA, TWRI, AgriLife Extension, Watershed Coordinator	$4,000	1	1	1	$12,000
STREAM RESTORATION						
Identify candidate locations and partners for stream restoration, rehabilitation, or preservation	Cities, Counties, SARA, EAA, MS4s, Watershed Coordinator	---	As many as possible			n/a[1]
Develop plans and install restoration or rehabilitation features	Cities, Counties, SARA, EAA	---	As identified, needed, funding available			n/a[2]
Plan and deliver education and outreach programs for landowners, residents, developers, and decision-makers	SARA, AgriLife Extension, Watershed Coordinator	$4,000	1	1	1	$12,000

[1] Funded wholly or partially through existing participant program

[2] Extent and cost will be determined during implementation based on engineering or other assessments

RIPARIAN RESTORATION						
Identify candidate locations and partners for restoration activities	TFS, Cities, Counties, SARA, EAA, MS4s, TSSWCB, NRCS, Watershed Coordinator	---	As many as possible			n/a[1]
Develop plans and conduct riparian restoration activities at priority locations	TFS, Cities, Counties, SARA, EAA, TSSWCB, NRCS, Watershed Coordinator	---	As identified, needed, funding available			n/a[2]
Plan and deliver riparian education and outreach programs	TFS, Cities, Counties, SARA, TWRI, AgriLife Extension, Watershed Coordinator	$4,000	1	1	1	$12,000
STREAM RESTORATION						
Identify candidate locations and partners for stream restoration, rehabilitation, or preservation	Cities, Counties, SARA, EAA, MS4s, Watershed Coordinator	---	As many as possible			n/a[1]
Develop plans and install restoration or rehabilitation features	Cities, Counties, SARA, EAA	---	As identified, needed, funding available			n/a[2]
Plan and deliver education and outreach programs for landowners, residents, developers, and decision-makers	SARA, AgriLife Extension, Watershed Coordinator	$4,000	1	1	1	$12,000

[1] Funded wholly or partially through existing participant program

[2] Extent and cost will be determined during implementation based on engineering or other assessments

Chapter 9: Resources

This chapter identifies potential technical and financial assistance sources available to implement management measures described in Chapter 6. Grant funding will be a substantial source of implementation funding given the type and variety of needs identified. In addition to technical and financial assistance, the Watershed Coordinator position serves a critical role for ensuring WPP success. It is recommended that local funds be identified and used to hire a local Watershed Coordinator to guide WPP implementation and facilitate long-term success.

Technical Assistance

Designing, planning, and implementing many management recommendations in the plan will require technical expertise. In these cases, appropriate technical support will be sought. Funding required to secure needed expertise will be included as appropriate in requests for specific projects. Potential technical assistance sources for each management measure are listed below (Table 9-1).

Table 9-1. Summary of potential sources of technical assistance.

Management Measure	Potential sources
SSOs and Unauthorized Discharges	TCEQ, SAWS, WWTFs, private firms
OSSF Management	Design technicians from counties, AgriLife Extension
Pet Waste Management	Cities, Counties, AgriLife Extension, SARA, MS4s
Stormwater Management	MS4s, SARA, EAA, AgriLife Extension
Implement WQMPs or CPs	TSSWCB, local SWCDs, NRCS
Feral hog management	AgriLife Extension, TPWD, NRCS, TSSWCB, TWS
Reduce illicit dumping	Cities, counties, MS4s, SARA, AgriLife Extension
Riparian and Stream Restoration	SARA, NRCS, TFS, private firms

County or City Designated Representatives

OSSF construction or replacement in Atascosa, Bandera, Bexar, or Medina counties requires a permit on file with local authorized agents. Permits must be applied for through a TCEQ-licensed professional installer. The county or city's designated representative is responsible for approving or denying permits. Site evaluations must be done by a TCEQ-licensed site and soil evaluator, licensed maintenance provider, or licensed professional installer.

Edwards Aquifer Authority

The EAA is a regional water management agency that regulates the use of the Edwards Aquifer, which provides water to over 2.5 million people. The EAA was created in 1993 to protect the aquifer from federal takeover and to preserve threatened and endangered species. The EAA has regulatory jurisdiction in all of Bexar, Medina and Uvalde counties and portions of Atascosa, Caldwell, Comal, Guadalupe, and Hays counties. The organization operates its Field Research Park for the purpose of conducting various field experiments and conduct long-term research on the aquifer system.

Natural Resources Conservation Service

NRCS provides conservation planning and technical assistance to private landowners. For decades, private landowners have voluntarily worked with NRCS personnel to prevent erosion, improve water quality, and promote sustainable agriculture. Assistance is available to help landowners maintain and improve private lands, implement improved land management technologies, protect water quality and quantity, improve wildlife and fish habitat, and enhance recreational opportunities. Local NRCS centers are located in Hondo, Bandera, Pleasanton, and San Antonio.

Private Firms

The technical expertise provided by firms may be required for wastewater infrastructure projects or stormwater BMP and GI/LID design. Private firms provide consulting, engineering, and design services. Private firms specializing in water and wastewater services offer onsite training to their clients as part of their water and wastewater treatment services. This is accomplished through hands-on instruction and seminars on basic water treatment practices and procedures control testing, and the safe handling of chemicals. Extensive work has been conducted by the Texas General Land to develop manuals and recommended strategies that can be incorporated into engineering designs. Existing resources can be leveraged by engineering firms to ensure future plans are aligned with the goals and regulatory guidelines of partnering organizations. Funding for services will be identified and written into project budgets as required.

San Antonio River Authority

SARA has a jurisdictional area that includes all of Bexar, Wilson, Karnes, and Goliad Counties, but provides valuable assistance throughout the San Antonio River Basin. SARA conducts water quality monitoring activities and special studies, education and outreach, as well as ecosystem restoration. SARA’s programs encourage public use of water and natural areas, enhance water quality, and preserve aquatic and riparian habitat. SARA will be a source of environmental technical assistance across the watershed.

San Antonio Water System

Formally established in 1992 from various smaller utilities, SAWS works closely with the City of San Antonio and other customers to provide drinking water, wastewater, and stormwater services in the region. An important component of SAWS' planning role is the responsibility to protect the purity of the city's water supply coming from the Edwards Aquifer, including enforcing certain city ordinances related to subdivision development.

Soil and Water Conservation Districts

A SWCD, like a county or school district, is a subdivision of the state government. SWCDs are administered by a board of five directors who are elected by their fellow landowners. There are 216 individual SWCDs organized in Texas. It is through this conservation partnership that local SWCDs can furnish technical assistance to farmers and ranchers for the preparation of a complete soil and water CP to meet each land unit's specific capabilities and needs. The local SWCDs include Atascosa County SWCD, Bandera SWCD, Medina Valley SWCD, and Alamo SWCD.

Texas A&M AgriLife Extension

AgriLife Extension is a statewide outreach education agency with offices in every county of the state. AgriLife Extension provides a network of professional educators, volunteers, and local county extension agents. AgriLife Extension will be consulted to develop and deliver education programs, workshops, and materials as needed.

Texas Wildlife Services (TWS) is a division of the Texas A&M AgriLife Extension Service. This agency protects the resources, property, and well-being of Texans from damage related to wildlife. TWS serves rural and urban areas with technical assistance, education, and direct control for wildlife damage management of both native wildlife and non-domestic animals.

Texas Commission on Environmental Quality

TCEQ offers a variety of programming and personnel resources that can provide technical support for WPP Implementation. TCEQ's SSO Initiative is a voluntary program for permitted WWTFs and municipalities. Through the initiative, an SSO plan is developed outlining the causes of SSOs, mitigative and corrective actions, and a timeline for implementation. Assistance for SSO planning and participation in the SSO Initiative is available through the TCEQ regional office (Region 13, San Antonio) and the TCEQ Small Business and Environmental Assistance Division.

TCEQ regional offices also provide resources and expertise for environmental monitoring activities, investigating compliance at permitted facilities and responding to complaints, developing enforcement actions for violations, and performing environmental education and technical assistance for communities as needed. Regional offices also respond to environmental emergencies (disasters, spills, etc.) and evaluate public exposure to hazardous materials.

Texas Parks and Wildlife Department

TPWD's Private Land Services is a program to provide landowners with practical information on ways to manage wildlife resources that are consistent with other land use goals, to ensure plant and animal diversity, to provide aesthetic and economic benefits and to conserve soil, water, and related natural resources. TPWD offers assistance in developing property-specific wildlife habitat management plans and can aid in tracking the expected water quality improvements. Additionally, TPWD offers a habitat management workshop through their regional biologists. To participate, landowners may request assistance by contacting the TPWD district serving their county. District 4 (Kerrville) serves Bandera County, while District 8 (Pleasanton) serves Atascosa, Bexar, and Medina Counties.

Texas State Soil and Water Conservation Board

TSSWCB supports the operation of local SWCDs and leads the WQMP program by providing technical assistance for developing management and conservation plans at no charge to agricultural producers. A visit with the local SWCD offices is the first step for operators to begin the plan development process.

Financial Resources

Successful WPP implementation will require substantial fiscal resources. Diverse funding sources will be sought to meet these needs. Resources will be leveraged where possible to extend the impacts of acquired and contributed implementation funds.

Grant funds will be relied upon to initiate implementation efforts. Existing state and federal programs will also be expanded or leveraged with acquired funding to further implementation impacts. Grant funds are not a sustainable source of financial assistance but are necessary to assist in WPP implementation. Other sources of funding will be used, and creative funding approaches will be sought where appropriate. Sources of funding that are applicable to this WPP will be sought as appropriate and are described in this chapter.

Federal Sources

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

EPA provides grant funding to Texas to implement projects that reduce NPS pollution through the §319(h) Nonpoint Source Grant Program. These grants are administered by TCEQ and TSSWCB. WPPs that satisfy the nine key elements of successful watershed-based plans are eligible for funding through this program. To be eligible for funding, implementation measures must be included in the accepted WPP and meet other program rules. Some commonly funded items include but are not limited to:

- development and delivery of education programs;
- water quality monitoring;
- OSSF repairs and replacements;
- BMP installation and demonstrations; and
- water body cleanup events.

Further information can be found at: https://www.tceq.texas.gov/waterquality/nonpoint-source/grants/grant-pgm.html and https://www.tsswcb.texas.gov/programs/texas-nonpoint-source-management-program

Conservation Stewardship Program

The Conservation Stewardship Program (CSP) is a voluntary conservation program administered by NRCS that encourages producers to address resource concerns in a comprehensive manner by undertaking additional conservation activities and improving, maintaining, and managing existing conservation activities. The program is available for private agricultural lands including cropland, grassland, prairie land, improved pasture, and rangeland. CSP encourages landowners and stewards to improve conservation activities on their land by installing and adopting additional conservation practices including but not limited to prescribed grazing, nutrient management planning, precision nutrient application, manure application, and integrated pest management. Program information can be found at: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/

Conservation Reserve Program

The Conservation Reserve Program is a voluntary program for agricultural landowners administered by the USDA Farm Service Agency. Individuals may receive annual rental payments to establish long-term, resource-conserving covers on environmentally sensitive land. The goal of the program is to reduce runoff and sedimentation to protect and improve lakes, rivers, ponds, and streams. Financial assistance is available to establish approved conservation practices, enrollment payments, and performance payments are available through the program. Information on the program is available at: https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index

Environmental Quality Incentives Program (EQIP)

NRCS operates EQIP, which is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of 10 years. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and provides opportunities to improve soil, water, plant, animal, air, and related resources on agricultural land and nonindustrial private forestland. Individuals engaged in livestock or agricultural production on eligible land are permitted to participate in EQIP. Practices selected address natural resource concerns and are subject to NRCS technical standards adapted for local conditions. They also must be approved by the local SWCD. Local work groups are formed to provide recommendations to NRCS that advise the agency on allocations of EQIP county-based funds and identify local resource concerns. Watershed stakeholders are strongly encouraged to participate in their local work group to promote the objectives of this WPP with the resource concerns and conservation priorities of EQIP. Information regarding EQIP can be found at: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/

National Water Quality Initiative

The National Water Quality Initiative is administered by NRCS and is a partnership between NRCS, state water quality agencies, and EPA to identify and address priority impaired water bodies through voluntary conservation. Conservation systems include practices to promote soil health and reduce erosion and nutrient runoff. Further information is available at: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/?cid=stelprdb1047761

Regional Conservation Partnership Program

The Regional Conservation Partnership Program (RCPP) is a comprehensive and flexible program that uses partnerships to stretch and multiply conservation investments and reach conservation goals on a regional or watershed scale. Through RCPP and NRCS, state, local, and regional partners coordinate resources to help producers install and maintain conservation activities in selected project areas. Partners leverage RCPP funding in project areas and report on the benefits achieved. The Camp Bullis Sentinel Landscape RCPP was initiated in 2022 and includes upper portions of the watershed.

Information regarding RCPP and the Camp Bullis project can be found at: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/rcpp/ and at https://rise.articulate.com/share/b41rEliehemd_HIChxGJ0K-lf_zR1k_x#/

Rural Development Water and Environmental Programs

USDA Rural Development provides grants and low interest loans to rural communities for potable water and wastewater system construction, repair, or rehabilitation. Funding options include:

- Rural repair and rehabilitation loans and grants: provide assistance to make repairs to low-income homeowners' housing to improve or remove health and safety hazards
- Technical assistance and training grants for rural waste systems: provide grants to nonprofit organizations that offer technical assistance and training for water delivery and waste disposal

- Water and waste disposal direct loans and grants: assist in developing water and waste disposal systems in rural communities with populations less than 10,000 individuals.

More information about the USDA Rural Development program can be found at: https://www.rd.usda.gov/programs-services/water-environmental-programs

Urban Water Small Grants Program

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

More information about the Urban Waters Small Grants Program can be found at: https://www.epa.gov/urbanwaters/urban-waters-small-grants

Community Development Block Grants

Grants are available through the U.S. Housing and Urban Development program. The Community Development Block Grant (CDBG) Program provides annual grants on a formula basis to states, cities, and counties to develop viable urban communities by providing decent housing and a suitable living environment, and by expanding economic opportunities, principally for low- and moderate-income persons. More information about the Community Development Block Grants Program can be found at: https://www.hud.gov/program_offices/comm_planning/cdbg

State Sources

Clean Rivers Program

TCEQ administers Texas CRP, a state fee-funded program that provides surface water quality monitoring, assessment, and public outreach. Allocations are made to 15 partner agencies (primarily river authorities) throughout the state to assist in routine monitoring efforts, special studies, and outreach efforts. SARA is the partner for the San Antonio River basin and Medina River watershed. The program supports water quality monitoring and annual water quality assessments and engages stakeholders in addressing water quality concerns. More information about the NRA CRP is available at: https://nracleanriversprogram.org/

Clean Water State Revolving Fund

The Clean Water State Revolving Fund, authorized through the CWA and administered by the TWDB, provides low-interest loans to local governments and service providers for infrastructure projects that include stormwater BMPs, WWTFs, and collection systems. The loans can spread project costs over a repayment period of up to 20 years. Repayments are cycled back into the fund and used to pay for additional projects.

Through 2020, the program has committed approximately $10 billion for projects across Texas. More information on Clean Water State Revolving Fund is available at: http://www.twdb.texas.gov/financial/programs/CWSRF/

Landowner Incentive Program

TPWD administers the Landowner Incentive Program (LIP) for private landowners to implement conservation practices that benefit healthy aquatic and terrestrial ecosystems and create, restore, protect, or enhance habitat for rare or at-risk species. The program provides financial assistance but does require the landowner to contribute through labor, materials, or other means. Further information about this program is available at: https://tpwd.texas.gov/landwater/land/private/lip/

Supplemental Environmental Projects

The Supplemental Environmental Program (SEP) program, administered by TCEQ, directs fines, fees, and penalties for environmental violations toward environmentally beneficial uses. Through this program, a respondent in an enforcement matter can choose to invest penalty dollars to improve the environment, rather than paying into the Texas General Revenue Fund. Program dollars may be directed to OSSF repair, trash clean up, and wildlife habitat restoration or improvement, among other things. Program dollars may be directed to entities for single, one-time projects that require special approval from TCEQ or directed entities (such as Resource Conservation and Development Councils) with pre-approved “umbrella” projects. Further information about SEP is available at: https://www.tceq.texas.gov/compliance/enforcement/sep/sep-main

Texas Farm and Ranch Lands Conservation Program

The Texas Farm and Ranch Lands Conservation Program was established and is administered by TPWD to conserve high value working lands to protect water, fish, wildlife, and agricultural production that are at risk of future development. The program’s goal is to educate citizens on land resource stewardship and establish conservation easements to reduce land fragmentation and loss of agricultural production. Program information is available from TPWD at: https://tpwd.texas.gov/landwater/land/private/farm-and-ranch/

Other Sources

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

- Cynthia and George Mitchell Foundation: provides grants for water and land conservation programs to support sustainable protection and conservation of Texas’ land and water resources
- Dixon Water Foundation: provides grants to nonprofit organizations to assist in improving/maintaining watershed health through sustainable land management

- Meadows Foundation: provides grants to nonprofit organizations, agencies and universities engaged in protecting water quality and promoting land conservation practices to maintain water quality and water availability on private lands
- Partnerships with local industry in the watersheds could also provide in-kind donations or additional funding for implementation projects
- Texas Agricultural Land Trust: funding provided by the trust assists in establishing conservation easements for enrolled lands

Chapter 10: Measuring Success

This Chapter describes the various processes and information that will be used to monitor and measure success of the WPP. Implementing the WPP requires coordination with many stakeholders over the next 10 years and will focus on addressing readily manageable bacteria sources in the watersheds to achieve water quality targets. This plan identifies substantial financial resources, technical assistance, and education required to achieve these targets. Management measures identified in this WPP are voluntary but supported at the recommended levels by watershed stakeholders.

Measuring WPP implementation impacts on water quality is a critical process. Planned water quality monitoring at critical locations will provide data needed to document progress toward water quality goals. While improvements in water quality are the preferred measure of success, documenting implementation accomplishments can also be used. Combining water quality data and implementation accomplishments helps facilitate adaptive management by illustrating which recommended measures are working and which measures need modification.

Water Quality Targets

An established water quality goal defines the target for future water quality and allows the needed bacteria load reductions to be defined. The water quality goal in the Medina River WPP watershed is the existing primary contact recreation standard for E. coli of 126 cfu/100 mL (Table 10-1). If there are revisions or adoption of new water quality standards, such as for nutrients, these targets may be revised or amended as appropriate.

Table 10-1. Water quality targets for the Medina River and Medio Creek.

Year	Medina River (Station 12814)	Medio Creek (Station 12916)
	E. coli† (cfu/100mL)	E. coli† (cfu/100mL)
Year 0	223	175
Year 5	175	151
Year10	126	126

† Geometric mean in units of most probable numbers of E. coli per 100 milliliters of water

Additional Data Collection Needs

Continued water quality monitoring in the Medina River and Medio Creek watersheds is necessary to track water quality changes resulting from WPP implementation. Routine water quality monitoring at stations used in state water quality assessment is critical for future evaluations and should be continued. Additionally, stations 12814 and 12916 were used in LDC analysis to determine needed load reductions to meet the water quality targets listed above. Continued data collection over time is imperative for changes in bacteria loading to be evaluated.

The current monitoring site distribution and data collection frequency across the watersheds may limit potential to observe changes water quality that result from targeted WPP implementation. Defining localized water quality impacts from specific WPP implementation activities will require focused water quality monitoring efforts, which can only be planned once specific WPP implementation activities and locations are known. Focused monitoring plans would require funding support and may be used to assess implementation effectiveness.

Through the adaptive management process and WPP updates, future water quality monitoring needs will be evaluated and adjusted as necessary. This could include adding new sites to address new concerns or areas of interest in the watersheds.

Data Review

The Watershed Coordinator will assist stakeholders in evaluating WPP implementation impacts on instream water quality. TCEQ's statewide biennial water quality assessment approach, which uses a moving 7-year geometric mean of bacteria data collected, will be the primary means of gauging water quality improvement and ultimate success of the WPP. This assessment is published in the *Texas Integrated Report and 303(d) List* and is available online at https://www.tceq.texas.gov/waterquality/assessment/305_303.html. It is noted that a 2-year lag occurs in data reporting and assessment; therefore the 2028 or 2030 *Texas Integrated Report* will likely be the first to include water quality data collected during WPP implementation.

Identifying water quality improvements from WPP implementation is challenging if only relying on the 7-year data window used for the *Texas Integrated Report*. Therefore, another method to evaluate water quality improvements is using the geometric mean of the most recent 3 years of water quality data identified within TCEQ's Surface Water Quality Monitoring Information System. To support data assessment as needed, trend analysis and other appropriate statistical analyses will be used. Regardless of method used, water quality changes resulting from WPP implementation will be difficult to determine and may be overshadowed by activity in the watersheds that negatively influences water quality. As such, data review will not be relied on exclusively to evaluate WPP effectiveness. Data will be summarized and reported to watershed stakeholders at least annually through stakeholder meetings and SARA's annual CRP meeting.

The Watershed Coordinator will be responsible for tracking implementation targets and water quality in the watersheds. Implementation progress and water quality will be evaluated to describe the success of WPP implementation to that point. Should implementation targets or water quality lag significantly, adaptive management efforts will be initiated to reevaluate management recommendations and targets included in the WPP.

Interim Measurable Milestones

WPP implementation will occur over a 10-year timeframe. Milestones can be useful in evaluating incremental implementation progress of management measures described in the WPP. Milestones outline a clear process for progression throughout implementation. Interim measurable milestones for management measures and education and outreach are addressed in Table 8-1. Responsible parties and estimated costs (where available) are included in the schedule. In some cases, funding acquisition, personnel hiring, or program initiation may delay the start of some items. This approach provides incremental targets to measure progress throughout WPP implementation. Adaptive management may be used where necessary to reorganize or prioritize varying implementation aspects to achieve overarching water quality goals.

Adaptive Management

Watersheds are dynamic by nature, with countless variables governing landscape processes; therefore, uncertainty is expected and the WPP was developed with this in mind. As WPP implementation progresses, it is necessary to track water quality over time and make needed adjustments to the implementation strategy. Including an adaptive management approach in the WPP provides flexibility that enables such adjustments.

Adaptive management is the ongoing process of accumulating knowledge regarding impairment causes and water quality response as implementation efforts progress and adjusting management efforts as needed. As implementation activities are instituted, water quality is tracked to assess impacts. This information can be used to guide adjustments to future implementation activities. This ongoing, cyclical implementation and evaluation process can focus project efforts and optimize its impacts. Watersheds where impairments are dominated by NPS pollutants are good candidates for adaptive management. Progress toward achieving established water quality targets will also be used to evaluate the need for adaptive management. An annual implementation progress and water quality trends review will be presented to stakeholders during meetings. Due to numerous factors that can influence water quality and the time lag that often appears between implementation efforts and resulting water quality improvements, sufficient time should be allowed for implementation to occur before triggering adaptive management. In addition to water quality targets, if satisfactory progress toward achieving milestones is determined to be infeasible due to funding, implementation scope, or other reasons that would prevent implementation, adaptive management provides an opportunity to revisit and revise the implementation strategy. If stakeholders determine inadequate progress toward water quality improvement or milestones is being made, efforts will be made to increase BMP adoption and adjust strategies or focus areas as appropriate.

References

AVMA (American Veterinary Medical Association). 2022. U.S. Pet Population. In U.S. Pet Ownership & Demographics Sourcebook. Schaumburg, IL. https://ebusiness.avma.org/files/ProductDownloads/eco-pet-demographic-report-22-low-res.pdf

Gregory, L., Blumenthal, B., Wagner, K., Borel, K., Karthikeyan, R. 2013. Estimating On-site Sewage Facility Density and Distribution Using GeoSpatial Analyses. J. of Natural Environmental Sciences. 4(1): 14-21.

Griffith, G.E., S.A. Bryce, J.M. Omernik, J.A. Comstock, A.C. Rogers, B. Harrison, S.L. Hatch, and D. Bezanson. 2004. Ecoregions of Texas. (2 sided color poster with map, descriptive text, and photographs). U.S. Geological Survey, Reston, VA. Scale 1:2,500,000.

Rattan, J, B. Higginbotham, D. Long, T. Campbell. 2010. Exclusion Fencing for Feral Hogs at White-tailed Deer Feeders. The Texas Journal of Agriculture and Natural Resource 23:83-89(2010)

SARA (San Antonio River Authority). 2024. Watershed Master Plan Viewer. Accessed 10/2/2024. https://experience.arcgis.com/experience/d9e510a7bfbb456fa3243c9f7ba20766

TDC (Texas Demographic Center). 2024. Projections of the Total Population of Texas and Counties in Texas, 2020-2060. https://demographics.texas.gov/Projections/2022/TotalMethodology.pdf

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.

Texas Land Trust Council. 2024. Texas Conservation Lands Inventory Data By County. Accessed 10/1/2024. https://texaslandtrustcouncil.org/what-we-do/conservation-lands-inventory/

Timmons, J., Higginbotham, B., Lopez, R., Cathey, J., Mellish, J., Griffin, J., Sumrall, A., Skow, K. 2012. Feral Hog Population Growth, Density and Harvest in Texas. College Station, Texas: Natural Resources Institute. SP-472. https://nri.tamu.edu/media/3203/sp-472-feral-hog-population-growth-density-and-harvest-in-texas-edited.pdf

TPWD (Texas Parks and Wildlife Department). 2020. Big Game Research and Surveys Performance Report.

TWDB (Texas Water Development Board). 2013. Evaluation of NCD versus Traditional SW Infrastructure in Texas. Accessed 9/12/2024. https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1148321308_channeldesign.pdf

TWDB. 2024. Nature-based Solutions for Flood Mitigation in Texas. Accessed 10/10/2024. https://www.twdb.texas.gov/flood/research/Nature-based-Solutions-2022/index.asp

USCB (U.S. Census Bureau). 2020. TIGER/Line Census Block Shapefiles. https://www.census.gov/cgi-bin/geo/shapefiles/index.php.

USDA NASS (U.S. Department of Agriculture National Agricultural Statistics Service). 2022 Census of Agriculture United States Summary and State Data. https://www.nass.usda.gov/Publications/AgCensus/2022/

USDA NASS. 2022. Crop data layer https://croplandcros.scinet.usda.gov.

USDA NRCS (United States Department of Agriculture Natural Resources Conservation Service). 2023 Web Soil Survey. Available online. https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

USEPA (U.S. Environmental Protection Agency). 2000. EPA Office of Water. Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management. Federal Register, October 18, 2000

USEPA 2024b. Enforcement and compliance history online (ECHO). https://echo.epa.gov/

USEPA. 2008. EPA Office of Water, Nonpoint Source Control Branch. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. Federal Register, March 2008

USEPA. 2013. Level III and IV ecoregions of the continental United States: Corvallis, Oregon, U.S. EPA, National Health and Environmental Effects Research Laboratory

USEPA. 2024a. EJScreen. Retrieved: June 20, 2024 from www.epa.gov/ejscreen

USNWS (United States National Weather Service) 2024. Automated Surface Observing System (ASOS) data for Stinson Municipal Airport, Texas. 2024

Wagner, K. L. and Moench, E. 2009. Education Program for Improved Water Quality in Copano Bay. Task Two Report. College Station, Texas: Texas Water Resources Institute. TR-347. http://twri.tamu.edu/reports/2009/ tr347.pdf

Williams, B.K., Szaro, R.C., Shapiro, C.D. 2009. Adaptive management: the U.S. Department of the Interior Technical Guide. Washington D.C

Appendix A: Land Use, Population, and Load Projections

The Medina River Below Medina Diversion Lake watershed is undergoing rapid changes in land use and land cover due to growth of San Antonio, Bexar County, and the Texas Hill Country regionally.

Potential sources of E. coli identified in the WPP that are directly associated with land uses or habitat include livestock, deer, and feral hogs. Those sources more closely associated with human population include pet waste, on-site sewage facilities (OSSF), and wastewater treatment facilities (WWTF). As population-driven changes in land uses, habitat and grazeable land distribution, and land development occur, the number and distribution of these sources are expected to change accordingly.

Based on stakeholders' local knowledge and guidance, present-day potential bacteria loads were calculated and projected into the future based on trends in land development and population growth rates. These projections allow informed decision making on management strategies to reduce bacteria loading now and into the future, and provide a strong basis for adaptive management of WPP implementation strategies and priorities.

Land Use Projection

Changes in LULC were projected for a 10-year period ending in 2036. Changes in coverage of LULC categories were predicted by combining current and historical NLCD data (2001 – 2021) with land development information using GIS tools. Information on county-approved subdivision plats, provided by Medina and Bexar counties, was used as a proxy for land development and provide the basis for projecting watershed-scale land use trends for specific LULC categories.

Bexar County subdivision records were obtained, including subdivision name, spatial information, and date of plat approval records. Medina County records included spatial information and subdivision name (Figure A-1). Approval dates for Medina County records were acquired through the Medina County Clerk website. Where no plat record was listed, the earliest warranty deed or deed of trust date for the subdivision was used. The Microsoft excel function FORECAST.LINEAR was used to project cumulative subdivision areas for 2026, 2031, and 2036 (**Error! Reference source not found.**). Trends developed based on combined Medina and Bexar county data were extrapolated to the entire watershed.

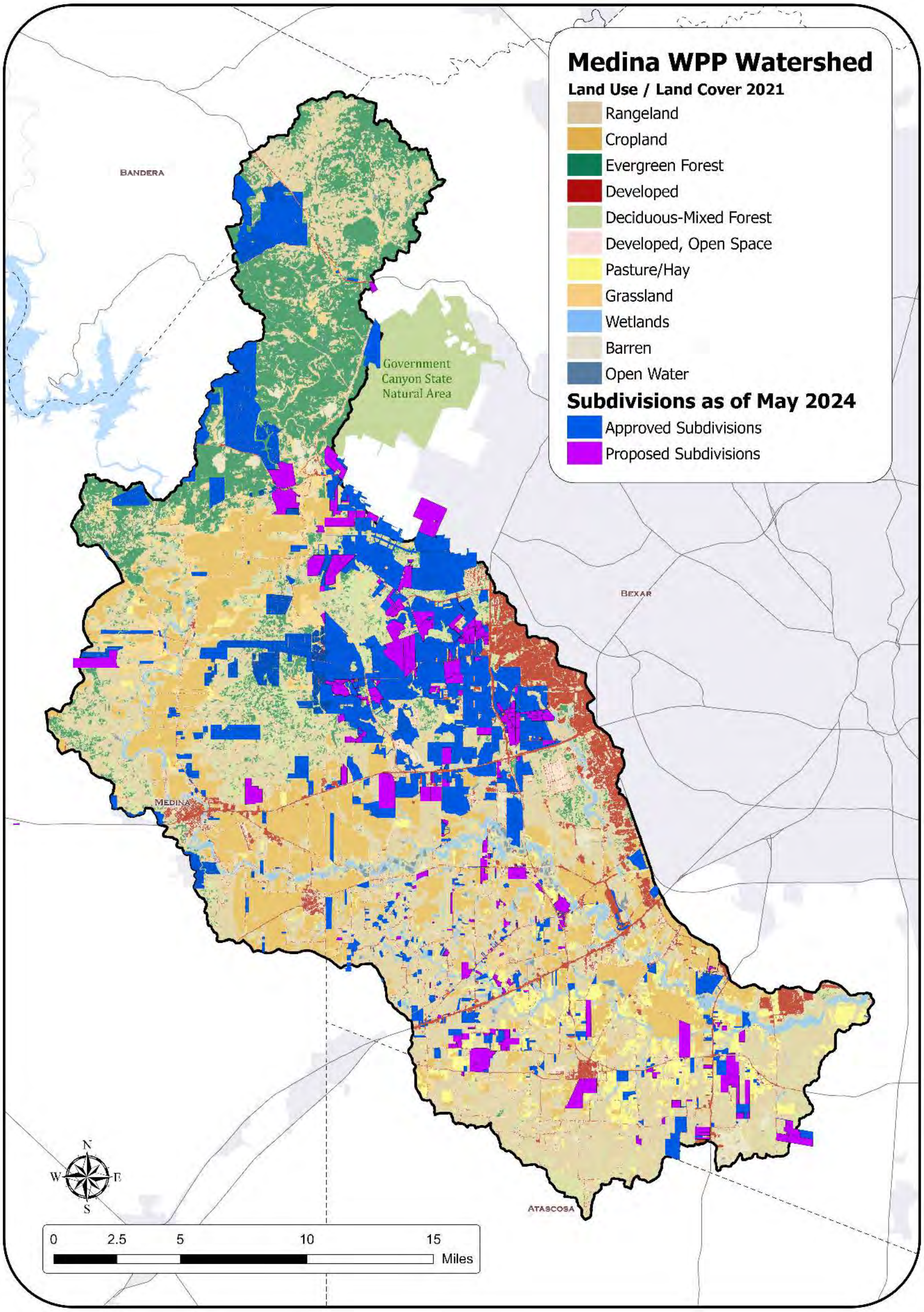

Figure A-1. Approved and proposed subdivisions, 1928 - 2024.

Table A 1. Cumulative combined acreage for Medina and Bexar County subdivisions during each year NLCD Land Use and Land Cover data were available.

Year	2001	2004	2006	2008	2011	2013	2016	2019	2021
Cumulative Acreage	25,728	27,658	30,605	32,177	33,856	35,437	37,834	42,974	46,611

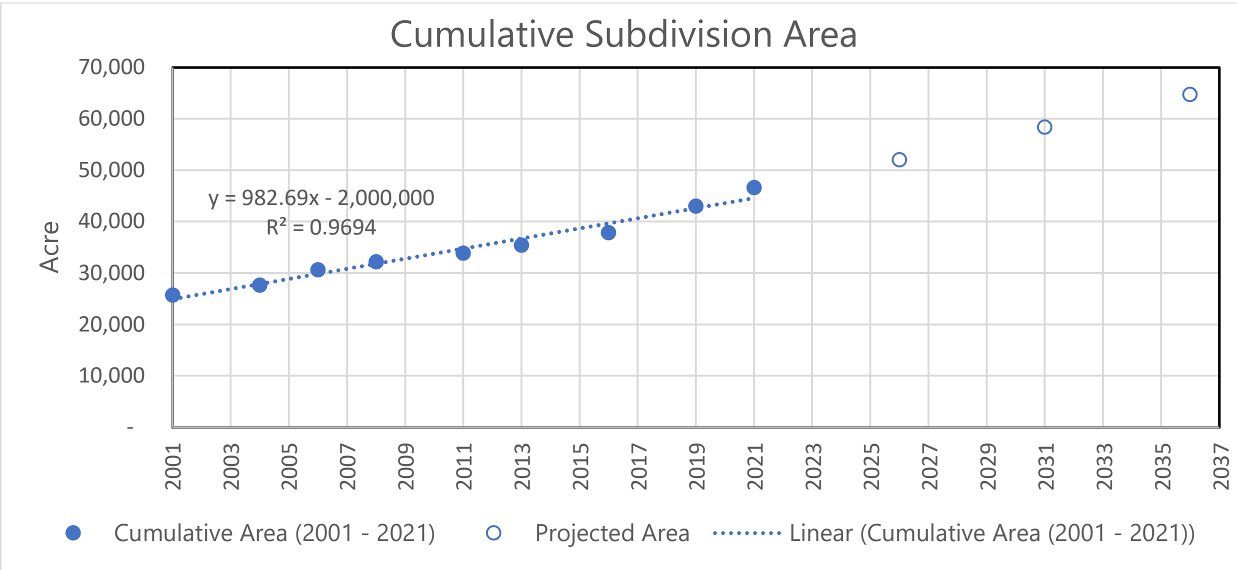

Figure A 1. Cumulative subdivision area for Medina and Bexar Counties from 2011 through 2021, with projected area values for 2026, 2031, and 2036.

GIS was used to determine the total acreage of each LULC category within approved subdivisions and remove them from the areas of grazeable land for cattle and habitat for deer and feral hogs, as discussed below. While some areas within subdivision plats may still be used for grazing or wildlife, trends indicate the vast majority of subdivisions in the watershed are converted to some level of urban uses. The remaining areas were used to predict potential future E. coli loadings for livestock, deer, and feral hogs based on projected land use changes.

Livestock Load Projection

Livestock bacteria loadings were calculated by multiplying an animal density by the total grazeable land (see Appendix C). Grazeable land use includes mixed-deciduous forest, rangeland, grassland, and hay/pasture. Using GIS, grazeable lands located in a subdivision were removed from the total grazeable acreage for each year of the NLCD LULC from 2001 to 2021 (**Error! Reference source not found.**; USGS 2022). Once acreage totals for grazeable land were adjusted for subdivisions, the subdivision cumulative acreage for each NLCD LULC year from 2001-2021 were graphed with grazeable land. As expected, grazeable land area reductions mirror cumulative subdivision area for each year but does not match it exactly (Figure A 2). Cumulative subdivision area was then graphed against grazeable land to determine the nature of the relationship. This relationship was used to project grazeable land coverage into the future (**Error! Reference source not found.**).

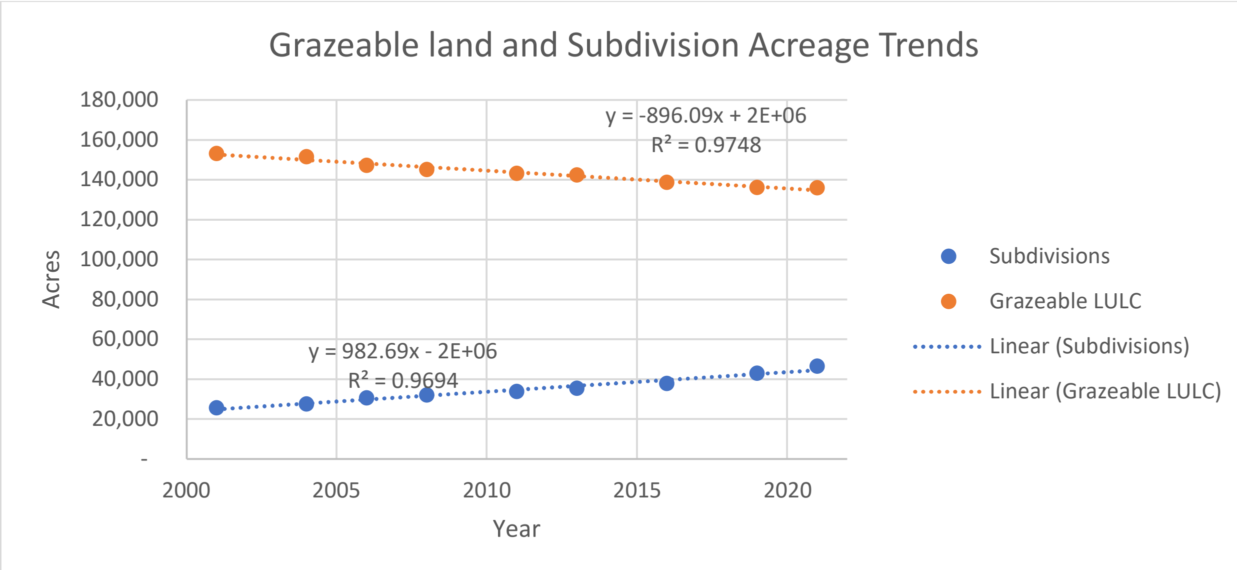

Figure A 2. Comparison of adjusted grazeable land based on cumulative subdivision area for the Medina River Below Medina Diversion Lake watershed.

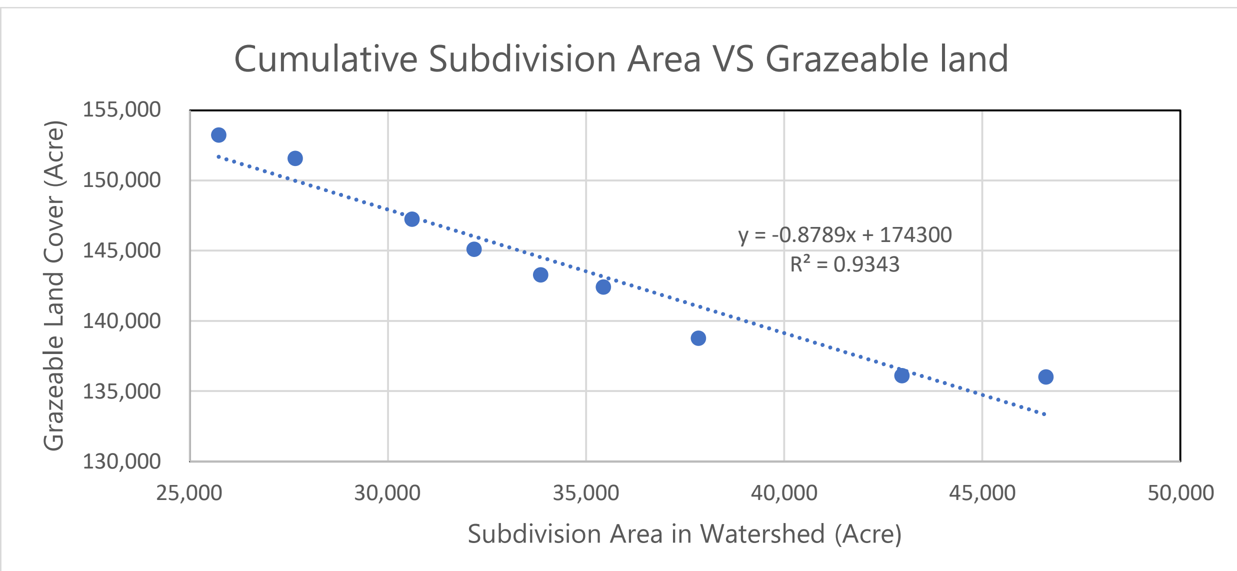

Figure A 3. Analysis of the relationship between cumulative subdivision area and grazeable land for the Medina River Below Medina Diversion Lake watershed.

In this example, for every acre increase in subdivision area, grazeable land was reduced by 0.8789 acres (see trendline equation on **Error! Reference source not found.**). This is not a one-to-one relationship as subdivisions overlay other LULC types besides grazeable land. The y-intercept of this equation, 174,300, was not used as it represents grazeable land when there was no subdivision area recorded in the late 1920s and 1930s. The y-intercept was manually calculated for projection of LULC in 2021 using known grazeable land of 120,982 acres and known cumulative subdivision acreage of 46,611 acres (Formula A-1). The relationship was then applied to the projected cumulative subdivision acreage for 2026, 2031, and 2036 (**Error! Reference source not found.**).

Formula A-1:

$$Grazeable\ LULC\ = -0.8789 * Cumulative\ Subdivison\ Acreage +\ 161{,}948$$

Table A 2. Projected cumulative subdivision acreage for Medina and Bexar Counties within the Medina River Below Medina Diversion Lake watershed and the calculated suitable grazeable land for livestock.

	2026	2031	2036
Projected Cumulative Subdivision Area (Acre)	52,046	58,397	64,749
Projected Grazeable Land (Acre)	116,205	110,623	105,040
Total Projected Livestock Load (CFU/day)	1.51E+14	1.43E+14	1.36E+14

To obtain a projected bacteria loading for livestock in 2026, 2031, and 2036, grazeable land area was multiplied by the total load per acre in 2021 (Formula A-2). The load per acre was used for the projection instead of other strategies used for 2021 loading calculation (see Appendix C) as there wasn't a way to project stocking rates into the future. Projected livestock bacteria loading shows a downward trend as areas within the watershed continue to develop and introduce new subdivisions (Figure A 4; Table A 2).

Formula A-2:

$$Total\ Projected\ Livestock\ Load\ = \left(\frac{Total\ Livestock\ Load\ in\ 2021}{Grazable\ Land\ Area\ in\ 2021}\right) * Projected\ Grazeable\ Land$$

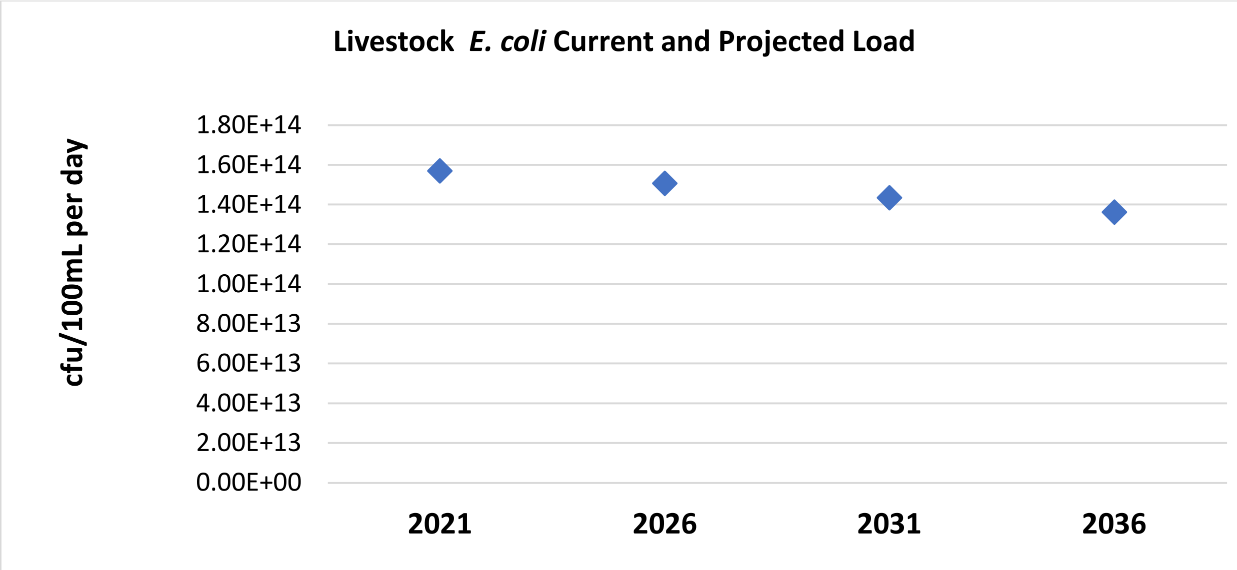

Figure A 4. Projected bacteria loading for livestock within the Medina River Below Medina Diversion Lake watershed.

Deer and Feral Hog Load Projection

Bacteria loadings for deer and feral hogs were calculated by multiplying each respective animal density by the suitable habitat for wildlife (see Appendix C). For both feral hogs and deer, suitable habitat includes the LULC categories of mixed-deciduous forest, evergreen forest, rangeland, grassland, hay/pasture, cultivated crops, and wetlands. Similar to the previous projection method for livestock, all suitable habitat for feral hogs or deer within the watershed overlain by subdivisions were removed from the total suitable habitat area for each year of the NLCD LULC from 2001 to 2021. Once acreage totals for suitable habitat were adjusted, subdivision cumulative acreage for each NLCD LULC year from 2001-2021 were graphed with suitable habitat (Figure A 5). Similarly to livestock projections, the suitable wildlife habitat area mirrors cumulative subdivision area for NLCD LULC years from 2001 – 2021 but is not an exact reflection. To further characterize the relationship between cumulative subdivision area and suitable habitat for each year of the NLCD LULC the variables were graphed against each other (Figure A 6). The relationship was confirmed as a linear relationship using the R-squared value.

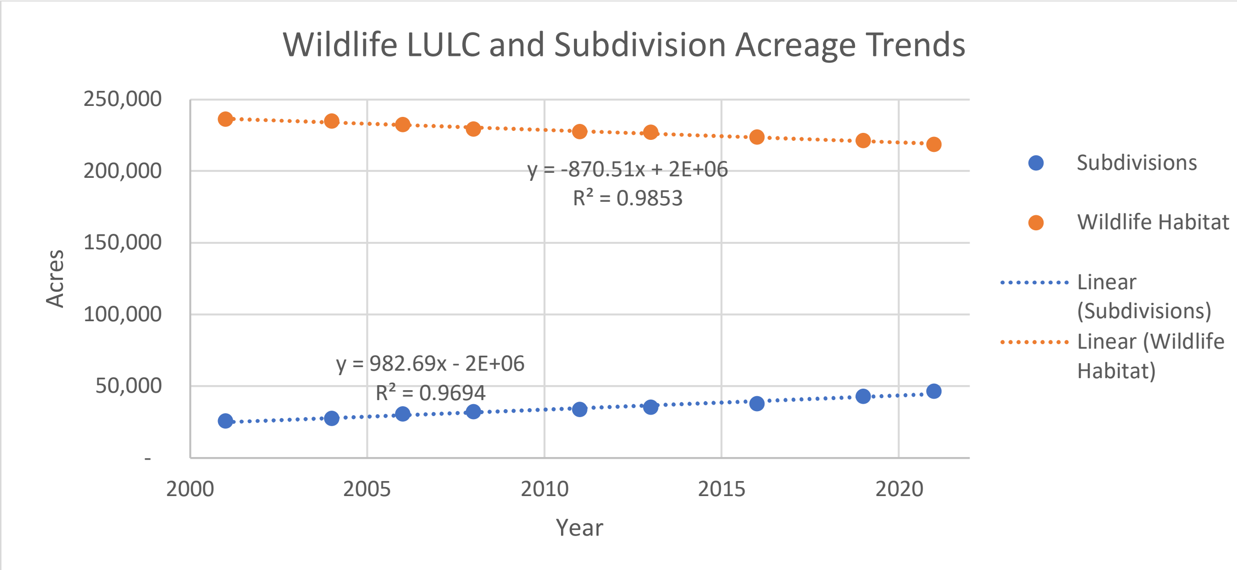

Figure A 5. Comparison of adjusted suitable wildlife LULC based on cumulative subdivision area for the Medina River Below Medina Diversion Lake watershed.

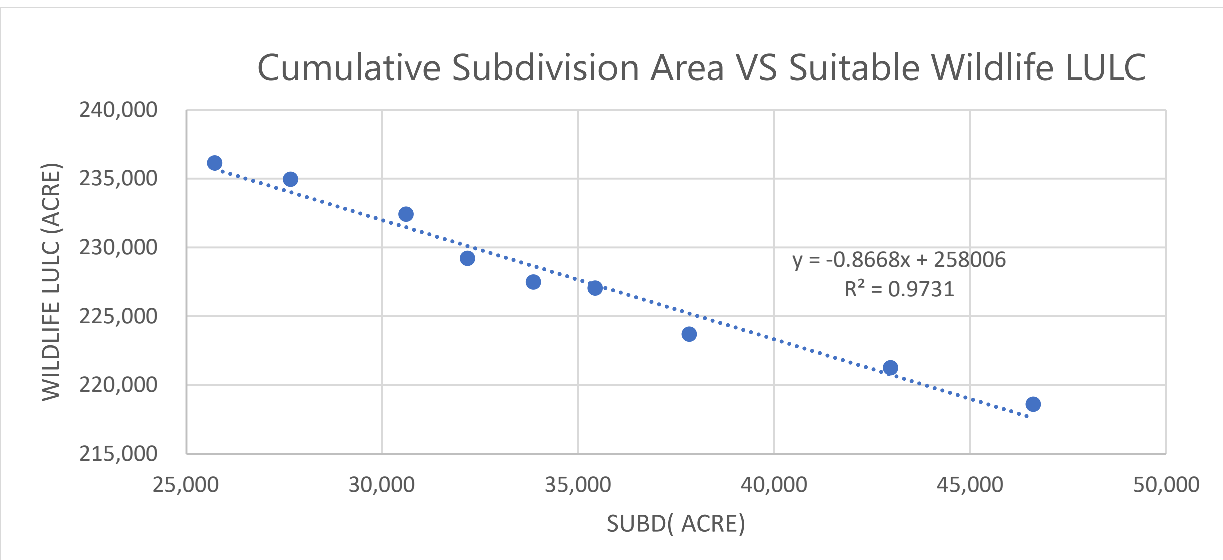

Figure A 6. Analysis of the relationship between cumulative subdivision area and suitable wildlife LULC for the Medina River Below Medina Diversion Lake watershed.

In this example, for every acre increase in subdivision area, suitable habitat is reduced by 0.8668 acres (see trendline equation on Figure A 6**Error! Reference source not found.**). Similar to the previous projection method with grazeable land, this is not a one-to-one relationship as subdivisions overlay other LULC types. The y-intercept of this equation, 258,006, was not used as it represents suitable wildlife LULC when there were no subdivisions recorded in the late 1920s and 1930s. The y-intercept was manually calculated for projection of LULC in 2021 using known suitable wildlife habitat of 192,025 acres and known cumulative subdivision acreage of 46,611 acres (Formula A-3). From there, the relationship was applied to the projected cumulative subdivision acreage for 2026, 2031, and 2036 (Table A 3).

Formula A-3:

$$Suitable\ Wildlife\ Habitat\ =\ -0.8668 * Cumulative\ Subdivison\ Acreage +\ 232{,}426$$

Table A 3. Projected cumulative subdivision acreage for Medina and Bexar Counties within the Medina River Below Medina Diversion Lake watershed and the calculated suitable wildlife LULC.

Year	2026	2031	2036
Projected Cumulative Subdivision Area (Acre)	52,046	58,397	64,749
Projected Suitable Wildlife LULC (Acre)	116,205	110,623	105,040
Projected Feral Hog Load (CFU/day)	5.58E+11	5.41E+11	5.25E+11
Projected Deer Load (CFU/day)	1.7840E+13	1.73E+13	1.68E+13

Projected bacteria loading for feral hogs in 2026, 2031, and 2036 was calculated through the same process as 2021 bacteria loadings, but using the projected suitable habitat area instead (see Appendix C). Multiplying feral hog density and population (Wagner & Moench, 2009), habitat area, *E. coli* conversion rate (Wagner & Moench, 2009), fecal coliform production rate (Wagner & Moench, 2009), and an animal unit conversion factor results in an estimated projected bacteria loading for feral hogs (Formula A-4). Projected feral hog loads display a downward trend as development continues within the watershed (Figure A 7; Table A 3).

Formula A-4:

$$Projected\ Feral\ Hog\ Load\ = 0.03\ * Projected\ Wildlife\ Habitat * 0.63 * 1.21E + 09 * 0.125$$

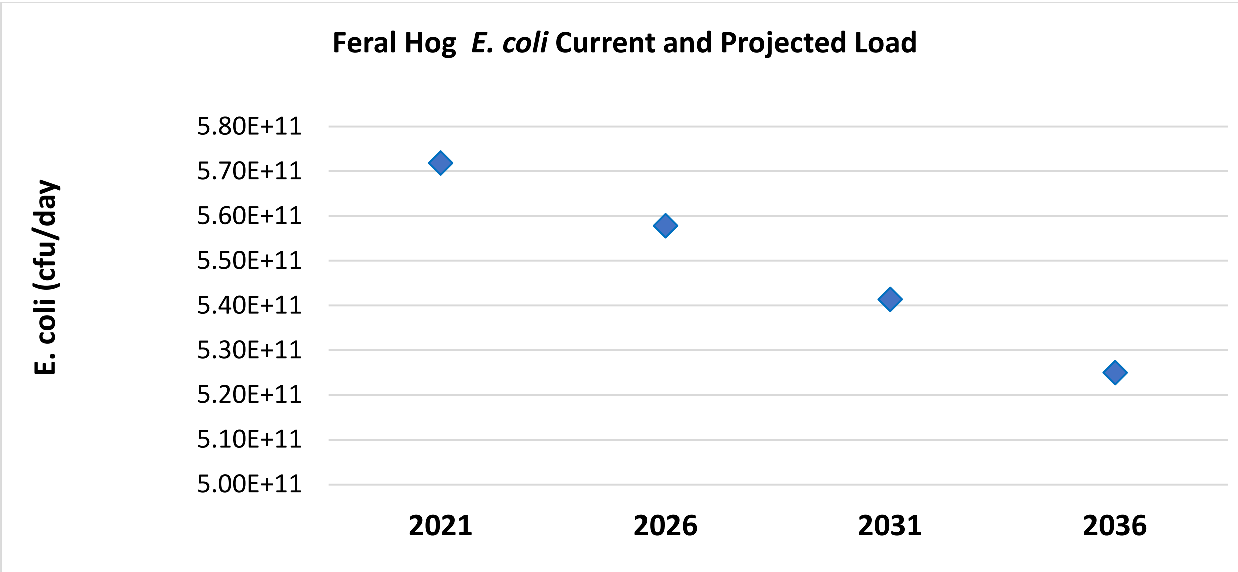

Figure A 7. Projected bacteria loading for feral hogs within the Medina River Below Medina Diversion Lake watershed.

Projected bacteria loading for deer in 2026, 2031, and 2036 was calculated through the same process as feral hogs, however, a deer density per acre was manually calculated based on 2021 deer head per suitable habitat area. Multiplying deer density, projected wildlife habitat area, *E. coli* conversion rate (Wagner & Moench, 2009), fecal coliform production rate (Wagner & Moench, 2009), and an animal unit conversion factor resulted in a project bacteria loading for deer within the watershed (Formula A-5). Projected deer loads display a downward trend. (Figure A 8; Table A 3).

Formula A-5:

$$Projected\ Deer\ Load = \left(\frac{Livestock\ Load\ in\ 2021}{Suitable\ Wildlife\ Habitat\ Area\ in\ 2021}\right) * Projected\ Wildlife\ Habitat * 0.63 * 1.50E+09 * 0.112$$

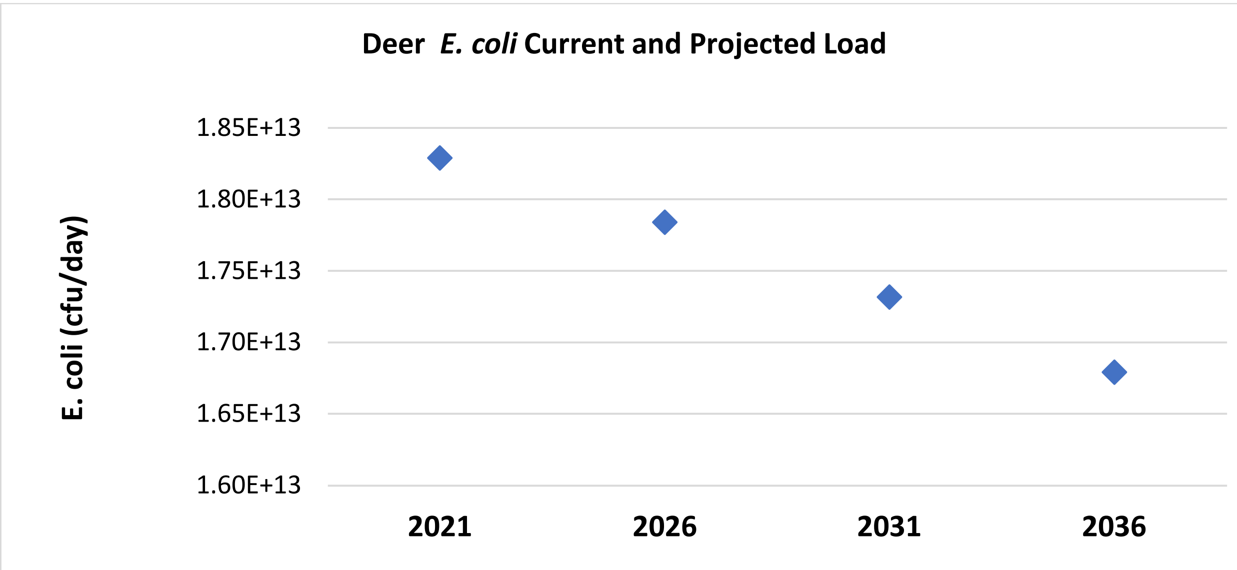

Figure A 8. Projected bacteria loading for deer within the Medina River Below Medina Diversion Lake watershed.

Population Growth Rate Projection

Changes in watershed population were predicted for a 10-year period ending in 2035 by combining reported and projected student enrollment estimates with current census data. Stakeholders felt that local analyses conducted by the Medina Valley Independent School District (MVISD) are accurately representing growth in the watershed rather than regional or statewide population projections by the Texas Demographic Center.

The MVISD school district covers large swaths of the watershed (Figure A 9) and was suggested by stakeholders as a local data source. This projection was done for 2025, 2030, and 2035. Note that this differs from the previous land use projection methods as population projections were based on census data for 2020, whereas land use projections were based on NLCD LULC up to 2021.

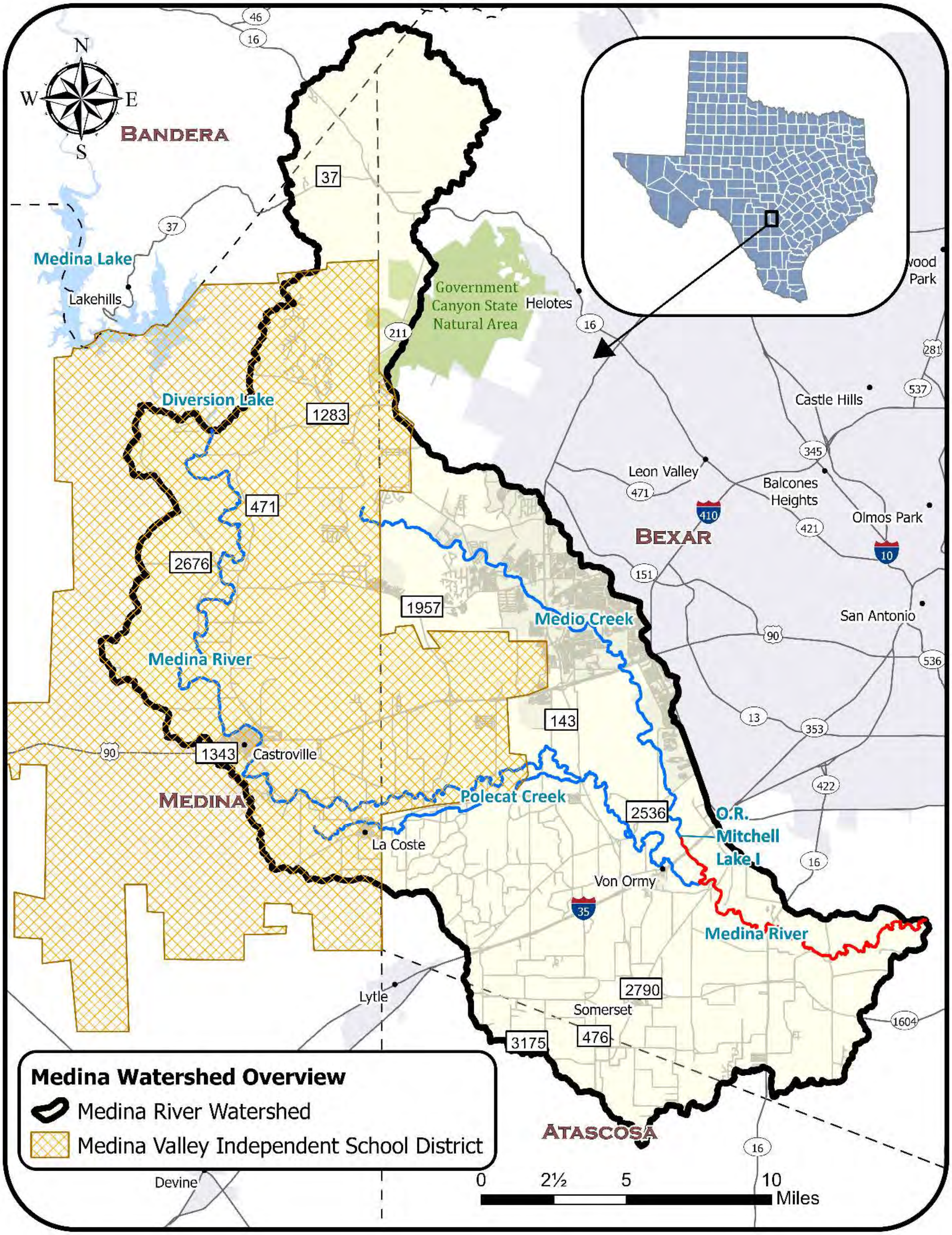

Figure A 9. Medina Valley Independent School District (MVISD) boundaries.

MVISD reported enrollment from 2016 – 2024 and projected enrollment for 2025 – 2034 were acquired from school district quarterly reports (MVISD 2023). Projected enrollment was estimated for 2035 using the 10 years of MVISD projected enrollment and a LINEAR.FORECAST in Microsoft Excel. The yearly dataset from 2020 through 2035 is used to calculate the projected watershed population.

Total MVISD enrolled students per school year were converted to a total number of households containing students in the district by multiplying total students by the census statistic for Medina County, "*households with one or more people under 18 years"* (USCB , 2020). Note that there is some error in the estimate as children under the age of 5 years old have not started school yet and wouldn't be included in actual enrollment for MVISD. For this analysis, the total households in the watershed for 2020 was derived using GIS tools, and may be slightly different than the number of households used in other analyses. Once the number of households with students in the district was determined, a ratio was calculated between the number of households with the MVISD district and the total households within the watershed during the 2020 census (USCB, 2020) was used to scale up MVISD numbers. This ratio of 2.57% MVISD student households to the overall watershed households was then used to calculate the total household in the watershed for each subsequent year. Finally, total households within the watershed were multiplied by 2.65 average persons per household within the watershed based on the 2022 American Communities Survey (Table ; USCB, 2022). The projected population growth approved by stakeholders shows a substantial increase in the overall watershed population (Figure A 10).

Table A 4. Sample of population growth projection statistics for Medina River Below Medina Diversion Lake.

	2020	**2025**	**2030**	**2035**
MVISD Total Students	5,852	9,484	14,302	20,020
MVISD Total Households with Students	1,990	3,225	4,863	6,807
Total Households in Watershed	77,375	125,443	189,169	264,806
Estimated Watershed Population	205,118	332,423	501,298	701,737
Population Growth Rate	-	62.06%	47.63%	39.98%

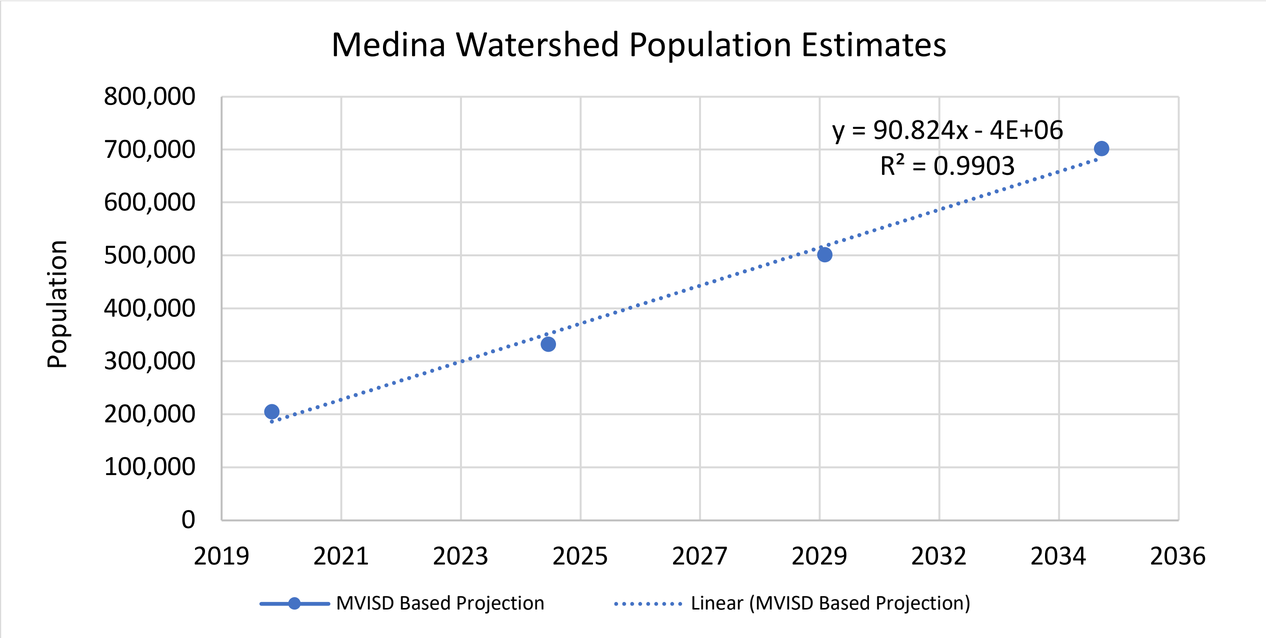

Figure A 10. Watershed population projection, 2020 – 2035..

Domestic Pet Load Projection

Projected domestic dog population was calculated using projected households in the watershed for 2025, 2030, and 2035 (Table), dog ownership rate of 0.4460, and the estimated number of dogs per household of 1.46 (AVMA 2022) (Table A-5).

A projected bacteria loading for dogs in 2025, 2030, and 2035 were calculated using the same process as 2020 bacteria loadings, but using the projected households in the watershed for each respective year instead (see Appendix C). Multiplying dog population, *E. coli* conversion rate (Wagner & Moench, 2009), and fecal coliform production rate for dogs (Wagner & Moench, 2009) produces an estimated projected bacteria loading for dogs (Formula A-6). The resulting projected dog bacteria loadings show a significant increase over time (Figure A 11).

Formula A-6:

$$Projected\ Dog\ Load\ = Total\ Dogs\ in\ Watershed\ * 0.63 * 5.00E + 09$$

Table A 5.Projected dog population and bacteria loading for the Medina River Below Medina Diversion Lake watershed.

	2020	2025	2030	2035
Total Dogs in Watershed	50,512	81,654	120,543	168,740
Total Projected Dog Load (CFU/day)	1.59E+14	2.57E+14	3.80E+14	5.32E+14

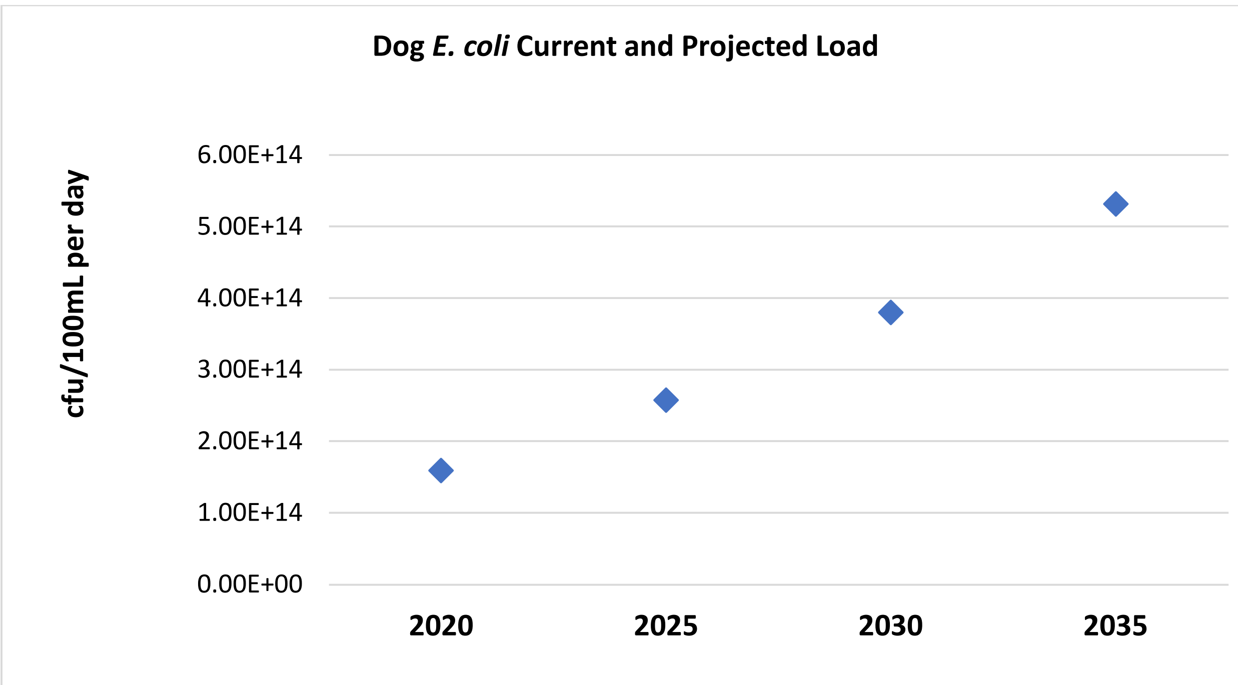

Figure A 11. Projected bacteria loading for dogs within the Medina River Below Medina Diversion Lake watershed.

OSSF Load Projection

Estimated potential future bacteria loadings were calculated for OSSFs using projected populations of the watershed for 2025, 2030, and 2035. The percent change between subwatershed populations for five-year periods between 2020 and 2035 were calculated and multiplied by the total watershed households and populations (Table). Then, each subwatershed population was divided by the number of households to calculate an average person per household by subwatershed. Next, the estimated number of OSSFs in each county within each subwatershed was multiplied by the percent change (see Appendix C for more details on OSSF enumeration and failure rates).

Potential bacteria loadings from OSSFs were calculated for each county within each subwatershed by multiplying the OSSF count by the failure rate, the default wastewater per person, average person per household (Borel et al. 2015), *E. coli* conversion rate (Wagner & Moench, 2009), the fecal coliform production rate for OSSFs (USEPA 2001), a constant for unit conversions, then dividing by 100 (Formula A-7; Table A 6; Figure A 12).

Formula A-7:

$$Projected\ OSSF\ Load\ = (OSSF\ Count\ * 70 * Average\ Person\ Per\ Household * 0.63 * 1.00E + 07 * 3758.2)/100$$

Table A 6. Total projected bacteria load from OSSFs within the Medina River Below Medina Diversion Lake watershed.

	2020	2025	2030	2035
Total Projected OSSF Load (CFU/day)	6.47E+13	1.05E+14	1.58E+14	2.21E+14

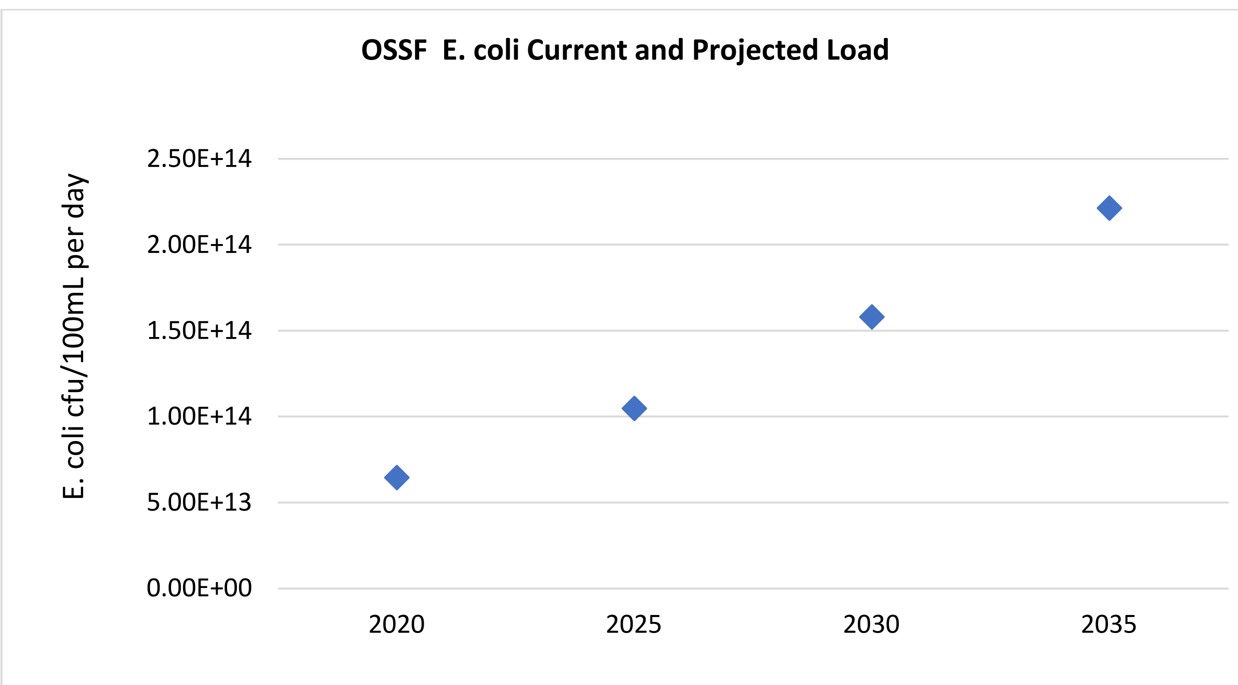

Figure A 12. The total OSSF bacteria loading for the Medina River Below Diverison Lake watershed.

WWTF Load Projection

Similar to previous estimation methods, future bacteria loadings were calculated for WWTFs using projected populations of the watershed for 2025, 2030, and 2035. Current permitted discharge limits were used as the baseline discharge volume, except for phased permits where the maximum permitted flow for each permit was used. The percent change between watershed populations from 2020 to 2025 and each subsequent five-year period was calculated (Table). Population growth rate was applied to each respective year's reported WWTF flow to estimate potential future discharge (Formula A-8; Table A 7).

By 2025 an additional WWTF is expected to come online within the watershed, the Forest Glen WRRF3 WWTF (PUC 2022). Combining bacteria loading from WWTF plants across the watershed and plotting across the next fifteen years shows a steady increase in pollutants (Figure A 13).

Formula A-8:

$$Projected\ WWTF\ Load\ = Reported\ Flow * \frac{126}{100} *\ 1.00E\ + 06\ *\ 3758.2$$

Table A 7. Example calculation of parameters used to calculate bacteria loading for each WWTF in the Medina River Below Medina Diversion Lake watershed.

Year	WWTF	Population Growth Rate	Reported Flow (MGD)
2020	Portranco Ranch Subdivision WWTF	-	0.079
2025	Portranco Ranch Subdivision WWTF	62.06%	0.1280
2030	Portranco Ranch Subdivision WWTF	50.80%	0.1931
2035	Portranco Ranch Subdivision WWTF	39.98%	0.2703

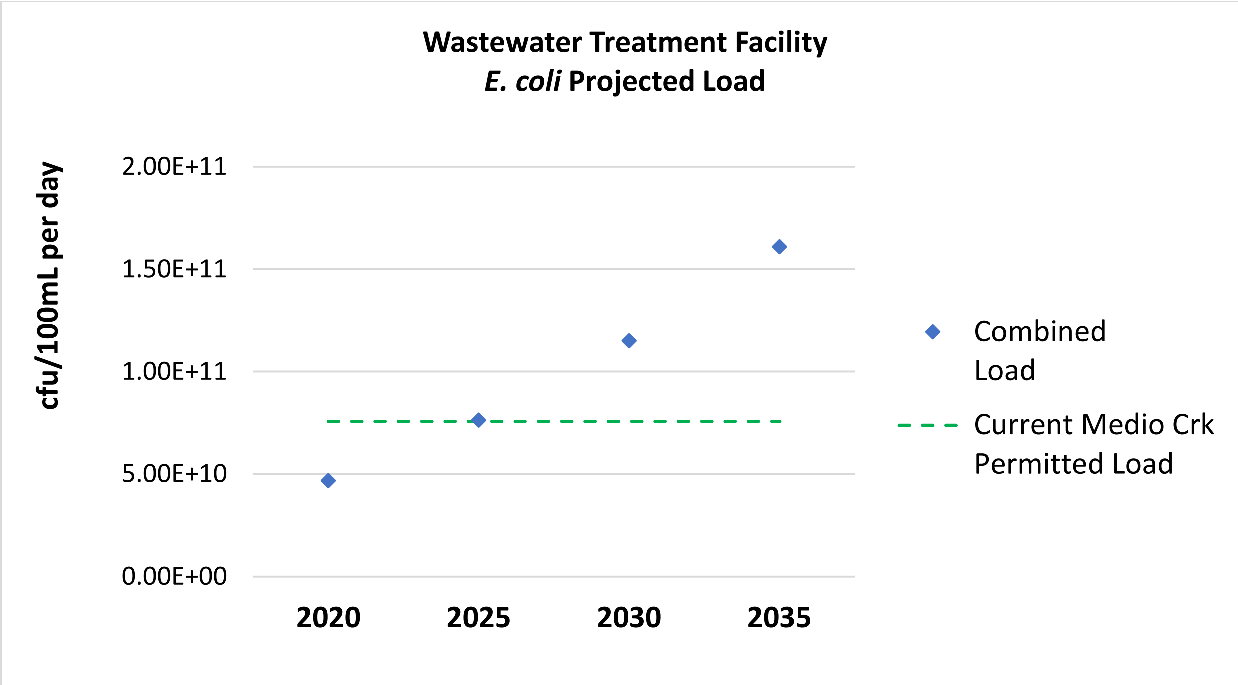

Figure A 13. Combined bacteria loading from all WWTF within the Medina River Below Medina Diversion Lake watershed.

Appendix A References

AVMA (American Veterinary Medical Association). 2022. 2022 U.S. Pet Ownership & Demographics Sourcebook. Schaumberg, IL: American Veterinary Medical Association. https://www.avma.org/resources-tools/reports-statistics/us-pet-ownership-statistics

Borel, K., Karthikeyan, R., Berthold, T.A., and Wagner, K. 2015. Estimating E. coli and Enterococcus loads in a coastal Texas watershed. Texas Water Journal. 6(1), 33-44.USCB (U.S. Census Bureau). 2020. 2020 Census.

PUC (Public Utility Commission). 2022. Application to Obtain or Amend a Water or Sewer Certificate of Convenience and Necessity. CCN No 21070

USCB (U.S. Census Bureau). 2022. American Communities Survey.

USEPA (U.S. Environmental Protection Agency). 2001. Protocol for developing pathogen TMDLs: Source Assessment, 5-1-5-18 1st edition [Internet]. Washington (District of Columbia): U.S. Environmental Protection Agency; [cited 2024 December 1]. 132 p. Available from: http://www.epa. gov/owow/tmdl/pathogen_all.pdf [USEPA] U.S. Environmental Protecti

USDA NASS (United States Department of Agriculture - National Agricultural Statistics Service). 2024. Quick Stats (2022 Census). https://www.nass.usda.gov/Quick_Stats/

USGS (United States Geological Survey). 2023. National Hydrography Dataset (NHD). Retrieved April 15, 2023, from https://apps.nationalmap.gov/downloader/

USGS (United States Geological Survey). 2022. National Land Cover Database 2021 (NLCD2021). Retrieved May 30, 2023, from Multi-resolution Land Characteristics Consortium (MRLC). https://www.mrlc.gov/data?f%5B0%5D=project_tax_term_term_parents_tax_term_name%3AAnnual%20NLCD

Wagner K.L. and Moench, E. 2009. Education Program for Improved Water Quality in Copano Bay. Task Two Report. College Station, TX: Texas Water Resources Institute. TR-347.

Appendix B: Load Duration Curves

Load Duration Curves (LDC) are a widely accepted method to characterize water quality data across different flow regimes. Due to inherent variability in monitoring locations across watersheds, streamflow and water quality data must come from the same site to ensure accuracy. Based on Flow Duration Curves (FDC), this type of analysis can allow stakeholders and technical specialists to estimate pollutant load reductions needed to meet water quality standards.

Flow Duration Curve

The precursor to an LDC, FDCs are constructed to analyze flow volume and frequency of that flow (also known as exceedance), creating a 'fingerprint' for the watershed. This plot will contain exceedance probability on the x-axis and streamflow on the y-axis.

FDCs are developed by aggregating historical flow data for the stream. For many WPPs, the USGS streamflow gages can be used for flow data. There are several USGS stream gages located in the watershed, however, finding USGS gages with continuous streamflow data in conjunction with nearby water monitoring sites and adequate water quality data was a challenge. During these events, instantaneous streamflows are paired with bacteria counts. Due to inherent variability in monitoring locations across watersheds, streamflow and water quality data must come from similar monitoring sites within the same stream assessment unit. For this analysis only water quality monitoring data from the most recent state water quality assessment was used (TCEQ, 2022).

To construct an FDC, flow data for a specific sampling location are sorted in order of highest to lowest and then ranked. From here, a streamflow exceedance probability can be calculated and the resulting graph of streamflow volume versus exceedance is created (Formula B-1).

Formula B-1:

$$p = \frac{i}{(n + 1) * 100}$$

Where:

p = exceedance probability
i = rank of a given streamflow
n = number of observations

The visualization is then analyzed and flow regimes are categorized for the watershed at certain frequencies. These flow regimes are typically identified as areas of the FDC where slope of the graph changes. For example, on Medina River assessment unit

1903_03, three flow regimes were chosen based on major changes in the relationship between streamflow (Figure B). Based on this FDC, flows exceeded 100 cubic feet per second (cfs) for 21 percent of the time.

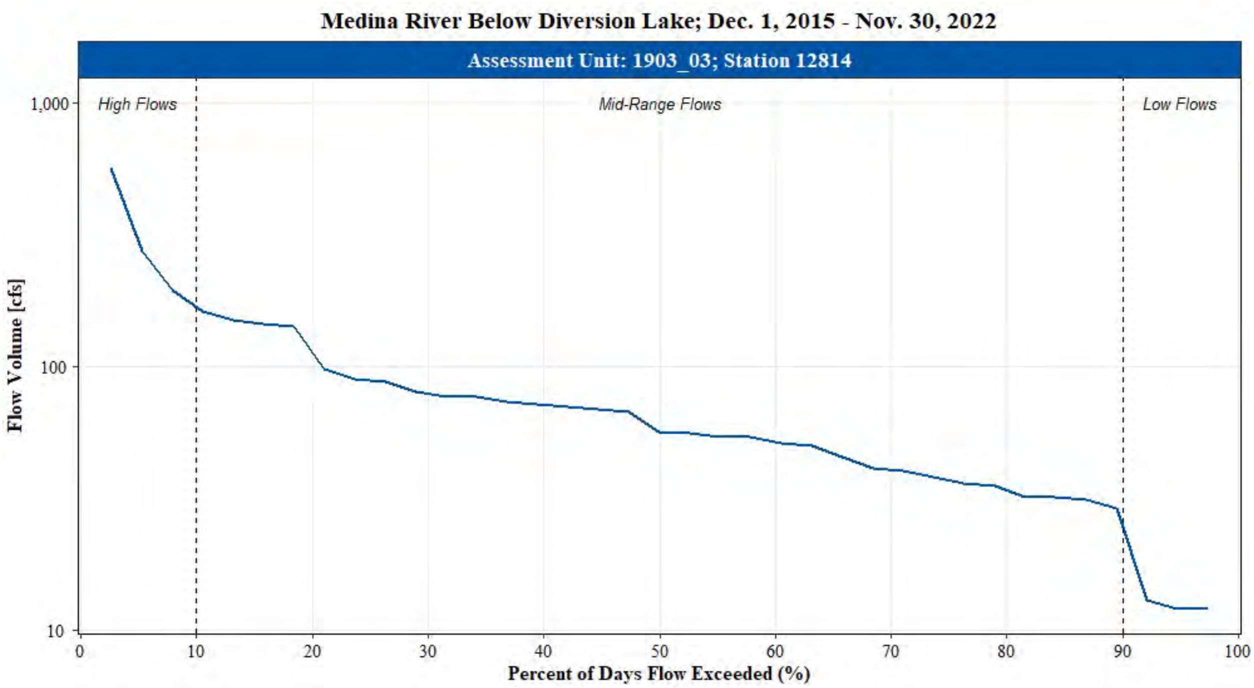

Figure B 1. Example FDC for the Medina River Below Medina Diversion Lake at assessment unit 1903_03.

This process was also applied to data from assessment unit 12912_01 on Medio Creek (**Error! Reference source not found.**). Data was collected during the most recent 2024 *Texas Integrated Report* assessment period to better understand current instream flow conditions and bacteria loadings.

Table B 1. FDCs and LDCs were created for these AUs using data from the 2024 Texas Integrated Report time-period.

Water body	Assessment Unit	SWQM Station	Water Quality Data Points Used	Time Period Collected
Medina River	1903_03	12814	37	December 1st, 2015 – November 30th, 2022
Medio Creek	1912_01	12916	41	

Load Duration Curve

Once the FDC has been constructed, the curve can be multiplied by the state water quality criterion for bacteria (126 MPN/100 mL) to produce an LDC. This is known as the pollutant "allowable load," and is indicated by the solid line in the LDC graph (Figure B 1). Bacteria data from water quality samples are also multiplied by their respective flow values and are superimposed on the graph, which is demonstrated by the blue circles. This shows the prevalence and magnitude of bacteria values in each flow category.

Additional analysis of bacteria data can be conducted using a regression analysis. For this strategy, RStudio was used to perform a linear regression resulting in a "line of best fit" for the monitored samples, referred to as the "existing load" and is indicated by the dashed line in the LDC graph. Where the dashed line is below the solid black line, bacteria loading is likely in compliance with the water quality criterion. When the dashed line is above the solid black line, monitoring data indicates that the bacteria loading is exceeding the water quality standards. This helps visualize which flow categories require the greatest reduction in bacteria loads.

In addition to the regression analysis, a geometric mean of the discrete data point loads within each flow category was calculated, indicated by the squares in the LDC graph. This helps quantify the total bacteria load for each flow category and aids in establishing a numeric target of reductions needed to achieve water quality standards.

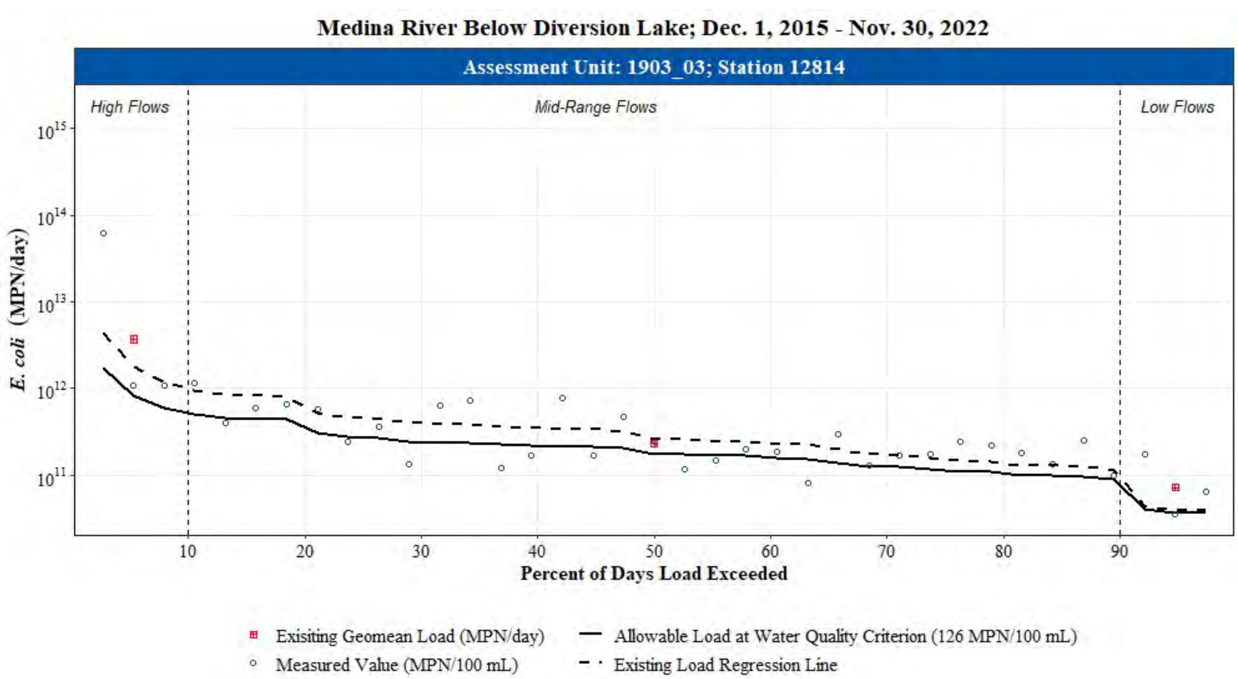

Figure B 1. LDC for Medina River Below Medina Diversion Lake at AU 1903_03.

Appendix B References

TCEQ (Texas Commission on Environmental Quality). 2022. 2022 Texas Integrated Report of Surface Water Quality for the Clean Water Act Sections 305(b) and 303(d). Austin, TX: Texas Commission on Environmental Quality. https://www.tceq.texas.gov/waterquality/ assessment/22twqi/22txir

Appendix C: Potential Loads and Load Reduction Calculations

The Spatially Explicit Load Enrichment Calculation Tool (SELECT) was developed by Teague et al. (2009) in the Biological and Agricultural Engineering Department at Texas A&M University. SELECT is used to characterize and estimate potential bacteria loads based on unique sources across the watershed so that critical source areas of pollution can be prioritized. This model is also used to analyze changes in potential bacteria loading for various best management practices.

The SELECT method relies on Geographic Information Systems (GIS) software to divide the larger watershed into smaller subwatersheds and estimate total potential bacteria loading for each individual subwatershed based primarily on both land use and land cover classifications and known point sources. Depending on the source, the loading estimates are further refined by considering literature estimates and relying on stakeholder feedback.

Estimates for potential loads are based on the best available data (e.g., local, state, and federal databases, scientific research) and local stakeholder input (e.g., local livestock stocking practices, wildlife densities). Potential loading rates assume a worst-case scenario and are primarily used to calculate where management measures should be implemented first to maximize effectiveness in potential load reductions.

The watershed was divided into 11 hydrologically similar subwatersheds using 12-digit Hydrologic Unit Codes (HUC) watershed boundaries from the National Hydrography Dataset (NHD) from United States Geological Survey (USGS) (USGS, 2023). For required land cover/land use classification information, the 2021 NLCD for the contiguous United States was obtained (USGS, 2022). As previously stated, the watershed is undergoing a significant amount of development, therefore all land use and land cover for potential load calculations had areas where subdivisions are proposed and/or completed removed from total land use and land cover area.

Livestock

Calculating potential bacteria loads from livestock requires an estimate of total animal population for each subwatershed. USDA Farm Service Agency provides recommended livestock stocking rates by county based on livestock census data (C. Koenig, personal communication, March 15, 2024). Additionally, USDA provides a Census of Agriculture that provides county-wide population estimates (USDA NASS, 2022). These two sources helped provide stakeholders with estimates of livestock population as a basis to present to stakeholders in the watersheds. Stakeholder feedback on these initial population estimates was that the population based on stocking rates was too low and the population based on the NASS census was too high, however, all other livestock estimates with the NASS census were accurate. To remedy this, the two cattle population estimates were averaged together for each subwatershed. Actual animal numbers fluctuate annually based on local conditions; however, these approaches provide a baseline to estimate potential loadings. Given that animal numbers fluctuate annually and actual stocking rates are difficult to determine, reliance on local stakeholders was critical to properly estimating cattle populations.

Cattle

Cattle are the dominant livestock species in the watersheds and were assessed separately from other livestock. As stated previously, cattle estimates using Farm Service Agency stocking rates were compared to NASS population estimates for watershed counties (Table C 1). The estimates produced by these two methods differed by 6,193 animal units, with a cattle population estimate of 13,028 using the NASS method, and 6,835 using the FSA stocking rate. Stakeholders felt that both methods were inaccurate, and a more appropriate estimate lay somewhere in between the two extremes. Therefore, the calculated cattle population within the watershed is 9,505, an average of the two methods within GIS analysis.

Table C 1. U.S. Department of Agriculture-recommended cattle stocking rates for Medina County.

	Pasture/ Hay	**Grassland**	**Rangeland**	**Deciduous-Mixed Forest**
Cattle Stocking Rates (ac/AnU)	6	15	25.50	28

Using the cattle population estimates generated, potential *E. coli* loading across the watersheds and for individual subbasins was estimated using land use and land cover within GIS. The annual load from cattle was calculated (Formula C-1). The estimated potential annual loading across all subbasins due to cattle is 1.87×10^{16} cfu *E. coli*/year.

Formula C-1:

$$PALcattle = AnU * FCcattle * Conversion * \frac{365\ days}{1\ year}$$

Where:

PAL_{cattle} = *Potential annual E. coli loading attributed to cattle*
AnU = *Animal units of cattle (~1,000 lbs of cattle)*
FC_{cattle} = *Fecal coliform loading rate of cattle; 8.55×10^{9} cfu fecal coliform/AnU/day (Wagner and Moench 2009)*
$Conversion$ = *Estimated fecal coliform to E. coli conversion rate; 126/200 = 0.63 (Wagner and Moench 2009)*

Other Livestock

To estimate stocking for goats, sheep, and horses, the numbers reported by NASS were scaled down to the combined watershed area in appropriate landcovers using GIS. Potential *E. coli* loading for individual subbasins were calculated using these estimates. The annual load from other livestock was calculated (Formula C-2).

Formula C-2:

$$PAL_{OL} = [(AnU * FC_{goat}) + (AnU * FC_{horse}) + (AnU * FC_{sheep})] * Conversion * \frac{365\ days}{1\ year}$$

Where:

PAL_{OL} = *Potential annual E. coli loading attributed to other livestock*
AnU = *Animal units (~1,000 lbs of live animal weight)*
FC_{goat} = *Fecal coliform loading rate of cattle; 4.32×10^{9} cfu fecal coliform/AnU/day (Wagner and Moench 2009)*
FC_{horse} = *Fecal coliform loading rate of cattle; 3.64×10^{8} cfu fecal coliform/AnU/day (Wagner and Moench 2009)*
FC_{sheep} = *Fecal coliform loading rate of cattle; 5.8×10^{10} cfu fecal coliform/AnU/day (Wagner and Moench 2009)*
$Conversion$ = *Estimated fecal coliform to E. coli conversion rate; 126/200 = 0.63 (Wagner and Moench 2009)*

Bacteria Load Reductions from Livestock Management

To estimate expected *E. coli* reductions, stakeholder recommended efficacy value of 75% was used. The potential load reduction achieved by implementing conservation practices depends on the specific BMPs implemented by each individual landowner, the number of animals in each operation, existing practices, and existing land condition. With an estimate of 24 annual conservation plans over the course of 10 years totaling 240 conservation plans (Formula C-3). Using above-described inputs, estimated annual *E. coli* reductions from livestock management total 1.43x10^{15} cfu, or approximately 2.72% of annual bacteria loading from livestock in the watershed.

Formula C-3:

$$LR = Nplans * FCanimal * Conversion * \frac{365\ days}{1\ year} * BMP\ Efficacy$$

Where:

LR = Potential annual load reduction of E. coli through management efforts
Nplans = Number of WQMPs and CPs, 240 are proposed by this plan
AnU/Plan = Animal Units of cattle, sheep/lambs, goats, and horses per management plan
FC_{animal} = Fecal coliform loading rate in cfu fecal coliform/AnU/day (Wagner and Moench 2009);
Cattle = 8.55×10^{9},
Sheep/Lambs = 2.90×10^{11},
Goats = 2.54×10^{10},
Horse = 1.21×10^{9}
Conversion = Estimated fecal coliform to E. coli conversion rate; 126/200 = 0.63 (Wagner and Moench 2009)
Efficacy = Median BMP efficacy value; 0.75

Feral Hogs

Feral hog populations were estimated using a population density of 32 ac per hog of suitable habitat (Wagner and Moench 2009). Suitable habitat includes mixed-deciduous forest, evergreen forest, rangeland, grassland, cultivated crops, and wetland land use and land cover. GIS analysis was used to estimate watershed-wide and subbasins feral hog populations. Based on this analysis, an estimated 6,001 feral hogs exist within the watershed. Like other population estimates, these numbers provide general estimates that change based on conditions within the watershed. Furthermore, feral hogs roam across large areas that might be larger than individual subbasins; however, these estimates provide guidance on where to focus control efforts based on suitable habitats. Using the feral hog population estimates, the potential *E. coli* loading across the watersheds and for individual subbasins was estimated. The annual load from feral hogs was calculated (Formula C-4). The estimated potential annual loading across all subbasins due to feral hogs is 2.09×10^{14} cfu *E. coli*/year.

Formula C-4:

$$PAL_{fh} = N_{fh} * AnUC * FC_{fh} * Conversion * \frac{365\ days}{1\ year}$$

Where:

PALfh = Potential annual E. coli loading attributed to feral hogs
Nfh = Number of feral hogs
AnUC = Animal unit conversion; 0.125 AnU/feral hog (Wagner and Moench 2009)
FCfh = Fecal coliform loading rate of feral hogs; 1.21×109 cfu fecal coliform/AnU/day (Wagner and Moench 2009)
Conversion = Estimated fecal coliform to E. coli conversion rate; 126/200 = 0.63 (Wagner and Moench 2009)

Bacteria Load Reductions from Feral Hog Management

Loading reductions for feral hogs assume that existing feral hog populations can be reduced and maintained by a certain amount on an annual basis. Therefore, the total potential load reduction is calculated from the population reduction in feral hogs achieved in the watersheds (Formula C-5). The established goal is to reduce and maintain the overall population by 8%, which translates to approximately 50 feral hogs per year. The estimated annual potential loading reduction from feral hog management totals 1.74×10^{13} cfu or approximately 8.33% of annual bacteria loading from feral hogs in the watershed.

Formula C-5:

$$LRfh = Nfh * FCfh * Conversion * \frac{365\ days}{1\ year}$$

Where:

LR_{fh}= Potential annual E. coli load reduction attributed to feral hog removal
Nfh = Number of feral hogs removed
$FCfh$ = Fecal coliform loading rate of feral hogs; 1.21×10^9 cfu fecal coliform/AnU/day (Wagner and Moench 2009)
Conversion = Estimated fecal coliform to E. coli conversion rate; 126/200 = 0.63 (Wagner and Moench 2009)

Deer

White-tailed deer populations were estimated using a calculated population density obtained from averaged the last 5 years of densities per deer management unit (DMU) from Texas Parks and Wildlife Deer Management Unit Survey (TPWD staff, personal communication, January 29, 2024)

Table C 2). It's important to note that this document only pertained to white-tailed deer. Suitable habitat includes mixed-deciduous forest, evergreen forest, rangeland, grassland, cultivated crops, and wetland land use and land cover. Portions of four DMUs are located within the watershed, however, no deer density was recorded for Urban San Antonio DMU. While there is likely some number of deer living within this DMU, without a density no reasonable estimate can be made. GIS analysis was used to estimate watershed-wide deer populations using land use and land cover per each DMU per each subwatershed.

Table C 2. Deer densities per 1000 acres based on the TPWD Deer Management Unit Survey.

08 West	Deer/1000 acres	08 East	Deer/1000 acres	07 North	Deer/1000 acres	Urban San Antonio	Deer/1000 acres
2021	34.14	2022	34.7	2021	168.11	NA	NA
2019	40.27	2020	24.3	2019	174.97	NA	NA
2017	37.06	2018	15.58	2017	125.18	NA	NA
2016	22.03	2016	19.6	2016	155.11	NA	NA
2015	19.04	2015	33.98	2015	159.79	NA	NA
Average	30.508	Average	25.632	Average	156.632	NA	NA

Based on this analysis, an estimated 17,280 deer exist within the watershed. Like other population estimates, these numbers provide general estimates that change based on conditions within the watershed. Using the deer population estimates, the potential *E. coli* loading across the watersheds and for individual subbasins was estimated. The annual load from deer was calculated (Formula C-6). The estimated potential annual loading across all subbasins due to deer is 6.68 x 10^{15} cfu *E. coli*/year.

Formula C-6:

$$PAL_{deer} = N_{deer} * AnUC * FC_{deer} * Conversion * \frac{365\ days}{1\ year}$$

Where:

PAL_{deer} = *Potential annual E. coli loading attributed to deer*
N_{deer} = *Number of deer*
$AnUC$ = *Animal unit conversion; 0.112 AnU/deer (Wagner and Moench 2009)*
FC_{deer} = *Fecal coliform loading rate of deer; 1.50×10^{10} cfu fecal coliform/AnU/day (Wagner and Moench 2009)*
$Conversion$ = *Estimated fecal coliform to E. coli conversion rate; 126/200 = 0.63 (Wagner and Moench 2009)*

Bacteria Load Reductions from Deer Management

No management measures were identified for reducing bacteria loads from white-tailed deer, therefore no load reductions are calculated.

Domestic Pets

Dog population estimates were generated using a total percentage of households owning dogs (44.6%) multiplied by the average number of dogs per pet-owning household applied to 2020 U.S. Census block household data for the watershed (AVMA 2022). Within the watershed, there are an estimated 50,384 dogs. Based on stakeholder input, it was assumed that no significant number of dog owners in the watershed pick up dog waste. Using the resulting dog population estimate, the annual load due to dogs was estimated (Formula C-7). The estimated potential annual loading attributed to dogs is 5.79×10^{16} cfu *E. coli*/year in the watershed.

Formula C-7:

$$PAL_d = N_d * FC_d * Conversion * 365 \frac{days}{year}$$

Where:

PAL_d = Potential annual E. coli loading attributed to dogs
N_d = Number of dogs that owners do not pick up after
FC_d = Fecal coliform loading rate of dogs; 5.00×10^9 cfu fecal coliform/dog/day (EPA 2001)
Conversion = Estimated fecal coliform to E. coli conversion rate; 126/200 = 0.63 (Wagner and Moench 2009)

Bacteria Load Reductions from Dog Management

The watershed contains approximately 50,384 dogs. To reduce bacteria loading for domestic pets, management efforts focus on increasing the number of dog owners who pick up dog waste. Load reduction calculations included goals of increasing the overall number of households managing waste by 15%, and that these households clean up dog waste at least 25% of the time (Formula C-8). The annual estimated potential load reduction attributable to dog waste management is 2.17×10^{15} cfu.

Formula C-8:

$$LRd = Mgmt\ Goal\ 1 * Mgmt\ Goal\ 2 * FC_d * Conversion * 365 \frac{days}{year}$$

Where:

LR_d = Potential annual E. coli loading attributed to proper dog waster diposal
Management Goal 1 = Number of additional households managing waste; goal is 15%
Management Goal 2 = How often owners pick up dog waste; goal is 25%
FC_d = Fecal coliform loading rate of dogs; 5.00×10^9 cfu fecal coliform/dog/day (EPA 2001)
Conversion = Estimated fecal coliform to E. coli conversion rate; 126/200 = 0.63 (Wagner and Moench 2009)

OSSFs

Potential *E. coli* loading for individual subbasins was estimated using the watershed OSSF estimates and distribution. Potential bacteria loadings from OSSFs were calculated for each county within each subwatershed by multiplying the OSSF count by the failure rate, the default wastewater per person, average person per household (Borel et al. 2015), *E. coli* conversion rate (Wagner & Moench, 2009), the fecal coliform production rate for OSSFs (USEPA 2001), a constant for unit conversions, then dividing by 100.

Estimated failure rates for aerobic and conventional systems in Medina county were provided by county officials. Failure rates for Atascosa, Bandera, and Bexar counties were derived from (Reed-Stowe & Yanke 2001). Atascosa and Bandera counties are located in Region II, with an average failure rate of 12% across all system types. Bexar county failure rates were estimated to be an average of Regions II and III rates of 12% and 3%, respectively, across all system types. Methods to estimate OSSF locations and numbers are described in Chapter 4 of this WPP. The annual load from OSSFs was calculated (Formula C-9). The estimated potential annual loading across all subbasins due to OSSFs is 2.36 x 10^{16} cfu *E. coli*/year in the watershed.

Formula C-9:

$$PAL_{ossf} = N_{ossf} * N_{hh} * Production * Failure\ Rate * FC_s * Conversion * 365\frac{days}{year}$$

Where:

PAL_{ossf} = *Potential annual E. coli loading attributed to OSSFs*
N_{ossf} = *Number of OSSFs*
N_{hh} = *Average number of people/household per subwatershed, using the 2020 US Census*
$Production$ = *Assumed sewage discharge rate; 70 gallons/person/day (Borel et al. 2015)*
$Failure\ Rate$ = *Different for each county, see*
Table C 3.
FC_s = *Fecal coliform concentration in sewage; 1.0×106 cfu/100 mL (EPA 2001)*
$Conversion$ = *Conversion rate from fecal coliform to E. coli; 126/200 = 0.63 (Wagner and Moench 2009) and mL to gallon (3785.4 mL/gallon)*

Table C 3. Estimated failure rates of OSSFs in the watershed.

County	Aerobic Systems	Conventional Systems
Medina	65%	10%
Bexar	7.5%	7.5%
Atascosa	12%	12%
Bandera	12%	12%

Bacteria Load Reductions from OSSF Management

Load reductions for OSSFs are calculated based on the number of failing OSSFs that are repaired or replaced (Formula C-10).

Formula C-10:

$$LRossf = N_{ossf} * N_{hh} * Production * FC_s * Conversion * 365 \frac{days}{year}$$

Where:

LR_{OSSF}= *Potential annual E. coli loading attributed to OSSFs*
N_{ossf} = *Number of OSSFs*
N_{hh} = *Average number of people per household according to 2020 US Census; 2.8*
$Production$ = *Assumed sewage discharge rate; 70 gallons/person/day (Borel et al. 2015)*
FC_s = *Fecal coliform concentration in sewage; 1.0×10*^{7} *cfu/100 mL (EPA 2001)*
$Conversion$ = *Conversion rate from fecal coliform to E. coli; 126/200 = 0.63 (Wagner and Moench 2009) and mL to gallon (3785.4 mL/gallon)*

For this WPP, the goal is to address 60 failing OSSSFs annually (20 aerobic and 10 conventional in Medina County, 20 conventional in Bandera County and 10 conventional systems in Atascosa and Bandera counties). This results in a potential annual reduction of 1.04×10^{15} cfu. This translates to a reduction of approximately 4.4% of bacteria loading from OSSFs annually.

WWTFs

Potential loadings from WWTFs were calculated for all permitted dischargers with a bacteria monitoring requirement. Except for the Medio Creek Water Recycling Center, potential loads were calculated as the sum of the maximum permitted discharges of all WWTFs multiplied by the maximum permitted *E. coli* concentration. For the Medio Creek Water Recycling Center, the reported discharge was used (Formula C- 11).

Formula C-10:

$$PAL_{wwtf} = Discharge * Concentration_{max} * Conversion * \frac{365\ days}{year}$$

Where:

PAL_{wwtf} = *Potential annual E. coli loading due to WWTF discharges*
$Discharge$ = *Maximum permitted daily discharge*
$Concentration_{max}$ = *Maximum average permitted concentration of E. coli in wastewater discharge (126 cfu/100 mL)*
$Conversion$ = *Unit conversion (3785.4 mL/gallon)*

The estimated potential annual loading across all subbasins due to WWTF discharges are 1.88×10^{13} cfu *E. coli*/year to the watershed. This is a very small portion of the combined bacteria loading of all potential sources.

Bacteria Load Reductions from WWTF Management

No management measures selected for WWTF management and therefore no bacteria load reductions were calculated. Stakeholders chose to focus on more effective management measures.

Appendix C References

AVMA (American Veterinary Medical Association). 2022. 2022 U.S. Pet Ownership & Demographics Sourcebook. Schaumberg, IL: American Veterinary Medical Association. https://www.avma.org/resources-tools/reports-statistics/us-pet-ownership-statistics

Borel, K., Gregory, L., Karthikeyan, R. 2012. Modeling Support for the Attoyac Bayou Bacteria Assessment using SELECT. College Station, TX: Texas Water Resources Institute. TR-454. https://twri.tamu.edu/publications/technical-reports/2012-technical-reports/tr-454/

Brenner, F.J., Mondok, J.J, McDonald, Jr, R.J. 1996. Watershed Restoration through Changing Agricultural Practices. Proceedings of the AWRA Annual Symposium Watershed Restoration Management: Physical, Chemical and Biological Considerations. Herndon, VA: American Water Resources Association, TPS-96-1, pp. 397-404.

Byers, H. L., Cabrera, M. L., Matthews, M. K., Franklin, D. H., Andrae, J. G., Radcliffe, D. E., McCann, M. A., Kuykendall, H. A., Hoveland, C. S., Calvert II, V. H. 2005. Phosphorus, sediment, and *Escherichia coli* loads in unfenced streams of the Georgia Piedmont, USA. Journal of Environmental Quality. 34 (6): 2293-2300. https://doi.org/10.2134/jeq2004.0335.

EPA. 2001. Protocol for Developing Pathogen TMDLs: Source Assessment. 1st Edition.

EPA. 2010. Section 319 Nonpoint Source Program Success Story Oklahoma Implementing Best Management Practices Improves Water Quality. Washington, DC: EPA Office of Water. 841-F-10-001F. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1006RU2.PDF.

Hagedorn, C., Robinson, S. L., Filts, J. R., Grubbs, S. M., Angier, T. A., Reneau Jr., R. B. 1999. Determining sources of fecal pollution in a rural Virginia watershed with antibiotic resistance patterns in fecal streptococci. Applied and Environmental Microbiology. 65:5522-5531. https://doi.org/10.1128/aem.65.12.5522-5531.1999.

Peterson, J. L., Redmon, L. A., McFarland, M. L. 2011. Reducing Bacteria with Best Management Practices for Livestock: Heavy Use Area Protection. College Station, TX: Texas A&M AgriLife Extension Service. ESP-406. https://agrilifeextension.tamu.edu/library/ranching/reducing-bacteria-heavy-use-area-protection/.

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

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

USGS (United States Geological Survey). 2023. National Hydrography Dataset (NHD). Retrieved April 15, 2023, from https://apps.nationalmap.gov/downloader/

USDA NASS (United States Department of Agriculture - National Agricultural Statistics Service). 2024. Quick Stats (2022 Census). https://www.nass.usda.gov/Quick_Stats/

Wagner K.L. and Moench, E. 2009. Education Program for Improved Water Quality in Copano Bay. Task Two Report. College Station, TX: Texas Water Resources Institute. TR-347.