Canyon Lake Data Report

July 2014

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The preparation of 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.

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. These methods are utilized by Texas Stream Team due to higher equipment costs, training requirements, and stringent laboratory procedures that are required of the professional community. As a result, Texas Stream Team data do not have the same accuracy or precision as professional data, and is not directly comparable. 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 at all, or monitor as frequently. 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 partner reports, such as Basin Summary Reports and Highlight Reports
- TCEQ Total Maximum Daily Load reports
- TCEQ and Texas State Soil and Water Conservation Board Nonpoint Source Program funded reports, including Watershed Protection Plans

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

Watershed Location and Physical Description

Location and Climate

Canyon Lake is located about 16 miles northwest of New Braunfels on the Guadalupe River in Comal County (Breeding). Comal County is in the Edwards Plateau ecoregion, which is prone to frequent and prolonged droughts as well as flash flooding (Texas Parks & Wildlife Department (TPWD) "Ecoregion 7 – Edwards Plateau"). The eastern portion of the Edwards Plateau, in which Comal County is located, receives more than 33 inches of rain annually (TPWD "Ecoregion 7 – Edwards Plateau"). The soil here is composed of shallow clays and clay loams underlain by limestone (Native Prairies Association of Texas (NPAT).

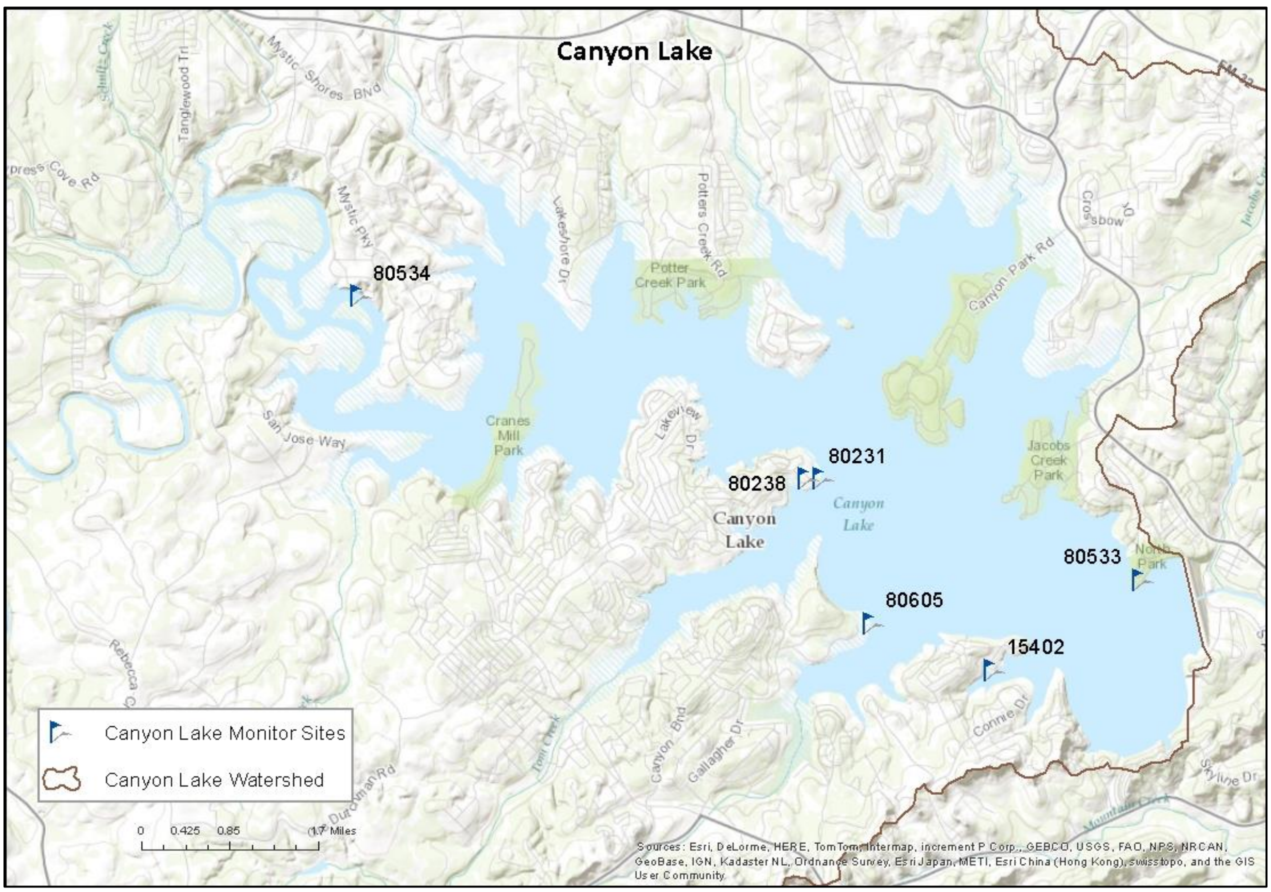

Figure 1: Map of Canyon Lake with Sampling Sites

Physical Description and Land Use

Canyon Lake Dam provides flood control for the 1,432 square miles of drainage above the dam, with a flood control pool level of 943 feet mean sea level (ft-msl) (U.S. Army Corps of Engineers (USACE) "History of Canyon Lake"). Canyon Lake has a 382,000 acre-feet capacity at conservation pool level and a surface area of 8,230 acres with 80 miles of shoreline (USACE "History of Canyon Lake"). The area directly surrounding Canyon Lake is primarily residential, with several neighborhood communities developed after the lakes construction (Goff 2011). Vegetation around Canyon Lake includes species of Ash, Juniper, and Oak trees; grasses include Indian grass (*Sorghastrum nutans)*, switchgrass (*Panicum virgatum)*, and species of bluestem (NPAT). The lake provides water for several hydroelectric power plants in New Braunfels, as well as municipal water supply, irrigation, industrial, and recreational uses (USACE "History of Canyon Lake"). Some recreation activities include boating, swimming, and fishing for species of bass and catfish (TPWD "Fishing Canyon Lake"). Boating and other activities can cause the introduction of some invasive species such as Giant Salvinia (*Salvinia molesta)* or Zebra Mussels *(Dreissena polymorpha)* (USACE "Invasive Species"). To protect the lake from invasive species, users must be aware of what plants and animals they may unwittingly introduce to Canyon Lake.

History

To help control floods and aid water conservation, construction of the Canyon Lake Dam began in 1958 and was completed in 1964 (USACE "History of Canyon Lake). The area designated for Canyon Lake would inundate a lot of ranch and farmland, including the two small towns of Hancock and Cranes Mill (Goff 2011). After the dam was completed, water impoundment began and was filled to conservation level by 1968 (USACE "History of Canyon Lake"). In 2002, the lake overflowed its capacity for the first time with a record elevation of 950.32 ft msl (USACE "History of Canyon Lake"). An estimated twice the amount of the lake's volume spilled over the spillway (USACE "History of Canyon Lake"). However, had the dam not been in place, flooding and damages would have been significantly worse (USACE "History of Canyon Lake").

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 can be used for general comparison purposes.

The DO concentrations can 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 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 (su). The pH of water can provide useful information regarding acidity or alkalinity. The range is logarithmic; therefore, every 1 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 results 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 EPA 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 CFU/100 mL. The standard for contact recreational use of a water body such as Canyon Lake 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 a 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 Quality Assurance Project Plan (QAPP).

Table 1: Sample Storage, Preservation, and Handling Requirements

Parameter	Matrix	Container	Sample Volume	Preservation	Holding Time
E. coli	Water	Sterile Polystyrene (SPS)	100	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.

For all *E. coli* sampling events, station ID, location, sampling time, date, depth, sample collector's name/signature, group identification number, incubation temperature, incubation duration, *E. coli* colony counts, dilution aliquot, field blanks, and media expiration dates are checked and recorded if expired. Values for all measured parameters are recorded. If reagents or media are expired, it is noted and communicated to Texas Stream Team.

Sampling is still encouraged with expired reagents and bacteria media; however, the corresponding values will be flagged in the database. 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 monitors 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 the 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 monitor enters data electronically, the system will automatically flag data outside of the data limits and the monitor 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.

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 monitor 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 10% 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 2014 Texas Surface Water Quality Standards report is used to calculate the exceedances for Canyon Lake, as seen below in Table 2.

Table 2: Summary of Surface Water Quality Standards for Canyon Lake

Parameter	Texas Surface Water Quality Standard 2014
Water Temperature (°C)	32.2
Total Dissolved Solids (mg/L)	400
Dissolved Oxygen (mg/L)	6.0
pH (su)	6.5-9.0
E.coli (CFU/100 mL)	126 (geomean during sampling period)

Methods of Analysis

All data collected from Canyon Lake were exported from the Texas Stream Team database and were then grouped by site. Data was reviewed and, for the sake of data analysis, only one sampling event per month, per site was selected for the entire study duration. If more than one sampling event occurred per month, per site, the most complete, correct, and representative sampling event was selected.

Once compiled, data was sorted and graphed in Microsoft Excel 2010 using standard methods. Upstream to downstream trends and 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 volunteers, 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.

Canyon Lake Data Analysis

Canyon Lake Maps

Numerous maps were prepared to show spatial variation of the parameters. The parameters mapped include DO, pH, TDS, and *E. coli*. There is also a reference map showing the locations of all active. 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.

Canyon Lake Trends over Time

Sampling Trends over Time

Sampling in Canyon Lake began in December, 2004 and continue to this day. For the purpose of this report, the data collected from December, 2004 to June, 2014 was analyzed. A total of 367 monitoring events from 6 sites were analyzed. The highest percentage of samples collected was in 2013, and the number of samples per year has stayed the same or increased with each year. Sampling in Canyon Lake was mostly evenly distributed among the months with November having the fewest number of samples. Sampling occurred from 07:00 to 16:00 during the course of the day, with 10:00 and 13:00 being the hours with the most number of monitoring events. The hours of 07:00 and 16:00 had the least number of monitoring events. Samples were collected from a local stream team group that composes primarily of Texas Master Naturalists from the Lindheimer Master Naturalists Chapter. The Stream Team monitoring Canyon Lake is supported by the Guadalupe Blanco River Authority.

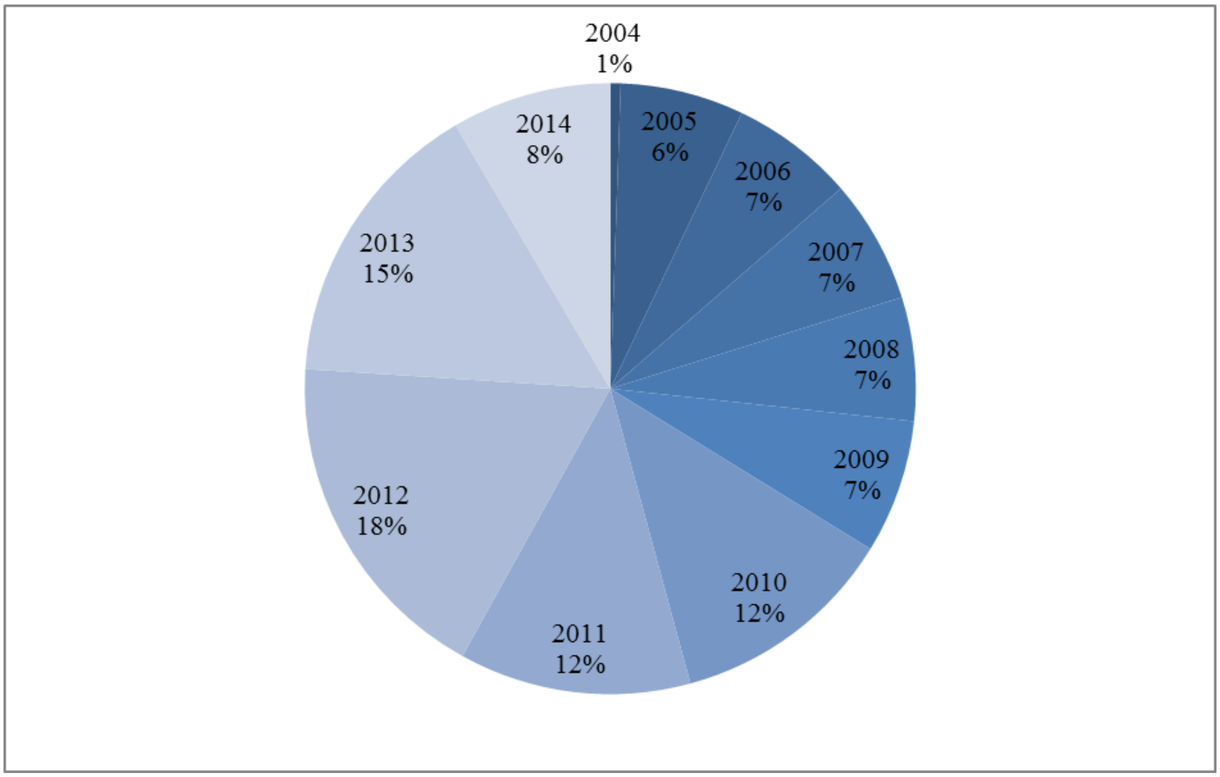

Figure 2: Samples by Year at Canyon Lake

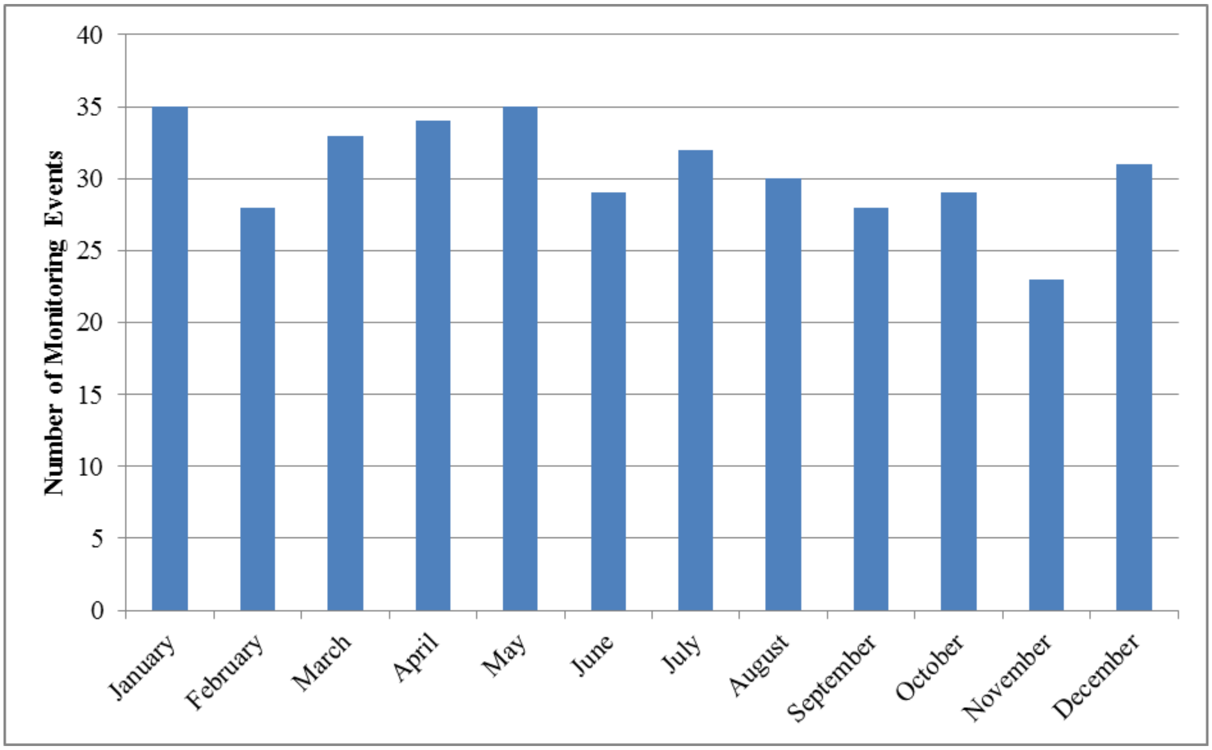

Figure 3: Breakdown of Sampling by Month for Canyon Lake

Table 3: Descriptive parameters for all sites in Canyon Lake

Canyon Lake December 2004 – June 2014				
Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	356	265 ± 36	221	735
Water Temperature (°C)	366	21.5 ± 6.4	3	37
Dissolved Oxygen (mg/L)	352	7.4 ± 1.4	2.9	11.3
pH (su)	363	7.7 ± 0.4	6.9	8.8
E. coli (CFU/100 mL)	102	6	0	800

There were a total of 367 sampling events between 12/2004 and 06/2014. E.coli mean was calculated as a geometric mean using Microsoft Excel.

Trend Analysis over Time

Air and water temperature

A total of 366 air and water samples were collected at Canyon Lake between 2004 and 2014. Water temperature exceeded the TCEQ optimal temperature standard of 32.2°C three times during this time. Air temperature varied between 3 and 39°C.

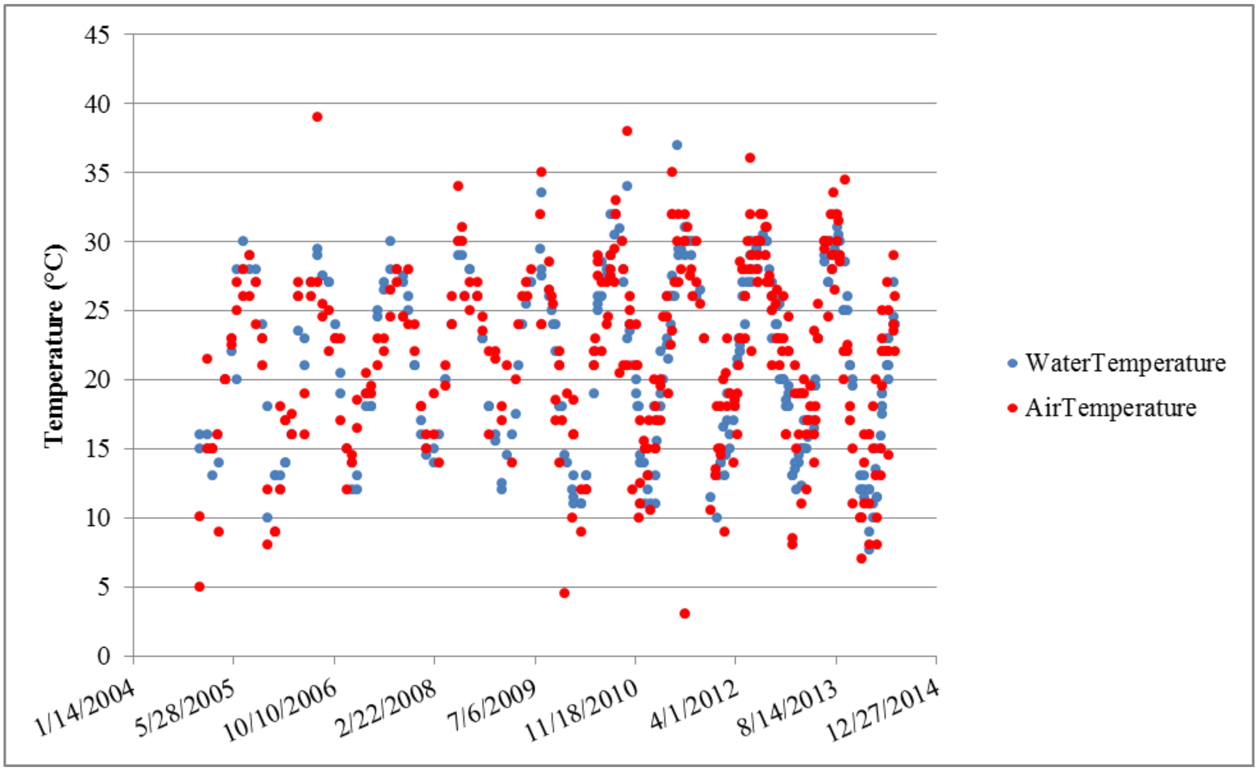

Figure 4: Air and water temperature over time at all sites at Canyon Lake.

Total Dissolved Solids

Citizen scientists collected 356 TDS samples at Canyon Lake. The TDS measurement was completed for 97% for all monitoring events. The average TDS measurements for all sites on the lake was 265 mg/L. There was a significant decrease in TDS values over time ($p = 0.036$), but the small R^2 value of 0.0123 indicates a small correlation in TDS concentrations over time.

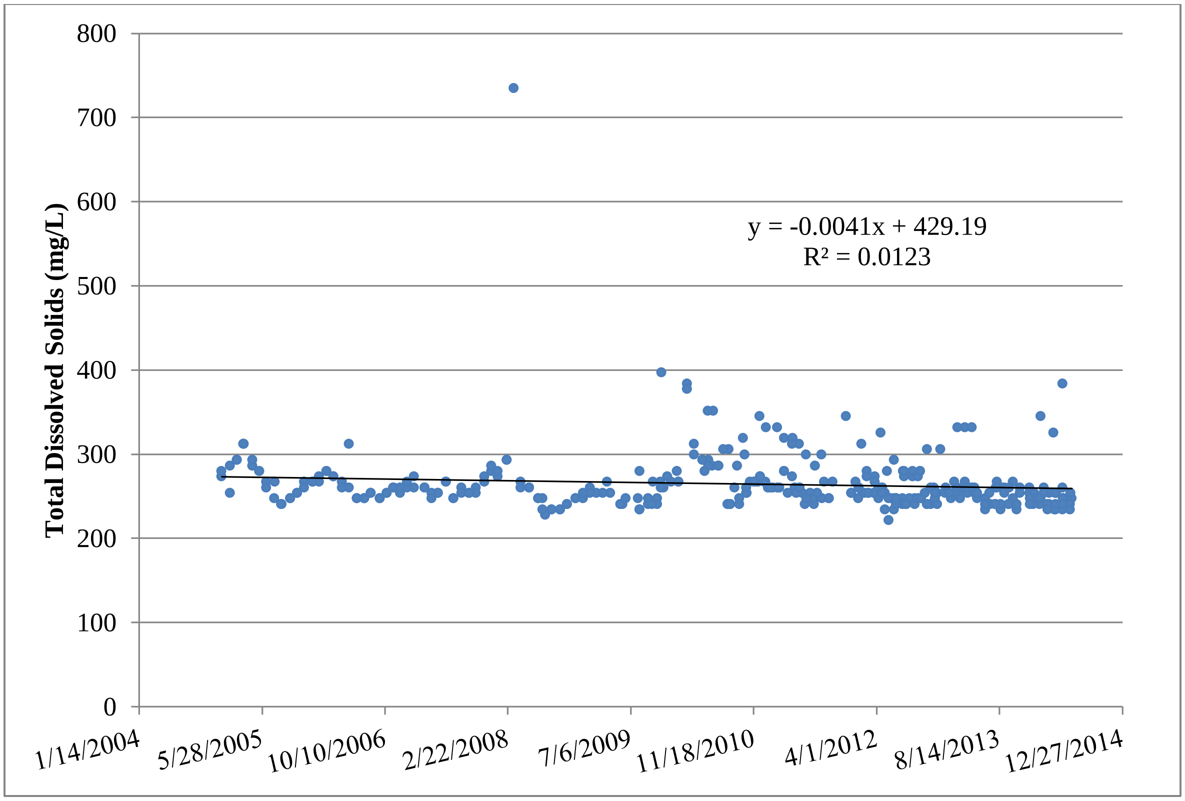

Figure 5: Total Dissolved Solids over time at all sites on Canyon Lake

Dissolved Oxygen

Citizen scientists collected a total of 352 DO samples at Canyon Lake representing 96% of all monitoring events. Dissolved oxygen fluctuated seasonally with the values increasing when the water was cooler and decreasing when the water was warmer. This is because colder water holds more dissolved gasses than warmer water. The mean DO was 7.4 mg/L and it ranged from a low of 2.9 mg/L in July of 2008 to a high of 11.3 mg/L in March of 2014.

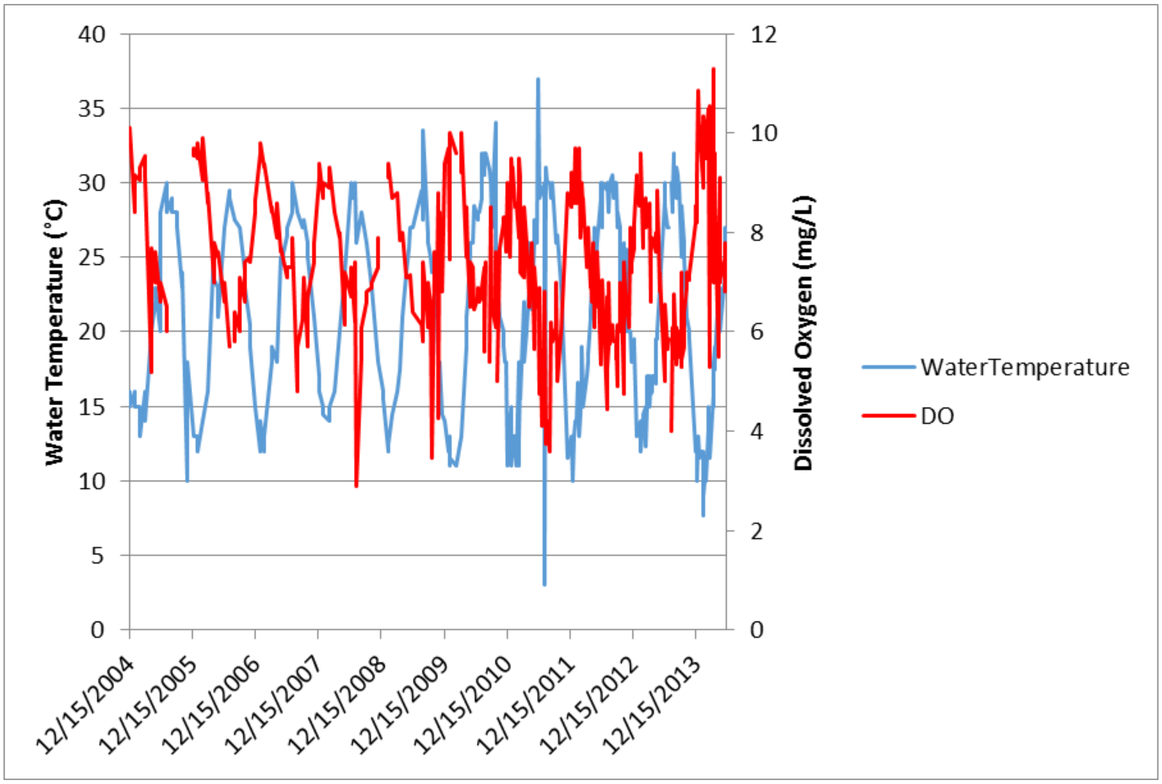

Figure 6: Dissolved oxygen and water temperature at all sites on Canyon Lake

Table 4: Average Dissolved Oxygen values by Sampling Time in Canyon Lake

Time	Average DO (mg/L)	Standard Deviation
07:00 – 08:00	6.6	0.8
08:00 – 09:00	6.9	0.9
09:00 – 10:00	7.4	1.5
10:00 – 11:00	7.4	1.4
11:00 – 12:00	7.7	1.4
12:00 – 13:00	7.2	1.4
13:00 – 14:00	7.5	1.5
14:00 – 15:00	7.4	1.5
15:00 – 16:00	7.6	1.6
16:00 – 17:00	9.1	0.8

pH

pH was completed for 99% of all sampling events. There were 363 pH measurements taken at Canyon Lake, and the mean pH was 7.7. The pH for all of the sites ranged from 6.9 to 8.8. There was no statistically significant correlation between pH and time detected.

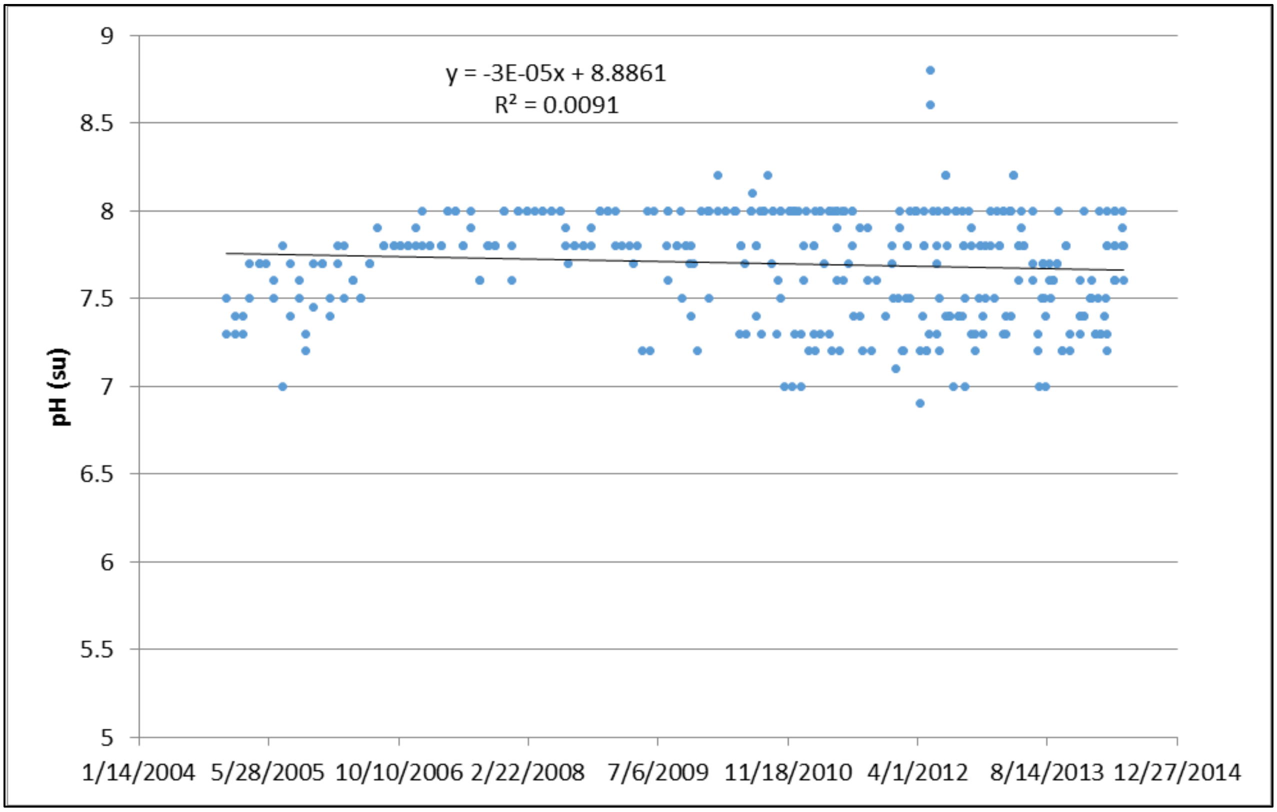

Figure 7: pH at all sites on Canyon Lake

E. coli Bacteria

There were 102 E. coli samples taken from 5 of the 6 sites on Canyon Lake. The geometric mean of E. coli was 6 CFU/100 mL. The E. coli counts ranged from none detected to 800 CFU/100 mL. There was no significant correlation between E. coli and time detected.

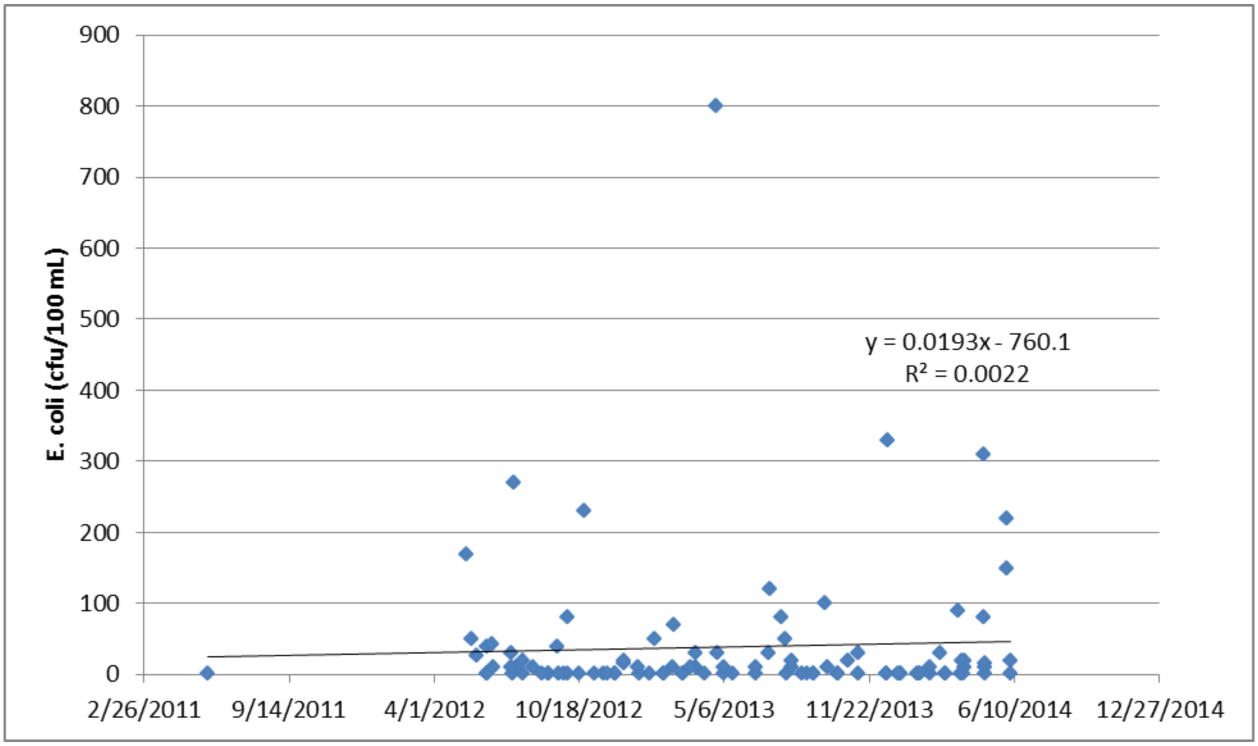

Figure 8: E. coli at all sites on Canyon Lake

Canyon Lake Site by Site Analysis

The following sections will provide a brief summarization of analysis, by site. The average minimum and maximum values recorded in the watershed. These 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. The *E. coli* is presented as a geomean. Please see Table 5 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 80534 had the highest overall average for TDS, with a result of 317 ± 31 mg/L. Site 15402 had the lowest average TDS, with a result of 248 ± 7 mg/L.

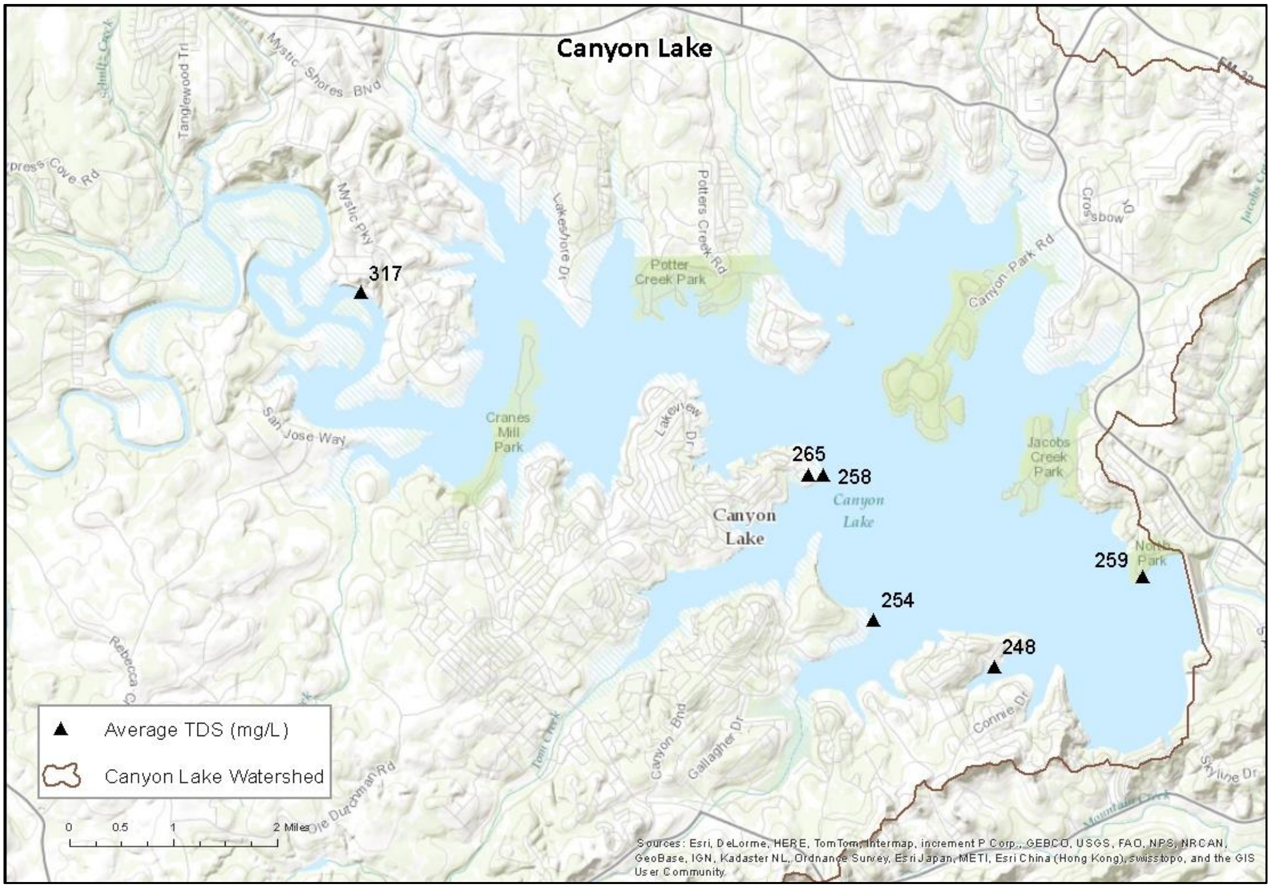

Figure 9: Map of average Total Dissolved Solids at Sites on Canyon Lake

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 than there will be an increase in surface vegetation growth, which can then reduce photosynthesis in the subsurface, thus decreasing the level of DO. Low DO can be dangerous for aquatic inhabitants, which rely upon the dissolved oxygen to breathe. The DO levels can also be impacted by temperature; a high temperature can limit the amount of oxygen solubility, which can also lead to a low DO measurement. Site 80534 had the lowest average DO reading, with a result of 6.5 ± 1.7 mg/L. Site 80231 had the highest average DO reading, with a result of 7.8 ± 1.3 mg/L.

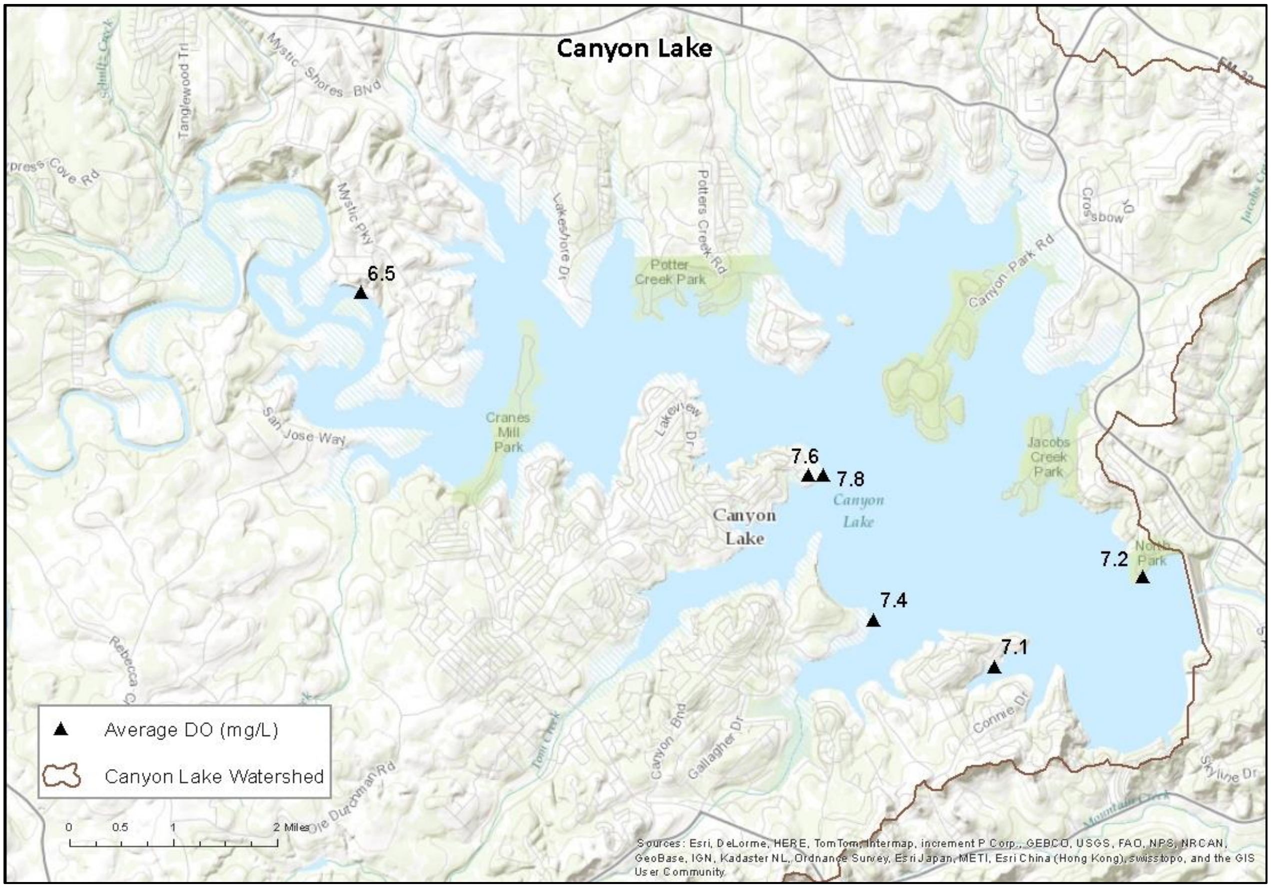

Figure 10: Map of average Dissolved Oxygen at Sites on Canyon Lake

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 reported pH levels outside of this widely accepted range. Sites 80238, 80231, and 80605 all had the highest average pH level, with a result of 7.8 ± 0.3. Site 80534 had the lowest average pH level, with a result of 7.4 ± 0.1.

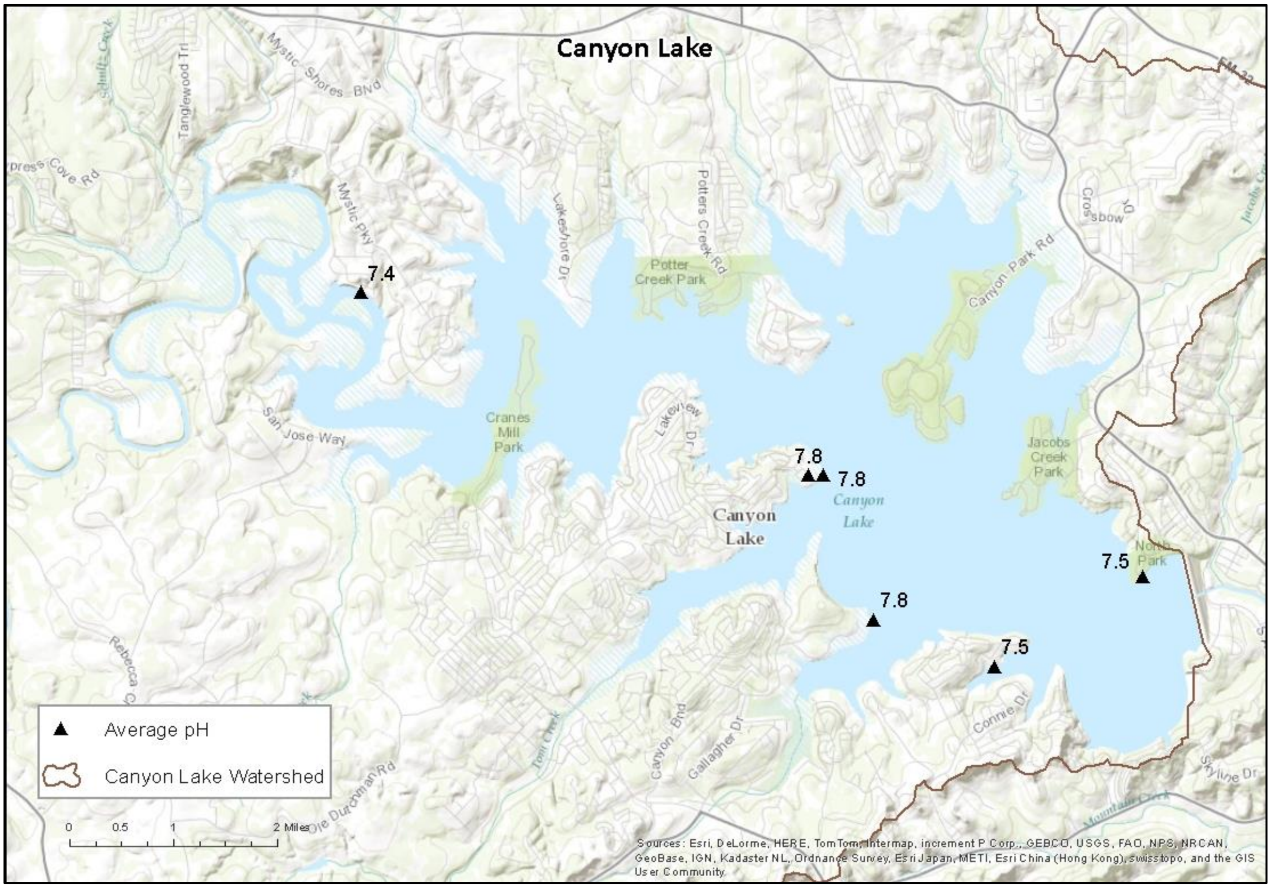

Figure 11: Map of average pH at Sites on Canyon Lake

E. coli bacteria originate in the digestive tract of endothermic organisms. The EPA 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 which takes into account the high variability of parameters such as E. coli which can vary from zero to tens of thousands of CFU/100 mL. Site 80534 had the highest average geomean, with a result of 54 CFU/100mL. Site 80533 had the lowest average geomean, with at result of 2 CFU/100mL.

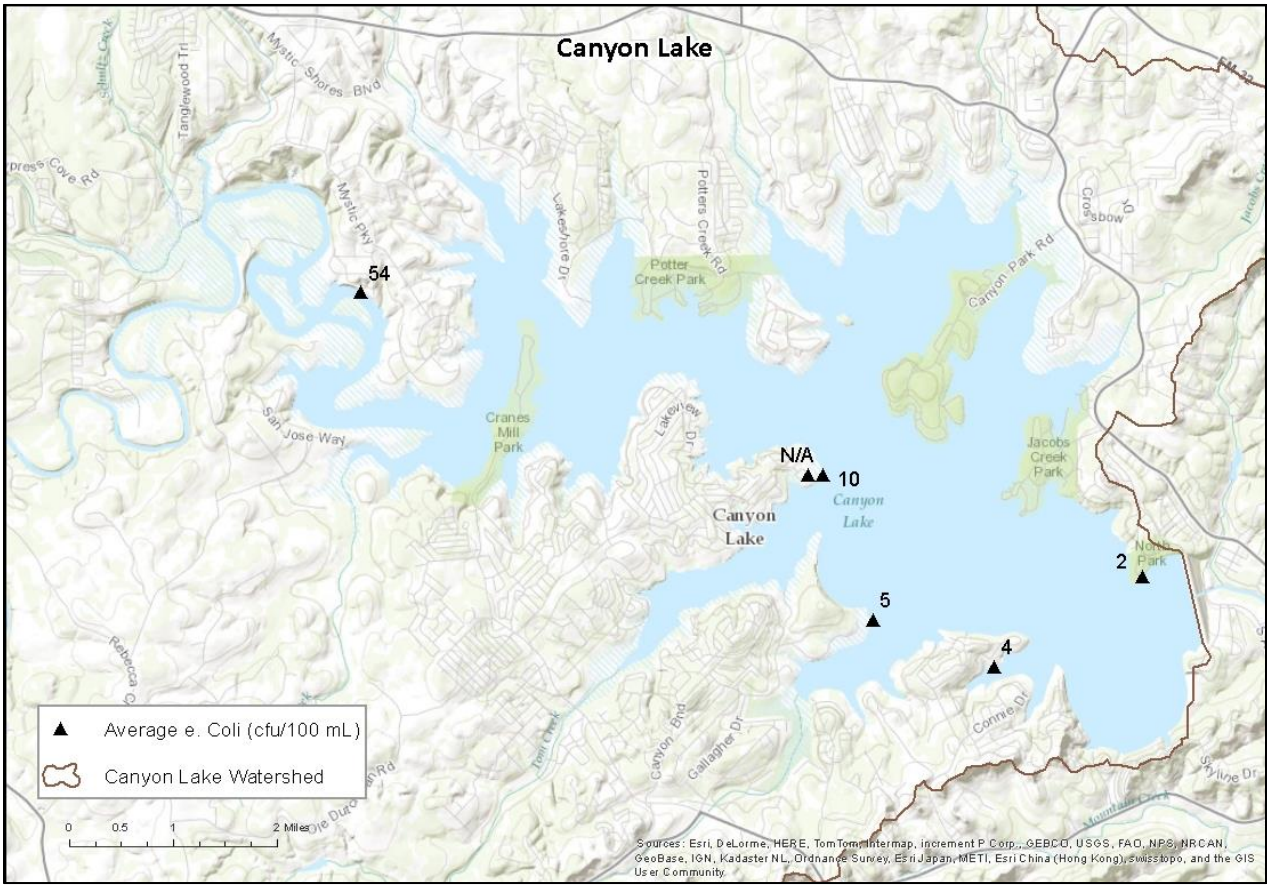

Figure 12: Map of average E. coli at Sites on Canyon Lake

Please see Table 5 for a summary of average results at all sites. 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. While this is a quick overview of the results, it is important to keep in mind that there is 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 5: Average Values for all Canyon Lake sites

Site Number	TDS (mg/L)	DO (mg/L)	pH	E. coli (cfu/100 mL)
80534	317 ± 31 (max)	6.5 ± 1.7 (min)	7.4 ± 0.1 (min)	54 (max)
80238	265 ± 50	7.6 ± 1.3	7.8 ± 0.3 (max)	N/A
80231	258 ± 22	7.8 ± 1.3 (max)	7.8 ± 0.2 (max)	10
80605	254 ± 12	7.4 ± 1.5	7.8 ± 0.3 (max)	5
15402	248 ± 7 (min)	7.1 ± 1.4	7.5 ± 0.3	4
80533	259 ± 13	7.2 ± 1.5	7.5 ± 0.4	2 (min)

Site 80534 – Guadalupe River Above Canyon Lake at Boat Ramp 11

Site Description

This site is located on the Guadalupe River as it opens into Canyon Lake. This site is at a public boat ramp on the north end of the lake. The surrounding area is rocky limestone with juniper trees. There are a few large houses on the banks of the river, but for the most part, the area is undeveloped.

Sampling Information

This site was sampled 36 times between 8/12/2009 and 4/29/2014. The site was sampled between 07:00 and 14:00.

Table 6: Descriptive parameters for Site 80534

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	32	317 ± 31	267	397
Water Temperature (°C)	36	22.5 ± 7.3	24	30
Dissolved Oxygen (mg/L)	34	6.5 ± 1.7	3.5	10.0
pH (su)	36	7.4 ± 0.1	7.2	7.7
E. coli (cfu/100 mL)	12	54	0	270

Site was sampled 36 times between 8/12/2009 and 4/29/2014. E. coli calculated as geomean.

Air and water temperature

Air and water temperatures were measured 36 times during this period. Air temperatures fluctuated in a seasonal pattern with a minimum of 10.5°C in November, 2011 and a maximum temperature of 36°C in July of 2012. The minimum water temperature was 7.7°C in January, 2014 to a maximum of 33.5°C in August, 2009.

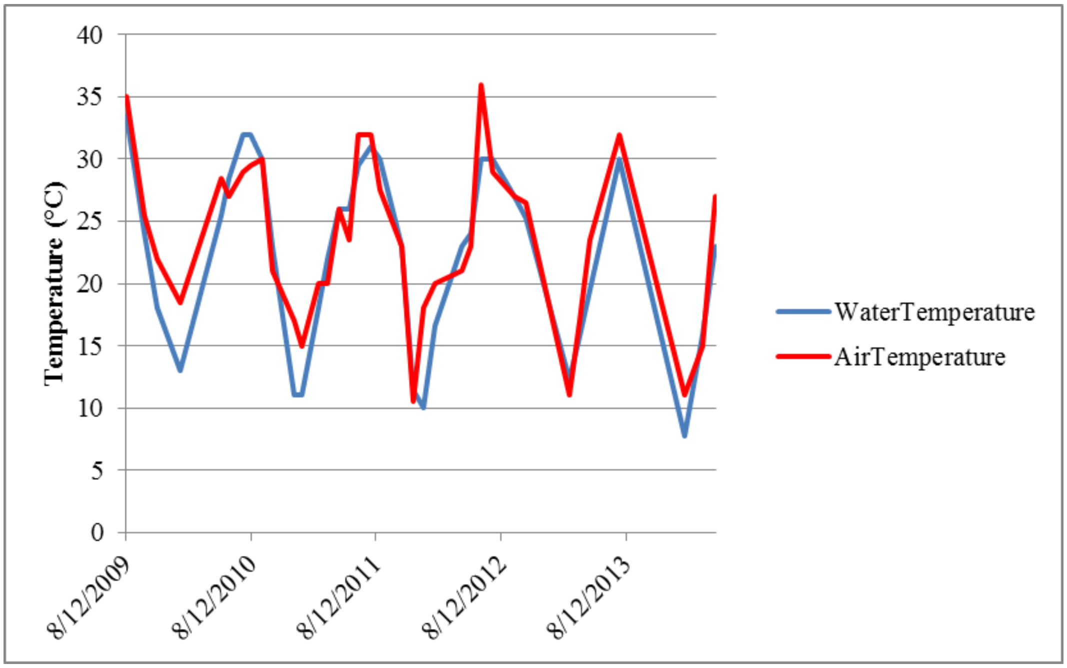

Figure 13: Air and water temperature at Site 80534

Total Dissolved Solids

Citizen scientists collected 32 TDS samples from this site during the time analyzed. The mean value was 317 mg/L. The maximum value was 397 mg/L and was recorded in November of 2009. The minimum value was 267 mg/L and was recorded in October, 2009. There was no significant increase or decrease in TDS values over time observed.

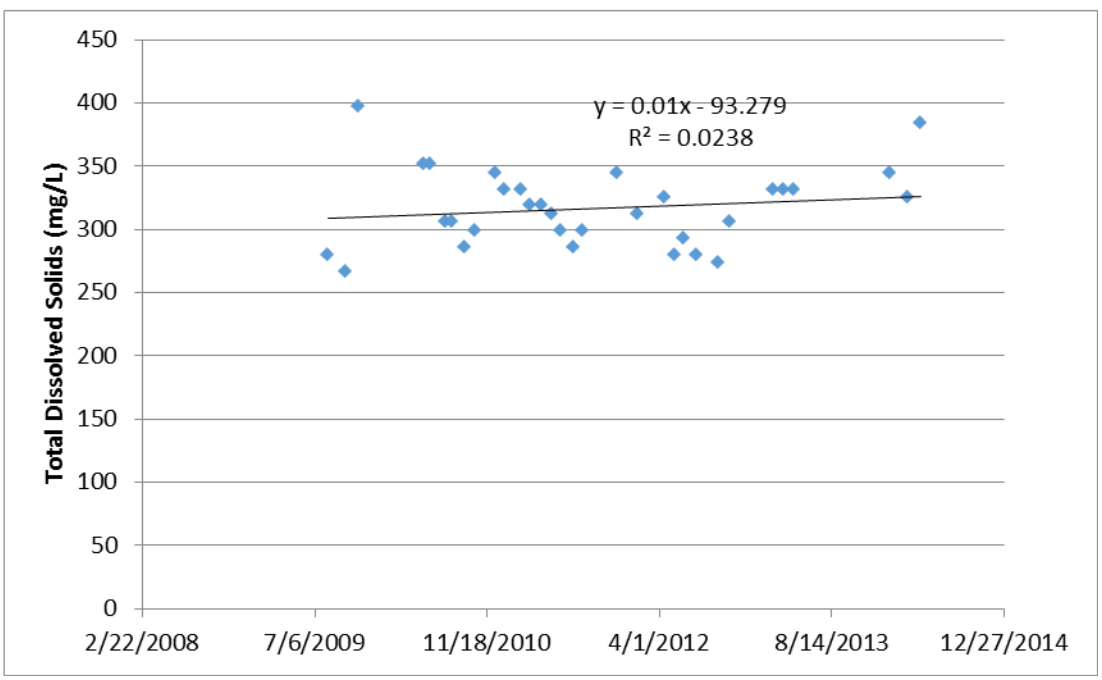

Figure 14: Total Dissolved Solids at Site 80534

Dissolved Oxygen

A total of 34 dissolved oxygen samples were taken at this site. The mean DO concentration was 6.5 mg/L. The minimum DO value was 3.5 mg/L and was recorded in October of 2009. The maximum TDS value was 10.0 mg/L and was recorded in January, 2014. There was no significant increase or decrease in DO concentrations over time observed.

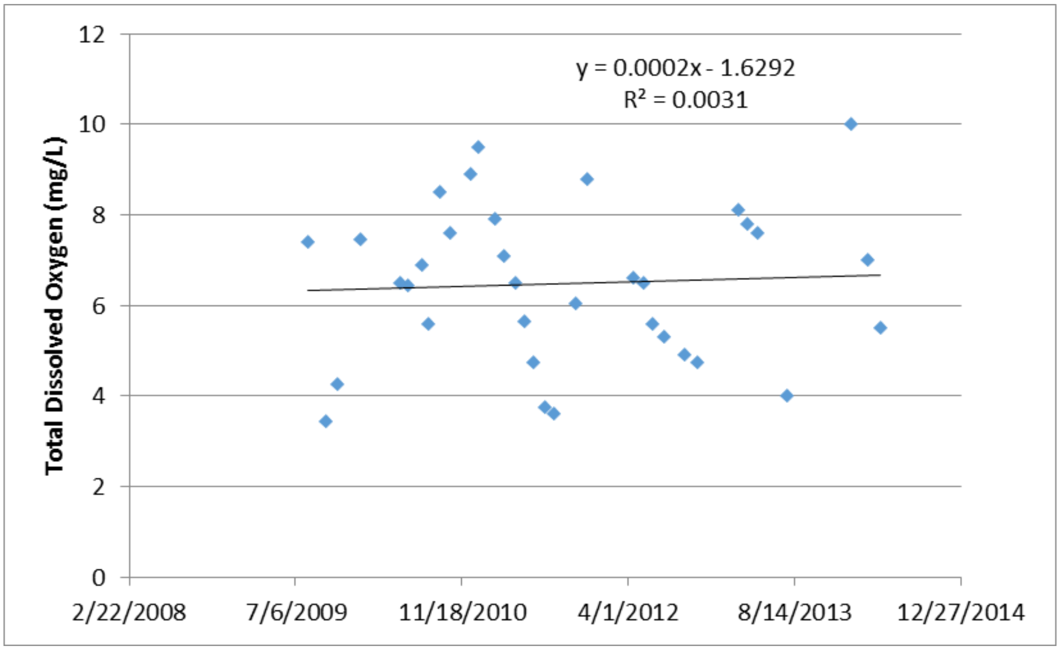

Figure 15: Dissolved Oxygen at Site 80534

pH

A total of 36 pH samples were taken for this site. The mean pH was 7.4 and it ranged from a minimum of 7.2 in January of 2012, to a maximum of 7.7 in September, 2010. There was no significant correlation between pH and time observed for this site.

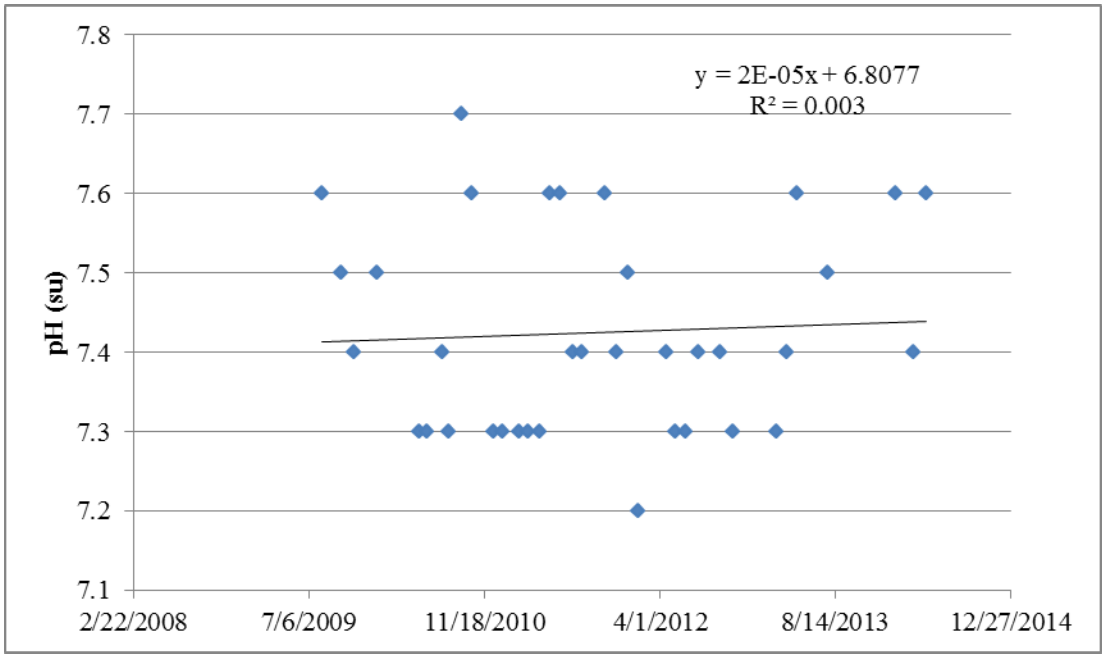

Figure 16: pH at Site 80534

Secchi disk and total depth

There were only 4 instances where secchi disk depth was greater than total depth, indicating that the water visibility did not go all the way down to the bottom of the sample location. The average Secchi disk depth was 0.43 m for this location, and the average total depth was 0.93 m.

Field Observations

Flow was recorded as either normal or low during this time period. Algae cover was recorded as absent or rare. The water color was commonly described as greenish brown, and the water either had no odor, or in some cases it was described as having a musky odor.

E. coli Bacteria

There were 12 E. coli samples taken at this site. The geomean for E. coli was 54 CFU/100 mL. The E. coli concentration ranged from 0 CFU/100 mL to a maximum of 270 CFU/100 mL in July of 2012. Although the concentration of E. coli appears to decrease over time at this site, the variability was such that no significant correlation could be determined using regression analysis.

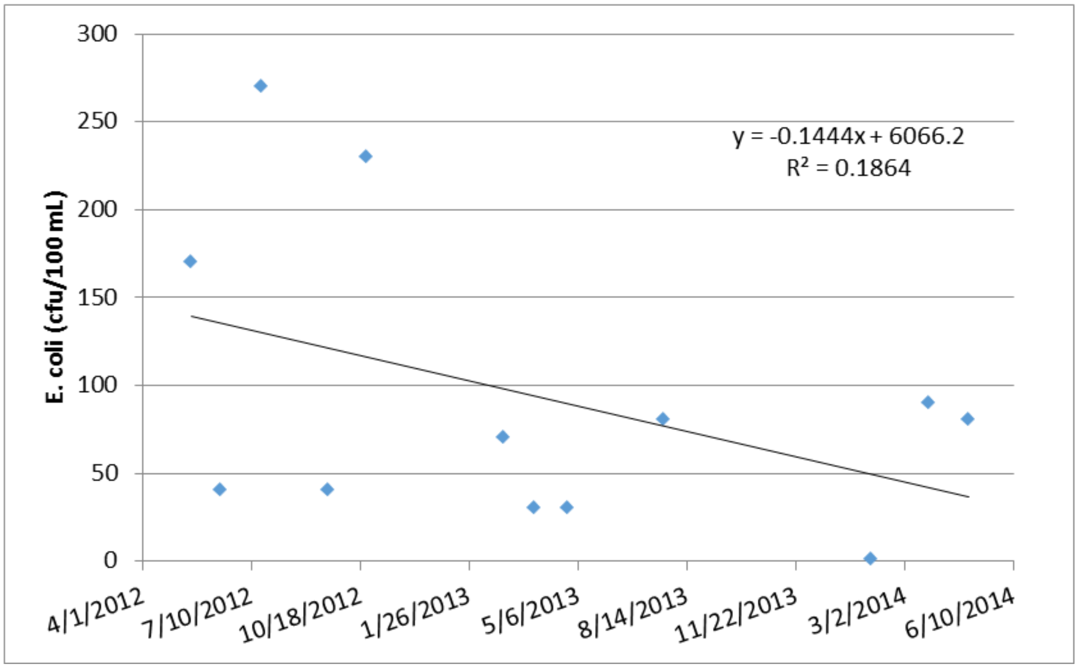

Figure 17: E. coli at Site 80534

Site 80238 – Tom Creek Tributary to Canyon Lake

Site Description

This site is where Tom Creek enters into Canyon Lake. The tributary forms a cove on the southern side of the reservoir. There are several houses in developments on both sides of the cove. The beach is composed of rocky limestone, and a prolonged drought has increased the space between the water in the lake and the houses in the development. Vegetation has sprung up on dry land that is usually underwater when the lake is at its traditional level.

Sampling Information

This site was sampled 109 times between 12/15/2014 and 5/30/2014. The time of sampling varied between 07:30 and 17:00.

Table 7: Descriptive parameters for Site 80238

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	107	265 ± 50	234	735
Water Temperature (°C)	109	21.3 ± 6.1	11	37
Dissolved Oxygen (mg/L)	103	7.6 ± 1.3	4.8	10.5
pH (su)	106	7.8 ± 0.2	7.0	8.6
E. coli (cfu/100 mL)	N/A	N/A	N/A	N/A

Site was sampled 109 times between 12/15/2004 and 5/30/2014. E. coli calculated as geomean.

Air and water temperature

Air and water temperatures were measured 109 times during this period. The air temperature fluctuated seasonally with a minimum of 5°C in December of 2004, to a maximum temperature of 35°C in May, 2011. The mean water temperature was 21.3°C and varied from a low of 11°C in February, 2010, to a high of 37°C in June of 2011.

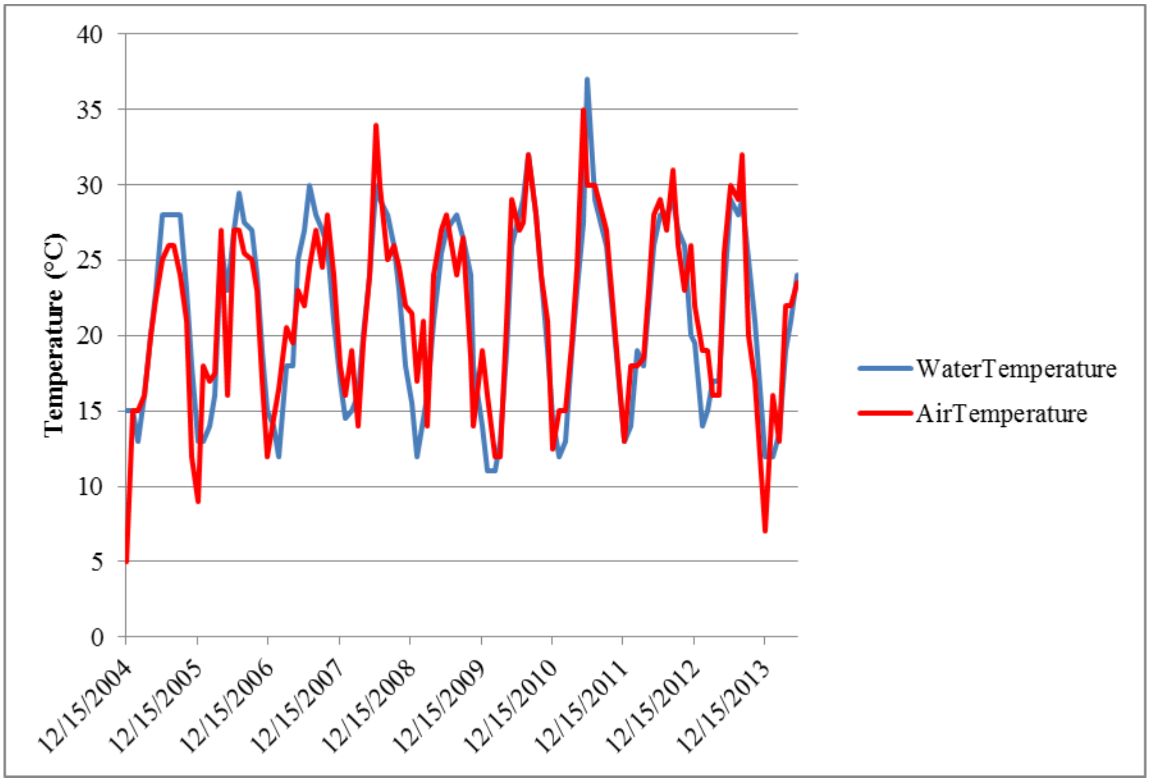

Figure 18: Air and Water Temperature at Site 80238

Total Dissolved Solids

Citizen scientists collected 107 TDS measurements at this site. The mean TDS concentration was 265 mg/L. The minimum TDS value recorded was 234 mg/L in February, 2014. The maximum TDS value recorded was 734 mg/L in March of 2008. There was no significant increase or decrease in TDS concentrations observed over time for this site.

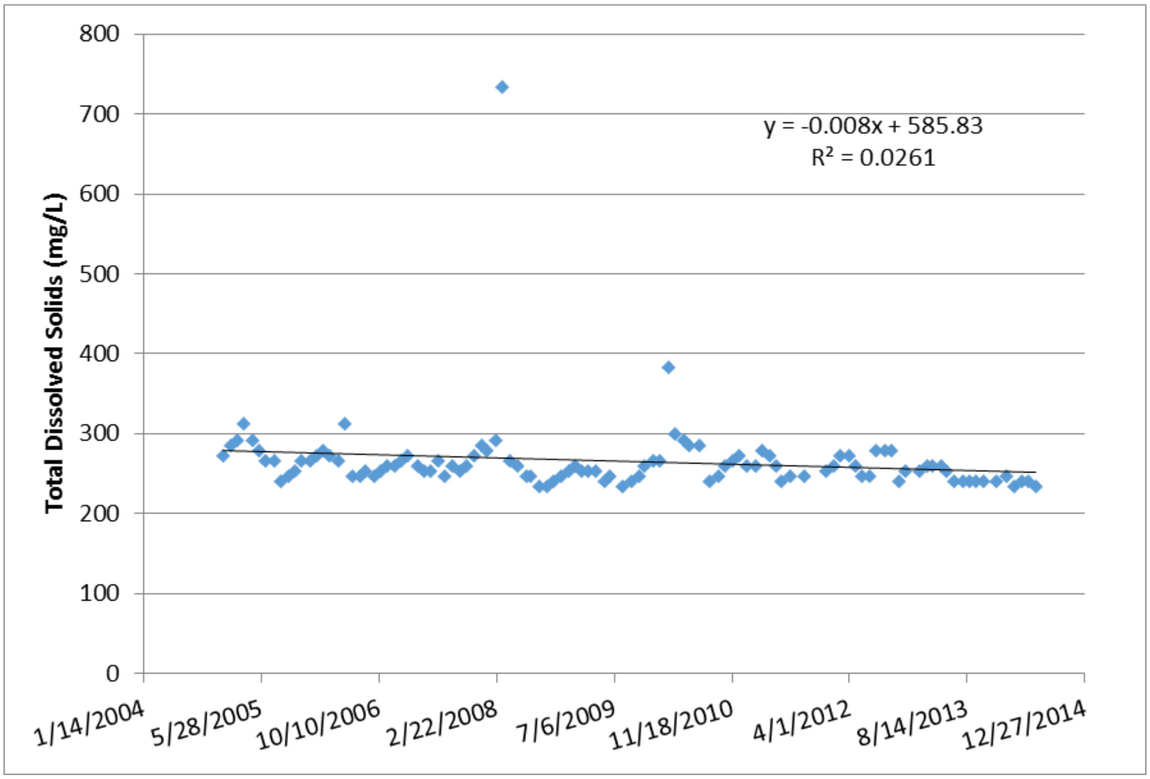

Figure 19: Total Dissolved Solids at Site 80238

Dissolved Oxygen

Citizen scientists collected 103 dissolved oxygen samples at this site during this time period. The mean DO concentration was 7.6 mg/L. The lowest DO concentration recorded was 4.8 mg/L recorded in August, 2007. The highest DO concentration recorded was 10.5 mg/L and was recorded in February, 2014. There was no significant correlation between DO concentrations and time observed for this site.

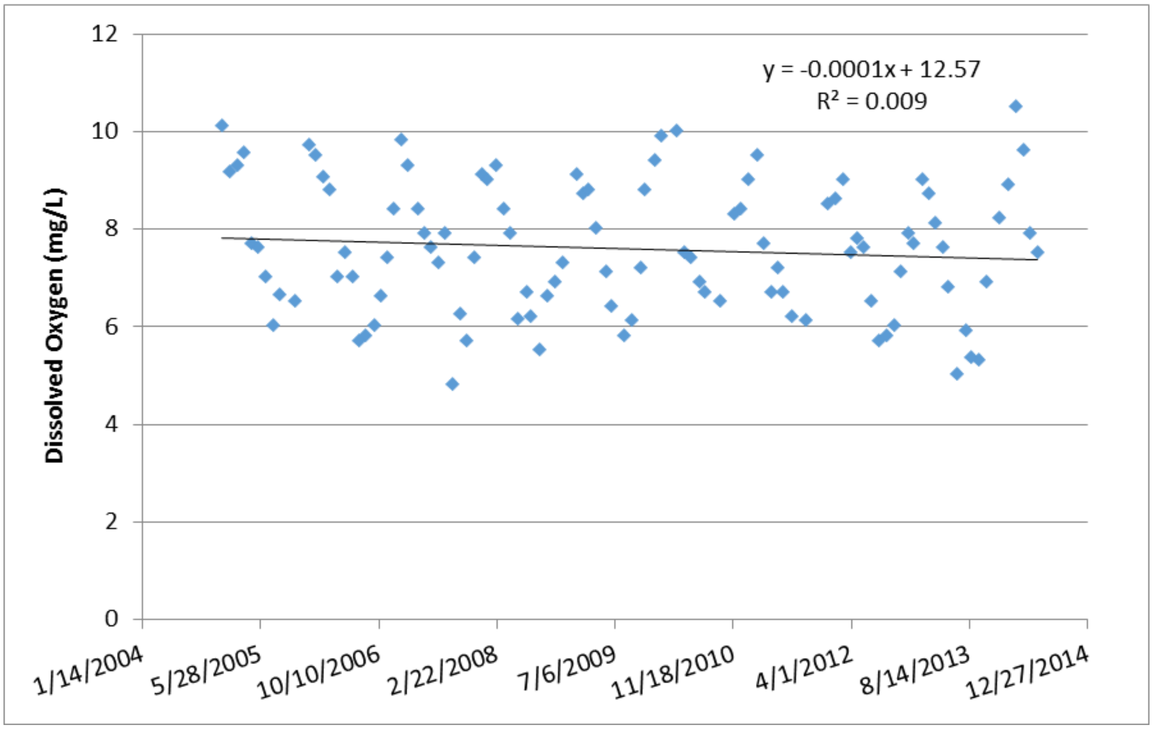

Figure 20: Dissolved Oxygen at Site 80238

pH

There were 106 pH measurements taken at this site. The mean pH was 7.8 and it ranged from a low of 7.0 in July of 2005, to a high of 8.6 in May of 2012. There was a significant increase in pH over time observed ($p = 0.01$), with a R^2 value of 0.1068 indicating that this relationship explains a little over 10% of the variation in the data.

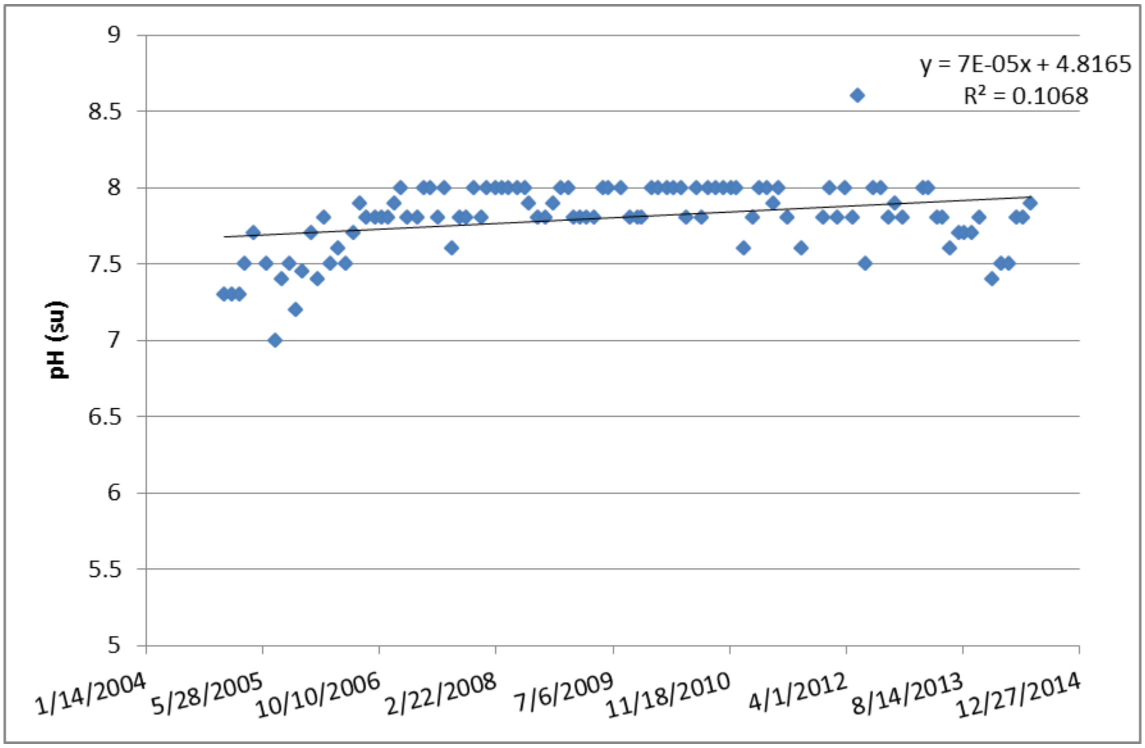

Figure 21: pH at Site 80238

Secchi disk and total depth

The average depth at this sampling site was 0.6 m. In almost all cases, the Secchi disk depth was recorded as greater than the total depth, indicating that the water at this site is usually clear all the way to the bottom.

Field Observations

The flow at this site was most commonly recorded as low. Algae cover was commonly recorded as absent. The water was described as having no color or odor, and the clarity was almost always clear.

Site 80231 – Canyon Lake at Canyon Lake Hills Paradise Point

Site Description

This site is located on the shoreline where Paradise Point juts out into the main body of the reservoir. The point is created by the main channel of the Guadalupe and the cove formed at the tributary with Tom Creek. The shoreline is composed of rocky limestone, and there is a large development of houses on the point.

Sampling Information

This site was sampled 106 times between 12/15/2014 and 5/30/2014. The sampling time varied between 07:30 and 16:30.

Table 8: Descriptive parameters for Site 80231

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	104	258 ± 22	221	377
Water Temperature (°C)	106	21.0 ± 6.3	8	32
Dissolved Oxygen (mg/L)	100	7.8 ± 1.3	2.9	11.3
pH (su)	105	7.8 ± 0.2	7.2	8.8
E. coli (cfu/100 mL)	24	10	0	800

Site was sampled 106 times between 12/15/2004 and 5/30/2014. E. coli calculated as geomean.

Air and water temperature

Air and water temperatures were taken 106 times during this time period. The air temperature fluctuated seasonally, and varied between a low of 8°C in November of 2005, and a high of 39°C in July of 2006. The water temperature ranged between 10°C in November of 2005 and 32°C in August 2006. The mean water temperature was 21.0 °C.

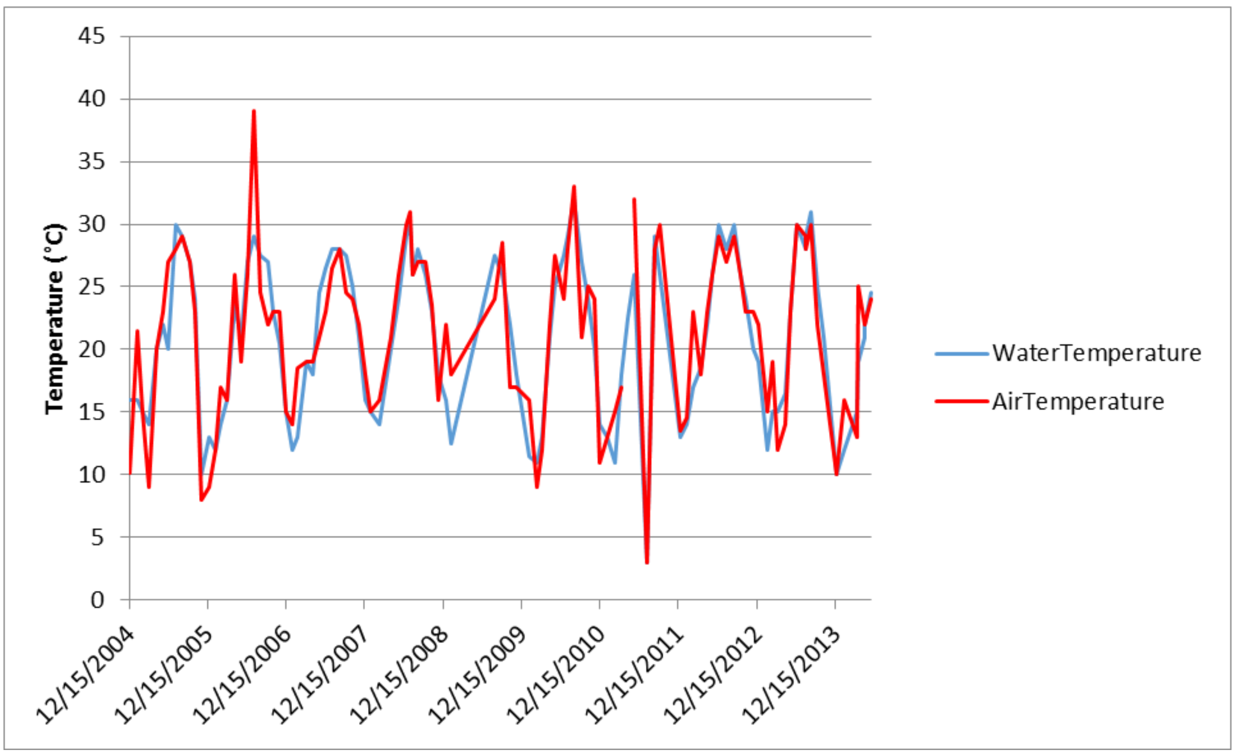

Figure 22: Air and Water Temperatures at Site 80231

Total Dissolved Solids

There were 104 TDS measurements taken at this site. The mean TDS concentration was 258 mg/L. The TDS values varied between 221 mg/L in May, 2012 to 377 mg/L recorded in February of 2010. There was a significant correlation between TDS and time with TDS concentrations decreasing over time at this location (p=0.02). However, the low R^2 value indicates that this relationship explains only a small percentage of variability in the data.

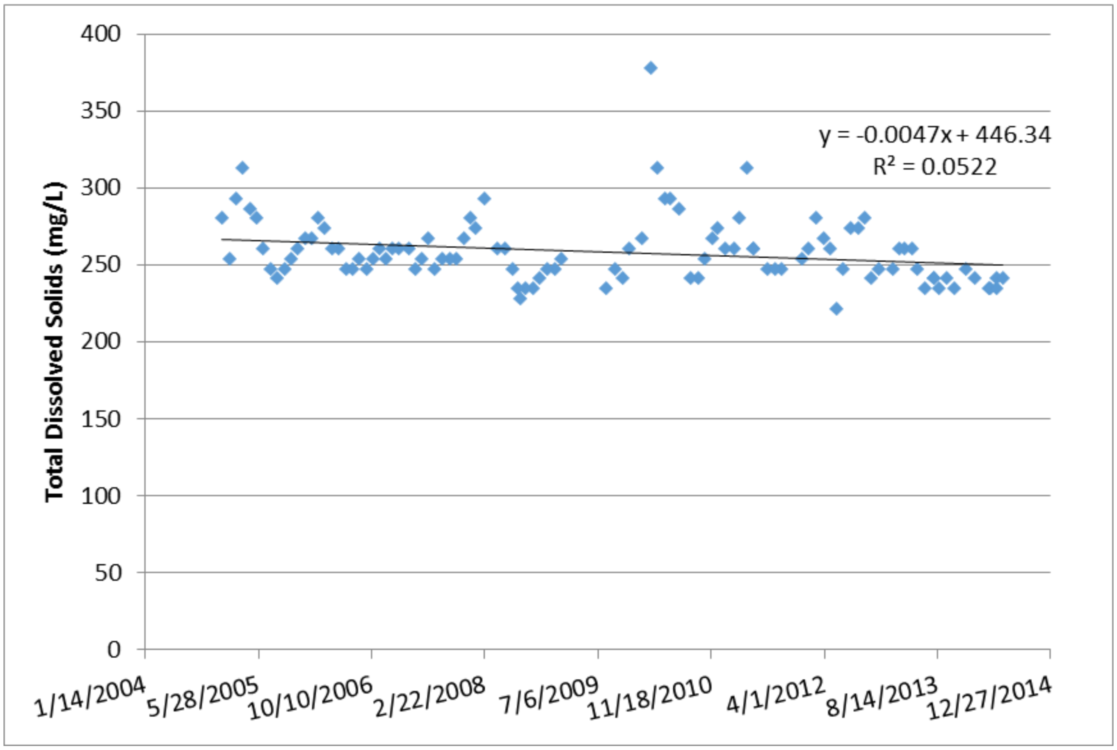

Figure 23: Total Dissolved Solids at Site 80231

Dissolved Oxygen

There were 100 dissolved oxygen samples taken at this site. The mean DO concentration was 7.8 mg/L. DO concentrations ranged from a low of 2.9 mg/L in July, 2008 to a high of 11.3 mg/L in March, 2014. There was no significant increase or decrease in DO concentrations observed over time at this site.

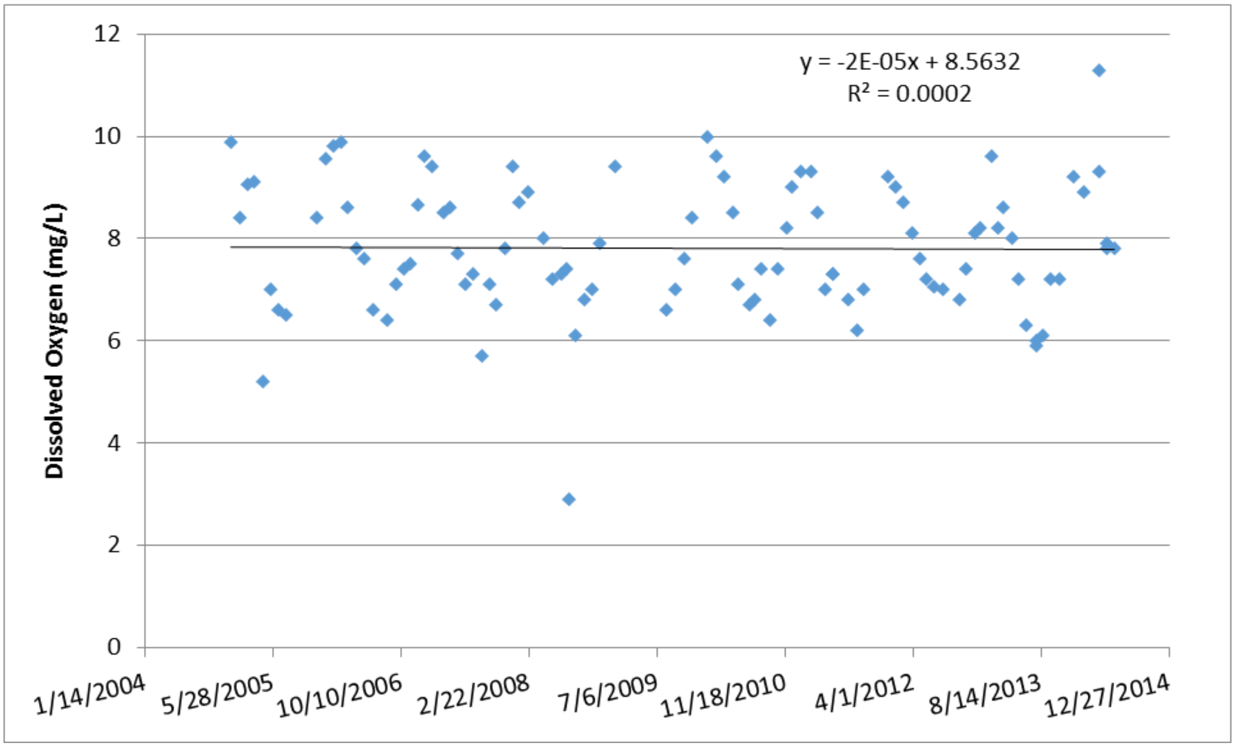

Figure 24: Dissolved Oxygen at Site 80231

pH

There were 105 pH measurements taken at this site. The mean pH was 7.8 and pH ranged from a low of 7.2 in July, 2012 to a high of 8.8 in May of 2012. There was a significant increase in pH over time observed ($p = 0.01$), with a R^2 value of 0.0624 indicating that this relationship explains a small amount of the variation in the data.

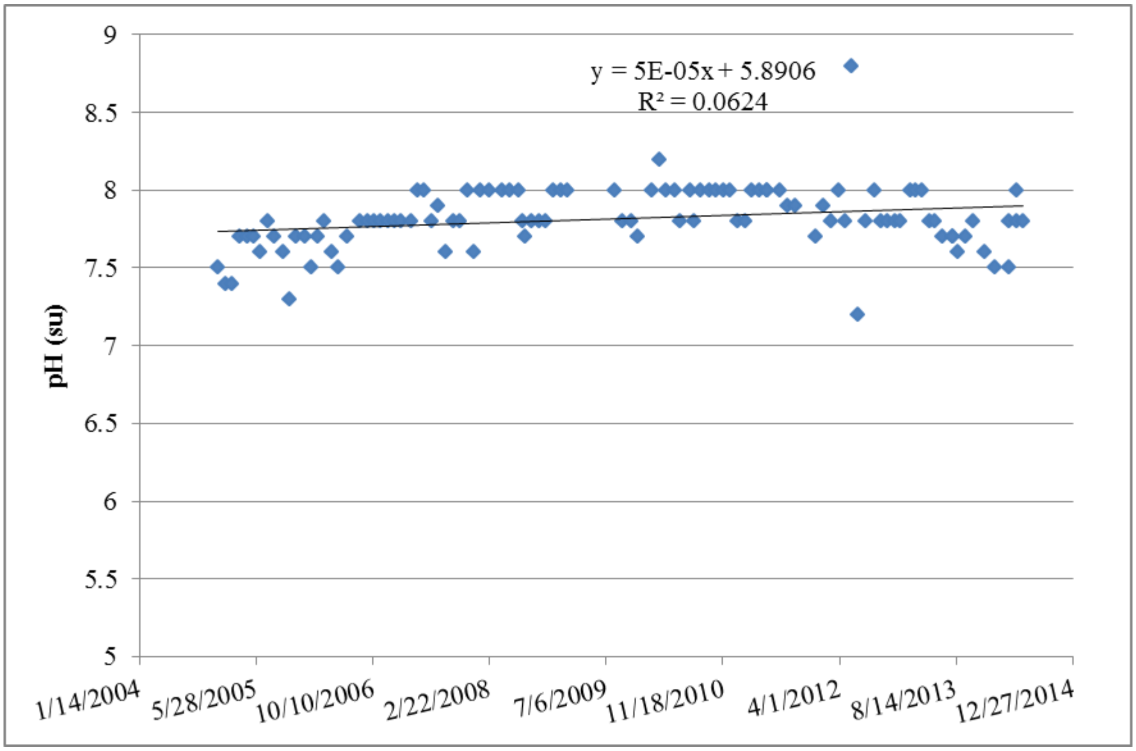

Figure 25: pH at Site 80231

Secchi disk and total depth

The average total depth at this site was 0.75m. The Secchi disk depth was greater than total depth in all sampling events except 3 which indicates that the water at this site was usually clear all the way to the bottom.

Field Observations

Flow was recorded a low or normal for this site. Algae cover was always recorded as absent. The water had no color or odor. Water clarity was recorded as clear, with 17 events where the water was described as cloudy.

E. coli Bacteria

There were 24 E. coli samples taken at this site. The geomean for E.coli was 10 CFU/100mL. E. coli ranged from none detected to 800 CFU/100 mL in April, 2013. There was no significant correlation between E. coli and time observed for this site.

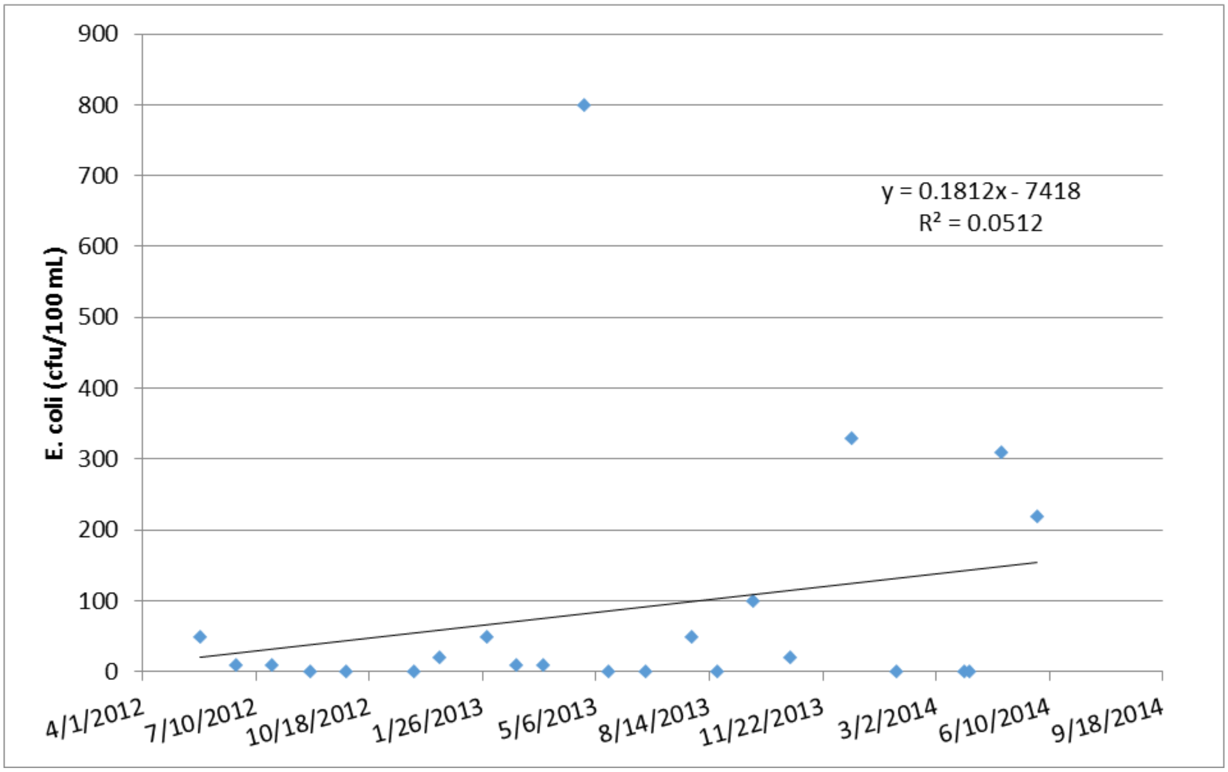

Figure 26: E. coli at Site 80231

Site 80605 – Canyon Lake at Comal Park Swim Beach

Site Description

This site is located in a county park with an artificial beach that is roped off as a designated swimming area. The beach is composed of imported sand. The beach is on a point that forms the north side of a small cove on the south side of the reservoir. The shoreline is treeless, and contains two large parking lots for visitors.

Sampling Information

This site was sampled 33 times between 10/22/2014 and 5/31/2014. The time of sampling varied between 11:00 and 17:00.

Table 9: Descriptive parameters for Site 80605

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	32	254 ± 12	241	305
Water Temperature (°C)	32	21.6 ± 6.5	9.0	30.5
Dissolved Oxygen (mg/L)	32	7.4 ± 1.5	5.0	10.9
pH (su)	33	7.8 ± 0.3	7.0	8.0
E. coli (cfu/100 mL)	20	5	0	150

Site was sampled 33 times between 10/22/2010 and 5/31/2014. E. coli calculated as geomean.

Air and water temperature

Citizen scientists collected 32 air and water temperatures taken from this site during this time period. The air temperature fluctuated seasonally and ranged from a low of 8°C in January, 2014 to a high of 25.5°C in October 2012. The mean water temperature was 21.6°C and ranged from 9°C in January of 2014 to 30.5°C in August of 2013.

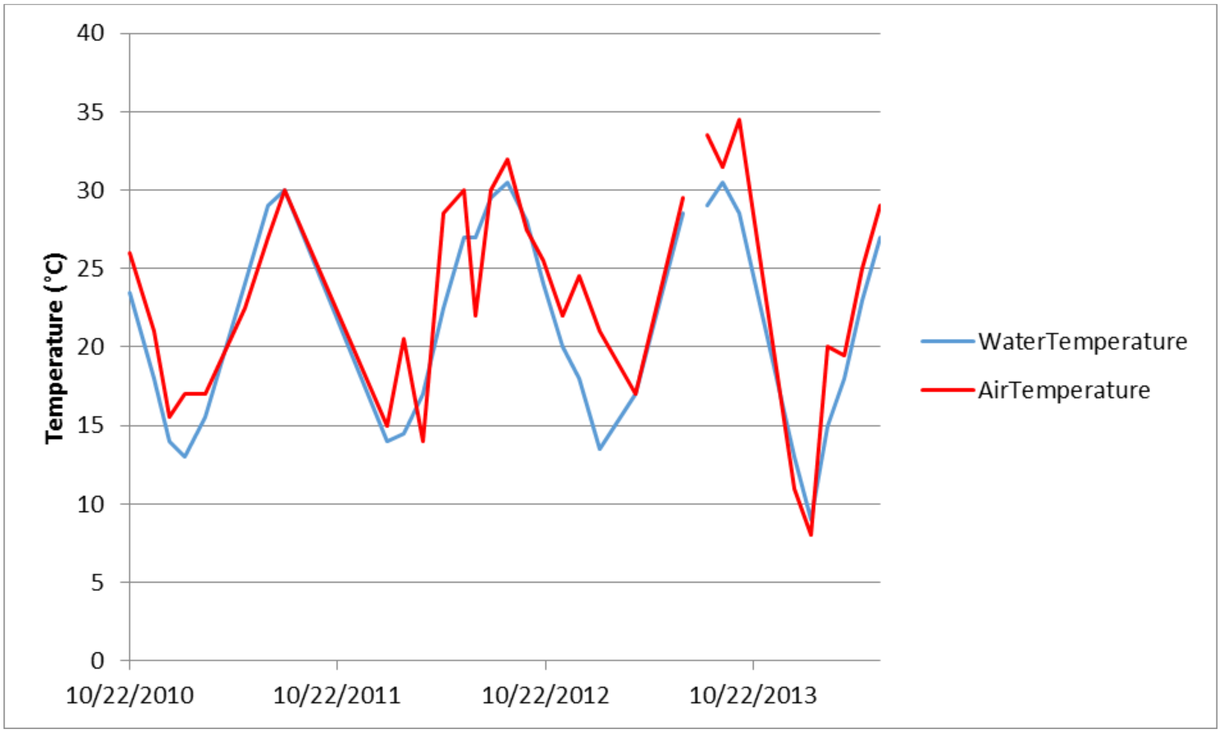

Figure 27: Air and Water Temperature at Site 80605

Total Dissolved Solids

Citizen scientists collected 32 TDS measurements at this site during this time period. The mean TDS concentration was 254 mg/L. The minimum TDS concentration was 241 mg/L and was recorded 5 times during the sampling period. The maximum TDS concentration was 306 mg/L and was recorded in July, 2013. There was no correlation between TDS concentration and time observed for this site.

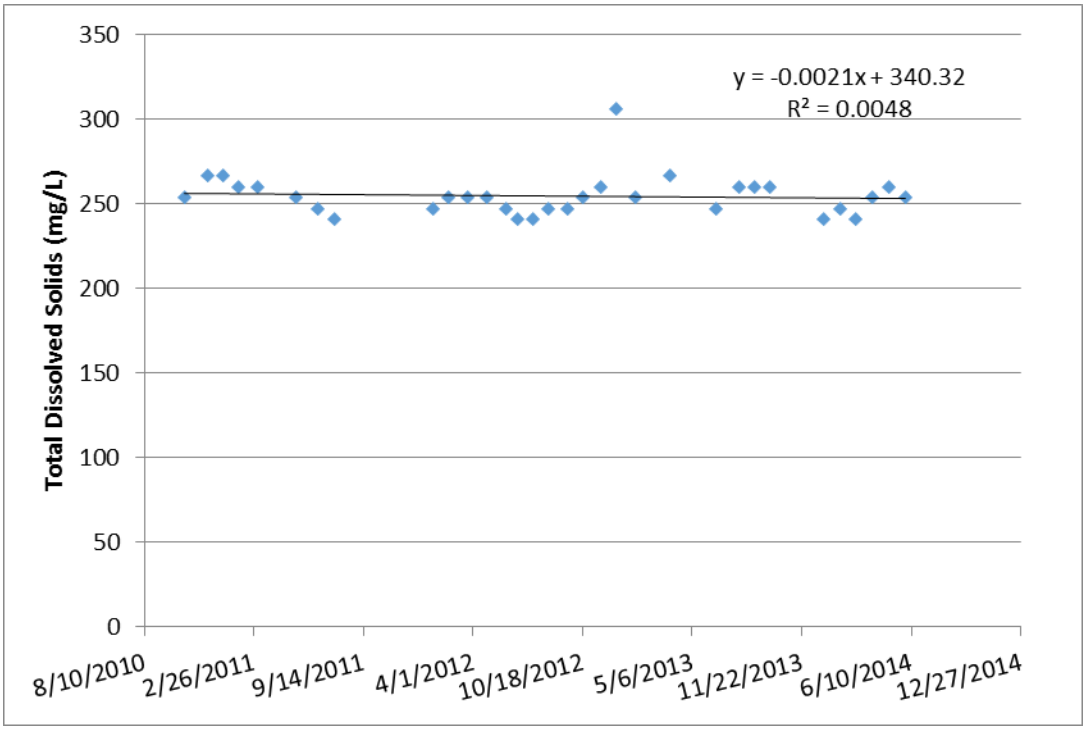

Figure 28: Total Dissolved Solids at Site 80605

Dissolved Oxygen

There were 32 dissolved oxygen samples taken at this site. The mean DO concentration was 7.4 mg/L. The minimum DO value was 5.0 mg/L and was recorded in October of 2010. The maximum DO value was 10.9 mg/L, and was recorded in December of 2013. There was no significant increase or decrease in DO concentrations over time observed at this site.

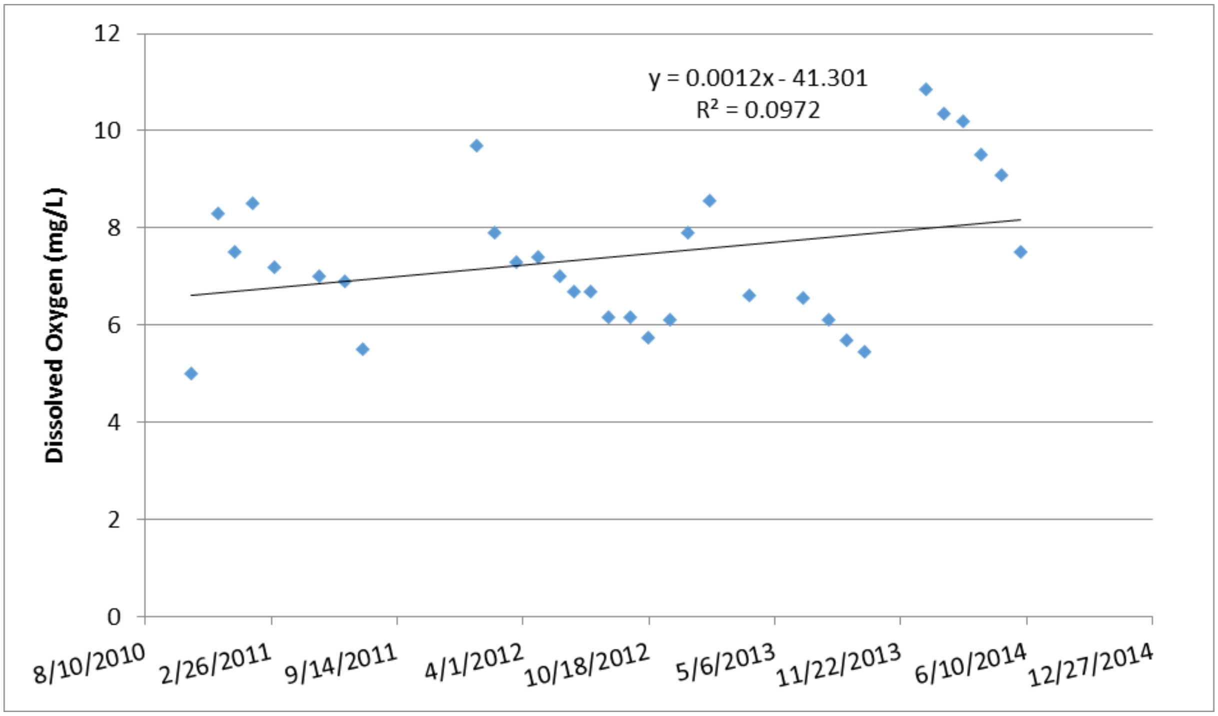

Figure 29: Dissolved Oxygen at Site 80605

pH

There were 33 pH measurements taken at this site. The mean pH was 7.8 and varied between a low of 7.0 in August and May, 2012 to a high of 8.0 recorded several times. There was no significant increase or decrease pH observed at this site.

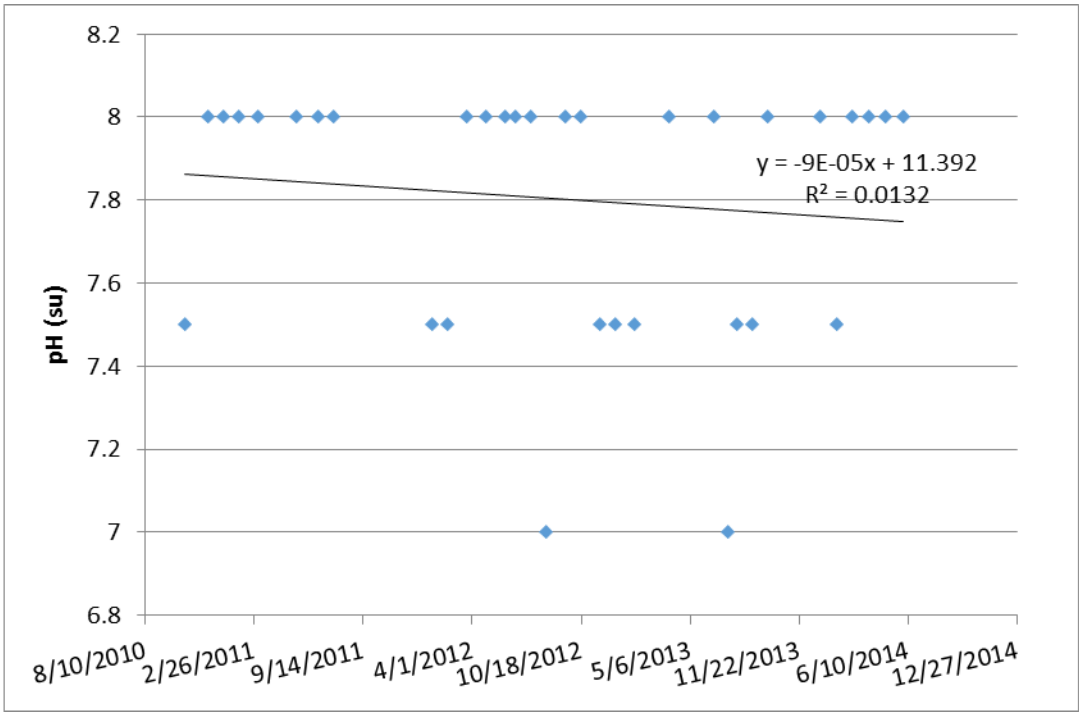

Figure 30: pH at Site 80605

Secchi disk and total depth

The average depth at this site was 0.5 m. In all cases, the Secchi disk depth was greater than the total depth indicating that the water was clear all the way to the bottom at this site.

Field Observations

This site had algae cover that was recorded as abundant (51-75%) or dominant (>75%). The water was described as having no color and no odor. The water clarity was clear for all sampling events.

E. coli Bacteria

There were 20 E. coli samples collected at this site. The geomean for E. coli was 5 CFU/100 mL for this site. E. coli counts varied from 0 CFU/100 mL to a high of 150 CFU/100 mL collected in October of 2010. There was no significant correlation between E. coli and time observed for this site.

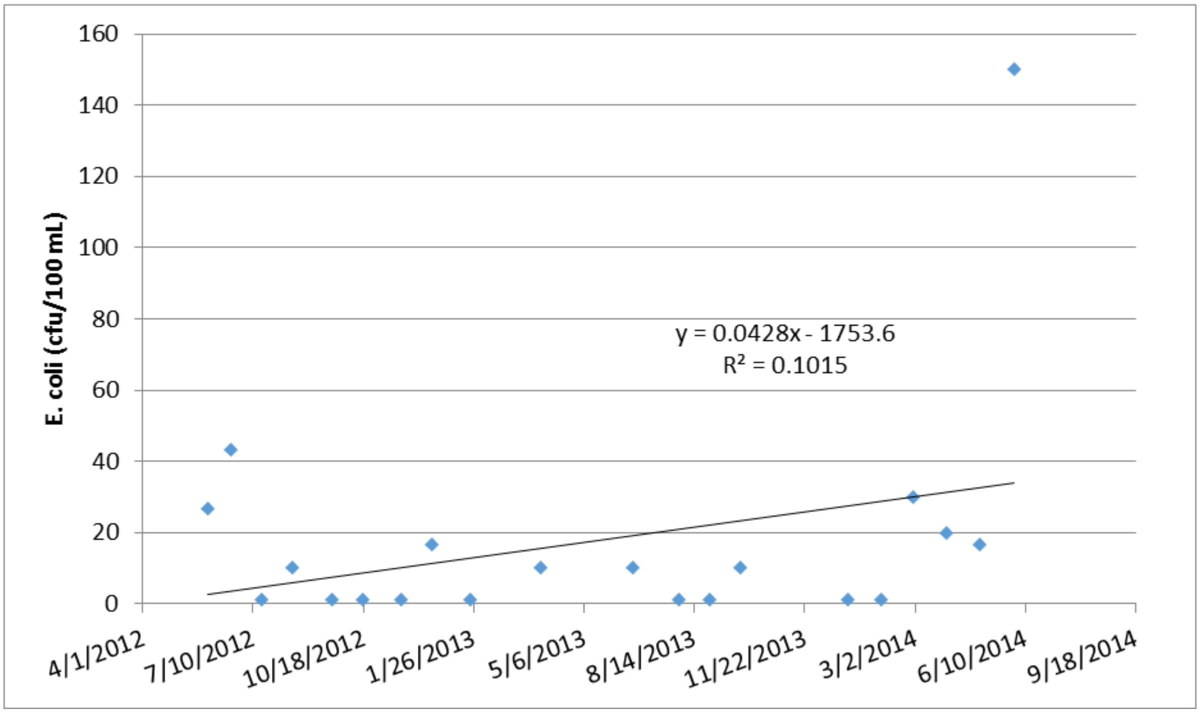

Figure 31: E. coli at Site 80605

Site 15402 – Canyon Lake at Turkey Cove

Site Description

This site is located on the north shore of Turkey Cove, which is located on the southern end of Canyon Lake. The site is at a public boat ramp with a large parking lot. There is a large development of houses along the north shore of Turkey Cove, but none of the houses in the area are on the waterfront. The shoreline mainly consists of steep banks of limestone.

Sampling Information

Citizen Scientists sampled this site 28 times between 3/1/2012 and 6/5/2014. The time of sampling varied between 12:00 and 16:00.

Table 10: Descriptive parameters for Site 15402

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	28	247 ± 7	234	260
Water Temperature (°C)	28	21.4 ± 6.5	11	32
Dissolved Oxygen (mg/L)	28	7.1 ± 1.4	4.5	10.2
pH (su)	28	7.5 ± 0.3	7.0	8.2
E. coli (cfu/100 mL)	23	4	0	120

Site was sampled 28 times between 3/1/2012 and 6/5/2014. E. coli calculated as geomean.

Air and water temperature

There were 28 air and water temperatures taken at this site. The air temperature fluctuated seasonally with a low of 8°C in January, 2013 to a high of 32°C in June of 2012. The mean water temperature was 21.4°C. The minimum water temperature was 11°C and was recorded in February, 2014. The maximum water temperature was 32 °C and was recorded in August of 2013.

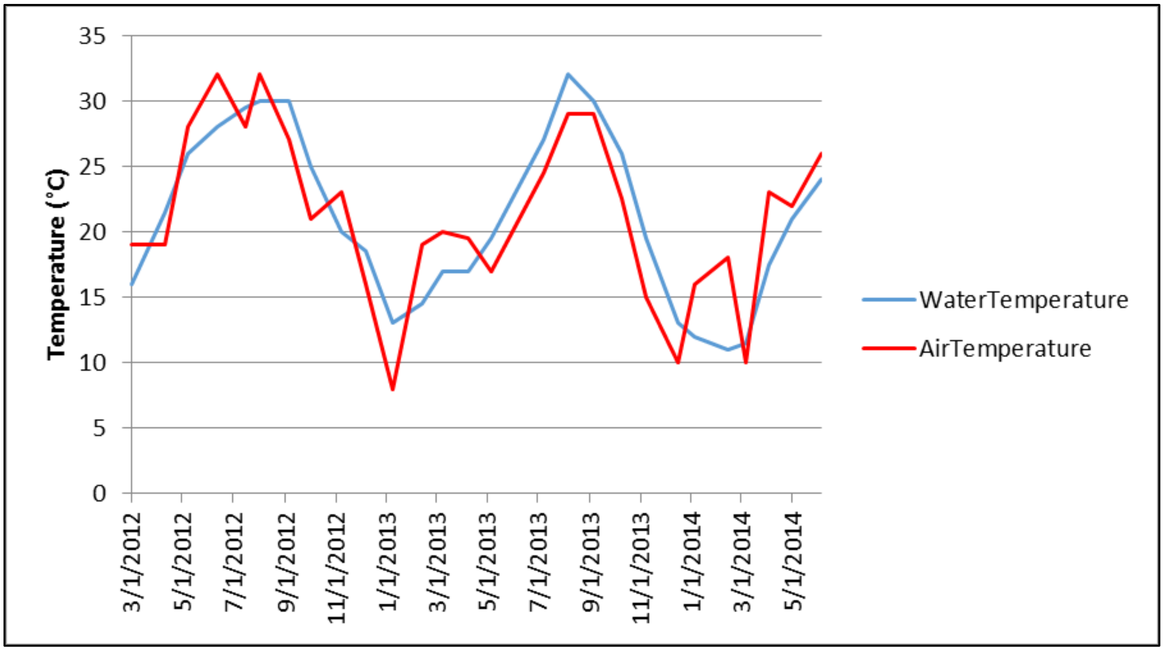

Figure 32: Air and Water Temperature at Site 15402

Total Dissolved Solids

There were 28 TDS measurements taken at this site. The mean TDS concentration was 247 mg/L. The minimum TDS concentration was 234 mg/L and was recorded in May and June of 2012. The maximum TDS concentration was 260 mg/L and was recorded in April and August of 2013. There was no correlation between TDS concentration and time observed for this site.

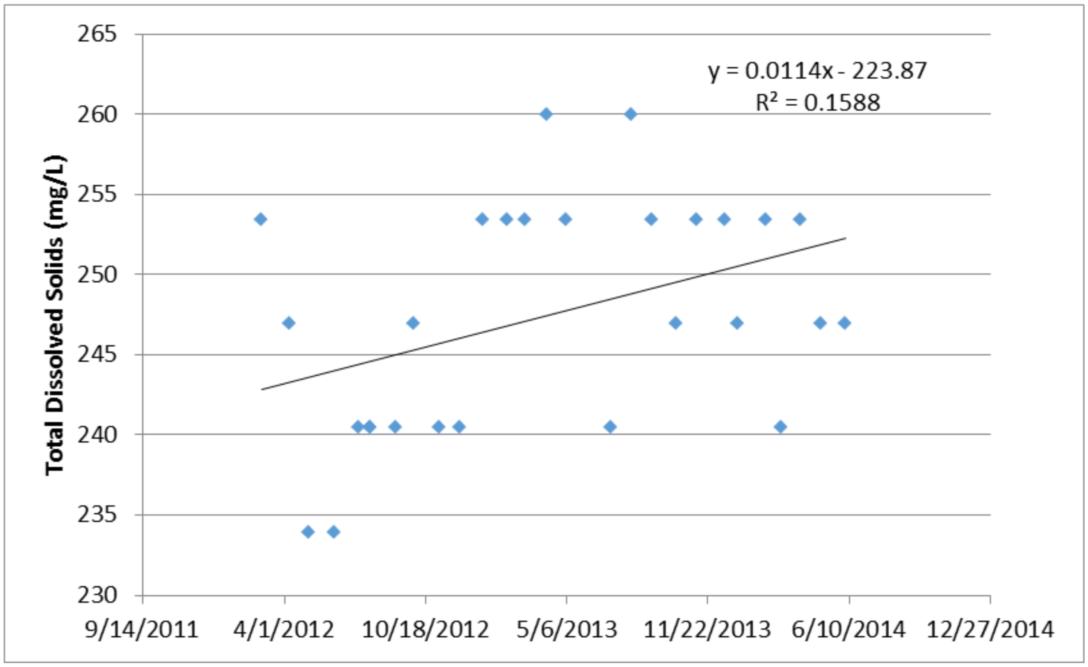

Figure 33: Total Dissolved Solids at Site 15402

Dissolved Oxygen

Citizen scientists collected 28 dissolved oxygen samples at this site during this time period. The mean DO concentration was 7.1 mg/L. The minimum DO concentration was 4.5 mg/L and was recorded in July of 2012. The maximum DO concentration was 10.2 mg/L and was recorded in January of 2014. There was no significant increase or decrease in DO observed over time at this site.

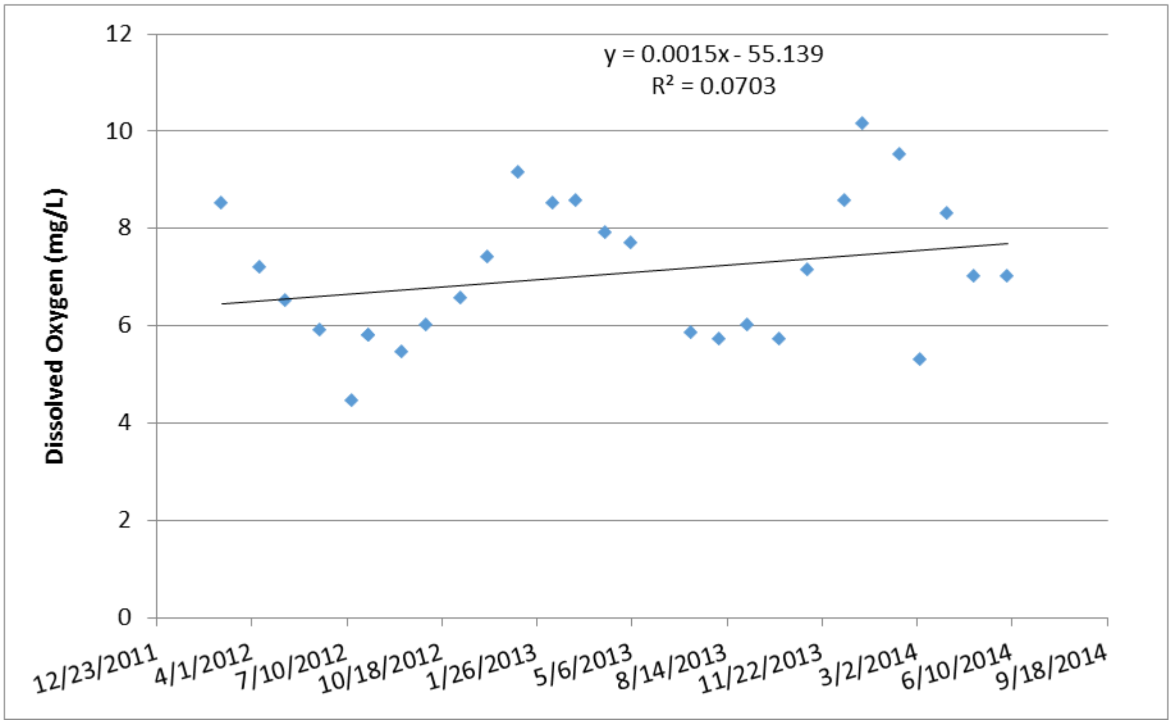

Figure 34: Dissolved Oxygen at Site 15402

pH

There were 28 pH measurements taken at this site. The mean pH was 7.5 and ranged from a low of 7.0 in October of 2012 to a high of 8.2 in July of 2012 and April, 2013. There was no significant correlation between pH and time observed for this site.

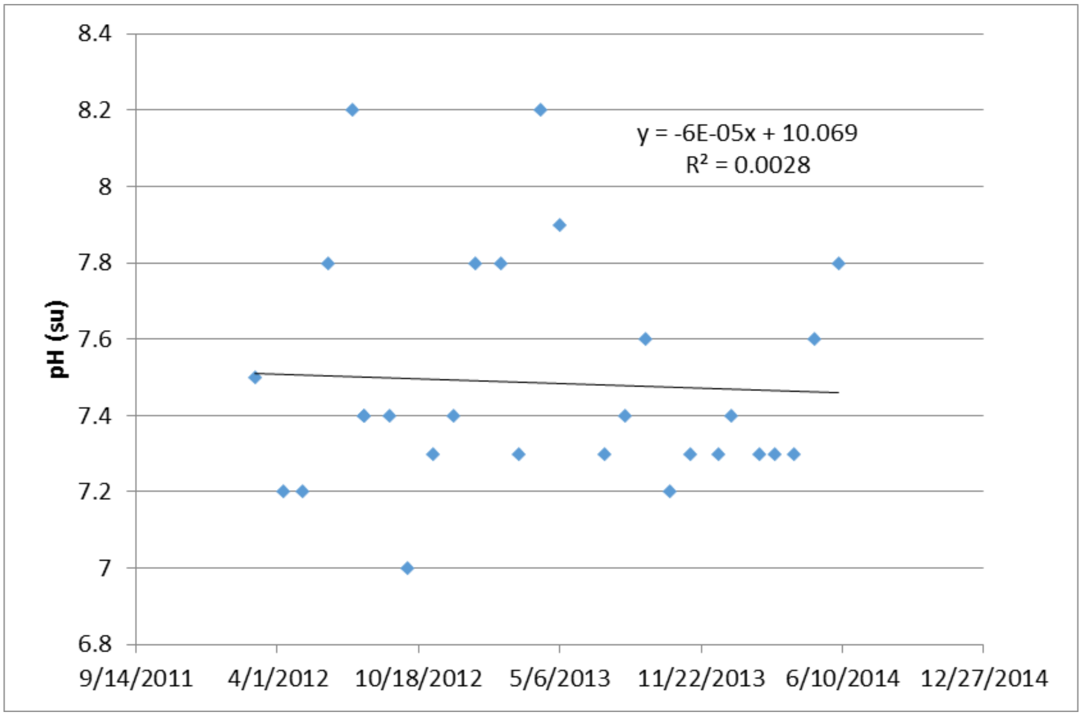

Figure 35: pH at Site 15402

Field Observations

There was no algae cover observed at this site. The water color was described as dark green. Water clarity was classified as clear, and there was no distinguishable water odor.

E. coli Bacteria

There were 23 E. coli samples taken at this site. The E. coli counts ranged from 0 CFU/100 mL to 120 CFU/100 mL in July, 2013. The E. coli geomean was 4 CFU/100 mL for this site. There was no increasing or decreasing trend in E. coli observed for this site.

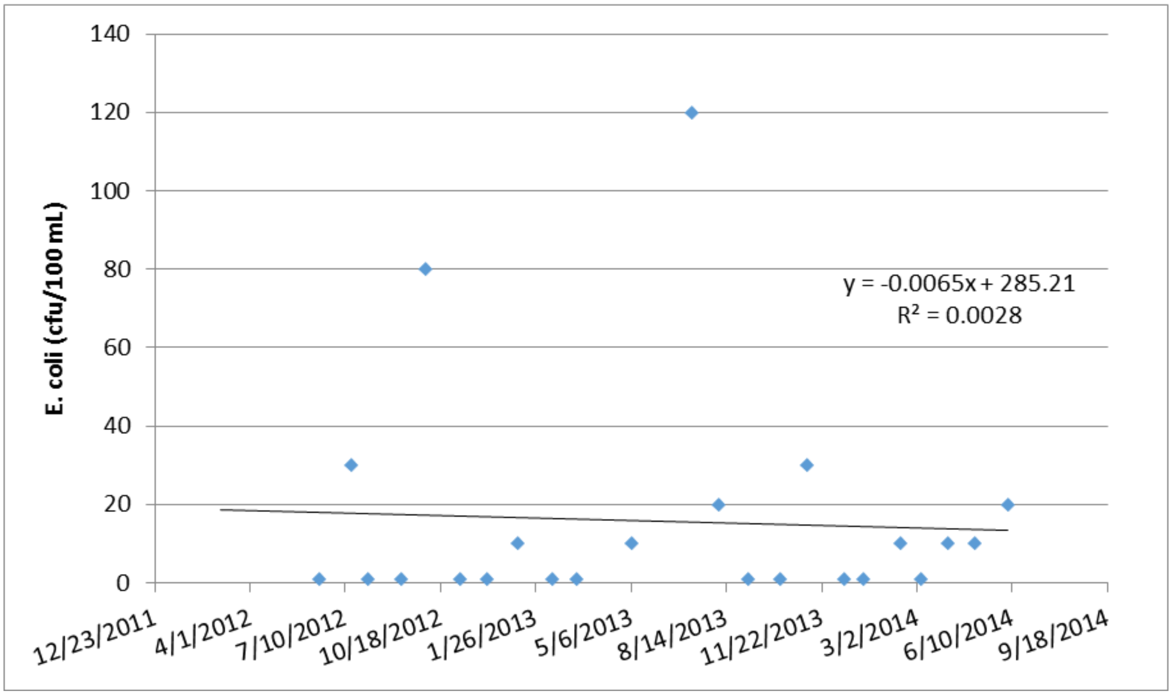

Figure 36: E. coli at Site 15402

Site 80533 – Canyon Lake Above Dam

Site Description

This site is located at the north end of the Canyon Lake Dam in North Park. The park has steep rocky banks of limestone, and the area above the shoreline is heavily wooded with juniper trees. The location of the site is on a small point that juts out into the main body of Canyon Lake.

Sampling Information

This site was sampled 55 times between 4/2/2009 and 6/5/2014. The time of sampling ranged from 12:00 to 15:00.

Table 11: Descriptive parameters for Site 80533

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Total Dissolved Solids (mg/L)	53	259 ± 13	241	319
Water Temperature (°C)	55	21.8 ± 6.6	10	34
Dissolved Oxygen (mg/L)	55	7.2 ± 1.5	4.1	10.6
pH (su)	54	7.5 ± 0.4	6.9	8.2
E.coli (cfu/100 mL)	23	2	0	30

Site was sampled 55 times between 4/2/2009 and 6/5/2014. E. coli calculated as geomean.

Air and water temperature

There were 55 air and water temperatures taken at this site. Air temperature fluctuated seasonally and ranged from a low of 4.5°C in December, 2009 to a high of 38°C in October of 2010. The mean water temperature was 21.8°C and ranged from 10°C in February, 2014 to 34°C in October, 2010.

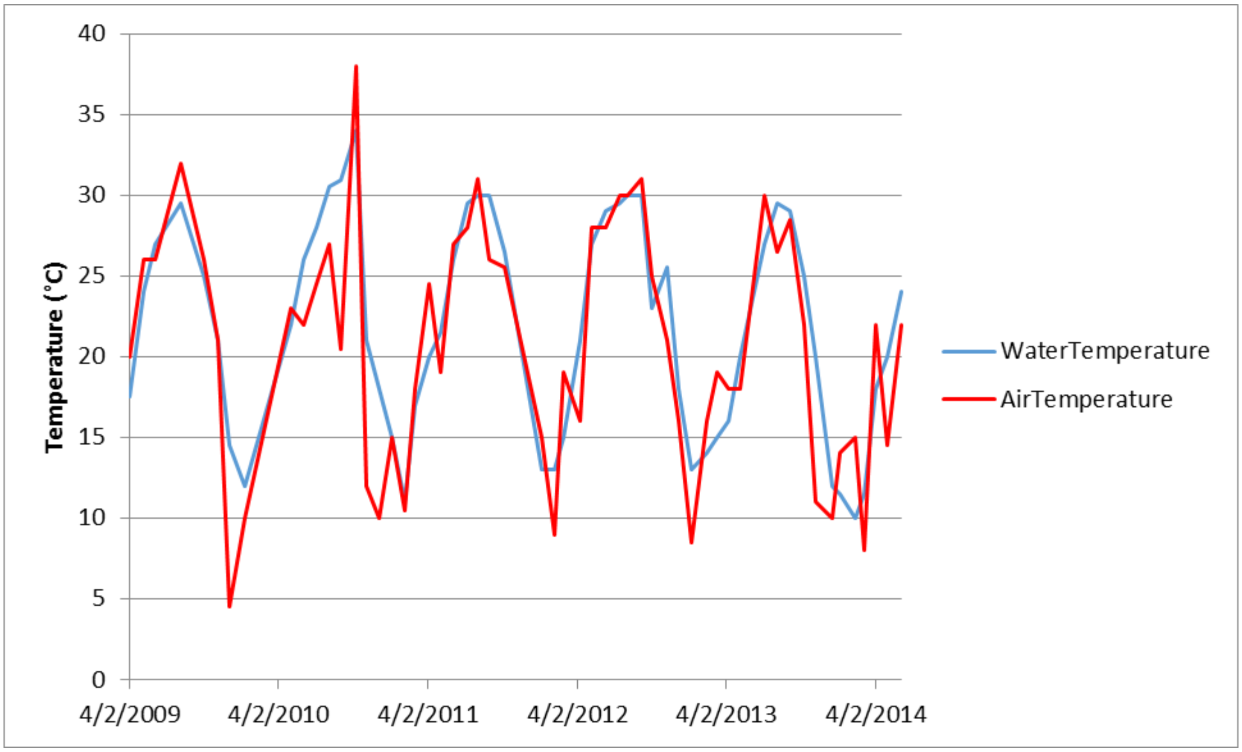

Figure 37: Air and Water Temperature at Site 80533

Total Dissolved Solids

There were 53 total dissolved solids measurements taken at this site. The mean TDS concentration was 259 mg/L. The minimum TDS concentration was 240 mg/L on several occasions, and a maximum TDS concentration of 319 on October of 2010. There was no significant increasing or decreasing trend in TDS concentrations observed for this site.

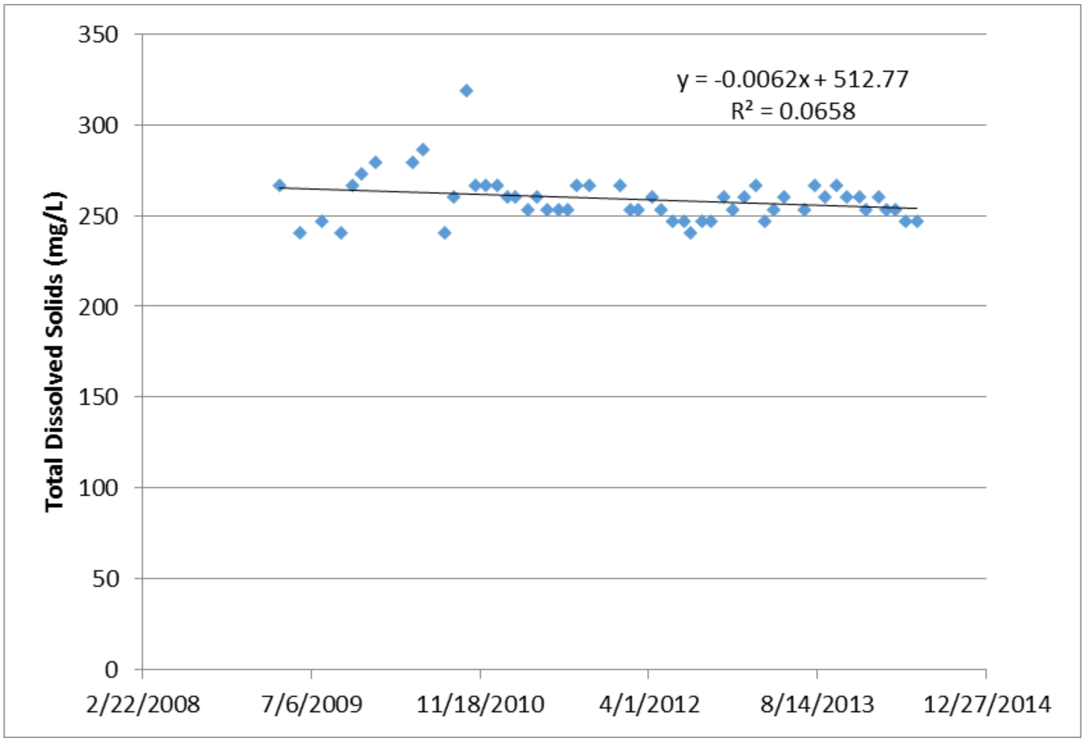

Figure 38: Total Dissolved Solids at Site 80533

Dissolved Oxygen

There were 55 dissolved oxygen samples taken at this site. The mean DO was 7.2 mg/L and DO ranged from a low of 4.1 mg/L in July of 2011 to a high of 10.6 mg/L in March of 2014. There was no significant increasing or decreasing trend in DO observed for this site.

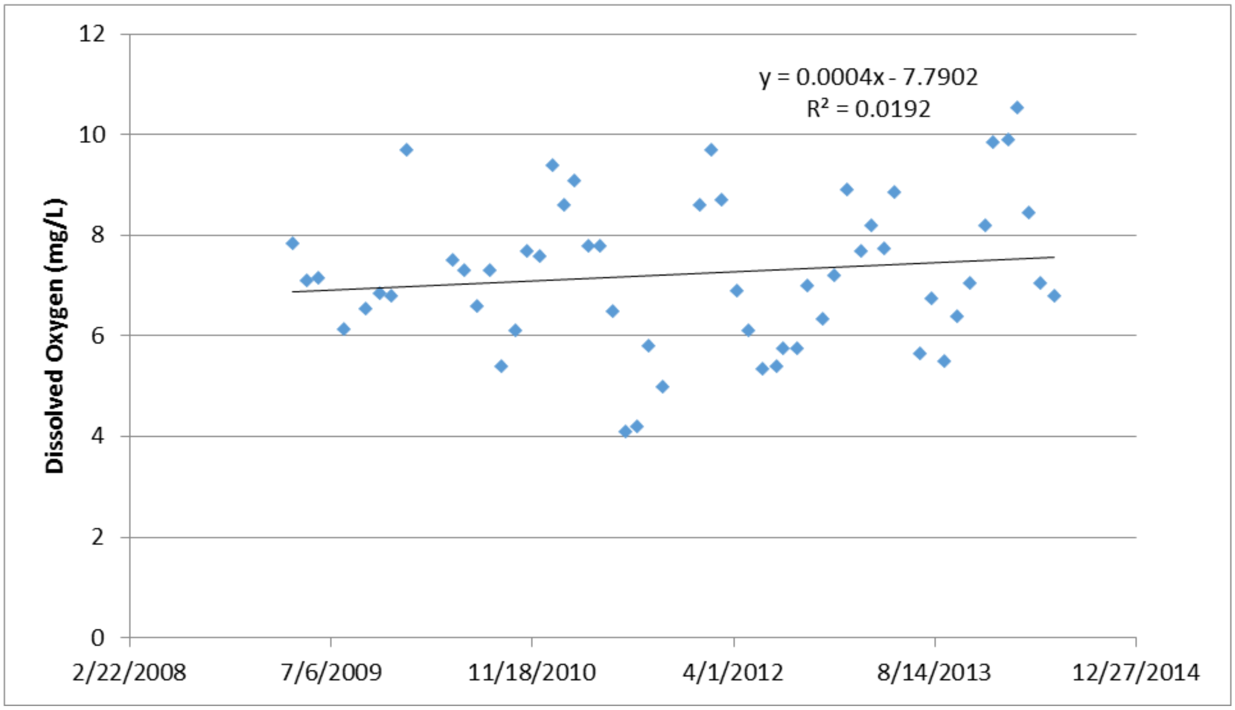

Figure 39: Dissolved Oxygen at Site 80533

pH

There were 54 pH measurements taken at this site. The mean pH was 7.5. The pH ranged from a low of 6.9 in April, 2012 to a high of 8.2 on several occasions. There was no significant trend in pH over time observed for this site.

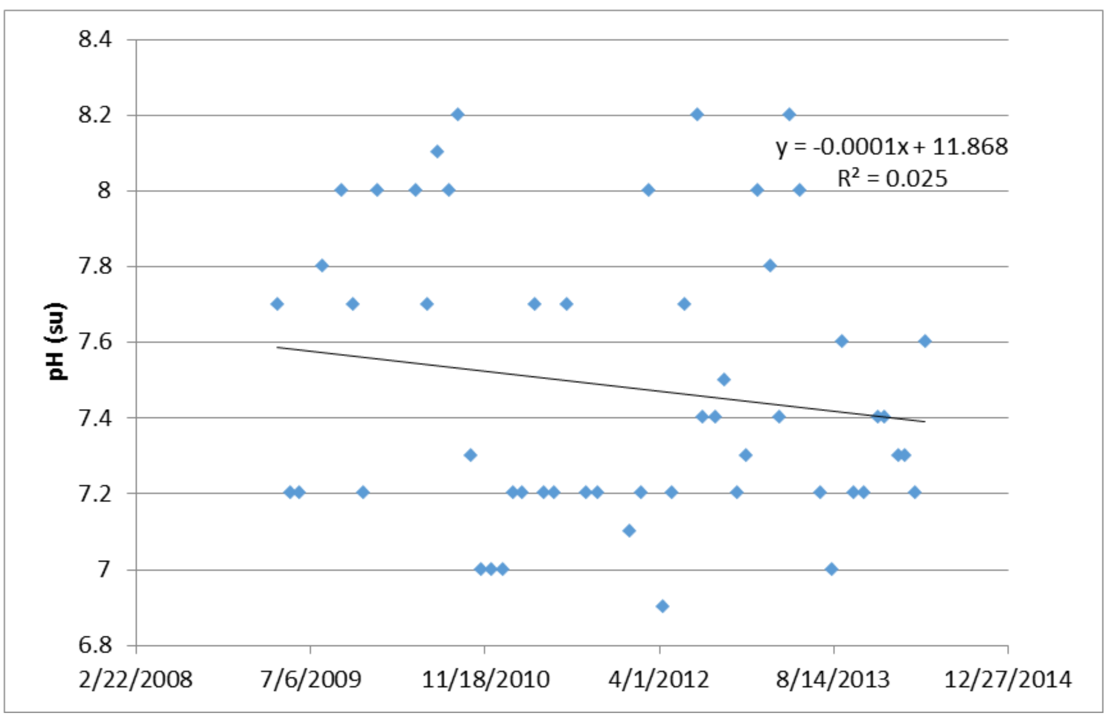

Figure 40: pH at Site 80533

Field Observations

There was no algae cover observed at this site. The water color was described as a light green and water clarity was always clear. There was no distinguishable water odor at this site.

E. coli Bacteria

There were 23 E. coli samples taken at this site. The geomean for E. coli was 2 CFU/100 mL. E. coli counts ranged from none detected to 30 CFU/100 mL in July of 2013. There was no significant trend in E. coli counts over time observed for this site.

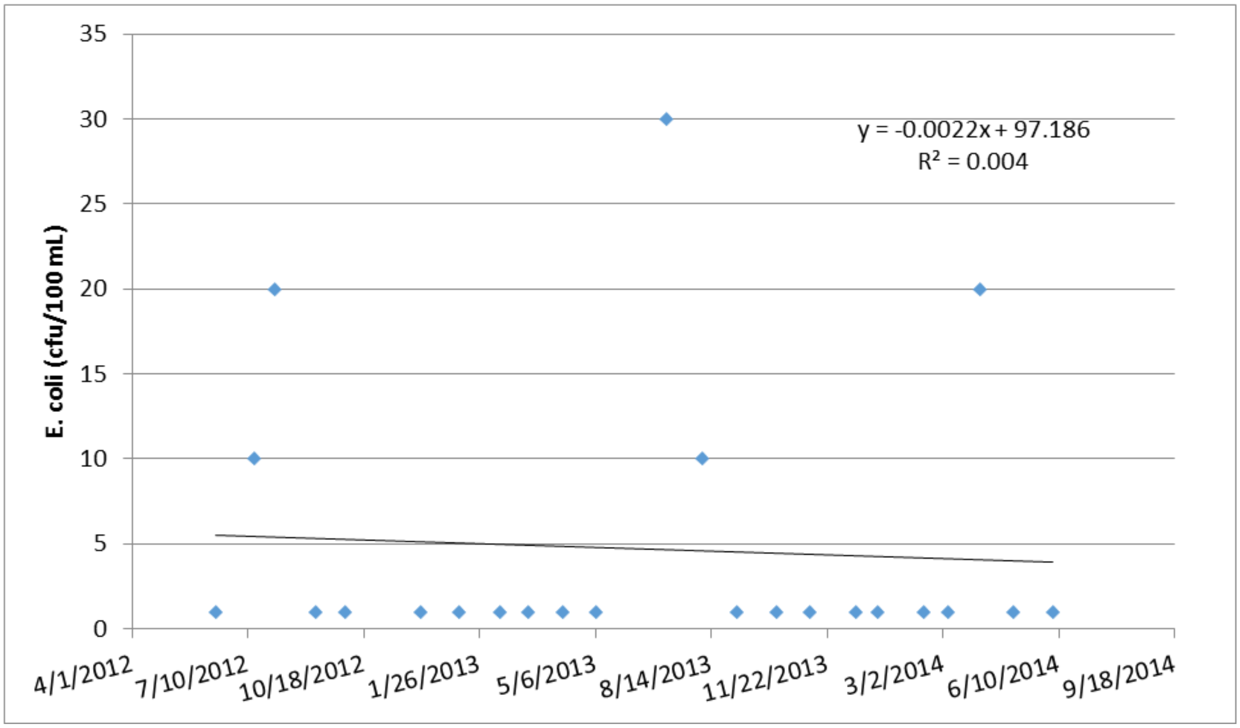

Figure 41: E. coli at Site 80533

Get Involved with Texas Stream Team!

Once trained, citizen monitors can directly participate in monitoring by communicating their data to various stakeholders. Some options include: participating in the Clean Rivers Program (CRP) Steering Committee Process, providing information during "public comment" periods, attending city council and advisory panel meetings, developing relations with local Texas Commission on Environmental Quality (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 general 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.

Canyon Lake References

Breeding, Seth D. Texas State Historical Association, "Canyon Lake." Accessed November 14, 2013. http://www.tshaonline.org/handbook/online/articles/roc04.

Goff, Myra Lee. The Sophienburg, "So, what exactly is under Canyon Lake?." Last modified October 18, 2011. Accessed November 14, 2013. http://sophienburg.com/blog/?p=1704.

Native Prairies Association of Texas, "Edwards Plateau." Accessed November 14, 2013. http://texasprairie.org/index.php/npat_prairies/region_info/edwards_plateau/.

Texas Parks & Wildlife Department, "Ecoregion 7 - Edwards Plateau." Accessed November 14, 2013. http://www.tpwd.state.tx.us/huntwild/wild/wildlife_diversity/wildscapes/ecoregions/ecoregion_7.phtml.

Texas Parks & Wildlife Department, "Fishing Canyon Lake." Accessed November 14, 2013. http://www.tpwd.state.tx.us/fishboat/fish/recreational/lakes/canyon/.

U.S. Army Corps of Engineers, "History of Canyon Lake." Last modified May 05, 2011. Accessed November 14, 2013. http://www.swf-wc.usace.army.mil/canyon/Information/History.asp.

U.S. Army Corps of Engineers, "Invasive Species." Last modified August 20, 2013. Accessed November 14, 2013. http://www.swf-wc.usace.army.mil/canyon/NaturalResources/InvasiveSpecies.asp.

Appendix A- List of Maps, Tables, and Figures

Maps

Tables

Figures