UPPER SAN ANTONIO RIVER WATERSHED DATA REPORT

December 2022

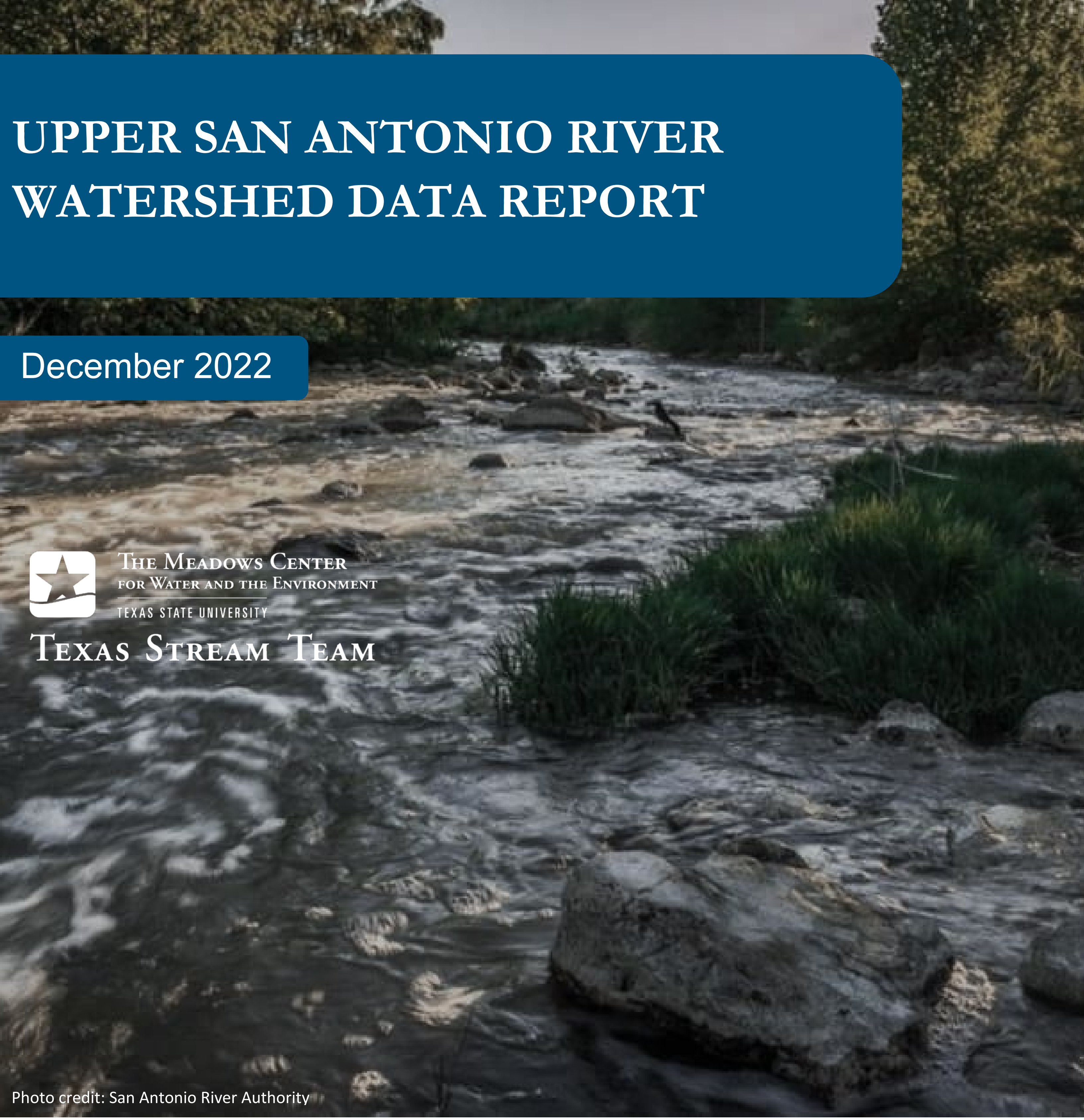

Photo credit: San Antonio River Authority

The Meadows Center for Water and the Environment
Texas State University
Texas Stream Team

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ACKNOWLEDGEMENTS

The Texas Stream Team encourages life-long learning about the environment and people's relationship to the environment through its multidisciplinary citizen science programs. We also provide hands-on opportunities for Texas State University students and inspire future careers and studies in natural resource related fields. Preparation of this report fulfills a contract deliverable for the granting entity, but it also serves as a valuable educational experience for the students that assisted in preparing the report. The Texas Stream Team staff values the student contributions and recognizes each individual for their role. The following staff and student workers assisted in the preparation of this report and are acknowledged for their contributions:

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INTRODUCTION

Texas Stream Team

Texas Stream Team is a volunteer citizen science water quality monitoring program. Citizen scientist water quality monitoring occurs at predetermined monitoring sites, at approximately the same time of day each month. Information collected by Texas Stream Team citizen scientists is covered by a Texas Commission on Environmental Quality-approved Quality Assurance Project Plan to ensure a standard set of methods are used. Citizen scientist data may be used to identify surface water quality trends, target additional data collection needs, identify potential pollution events and sources of pollution, and to test the effectiveness of water quality management measures. Texas Stream Team citizen scientist data are not used by the state to assess whether water bodies are meeting the designated surface water quality standards. Data collected by Texas Stream Team provide valuable information, often collected in water bodies professionals are not able to monitor frequently or monitor at all.

For additional information about water quality monitoring methods and procedures, including the differences between professional and volunteer citizen science monitoring, please refer to the following sources:

- Texas Stream Team Core Water Quality Citizen Scientist Manual
- Texas Stream Team Advanced Water Quality Citizen Scientist Manual
- Texas Stream Team Program Volunteer Water Quality Monitoring Program Quality Assurance Project Plan
- Texas Commission on Environmental Quality Surface Water Quality Monitoring Procedures

The purpose of this report is to provide a summary of the data collected by Texas Stream Team citizen scientists. The data presented in this report should be considered in conjunction with other relevant water quality reports for a holistic view of water quality in the Upper San Antonio River Watershed in the San Antonio River Basin. Such sources may include, but are not limited to, the following:

- Texas Surface Water Quality Standards
- Texas Water Quality Inventory and 303(d) List (Integrated Report)
- Texas Clean Rivers Program partner reports, such as Basin Summary and Highlight Reports
- Texas Commission on Environmental Quality Total Maximum Daily Load reports
- Texas Commission on Environmental Quality and Texas State Soil and Water Conservation Board Nonpoint Source Program funded reports, including watershed protection plans

To get involved with Texas Stream Team or for questions regarding this watershed data report contact us at TxStreamTeam@txstate.edu or at (512) 245-1346. Visit our website for more information on our programs at www.TexasStreamTeam.org.

WATERSHED DESCRIPTION

Location and Climate

The Upper San Antonio River Watershed spans 506-square miles (Figure 1) and is located within the larger San Antonio River Basin. The Upper San Antonio River Watershed encompasses the City of San Antonio (498-square miles), the county seat of Bexar County, and extends into Wilson County (National Land Cover Data, 2016). This area is important locally for aesthetics, recreation, and for the ecosystem it supports, but it is also historically significant, provides a business-friendly environment, and is a popular urban tourism destination (City of San Antonio, 2022).

The San Antonio River was named by Domingo Terán de los Ríos in 1691 for San Antonio de Padua, "Saint Anthony of Padua" (TWDB, 2022). Beginning in the early 18th century, this area served as a major thoroughfare from the Alamo to Goliad, and later for cattle drives and transportation. Because the spring-fed river provided water for drinking, irrigation, and hydropower, the area became the center of Spanish activities in Texas (Donecker, 2019). Over the past century, the waters of the Upper San Antonio River Watershed have experienced reduced base flows due to over pumping of groundwater (TWDB, 2022).

The Texas Commission on Environmental Quality designates classifications for stream segments in the Upper San Antonio River Watershed and throughout Texas (Table 1). Salado Creek (Segment 1910) rises in the Balcones Escarpment and flows into the Upper San Antonio River (Segment 1911) south of San Antonio Missions National Historical Park and north of Victor Braunig Lake. Salado Creek and the Upper San Antonio River are classified segments. Other unclassified segments that flow to the Upper San Antonio River include Olmos (Segment 1911A), Apache (Segment 1911B), and Alazan (Segment 1911C) Creeks.

The climate in this part of the state is described as subtropical-subhumid, with warm and hot summers, and mild winters (Long, 2019 and 2020). National Oceanic and Atmospheric Administration climate data from a weather station at San Antonio Incarnate Word in San Antonio, Texas was acquired from the National Data Center (NOAA, 2020). Average annual precipitation at San Antonio Incarnate Word was 34.0 inches and occurred year-round (Figure 2). Long-term monthly average precipitation has a bimodal distribution with peaks occurring in May and October. Average rainfall during these months was 4.4 and 3.9 inches each month, respectively. The least amount of rainfall (1.9 inches) occurred in February. The warmest and coldest months of the year were August (29.3°C) and January (10.9°C), respectively.

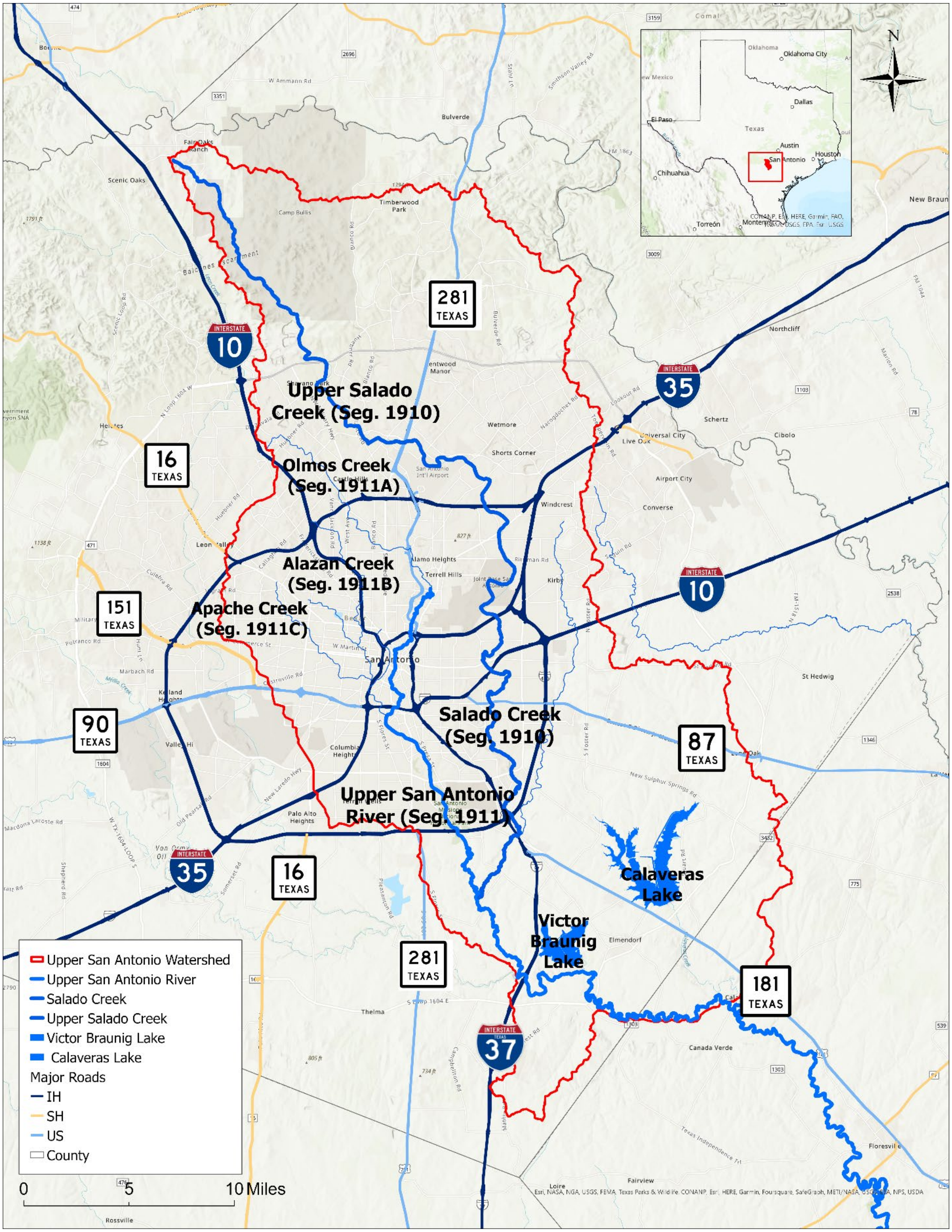

Figure 1. Upper San Antonio River Watershed in Bexar and Wilson Counties, Texas.

Table 1. Texas Commission on Environmental Quality segment classifications (Texas Commission on Environmental Quality, 2022).

Segment Number	Segment Name	Segment Description
1910	Salado Creek	From the confluence with the San Antonio River in Bexar County to the confluence of Beitel Creek in Bexar County.
1911	Upper San Antonio River	From a point 600 meters (660 yards) downstream of FM 791 at Mays Crossing near Falls City in Karnes County to a point 100 meters (110 yards) upstream of Hildebrand Avenue at San Antonio in Bexar County.

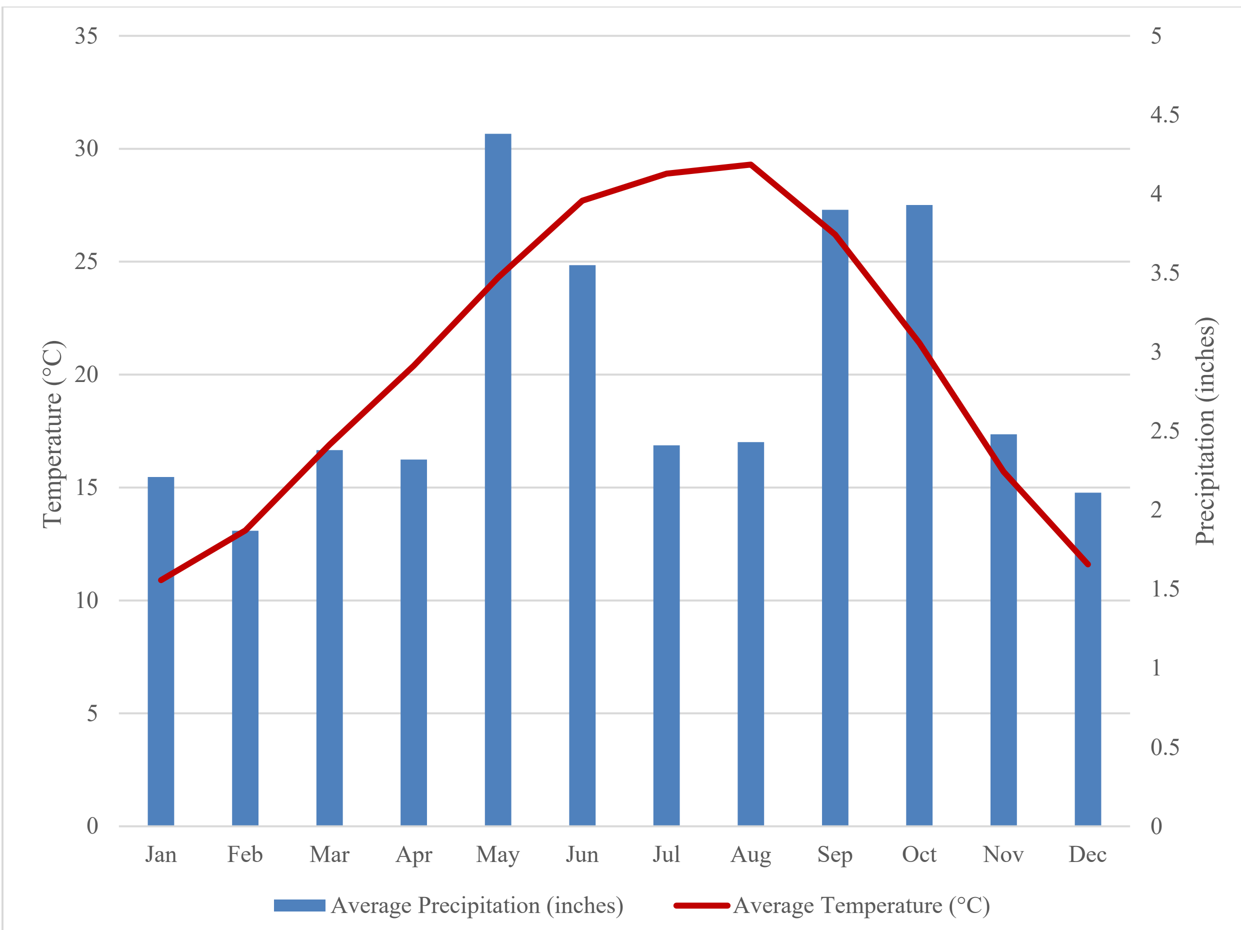

Figure 2. Long-term (1991-2020) monthly average precipitation (inches) and air temperature (°C) from San Antonio Incarnate Word in San Antonio, Texas (National Oceanic and Atmospheric Administration Climate Data, 2020).

Physical Description

The Upper San Antonio River Watershed is in the San Antonio River Basin contained primarily in Bexar County where Salado Creek flows into the Upper San Antonio River. The landscape is described as undulating to hilly terrain in the north, being crossed by the Balcones Escarpment in the northwest, and level to gently rolling terrain in the far south. Edwards Plateau, South Texas Plains, and Blackland Prairie vegetation is comprised of oak, juniper, mesquite, thorny bushes, blackjack, grasses, and cacti. Soils that support the landscape include alkaline deep to shallow loamy soils, clay soils, and clay subsoils. Mineral resources found in the area include sulfur springs, limestone, kaolin, clay, fuller's earth, greensand, lignite, petroleum, and natural gas (Long, 2019 and 2020).

This area supports diverse wildlife including white-tailed deer, raccoons, skunks, ringtails, rock squirrels, foxes, coyotes, turkeys, doves, red-tailed hawks, great horned owls, ground skinks, Texas blind snakes, Texas spiny lizards, and Gulf Coast toads (TMN Alamo Chapter, 2022).

Land Use

Land cover types were identified and mapped for the Upper San Antonio River Watershed (Figure 3) (National Land Cover Data, 2016). Ninety-four percent of the land cover in the watershed consists of developed land (55%), shrub (16%), forest (12%), and planted/cultivated (11%) (Table 2). The remaining land use types, woody wetlands (2%), open water (2%), grassland (1%), bare (1%), and emergent herbaceous wetlands (<0.1%) comprise approximately 6% of the remainder of the watershed by area.

Table 2. Land use in the Upper San Antonio River Watershed in Bexar County and Wilson County, Texas (National Land Cover Data, 2016).

Land Use Type	**Acres (ac)**	**Hectares (ha)**	**Percent (%)**
Developed	179,169	72,507	55%
Shrub	53,418	21,618	16%
Forest	38,947	15,761	12%
Planted/Cultivated	36,806	14,895	11%
Woody Wetlands	7,135	2,887	2%
Open Water	5,435	2,200	2%
Bare	1,684	682	1%
Grassland	1,619	655	1%
Emergent Herbaceous Wetlands	187	76	<0.1%
Total	**324,400**	**131,281**	**100**

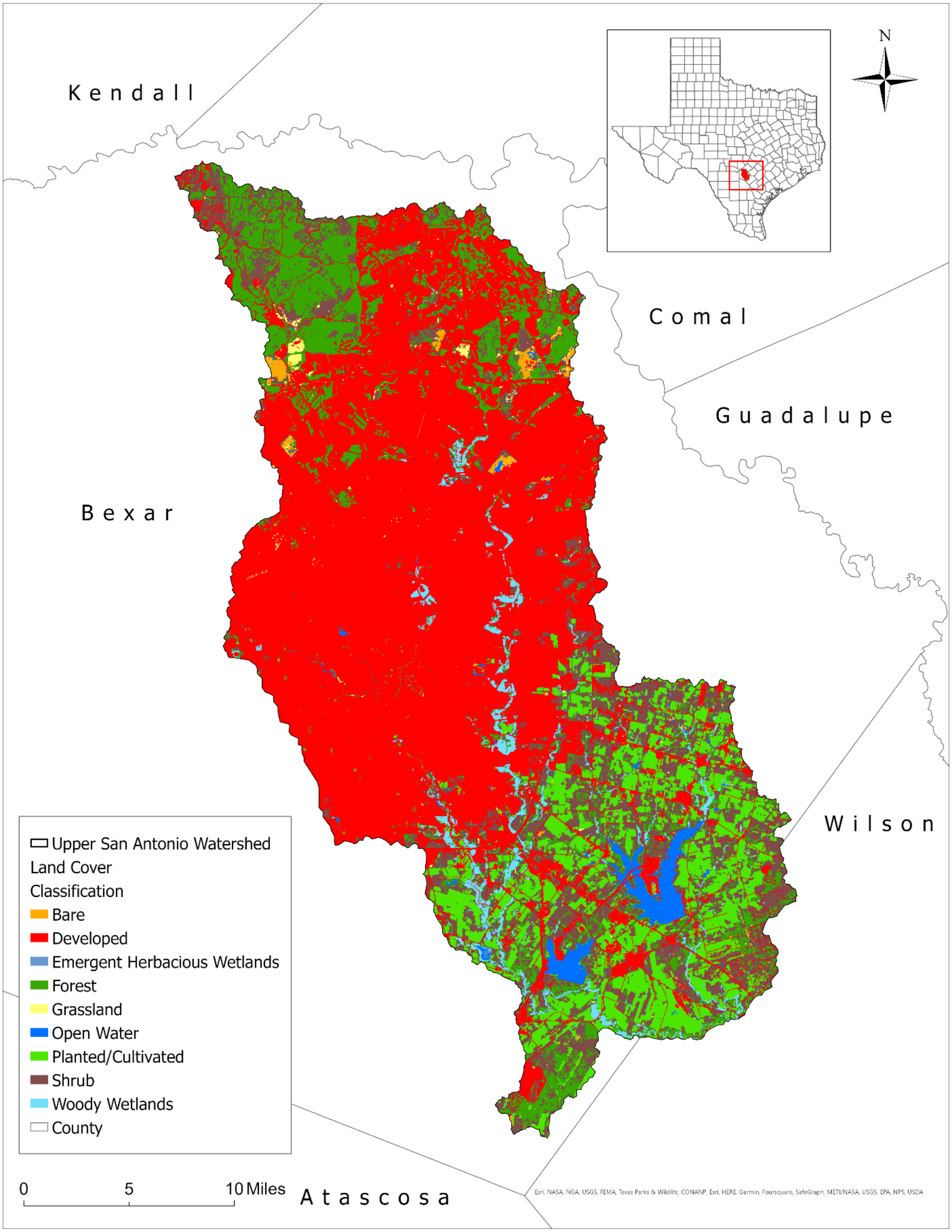

Figure 3. Land cover for the Upper San Antonio River Watershed in Bexar and Wilson Counties, Texas (National Land Cover Data, 2016).

History

Bexar and Wilson Counties were established by hunter-gatherer communities more than 10,000 years ago, and were occupied by Coahuiltecans, Comanche, Tonkawa, and Lipan Apache indigenous peoples. Spanish explorers arrived in the early 18th century before establishing temporary settlements for vaqueros (herdsmen) and ranchers. Farming communities settled around Spanish missions and irrigated the land with acequias (irrigation ditches). During the Texas Revolution, the area housed numerous battles and conflicts (Long, 2020).

Anglo-Americans began colonizing the area in the 19th century, followed by German and Polish colonists, after Texas entered the Union. The area experienced rapid population growth and ethnic diversity, primarily because of the prosperous cattle trail drives, wool, and military industries. The development of railroads would spur a new period of economic growth. This prosperity resulted in construction of needed public facilities and the populous area we know today (Jasinski, 2022).

Endangered Species and Conservation Needs

The common names of 28 species listed as threatened or endangered (under the authority of Texas state law and/or under the US Endangered Species Act) within the Upper San Antonio River Sub Basin are included in Appendix A at the end of this report. A summary of the number of species per taxonomic group listed as state or federally endangered, threatened, G1 or G2 (critically imperiled or imperiled), species of greatest conservation need, and/or endemic are provided in Table 3.

Table 3. State and federally listed species in the Upper San Antonio River Watershed in Bexar and Wilson Counties, Texas.

Taxon	Endangered (Federal or State)	Threatened (Federal or State)	G1 or G2 (Critically imperiled or imperiled)	Species of Greatest Conservation Need (NPWD) (S1 or S2)	Endemic Total Count
Amphibians	0	2	1	2	5
Birds	2	5	2	8	15
Fish	0	2	2	2	5
Mammals	0	2	0	5	16
Reptiles	0	3	0	6	14
Crustaceans	0	0	4	3	4
Insects	3	0	8	8	18
Arachnids	3	0	7	8	9
Mollusks	1	1	2	3	3
Arthropods	0	0	0	2	2
Plants	0	1	8	11	41
Total Count	**9**	**16**	**34**	**58**	**132**

Texas Water Quality Standards

The Texas Surface Water Quality Standards establish explicit goals for the quality of streams, rivers, lakes, and bays throughout the state. The standards are developed to maintain the quality of surface waters in Texas to support public health and protect aquatic life, consistent with the sustainable economic development of the state. Water quality standards identify appropriate uses for the state's surface waters, including aquatic life, recreation, and sources of public water supply as drinking water. The criteria for evaluating support of those uses in the classified segments of Salado Creek (Segment 1910) and the Upper San Antonio River (Segment 1911) included in this report are provided in Table 4. The total dissolved solids criteria are for maximum annual averages, the dissolved oxygen criteria are for minimum 24-hour dissolved oxygen means at any site within the segment, the minimum and maximum values for pH apply to any site within the segment, the *E. coli* indicator bacteria for freshwater is a geometric mean, and the temperature criteria is a maximum value at any site within the segment.

The Texas Surface Water Quality Standards also contain narrative criteria (verbal descriptions) that apply to all waters of the state and are used to evaluate support of applicable uses. Narrative criteria include general descriptions such as the existence of excessive aquatic plant growth, foaming of surface waters, taste- and odor-producing substances, sediment build-up, and toxic materials. Narrative criteria are evaluated by using screening levels, if they are available, and other information, including water quality studies, existence of fish kills or contaminant spills, photographic evidence, and local knowledge. Screening levels serve as a reference to indicate when water quality parameters may be approaching levels of concern.

Table 4. State water quality criteria for classified stream segments in the Upper San Antonio River Watershed in Bexar and Wilson Counties, Texas (Texas Commission on Environmental Quality, 2022).

Segment	**Total Dissolved Solids (mg/L)**	**Dissolved Oxygen (mg/L)**	**pH Range (s.u.)**	***E. coli* Bacteria (#/100 mL)**	**Temperature (°C)**
1910 – Salado Creek	600	Grab screening level and min. 24-hour mean: 5.0 Grab min.: 3.0	6.5-9.0	Primary Contact Recreation 1: 126 geometric mean, 399 single sample	32.2
1911 – Upper San Antonio River	750	Grab screening level and min. 24-hour mean: 5.0 Grab min.: 3.0	6.5-9.0	Primary Contact Recreation 1: 126 geometric mean, 399 single sample	32.2

Water Quality Impairments

The *2022 Texas Integrated Report of Surface Water Quality for Clean Water Act Sections 305(b) and 303(d)* (Integrated Report) includes an index of water quality impairments. The classified segments, Salado Creek (Segment 1910) and Upper San Antonio River (Segment 1911), and the unclassified segments Apache and Alazan Creeks have impairments for fish and macrobenthic communities, bacteria, and depressed dissolved oxygen in water. These segments are designated as a Category 5C, additional data and information will be collected or evaluated before a management strategy is selected, or Category 4a, a state-developed Total Maximum Daily Load has been approved by Environmental Protection Agency or a Total Maximum Daily Load has been established by Environmental Protection Agency for any water-pollutant combination.

WATER QUALITY PARAMETERS

Water Temperature

Water temperature influences the physiological processes of aquatic organisms, and each species has an optimum temperature for survival. High water temperatures increase oxygen-demand for aquatic communities and can become stressful for fish and aquatic insects. Water temperature variations are most detrimental when they occur rapidly, leaving the aquatic community no time to adjust. Additionally, the ability of water to hold oxygen in solution (solubility) decreases as temperature increases. This effect is exacerbated in coastal water bodies influenced by tidal, saline waters.

Warm water temperatures occur naturally with seasonal variation, as water temperatures tend to increase during summer and decrease in winter in the Northern Hemisphere. Daily (diurnal) water temperature changes occur during normal heating and cooling patterns. Man-made sources of warm water include power plant effluent after it has been used for cooling or hydroelectric plants that discharge warm water. Citizen scientist monitoring may not identify fluctuating patterns due to diurnal changes or events such as power plant releases because of the monthly sampling frequency. While citizen scientist data may not show diurnal temperature fluctuations, they could demonstrate the fluctuations over seasons and years when collected consistently at predetermined monitoring sites and monthly frequencies.

Specific Conductance and Salinity

Specific conductance is a measure of the ability of a body of water to conduct electricity. It is measured in microsiemens per centimeter (μS/cm). A body of water is more conductive if it has more total dissolved solids such as nutrients and salts, which indicates poor water quality if they are overly abundant. High concentrations of nutrients can lead to eutrophication, which results in lower levels of dissolved oxygen. High concentrations of salt can inhibit water absorption and limit root growth for vegetation, leading to an abundance of more drought tolerant plants, and can cause dehydration of fish and amphibians. Sources of total dissolved solids can include agricultural runoff, domestic runoff, or discharges from wastewater treatment plants.

Salinity is a measure of the saltiness or the dissolved inorganic salt concentration in water. Salinity is often measured in ocean, estuarine, or tidally-influenced waters, but in Texas there are some inland streams that have a high salt content due to the local geology and require salinity measurements. Some common ions measured as salinity include sodium, chloride, magnesium, sulfate, calcium, and potassium. Seawater typically has a salt content of 35 parts per thousand (ppt or ‰). Like other water quality parameters, salinity affects the homeostasis or the balance of water and solutes within both plants and animals. Too much or too little salt can affect plant and animal cell survival and growth, therefore salinity is an important measurement.

Dissolved Oxygen

Oxygen is necessary for the survival of organisms like fish and aquatic insects. The amount of oxygen needed for survival and reproduction of aquatic communities varies according to species composition and adaptations to watershed characteristics like stream gradient, habitat, and available streamflow.

The dissolved oxygen concentrations can be influenced by other water quality parameters such as nutrients and temperature. High concentrations of nutrients can lead to excessive surface vegetation and algae growth, which may starve subsurface vegetation of sunlight and, therefore, reduce the amount of oxygen they produce via photosynthesis. This process is known as eutrophication. Low dissolved oxygen can also result from high groundwater inflows (which have low dissolved oxygen due to minimal aeration), high temperatures, or water releases from deeper portions of dams where dissolved oxygen stratification occurs. Supersaturation typically occurs underneath waterfalls or dams with water flowing over the top where aeration is abundant.

pH

The pH scale measures the concentration of hydrogen ions on a range from zero to 14 and is reported in standard units (s.u.). The pH of water can provide information regarding acidity or alkalinity. The range is logarithmic; therefore, every one-unit change is representative of a 10-fold increase or decrease in acidity or alkalinity. Acidic sources, indicated by a low pH level, can include acid rain and runoff from acid-laden soils. Acid rain is predominantly caused by coal powered plants with minimal contributions from the burning of other fossil fuels and other natural processes, such as volcanic emissions. Soil-acidity can be caused by excessive rainfall leaching alkaline materials out of soils, acidic parent material, crop decomposition creating hydrogen ions, or high-yielding fields that have drained the soil of all alkalinity. Sources of high pH (alkaline) include geologic composition, as in the case of limestone increasing alkalinity and the dissolving of carbon dioxide in water. Carbon dioxide is water soluble, and as it dissolves it forms carbonic acid. A suitable pH range for healthy organisms is between 6.5 and 9.0 s.u.

Water Transparency and Total Depth

Two instruments can be used by Texas Stream Team citizen scientists to measure water transparency, a Secchi disc or a transparency tube. Both instruments are used to measure water transparency or to determine the clarity of the water, a condition known as turbidity. The Secchi disc is lowered into the water until it is no longer visible, then raised until it becomes visible, and the average of the two depth measurements is recorded. A transparency tube is filled with sample water and water is released until the Secchi pattern at the bottom of the tube can be seen. The tube is marked with two-millimeter increments and is used to measure water transparency. Transparency measurements less than the total depth of the monitoring site are indicative of turbid water. Readings that are equal to total depth indicate clear water. Highly turbid waters pose a risk to wildlife by clogging the gills of fish, reducing visibility, and carrying contaminants. Reduced visibility can harm predatory fish or birds that depend on good visibility to find their prey. Turbid waters allow less light to penetrate deep into the water, which, in turn, decreases the density of phytoplankton, algae, and other aquatic plants. This reduces the dissolved oxygen in the water due to reduced photosynthesis. Contaminants are mostly transported in sediment rather than in the water. Turbid waters can result from sediment runoff from construction sites, erosion of farms, or mining operations.

E. coli and Enterococci Bacteria

E. coli bacteria originate in the digestive tract of endothermic organisms. The United States Environmental Protection Agency has determined *E. coli* to be the best indicator of the degree of pathogens in a freshwater system. A pathogen is a biological agent that causes disease.

Enterococci bacteria are a subgroup of fecal streptococci bacteria (mainly *Streptococcus faecalis* and *Streptococcus faecium*) that are present in the intestinal tracts and feces of warm-blooded animals. It is used by the Texas Commission on Environmental Quality as an indicator of the potential presence of pathogens in tidally-influenced saltwater along the Texas Gulf Coast.

The classified segments within the Upper San Antonio River Watershed are designated a primary contact recreation 1 use. This means that recreation activities are presumed to involve a significant risk of ingestion of water (e.g., wading by children, swimming, water skiing, diving, tubing, surfing, hand fishing as defined by Texas Parks and Wildlife Code, §66.115, and the following whitewater activities: kayaking, canoeing, and rafting).

The standard for a bacteria impairment is based on the geometric mean (geomean) of the bacteria measurements collected. A geometric mean is a type of average that incorporates the high variability found in parameters such as *E. coli* and enterococci which can vary from zero to tens of thousands of colony forming units per 100 milliliters (CFU/100 mL). The standard for contact recreational use of a water body is 126 CFU/100 mL for *E. coli* in freshwater or 35 CFU/100 mL for enterococci in saltwater. A water body is considered impaired if the geometric mean is higher than the corresponding water quality standard.

Texas Stream Team does not currently monitor water quality for enterococci in coastal waters, instead citizen scientists can get certified in *E. coli* bacteria monitoring, the indicator used by the Texas Commission on Environmental Quality for freshwater streams.

Nitrate-Nitrogen

Nitrogen is present in terrestrial or aquatic environments as nitrate-nitrogen, nitrites, and ammonia. Nitrate-nitrogen tests are conducted for maximum data compatibility with Texas Commission on Environmental Quality and other partners. Just like phosphorus, nitrogen is a nutrient necessary for the growth of most living organisms. Nitrogen inputs into a water body may be from livestock and pet waste, excessive fertilizer use, failing septic systems, and industrial discharges that contain corrosion inhibitors. The effect excess nitrogen has on a water body is known as eutrophication and is described previously in the “Dissolved Oxygen” section. Nitrate-nitrogen dissolves more readily than orthophosphate, which tend to be attached to sediment, and, therefore, can serve as a better indicator of possible sewage or manure pollution during dry weather.

Phosphate

Phosphorus almost always exists in the natural environment as phosphate and continually cycles through the ecosystem as a nutrient necessary for the growth of most organisms. Testing for phosphate in the water excludes the phosphate bound up in plant and animal tissue. There are other methods to retrieve the phosphate from the material to which it is bound, but they are too complicated and expensive to be conducted by citizen scientists. Testing for phosphate provides an idea of the degree of phosphorus in a water body. It can be used for problem identification, which can be followed up with more detailed professional monitoring, if necessary. Phosphorus inputs into a water body may be caused by the weathering of soils and rocks, discharge from wastewater treatment plants, excessive fertilizer use, failing septic systems, livestock and pet waste, disturbed land areas, drained wetlands, water treatment, and some commercial cleaning products. The effect excess phosphate has on a water body is known as eutrophication and is described above in the “Dissolved Oxygen” section.

DATA COLLECTION, MANAGEMENT AND ANALYSIS

Data Collection

The field sampling procedures implemented by trained citizen scientists are documented in the Texas Stream Team Core Water Quality Citizen Scientist Manual and the Texas Stream Team Advanced Water Quality Citizen Scientist Manual. The sampling protocols in the manuals adhere closely to the Texas Commission on Environmental Quality Surface Water Quality Monitoring Procedures Manual, Volume 1 (August 2012). Additionally, all data collection adheres to Texas Stream Team's approved Quality Assurance Project Plan.

Procedures documented in Texas Stream Team Water Quality Citizen Scientist Manuals or the Texas Commission on Environmental Quality Surface Water Quality Monitoring Procedures Manual, Volume 1 (August 2012) outline the necessary steps to prevent contamination of samples, including direct collection into sample containers, when possible. Field quality control samples are collected and analyzed to detect whether contamination has occurred and to ensure data accuracy and precision.

Field sampling activities are documented on Environmental Monitoring Forms. The following items are recorded for each field sampling event: station ID, location, sampling time, date, depth, sample collector's name/signature, group identification number, meter calibration information, and reagent expiration dates. Specific conductance values are converted to total dissolved solids using a conversion factor of 0.65 and are reported as mg/L.

Values for measured parameters are recorded. If reagents or media are expired, it is noted, and data are flagged and communicated to Texas Stream Team staff. Sampling is not permitted with expired reagents or bacteria media; the corresponding values will be flagged in the database and excluded from data reports. Detailed observational data recorded include water appearance, weather, field observations (biological activity and stream uses), algae cover, unusual odors, days since last significant rainfall, and flow severity. Comments related to field measurements, number of participants, total time spent sampling, and total round-trip distance traveled to the sampling site are also recorded for grant reporting and administrative purposes.

Data Management

The citizen scientists collect field data and report the measurement results to Texas Stream Team, by submitting a hard copy of the Environmental Monitoring Form, entering the data directly into the online Waterways Dataviewer, or by using the electronic Monitoring Form. All data are reviewed to ensure they are representative of the samples analyzed and locations where measurements were made. The measurements and associated quality control data are also reviewed to ensure they conform to specified monitoring procedures and project specifications as stated in the approved Quality Assurance Project Plan.

Data review and verification is performed using a quality control checklist and self-assessments, as appropriate to the project task, followed by automated database functions that validate data as the information is entered into the database. The data are verified and evaluated against project specifications and are checked for errors, especially errors in transcription, calculations, and data input. Potential errors are identified by examination of documentation and by manual and computer-assisted examination of corollary or unreasonable data. Issues that can be corrected are corrected and documented. Once entered, the data can be accessible publicly through the online Texas Stream Team Datamap.

Data Analysis

Data were compiled, analyzed, summarized, and compared to state water quality standards and/or criteria to provide readers with a reference point for parameters that may be of concern. The statewide, biennial assessment performed by the Texas Commission on Environmental Quality involves more stringent monitoring methods and oversight than those used by citizen scientists and staff in this report. The Texas Stream Team citizen scientist water quality monitoring data are not currently used in the Texas Commission on Environmental Quality assessments mentioned above. However, the Texas Stream Team data are intended to inform stakeholders about general characteristics and assist professionals in identifying areas of potential concern to plan future monitoring efforts.

All data collected by citizen scientists in the study watersheds were exported from the Texas Stream Team database and grouped by site. Sites with 10 or more monitoring events were maintained in the dataset for analysis. Sites with fewer than 10 monitoring events were excluded from the analysis for this report but may be used in future data summary reports. Once compiled, data were sorted, summary statistics were generated and reviewed, and results were graphed in JMP Pro 14.0.0 (SAS Institute Inc., 2018) using standard methods. Best professional judgement was used to verify outliers. Outlier box or scatter plots were prepared to provide a compact view of the distribution of the data for each parameter and site(s). The horizontal line within the box plot represents the median sample value, while the ends of the box represent the 25^{th} and 75^{th} quantiles or the interquartile range. The lines extending from each end of the box, or whiskers, are computed using the $25^{th}/75^{th}$ quartiles ± 1.5 x (interquartile range). Outliers are plotted as points outside the box plot.

DATA RESULTS

Water quality data from nine Texas Stream Team monitoring sites in the Upper San Antonio River Watershed were acquired for analysis (Figure 4). One site is on Salado Creek, while the remaining sites are on the Upper San Antonio River or contributing tributaries. Trained citizen scientists conducted between 10 and 66 sampling events at each site, for a total of 188 monitoring events (Table 5). The period of record for the sampling events ranged from December 1992 to September 2022, with all sites experiencing temporal intermittent sampling.

Site Analysis

Water quality monitoring data from the nine sites were analyzed and summarized including the number of samples, mean/geometric mean, standard deviation, and range of values (Table 6). Citizen scientists monitored the sites for standard core water quality monitoring parameters, including air and water temperature, conductivity, total dissolved solids, dissolved oxygen, pH, Secchi disc/tube transparency, and total depth.

Air and Water Temperature

Average air temperature for all sites ranged from 21.4 to 28.7°C (Table 6). The lowest mean air temperature (21.4°C) was observed in Olmos Creek in the upper reach of the San Antonio River (Site 80880). The highest mean air temperature (28.7°C) was observed in the lower reach of the San Antonio River at Greenline Park (Site 81637).

Table 5. Texas Stream Team monitoring sites in the Upper San Antonio River Watershed within the San Antonio River Basin in Bexar and Wilson Counties, Texas.

Site ID	Description	Number of Monitoring Events (n)	Period of Record
Salado Creek (Segment 1910)			
13596	Salado Creek @ Comanche Park	24	12/6/1992 – 7/11/1993 5/12/2021 – 8/9/2022
Upper San Antonio River (Segment 1911)			
80880	Olmos Creek @ Olmos Basin Greenway	66	7/27/2015 – 8/29/2022
16277	San Antonio River @ Johnson St	30	12/10/1992 – 3/15/1995 12/12/2020 – 8/11/2022
81636	Roosevelt Park Near Lone Star Blvd and Mission Road	10	12/2/2020 – 8/28/2022
81661	Woodlawn Lake At Boat Dock, Alazan Creek	10	10/3/2021 – 9/3/2022
81638	Lake Elmendorf At Elmendorf Lake Park	13	12/23/2020 – 8/17/2022
81635	Concepcion Park Near E. Theo Ave	11	12/2/2020 – 8/28/2022
81634	Padre Park Off Padre Dr. and Park Ed	11	1/27/2020 – 8/28/2022
81637	The Greenline Park	13	12/23/2020 – 8/29/2022
	TOTAL	**188**	

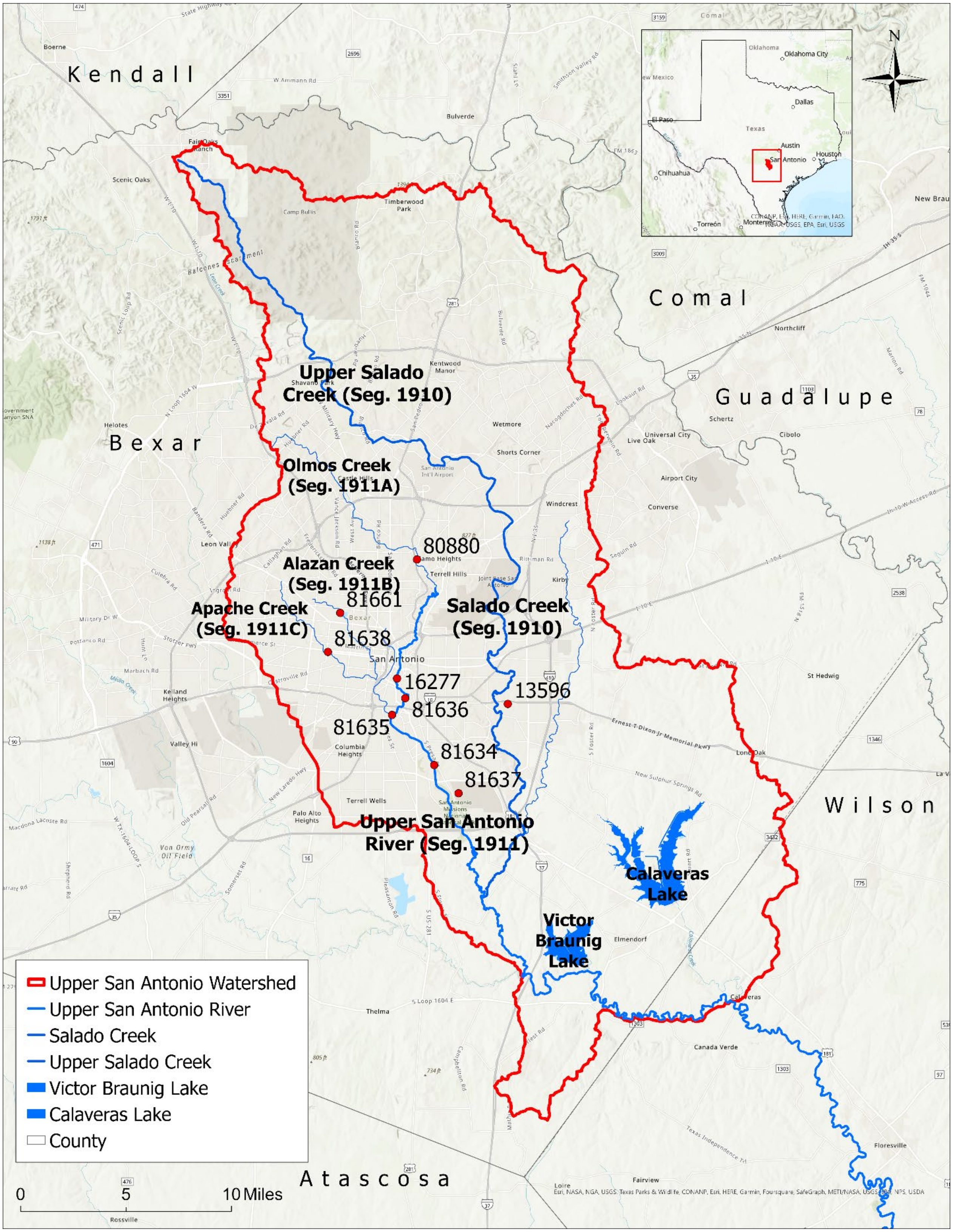

Figure 4. Texas Stream Team monitoring sites in Upper San Antonio River Watershed within the San Antonio River Basin in Bexar and Wilson Counties, Texas.

Average water temperature ranged from 19.8°C at Olmos Creek in the upper reach of the San Antonio River (Site 80880) to 26.8°C in the lower reach of the San Antonio River at Greenline Park (Site 81637) (Table 6). Water temperatures exceeded the water quality standard (32.2°C) at two sites (81637 and 81638) in May 2021 and one site (16277) in July 2022 (Figure 5).

Specific Conductance and Total Dissolved Solids

Total dissolved solid values were derived from specific conductance measurements. Average total dissolved solid values ranged from 331 mg/L at Lake Elmendorf (Site 81638) on Apache Creek, a tributary to the Upper San Antonio River, to 533 mg/L at Greenline Park (Site 81637) on the lower reach of the watershed (Table 6). The total dissolved solid water quality standard for Salado Creek is 600 mg/L and 750 mg/L for the Upper San Antonio River. Average total dissolved solids were below the standard at all sites (Table 6). However, some sites periodically exhibited discreet measurements greater than the water quality standard during the period of record for this study (Figure 6).

Table 6. Texas Stream Team data summary for sites on Salado Creek and the Upper San Antonio River within the Upper San Antonio River Watershed (Dec 1992 to Sep 2022).

Parameter	Salado Creek	Upper San Antonio River							
Site ID	13596	80880	16277	81636	81661	81638	81635	81634	81637
Number of events	n =24	n = 66	n = 30	n =10	n =10	n =13	n =11	n =11	n =13
Air Temp. (°C)	22.0±6.7 (21)	21.4±6.3 (23)	23.2±5.8 (20)	22.8±5.5 (15)	23.7±4.3 (12)	28.2±7.5 (27)	23.5±4.5 (14)	24.4±4.9 (15)	28.7±7.8 (24)
Water Temp. (°C)	20.6±6.0 (19)	19.8±6.2 (19)	22.8±4.4 (15)	22.3±5.0 (14)	23.1±5.0 (16)	26.7±7.0 (25)	22.8±4.8 (15)	23.5±5.4 (16)	26.8±7.0 (24)
Specific Conductance (µS/cm)	646±185 (743)	731±228 (880)	619±272 (1121)	666±178 (467)	540±356 (1000)	510±302 (918)	704±206 (668)	641±173 (549)	820±312 (927)
*Total Dissolved Solids (mg/L)	420±120 (483)	475±148 (572)	402±177 (729)	433±116 (304)	351±231 (650)	331±196 (597)	458±134 (434)	417±112 (357)	533±203 (603)
Dissolved Oxygen (mg/L)	5.3±3.4 (9.6)	4.4±1.9 (8.6)	6.0±0.6 (2)	6.2±1.4 (4.2)	6.3±3.4 (10.9)	8.7±2.6 (9.1)	7.3±1.8 (5.0)	7.0±1.7 (5.7)	7.9±2.4 (9.0)
pH (s.u.)	7.5±0.3 (1.5)	7.4±0.3 (1.3)	8.0±0.3 (1.5)	7.6±0.2 (0.5)	7.8±0.4 (1)	8.5±0.5 (1.4)	7.9±0.3 (1)	8.0±0.5 (1.5)	8.1±0.5 (1.5)
Secchi Disc Transp. (m)	0.5±0.2 (0.8)	1.6±4.6 (37.1)	1.2±0.5 (1.1)	2.6±2.4 (5.2)	5.4±7.2 (17.0)	1.1±1.7 (5.8)	2.4±1.8 (5.4)	1.7±1.9 (5.7)	2.0±2.6 (7.4)
Transparency Tube (m)	0.7±0.3 (0.7)	1.0±0.3 (1.0)	ND	ND	ND	ND	ND	ND	ND
Total Depth (m)	0.6±0.4 (1.2)	1.2±0.2 (0.8)	1.4±0.6 (1.4)	1.3±0.4 (0.8)	1.3±0.7 (2.3)	0.9±0.2 (0.8)	2.2±0.3 (1)	3.5±0.5 (1.5)	0.9±0.5 (1.7)

*Total dissolved solids (TDS) were calculated from specific conductance (TDS = specific conductance * 0.65).

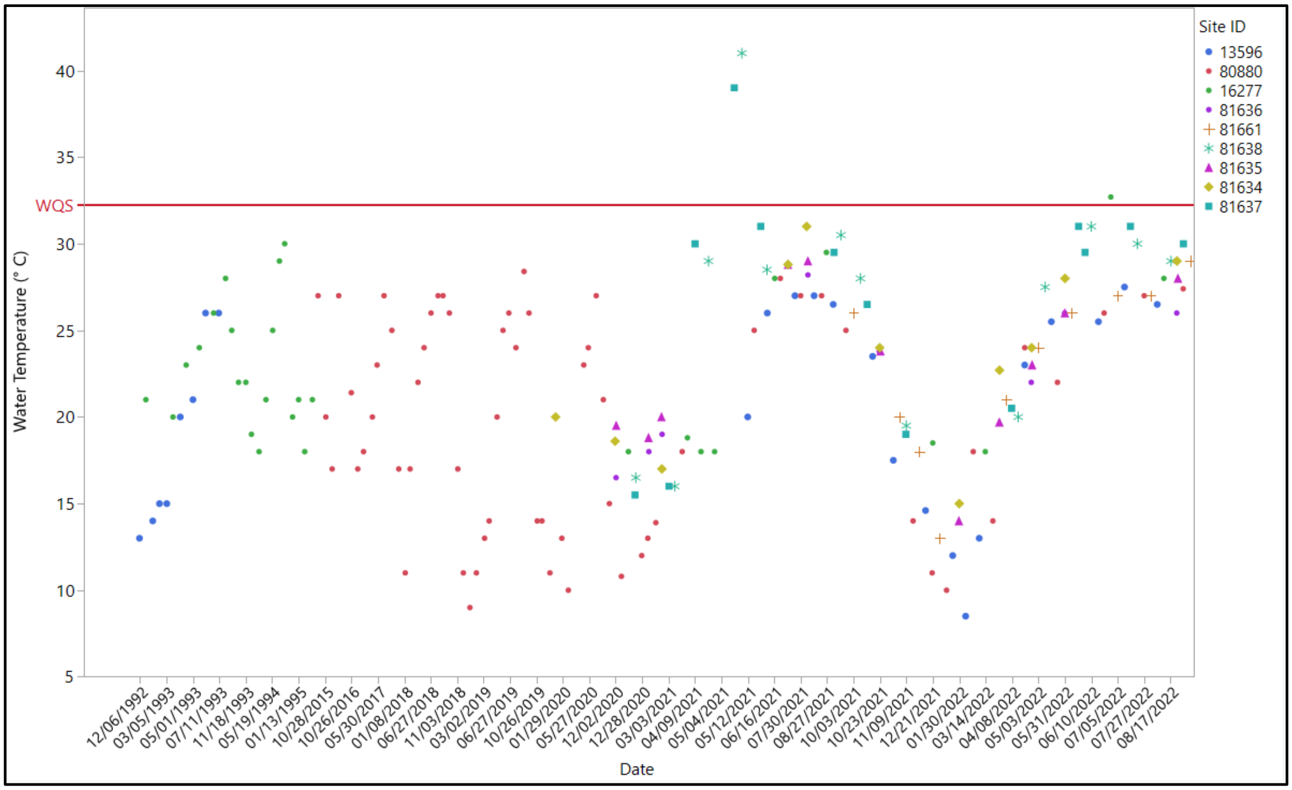

Figure 5. Water temperature for Texas Stream Team sites on Salado Creek and Upper San Antonio River within the Upper San Antonio River Watershed (Dec 1992 to Sep 2022). WQS = Water Quality Standard.

Dissolved Oxygen

The range of average dissolved oxygen values for all sites spanned from 4.4 to 8.7 mg/L. The average 24-hour dissolved oxygen values at eight of the nine sites were above the water quality standard of 5.0 mg/L (Table 6). The Olmos Basin Greenway site (#80880) had an average 24-hour dissolved oxygen value of 4.4 mg/L which fell below the water quality standard. The minimum grab standard for dissolved oxygen (3.0 mg/L) was not met on several occasions during the period of record evaluated at two sites, Olmos Basin Greenway (Site 80880) and Comanche Park on Salado Creek (Site 13596) (Figure 7).

pH

Average pH values at all sites were within the range of the water quality standards (6.5 to 9.0 s.u.) (Table 6). The average range of values was between 7.4 and 8.5 s.u. at all sites. One site on the Upper San Antonio River at Lake Elmendorf (Site 81638) exceeded the upper limit of the standard during the period of record evaluated (Figure 8).

Transparency and Total Depth

Secchi discs and transparency tubes were used for measuring transparency at the sites monitored in the Upper San Antonio River Watershed (Table 6). The average Secchi disc values reported at all sites ranged from 0.5 to 2.6 m. The average transparency tube values from the two sites, 13596 on Salado Creek and 80880 on Olmos Creek, where this parameter was measured was 0.7 and 1.0 m, respectively (Table 6).

Total depth was measured at all sites monitored (Table 6). The average deepest site (3.5 m) was at Padre Park on the Upper San Antonio River (Site 81637), while the average shallowest site (0.6 m) was on Salado Creek (Site 13596).

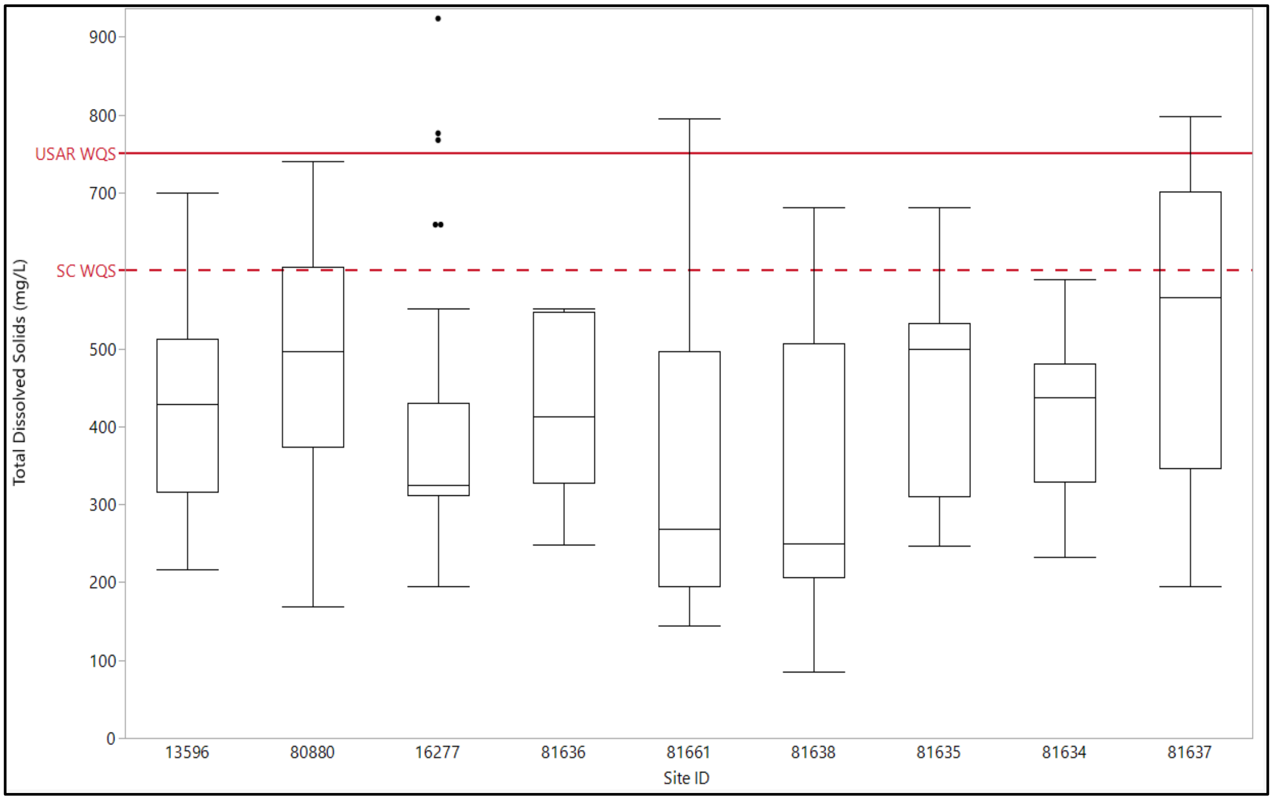

Figure 6. Total dissolved solids (mg/L) for Texas Stream Team sites on Salado Creek and Upper San Antonio River within the Upper San Antonio River Watershed (Dec 1992 to Sep 2022). USAR WQS = Upper San Antonio River Water Quality Standard and SC WQS = Salado Creek Water Quality Standard.

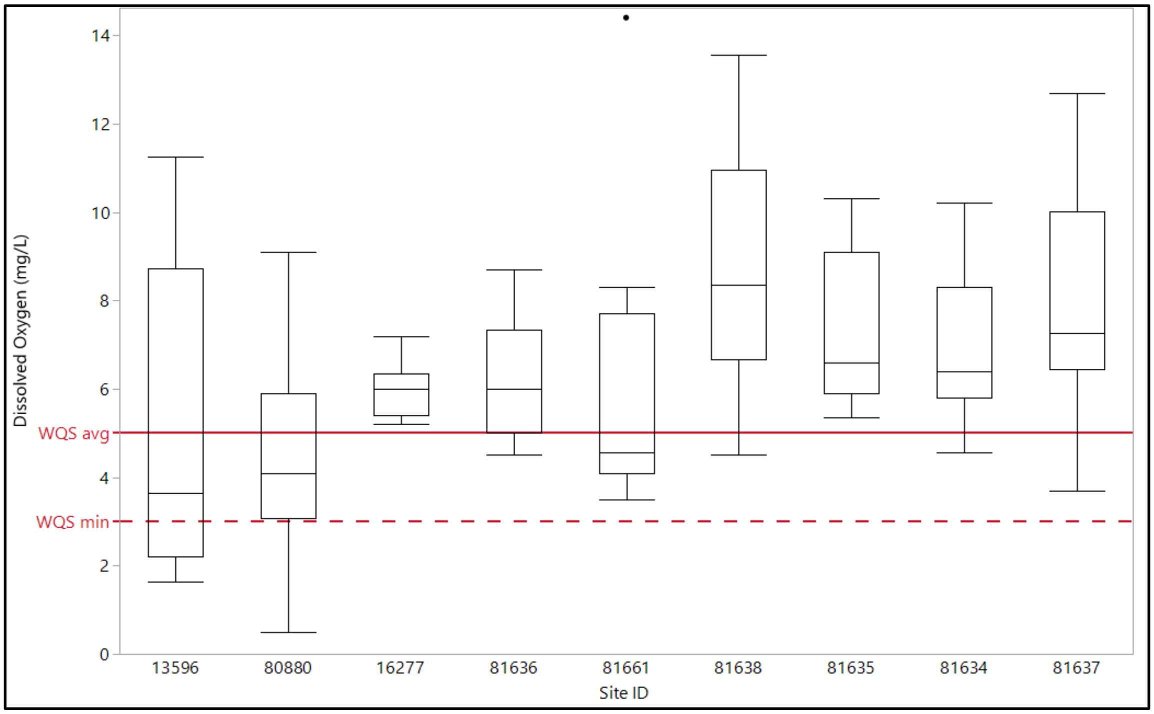

Figure 7. Dissolved oxygen (mg/L) for Texas Stream Team sites on Salado Creek and Upper San Antonio River within the Upper San Antonio River Watershed (Dec 1992 to Sep 2022). WQS avg = average 24-hour and WQS min = minimum grab.

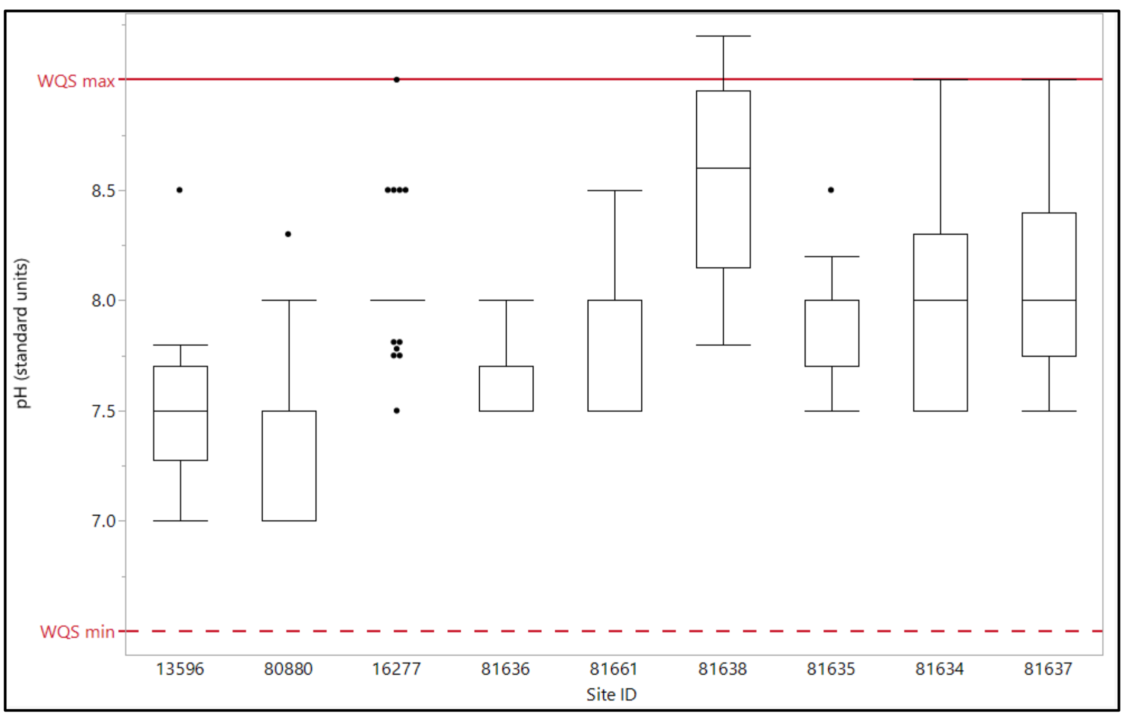

Figure 8. pH (s.u.) for Texas Stream Team sites on Salado Creek and Upper San Antonio River within the Upper San Antonio River Watershed (Dec 1992 to Sep 2022). WQS max = maximum range and WQS min = minimum range.

WATERSHED SUMMARY

Texas Stream Team citizen scientists monitored standard core parameters at nine sites in the Upper San Antonio River Watershed from December 1992 to September 2022. One site (Site 13596) is on Salado Creek (Segment 1910), while the remaining eight sites are on the Upper San Antonio River (Segment 1911). Three unclassified segments drain to the Upper San Antonio River, and each contains a monitoring site, Olmos Creek (Segment 1911A, Site 80880), Apache Creek (Segment 1911B, Site 81638), and Alazan Creek (Segment 1911C, Site 81661). Collectively these classified and unclassified segments and sites monitored for the Texas Stream Team by trained citizen scientists are within the Upper San Antonio River Watershed.

Parameters monitored by Texas Stream Team citizen scientists included water and air temperature, specific conductance, total dissolved solids, dissolved oxygen, pH, transparency, and total depth. Data from the nine monitoring sites were analyzed and summarized in this report.

The classified segments, Salado Creek and Upper San Antonio River, and the unclassified segments, Olmos, Apache and Alazan Creeks, were assessed by the Texas Commission on Environmental Quality in the 2022 Texas Integrated Report. The Integrated Report includes an index of water quality impairments and identified impairments for fish and macrobenthic communities, bacteria, and depressed dissolved oxygen in water. The Texas Stream Team citizen scientists did not monitor fish, macrobenthic communities, or bacteria, therefore no data was available for comparison of those impairments. However, the Texas Commission on Environmental Quality findings for the dissolved oxygen impairment coincides with the findings in this data summary report, with exceedances of the water quality standard for the aquatic life use identified in the Olmos Creek site (#80880) for both the average 24-hour (5.0 mg/L) and the minimum grab (3.0 mg/L) water quality standard. The minimum grab standard was also exceeded at Comanche Park on Salado Creek (Site 13596) during the period of record evaluated in this report. With the growing human population and increased development in this part of the state, these findings should be of concern to residents and decision-makers.

Other noteworthy results presented in this data report include exceedances of the water temperature standard (32.2°C) at two sites (81637 and 81638) in May 2021 and one site (16277) in July 2022. The values reported ranged from 41 to 32.7°C at these sites and they are the only exceedances of the water quality standard in the past 30-year period of record.

The Texas Stream Team citizen scientists monitoring standard core water quality parameters in the Upper San Antonio River Watershed are encouraged to continue monitoring and consider adding advanced and *E. coli* bacteria monitoring to the existing monitoring regime. Continuation of the ongoing monitoring is crucial due to the results presented here and the potential for increased development in the watershed. Continued water quality monitoring is important for the development of long-term data sets that describe current water quality conditions and for historical and future trends to capture changes in water quality as the area grows. Texas Stream Team will continue to support citizen scientists by providing technical support, creating new monitoring sites, and re-activating existing sites. We look forward to training new citizen scientists to expand, grow, and sustain the water quality monitoring efforts in this area and beyond. For more information about Texas Stream Team and upcoming trainings contact us at TxStreamTeam@txstate.edu or visit the calendar of events on our website at www.TexasStreamTeam.org.

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Appendix A.

Table 7. Endangered species located within the Upper San Antonio River Watershed.

Species Type	Common Name	Federal/State Listing
Birds	Whooping Crane	Federally Listed as Endangered, State Listed as Endangered

Table 8. Threatened species located within the Upper San Antonio River Watershed.

Species Type	Common Name	Federal/State Listing
Birds	White-faced Ibis	State Listed as Threatened
	Wood Stork	State Listed as Threatened
	Black Rail	Federally Listed as Threatened, State Listed as Endangered
	Piping Plover	Federally Listed as Threatened, State Listed as Endangered
	Rufa Red Knot	Federally Listed as Threatened, State Listed as Endangered
Fish	Shovelnose Sturgeon	State Listed as Threatened
	Paddlefish	State Listed as Threatened
	Chub Shiner	State Listed as Threatened
	Blue Sucker	State Listed as Threatened
Mammals	Black Bear	State Listed as Threatened
Reptiles	Alligator Snapping Turtle	State Listed as Threatened
	Texas Horned Lizard	State Listed as Threatened
Mollusks	Louisiana Pigtoe	State Listed as Threatened
	Texas Heelsplitter	State Listed as Threatened