COMAL RIVER WATERSHED DATA REPORT

September 2023

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

Photo Credit: Robin Jerstad

United States Environmental Protection Agency

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Texas State University
The rising STAR of Texas

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The Texas Stream Team encourages life-long learning about the environment and people's relationship to the environment through its multidisciplinary community 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 community science water quality monitoring program. Community scientist water quality monitoring occurs at predetermined monitoring sites, at approximately the same time of day each month. Information collected by Texas Stream Team community scientists is covered by a Texas Commission on Environmental Quality-approved Quality Assurance Project Plan to ensure a standard set of methods is used. Community 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 community scientist data are not used by the state to assess whether water bodies are meeting the designated surface water quality uses and 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 community science monitoring, please refer to the following sources:

- Texas Stream Team Core Water Quality Community Scientist Manual
- Texas Stream Team Advanced Water Quality Community 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 community 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 Comal River Watershed within the Guadalupe 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 Comal River Watershed spans approximately 133 square miles, is the shortest navigable river in Texas, and is a spring fed river (Figure 1) (City of New Braunfels, 2023). The Comal River Watershed is located in the City of New Braunfels, the county seat of Comal County, and drains into the Guadalupe River. This area is important locally for aesthetics, recreation, and for the ecosystem it supports, but it is also historically significant and provides a variety of activities for tourists (City of New Braunfels, 2023).

Comal River was named Guadalupe by early Spanish explorers before being named Comal after 1727, meaning “flat dish” in Spanish for the surrounding flat landscape (Ogilvie and Greene, 2020). The area was primarily inhabited by Tonkawa and Waco indigenous peoples until German and Anglo settlement began in the mid-19th century (Greene, 2020). Ranching, farming, manufacturing, and processing industries would contribute to county population and economic growth throughout the 19th and early 20th centuries, and tourism would become a dominant industry in the late 20th century (Greene, 2020).

The Texas Commission on Environmental Quality designates classifications for streams, rivers, lakes, and bays in the Comal River Watershed and throughout Texas (Table 1). Comal River (Segment 1811) rises from the Comal Springs with its headwaters at Landa Park in New Braunfels, Texas. Dry Comal Creek (Segment 1811A) begins near Smithson Valley, Texas where it flows along the Southwestern portion of the watershed before joining the Comal River. Both river segments discharge into the lower Guadalupe River (Segment 1804) also located in New Braunfels, Texas. The Comal River and lower Guadalupe River are classified segments, while Dry Comal Creek (Segment 1811A) is an unclassified segment.

The climate in this part of the state is described as mild-subtropical with hot humid summers and mild winters (Smyrl, 2020). National Oceanic and Atmospheric Administration climate data from a weather station at New Braunfels, Texas, was acquired from the National Data Center (National Oceanic and Atmospheric Administration, 2021). Average annual precipitation at New Braunfels is 33.5 inches and typically occurs year-round (Figure 2). Long-term monthly average precipitation has a near bimodal distribution with peaks occurring in May and September. Average rainfall during these months is 3.6 and 3.5 inches each month, respectively. The least amount of rainfall (1.9 inches) occurs in February. The warmest and coldest months of the year are August (28.3°C) and January (9.6°C), respectively.

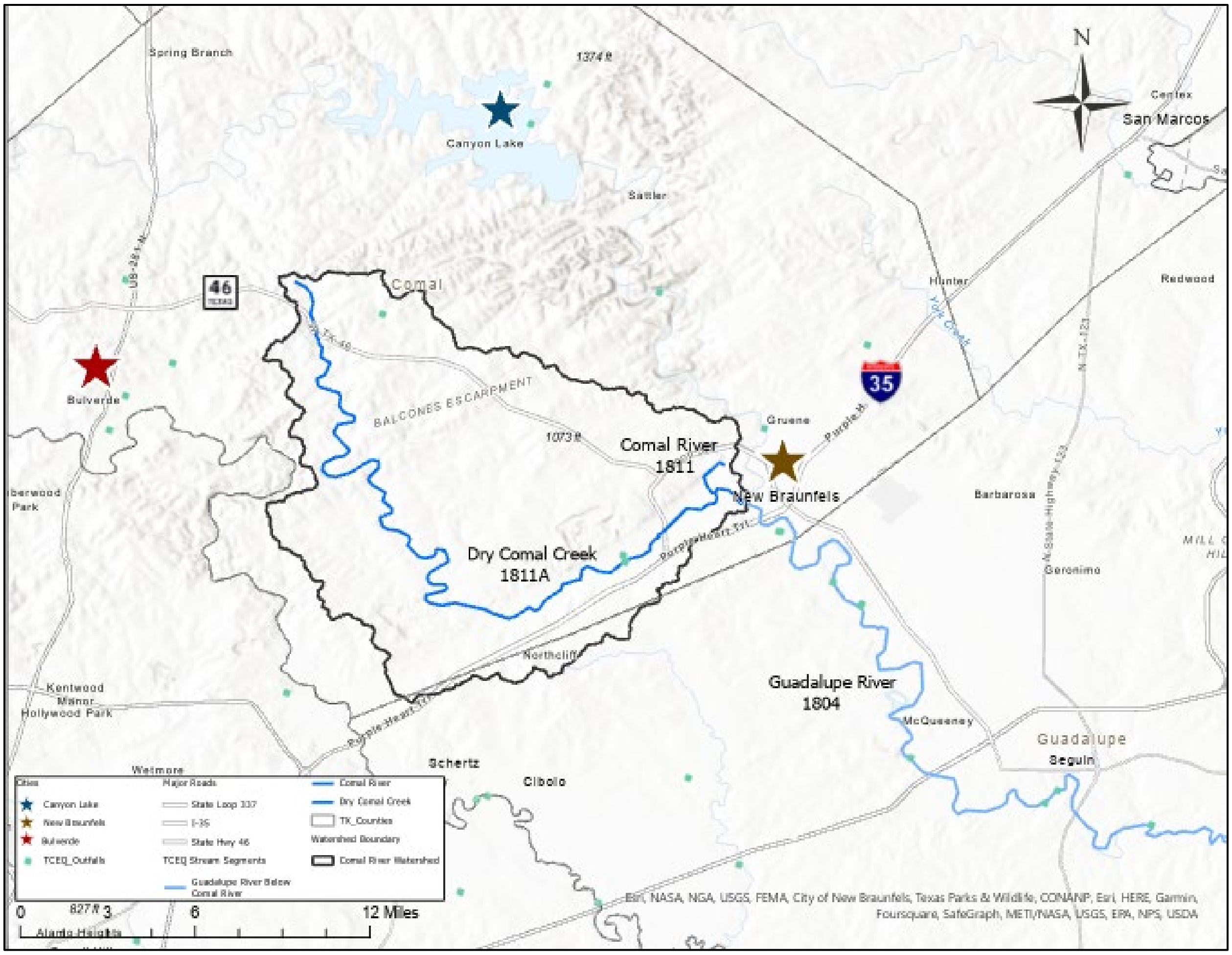

Figure 1. Comal River Watershed in Comal and Guadalupe Counties, Texas.

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

Segment Number	**Segment Name**	**Segment Description**
1804	Guadalupe River below Comal River	From a point immediately upstream of the confluence of the San Marcos River in Gonzales County to a point immediately upstream of the confluence of the Comal River in Comal County.
1811	Comal River	From the confluence with the Guadalupe River in Comal County to Klingemann Street at New Braunfels in Comal County.
1811A	Dry Comal Creek	From the confluence of the Comal River in New Braunfels in Comal County to the confluence with the West Fork Dry Comal Creek in Comal County.

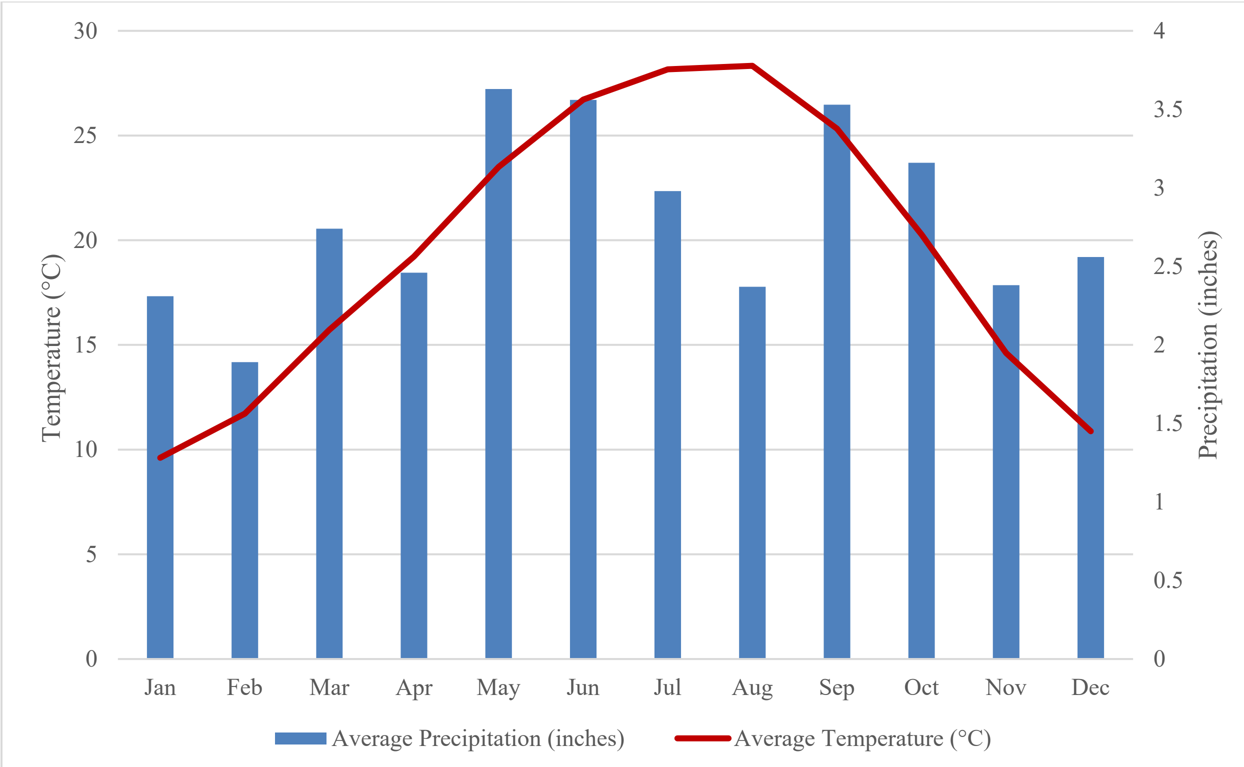

Figure 2. Long-term (1991-2020) monthly average precipitation (inches) and air temperature (°C) from New Braunfels, Texas (National Oceanic and Atmospheric Administration Climate Data, 2021).

Physical Description

The Comal River Watershed is almost entirely contained within Comal County, with a small portion of the southern edge of the watershed in Guadalupe County. Located along the boundary of the Texas Hill Country, the landscape is described as gently rolling to hilly terrain. The Edwards Plateau vegetation is comprised of oak, juniper, mesquite, hardwoods, conifers, and grasses (Texas Parks and Wildlife Department, 2023). Soils that support the landscape include clays and loams. Mineral resources found in the area include limestone, sand, and gravel (Greene, 2020a). This area supports diverse wildlife including deer, raccoons, rabbits, squirrels, foxes, coyotes, feral hogs, bobcats, and more (Greene, 2020a; and Smyrl, 2020).

Land Use

Land cover types were determined from spatial data sets processed in geographic information systems for the Comal River Watershed (Figure 3). Ninety-two percent of the land cover in the area consists of forest (41%), shrub/scrub (25%), developed land (18%), and grassland (8%) (Table 2). The remaining land use types, barren (3%), open water (2%), planted/cultivated (1%), woody wetlands (1%), hay/pasture (<1%), and emergent herbaceous wetlands (<1%) comprise approximately eight percent of the area.

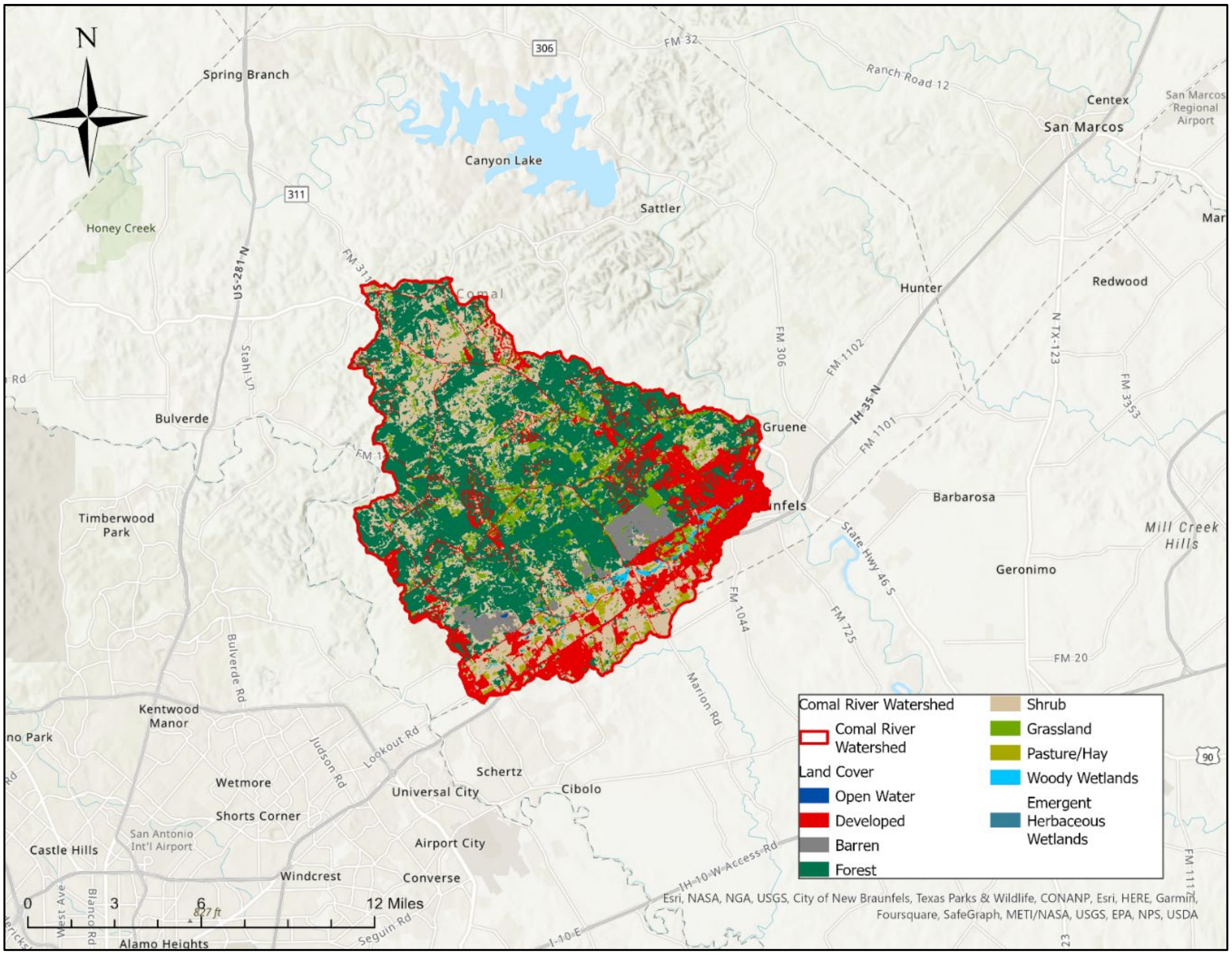

Figure 3. Land cover for the Comal River Watershed in Comal and Guadalupe Counties, Texas (National Land Cover Data, 2016).

Table 2. Land use in the Comal River Watershed in Comal and Guadalupe Counties, Texas (National Land Cover Data, 2016).

Land Use Type	**Acres (ac)**	**Hectares (ha)**	**Percent (%)**
Forest	34,998	14,163	41%
Shrub/Scrub	21,514	8,706	25%
Developed	15,200	6151	18%
Grassland	6,709	2,715	8%
Barren	2,841	1,150	3%
Open Water	1,754	710	2%
Planted/Cultivated Crops	1,174	475	1%
Woody Wetlands	510	206	1%
Hay/Pasture	112	45	<1%
Emergent Herbaceous Wetlands	29	12	<1%
Total	**84,841**	**34,333**	**100**

History

Comal County was established by hunter-gatherer communities with the Tonkawa and Waco indigenous people being the most prominent, and Lipan Apache and Karankawa indigenous people traveling though the county (Greene, 2020a). Spanish explores would pass through the area in the late 17th and mid-18th centuries but did not settle. Colonization of the area would not occur until the 19th century by Mexican, German, and Anglo settlers (Greene, 2020b).

The fertile soils gave rise to ranching and farming industries. After the Civil War, agricultural, manufacturing, and processing industries would contribute to county population and economic growth throughout the 19th and early 20th centuries. Largely due to historic German heritage and natural attractions of the Comal and Guadalupe Rivers, tourism would become a dominant industry in the county in the late 20th century (Greene, 2020a).

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 United States Endangered Species Act) within the Comal River Watershed are included in Appendix A. 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 Comal River Watershed in Comal and Guadalupe 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	1	3	3	4	11
Birds	2	5	2	8	17
Fish	1	2	2	3	8
Mammals	0	1	0	5	6
Reptiles	0	3	0	5	8
Crustaceans	1	0	5	5	11
Insects	2	0	11	11	24
Arachnids	0	0	3	3	6
Mollusks	3	3	9	10	25
Arthropods	0	0	0	1	1
Plants	0	1	8	12	21
Total Count	**10**	**18**	**43**	**67**	**138**

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 at monitoring sites in the Comal River (Segment 1811) included in this report are provided in Table 4. The dissolved oxygen criteria are for 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 the Comal River Watershed in Comal and Guadalupe Counties, Texas (Texas Commission on Environmental Quality, 2022).

Segment	**Dissolved Oxygen (mg/L)**	**pH Range (s.u.)**	**Total Dissolved Solids (mg/L)**	**Enterococci Bacteria (#/100 mL)**	**Temperature (°C)**
Comal River (1811)	Grab screening level: 5.0 Grab min.: 4.0	6.5-9.0	400	Primary Contact Recreation 1: 126 geometric mean, 399 single sample	26.6

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 segment, Comal River (Segment 1811), has impairments for bacteria in water. This segment is designated as Category 5C. Additional data and information will be collected or evaluated before a management strategy is selected.

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. Community 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 community 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 saltiness or the dissolved inorganic salt concentration in water. Salinity is often measured in ocean, estuarine, or tidal 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 in 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 community 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 Comal River in New Braunfels is 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, community 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 the 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 attach 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 phosphate from the material to which it is bound, but they are too complicated and expensive to be conducted by community 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 community scientists are documented in the Texas Stream Team Core Water Quality Community Scientist Manual and the Texas Stream Team Advanced Water Quality Community 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 Texas Commission on Environmental Quality-approved Quality Assurance Project Plan.

Procedures documented in Texas Stream Team Water Quality Community 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 community 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 Environmental 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 accessed 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 community scientists and staff in this report. The Texas Stream Team community 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 is 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 community 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 25th and 75th quantiles or the interquartile range. The lines extending from each end of the box, or whiskers, are computed using the 25th/75th quartiles ± 1.5 x (interquartile range). Outliers are plotted as points outside the box plot.

DATA RESULTS

Water quality data from eight Texas Stream Team monitoring sites in the Comal River Watershed were acquired for this report (Figure 4). The eight sites were monitored sporadically during the past 19 years from March 2005 through July 2023. Trained community scientists conducted between two and eighty-eight sampling events at each site, for a total of 316 monitoring events (Table 5). The period of record for the sampling events ranged from March 2005 through July 2023, with all sites experiencing temporal intermittent sampling. Only the five sites (i.e., 81604, 80687, 80987, 12574, and 12653) with ten or more sampling events were included in the analysis of this report to prevent seasonal bias in the results.

Site Analysis

Water quality monitoring data from five sites with ten or more sampling events were analyzed and summarized including the number of samples, mean, standard deviation, and range of values (Table 6). Community scientists monitored the sites for standard core parameters, including air and water temperature, specific conductance, total dissolved solids, dissolved oxygen, pH, Secchi disc transparency, and total depth.

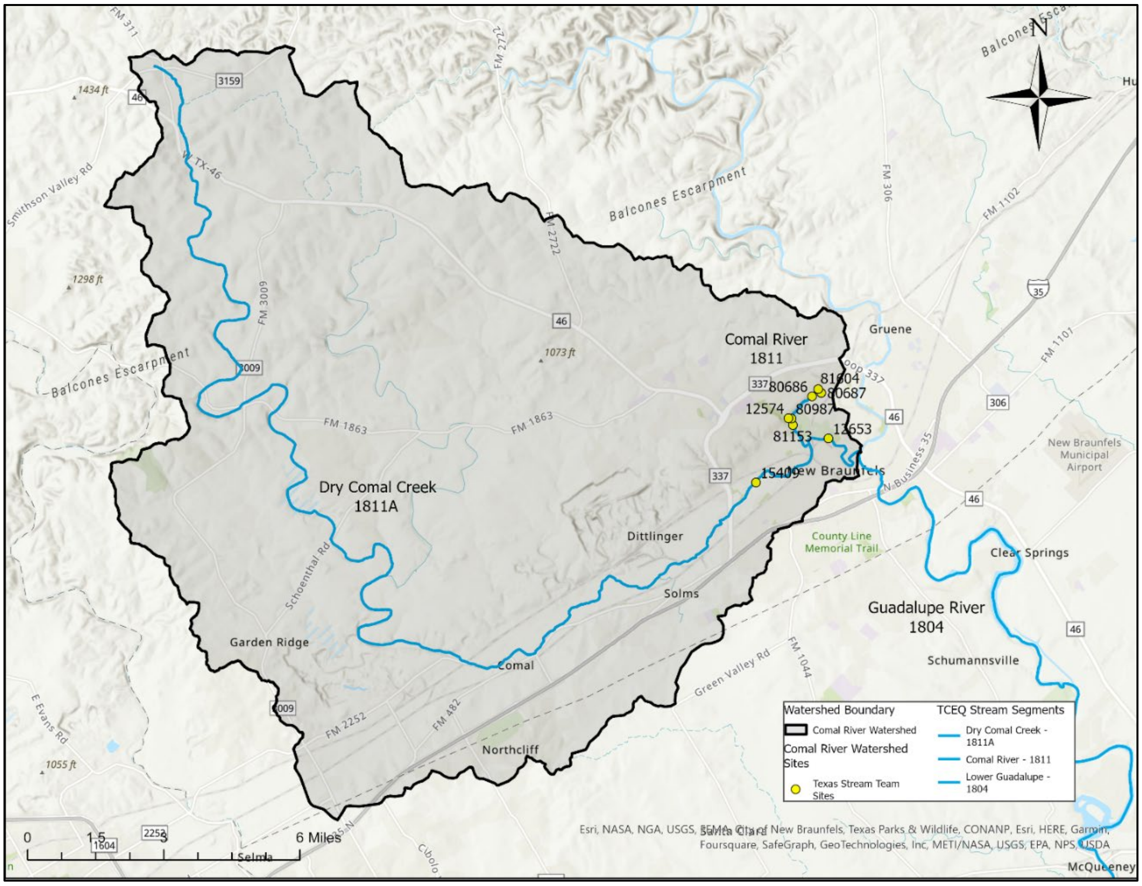

Figure 4. Texas Stream Team monitoring sites in Comal River Watershed in Comal and Guadalupe Counties, Texas.

Table 5. Texas Stream Team monitoring sites in the Comal River Watershed in Comal and Gudalupe Counties, Texas.

Site ID	Description	Number of Monitoring Events (n)	Period of Record
81604	Spring Run at The Headwaters of the Comal directly below the capped spring	88	2020-2023
80687	Bleeders Creek underwater plume near NBU gate	73	2011, 2020 - 2023
*80686	Comal River @ dead end of Union St	2	2011
80987	Landa Park pier	61	2013 - 2020
12574	Comal Springs @ Landa Park	13	2005, 2014, and 2019
*81153	Landa Lake	4	2015
12653	Comal River @ Hinman Island	73	2014 - 2020
*15409	Dry Comal Creek @ Live Oak Avenue	2	2010
	TOTAL	**316**	

*Sites with less than 10 monitoring events not included in the analysis of this report.

Table 6. Texas Stream Team data summary for sites in the Comal River Watershed, Comal and Guadalupe Counties, Texas. (Mar 2005 to July 2023).

Parameter/Site	81604 Spring Run	80687 Bleeders Creek	80987 Landa Park	12574 Comal Springs	15653 Comal River
Number of events	n = 88	n = 73	n = 61	n = 13	n = 73
Air Temperature (°C)	21.7±5.3 (21.1)	20.5±5.9 (26)	18.9±6.7 (21.5)	23.9±6.9 (25)	25.8±7.0 (28)
Water Temperature (°C)	23.3±1.6 (8.3)	21.4±4.2 (17)	22.6±1.0 (4)	23.3±0.8 (2.3)	22.9±1.2 (6)
Specific Conductance (µS/cm)	577±14 (122)	536±77 (470)	576±8 (30)	588±15 (40)	580±10 (60)
***Total Dissolved Solids (mg/L)**	375±9 (79)	348±50 (306)	374±5 (20)	382±10 (26)	377±7 (39)
Dissolved Oxygen (mg/L)	4.7±0.7 (3.6)	5.2±1.7 (7.2)	4.9±0.7 (3.7)	4.5±0.9 (3.0)	7.3±0.7 (3.5)
pH (s.u.)	7.4±0.3 (3)	7.5±0.2 (1)	7.0±0.3 (1.4)	7.1±0.2 (0.5)	7.0±0.1 (0.5)
Secchi Disk (m)	0.5±0.2 (1.0)	0.5±0.1 (0.6)	1.5±0.3 (1.6)	0.3±0.1 (0.5)	1.6±0.2 (1.0)
Total Depth (m)	0.5±0.2 (1.0)	0.5±0.1 (1.0)	1.5±0.3 (1.6)	0.5±0.7 (2.7)	1.5±0.2 (1.0)

*Total dissolved solids were calculated from specific conductance (TDS = specific conductance * 0.65).
ND = no data available.

Air and Water Temperature

Average air temperature for all sites ranged from 18.9 to 25.8°C (Table 6). The lowest mean air temperature (18.9°C) was observed at the Landa Park pier (site 80987), while the highest mean air temperature (25.8°C) was observed at Hinman Island in the Comal River (site 15653).

Average water temperature for all sites ranged from 21.4 to 23.3°C (Table 6). The lowest mean water temperature (21.4°C) was observed at Bleeders Creek (site 80687), while the highest mean water temperature (23.3°C) was observed at both Spring Run (site 81604) and Comal Springs (site 12574). Discreet water temperature measurements from all sites met the water quality standard (35°C) throughout the period of record of this report (Figure 5).

Specific Conductance and Total Dissolved Solids

Total dissolved solid values were calculated from specific conductance measurements when more than 10 measurements were available. The average total dissolved solids from all sites ranged from 348 mg/L to 382 mg/L (Table 6). The lowest mean total dissolved solids value (348 mg/L) was observed at Bleeders Creek (site 80687), while the highest mean total dissolved solids value (382 mg/L) was observed at Comal Springs (site 12574). Water quality standard exceedances (> 400 mg/L) were measured at Spring Run (site 81604), Bleeders Creek (site 80687), and Comal River (site 15653) (Figure 6).

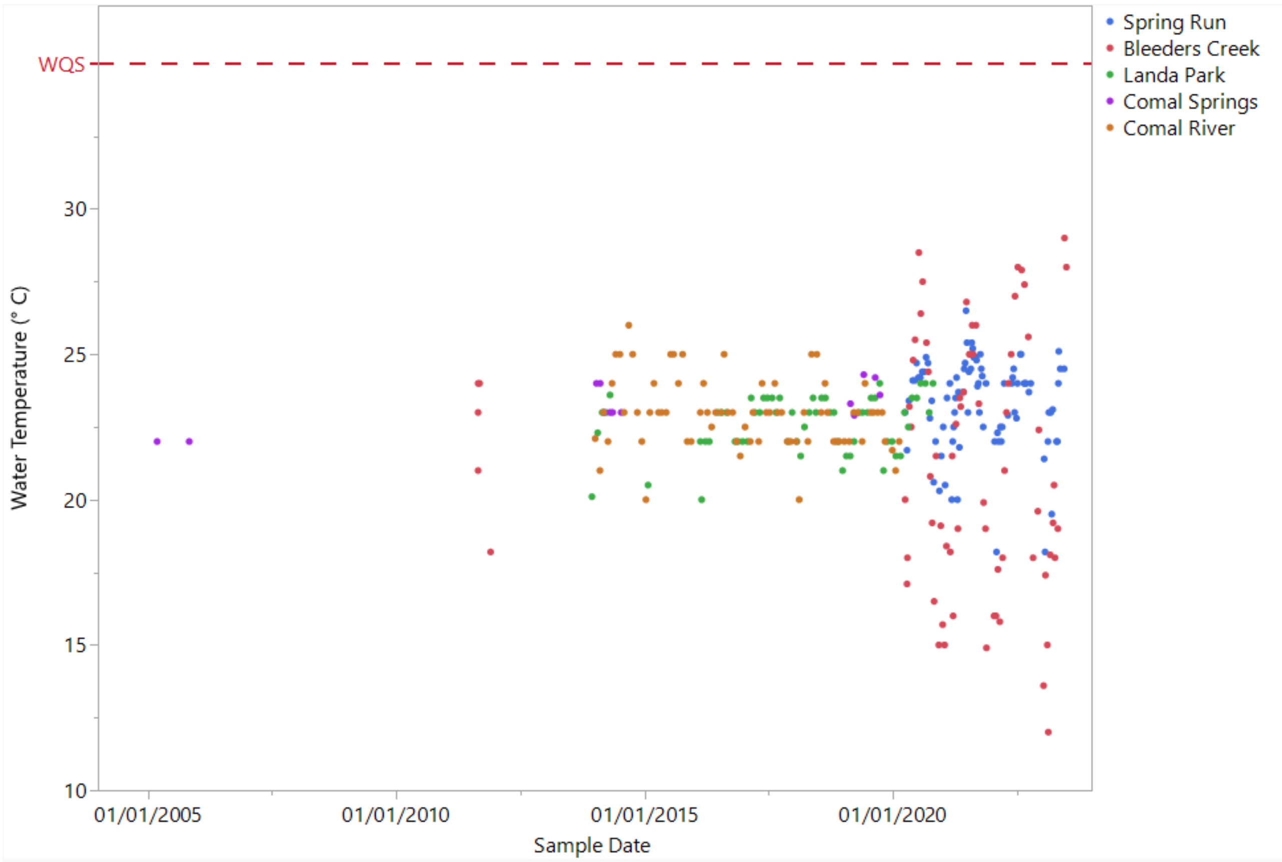

Figure 5. Water temperature for Texas Stream Team sites in the Comal River Watershed, Comal and Guadalupe Counties, Texas. (Mar 2005 to July 2023). WQS = Water Quality Standard.

Dissolved Oxygen

The range of average dissolved oxygen values for all sites spanned from 4.5 to 7.3 mg/L (Table 6). The average dissolved oxygen value at two sites (Bleeders Creek (80687) and Comal River (15653)) was above the average water quality standard of 5.0 mg/L, but not at the remaining three sites (Spring Run (81604), Landa Park (80987), or Comal Springs (12574)). Some discreet values measured at Spring Run (81604), Bleeders Creek (80687) and Comal Springs (12574) during the period of record for this study were below the minimum water quality standard of 4.0 mg/L (Figure 7). Although the average water quality standard at Bleeders Creek was achieved, this site experienced the greatest variability in dissolved oxygen measurements and also had values fall below the minimum water quality standard (Figure 7).

pH

The average range of values at all sites was between 7.0 and 7.5 s.u. (Table 6). Average pH values at all sites were within the range of the water quality standards (6.5 to 9.0 s.u.) (Figure 8).

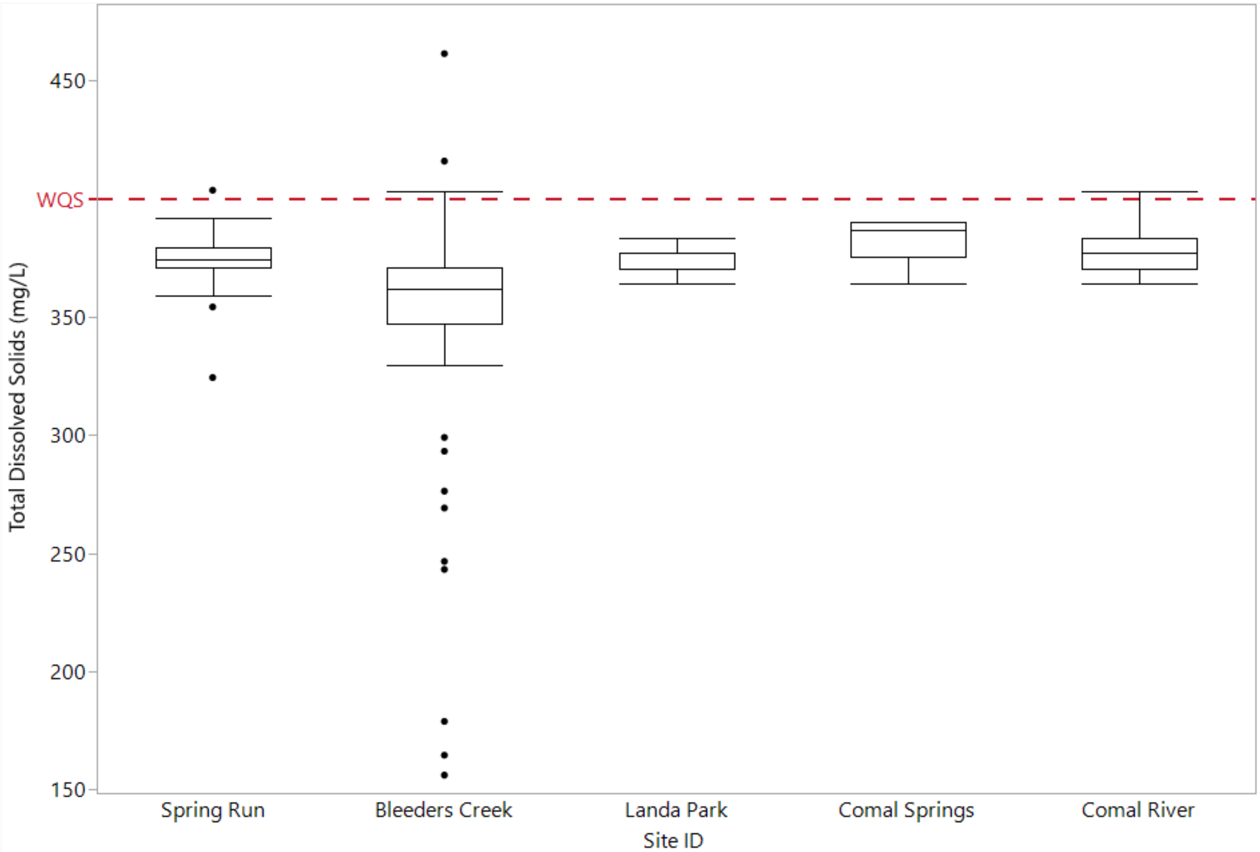

Figure 6. Total dissolved solids (mg/L) for Texas Stream Team sites in the Comal River Watershed, Comal and Guadalupe Counties, Texas. (Mar 2005 to July 2023). WQS = Water Quality Standard.

Transparency and Total Depth

Secchi disks were used to measure transparency at the sites monitored in the Comal River Watershed. The average transparency values measured at all sites ranged from 0.3 to 1.6 meters (Table 6). The largest variability in Secchi disk measurements was observed at Landa Park (site 80987) (Figure 9).

Total depth was measured at all sites monitored (Table 6). The average range of depths for all sites was 0.5 to 1.5 meters.

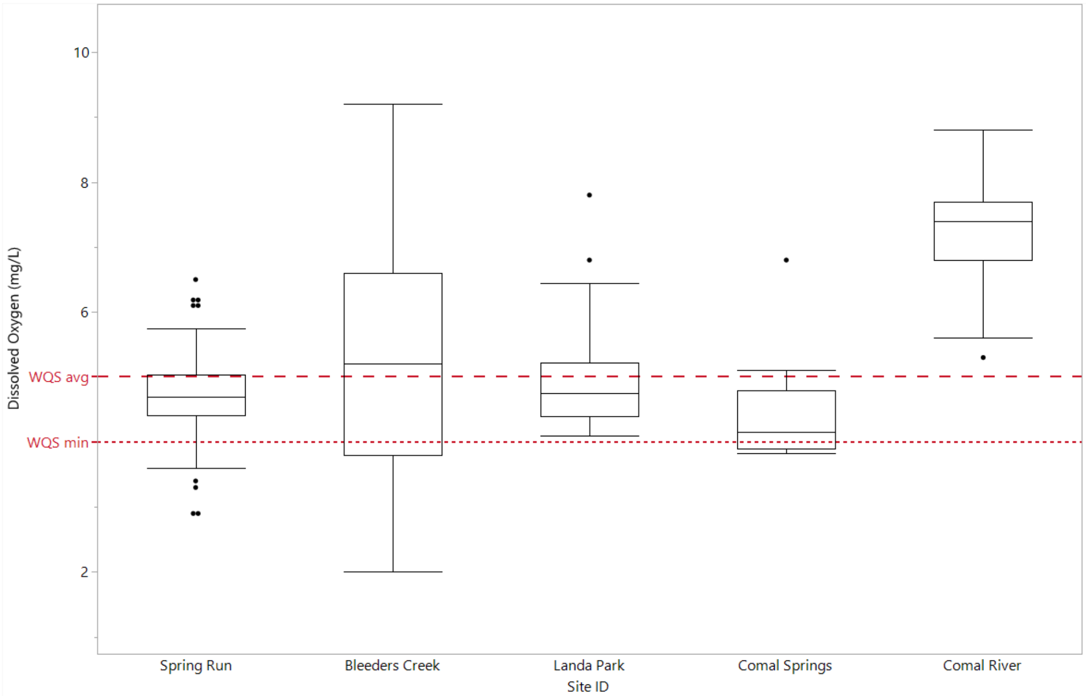

Figure 7. Dissolved oxygen in water for Texas Stream Team sites in the Comal River Watershed, Comal and Guadalupe Counties, Texas. (Mar 2005 to July 2023). WQS avg= average water quality standard; WQS min = minimum water quality standard.

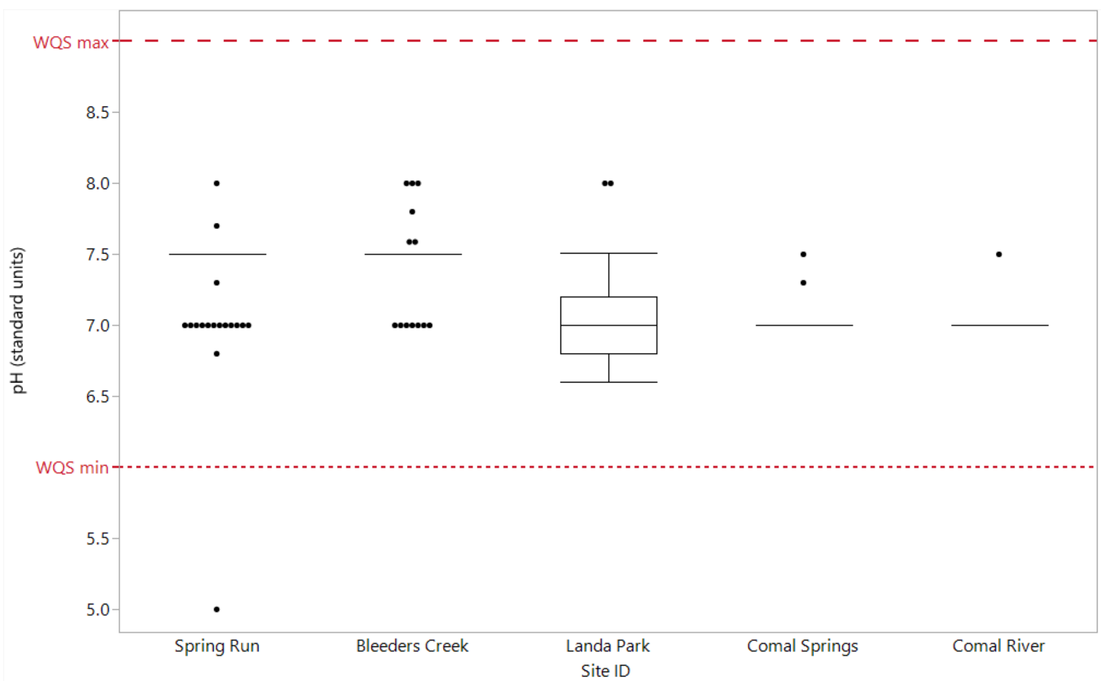

Figure 8. pH (s.u.) for Texas Stream Team sites in the Comal River Watershed, Comal and Guadalupe Counties, Texas. (Mar 2005 to July 2023). WQS max= maximum pH water quality standard; WQS min = minimum pH water quality standard.

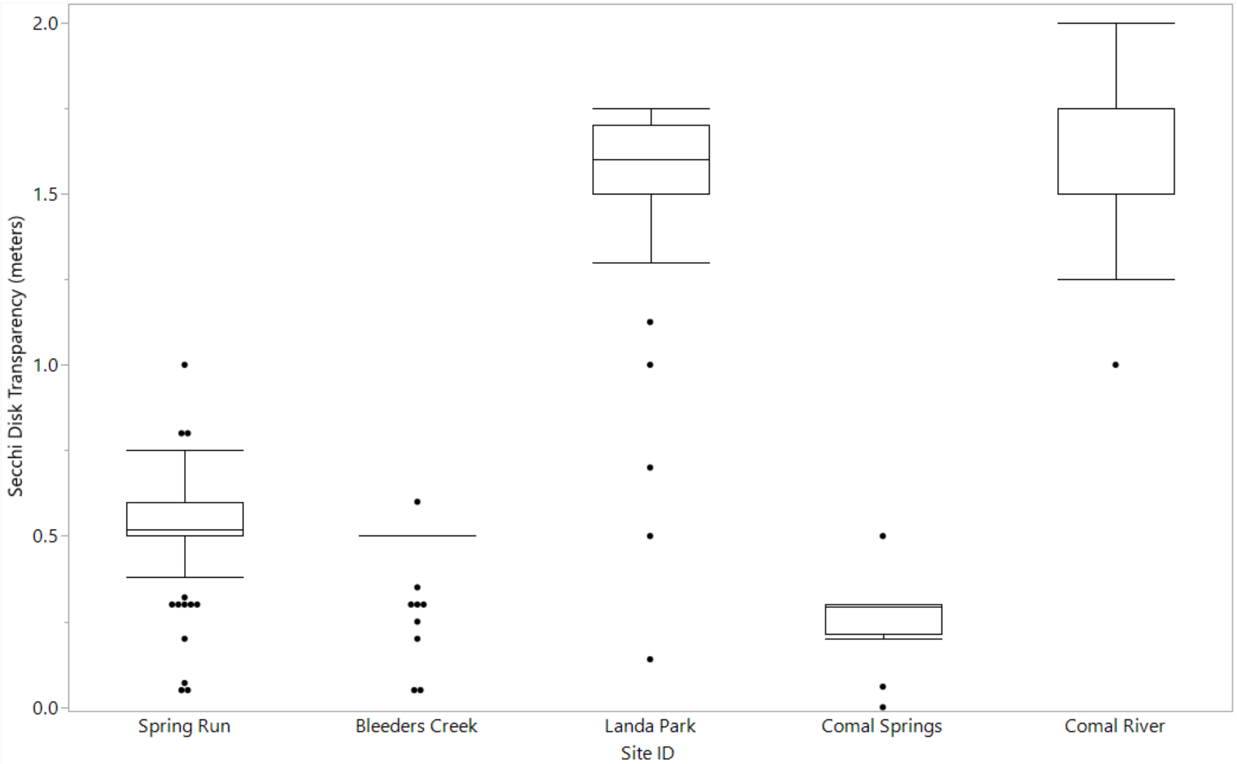

Figure 9. Secchi disk transparency measurements for Texas Stream Team sites in the Comal River Watershed, Comal and Guadalupe Counties, Texas. (Mar 2005 to Jul 2023).

WATERSHED SUMMARY

Texas Stream Team community scientists monitored standard core parameters intermittently at eight sites in the Comal River Watershed from March 2005 to July 2023. A total of 316 monitoring events were conducted by community scientists at all eight sites. Of the eight sites monitored, five sites had ten or more monitoring events and were included in this report. These five sites are all located on the Comal River (segment 1811) within Comal County. The Comal River is spring fed with springs located at The Headwaters of the Comal (site 81604) and Comal Springs at Land Park (site 12574). Collectively all sites included in this report were monitored by Texas Stream Team trained community scientists.

Parameters monitored by community scientists included water and air temperature, specific conductance, total dissolved solids, dissolved oxygen, pH, transparency, and total depth.

The 2022 Integrated Report prepared by the Texas Commission on Environmental Quality identified a bacteria impairment for the contact recreation use in the Comal River (segment 1811). However, no bacteria or advanced nutrient data were collected in the Comal River by the community scientists monitoring water quality.

Water quality standards associated with designated uses in the Comal River were compared to the results of this analysis to evaluate water quality. Discreet water temperature and pH measurements from all sites evaluated met the water quality standard for temperature (35°C) and pH (6.0 and 9.0 s.u.) during the period of record for this report. However, more variability in water temperature measurements appears to be occurring since 1999 (Figure 5). Although total dissolved solids water quality standard exceedances (> 400 mg/L) were measured at Spring Run (site 81604), Bleeders Creek (site 80687), and the Comal River (site 15653), the most variability was observed at Bleeders Creek. Bleeders Creek drains a residential urban area and total dissolved solid values are known to fluctuate with rainfall, especially in areas affected by spring water from aquifers where solutes dissolve more readily in groundwater and developed areas exhibiting impervious cover.

The range of average dissolved oxygen values for all sites in the Comal River spanned from 4.5 to 7.3 mg/L. The average dissolved oxygen value at Bleeders Creek and the Comal River was above the water quality standard, however the remaining three sites, Spring Run, Landa Park and Comal Springs, were not as fortunate. In fact, some discreet dissolved oxygen values from those three sites also did not meet the minimum water quality standard of 4.0 mg/L. Bleeders Creek experienced the greatest variability in dissolved oxygen measurements and should continue to be closely monitored. Although Bleeders Creek is not listed as impaired for dissolved oxygen, the area is showing signs of concern based on these results. With the growing human population and increased development in the New Braunfels area, these findings should be of concern to residents and decision-makers alike.

The Texas Stream Team community scientists monitoring standard core water quality parameters in the Comal River are encouraged to continue monitoring and consider adding the advanced parameters of nutrients and bacteria to their current monitoring efforts. Continuation of the ongoing monitoring is crucial due to the results presented here and the potential for increased development in New Braunfels and the surrounding central Texas Hill Country. 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 community scientists by providing technical support, creating new monitoring sites, and re-activating existing sites. We look forward to training new community 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 Comal River Watershed.

Species Type	Common Name	Federal/State Listing
Amphibians	Texas blind salamander	Federally Listed as Endangered, State Listed as Endangered
Birds	Whooping crane	Federally Listed as Endangered, State Listed as Endangered
	Golden-cheeked warbler	Federally Listed as Endangered, State Listed as Endangered
Fish	Fountain darter	Federally Listed as Endangered, State Listed as Endangered
Crustaceans	Peck's Cave amphipod	Federally Listed as Endangered, State Listed as Endangered
Insects	Comal Springs riffle beetle	Federally Listed as Endangered, State Listed as Endangered
	Comal Springs dryopid beetle	Federally Listed as Endangered, State Listed as Endangered
Mollusks	Guadalupe fatmucket	Federally Proposed as Endangered
	Guadalupe orb	Federally Proposed as Endangered
	False spike	Federally Proposed as Endangered

Table 8. Threatened species located within the Comal River Watershed.

Species Type	Common Name	Federal/State Listing
Amphibians	San Marcos salamander	Federally Listed as Threatened, State Listed as Threatened
	Texas salamander	State Listed as Threatened
	Cascade Caverns salamander	State Listed as Threatened
Birds	White-faced ibis	State Listed as Threatened
	Wood stork	State Listed as Threatened
	Swallow-tailed kite	State Listed as Threatened
	Black rail	Federally Listed as Threatened, State Listed as Threatened
	Piping plover	Federally Listed as Threatened, State Listed as Threatened
Fish	Plateau shiner	State Listed as Threatened
	Guadalupe darter	State Listed as Threatened
Mammals	White-nosed coati	State Listed as Threatened
Reptiles	Cagle's map turtle	State Listed as Threatened
	Texas tortoise	State Listed as Threatened
	Texas horned lizard	State Listed as Threatened
Mollusks	Guadalupe fatmucket	State Listed as Threatened
	Guadalupe orb	State Listed as Threatened
	False spike	State Listed as Threatened
Plants	Bracted twistflower	Federally Proposed as Threatened

Table 9. State and federally listed species in the Comal River Watershed in Comal and Guadalupe 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	1	3	3	4	11
Birds	2	5	2	8	17
Fish	1	2	2	3	8
Mammals	0	1	0	5	6
Reptiles	0	3	0	5	8
Crustaceans	1	0	5	5	11
Insects	2	0	11	11	24
Arachnids	0	0	3	3	6
Mollusks	3	3	9	10	25
Arthropods	0	0	0	1	1
Plants	0	1	8	12	21
Total Count	**10**	**18**	**43**	**67**	**138**