Upper Highland Lakes Watershed Data Report

December 2018

THE MEADOWS CENTER
FOR WATER AND THE ENVIRONMENT
TEXAS STATE UNIVERSITY

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Environmental Protection
Agency

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This report was prepared in cooperation with, and financed through, grants from the Texas Commission on Environmental Quality and the U.S. Environmental Protection Agency.

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Introduction

Texas Stream Team is a volunteer-based citizen water quality monitoring program. Citizen scientists collect surface water quality data that may be used in the decision-making process to promote and protect a healthy and safe environment for people and aquatic inhabitants. Citizen scientist water quality monitoring occurs at predetermined monitoring sites, at roughly the same time of day each month. Citizen scientist water quality monitoring data provides a valuable resource of information by supplementing professional data collection efforts where resources are limited. The data may be used by professionals to identify 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. Texas Stream Team citizen scientists use different methods than the professional water quality monitoring community. Texas Stream Team does not utilize those methods due to higher equipment costs, training requirements, and stringent laboratory procedures that are required of the professional community. However, the data collected by Texas Stream Team provides valuable records, often collected in portions of a water body that professionals are not able to monitor frequently, or monitor at all. This long-term data set is available, and may be considered by the surface water quality professional community to facilitate management and protection of Texas water resources. For additional information about water quality monitoring methods and procedures, including the differences between professional and volunteer monitoring, please refer to the following sources:

- Texas Stream Volunteer Water Quality Monitoring Manual
- Texas Commission on Environmental Quality (TCEQ) Surface Water Quality Monitoring Procedures

The information that Texas Stream Team citizen scientists collect is covered under a TCEQ-approved Quality Assurance Project Plan (QAPP) to ensure that a standard set of methods are used. All data used in watershed data reports are screened by the Texas Stream Team for completeness, precision, and accuracy, in addition to being scrutinized for data quality objectives and with data validation techniques.

The purpose of this report is to provide analysis of 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 in order to provide a holistic view of water quality in this water body. Such sources include, but are not limited to the following potential resources:

- Texas Surface Water Quality Standards
- Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d)
- Texas Clean Rivers Program (CRP) partner reports, such as Basin Summary Reports and Highlight Reports
- TCEQ Total Maximum Daily Load (TMDL) reports
- TCEQ and Texas State Soil and Water Conservation Board Nonpoint Source Programs funded reports, including Watershed Protection Plans (WPPs)

Questions regarding this watershed data report should be directed to the Texas Stream Team at (512) 245-1346.

Watershed Location and Physical Description

At over 800 miles long, the Colorado River is the longest river entirely within the boundaries of Texas, or any single state. The river carves its way through the rocky, flood-prone Hill Country, forming impressive canyons which proved efficient locations for reservoirs to control flooding, generate power, and provide water for a growing Austin and Central Texas (Sansom 2008). Its headwaters begin in northwest Texas, and the river flows southeast, supporting many different communities and ecosystems and eventually emptying into the Gulf of Mexico at Matagorda Bay. Along the way, its reservioirs form the Highland Lakes. The San Saba and Llano Rivers empty into the Colorado River, so their watersheds are considered part of the Colorado River's watershed, too (Colorado River Alliance 2018).

According to the Regions of Climate Classification in Texas, the Upper Highland Lakes Watershed is located within the approximate boundary of the Subtropical Subhumid Climate type. The Colorado River basin has always experienced floods and droughts, but changes to our climate are steadily making both the floods and droughts that we experience more frequent and more severe. The long-term vitality of the Colorado River depends on how clean and healthy it is (water quality) and also on how much water remains in the river, even in times of drought (water quantity) (Colorado River Alliance 2018). The Upper Highland Lakes Watershed is located within the Edwards Plateau ecoregion which comprises an area of Central Texas commonly known as the Texas Hill Country. Average annual rainfall ranges from 15 to 34 inches. Rainfall is highest in May or June and September. Soils of the Edwards Plateau are usually shallow with a variety of surface textures underlain by limestone. River systems dissect the surface, creating a rough and well-drained landscape. Today, the Edwards Plateau is characterized by grasslands, juniper/oak woodlands, and plateau live oak or mesquite savannah. Open grasslands and savannahs were more common in pre-settlement times than they are today. Ranching is the primary agricultural industry in the region (TPWD 2018).

San Saba River

The San Saba River is a scenic waterway located on the northern boundary of the Edwards Plateau in Texas. Flows of sparkling, clear water course through limestone bluffs and hills, supporting fish, wildlife, and recreation. The San Saba flows northeast until it empties into the Colorado River. From its beginnings in springs near the Schleicher-Menard county line, the San Saba flows approximately 100 miles east into Menard, Mason, McCulloch, and San Saba counties joining the Colorado River. The San Saba is a typical Hill Country river consisting of sparkling, clear water which flows through limestone bluffs and hills. Typical Hill Country vegetation such as pecan, oak, sycamore, elm, cedar, yucca, and cacti are prevalent along the banks. The river flows through predominantly ranch country although some farming activities are apparent near the flood plain. The San Saba remains relatively undeveloped and natural, since there is little residential development and no impoundments other than low water crossings exist.

Llano River

Dowstream of Lake Buchanan, a major tributary of the Colorado River arises in the Edwards Plateau and flows into the Highland Lake chain. The Llano River, which drains over 4,000 square miles, enters Lake Lyndon B. Johnson (LBJ) from the west. *Llano* is the Spanish word for "plains". The Llano River is flood-prone, in 1935 the Llano peaked at 380,000 cubic feet per second at the City of Llano upstream of Lake LBJ. The flood potential of these small and narrow limestone channel rivers of the Edwards Plateau

when combined with the rainfall potential of Central Texas is extraordinary and at times has been devastating.

Upper Llano River

The Upper Llano River watershed (1,890 square miles or approximately 1.2 million acres) begins in the heart of the Edwards Plateau. Elevation ranges from 2,487 feet (758 meters (m)) above mean sea level (MSL) in the upper reaches of the watershed to 1,637 feet (499 m) above MSL near the watershed outlet. The Edwards Plateau is capped with thick limestone that has been dissolved over time by water to form the largest continuous karst region in the United States (Anaya, 2004). The water stored in the karst emerges as springs along the canyon walls. The springs originate near an elevation of 1,900 feet and supply constant flow to the lower 20 miles of the South Llano and intermittent flow for the lower 27 miles of the North Llano. The two rivers join in the City of Junction, becoming the Llano River, which travels 100 miles before it terminates in Lake Lyndon B. Johnson (LBJ). The watershed encompasses portions of Edwards, Kerr, Kimble, Menard, Real and Sutton counties with the majority of the watershed lying within the boundaries of Edwards, Kimble and Sutton counties The North and South Llano rivers and their tributaries and springs support a diverse, vibrant terrestrial and aquatic ecosystem as well as provide municipal water supply, recreational opportunity and historic and cultural value (TSSWCB 2016).

Lake Buchanan

Lake Buchanan is the uppermost Highland Lake and the largest in surface area: 22,355 acres. Lake Buchanan was formed by the construction of Buchanan Dam by the Lower Colorado River Authority (LCRA) to provide a water supply for the region and to provide hydroelectric power. Buchanan Dam, a structure over 2 miles in length, was completed in 1939. Upstream of Lake Buchanan where the river still flows in its natural state lies Colorado Bend State Park, an impressive canyon with springfed waterfalls dropping into the Colorado River.

Inks Lake

Located 55 miles northwest of Austin, Texas on Highway 29, Inks Lake is the next lake down the Colorado River from Lake Buchanan. It starts just a short distance from the base of Buchanan Dam. Inks Lake State Park is a 1,200 acre panorama of cedar and oak woodlands bordering Inks Lake. Inks Lake was formed in 1938 by the construction of Inks Dam by the LCRA. Located near Burnet, the lake serves to provide flood control in tandem with Lake Buchanan and features the smallest hydroelectric power plant on the Highland Lakes chain. A small amount of water can be released through hydroelectric generation, but the bulk of floodwaters pass over an uncontrolled spillway.

Lake Lyndon B. Johnson

Lake LBJ was originally called Lake Granite Shoals. The dam would be renamed Wirtz Dam in 1952 for Alvin J. Wirtz, the first general counsel of the LCRA, and the lake was renamed to Lake LBJ in 1965 in honor of US President Lyndon Baines Johnson. Lake LBJ starts at Kingsland and goes all of the way to Horseshoe Bay, 45 miles northwest of Austin. Lake LBJ, along with Inks Lake and Lake Marble Falls, are pass-through lakes for Lake Buchanan and Lake Travis. There is no room in Lake LBJ for additional water storage, and water that comes in must go out. Therefore, Lake LBJ is at a near constant level, but the level can fluctuate, especially during a flood. The LCRA lowers the lake periodically for maintenance on Wirtz Dam and to allow landowners to remove sediment around their docks.

TMDL & Watershed Protection

A TMDL is a water resource management plan that targets pollutants in a stream or body of water. The TMDL Program works to improve water quality in impaired or threatened water bodies in Texas. The program is authorized by and created to fulfill the requirements of Section 303(d) of the federal Clean Water Act. The goal of a TMDL is to restore the full use of a water body that has limited quality in relation to one or more of its uses. The TMDL defines an environmental target and, based on that target, the state and stakeholders develop an implementation plan to mitigate sources of pollution within the watershed and restore full use of the water body.

A WPP is a coordinated framework for implementing prioritized and integrated water quality protection and restoration strategies driven by environmental objectives. Through the WPP process, stakeholders holistically address all of the sources and causes of impairments and threats to both surface and ground water. Developed and implemented through diverse, well integrated partnerships, a WPP assures the long-term health of the watershed with strategies for protecting unimpaired waters and restoring impaired waters. WPPs have a variety of ingredients and can take many forms but they are consistent with guidelines promulgated by the U.S. Environmental Protection Agency (EPA) in 2003.

Texas Stream Team has become involved in the development and implementation of WPPs and TMDLs. Citizen scientists have become knowledgeable about their local water quality planning efforts. Texas Stream Team citizen scientists monitoring efforts can supplement professional monitoring plans with identification of pollution hot spots. The data collected by the local citizen scientists are used for tracking water quality changes during implementation of WPPs and TMDLs. The Llano River Watershed Alliance has partnered with the Texas Stream Team during the implementation of the Upper Llano River WPP.

The LCRA partners with the Texas Stream Team by supplying Upper Highland Lakes Water Quality Monitors with supplies for certified citizen scientists to use. The Colorado River Watch Network (CRWN) began in 1988 when a handful of Austin citizens began sampling local creeks. Today, CRWN volunteers include citizens, teachers, students, scouts and groups such as the Austin Youth River Watch. On average, 85 volunteers sample for dissolved oxygen, pH, specific conductivity, nitrates and temperature at 100 stations annually. Many also test for E. coli bacteria. The zebra mussel watchers continue to provide early detection of this species, which threatens aquatic ecosystems and water utilities.

Endangered Species and Conservation Needs

San Saba County, Mills County, Lampasas County, Burnet County, Mason County and Llano County federal and state listed endangered or threatened species include:

Table 1: Endangered Species located within San Saba County, Mills County, Lampasas County, Burnet County, Mason County and Llano County

Arachnids	Bee Creek Cave harvestman
Birds	American Peregrine Falcon
	Arctic Peregrine Falcon
	Bald Eagle
	Black-capped Vireo
	Golden-cheeked Warbler
	Interior Least Tern
	Mountain Plover
	Peregrine Falcon
	Sprague's Pipit
	Western Burrowing Owl
	Whooping Crane
	Zone-tailed Hawk
	Baird's Sparrow
Crustaceans	An amphipod
	Bifurcated cave amphipod
	Reddell's cave amphipod
Fishes	Guadalupe bass
	Headwater catfish
	Smalleye shiner
	Sharpnose shiner
Mammals	Cave myotis
	Gray wolf
	Llano pocket gopher

	Plains spotted skunk
	Red wolf
	Black bear
Mollusks	False spike mussel
	Smooth pimpleback
	Texas fatmucket
	Texas fawnsfoot
	Texas pimpleback
Reptiles	Concho water snake
	Spot-tailed earless lizard
	Texas garter snake
	Texas horned lizard
Insects	Disjunct crawling water beetle
Plants	Basin bellflower
	Basin wild-buckwheat
	Edwards Plateau cornsalad
	Enquist's sandmint
	Granite spiderwort
	Hall's prairie clover
	Net-leaf bundleflower
	Plateau loosestrife
	Plateau milkvine
	Rock grape
	Rock quillwort
	Scarlet leather-flower
	Stanfield's beebalm
	Sycamore-leaf snowbell
	Texas almond

	Tree dodder
	Hill Country wild-mercury
	Elmendorf's onion
	Guadalupe beardtongue
	Llano butterweed
	Texas peachbush
	Buckley tridens
	Guadalupe beardtongue
	Turner’s hawthorn

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.

Natural sources of warm water are seasonal, 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 release warmer water. Citizen scientist monitoring may not identify fluctuating patterns due to diurnal changes or events such as power plant releases. While citizen scientist data does not show diurnal temperature fluctuations, it may demonstrate the fluctuations over seasons and years.

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 stream flow. The TCEQ Water Quality Standards document lists daily minimum dissolved oxygen (DO) criteria for specific water bodies and presumes criteria according to flow status (perennial, intermittent with perennial pools, and intermittent), aquatic life attributes, and habitat. These criteria are protective of aquatic life and may be used for general comparison purposes.

Table 2: Daily Minimum Dissolved Oxygen Requirements for Aquatic Life

Aquatic Life Sub-category	Daily Minimum Dissolved Oxygen (mg/L^{1})
Exceptional	4.0
High	3.0
Intermediate	3.0
Limited	2.0
Minimal	1.5

The DO concentrations may be influenced by other water quality parameters such as nutrients and temperature. High concentrations of nutrients can lead to excessive surface vegetation growth and algae, which may starve subsurface vegetation of sunlight, and therefore limit the amount of DO in a water body due to reduced photosynthesis. This process, known as eutrophication, is enhanced when the subsurface vegetation and algae die and oxygen is consumed by bacteria during decomposition. Low DO levels may also result from high groundwater inflows due to minimal groundwater aeration, high temperatures that reduce oxygen solubility, or water releases from deeper portions of dams where DO stratification occurs. Supersaturation typically only occurs underneath waterfalls or dams with water flowing over the top.

Specific Conductivity and Total Dissolved Solids

Specific conductivity is a measure of the ability of a body of water to conduct electricity. It is measured in micro Siemens per cubic centimeter ($\mu S/cm^3$). A body of water is more conductive if it has more dissolved solids such as nutrients and salts, which indicates poor water quality if they are overly abundant. High concentrations of nutrients can lower the level of DO, leading to eutrophication. 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 (TDS) can include agricultural runoff, domestic runoff, or discharges from wastewater treatment plants. For this report, specific conductivity values have been converted to TDS using a conversion factor of 0.65 and are reported as milligrams per liter (mg/L).

pH

The pH scale measures the concentration of hydrogen ions on a range of 0 to 14 and is reported in standard units. The pH of water can provide useful information regarding acidity or alkalinity. The range is logarithmic; therefore, everyone unit change is representative of a 10-fold increase or decrease in acidity. Acidic sources, indicated by a low pH level, can include acid rain and runoff from acid-laden soils. Acid rain is mostly caused by coal power 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. The most suitable pH range for healthy organisms is between 6.5 and 9.

Secchi disk and total depth

The Secchi disk is used to determine the clarity of the water, a condition known as turbidity. The disk is lowered into the water until it is no longer visible, and the depth is recorded. 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 very little light to penetrate deep into the water, which in turn decreases the density of phytoplankton, algae, and other aquatic plants. This reduces the DO in the water due to reduced photosynthesis. Contaminants are most commonly transported in sediment rather than in the water. Turbid waters can result from sediment washing away from construction sites, erosion of farms, or mining operations. Average Secchi disk transparency (a.k.a. Secchi depth) readings that are less than the total depth readings indicate turbid water. Readings that are equal to total depth indicate clear water. Low total depth observations have a potential to concentrate contaminants.

E. coli Bacteria

E. coli bacteria originate in the digestive tract of endothermic organisms. The Environmental Protection Agency has determined *E. coli* to be the best indicator of the degree of pathogens in a water body, which are far too numerous to be tested for directly, considering the amount of water bodies tested. A pathogen is a biological agent that causes disease. The standard for *E. coli* impairment is based on the geometric mean (geomean) of the *E. coli* measurements taken. A geometric mean is a type of average that incorporates the high variability found in parameters such as *E. coli* 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 such as Lake LBJ is 126 CFU/100 mL. A water body is considered impaired if the geometric mean is higher than this standard.

Orthophosphate

Orthophosphate is the phosphate molecule all by itself. Phosphorus almost always exists in the natural environment as phosphate, which continually cycles through the ecosystem as a nutrient necessary for the growth of most organisms. Testing for orthophosphate detects the amount of phosphate in the water itself, excluding 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 volunteer monitors. Testing for orthophosphate gives us an idea of the degree of phosphate 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 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 orthophosphate has on a water body is known as eutrophication and is described above under the "Dissolved Oxygen" section.

Nitrate-Nitrogen

Nitrogen is present in terrestrial or aquatic environments as nitrates, nitrites, and ammonia. Nitrate-nitrogen tests are conducted for maximum data compatibility with the TCEQ and other partners. Just like phosphorus, nitrogen is a nutrient necessary for the growth of most organisms. Nitrogen inputs into a water body may be livestock and pet waste, excessive fertilizer use, failing septic systems, and industrial discharges that contain corrosion inhibitors. The effect nitrogen has on a water body is known as eutrophication and is described above under the "Dissolved Oxygen" section. Nitrates dissolve more readily than phosphates, which tend to be attached to sediment, and therefore can serve as a better indicator of the possibility of sewage or manure pollution during dry weather.

Texas Surface 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 so that it supports public health and protects 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 (or drinking water). The criteria for evaluating support of those uses include DO, temperature, pH, TDS, toxic substances, and bacteria. 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, as well as other information, including water quality studies, existence of fish kills or contaminant spills, photographic evidence, and local knowledge. Screening levels serve as a reference point to indicate when water quality parameters may be approaching levels of concern.

Data Analysis Methodologies

Data Collection

The field sampling procedures are documented in Texas Stream Team Water Quality Monitoring Manual and its appendices, or the TCEQ Surface Water Quality Monitoring Procedures Manual, Volume 1 (August 2012). Additionally, all data collection adheres to Texas Stream Team's approved QAPP.

Table 3: Sample Storage, Preservation, and Handling Requirements

Parameter	Matrix	Container	Sample Volume	Preservation	Holding Time
E. coli	Water	Sterile Polystyrene (SPS)	100 mL	Refrigerate at 4ºC*	6 hours
Nitrate/Nitrogen	Water	Plastic Test Tube	10 mL	Refrigerate at 4ºC*	48 hours
Orthophosphate/Phosphorous	Water	Glass Mixing Bottle	25 mL	Refrigerate at 4ºC*	48 hours
Chemical Turbidity	Water	Plastic Turbidity Column	50 mL	Refrigerate at 4ºC*	48 hours

*Preservation performed within 15 minutes of collection.

Processes to Prevent Contamination

Procedures documented in Texas Stream Team Water Quality Monitoring Manual and its appendices, or the TCEQ 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 (QC) samples are collected to verify that contamination has not occurred.

Documentation of Field Sampling Activities

Field sampling activities are documented on the field data sheet. For all field sampling events the following items are recorded: station ID, location, sampling time, date, and depth, sample collector's name/signature, group identification number, conductivity meter calibration information, and reagent expiration dates are checked and recorded if expired. If reagents or media are expired, it is indicated on the datasheet. Sampling is not encouraged with expired reagents and bacteria media; the corresponding values will be flagged in the database and excluded from data reports. Detailed observational data are recorded, including 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 and administrative purposes.

Data Entry and Quality Assurance

Data Entry

The citizen scientists collect field data and report the measurement results on Texas Stream Team approved physical or electronic datasheet. The physical data sheet is submitted to the Texas Stream Team and local partner, if applicable. The electronic datasheet is accessible in the online DataViewer and, upon submission and verification, is uploaded directly to the Texas Stream Team Database.

Quality Assurance & Quality Control

All data are reviewed to ensure that they are representative of the samples analyzed and locations where measurements were made, and that the data and associated quality control data conform to specified monitoring procedures and project specifications. The respective field, data management, and Quality Assurance Officer (QAO) data verification responsibilities are listed by task in Section D1 of the QAPP, available on the Texas Stream Team website.

Data review and verification is performed using a data management checklist and self-assessments, as appropriate to the project task, followed by automated database functions that will 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. If there are errors in the calibration log, expired reagents used to generate the sampling data, or any other deviations from the field or *E. coli* data review checklists, the corresponding data is flagged in the database.

When the QAO receives the physical data sheets, they are validated using the data validation checklist, and then entered into the online database. Any errors are noted in an error log and the errors are flagged in the Texas Stream Team database. When a citizen scientist enters data electronically, the system will automatically flag data outside of the data limits and the citizen scientist will be prompted to correct the mistake or the error will be logged in the database records. The certified QAO will further review any flagged errors before selecting to validate the data. After validation, the data will be formally entered into the database. Once entered, the data can be accessible through the online DataViewer, with the exception of flagged data.

Errors, which may compromise the program's ability to fulfill the completeness criteria prescribed in the QAPP, will be reported to the Texas Stream Team Program Manager. If repeated errors occur, the citizen scientist and/or the group leader will be notified via e-mail or telephone.

Data Analysis Methods

Data are compared to state standards and screening levels, as defined in the Surface Water Quality Monitoring Procedures, to provide readers with a reference point for amounts/levels of parameters that may be of concern. The assessment performed by TCEQ and/or designation of impairment involves more complicated monitoring methods and oversight than used by volunteers and staff in this report. The citizen water quality monitoring data are not used in the assessments mentioned above, but are intended to inform stakeholders about general characteristics and assist professionals in identifying areas of potential concern.

Standards & Exceedances

The TCEQ determines a water body to be impaired if more than ten percent of samples, provided by professional monitoring, from the last seven years, exceed the standard for each parameter, except for *E. coli* bacteria. When the observed sample value does not meet the standard, it is referred to as an exceedance. At least ten samples from the last seven years must be collected over at least two years with the same reasonable amount of time between samples for a data set to be considered adequate. The 2018 Texas Surface Water Quality Standards report was used to calculate the exceedances for the Upper Highland Lakes Watershed, as seen below in Table 4.

Methods of Analysis

Quality assured data collected from the Upper Highland Lakes and its tributaries were exported from the Texas Stream Team database and were then grouped by site.

Once compiled, data was sorted and graphed in Microsoft Excel 2010 using standard methods. Trends over time were analyzed using a linear regression analysis in Minitab v 15. Statistically significant trends were added to Excel to be graphed. The cut off for statistical significance was set to a p-value of ≤ 0.05. A p-value of ≤ 0.05 means that the probability that the observed data matches the actual conditions found in nature is 95%. As the p-value decreases, the confidence that it matches actual conditions in nature increases.

For this report, specific conductivity measurements, gathered by citizen scientists, were converted to TDS using the TCEQ-recommended conversion formula of specific conductivity 0.65. This conversion was made so that volunteer gathered data could be more readily compared to state gathered data. Geomeans were calculated for *E. coli* data for trends and for each monitoring site. Due to the variability, the geometric mean is used to summarize bacteria data.

Segment No.	Segment Name	Description	Aquatic Life Use		Recreation Use			General Use		
			Dissolved Oxygen grab screening level (mg/L)	Dissolved Oxygen grab minimum (mg/L)	*E. coli* single sample (CFU/100mL)	*E. coli* geometric mean (CFU/100mL)	Water Temp (°C)	High pH (SU)	Low pH (SU)	TDS (mg/L)
1406	Lake Lyndon B. Johnson	From Alvin Wirtz Dam in Burnet County to Roy Inks Dam on the Colorado River Arm in Burnet/Llano County and to a point immediately upstream of the confluence of Honey Creek on the Llano River Arm in Llano County, up to the normal pool elevation of 825.6 feet (impounds Colorado River)	5.0	4.0	394	126	34	9.0	6.5	500
1407	Inks Lake	From Roy Inks Dam in Burnet/Llano County to Buchanan Dam in Burnet/Llano County, up to the normal pool elevation of 888 feet (impounds Colorado River)	5.0	4.0	394	126	32	9.0	6.5	600
1408	Lake Buchanan	From Buchanan Dam in Burnet/Llano County to a point immediately upstream of the confluence of Yancey	5.0	4.0	394	126	32	9.0	6.5	600

		Creek, up to the normal pool elevation of 1020.5 feet (impounds Colorado River)									
1415	Llano River	From a point immediately upstream of the confluence of Honey Creek in Llano County to FM 864 on the North Llano River in Sutton County and to SH 55 on the South Llano River in Edwards County	5.0	4.0	394	126	33	9.0	6.5	350
1416	San Saba River	From the confluence with the Colorado River in San Saba County to the confluence of the North Valley Prong and the Middle Valley Prong in Schleicher County	5.0	4.0	394	126	32	9.0	6.5	425

Table 4: TCEQ designated stream segments and standards, as applicable to citizen water quality data in this report (other standards may exist for these water bodies).

[1] TCEQ standards are given for total dissolved solids (max 400 mg/L), not conductivity. Because Stream Team monitors measure conductivity rather than total dissolved solids, the standard was converted following the TCEQ's 2010 Guidance for Assessing and Reporting Surface Water Quality in Texas: Conductivity standard = Total Dissolved Solids standard / 0.65

Upper Highland Lakes Watershed Data Analysis

Upper Highland Lakes Maps

Numerous maps were prepared to show spatial variation of the parameters. The parameters mapped include DO, pH, TDS, *E. coli*, and Nitrate-Nitrogen. There is also a reference map showing the locations of all active sites. For added reference points in all maps, layers showing monitoring sites, cities, counties, and major highways were included. All shapefiles were downloaded from reliable federal, state, and local agencies.

Figure **1**: Map of the **Upper Highland Lakes** Watershed with Texas Stream Team Monitor Site**s**

Upper Highland Lakes Watershed Trends over Time

Sampling Trends over Time

Sampling in the Upper Highland Lakes Watershed began in May of 1996. A total of 952 monitoring events from 9 sites collected between May 1996 to September 2018 were analyzed.

Table 5: Descriptive parameters for all sites in the Upper Highland Lakes Watershed

Upper Highland Lakes Watershed May 1996 – September 2018				
Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	827	306 ± 75	150	592
Water Temperature (°C)	949	20.3 ± 6.7	3.0	38.5
Dissolved Oxygen (mg/L)	948	7.2 ± 1.6	2.4	11.7
pH	931	7.9 ± 0.4	6.5	9.5
E. coli (CFU/100 mL)	311	16 ± 73	1.0	820
Nitrate-Nitrogen	583	0.88 ± 0.36	0.25	4.0

There were a total of 952 sampling events between 5/20/1996 and 9/17/2018.

Trend Analysis over Time

Air and water temperature

A total of 949 water temperatures and 950 air temperatures were recorded in this watershed. The mean water temperature was 20.3 °C. The minimum water temperature was 3.0 °C and was recorded in January of 2018. The maximum water temperature of 38.5 °C was recorded in August of 2006. The air temperature ranged from a low of -1.0 °C in January of 2011 to a high of 47.0 °C in July of 2000.

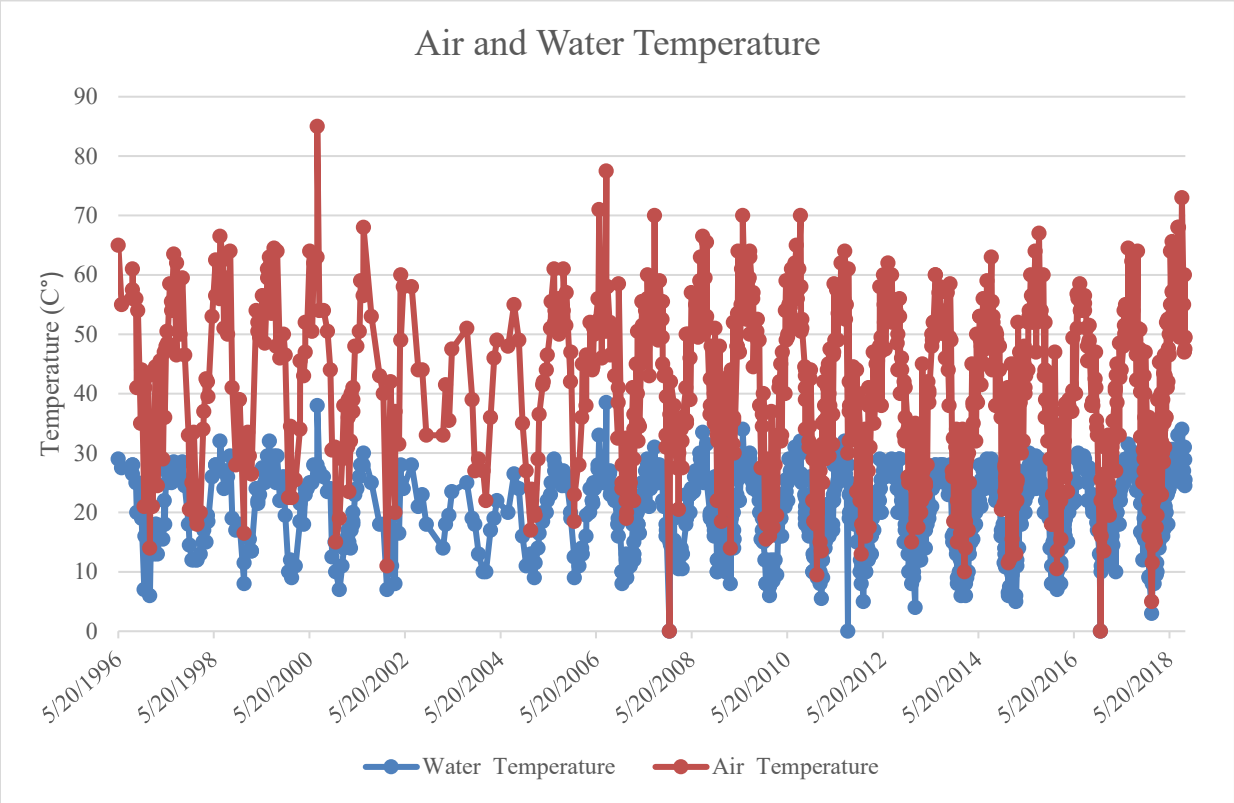

Figure 4: Air and water temperature over time at all sites within the Upper Highland Lakes Watershed

Total Dissolved Solids

Citizen scientists took 827 TDS measurements in the watershed. The mean TDS concentration in the watershed was 306 mg/L and it ranged from a low of 150 mg/L in October of 2011 to a high of 592 mg/L in May of 2003. There was no significant change observed in TDS concentrations over time in the watershed.

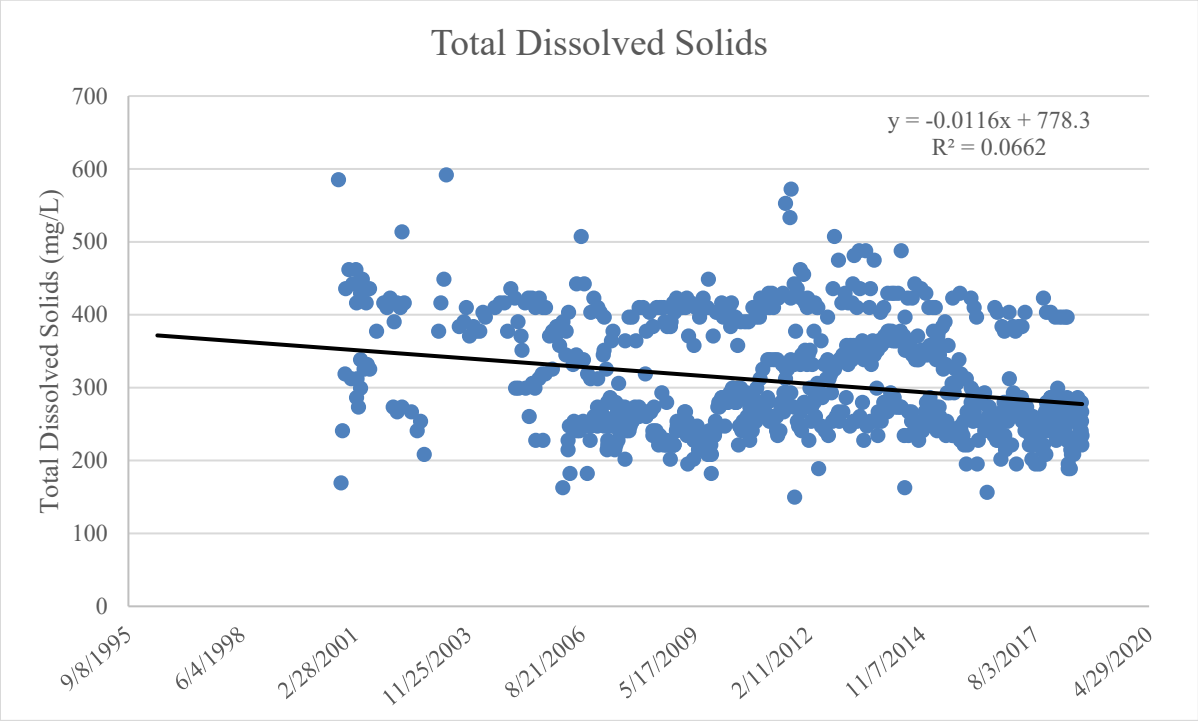

Figure 5: Total dissolved solids over time at all sites within the Upper Highland Lakes Watershed

Dissolved Oxygen

Citizen scientists took 948 DO samples in the watershed. The mean DO concentration was 7.2 mg/L and it ranged from a low of 2.4 mg/L in May of 2010 to a high of 11.7 mg/L in December of 1996. Other than seasonal and interannual variability in oxygen levels, there was no significant change observed in DO concentrations over time in the watershed.

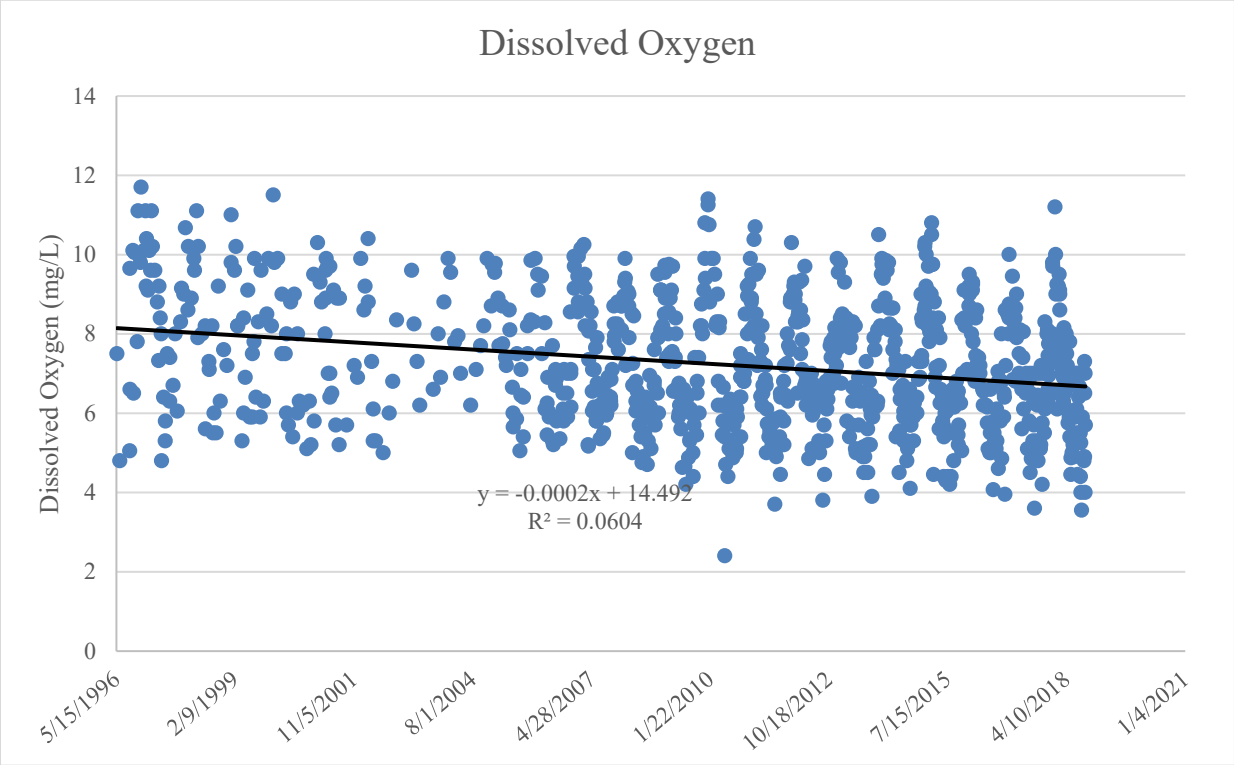

Figure 7: Measured dissolved oxygen over time at all sites within the Upper Highland Lakes Watershed

pH

Citizen scientists took 931 pH measurements in the watershed. The mean pH was 7.9 and it ranged from a low of 6.8 in September of 2007 to a high of 9.5 in May of 1996. There was no significant change observed in pH over time observed in the watershed.

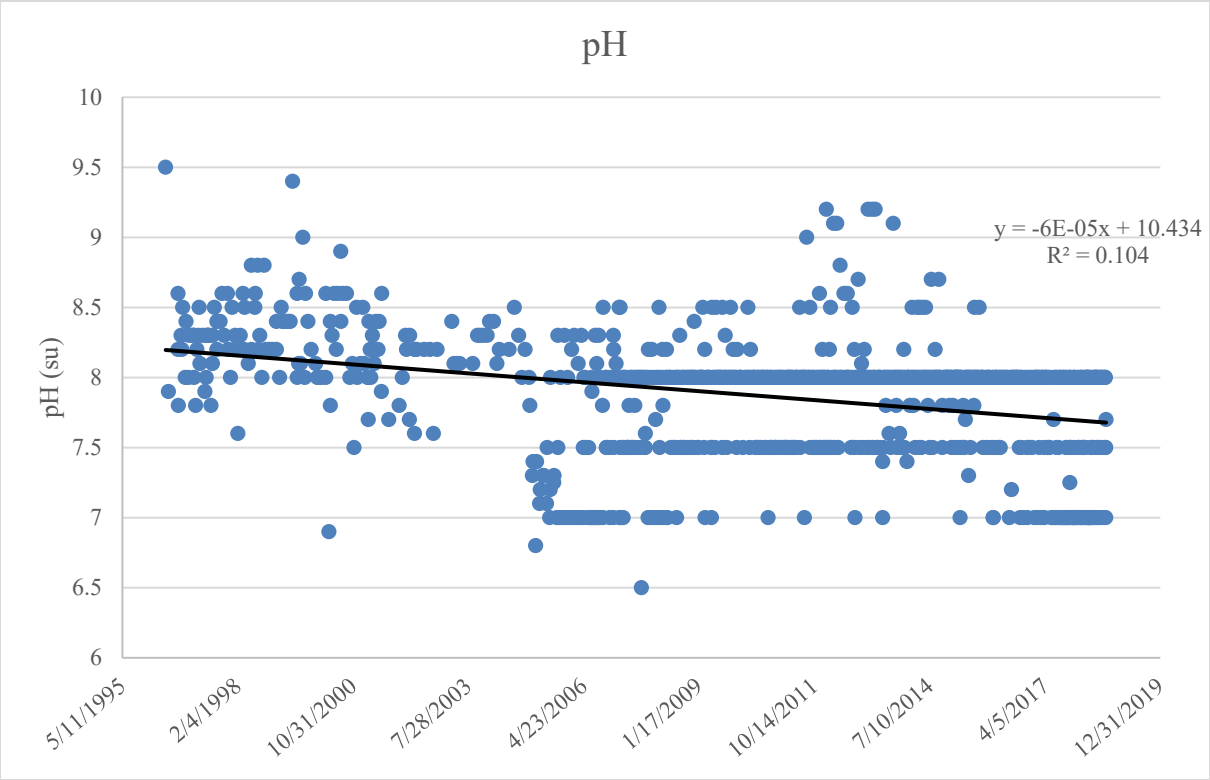

Figure 9: Measured pH over time within the Upper Highland Lakes Watershed

E. coli

Citizen scientists took 311 *E. coli* measurements in the watershed. The *E. coli* geomean in the watershed was 16 CFU/100 mL and it ranged from a low of 1.0 CFU/100 mL which occurred several times to a high of 820 CFU/100 mL in December of 2001. There was no significant change observed in *E. coli* levels over time in the watershed.

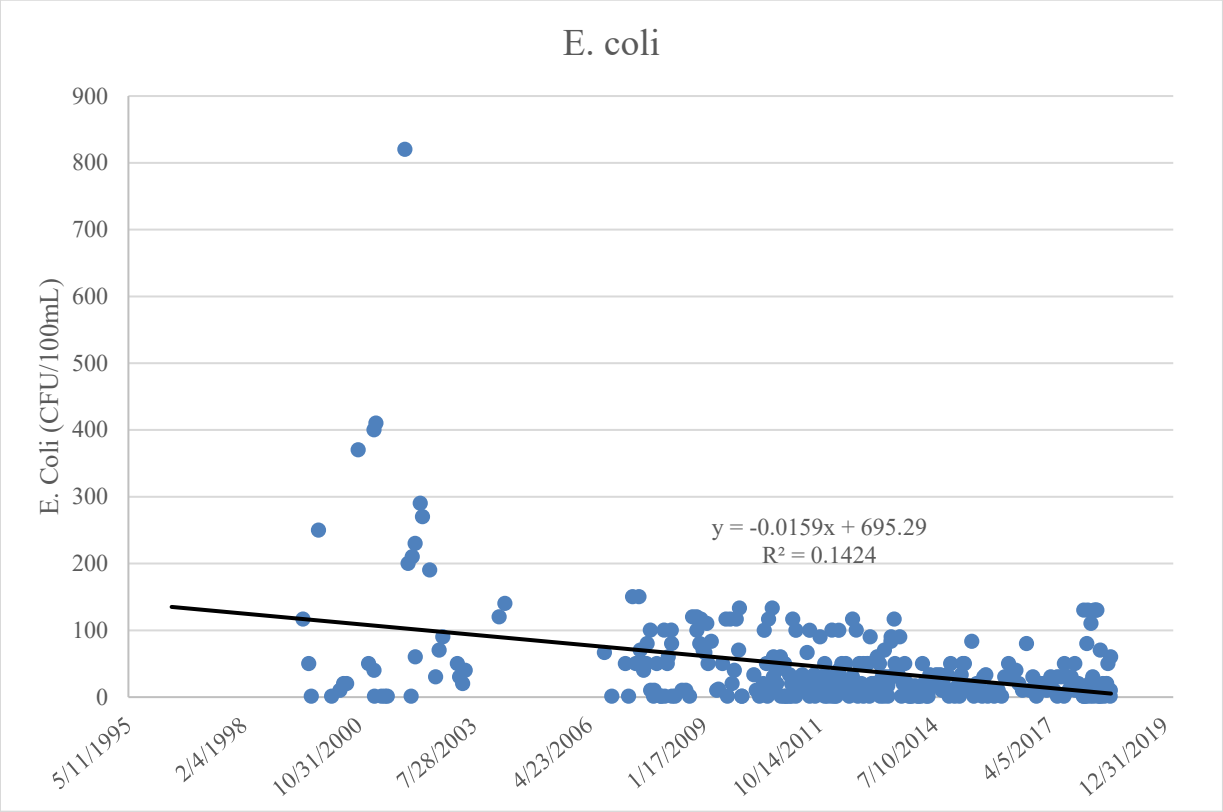

Figure 11: *E. coli* over time at all sites within the Upper Highland Lakes Watershed

Nitrate-Nitrogen

Citizen scientists took 583 Nitrate-Nitrogen measurements in the watershed. The average mg/L of nitrate-nitrogen samples taken in the watershed was 0.88 mg/L and it ranged from a low of 0.25 mg/L which occurred several times to a high of 4.0 mg/L in December of 1997 and December of 2000. There was no significant change observed in Nitrate-Nitrogen levels over time in the watershed.

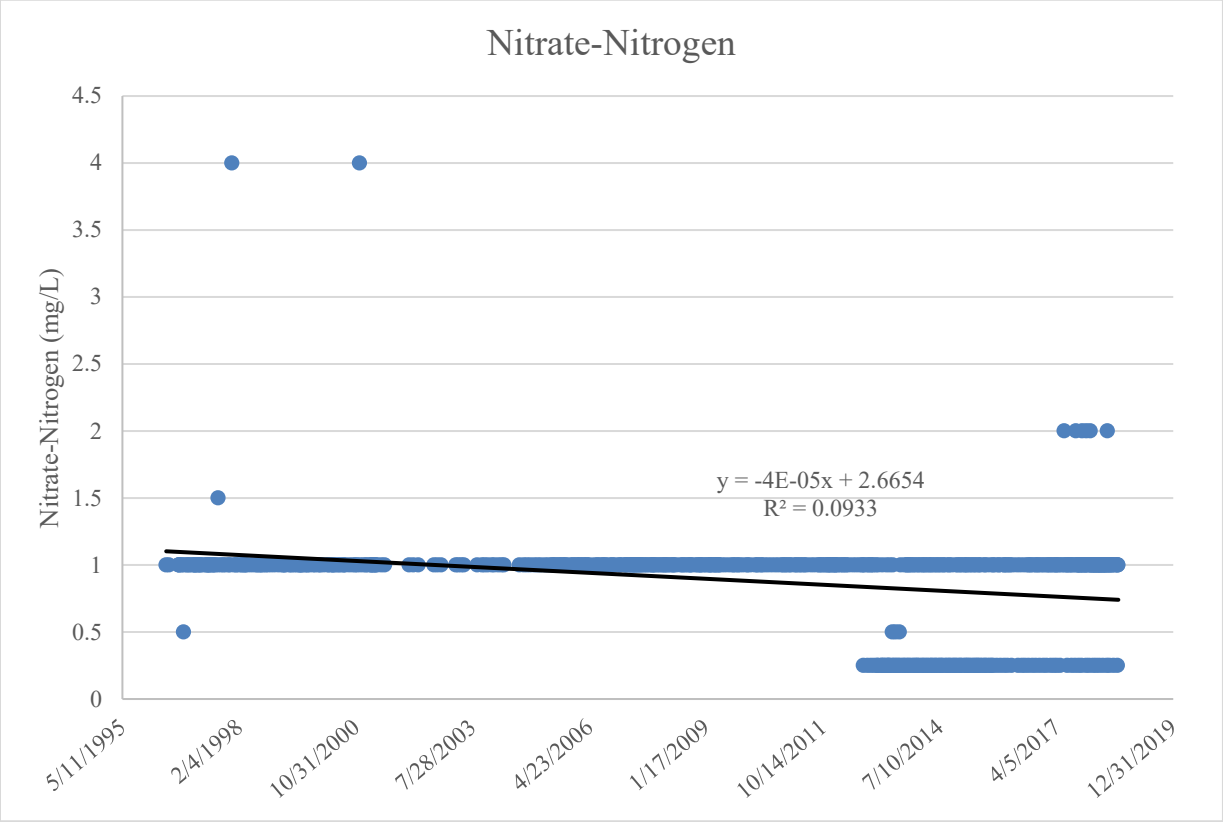

Figure 12: Nitrate-Nitrogen over time at all sites within the Upper Highland Lakes Watershed

Upper Highland Lakes Watershed Site by Site Analysis

The following sections will provide a brief summarization of analysis, by site. The average minimum and maximum values are reported in order to provide a quick overview of the watershed. The TDS, DO, and pH values are presented as an average, plus or minus the standard deviation from the average. Please see Table 6 on page 29, for a quick overview of the average results.

As previously mentioned in the 'Water Quality Parameters' section, TDS is an important indicator of turbidity and specific conductivity. The higher the TDS measurement, the more conductive the water is. A high TDS result can indicate increased nutrients present in the water. Site 13553 had the highest overall average for TDS, with a result of 408 ± 45 mg/L . Site 81501 had the lowest average TDS, with a result of 236 ± 25 mg/L.

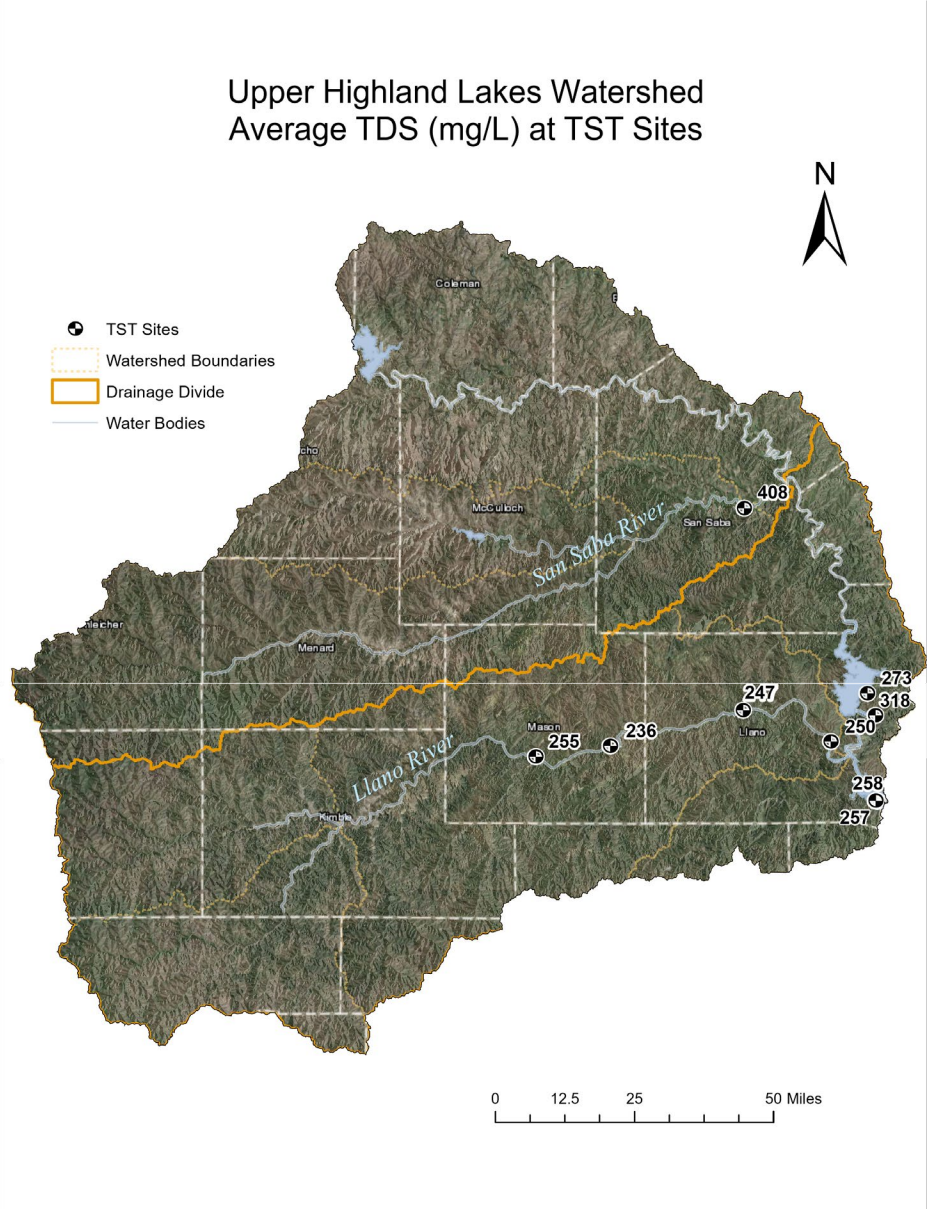

Figure 13: Map of the average TDS for sites in the Upper Highland Lakes Watershed

The DO measurement can help to understand the overall health of the aquatic community. If there is a large influx of nutrients into the water body then there will be an increase in surface vegetation growth, which can reduce photosynthesis in the subsurface, thus decreasing the level of DO. Low DO can be dangerous for aquatic inhabitants which rely upon the DO to breathe. The DO levels can also be impacted by temperature; high temperature can limit the amount of oxygen solubility, which can also lead to a low DO measurement. Site 81501 had the lowest average DO reading with a result of 6.2 ± 1.8 mg/L. Site 12338 had the highest average DO reading with a result of 7.5 ± 1.5 mg/L.

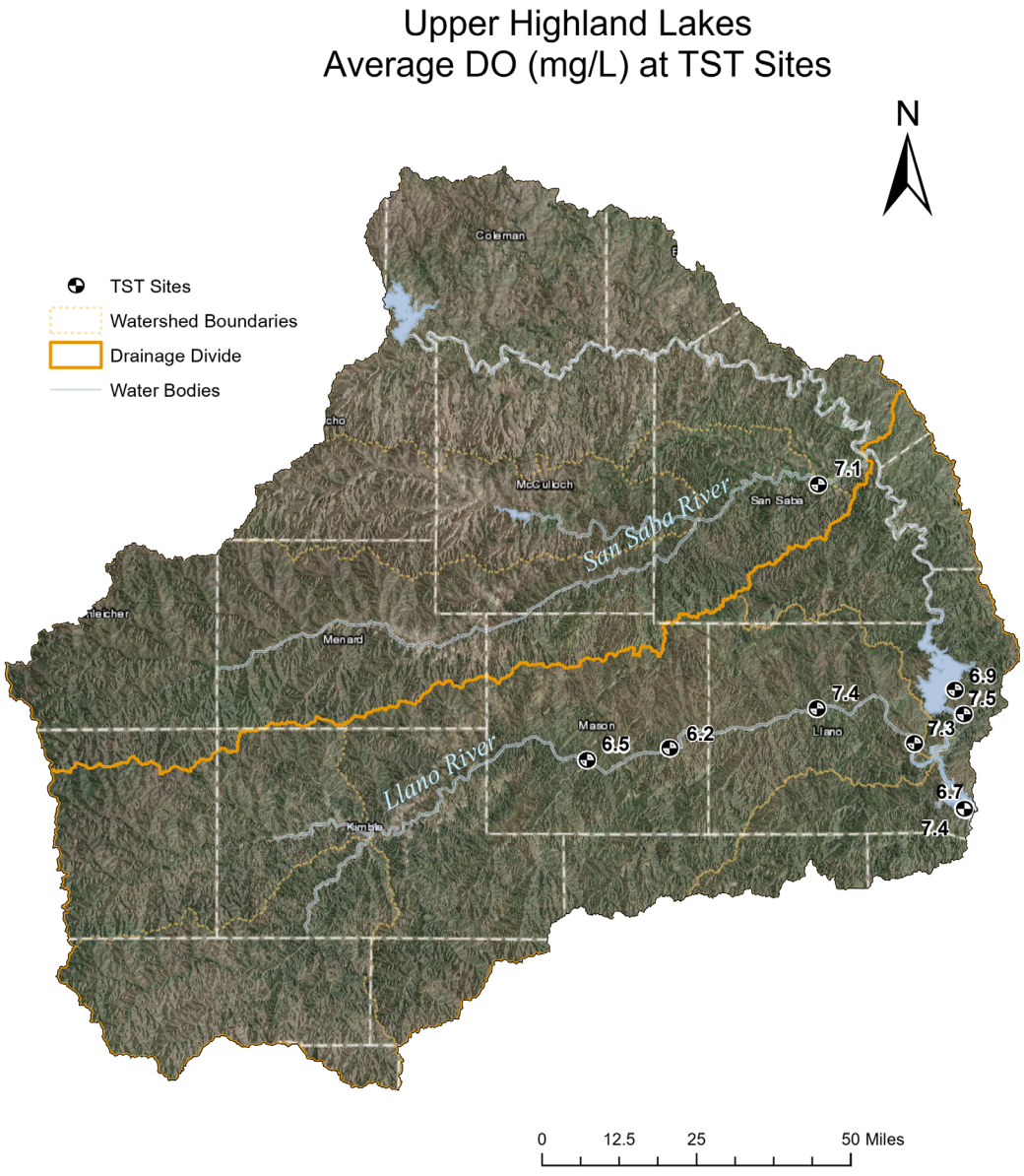

Figure 14: Map of the average DO for sites in the Upper Highland Lakes Watershed

The pH levels are an important indicator for the overall health of the watershed as well. Aquatic inhabitants typically require a pH range between 6.5 and 9 for the most optimum environment. Anything below 6.5 or above 9 can negatively impact reproduction or can result in fish kills. There were no sampling events analyzed with pH levels reported outside of this widely accepted range. Site 13553, Site 12387 and Site 12383 had the highest average pH levels, with results of 7.9 ± 0.1, 7.9 ± 0.5, and 7.9 ± 0.3. Site 81505 and 81503 had the lowest average pH level with a result of 7.0.

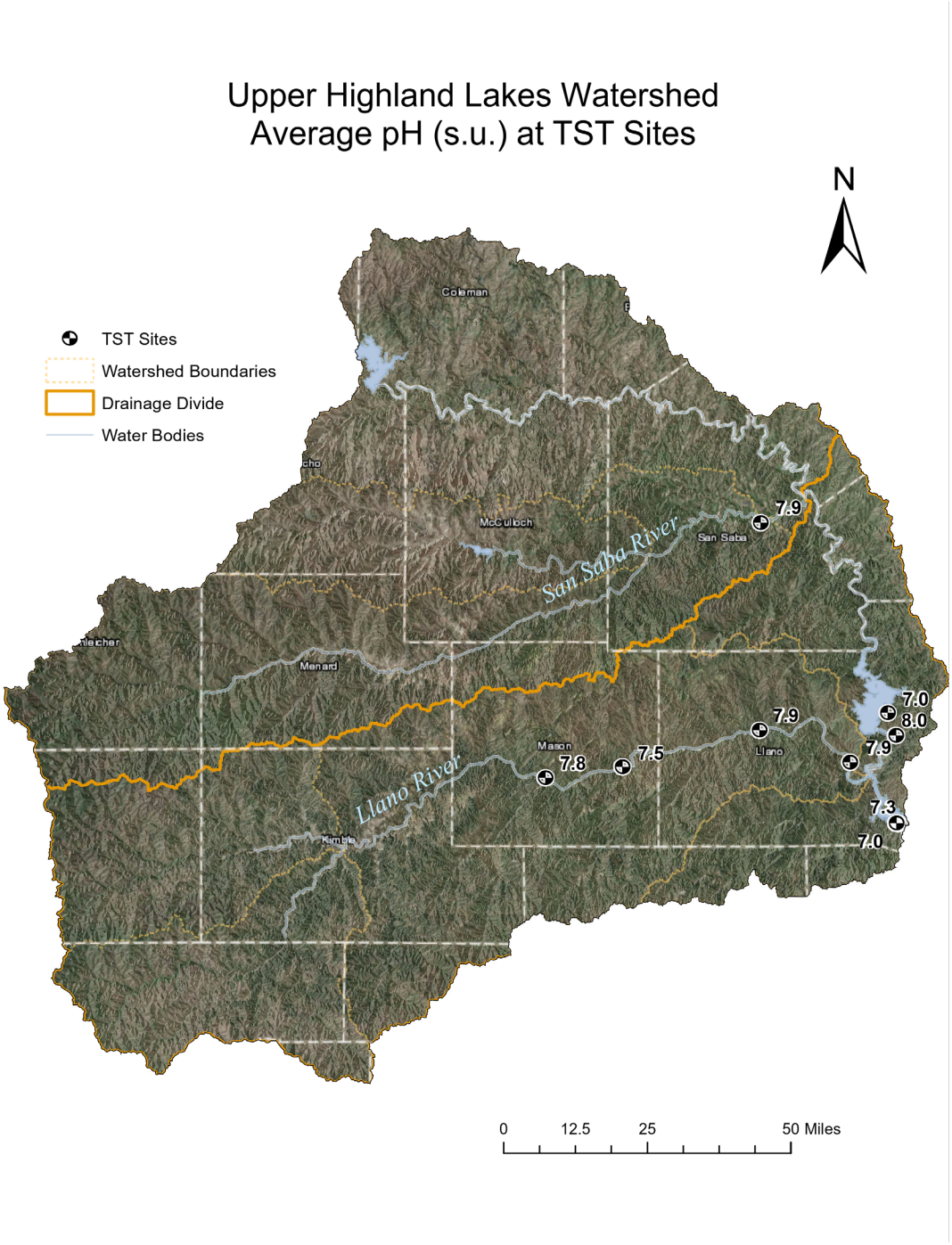

Figure 15: Map of the average pH for sites in the Upper Highland Lakes Watershed

E. coli can be used as an indicator of the degree of pathogens in a water body. Its presence above the TCEQ surface water quality standard for a single sample (394 CFU/100 mL) or geometric mean (126 CFU/100 mL) indicates a possible human health risk for primary contact recreation. There were a few sampling events at Site 13553, Site 80435, Site 12387 and Site 12338 with elevated *E. coli* levels. Site 13553 had the highest *E. coli* geomean of 69 ± 114 CFU/100 mL.

Figure 16: Map of the E. coli geometric mean for sites in the Upper Highland Lakes Watershed

Nitrates are essential plant nutrients, but in excess amount they can cause significant water quality problems. Excess nitrates can cause hypoxia (low DO) and can become toxic to warm-blooded animals at higher concentrations (10 mg/L or higher) under certain conditions. The natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/L); in the effluent of wastewater treatment plants, it can range up to 30 mg/L. Sources of nitrates include wastewater treatment plants, runoff from fertilized lawns and cropland, failing on-site septic systems, runoff from animal manure storage areas, and industrial discharges that contain corrosion inhibitors. Site 12383 had the minimum average nitrate-nitrogen concentration with 0.26 mg/L. Site 81501 had the highest average nitrate-nitrogen concentration with 1.40 mg/L.

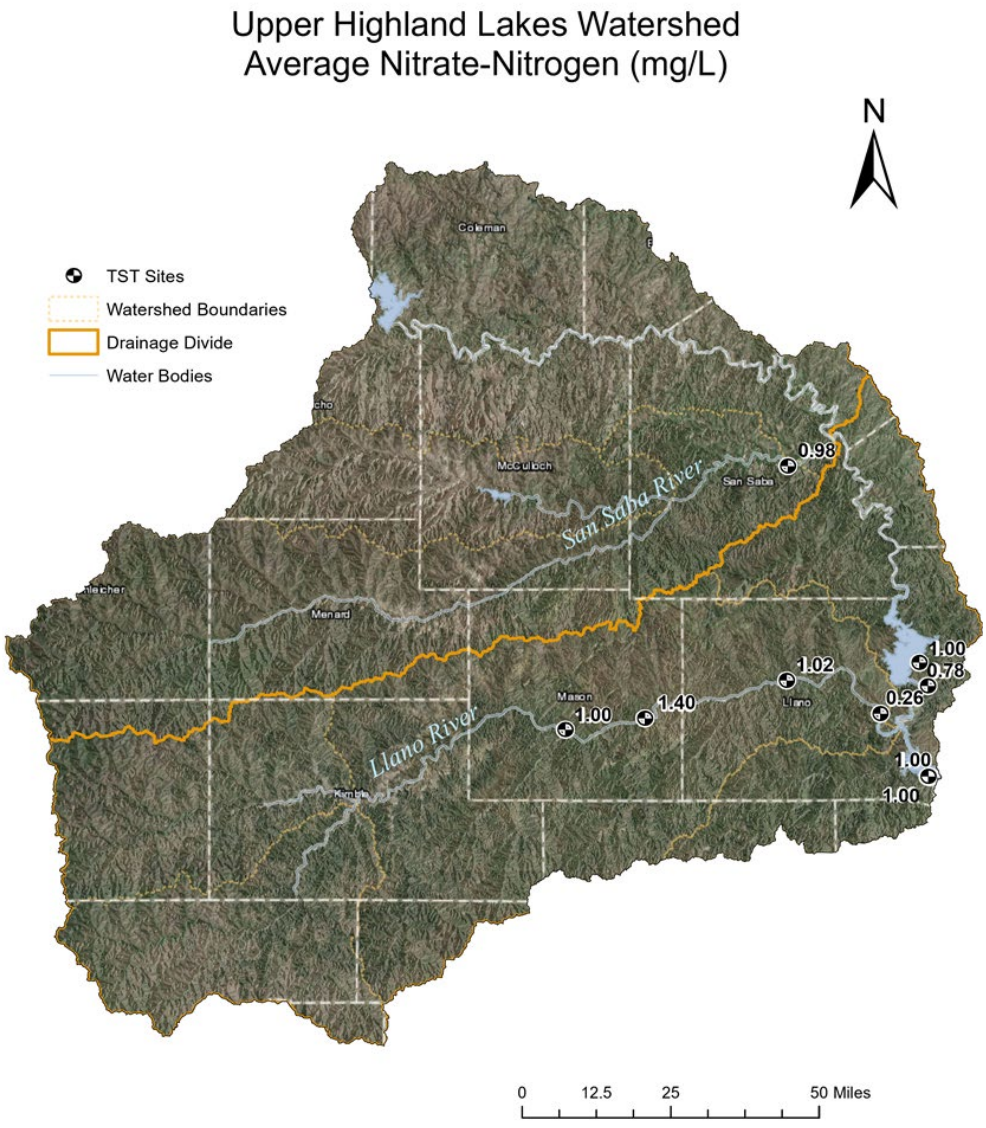

Figure 17: Map of the average nitrate-nitrogen for sites in the Upper Highland Lakes Watershed

See Table 6 for a summary of average results at all sites. Additionally, it is important to note that there was variation in the number of times each site was tested, the time of day at which each site was tested, and the time of month the sampling occurred. Another aspect to consider is that citizen scientists are asked to conduct water quality testing within a two-hour timeframe each month. While this is a quick overview of the results, it is important to note the natural diurnal and seasonal variation in these water quality parameters. Texas Stream Team citizen scientist data is not used by the state to assess whether water bodies are meeting the designated surface water quality standards.

Table 6: Average Values for all sites

Site	TDS (mg/L)	DO (mg/L)	pH (s.u.)	*E. coli* (CFU/ 100 mL)	Nitrate-Nitrogen (mg/L)
81505	273 ± 0	6.9 ± 0.1	7.0 ± 0	10 ± 0	1.00 ± 0.00
13553	408 ± 45	7.1 ± 1.6	7.9 ± 0.4	69 ± 114	0.98 ± 0.26
80435	255 ± 30	6.5 ± 1.5	7.8 ± 0.4	N/A	1.00 ± 0.00
81501	236 ± 25	6.2 ± 1.8	7.5 ± 0.3	8 ± 36	1.40 ± 0.49
12387	247 ± 29	7.4 ± 2.0	7.9 ± 0.5	35 ± 133	1.02 ± 0.27
12383	250 ± 28	7.3 ± 1.5	7.9 ± 0.3	8 ± 35	0.26 ± 0.09
12338	318 ± 38	7.5 ± 1.5	8.0 ± 0.5	11 ± 28	0.78 ± 0.34
81503	257 ± 6	7.4 ± 0.7	7.0 ± 0	N/A	1.00 ± 0.00
81506	258 ± 8.1	6.7 ± 0.8	7.3 ± 0.2	6 ± 24	1.00 ± 0.00

Site 81505 – Lake Buchanan at Cassie's

Site Description

This site is located on the shores of a residence within the census-designated place of Buchanan Dam, on the south east (deeper end) end of Lake Buchanan. Nearby landscapes and drainages showcase the geology of the Llano Uplift (also known as Central Texas Uplift) and are dominated by ranches and some small farms and vineyards. The immediate shores of the lake around this location, like many shores along this reservoir, are primarily residential.

Sampling Information

This site was sampled 5 times from March 2018 to July 2018.

Table 7: Descriptive parameters for Site 81505

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	5	273 ± 0.0	273	273
Water Temperature (°C)	5	25.2 ± 5.2	16.0	29.0
Dissolved Oxygen (mg/L)	5	6.9 ± 0.1	6.7	7.0
pH	5	7.0 ± 0.0	7.0	7.0
E. coli	1	10 ± 0	10	10
Nitrate-Nitrogen	4	1.0 ± 0	1.0	1.0

Site 81505 was sampled 5 times between 3/30/2018 and 7/28/2018.

Air and water temperature

There were 5 air and 5 water temperature measurements taken at this site. The mean water temperature was 25.2 °C. The minimum water temperature was 16.0 °C and was recorded in March of 2018. The maximum water temperature was 29.0 °C and was recorded in July of 2009. The air temperature ranged from a low of 23.0 °C recorded in March of 2018 to a high of 39.0 °C recorded in July of 2018.

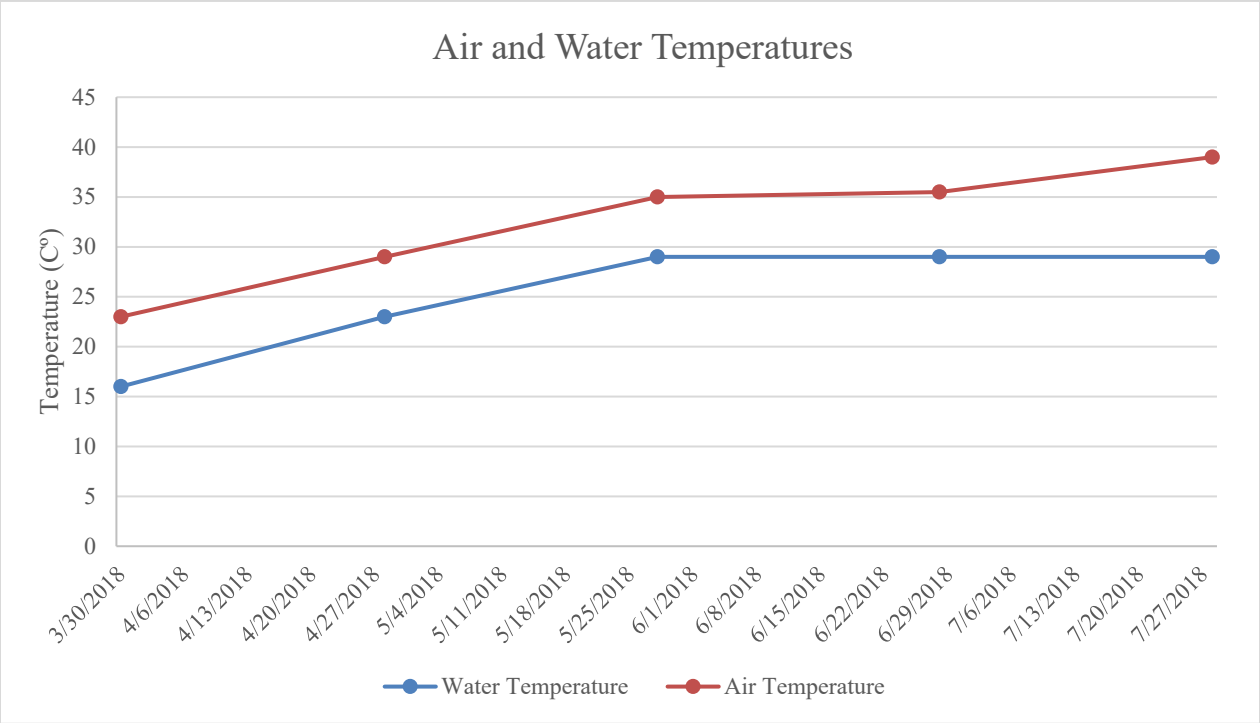

Figure 17: Air and water temperature at site 81505

Total Dissolved Solids

Citizen scientists collected 5 TDS measurements at this site. The mean TDS concentration was 273 mg/L, which was the measurement collected during each of the 5 sampling events. There was no relationship between TDS measurements and time observed at this site.

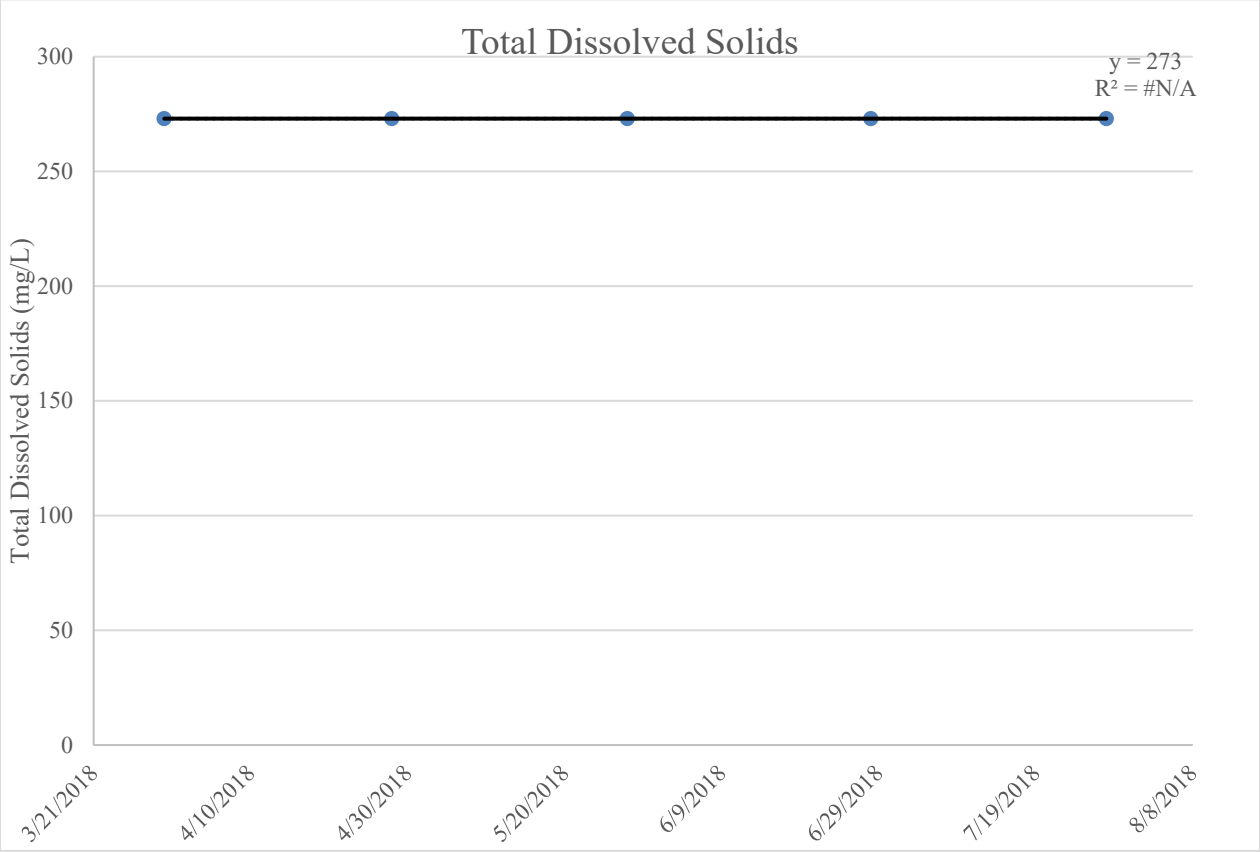

Figure 18: Total dissolved solids at site 81505

Dissolved Oxygen

Citizen scientists collected 5 DO samples at this site. The mean DO concentration was 6.9 mg/L and it ranged from a low of 6.7 mg/L in July of 2018 to a high of 7.0 mg/L measured in March, April, May, and June of 2018. There was no relationship between DO concentrations and time observed at this site.

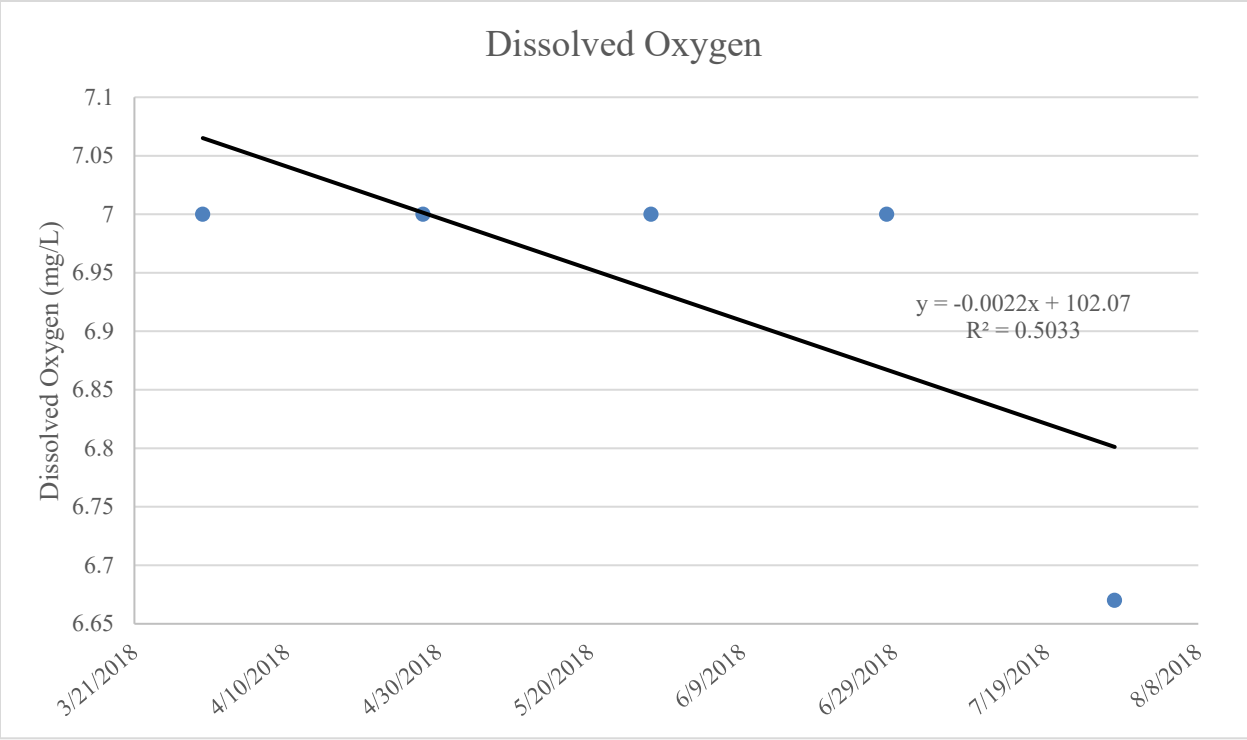

Figure 20: Dissolved Oxygen at site 81505

pH

There were 5 pH samples taken at this site. The mean pH was 7.0, which was the measurement collected from each of the sampling events. There was no significant relationship between pH and time observed at this site.

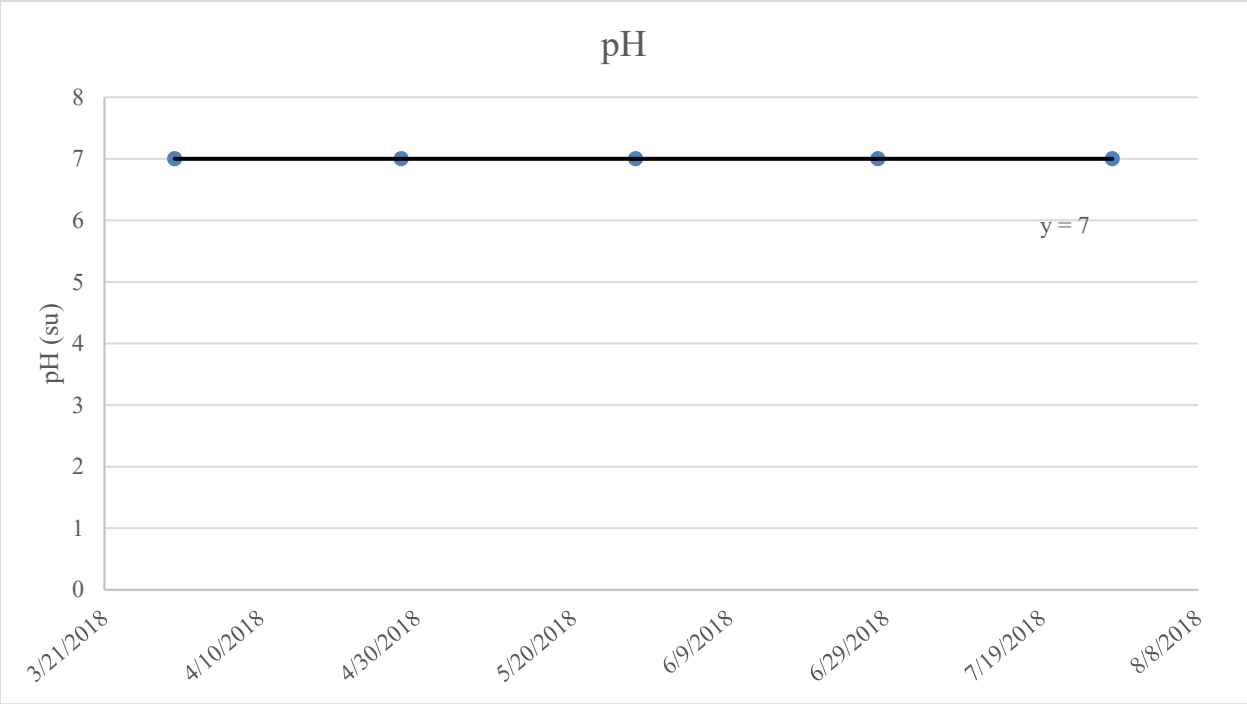

Figure 22: pH at site 81505

E. coli

Citizen scientists collected a total of 1 *E. coli* measurements at this site, which measured to be 10 CFU/100 mL.

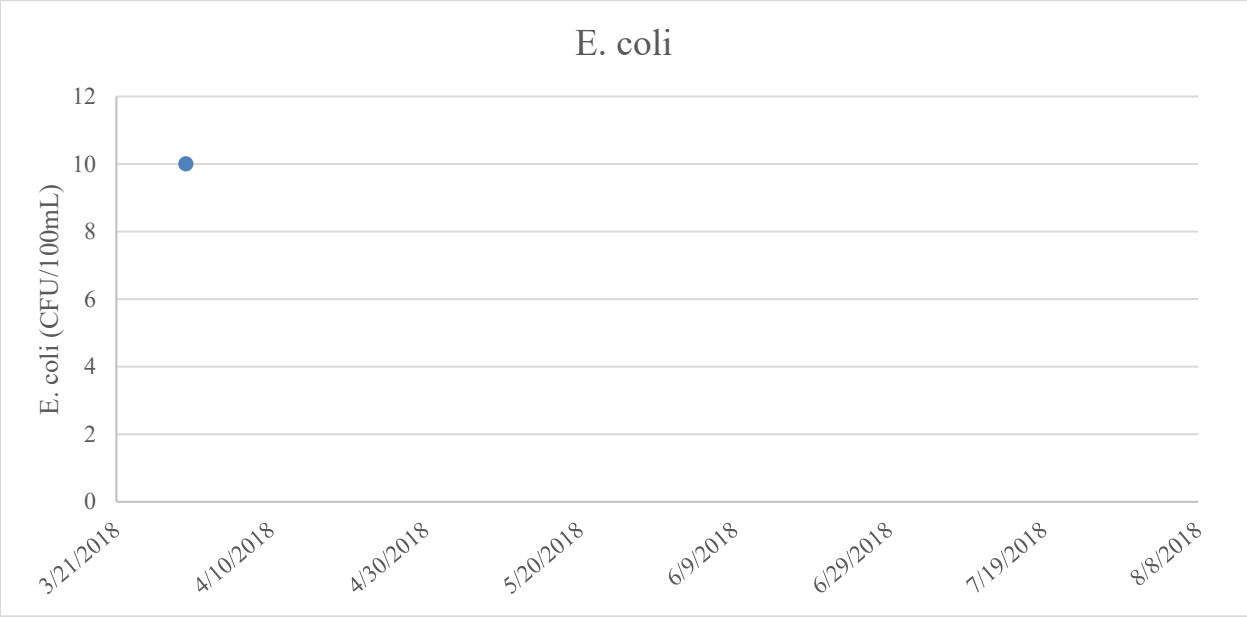

Figure 24: *E. coli* at site 81505

Nitrate Nitrogen

Citizen scientists collected 4 measuresments for Nitrate-Nitrogen, each calculating a value of 1 mg/L of Nitrate-Nitrogen.

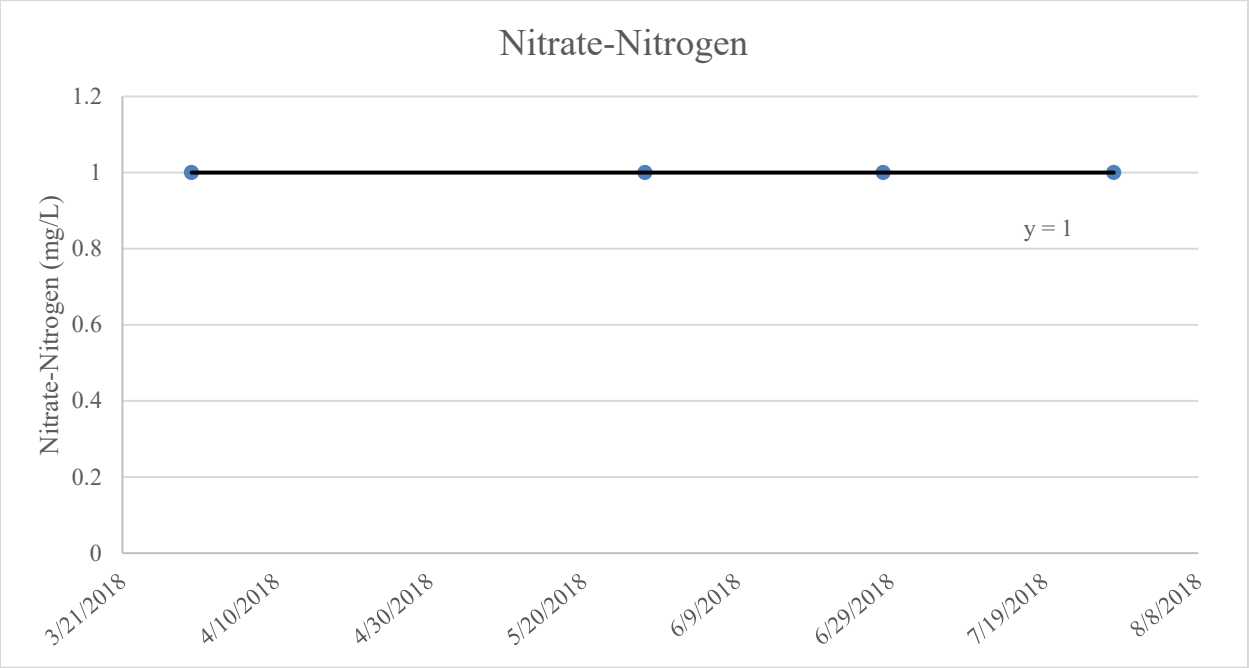

Figure 24: Nitrate-Nitrogen at site 81505

Site 13553 – San Saba River at Risien Park

Site Description

This site is located on the upstream end of the river as found within the shaded, 80-acre Risien Park in San Saba, TX, less than half a mile downstream of the Goran Ln crossing. The site is adjoined by the San Saba River Nature Park. Both parks characterize the stream here with tree-lined banks, pecan groves, small waterfalls, and park anemities. A section of the river downstream has been cemented in for swimming.

Sampling Information

This site was sampled 271 times from June 1996 to May 2018.

Table 8: Descriptive parameters for Site 13553

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	213	408 ± 45	241	592
Water Temperature (°C)	271	18.9 ± 6.4	5.0	33.5
Dissolved Oxygen (mg/L)	271	7.1 ± 1.6	2.4	11.4
pH	266	7.9 ± 0.4	6.5	8.9
E. coli	65	69 ± 114	1	820
Nitrate-Nitrogen	217	0.98 ± 0.26	0.25	4.00

Site 13553 was sampled 271 times between 6/14/1996 and 5/9/2018.

Air and water temperature

There were 271 air and water temperature measurements taken at this site. The mean water temperature was 18.9°C. The minimum water temperature was 5.0°C and was recorded in March of 2015. The maximum water temperature was 33.5°C and was recorded in August of 2008. The air temperature ranged from a low of 4.0°C recorded in April of 2013 to a high of 38°C recorded in August of 2010.

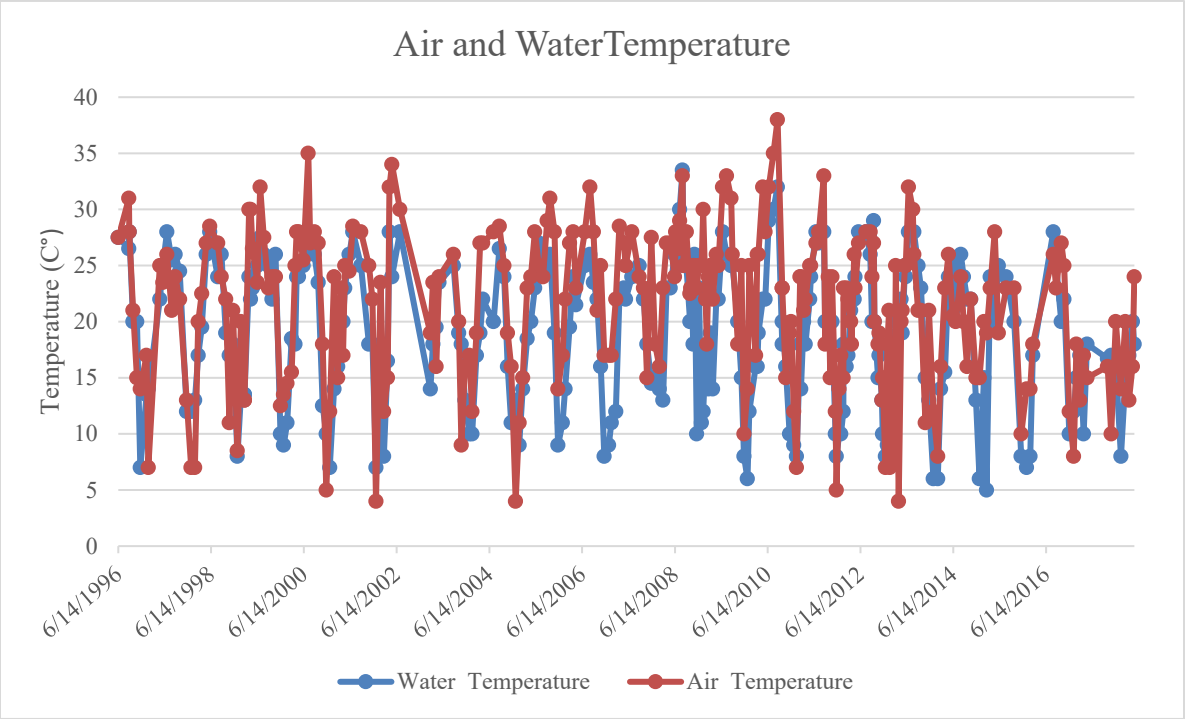

Figure 26: Air and water temperature at site 13553

Total Dissolved Solids

Citizen scientists collected 213 TDS measurements at this site. The mean TDS concentration was 408 mg/L. The minimum TDS measurement was recorded in November of 2000 and was 241 mg/L. The maximum TDS measurement was 592 mg/L and was recorded in May of 2003. There was no relationship between TDS concentrations and time observed at this site.

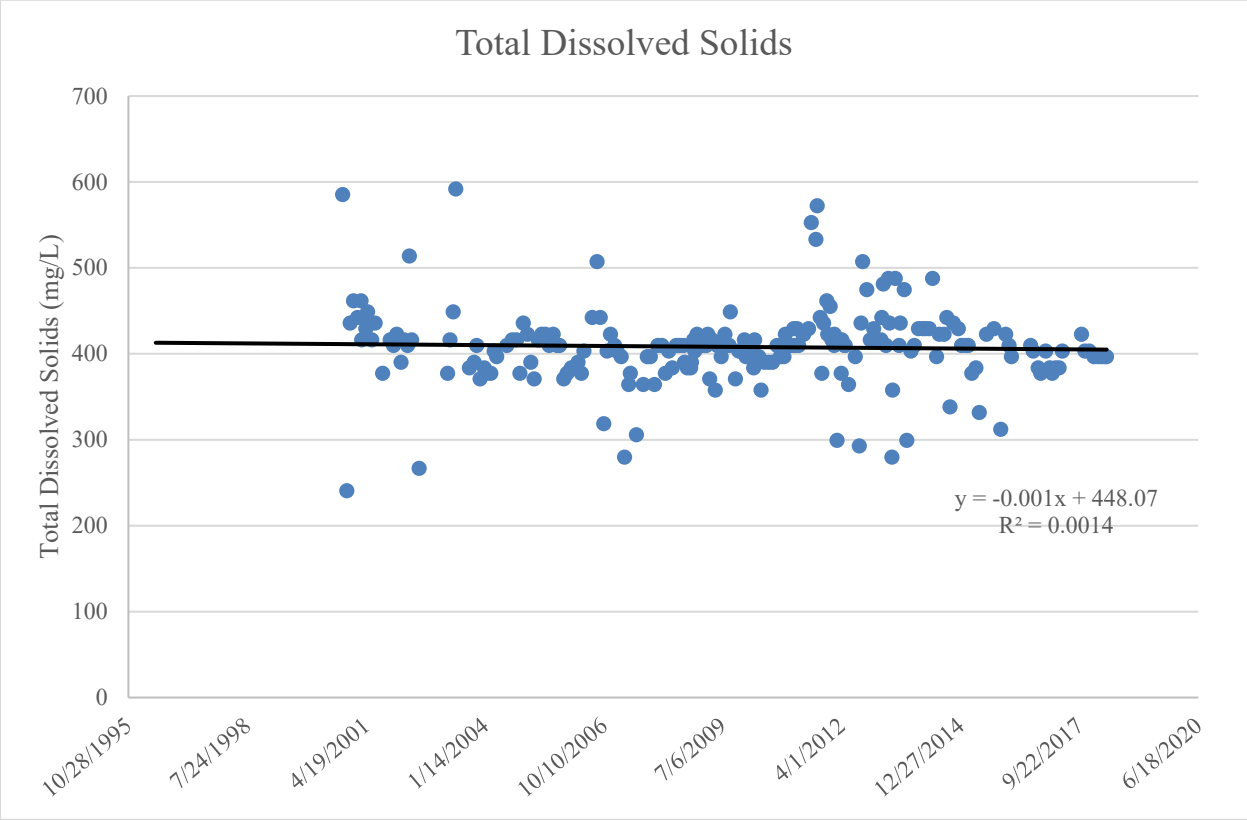

Figure 27: Total dissolved solids at site 13553

Dissolved Oxygen

Citizen scientists collected 271 DO samples at this site. The mean DO concentration was 7.1 mg/L and it ranged from a low of 2.4 mg/L in May of 2010 to a high of 11.4 mg/L in January of 2010. There was no relationship between DO concentrations and time observed at this site.

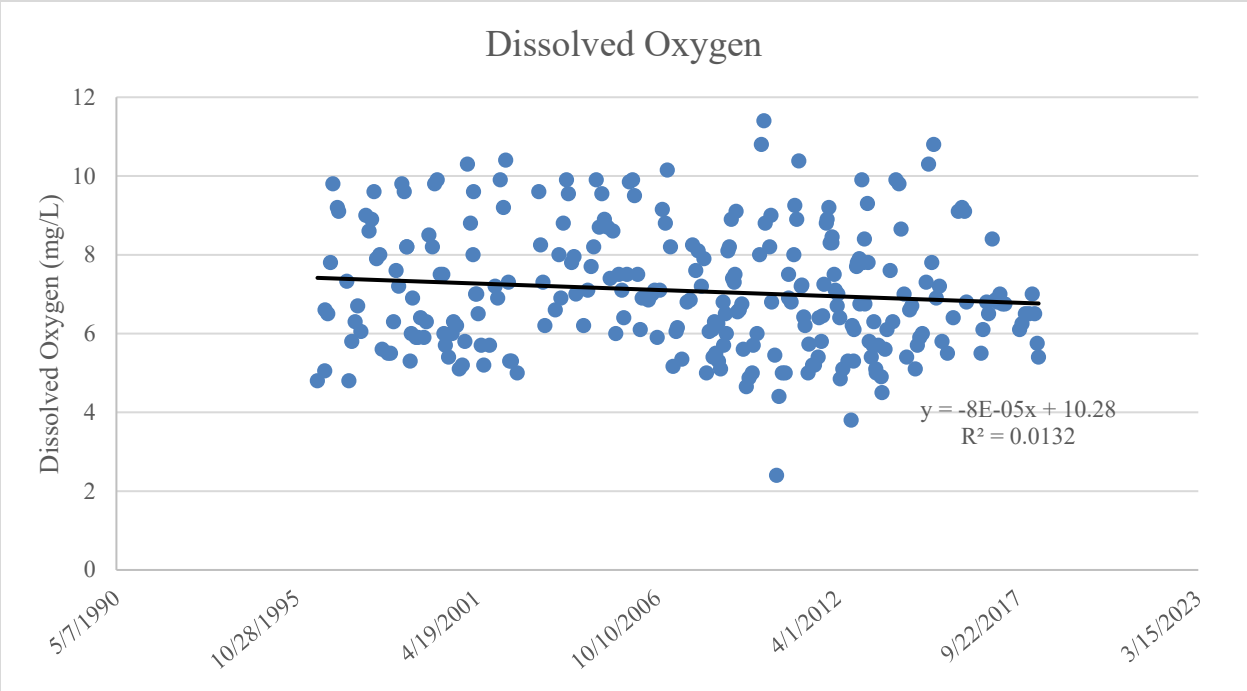

Figure 29: Dissolved oxygen at site 13553

pH

There were 266 pH samples taken at this site. The mean pH was 7.9 and it ranged from a low of 6.5 in September of 2007 to a high of 8.9 in July of 2000. There was no significant relationship between pH and time observed at this site.

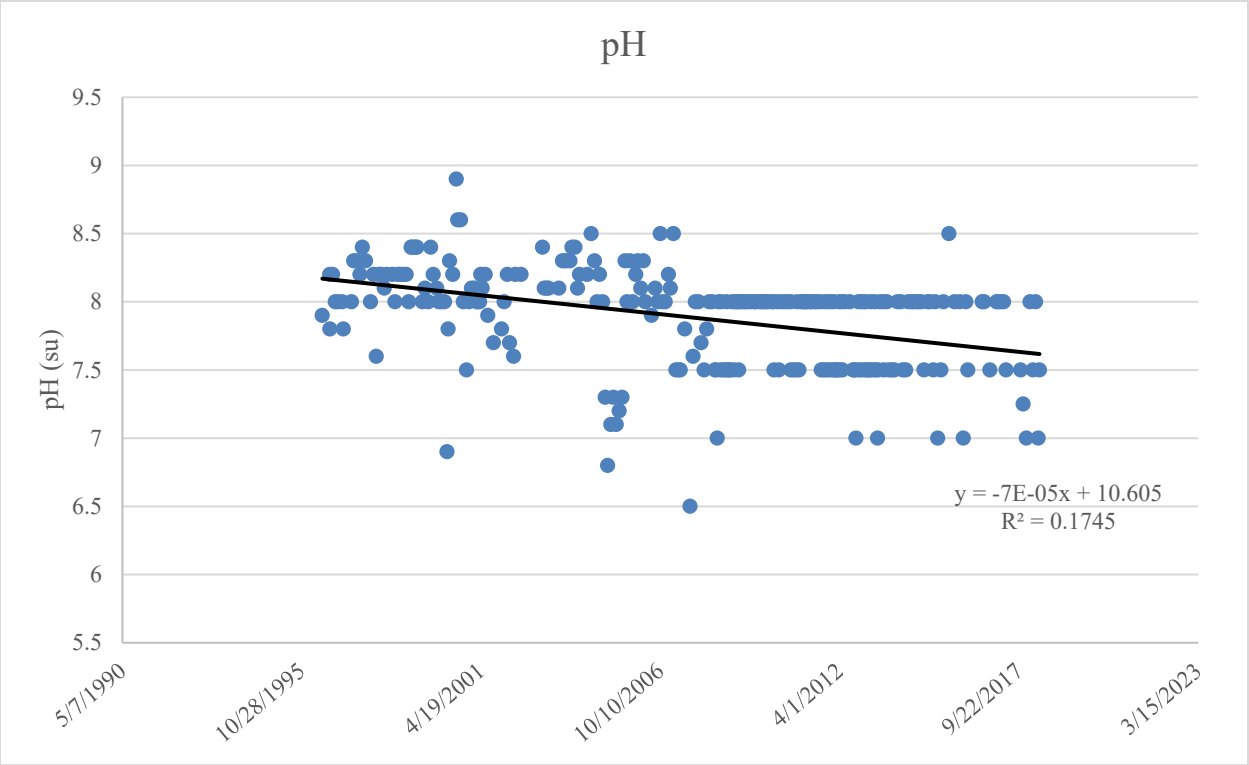

Figure 31: pH at site 13553

E. coli

Citizen scientists collected a total of 65 *E. coli* measurements at this site. The geomean was 69 CFU/100 mL. The minimum was 1 CFU/100 mL which occurred several times and the maximum was 820 CFU/100 mL which occurred in December of 2001. There was no significant increase or decrease in *E. coli* over time observed at this site.

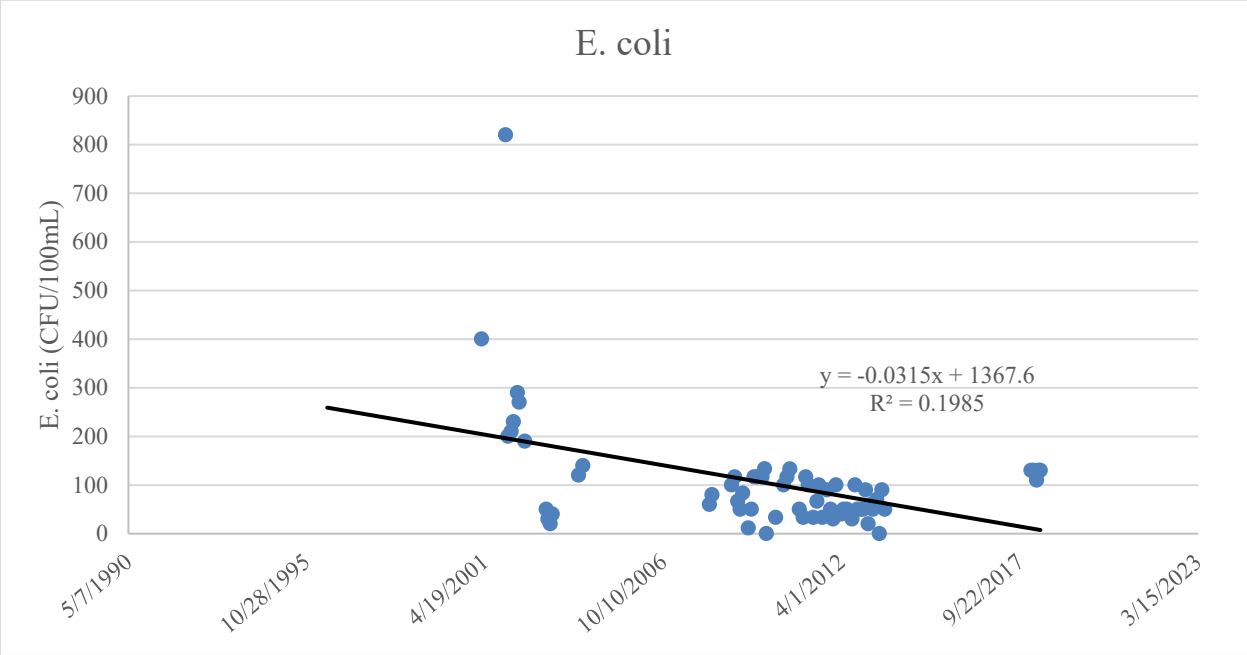

Figure 33: *E. coli* at site 13553

Nitrate Nitrogen

Citizen scientists collected 217 measuresments for Nitrate-Nitrogen. The mean value throughout the measurements was 0.98 mg/L, ranging from a low of 0.25 mg/L which occurred on multiple instances and had a high of 4.00 mg/L which occurred on December 1997.

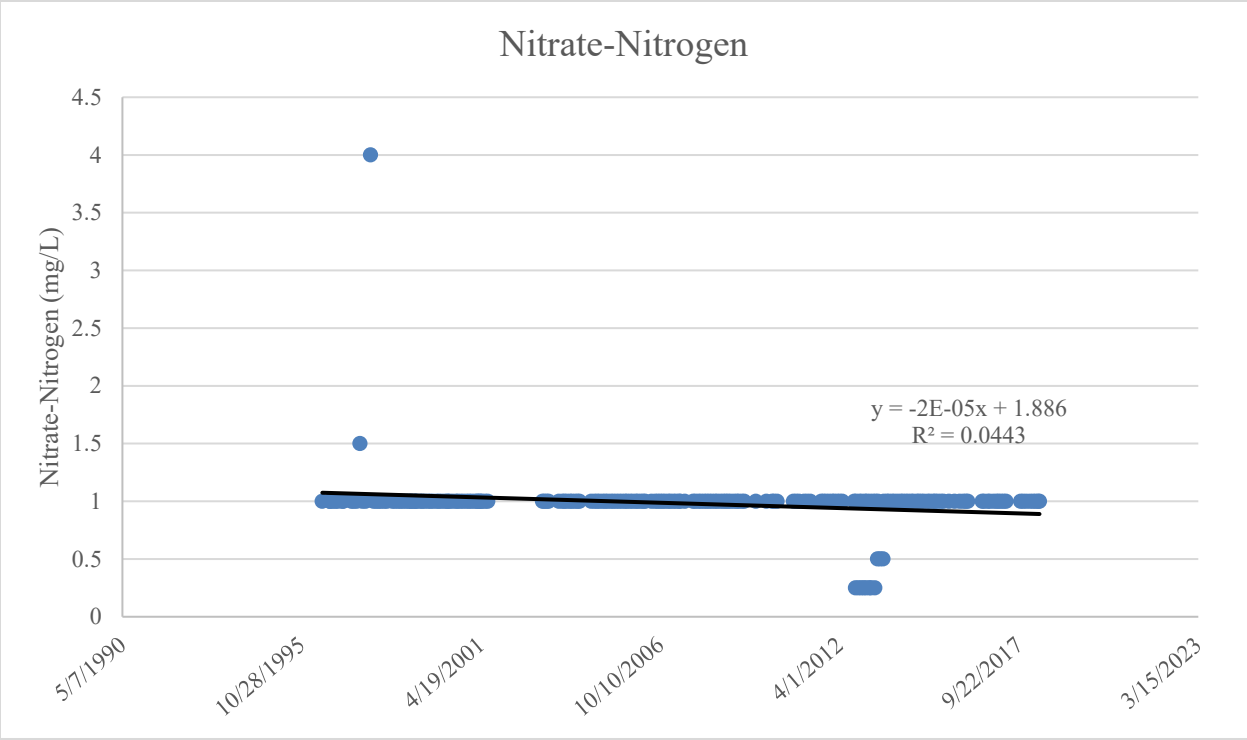

Figure 24: Nitrate-Nitrogen at site 13553

Site 80435 – Llano River at Mason County Road (CR) 2389

Site Description

Site 80435 is located on the lower, southernly section of the Llano River as it crosses CR 2389 in Mason County, TX, where the river bisects a large, dry, sparsly vegetated riverbed. The riverbed between the two sections of river crossed by CR 2389 appears to be subject to a high amount of illegal vehicular access. This site is immediately downstream of the James River and showcases a landscape dominated by ranches on rolling limestone terrain of the Edwards Plateau.

Sampling Information

This site was sampled 60 times from April 2007 to September 2018.

Table 8: Descriptive parameters for Site 80435

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	52	255 ± 30	195	377
Water Temperature (°C)	60	21.5 ± 6.8	9.0	34.0
Dissolved Oxygen (mg/L)	58	6.5 ± 1.5	3.6	10.0
pH	59	7.8 ± 0.4	7.0	8.5
Nitrate-Nitrogen	15	1.00 ± 0	1	1

Site 80435 was sampled 159 times between 4/17/2007 and 9/17/2018.

Air and water temperature

There were 60 air and water temperature measurements taken at this site. The mean water temperature was 21.5°C. The minimum water temperature was 9.0°C and was recorded in December of 2017. The maximum water temperature was 34.0°C and was recorded in August of 2009. The air temperature ranged from a low of 7.5 °C recorded in December of 2016 to a high of 36°C recorded in June of 2009.

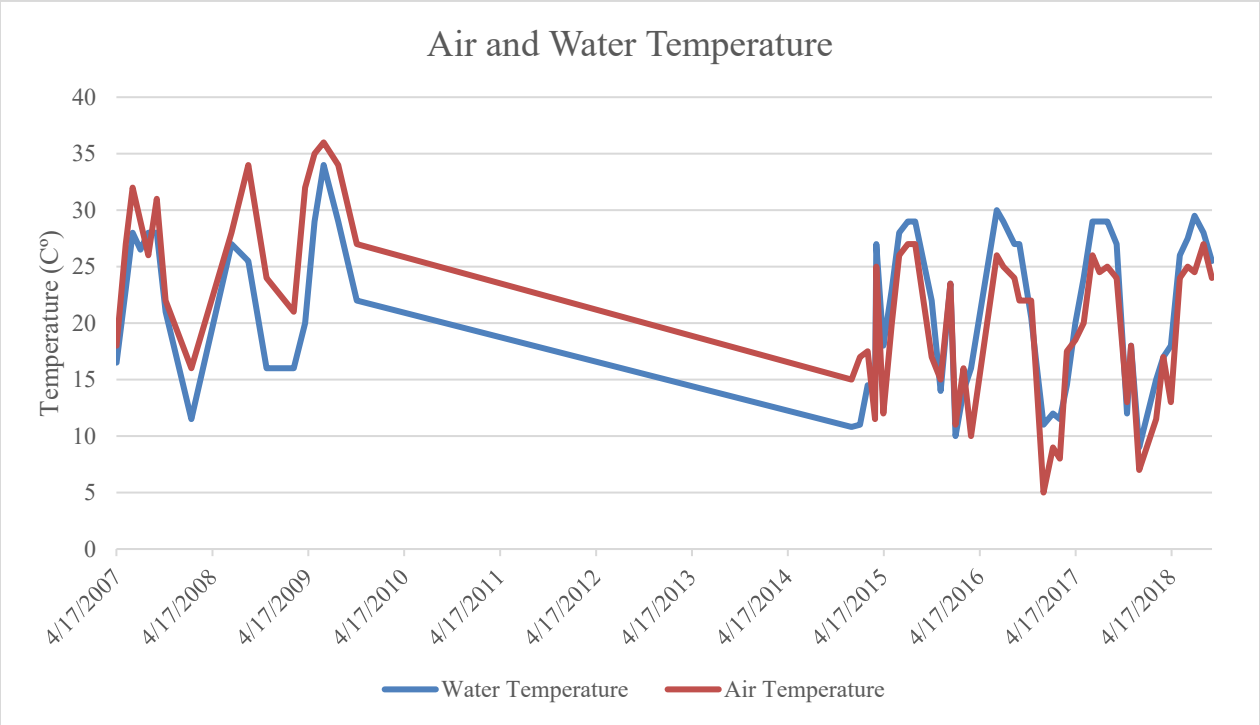

Figure 26: Air and water temperature at site 80435

Total Dissolved Solids

Citizen scientists collected 52 TDS measurements at this site. The mean TDS concentration was 255 mg/L. The minimum TDS measurement was recorded in May of 2018 and was 195 mg/L. The maximum TDS measurement was 377 mg/L and was recorded in February of 2015. There was no relationship between TDS concentrations and time observed at this site.

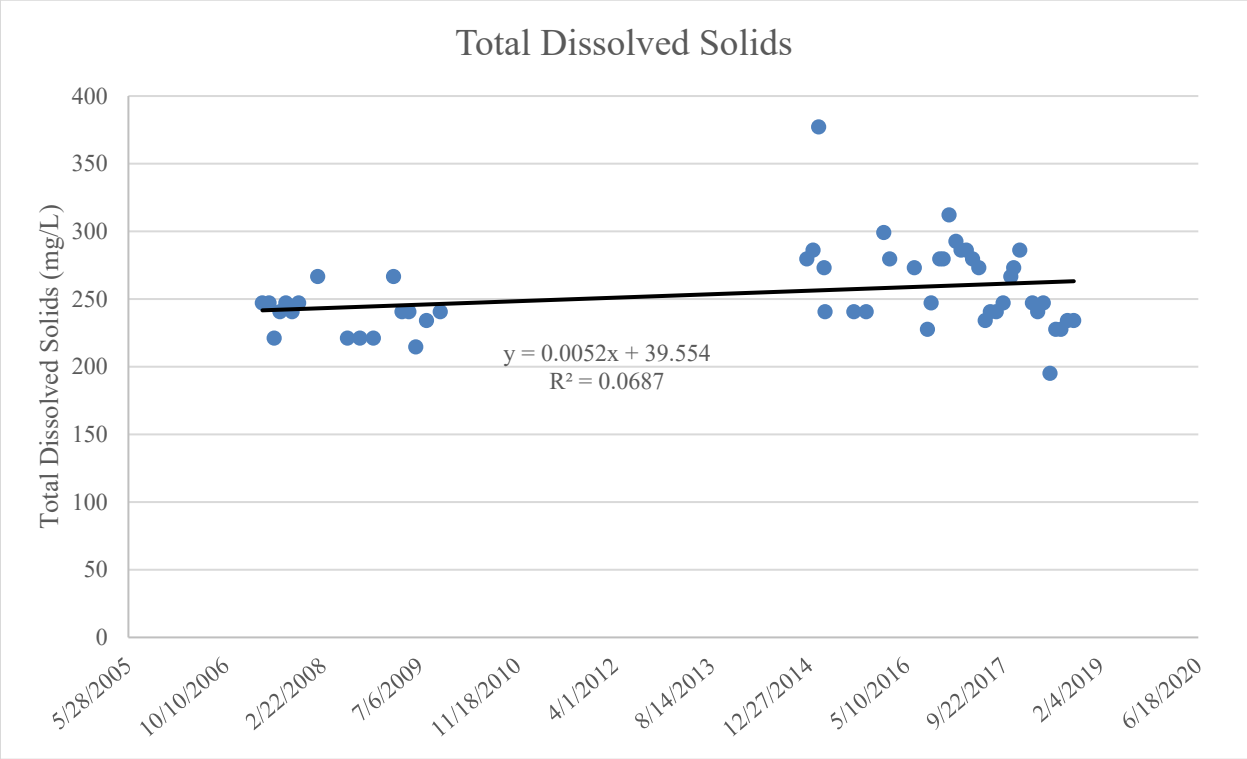

Figure 27: Total dissolved solids at site 80435

Dissolved Oxygen

Citizen scientists collected 58 DO samples at this site. The mean DO concentration was 6.5 mg/L and it ranged from a low of 3.6 mg/L in July of 2013 to a high of 10 mg/L in January of 2015. There was no relationship between DO concentrations and time observed at this site.

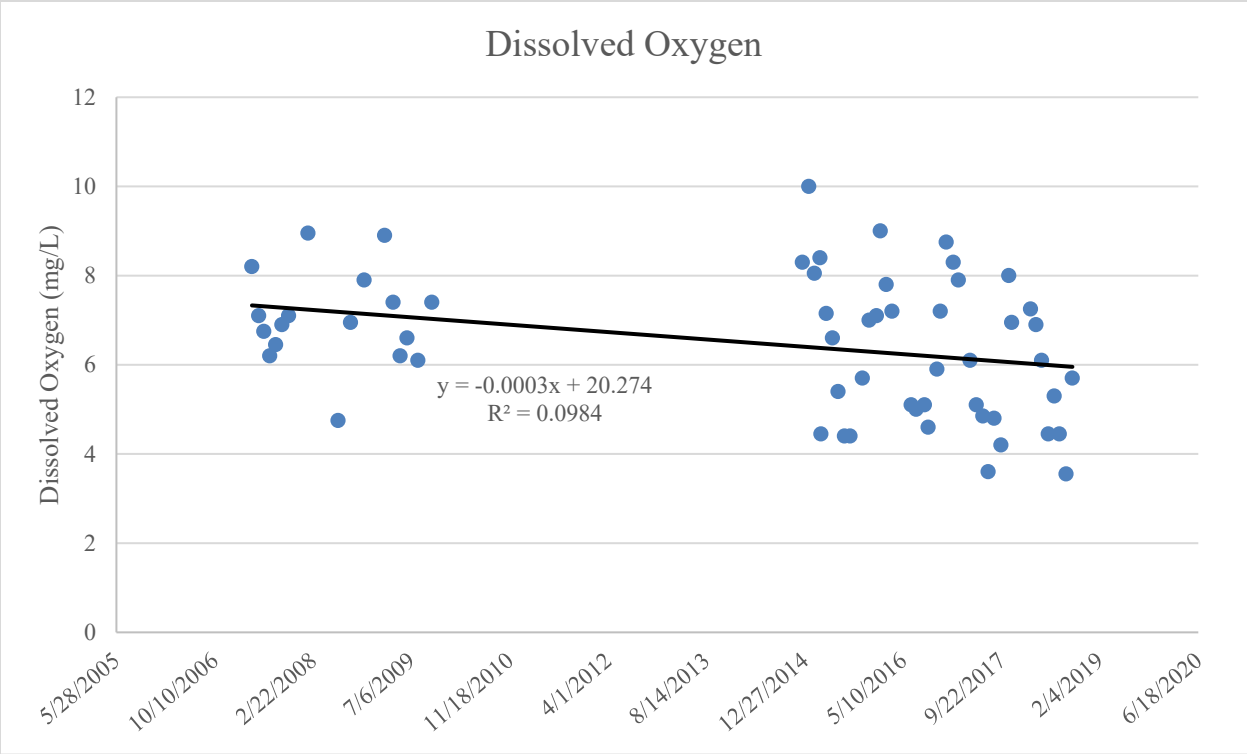

Figure 29: Dissolved oxygen at site 80435

pH

There were 59 pH samples taken at this site. The mean pH was 7.8 and it ranged from a low of 7.0 in multiple instances and to a high of 8.5 which also occurred several times. There was no significant relationship between pH and time observed at this site.

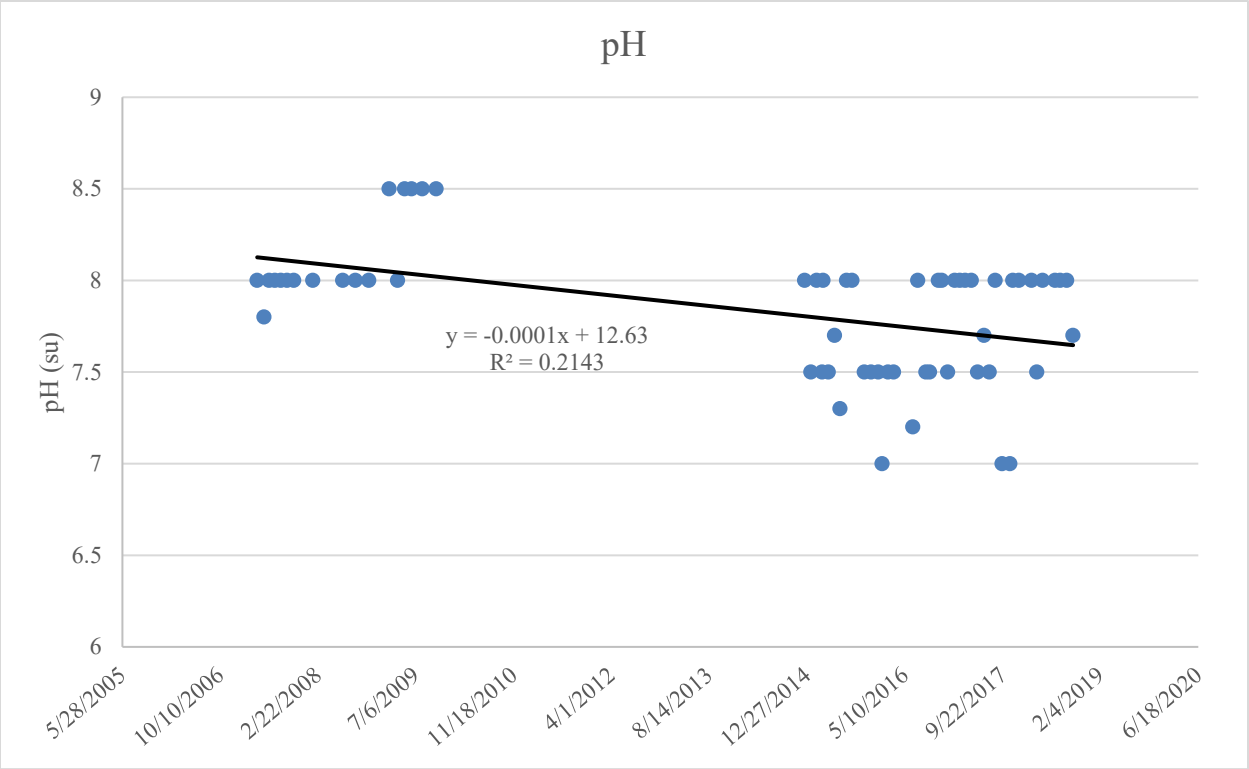

Figure 31: pH at site 80435

Nitrate-Nitrogen

Citizen scientists collected 15 measuresments for Nitrate-Nitrogen, each calculating a value of 1 mg/L of Nitrate-Nitrogen.

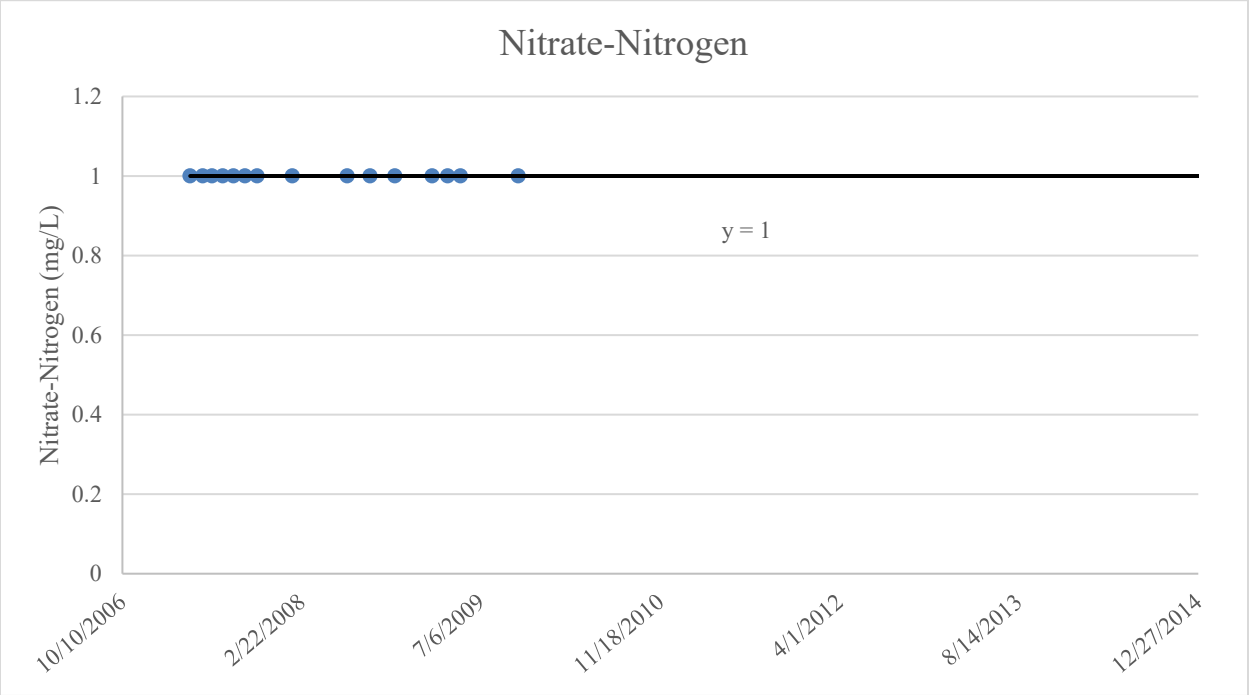

Figure 24: Nitrate-Nitrogen at site 80435

Site 81501 – Llano River at Willow Creek

Site Description

This site, near Mason, TX, is located immediately downstream of the Willow Creek confluence with the Llano River on the northern side of the river. Willow Creek is a seasonal stream which flows southward through the Edwards Plateau and Llano Uplift. Its headwaters drain ranches and small farms east of the Mason Mountain Wildlife Management Area, where there are numerous small dams on its headwater streams. Site 81501 is located approximately three miles downstream of U.S. Route 87 at the Llano river and is two miles downstream of the confluence with Beaver Creek, a seasonal stream which flows northward across the Edwards Plateau, draining rugged hill country and the unincorporated farming and ranching communities of Hilda, Doss, and Cherry Spring.

Sampling Information

This site was sampled 17 times from April 2017 to September 2018.

Table 8: Descriptive parameters for Site 81501

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	17	236 ± 25	189	286
Water Temperature (°C)	17	22.2 ± 6.9	9.2	31.5
Dissolved Oxygen (mg/L)	17	6.2 ± 1.8	4.0	9.7
pH	17	7.5 ± 0.3	7.0	8.0
E. coli	14	8 ± 36	1	130
Nitrate-Nitrogen	15	1 ± 0	1	2

Site 81501 was sampled 17 times between 4/1/2017 and 9/15/2018.

Air and water temperature

There were 17 air and water temperature measurements taken at this site. The mean water temperature was 22.2°C. The minimum water temperature was 9.2°C and was recorded in December of 2017. The maximum water temperature was 31.5°C and was recorded in July of 2017. The air temperature ranged from a low of 5.5°C recorded in December of 2017 to a high of 31.5°C recorded in July of 2017.

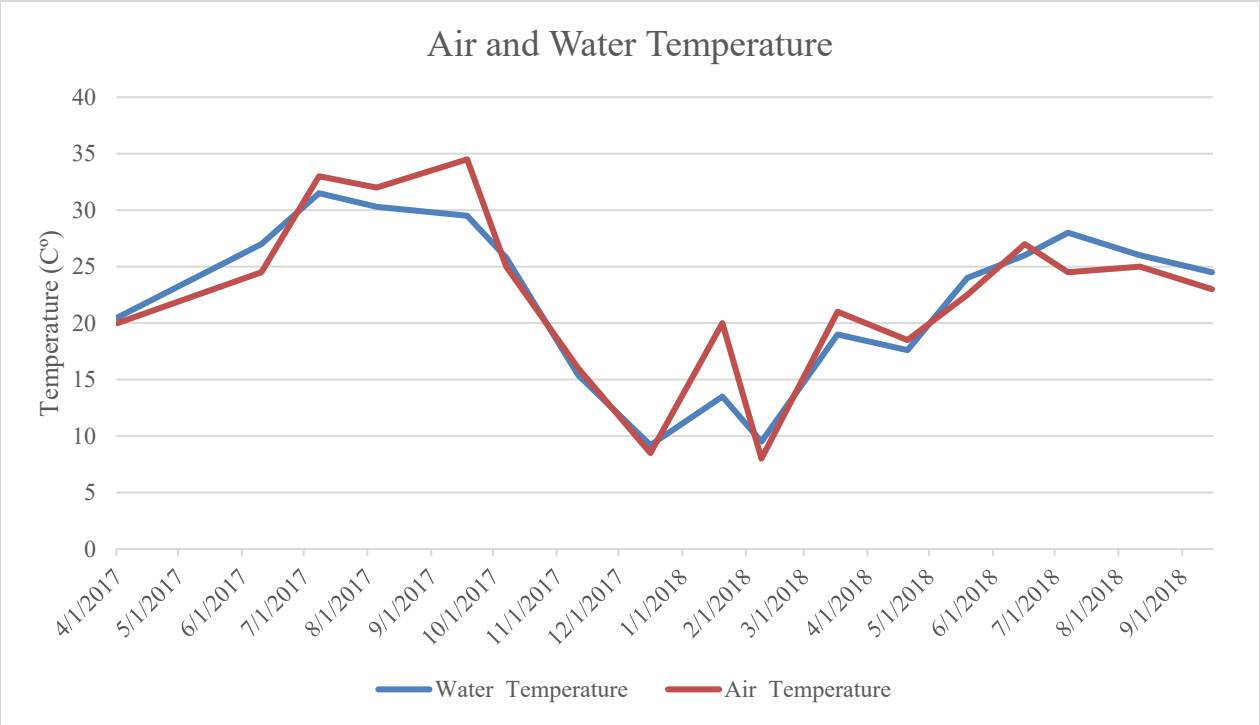

Figure 26: Air and water temperature at site 81501

Total Dissolved Solids

Citizen scientists collected 17 TDS measurements at this site. The mean TDS concentration was 236 mg/L. The minimum TDS measurement was recorded in May of 2018 and was 187 mg/L. The maximum TDS measurement was 286 mg/L and was recorded in April of 2017. There was no relationship between TDS concentrations and time observed at this site.

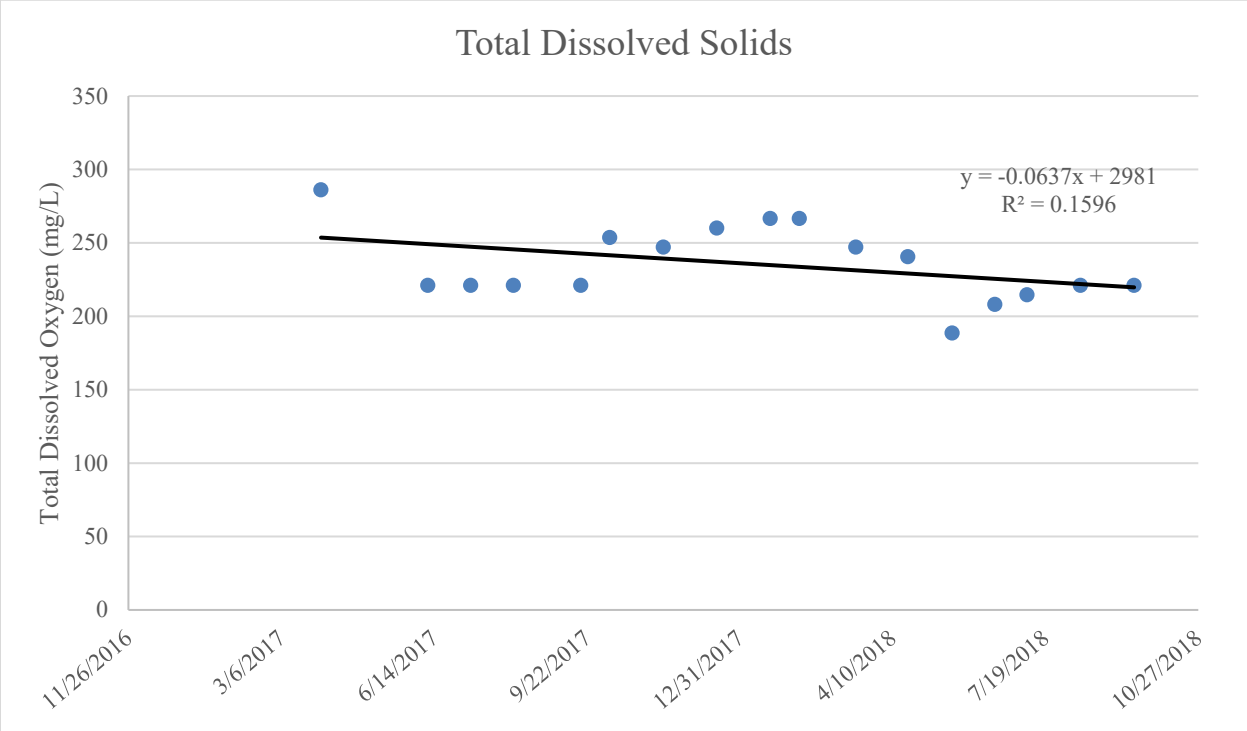

Figure 27: Total dissolved solids at site 81501

Dissolved Oxygen

Citizen scientists collected 17 DO samples at this site. The mean DO concentration was 6.2 mg/L and it ranged from a low of 4.0 mg/L in August of 2018 to a high of 9.7 mg/L in December of 2017. There was no relationship between DO concentrations and time observed at this site.

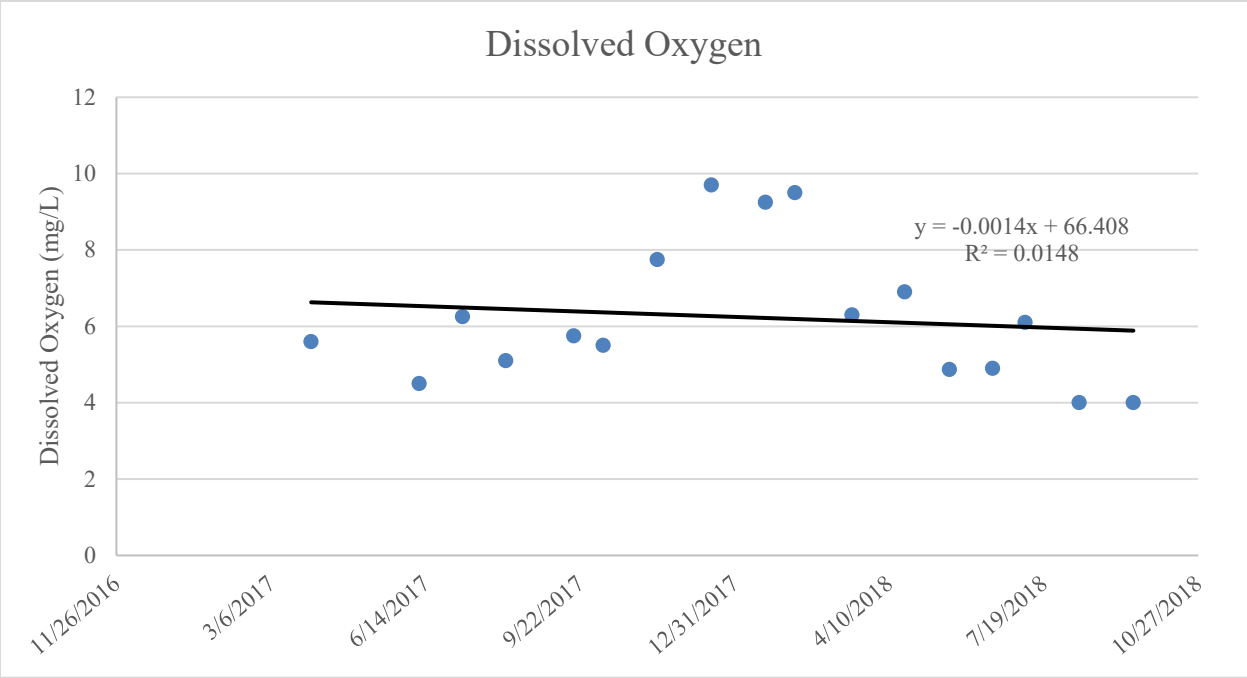

Figure 29: Dissolved oxygen at site 81501

pH

There were 17 pH samples taken at this site. The mean pH was 7.5 and it ranged from a low of 7.0 which occurred on multiple instances to a high of 8 which also occurred several times. There was no significant relationship between pH and time observed at this site.

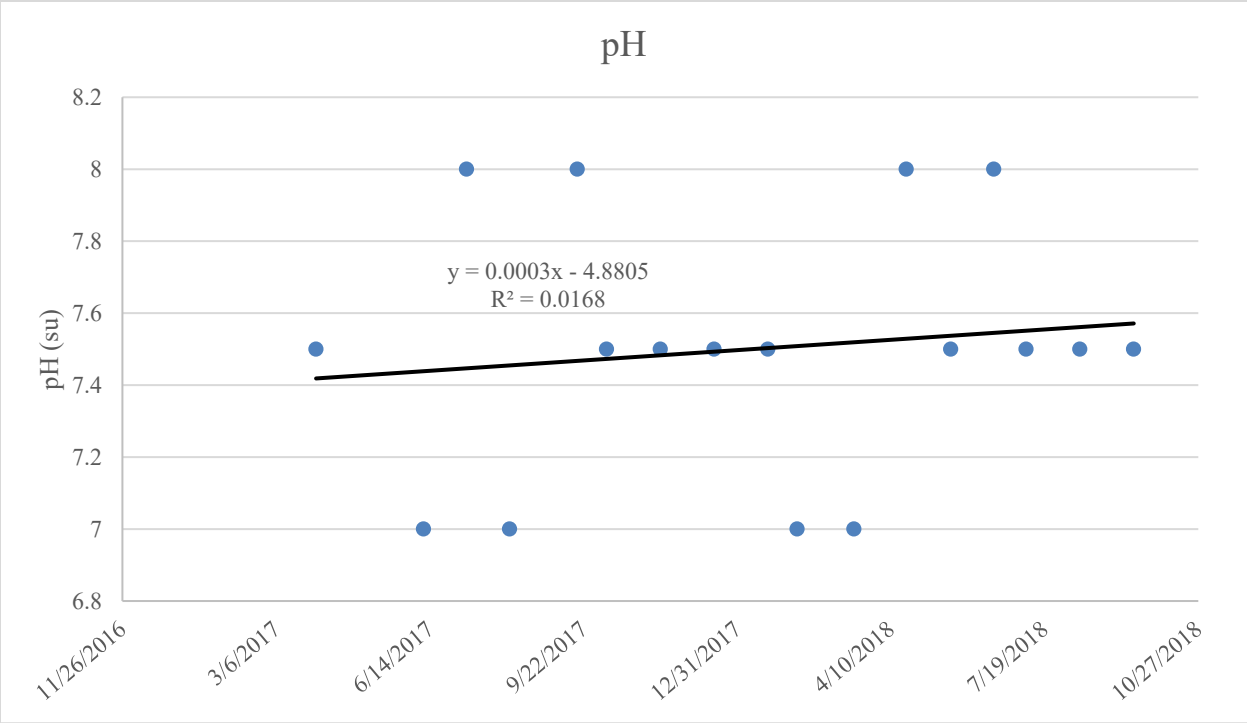

Figure 31: pH at site 81501

E. coli

Citizen scientists collected a total of 14 *E. coli* measurements at this site. The geomean was 8 CFU/100 mL. The minimum was 1 CFU/100 mL which occurred several times and the maximum was 130 CFU/100 mL which occurred in May of 2018. There was no significant increase or decrease in *E. coli* over time observed at this site.

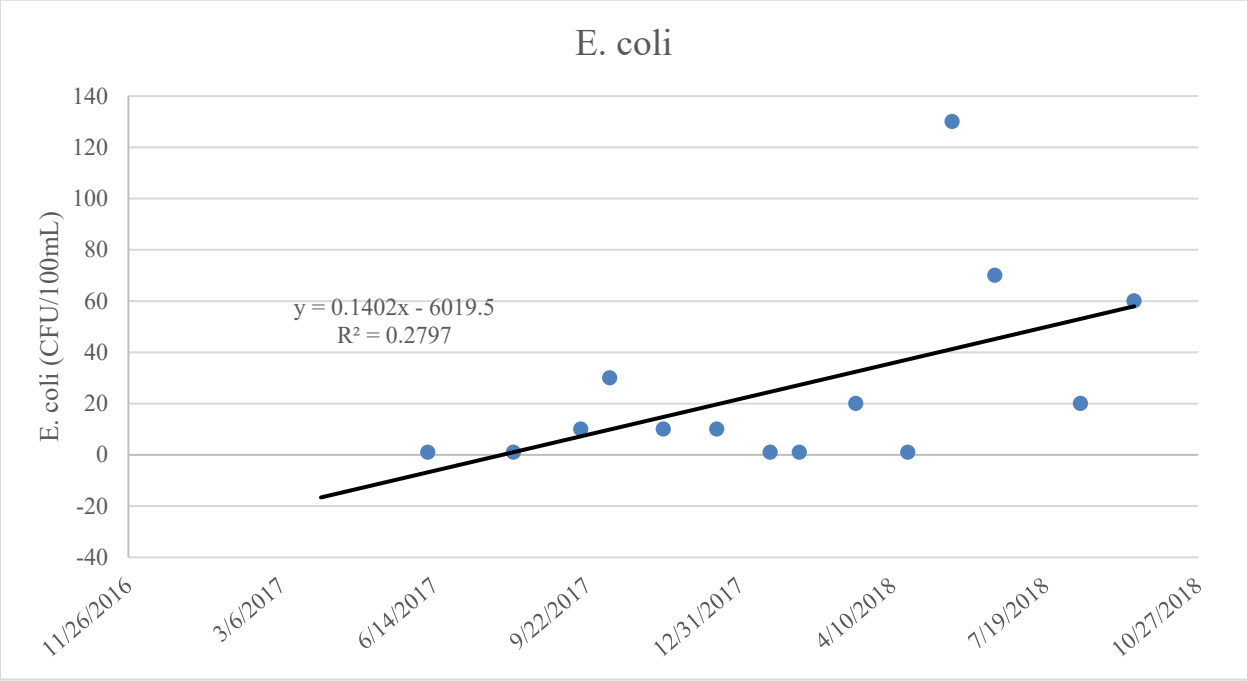

Figure 33: *E. coli* at site 81501

Nitrate Nitrogen

Citizen scientists collected 15 measuresments for Nitrate-Nitrogen with a mean value of 1 mg/L. The values ranged from 1 to 2 mg/L, each value occurring on multiple instances.

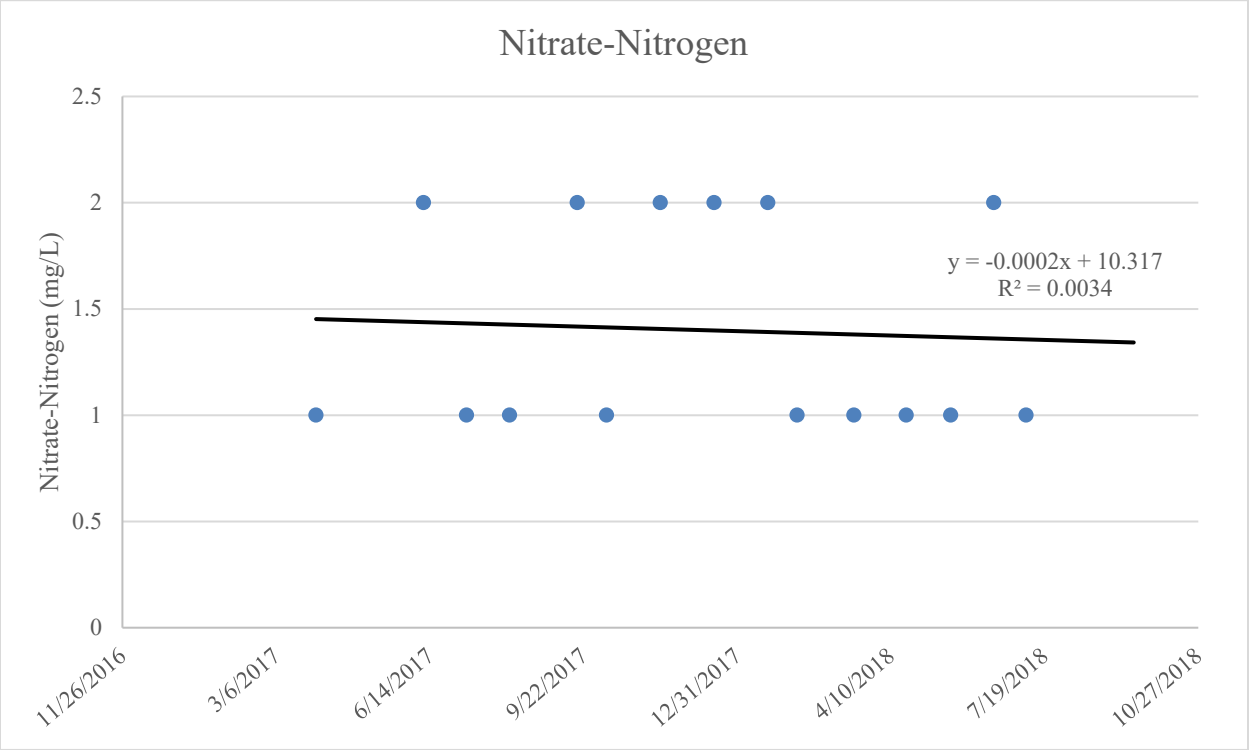

Figure 24: Nitrate-Nitrogen at site 81501

Site 12387 – Llano River 3.2 km west of Llano, Upstream of Dam in Robinson City Park

Site Description

Site 12387 monitors the river where it is dammed by a small dam as the Robinson City Park in Llano, TX. The site is approximately a mile downstream of the usually dry Johnson Creek, which flows southward towards the Llano River from the ranches and numerous farms between unincorporated Valley Spring and the City of Llano. The site is nearly 2 miles upstream of downtown Llano. In 2018, it was noted that instream sand-and-gravel mining operations were occurring on the Llano River here and immediately downstream of Site 12387.

Sampling Information

This site was sampled 130 times from May 1996 to September 2018.

Table 8: Descriptive parameters for Site 12387

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	110	247 ± 29	156	319
Water Temperature (°C)	130	20.0 ± 7.5	3.0	32.0
Dissolved Oxygen (mg/L)	130	7.4 ± 2.0	3.9	11.7
pH	125	7.9 ± 0.5	7.0	9.5
E. coli	13	35 ± 133	1	410
Nitrate-Nitrogen	127	1 ± 0.27	0.5	4.0

Site 12387 was sampled 130 times between 5/20/1996 and 9/5/2018.

Air and water temperature

There were 130 air and water temperature measurements taken at this site. The mean water temperature was 20.0°C. The minimum water temperature was 3.0 °C and was recorded in January of 2018. The maximum water temperature was 32.0 °C and was recorded in July of 1998 and 1999 and in August of 2011. The air temperature ranged from a low of 1.0°C recorded in February of 2014 to a high of 36°C recorded in May of 1996.

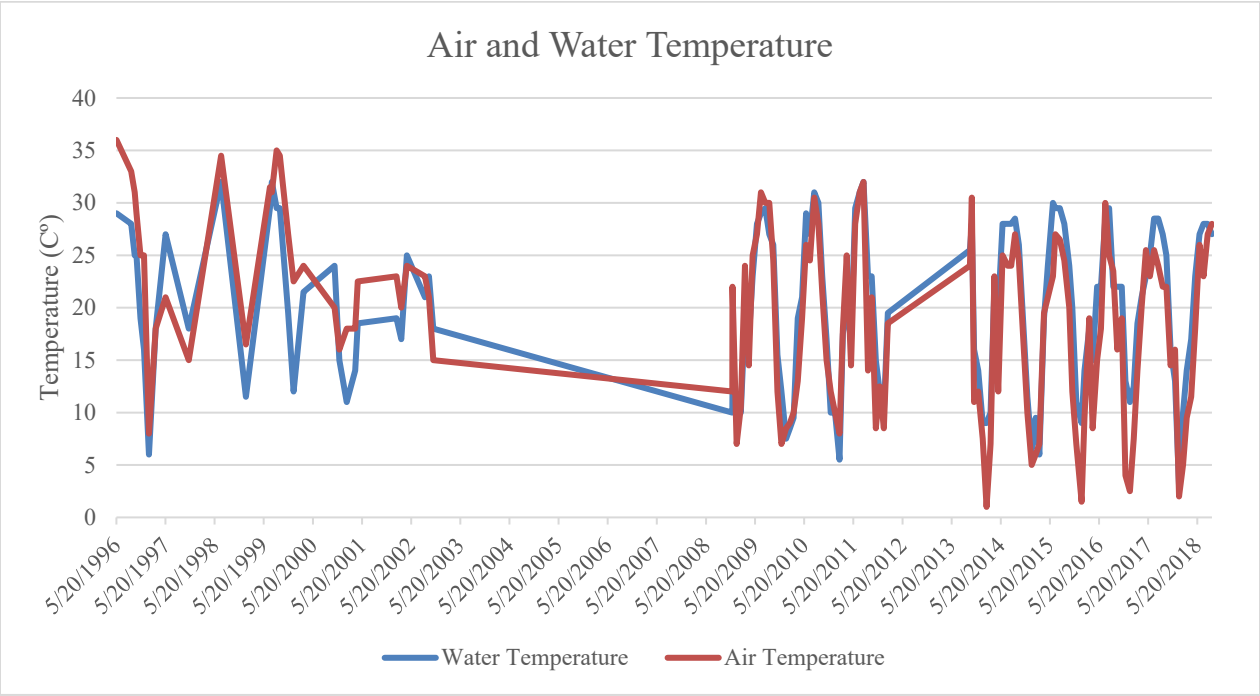

Figure 26: Air and water temperature at site 12387

Total Dissolved Solids

Citizen scientists collected 110 TDS measurements at this site. The mean TDS concentration was 247 mg/L. The minimum TDS measurement was recorded in June of 2016 and was 156 mg/L. The maximum TDS measurement was 319 mg/L and was recorded in December of 2000. There was no relationship between TDS concentrations and time observed at this site.

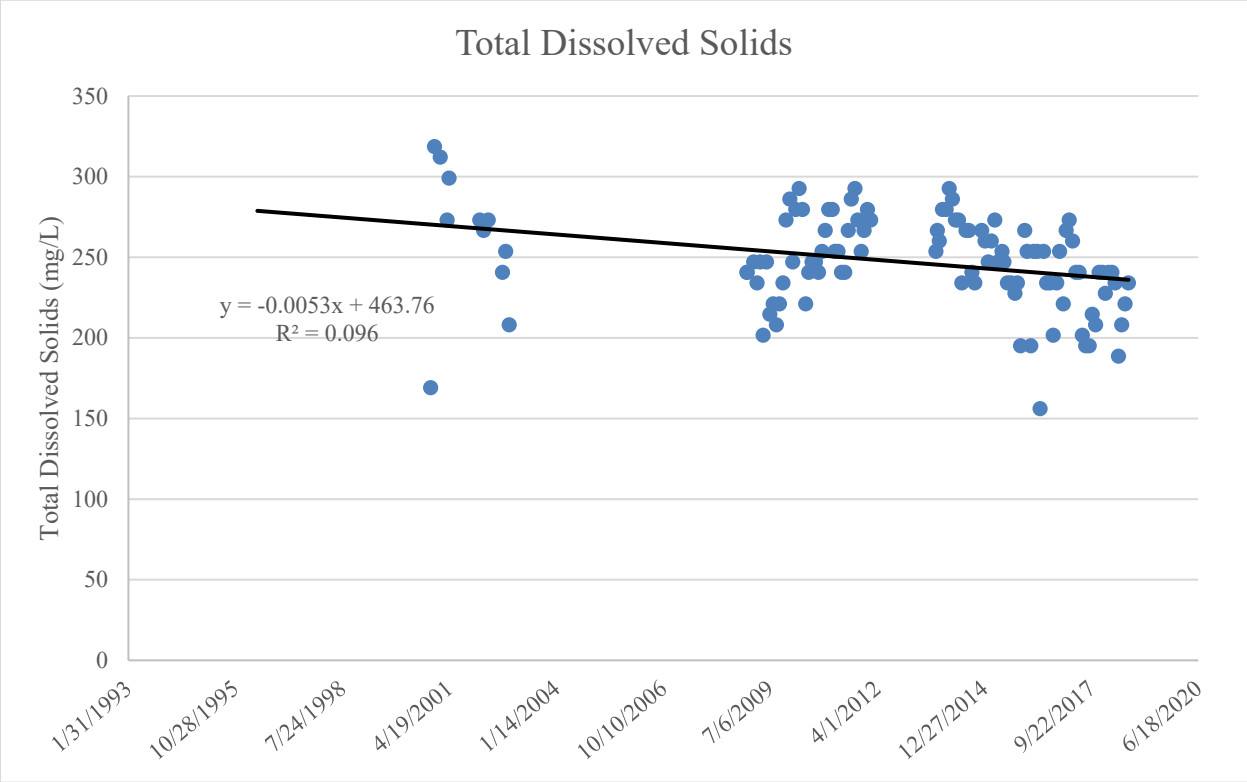

Figure 27: Total dissolved solids at site 12387

Dissolved Oxygen

Citizen scientists collected 130 DO samples at this site. The mean DO concentration was 7.4 mg/L and it ranged from a low of 3.9 mg/L in October of 2013 to a high of 11.7 mg/L in December of 1996. There was no relationship between DO concentrations and time observed at this site.

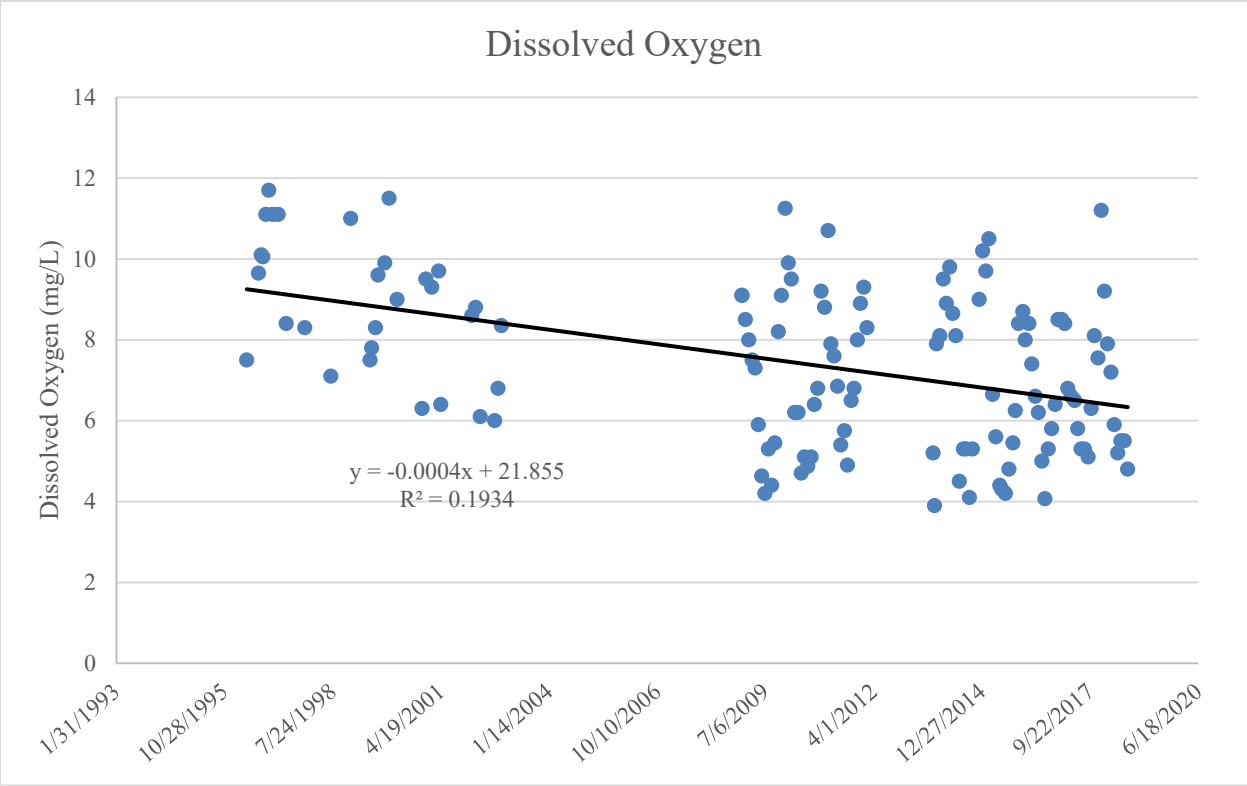

Figure 29: Dissolved oxygen at site 12387

pH

There were 125 pH samples taken at this site. The mean pH was 7.9 and it ranged from a low of 7.0 on multiple instances to a high of 9.5 which occurred in May of 1996. There was no significant relationship between pH and time observed at this site.

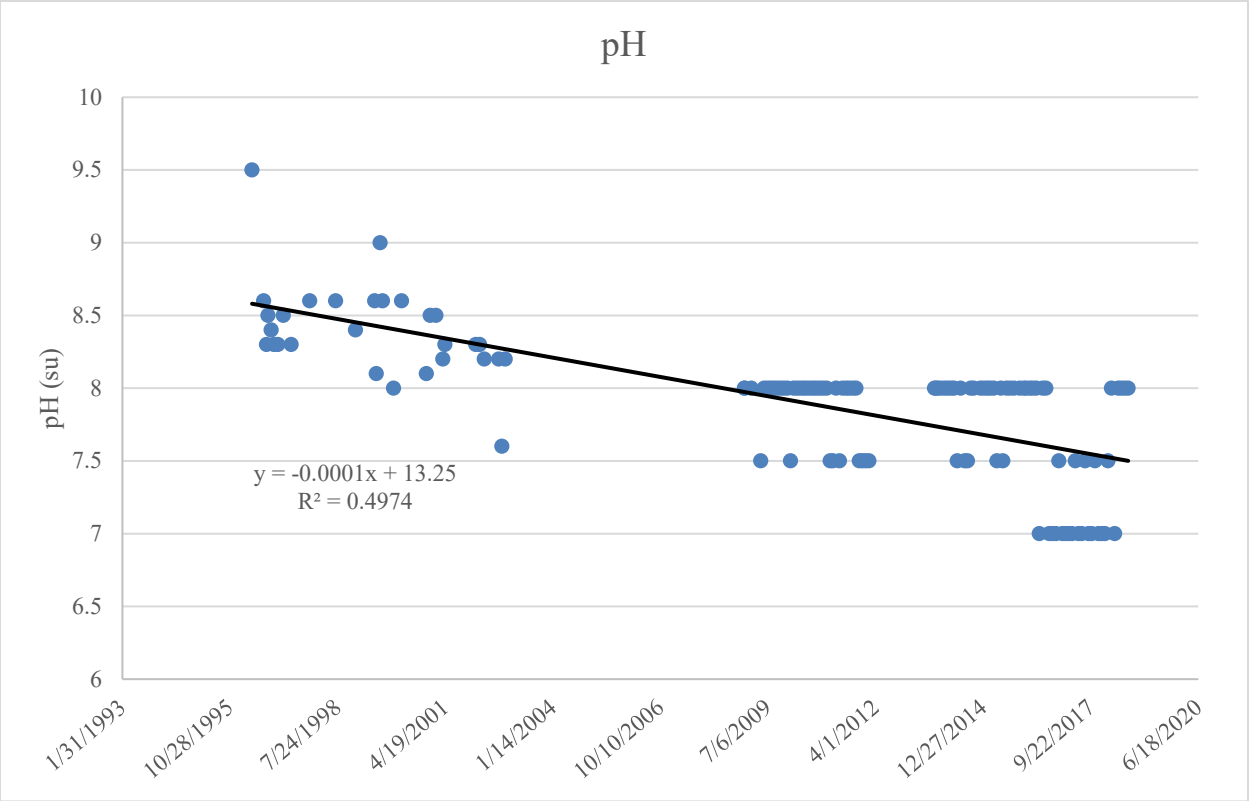

Figure 31: pH at site 12387

E. coli

Citizen scientists collected a total of 13 *E. coli* measurements at this site. The geomean was 35 CFU/100 mL. The minimum was 1 CFU/100 mL which occurred several times and the maximum was 410 CFU/100 mL which occurred in March of 2001. There was no significant increase or decrease in *E. coli* over time observed at this site.

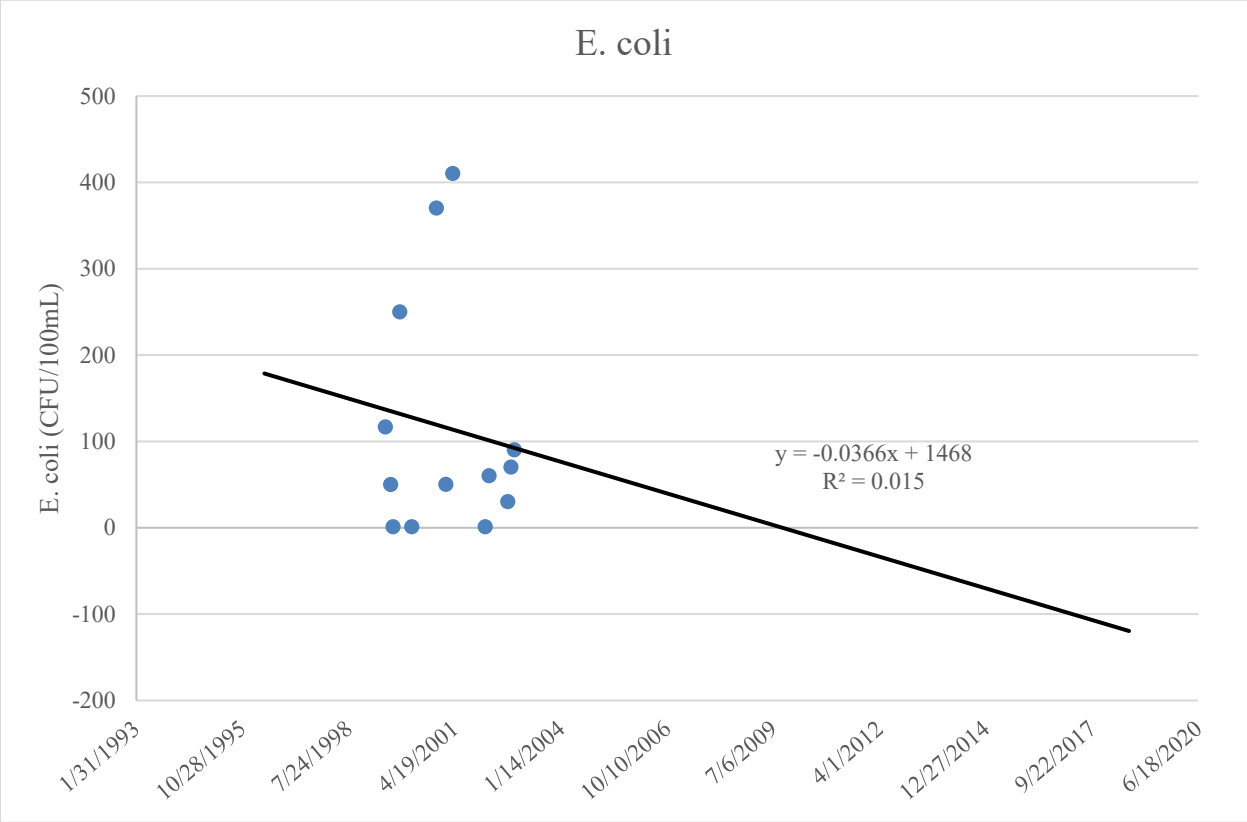

Figure 33: *E. coli* at site 12387

Nitrate-Nitrogen

Citizen scientists collected 127 measuresments for Nitrate-Nitrogen with a mean value of 1.02 mg/L. Values ranged from a low of 0.5 mg/L in September of 2014 to a high of 4 mg/L in December of 2000.

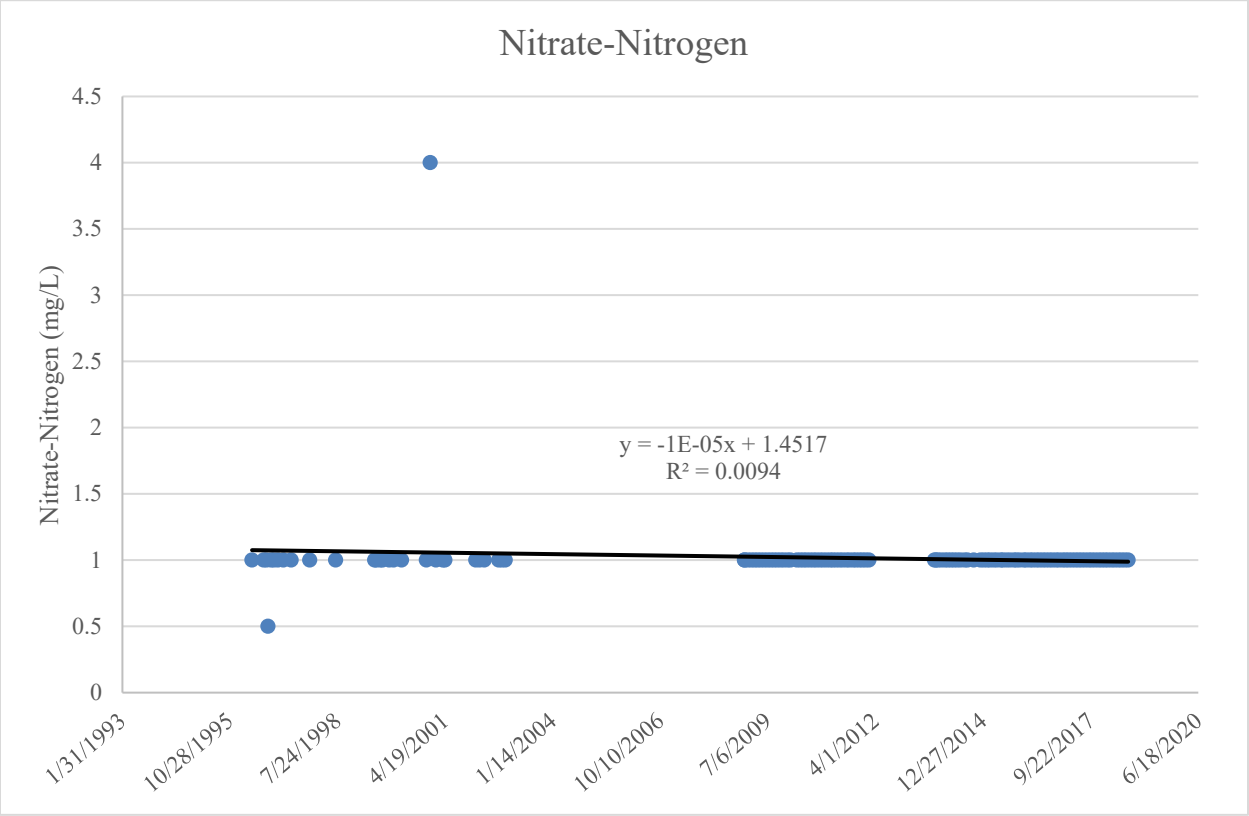

Figure 24: Nitrate-Nitrogen at site 12387

Site 12383 – Llano River at RR 3404

Site Description

This site is located on the Llano River at RR 3404, which is a popular spot for recreationists, known as "The Slab," on the northwestern edge of Kingsland, TX. The crossing of RR 3404 and the Llano River is nearly 2.2 kilometers upstream of the river's confluence with Honey Creek. Within a kilometer of this confluence, the Llano River begins to form its arm of Lake LBJ.

Sampling Information

This site was sampled 217 times from March 2001 to September 2018.

Table 8: Descriptive parameters for Site 12383

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	215	250 ± 28	150	423
Water Temperature (°C)	216	20.5 ± 6.1	8.0	33.0
Dissolved Oxygen (mg/L)	216	7.3 ± 1.5	3.7	10.8
pH	213	7.9 ± 0.3	7.0	9.0
E. coli	41	8 ± 35	1	120
Nitrate-Nitrogen	65	0.26 ± 0.09	0.25	1.0

Site 12338 was sampled 217 times between 3/13/2001 and 9/10/2018.

Air and water temperature

There were 217 air and 216 water temperature measurements taken at this site. The mean water temperature was 20.5°C. The minimum water temperature was 8.0 °C and was recorded in multiple instances. The maximum water temperature was 33°C and was recorded in June of 2006. The air temperature ranged from a low of 6.0 °C recorded in March of 2009 to a high of 39°C recorded in August of 2007.

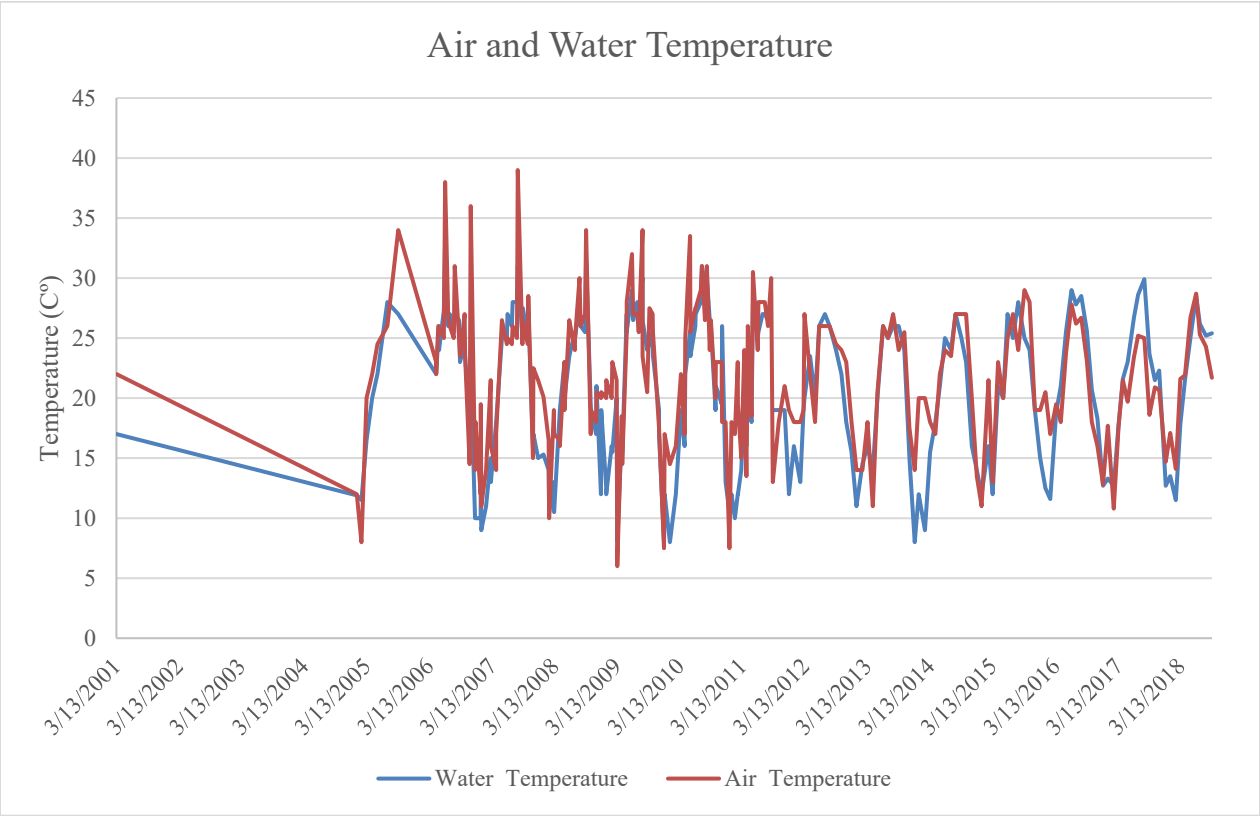

Figure 26: Air and water temperature at site 12383

Total Dissolved Solids

Citizen scientists collected 215 TDS measurements at this site. The mean TDS concentration was 250 mg/L. The minimum TDS measurement was recorded in October of 2011 and was 150 mg/L. The maximum TDS measurement was 423 mg/L and was recorded in September of 2011. There was no relationship between TDS concentrations and time observed at this site.

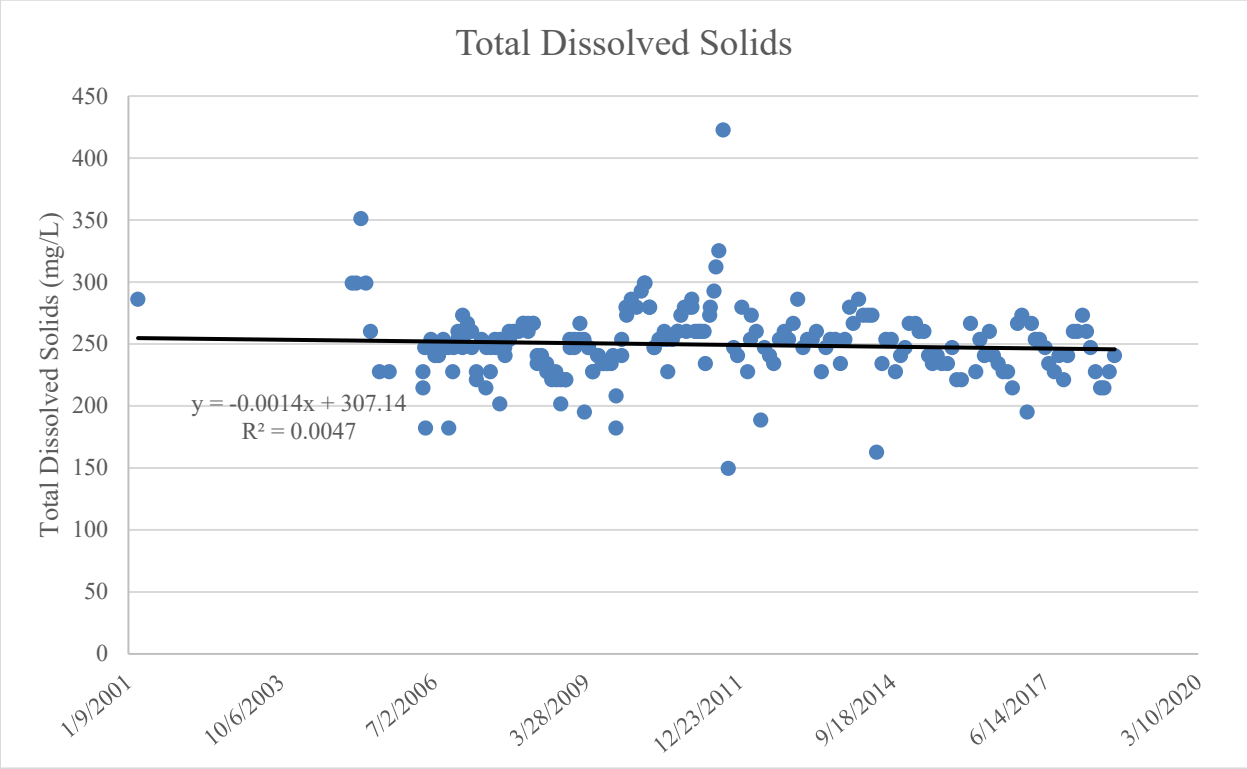

Figure 27: Total dissolved solids at site 12383

Dissolved Oxygen

Citizen scientists collected 215 DO samples at this site. The mean DO concentration was 7.3 mg/L and it ranged from a low of 3.7 mg/L in July of 2011 to a high of 10.8 mg/L in January of 2010. There was no relationship between DO concentrations and time observed at this site.

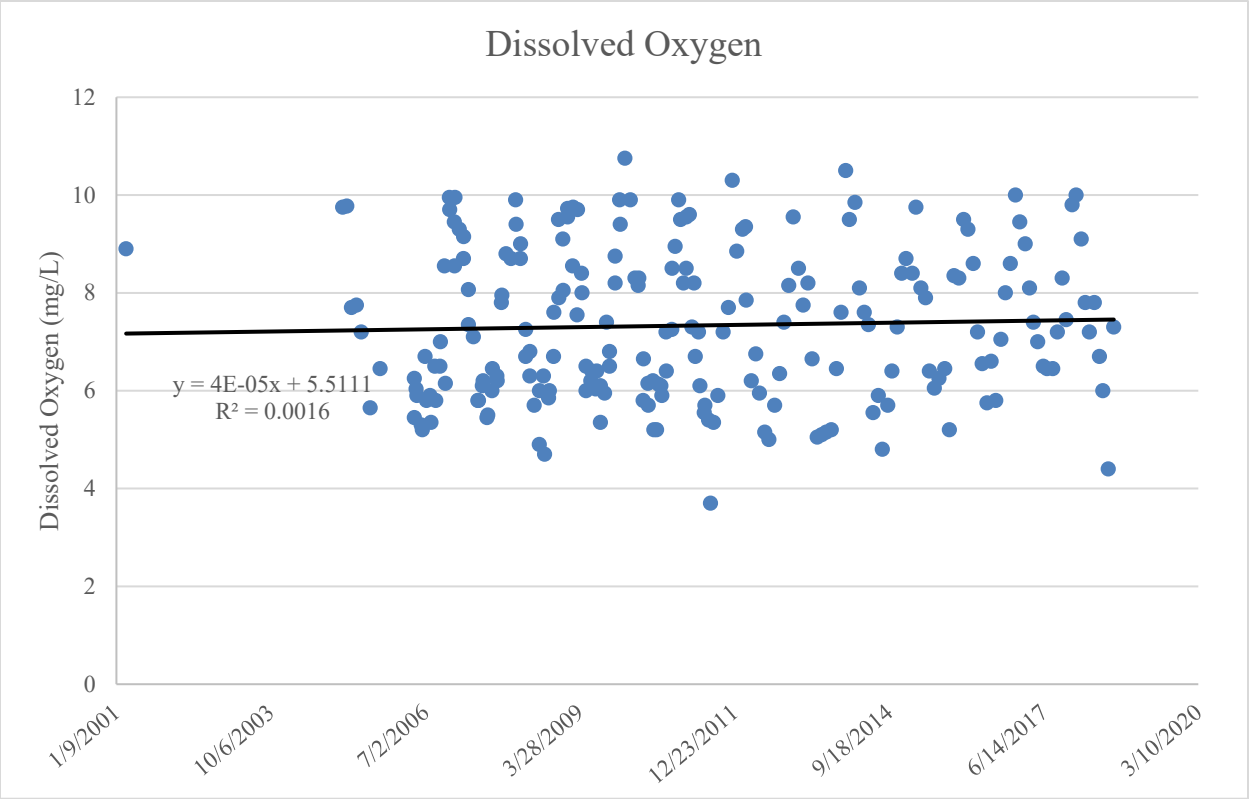

Figure 29: Dissolved oxygen at site 12383

pH

There were 213 pH samples taken at this site. The mean pH was 7.9 and it ranged from a low of 7.0 in multiple instances to a high of 9 in August of 2011. There was no significant relationship between pH and time observed at this site.

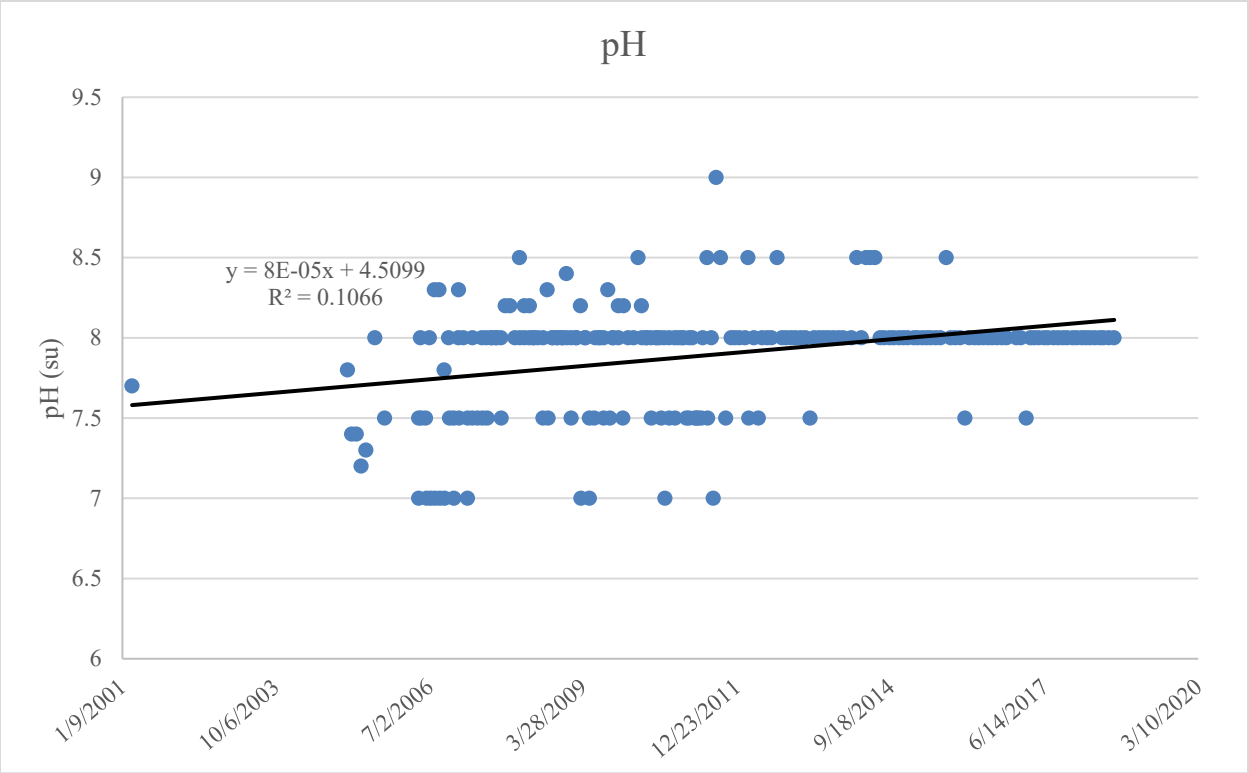

Figure 31: pH at site 12383

E. coli

Citizen scientists collected a total of 41 *E. coli* measurements at this site. The geomean was 8 CFU/100 mL. The minimum was 1 CFU/100 mL which occurred several times and the maximum was 120 CFU/100 mL which occurred in October and November of 2008. There was no significant increase or decrease in *E. coli* over time observed at this site.

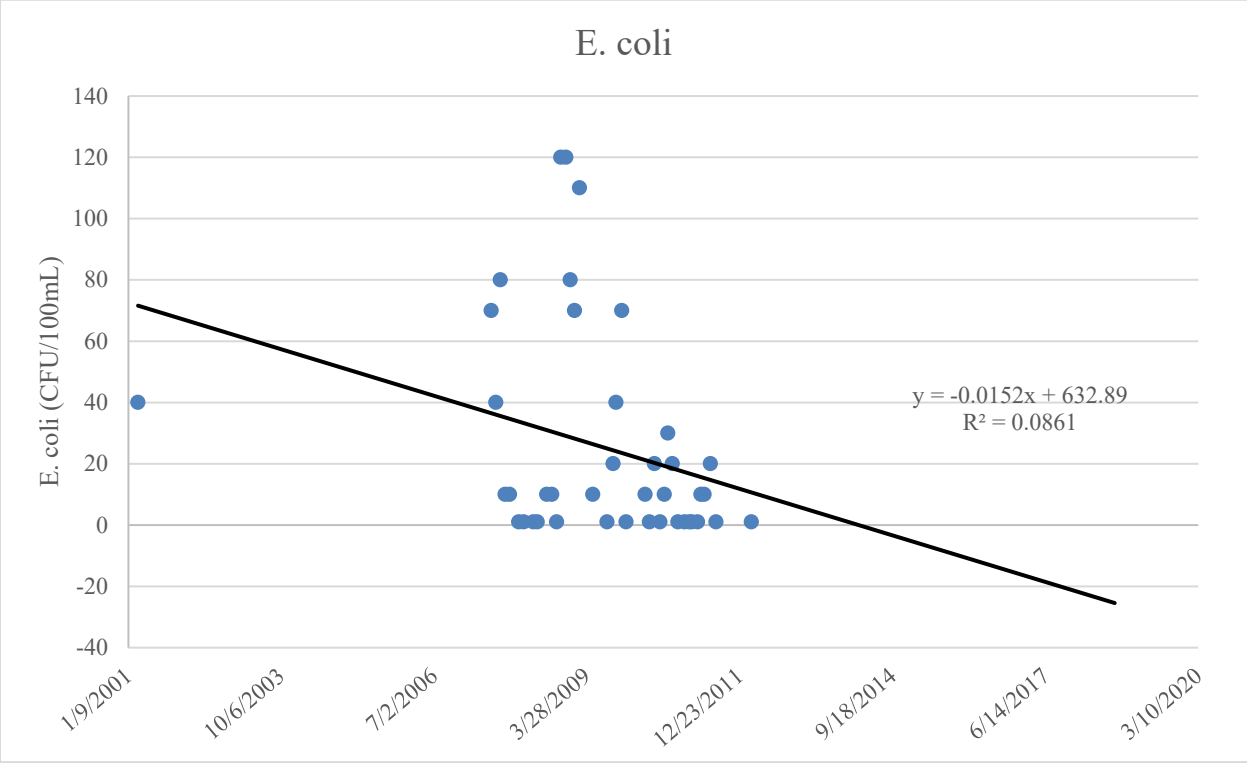

Figure 33: *E. coli* at site 12383

Nitrate-Nitrogen

Citizen scientists collected 65 measuresments for Nitrate-Nitrogen at this site. The values ranged from a low of 0.25 mg/L which occurred on multiple instances to a high of 1 which occurred in March of 2001.

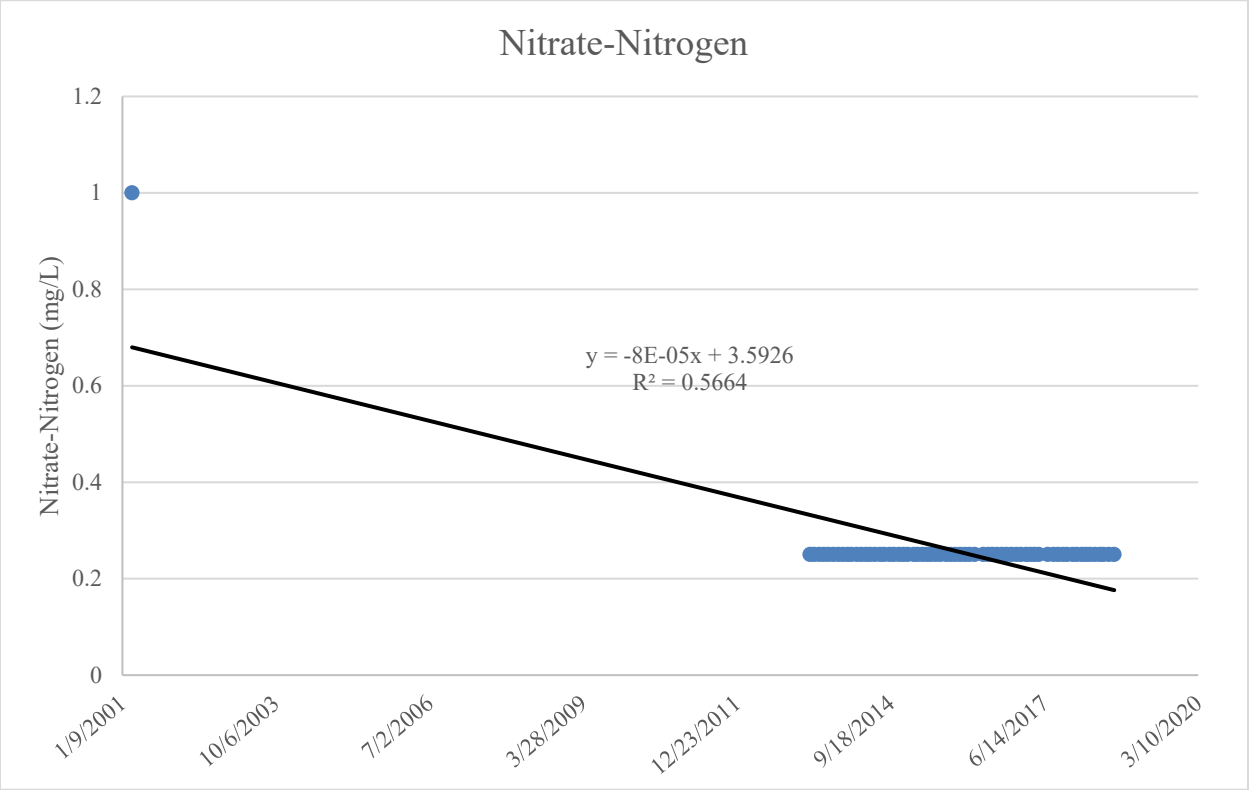

Figure 24: Nitrate-Nitrogen at site 12383

Site 12338 – Inks Lake in Spring Creek Cove

Site Description

This site is located within the Spring Creek Cove on the eastern part of Inks Lake. It is publically accessible through the Day Use Area and the Fishing Pier of Inks Lake State Park. Spring Creek is a shaded, seasonal stream flowing westward towards Inks Lake with headwater springs located nearly 5.3 kilometers west of downtown Burnet, TX. The site where it enters the lake is a popular swimming hole known as Devil's Waterhole, which is also accessible through the Inks Lake State Park.

Sampling Information

This site was sampled 225 times from January 1997 to September 2018.

Table 8: Descriptive parameters for Site 12338

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	188	318 ± 38	162	390
Water Temperature (°C)	223	21.0 ± 6.6	4.0	38.5
Dissolved Oxygen (mg/L)	224	7.5 ± 1.5	4.0	11.1
pH	220	8.0 ± 0.5	7.0	9.4
E. coli	166	11 ± 28	1	150
Nitrate-Nitrogen	114	0.78 ± 0.34	0.25	1.00

Site 12338 was sampled 225 imes between 1/4/1997 and 9/11/2018.

Air and water temperature

There were 223 air and water temperature measurements taken at this site. The mean water temperature was 21.0°C. The minimum water temperature was 4.0°C and was recorded in January of 2013. The maximum water temperature was 38.5°C and was recorded in August of 2006. The air temperature ranged from a low of -1.0°C recorded in January of 2011 to a high of 47°C recorded in July of 2000.

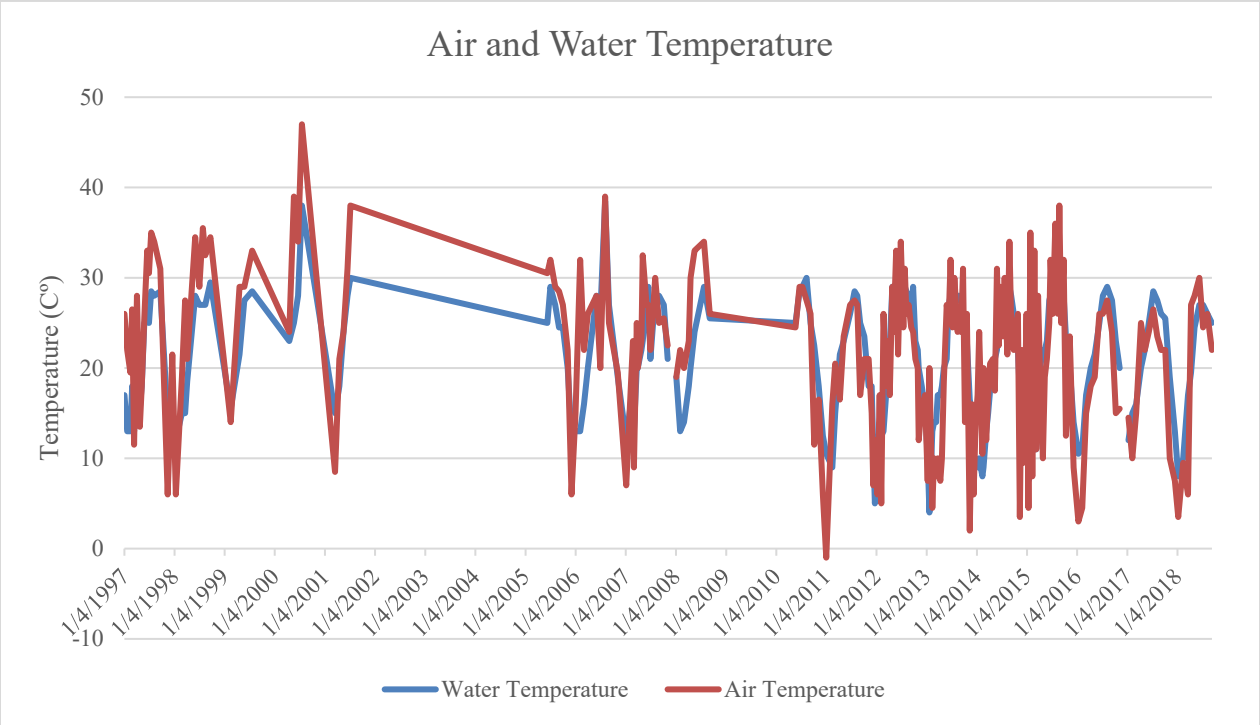

Figure 26: Air and water temperature at site 12338

Total Dissolved Solids

Citizen scientists collected 188 TDS measurements at this site. The mean TDS concentration was 318 mg/L. The minimum TDS measurement was recorded in March of 2006 and was 163 mg/L. The maximum TDS measurement was 390 mg/L and was recorded in May of 2015. There was no relationship between TDS concentrations and time observed at this site.

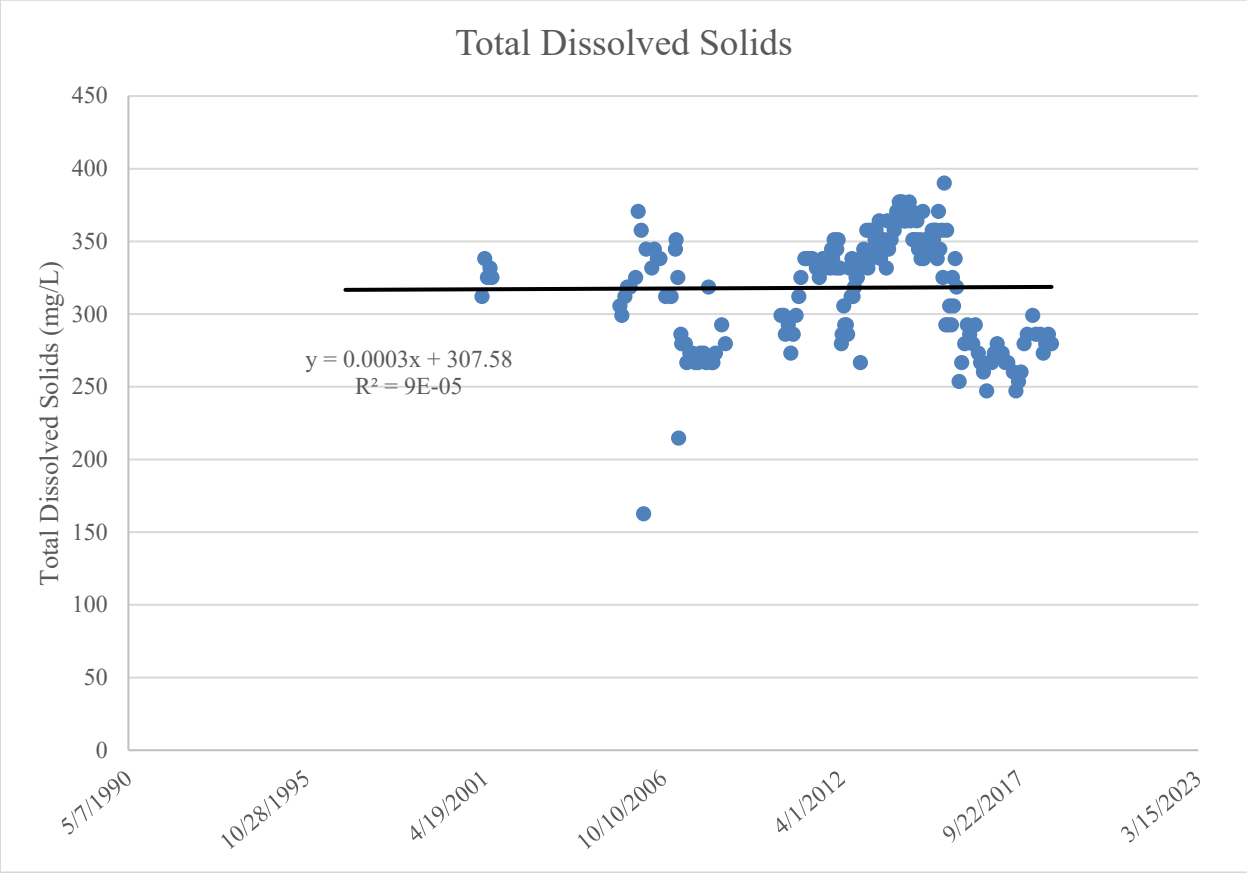

Figure 27: Total dissolved solids at site 12338

Dissolved Oxygen

Citizen scientists collected 224 DO samples at this site. The mean DO concentration was 7.5 mg/L and it ranged from a low of 4.0 mg/L in November of 2016 to a high of 11.1 mg/L in March of 1998. There was no relationship between DO concentrations and time observed at this site.

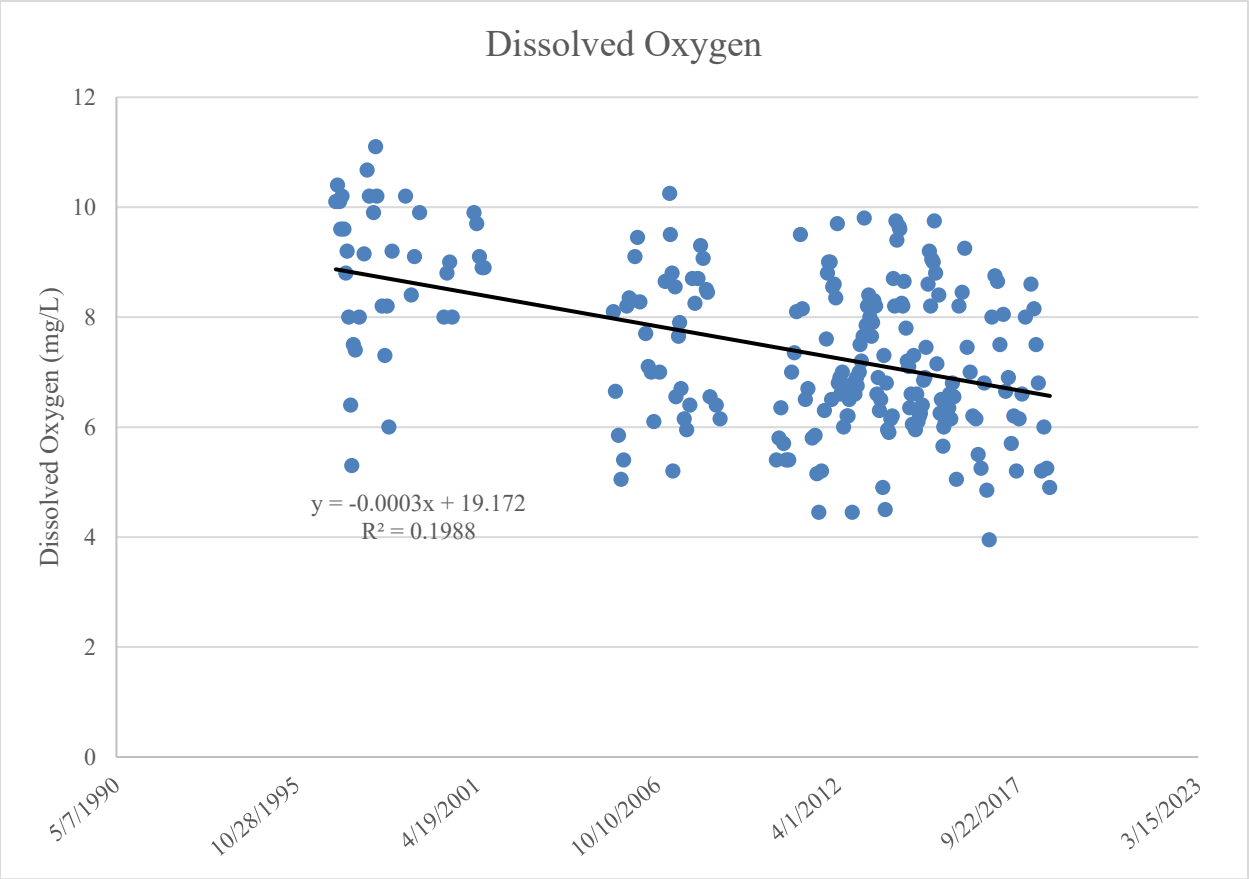

Figure 29: Dissolved oxygen at site 12338

pH

There were 220 pH samples taken at this site. The mean pH was 8.0 and it ranged from a low of 7.0 in multiple instances to a high of 9.4 in May of 1999. There was no significant relationship between pH and time observed at this site.

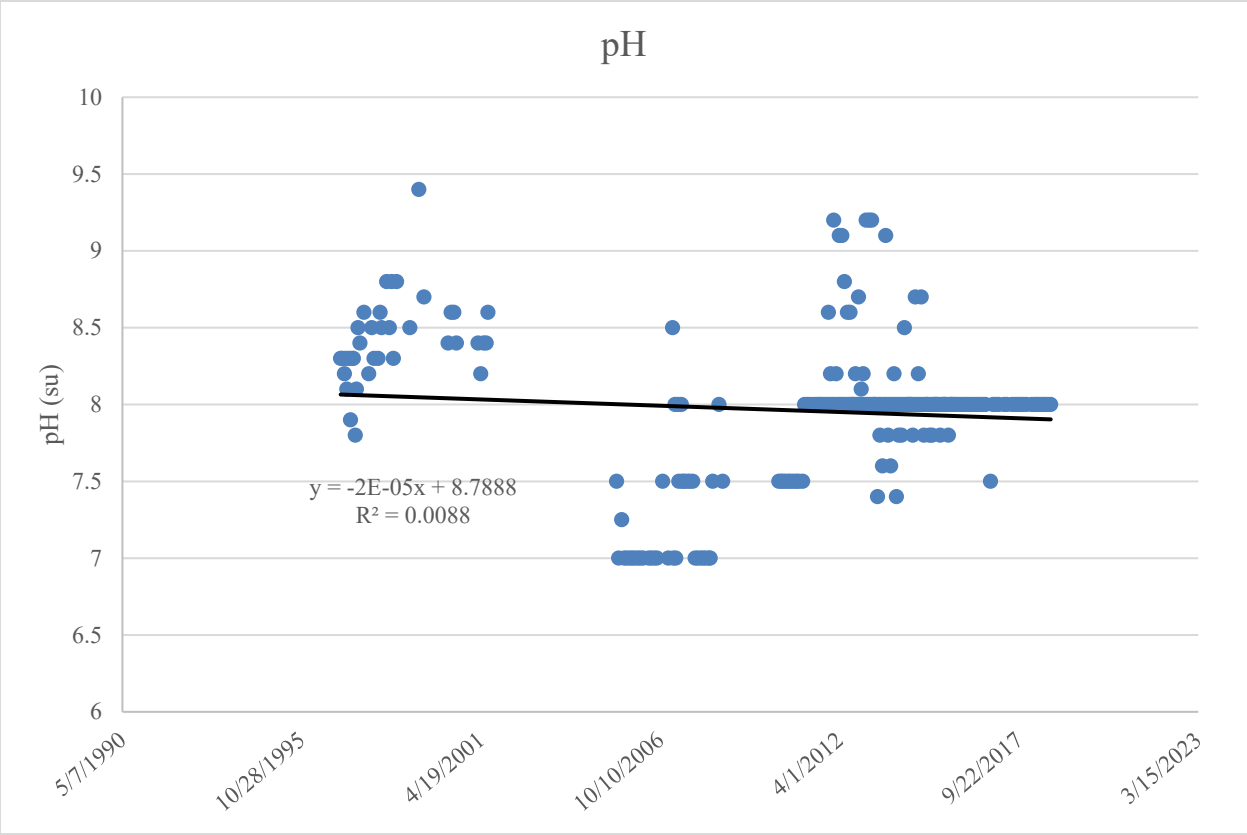

Figure 31: pH at site 12338

E. coli

Citizen scientists collected a total of 166 *E. coli* measurements at this site. The geomean was 11 CFU/100 mL. The minimum was 1 CFU/100 mL which occurred several times and the maximum was 150 CFU/100 mL which occurred in May and July of 2007. There was no significant increase or decrease in *E. coli* over time observed at this site.

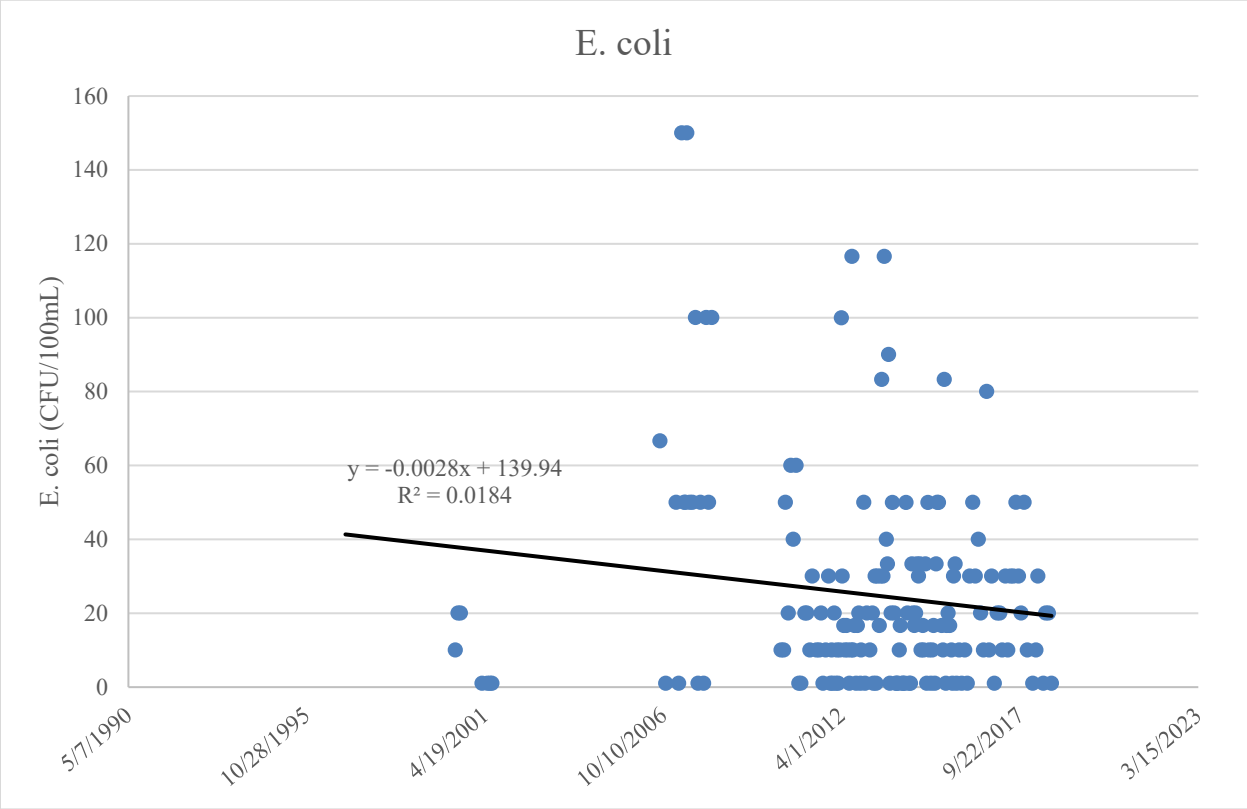

Figure 33: *E. coli* at site 12338

Nitrate-Nitrogen

Citizen scientists collected 114 measuresments for Nitrate-Nitrogen at this site. The mean Nitrate-Nitrogen was 0.78 mg/L and ranged from a low 0.25 mg/L in multiple instances to a high of 1 mg/L which also occurred multiple times.

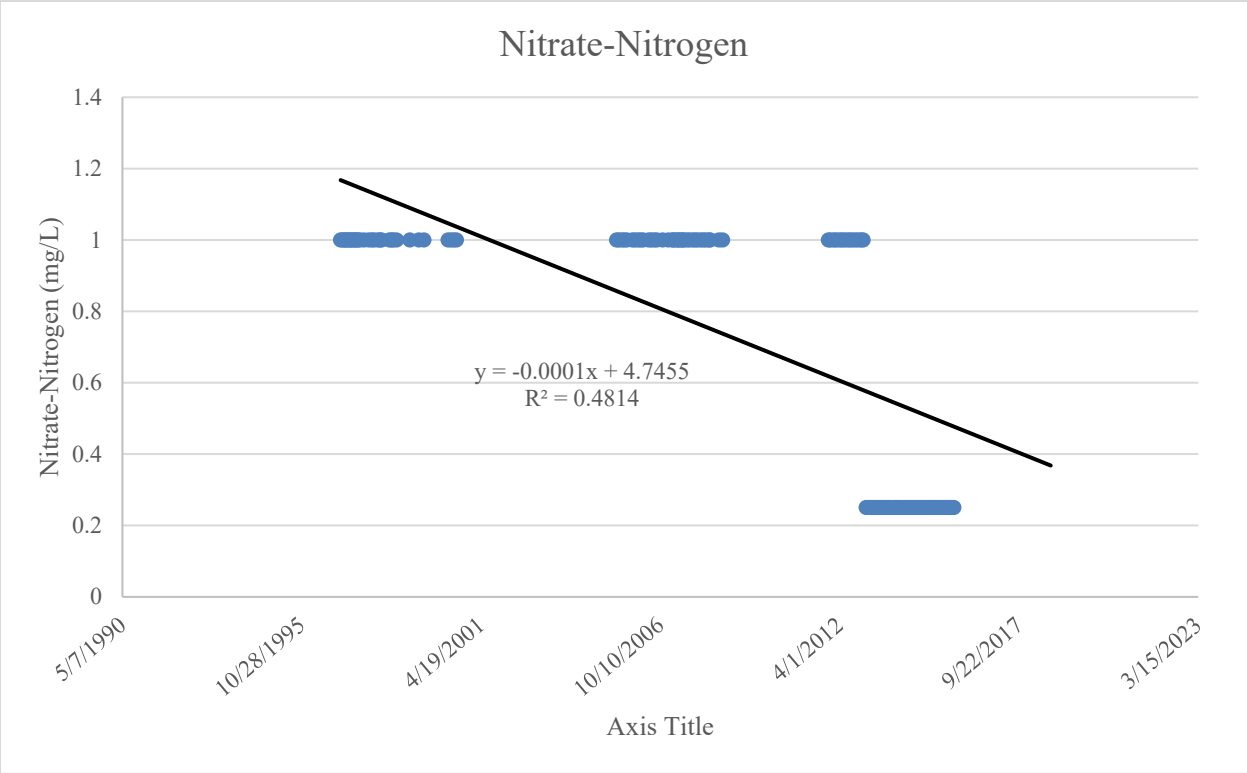

Figure 24: Nitrate-Nitrogen at site 12338

Site 81503 – Lake LBJ at Horseshoe Bay Marina

Site Description

Site 81503 monitors a site along the shores of the City of Horseshoe Bay at the Horseshow Bay Marina. Horseshoe Bay is a thoroughly developed bay for residences and marinas in the southern part of Lake LBJ, located nearly 2.3 kilometers west of Wirtz Dam. This site is located nearly 1.2 kilometers southeast of the natural gas-fueled Ferguson Power Plant which uses the lake for cooling.

Sampling Information

This site was sampled 15 times from June 2017 to September 2018.

Table 8: Descriptive parameters for Site 81503

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	15	257 ± 5.7	247	267
Water Temperature (°C)	15	23.4 ± 6.1	11.4	30.6
Dissolved Oxygen (mg/L)	15	7.4 ± 0.7	6.8	9.0
pH	14	7.0 ± 0	7.0	7.0
Nitrate-Nitrogen	14	1.0 ± 0	1.0	1.0

Site 81503 was sampled 15 times between 6/8/2017 and 9/14/2018.

Air and water temperature

There were 15 air and water temperature measurements taken at this site. The mean water temperature was 23.4°C. The minimum water temperature was 11.4°C and was recorded in January of 2018. The maximum water temperature was 30.6°C and was recorded in June of 2018. The air temperature ranged from a low of 3°C recorded in January of 2018 to a high of 35°C recorded in June of 2018.

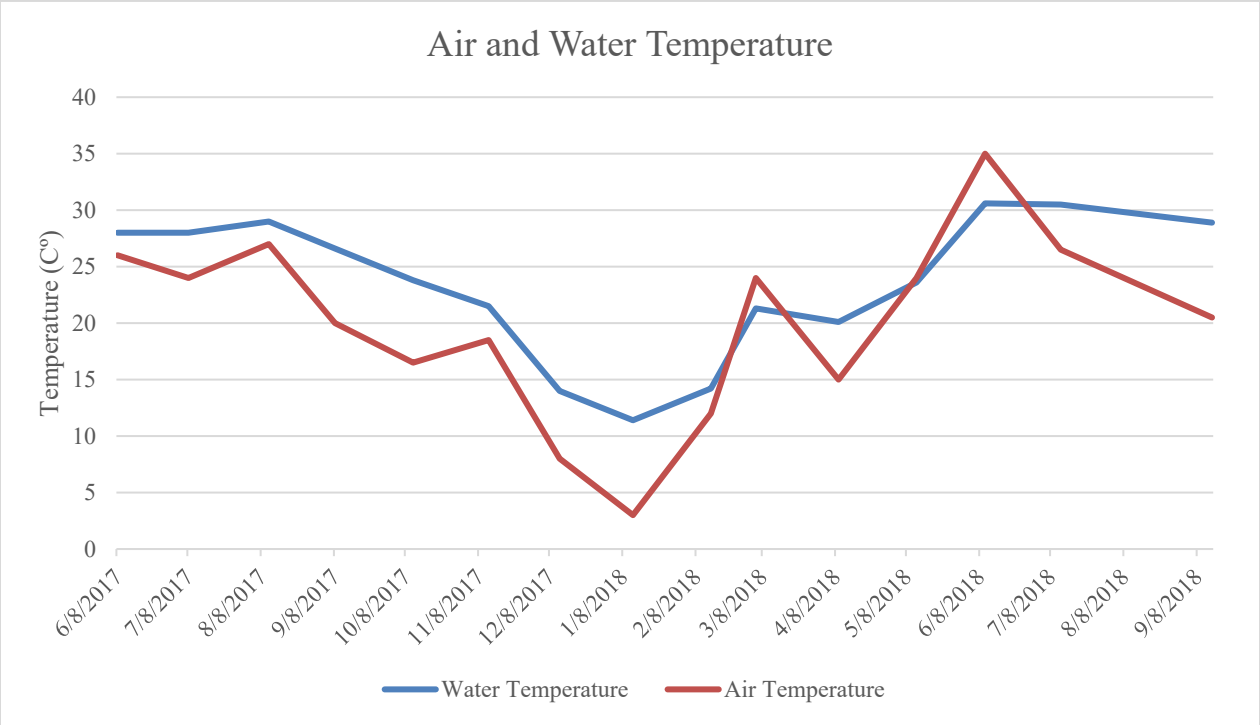

Figure 26: Air and water temperature at site 81503

Total Dissolved Solids

Citizen scientists collected 15 TDS measurements at this site. The mean TDS concentration was 257 mg/L. The minimum TDS measurement was recorded in June and September of 2017 and was 247 mg/L. The maximum TDS measurement was 267 mg/L and was recorded in April and September of 2018. There was no relationship between TDS concentrations and time observed at this site.

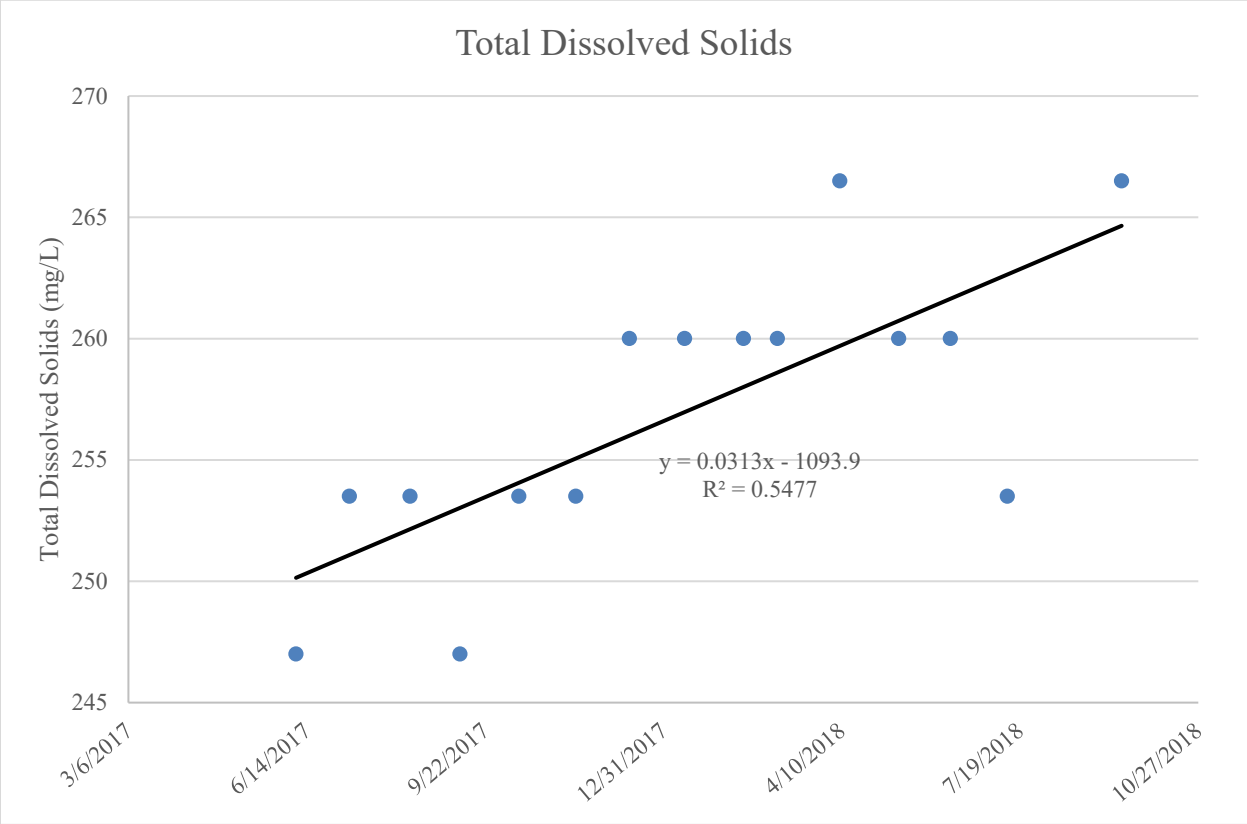

Figure 27: Total dissolved solids at site 81503

Dissolved Oxygen

Citizen scientists collected 15 DO samples at this site. The mean DO concentration was 7.4 mg/L and it ranged from a low of 6.8 mg/L in May of 2018 to a high of 9 mg/L in January and February of 2018. There was no relationship between DO concentrations and time observed at this site.

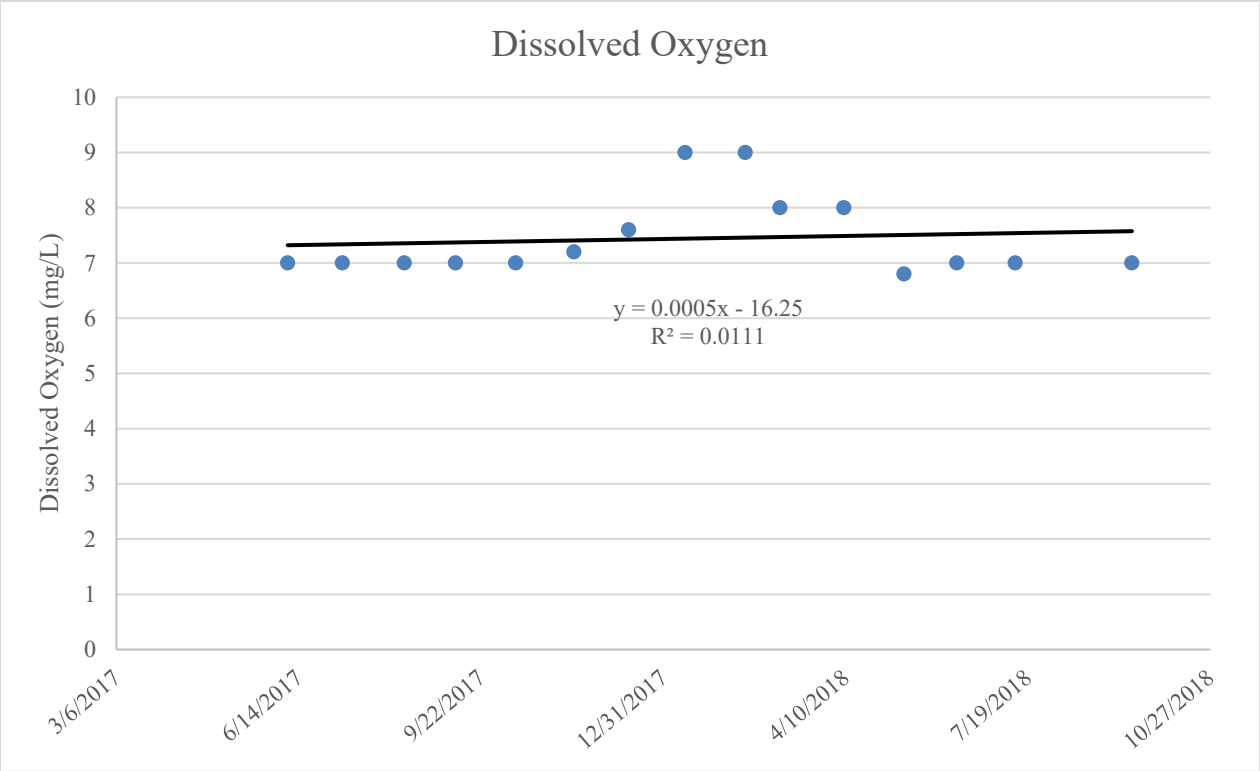

Figure 29: Dissolved oxygen at site 81503

pH

There were 14 pH samples taken at this site. The mean pH was 7.0 which is the value recorded for each of the 14 samples taken. There was no significant relationship between pH and time observed at this site.

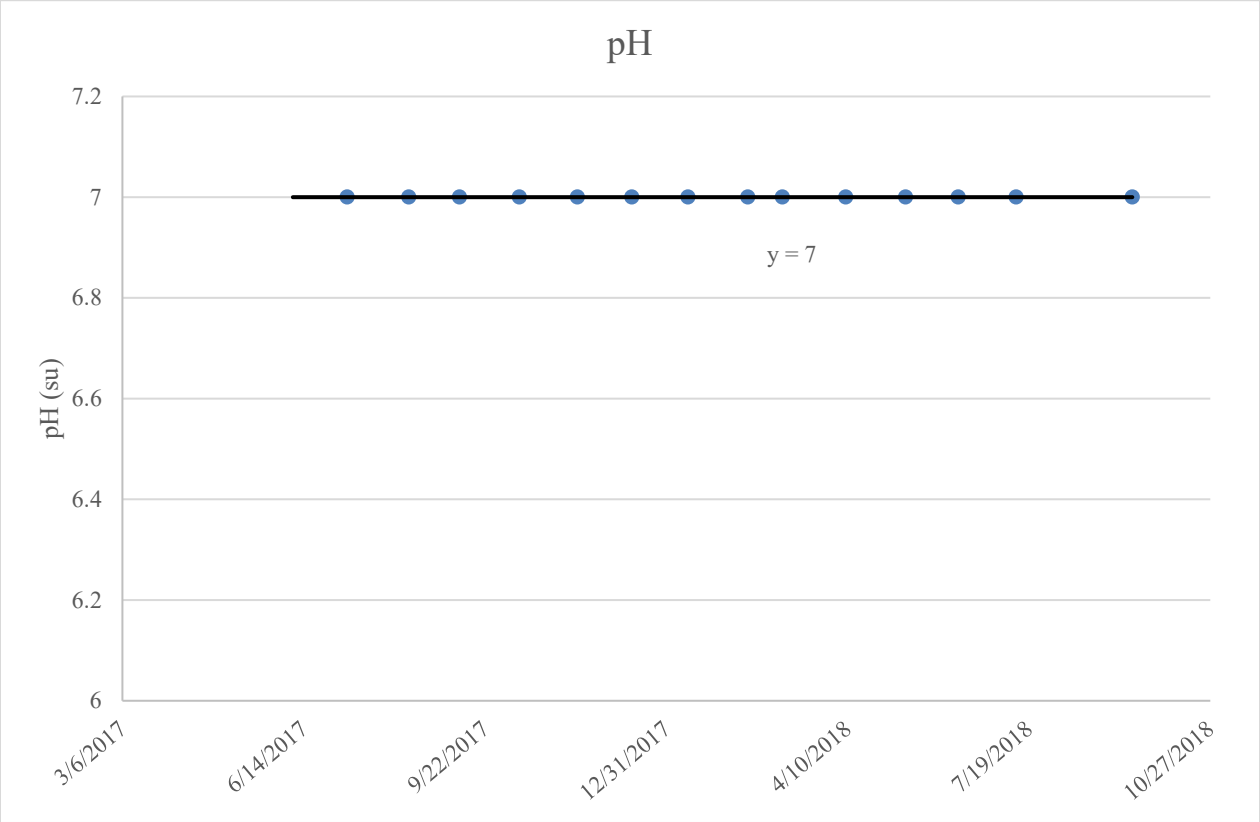

Figure 31: pH at site 81503

Nitrate Nitrogen

Citizen scientists collected 14 measuresments for Nitrate-Nitrogen, each calculating a value of 1 mg/L of Nitrate-Nitrogen.

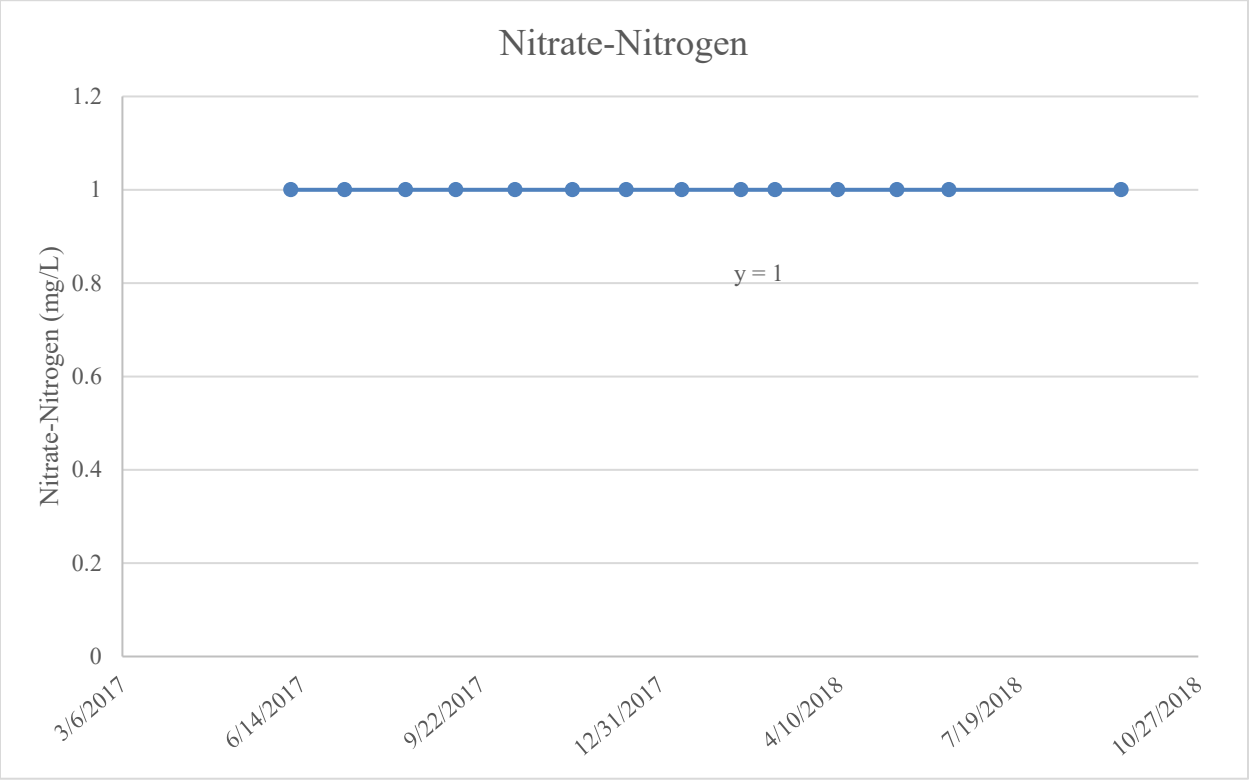

Figure 24: Nitrate-Nitrogen at site 81503

Site 81506 – Lake LBJ at Quail Point Community Center

Site Description

Site 81506 monitors a site along the shores of the City of Horseshoe Bay at the Quail Point Community Center. Horseshoe Bay is a thoroughly developed bay for residences and marinas in the southern part of Lake LBJ, located nearly 2.3 kilometers west of Wirtz Dam. The Quail Point Community Center is located nearly one kilometer southeast of the natural gas-fueled Ferguson Power Plant which uses the lake for cooling.

Sampling Information

This site was sampled 12 times from October 2017 to September 2018.

Table 8: Descriptive parameters for Site 81506

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	12	258 ± 8.1	241	267
Water Temperature (°C)	12	23.3 ± 7.7	10	34
Dissolved Oxygen (mg/L)	12	6.7 ± 0.8	5	8
pH	12	7.3 ± 0.2	7.0	7.5
E. coli	11	6 ± 24	1	80
Nitrate-Nitrogen	12	1.0 ± 0	1.0	1.0

Site 81506 was sampled 12 times between 10/24/2017 and 9/12/2018.

Air and water temperature

There were 12 air and 12 water temperature measurements taken at this site. The mean water temperature was 23.3 °C. The minimum water temperature was 10.0 °C and was recorded in January of 2018. The maximum water temperature was 34.0 °C and was recorded in August of 2018. The air temperature ranged from a low of 6.0 °C recorded in January of 2018 to a high of 39.0 °C recorded in August of 2018.

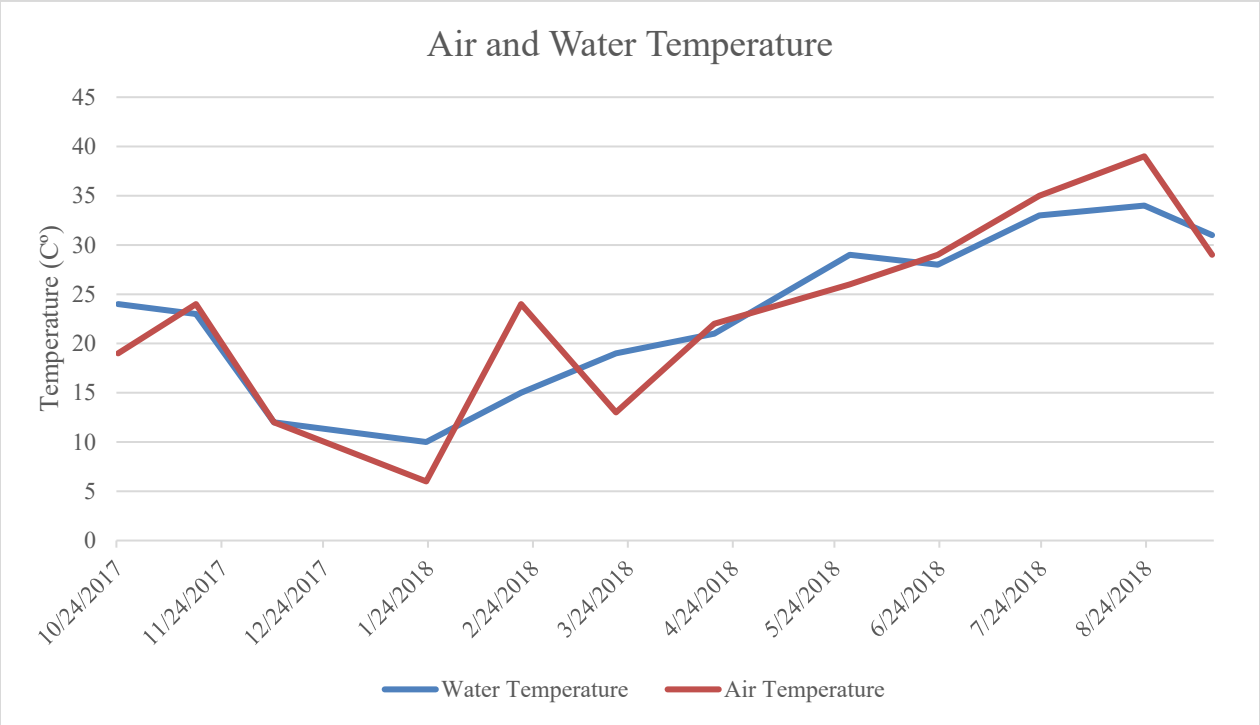

Figure 26: Air and water temperature at site 81506

Total Dissolved Solids

Citizen scientists collected 12 TDS measurements at this site. The mean TDS concentration was 258 mg/L. The minimum TDS measurement was recorded in October of 2017 and was 241 mg/L. The maximum TDS measurement was 267 mg/L and was recorded several times during 2018. There was no relationship between TDS concentrations and time observed at this site.

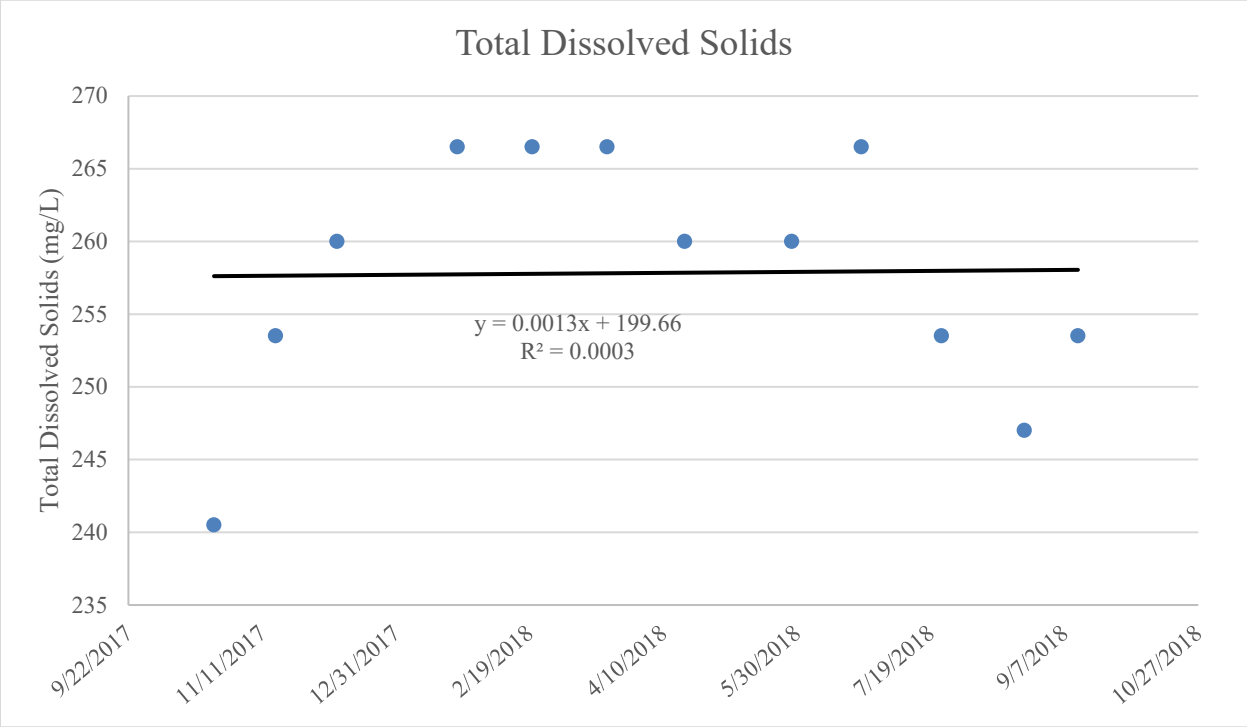

Figure 27: Total dissolved solids at site 81506

Dissolved Oxygen

Citizen scientists collected 12 DO samples at this site. The mean DO concentration was 6.7 mg/L and it ranged from a low of 5.0 mg/L in May of 2018 to a high of 8.0 mg/L in December of 2017. There was no relationship between DO concentrations and time observed at this site.

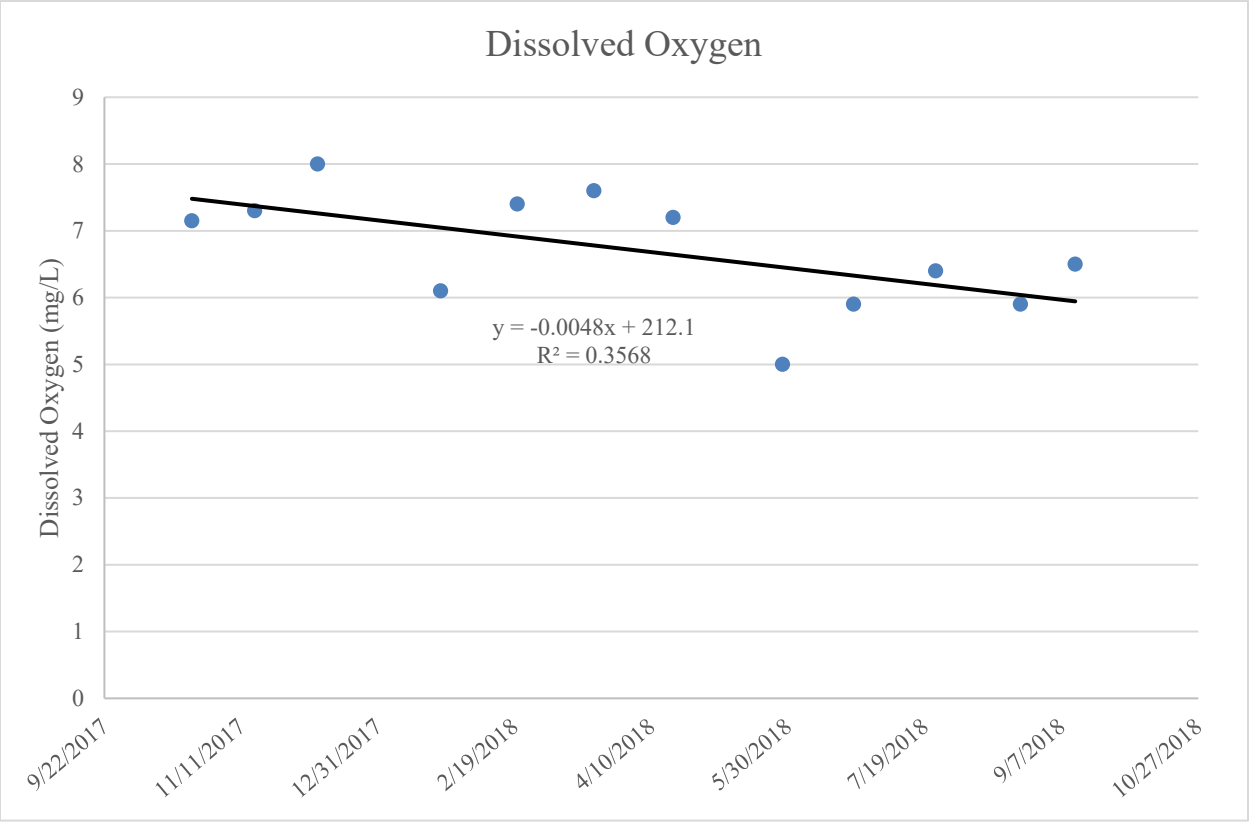

Figure 29: Dissolved oxygen at site 81506

pH

There were 12 pH samples taken at this site. The mean pH was 7.3 and it ranged from a low of 7.0 which occurred several times to a high of 7.5 which occurred several times. There was no significant relationship between pH and time observed at this site.

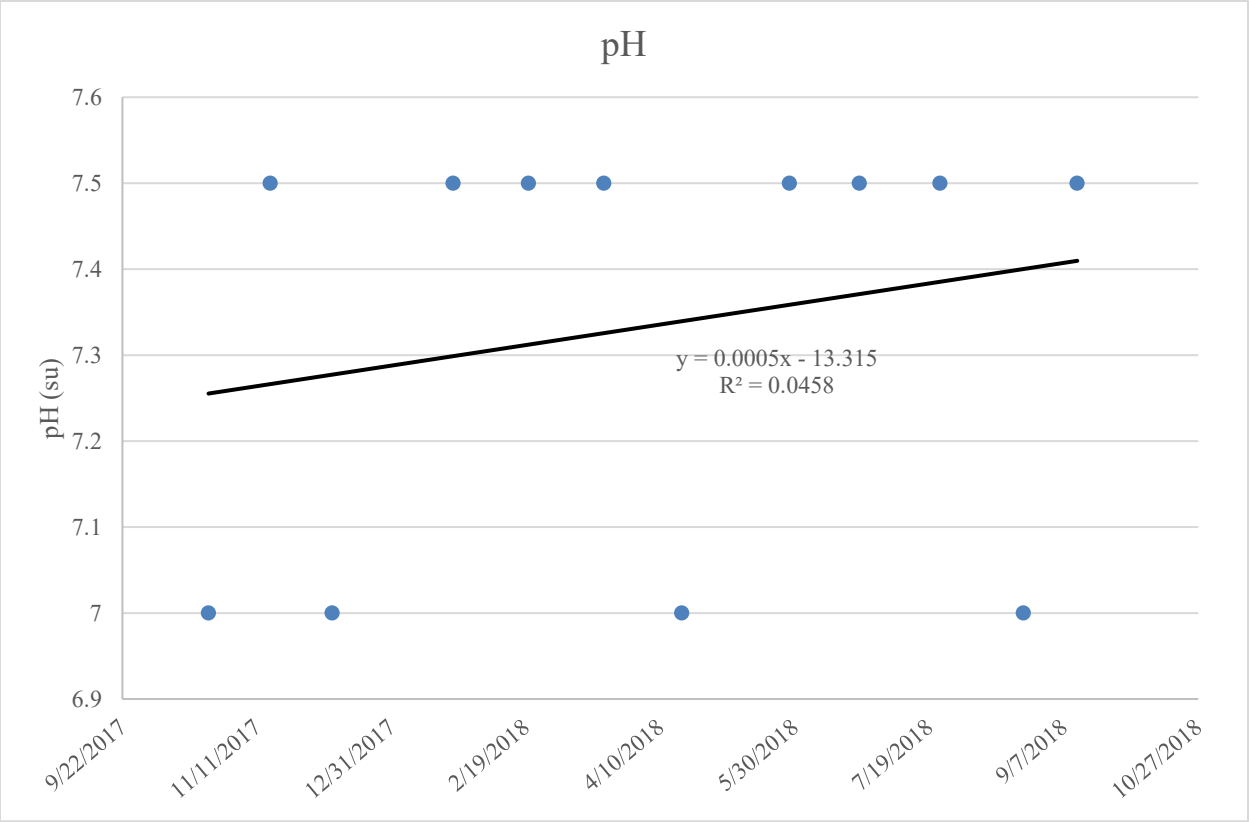

Figure 31: pH at site 81506

E. coli

Citizen scientists collected a total of 6 *E. coli* measurements at this site. The geomean was 6 CFU/100 mL. The minimum was 1 CFU/100 mL which occurred several times and the maximum was 80 CFU/100 mL which occurred in February of 2018. There was no significant increase or decrease in *E. coli* over time observed at this site.

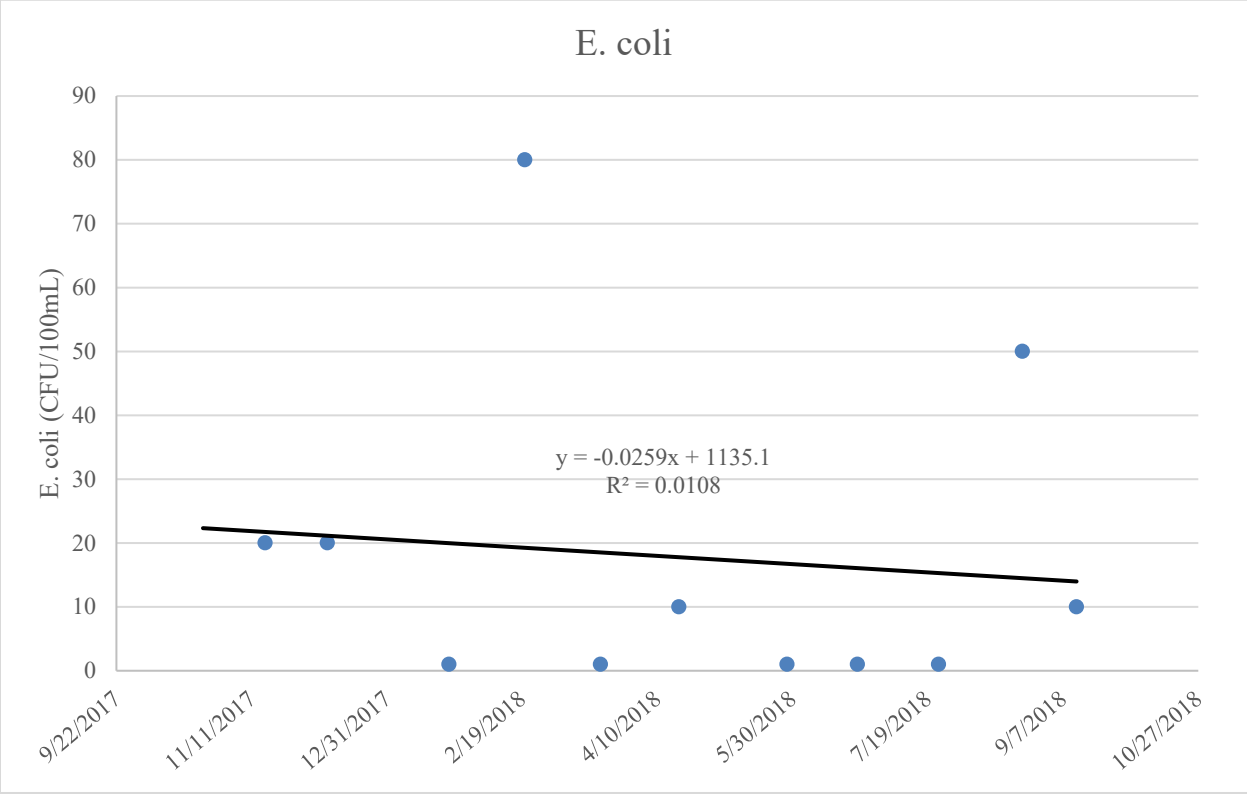

Figure 33: *E. coli* at site 81506

Nitrate Nitrogen

Citizen scientists collected 12 measuresments for Nitrate-Nitrogen, each calculating a value of 1 mg/L of Nitrate-Nitrogen.

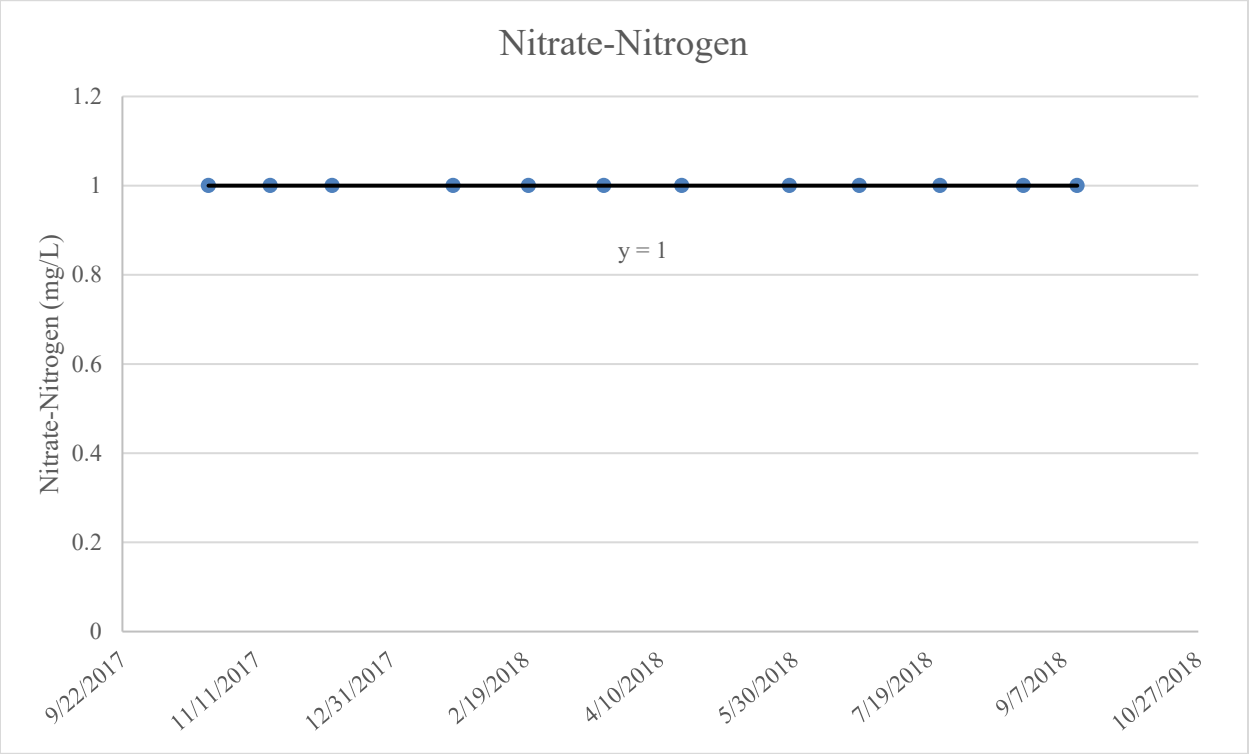

Figure 24: Nitrate-Nitrogen at site 81506

Upper Highland Lakes Watershed Summary

Texas Stream Team citizen scientists monitored several water quality parameters from 9 different sites from 1996 to 2018, including TDS, DO, pH levels, and *E. coli*. Data from the 9 monitoring sites was analyzed to find trends over the monitoring periods. During the time observed, there was no significant increase or decrease in TDS concentration within the watershed as a whole. At times, sites 13553 and 12387 had elevated levels of *E. coli* bacteria higher than TCEQ contact recreation standards for a single threshold value of 394 cfu / 100 mL. Besides seasonal variations, there have been no statistically significant relationships between a decrease in DO levels and time at individual sites. Colorado River Watch Network citizen scientist monitoring group will continue to monitor the water quality of the Upper Highland Lakes watersheds. LCRA will continue to support existing Texas Stream Team citizen ccientists with core supplies for local citizen scientists to collect and test samples for water quality. Additionally, the Llano River Watershed Alliance will continue to create new Texas Stream Team monitoring sites and activate existing sites within the Upper Llano River Watershed.

Get Involved with Texas Stream Team!

Once trained, citizen scientists can directly participate in monitoring by communicating their data to various stakeholders. Some options include: participating in the CRP Steering Committee process, providing information during "public comment" periods, attending city council and advisory panel meetings, developing relations with local TCEQ and river authority water specialists, and, if necessary, filing complaints with environmental agencies, contacting elected representatives and media, or starting organized local efforts to address areas of concern.

The Texas Clean Rivers Act established a way for the citizens of Texas to participate in building the foundation for effective statewide watershed planning activities. Each CRP partner agency has established a steering committee to set priorities within its basin. These committees bring together the diverse stakeholder interests in each basin and watershed. Steering committee participants include representatives from the public, government, industry, business, agriculture, and environmental groups. The steering committee is designed to allow local concerns to be addressed and regional solutions to be formulated. For more information about participating in these steering committee meetings, please contact the appropriate CRP partner agency for your river basin at:
http://www.tceq.state.tx.us/compliance/monitoring/crp/partners.html.

Currently, Texas Stream Team is working with various public and private organizations to facilitate data and information sharing. One component of this process includes interacting with watershed stakeholders at CRP steering committee meetings. A major function of these meetings is to discuss water quality issues and to obtain input from the public. While participation in this process may not bring about instantaneous results, it is a great place to begin making institutional connections and to learn how to become involved in the assessment and protection system that Texas agencies use to keep water resources healthy and sustainable.

Sources

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Appendix A- List of Tables and Figures

Tables

Figures

Appendix B- List of Acronyms

CFU – Colony-forming unit

CRA – Colorado River Alliance

CRP – Clean Rivers Program

DO – Dissolved Oxygen

EPA – Environmental Protection Agency

km^2 – square kilometers

LCRA – Lower Colorado River Authority

NPAT - Native Prairies Association of Texas

QAO - Quality Assurance Officer

QAPP - Quality Assurance Project Plan

TCEQ – Texas Commission on Environmental Quality

TDS – Total Dissolved Solids

TMDL – Total Maximum Daily Load

TPWD – Texas Parks & Wildlife Department

TWDB – Texas Water Development Board

USACE – United States Army Corps of Engineers

USDA – United States Department of Agriculture

WPP – Watershed Protection Plan