Upper San Marcos River Watershed Annual Water Quality Data Summary and Analysis Report FY20

Report: 2020-03
September 2020

THE MEADOWS CENTER FOR WATER AND THE ENVIRONMENT
TEXAS STATE UNIVERSITY

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Acknowledgments

The Meadows Center for Water and the Environment encourages life-long learning about the environment and people's relationship to the environment through its multidisciplinary citizen science programs. We also provide hands-on opportunities for Texas State University students and inspire future careers and studies in natural resource related fields. Preparation of final reports serve as contract deliverables for granting entities, but they also serve as valuable educational experiences for the students and staff that prepare the reports. The Meadows Center values the staff contributions and recognizes each individual for their role. The following staff assisted in the preparation of this report and are acknowledged for their contributions:

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Upper San Marcos River Watershed Annual Water Quality Data Summary and Analysis Report FY20

UPPER SAN MARCOS RIVER
EST. 2018
WATERSHED PROTECTION PLAN

Prepared by:

The Meadows Center for Water and the Environment, Texas State University
Watershed Services

Prepared for:

Texas Commission on Environmental Quality
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THE MEADOWS CENTER
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INTRODUCTION

In September 2018, the nine-element Upper San Marcos River Watershed Protection Plan (USMR WPP) was approved by US Environmental Protection Agency and Texas Commission on Environmental Quality (TCEQ). The USMR WPP sought to reduce water resource concerns by addressing water quality and quantity issues in the Upper San Marcos River Watershed. The plan addresses the 2010 TCEQ CWA§303(d) listed impairment for total dissolved solids (TDS), and additional parameters including E. coli, nutrients, sediment, and other pollutants associated with growth and development in the watershed.

The TCEQ, through its Texas Water Quality Standards, designates appropriate uses for the state's surface waters including aquatic life, recreation, and sources of public water supply. The criteria for evaluating support of those uses include dissolved oxygen, temperature, pH, TDS, toxic substances, and bacteria. The USMR consistently has better water quality than the state's water quality standards and screening levels. For this reason and because of the river's unique groundwater driven system, stakeholders developed water quality goals that were more stringent than the state's standards as part of the USMR WPP (Table 1).

Adverse effects on water quality resulting from urbanization and development within the USMR Watershed have been observed. Changes in water quality in the watershed are likely due to seasonal and annual climate variability, nonpoint source pollution (NPS), recharge and spring flow, and changes in land use and/or management. Issues of concern include excess sediment, high bacteria concentrations, and occasionally very high nutrient levels. Nutrient levels indicate potential NPS's of pollution including pet and animal waste, excess fertilizer application, and poorly performing septic systems. As more people move to the area, the watershed becomes burdened with increased stormwater runoff and pollutant loadings.

TCEQ designated the Upper San Marcos River (Segment 1814) a classified freshwater stream extending from a point 1.0 km (0.6 mi) upstream of the confluence of the Blanco River in Hays County to a point 0.7 km (0.4 mi) upstream of Loop 82 in San Marcos in Hays County including Spring Lake. The segment is in the Guadalupe River Basin in the central Texas hill country and the Upper San Marcos River watershed (Figure 1).

This report is being prepared to fulfill Task 6.3 Annual Water Quality Data Summary and Analysis Report for the Upper San Marcos River Watershed Protection Plan (WPP) Implementation TCEQ contract (#582-18-80176). The purpose of this task deliverable is to analyze surface, storm, and ground water quality data collected by watershed partners to determine changes and trends in water quality over time as the management measures described in the WPP are implemented.

Table 1. Upper San Marcos River Water Quality Standards and Targets (The Meadows Center for Water and the Environment, 2018).

Parameter	Chloride mg/L	Sulfate mg/L	TDS mg/L	Dissolved Oxygen mg/L	TSS* mg/L	Nitrate-Nitrogen mg/L	Phosphorus mg/L	Oil & Grease mg/L	E. coli CFU/100ml (Geomean)
TCEQ Standard	50	50	400	6.0	5.0	1.95	0.69	N/A	126
Target A by 2025	45 (10%)	45 (10%)	380 (5%)	6.6 (10%)	4.5 (10%)	1.775 (9%)	0.621 (10%)	5.0	113.4 (10%)
Target B by 2035	40 (20%)	40 (20%)	360 (10%)	7.2 (20%)	4.0 (20%)	1.60 (18%)	0.55 (20%)	5.0	101 (20%)

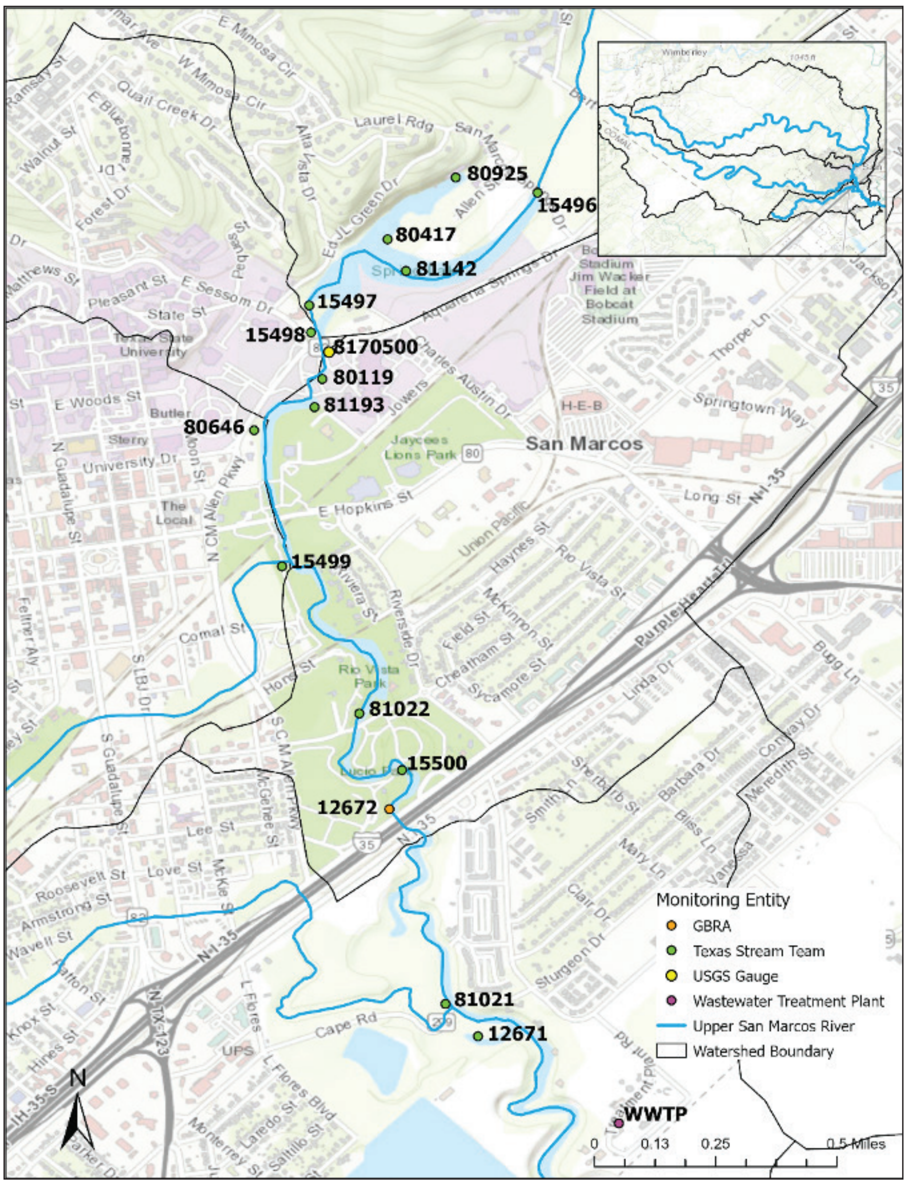


Figure 1. Water quality monitoring sites in the Upper San Marcos River watershed. Texas Water Development Board groundwater monitoring wells in the Upper San Marcos River watershed. Data cour (Esri, DeLorme, HERE, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, and the GIS User Community), TNRIS, NHD, Texas Stream Team, TWDB.

METHODS

Guadalupe-Blanco River Authority Clean Rivers Program Routine Surface Water Quality Monitoring Data

Water quality monitoring data at the USMR immediately upstream of the IH35 bridge at San Marcos (station ID 12672) was collected and analyzed by the Guadalupe-Blanco River Authority (GBRA) for the TCEQ Clean Rivers Program (CRP) (Figure. 1). This station is the only station actively monitored by the GBRA during the contract period of this project on the USMR. The data were collectively compiled from the TCEQ Surface Water Quality Information System (SWQMIS) and the GBRA (L. Gudgell pers. com.). A total of 1,848 records for routine type monitoring were compiled from the two data sources. The period of record for the data spanned sporadically from July 1992 to February 2020. Data collected after February 2019 was not in the SWQMIS production database at the time this report was prepared, therefore those data were requested from GBRA, have not been vetted through the TCEQ SWQMIS Data Management process, and are considered preliminary.

The parameters analyzed for this project include the following: water temperature, stream flow, Secchi disc transparency, specific conductance, dissolved oxygen, pH, total dissolved solids, total ammonia, total nitrate, total Kjeldal nitrogen (TKN), total phosphorous, total hardness, chloride, sulfate, E. coli, chlorophyll a, pheophytin a, turbidity, and flow severity.

The data were compiled in Microsoft Excel and imported to JMP Pro 14.0 statistical software for analysis. Summary statistics were calculated for each parameter and compared to the USMR Water Quality Standards and Targets (Table 1). Parameter distributions were analyzed and trend analyses were applied to data for the entire period of record and for the most-recent seven-year period, the latter mirrors the approach used by the TCEQ for the Texas Integrated Report.

Texas Stream Team Surface Water Quality Monitoring Data

Data collected by Texas Stream Team citizen scientists were queried from the Waterways Dataviewer. A total of 1,854 events were recorded at 19 stations (Figure 1) between December 30, 1999 and May 6, 2020 (Table 2). The core Texas Stream Team parameters measured by citizen scientists include air and water temperature, dissolved oxygen, pH, conductivity, E. coli, sample depth, Secchi disc transparency, flow severity, days since last significant rainfall and rainfall total (inches in last 3 days). Stations with fewer than 10 records were excluded from the data set.

Monitoring stations were grouped for presentation purposes into four major groups: Spring Lake Area (SLA), Below Spring Lake Area (BSLA), NW of IH35 (NW35), and SE of IH35 (SE35) (Table 2). The data were compiled in Microsoft Excel and imported to JMP Pro 14.0 statistical software for analysis. Summary statistics were calculated for each parameter. Parameter distributions were analyzed and trend analyses were applied.

Table 2. Texas Stream Team water quality monitoring stations, number of events and period of record in the Upper San Marcos River (December 2005 – May 2020).

Groups	Station ID	Description	Number of Events	Period of Record
Spring Lake Area (SLA)	15496	Sink	217	12/04/2005-03/10/2020
	81142	Spring Lake Boardwalk	59	03/12/2018-03/10/2020
	80925	Spring Lake	146	08/31/2012-03/10/2020
	80417	Spring Lake Headwaters at Landing Building	53	11/04/2006-11/03/2009
	15497	Spring Lake upstream of dam near Saltgrass	181	01/02/2006-03/10/2020
Below Spring Lake Area (BSLA)	15498	Sessoms Creek	183	01/04/2006-10/02/2019
	80119	Sewell Park	53	02/04/2013-03/09/2020
	80258*	City Park/Lions Club	1	09/17/2010
	81193	City Park Bridge	30	04/04/2018-03/11/2020
	80645*	Small outfall across from Lions Club	3	05/17/2012-08/02/1012
	80646	Stormwater outfall across from Lions Club	36	04/22/2011-01/29/2020
	80572*	City Park culvert pipe	5	11/09/2010-01/15/2013
NW of IH35 (NW35)	15499	Purgatory Creek	190	12/06/2005-03/05/2020
	80667*	Rio Vista Island	4	03/02/2018-04/20/2018
	81022	Downstream of Rio Vista/ Cheatham Bridge	39	06/19/2014-03/11/2020
	15500	Ramon Lucio Park	257	12/30/1999-03/01/2020
SE of IH35 (SE35)	12672	IH35 E Frontage Rd.	161	12/27/2005-03/16/2020
	81021	Thompson's Island Mill Race	26	06/19/2014-02/16/2020
	12671	Thompson Island	210	12/15/2005-05/06/2020

*Stations with fewer than 10 events excluded from report.

City of San Marcos (COSM) Monitoring Data

Two water quality monitoring data sets were identified from the COSM, one for stormwater and the other for drinking water. The stormwater data was available in Excel format and subsequently imported to JMP Pro 14.0 statistical software for analysis. The drinking water reports were provided in portable document format (pdf) and were summarized in tabular format.

Stormwater monitoring of E. coli bacteria took place approximately weekly at six sites along the Upper San Marcos River (Figure 2). The six sites ordered from the upstream headwaters to the most downstream site include Spring Lake Hotel, City Park, Rio Vista, I-35 Bridge, Upstream of WWTP, and Downstream of WWTP.

Data were compiled, summarized and compared to the TCEQ water quality standard and WPP targets for the contact recreation use.

The COSM produces Annual Drinking Water Quality Reports with important information about drinking water and efforts made by the water system to provide safe drinking water. Drinking water treated and delivered to residences in the COSM comes from both surface and groundwater sources, Canyon Lake and the Edwards Aquifer respectively. Data for the annual reports for 2016-2018 were compiled and summarized in tabular format for this data summary report.

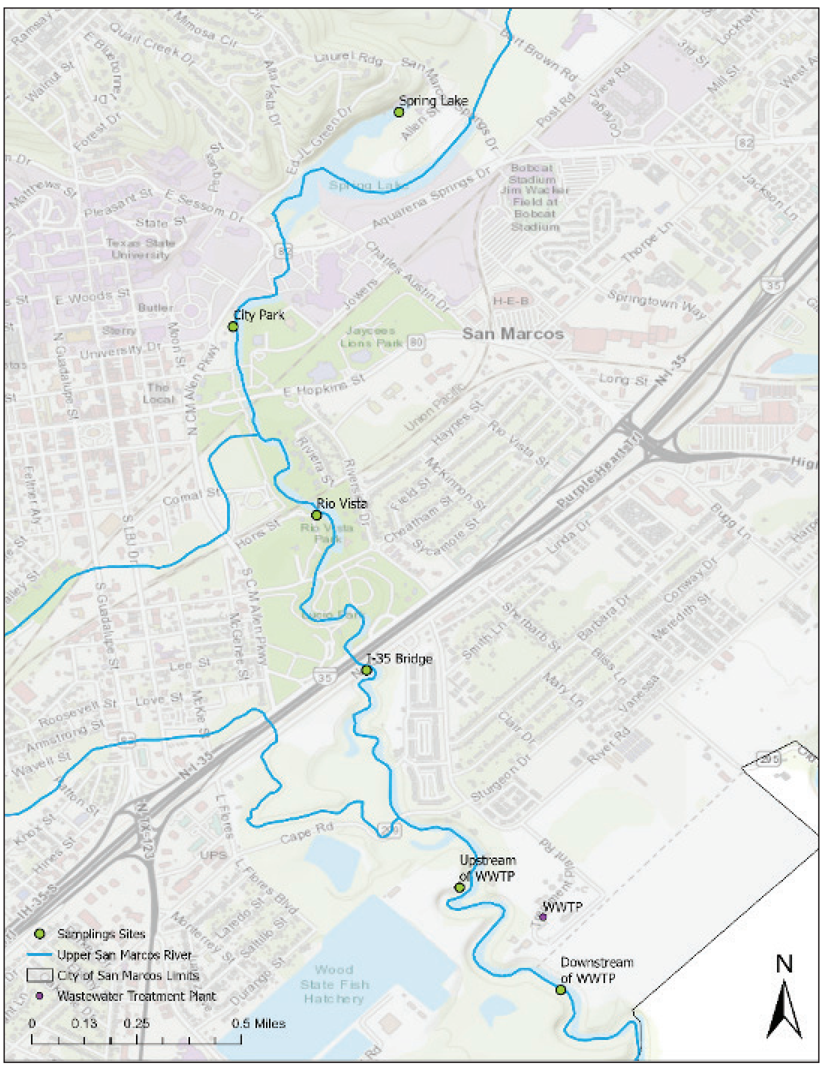


Figure 2. City of San Marcos stormwater monitoring sites. Data cour (Esri, DeLorme, HERE, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, and the GIS User Community), TNRIS, NHD.

US Geological Survey (USGS) Stream Flow Monitoring Data

The USGS measures flow at USGS gage 08170500 on the USMR in Hays County. Stream flow measurements are collected continuously at 15-minute intervals. Daily stream flow discharge (cfs) data was downloaded from the USGS from 9/1/2018 thru 5/26/2020 (https://waterdata.usgs.gov/nwis/inventory/?site_no=08170500&agency_cd=USGS&amp). Monthly averages were calculated and analyzed.

Texas Water Development Board Groundwater Monitoring Data

Groundwater well data were downloaded from the Texas Water Development Board's online Groundwater Database (GWEB) Reports website (https://www.twdb.texas.gov/groundwater/data/gwdbrpt.asp) (Figure 3). Groundwater wells were first filtered by wells labeled as Groundwater Conservation District observation wells. Results of that query were further selected by those listed as "current" within the USMR watershed boundary. The resulting wells were then identified by well number, reports were located in the documents database, and ground water level and chemistry data were acquired from the reports. Data were reformatted in Excel and merged into a spreadsheet for analysis. Ten groundwater wells resulted from the queries described above (Table 3). For well level data, only wells with more than 10 sampling events were analyzed for this report. For chemistry data, only one well had chemistry data within the project period, therefore no chemistry data were analyzed for this report.

Edwards Aquifer Habitat Conservation Plan (EAHCP) Biological Assessments (2012-present)

The Edwards Aquifer Habitat Conservation Plan is a plan designed to protect federally listed species and the water used by both the people and the organisms that inhabit the Edwards Aquifer, Comal Springs, and San Marcos Springs. Protection of these areas takes shape in the form of an Incidental Take Permit (ITP) granted to a consortium including the Edwards Aquifer Authority, COSM, City of New Braunfels, Texas State University, and the City of San Antonio. The ITP requires an annual report to the USFWS to document progress towards permit implementation. The EAHCP 2019 Annual Report describes actions taken in 2019 addressing springflow protection measures, habitat restoration in the Comal and San Marcos Spring Systems, and other supporting measures. Voluminous datasets collected by the entities implementing the EAHCP were not downloaded for this study, but instead the reader is directed to their website where reports can be accessed describing the EAA work in the USMR watershed. Project reports addressing issues in the USMR include:

- Final Report for Sessom Creek Sediment Export Study
- Aquatic Plant Boom Assessment in Spring Lake Final Report
- 2019 Refugia Research
- EAHCP Expanded Water Quality Monitoring Report
- Water Quality Real Time Instrumentation Data Collection Results
- Habitat Conservation Plan Biological Monitoring Program San Marcos Springs/River Ecosystem Annual Report

Table 3. Texas Water Development Board Groundwater wells in the Upper San Marcos River watershed.

Well No.	Well Owner	Aquifer	Period of Record for Water Level	Period of Record for Chemistry
6701403	Freeman Ranch Solar Well – TSU	Edwards (Balcones Fault Zone)	2009, 2015	2012
6709101	Crystal Clear Water Co Laurel Estates	Edwards (Balcones Fault Zone)	1965, 2007-2009, 2015-2016	1968
6709106	Bureau of Sports Fisheries & Wildlife	Edwards (Balcones Fault Zone)	1970, 2005-2010	1970, 1997, 1998, 2015, 2016
6709110	SWT Farms EAA	Edwards (Balcones Fault Zone)	1973-1975, 1977-1988, 1993, 2005-2010, 2015	None
6808501	Summer Mountain Ranch	Trinity	2001-2019	2018
6808602*	Freeman Ranch Laguna – TSU	Edwards (Balcones Fault Zone)	2009-2010	None
6808902	San Marcos Baptist Academy	Edwards (Balcones Fault Zone)	1996, 2005-2010	1998, 1999
6816601	E. Jackson	Edwards (Balcones Fault Zone)	2007-2010	1966-1970, 1972, 1974, 1976, 1977
6816303	Clovis Barker	Unassigned	2007-2010	None
6816304*	Wilford Wootan	Unassigned	2007-2009	None

*Denotes wells identified with fewer than 10 water level monitoring events not included in this report.

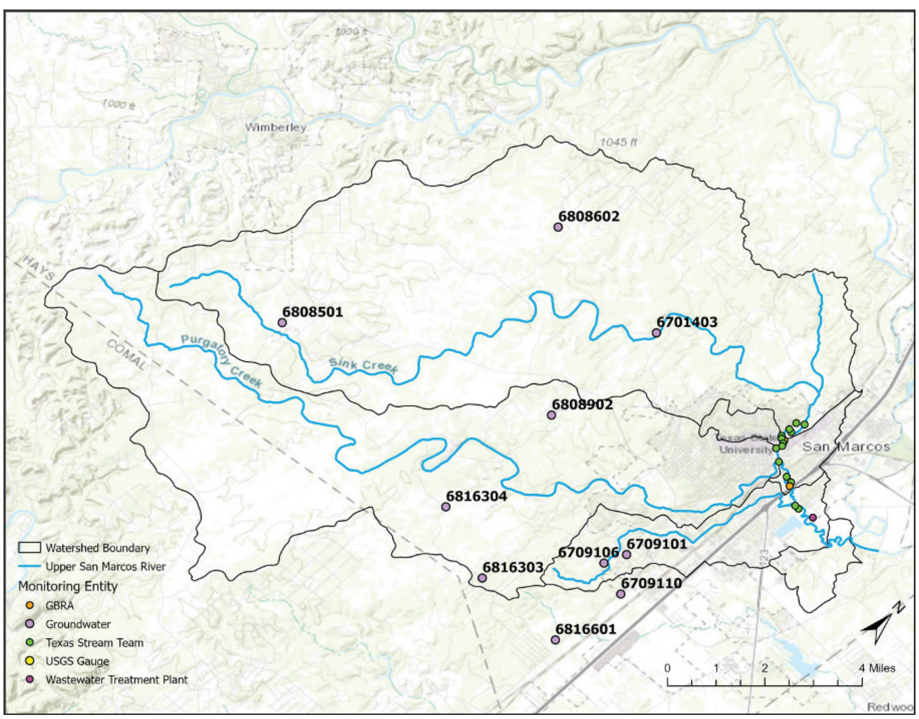


Figure 3. Texas Water Development Board groundwater monitoring wells in the Upper San Marcos River watershed. Data cour (Esri, DeLorme, HERE, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, and the GIS User Community), TNRIS, NHD, Texas Stream Team, TWDB.

RESULTS

GBRA CRP Routine Surface Water Monitoring Quality Data

Summary statistics of parameters analyzed from the USMR immediately upstream of the IH35 bridge in San Marcos are provided in Table 4.

Instantaneous stream flow was measured consistently at the USGS flow gauge (#08170500) and reported concurrently with the water quality sampling data. The mean flow for the period of record was 192.5 cfs (Table 4). The long-term (1992–2020) trend analysis for flow reveals a decreasing trend (Figure. 4), while the most recent seven-year (2013-2020) trend analysis reveals an increasing trend (Figure. 5).

The long-term mean chloride value (19.5 mg/L) is below the TCEQ water quality standard and targets established in the WPP (Table 4). The linear trend of the chloride data for the period of record (1992-2020) is generally decreasing, but weak (R2 = 0.005) (Figure. 6). Analysis of the most recent seven years of data (2013-2020), reveals a strong relationship (R2 = 0.617) of increasing chloride concentrations over time (Figure. 7).

The long-term mean sulfate value (25.8 mg/L) is below the TCEQ water quality standard and targets established in the WPP (Table 4). The range of values and the linear trend of the sulfate concentrations are all below the water quality standards and targets, but an increasing trend in the period of record is evident (Figure 8). Analysis of the most recent seven years of data (2013-2020) exhibits a relatively strong (R2 = 0.445), increasing trend of sulfate (Figure 9).

The long-term mean value for TDS (405.6 mg/L) is above the water quality standard and target values (Table 4). The long-term (Figure 10) and seven-year (Figure 11) analyses for TDS concentrations revealed weak increasing and decreasing trends, respectively.

Mean dissolved oxygen (9.9 mg/L) for the period of record (1992-2020) is well above the water quality standard and targets (Table 4). Although a decreasing trend is observed for dissolved oxygen, the correlation coefficient is weak (R2 = 0.036) (Figure. 12). Similar findings resulted for the analysis of the seven-year period (2013-2020).

The mean total nonfiltrable residue (or total suspended solids, TSS) (3.5 mg/L) was below the water quality standard and targets (Table 4). No discernable correlation was observed for TSS for the period of record (Figure. 13) or for the seven-year period 2013-2020.

The long-term mean total nitrate-nitrogen concentration (1.2 mg/L) in the Upper San Marcos River was below the water quality standard and targets (Table 4). The long-term data revealed an increasing trend in nitrate-nitrogen (R2=0.088) (Figure. 14), while the most recent seven-year period of record revealed a decreasing trend (R2=0.105) (Figure. 15).

All phosphorus values for the period of record are below the water quality standard and targets (Figure. 16). The long-term trend of phosphorus concentrations is decreasing in the USMR (R2=0.138), but increasing in the seven-year analysis (R2=0.087) (Figure. 17).

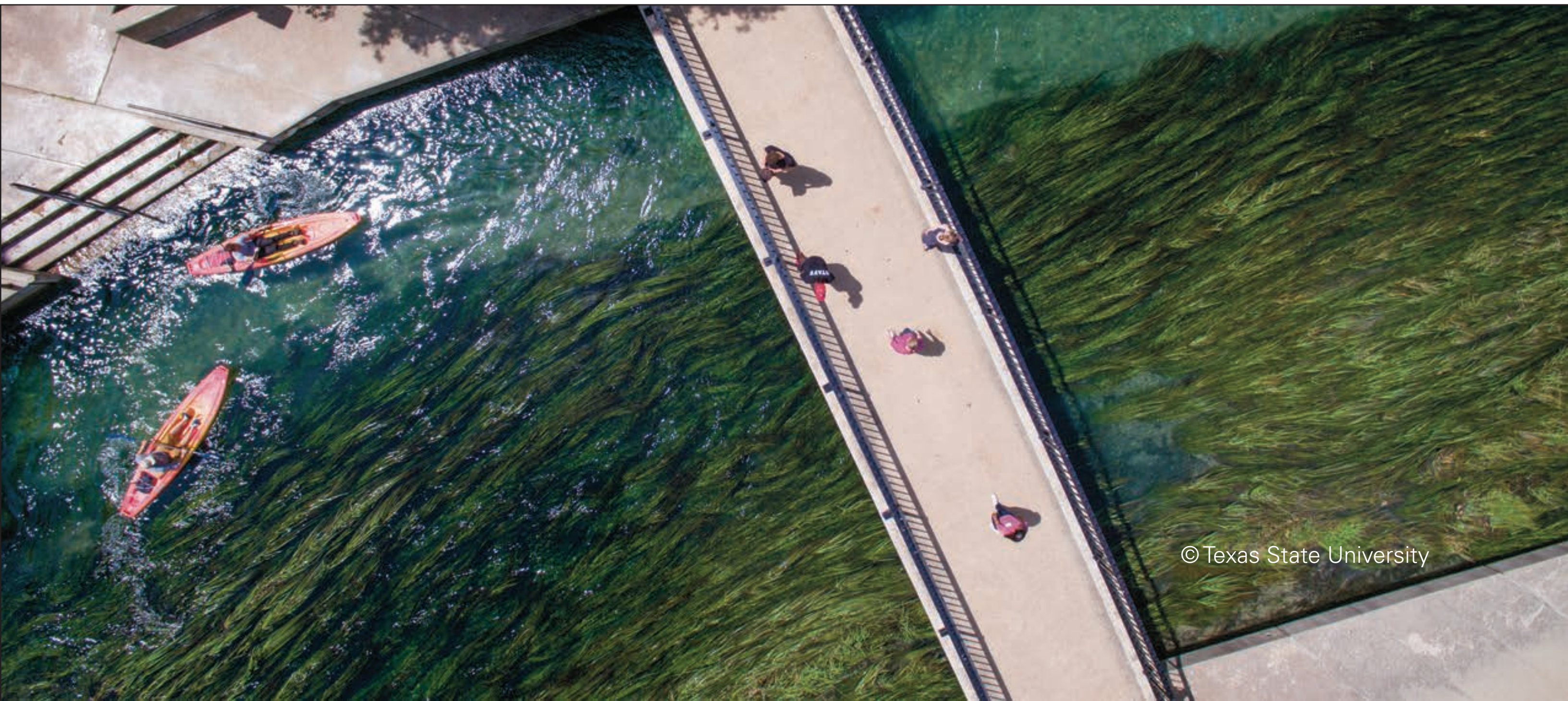
The long-term geometric mean for E. coli (65.5 MPN/100 mL) is below the water quality standard and targets (Table 4). The seven-year geometric mean for E. coli (89.9 MPN/100 mL) is also below the standard and targets, but is greater than the long-term value. Both the long-term (Figure. 18) and seven-year (Figure. 19) trend analyses reveal increasing, but weak, trends in E. coli over time.

Table 4. Water quality data summary statistics in the Upper San Marcos River, Texas (July 1992 to February 2020).

Parameter	N	Mean	Standard Deviation	Minimum	Maximum
Instantaneous Stream Flow (cfs)	79	192.5	77.1	86	437
Chloride (mg/L)	89	19.5	3.1	14	42.2
Sulfate (mg/L)	88	25.8	3.5	6	33.6
*TDS (mg/L)	113	405.5	39.4	339.3	760.5
Dissolved Oxygen (mg/L)	91	9.9	1.1	7.4	13
Total Nonfiltrable Residue (mg/L)	88	3.5	2.5	0.8	17.3
Total Nitrate Nitrogen (mg/L)	47	1.2	0.12	0.95	1.7
Total Phosphorus (mg/L)	85	0.05	0.05	0.01	0.28
E. coli (MPN/100 mL)	70	**65.5	232.9	1	1400
Water Temperature (°C)	92	22.4	1.3	19.2	25.2
Secchi Disc Transparency (m)	18	1.2	0.14	1	1.75
pH (s.u.)	91	7.6	0.23	6.9	8.7
Specific Conductance (µS/cm)	113	623.9	60.6	522	1170
Turbidity (NTU)	70	1.8	0.82	0.12	4
Total Hardness (mg/L)	70	297.3	30.4	120	346
Total Ammonia Nitrogen (mg/L)	86	0.07	0.07	0.01	0.51
Total Kjeldahl Nitrogen (mg/L)	47	0.23	0.11	0.1	0.69
Chlorophyll-a (µg/L)	72	1.2	0.83	1	5
Pheophytin-a (µg/L)	58	1.4	1.0	1	7

*TDS is calculated as follows: TDS = Specific conductance *0.65 (TCEQ, 2012)

**Geometric mean



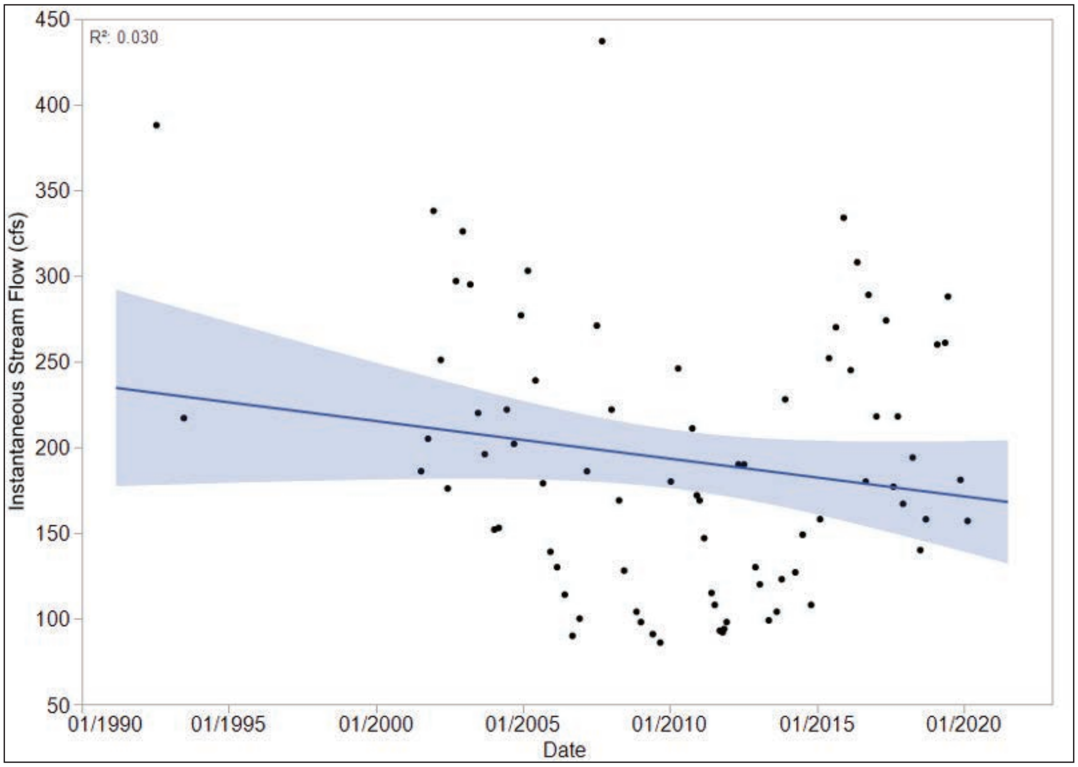


Figure 4. GBRA instantaneous stream flow (cfs) trend analysis in Upper San Marcos River (1992 to 2020).

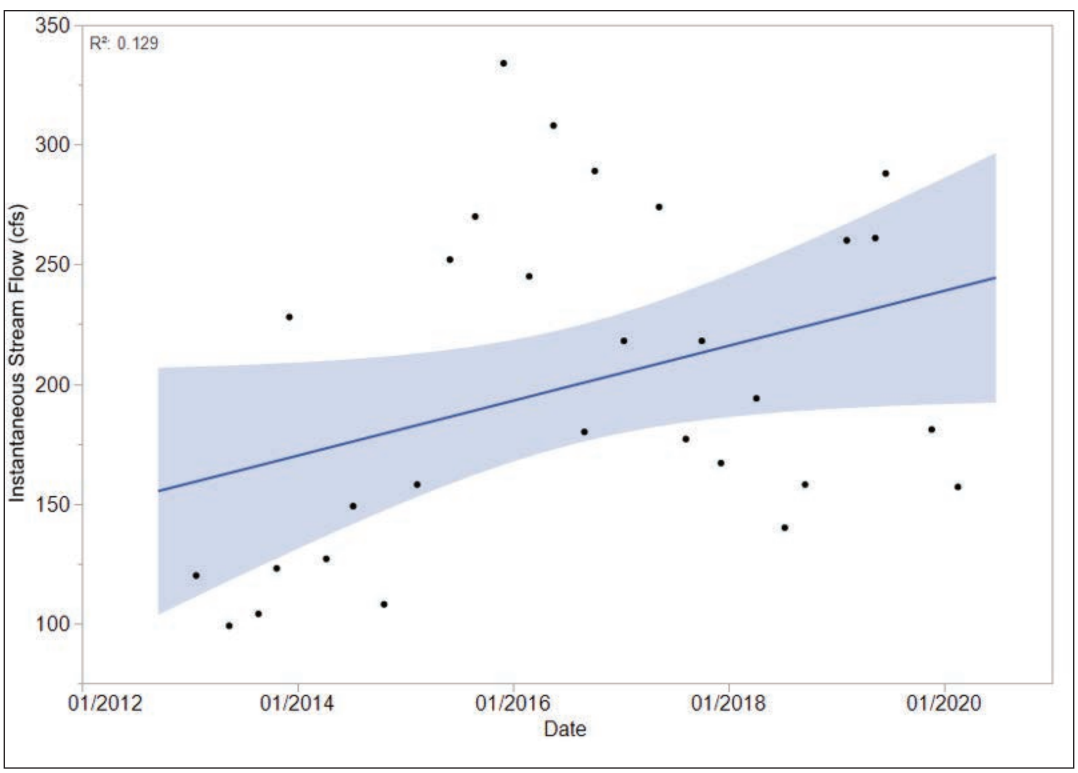


Figure 5. GBRA instantaneous stream flow (cfs) seven-year (2013-2020) trend analysis in Upper San Marcos River.

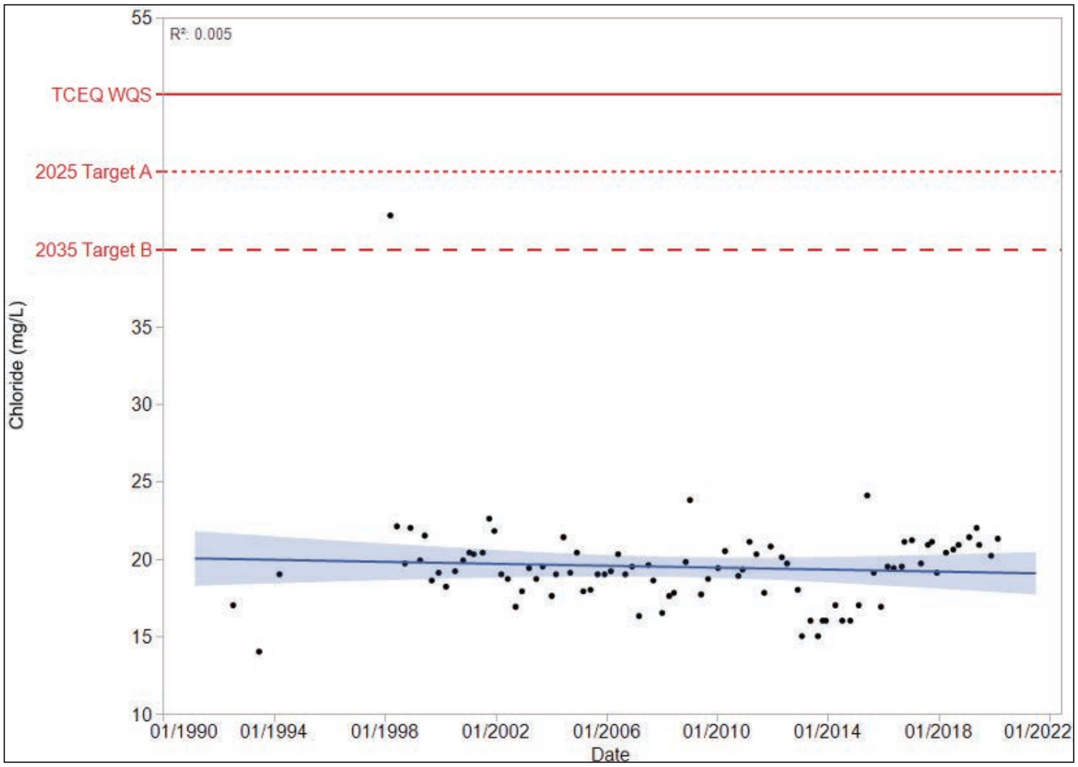


Figure 6. GBRA chloride (mg/L) trend analysis in Upper San Marcos River (1992-2020).

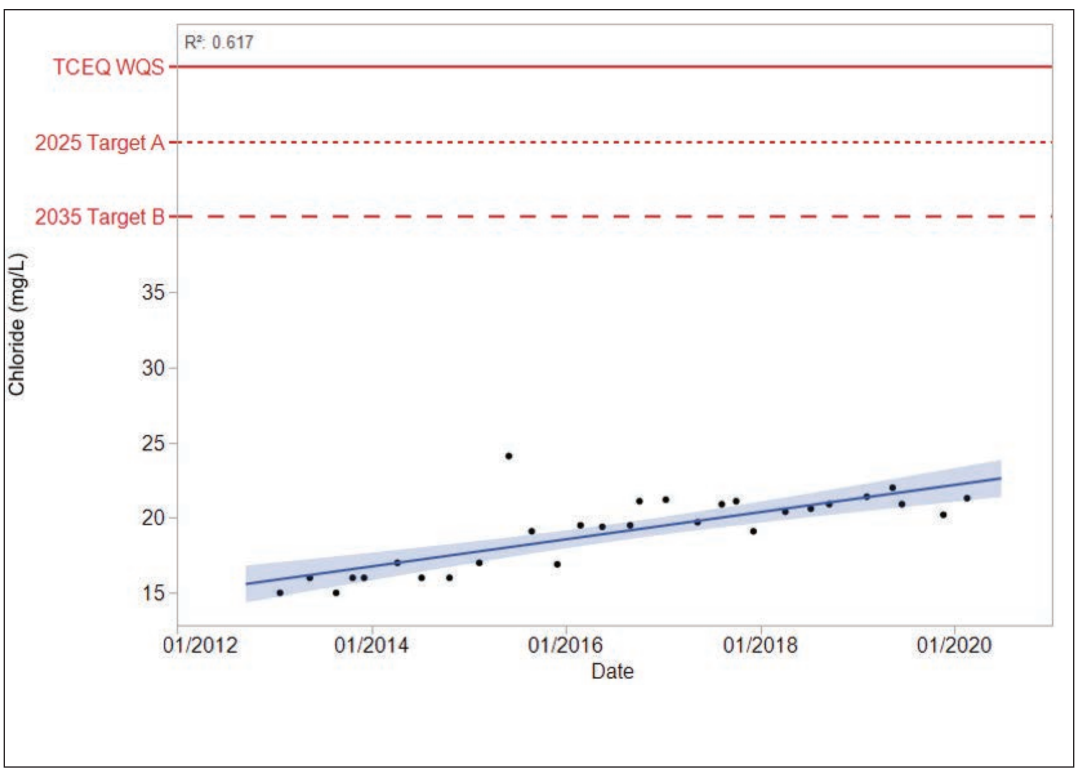


Figure 7. GBRA chloride (mg/L) seven-year (2013-2020) trend analysis in Upper San Marcos River.

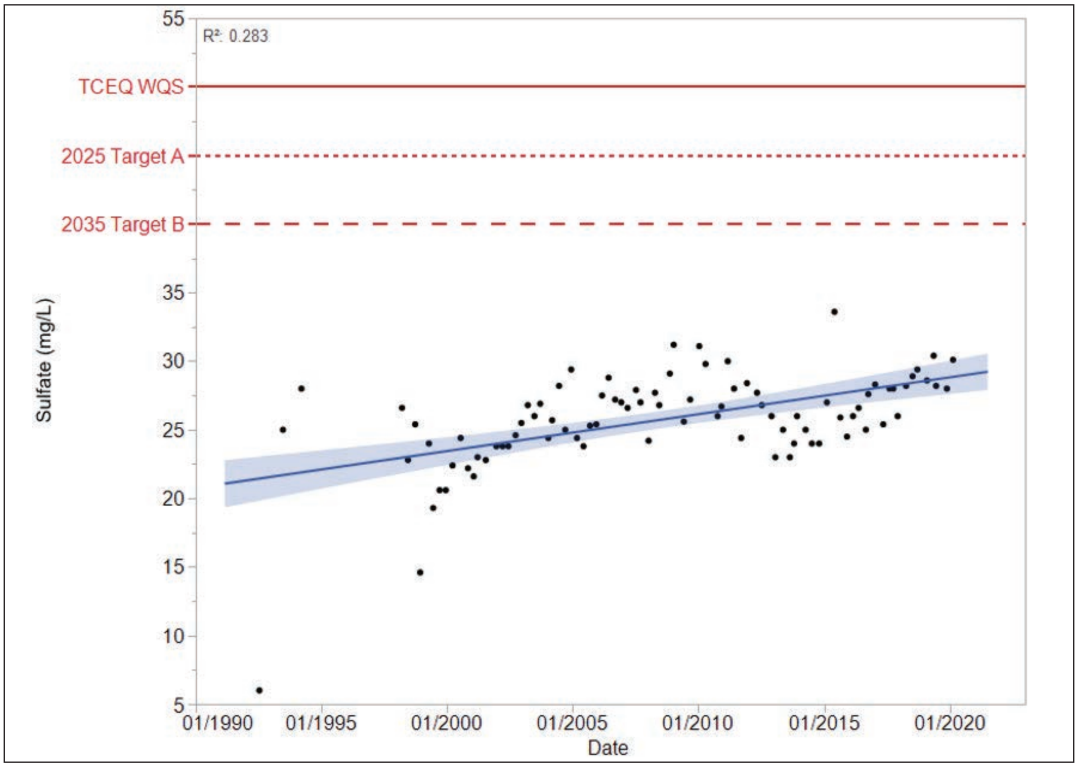


Figure 8. GBRA sulfate (mg/L) trend analysis in Upper San Marcos River (1992-2020).

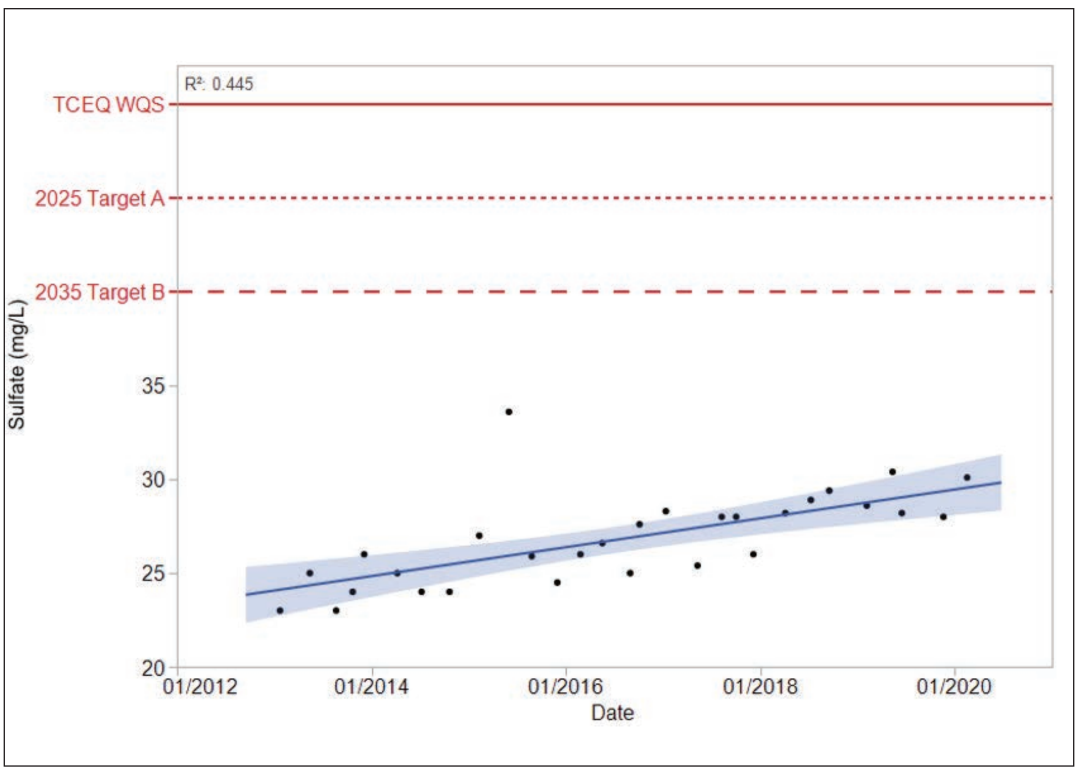


Figure 9. GBRA sulfate (mg/L) seven-year (2013-2020) trend analysis in Upper San Marcos River.

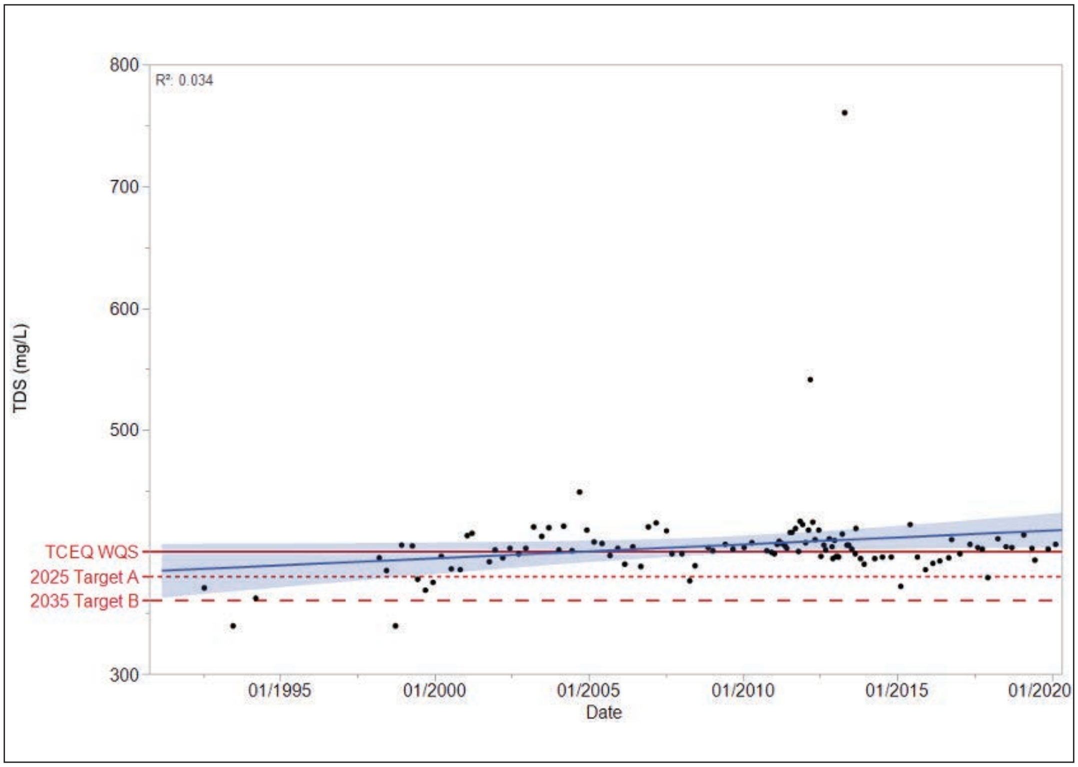


Figure 10. GBRA TDS (mg/L) trend analysis Upper San Marcos River (1992-2020).

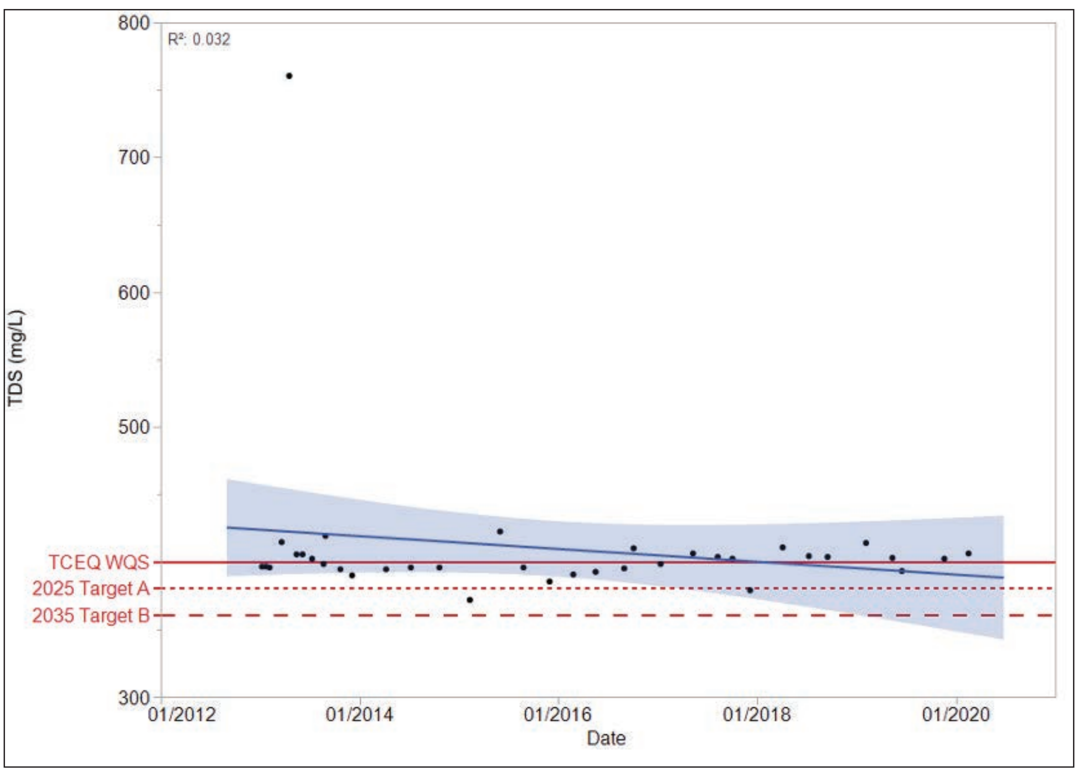


Figure 11. GBRA chloride (mg/L) seven-year (2013-2020) trend analysis in Upper San Marcos River.

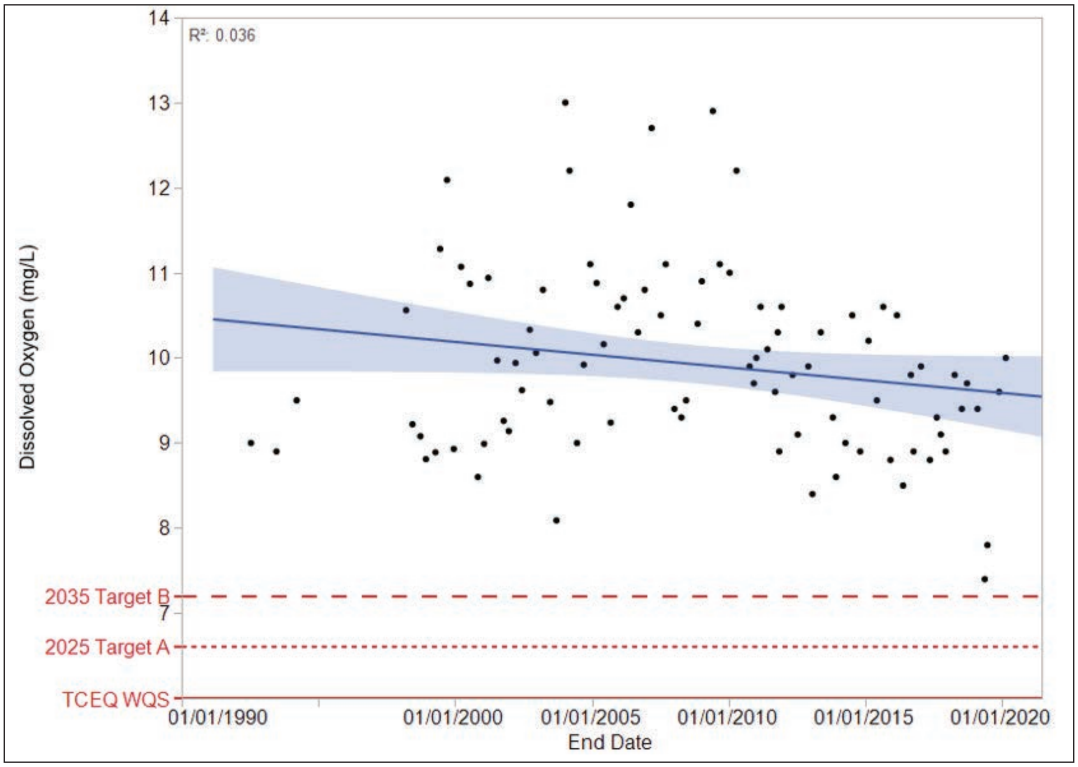


Figure 12. GBRA dissolved oxygen (mg/L) trend analysis in Upper San Marcos River (1992-2020).

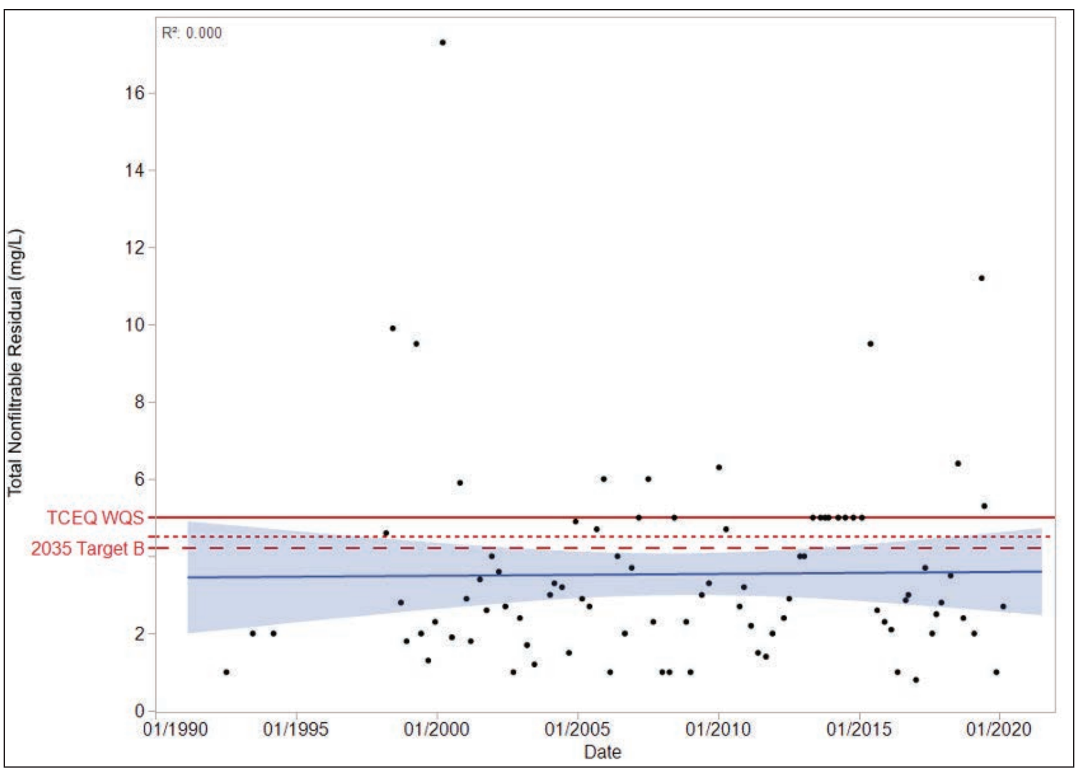


Figure 13. GBRA total nonfiltrable residual (mg/L) trend analysis in Upper San Marcos River (1992-2020).

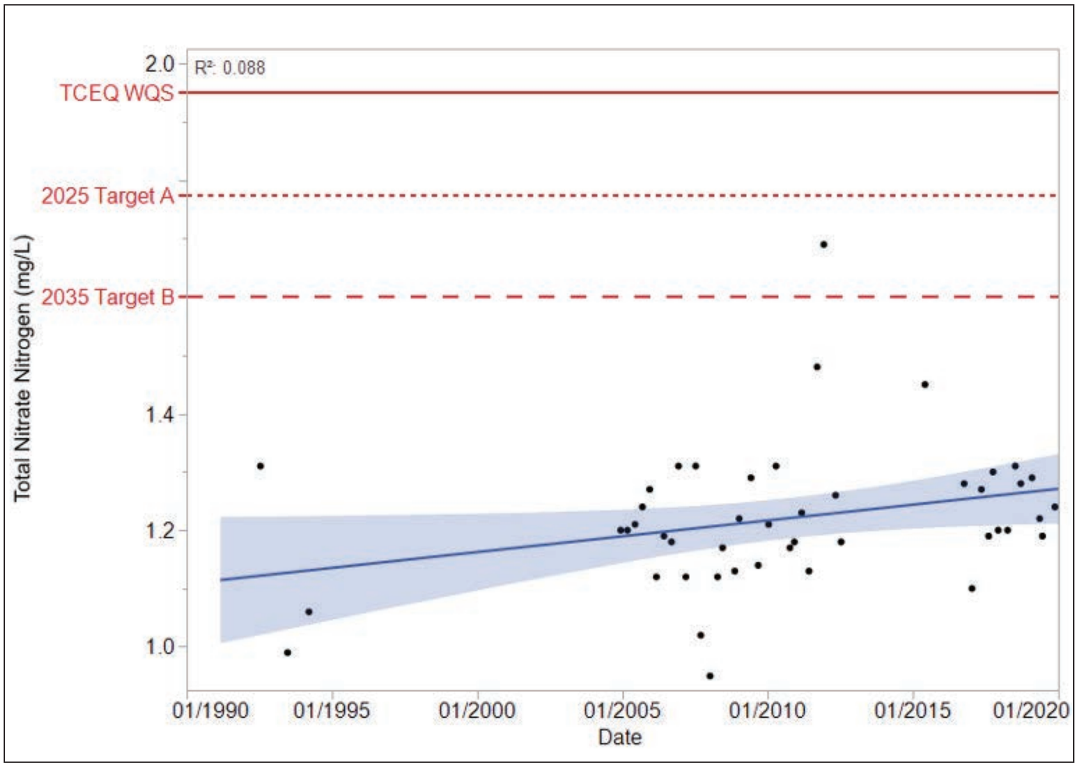


Figure 14. GBRA total nitrate nitrogen (mg/L) trend analysis in Upper San Marcos River (1992-2020).

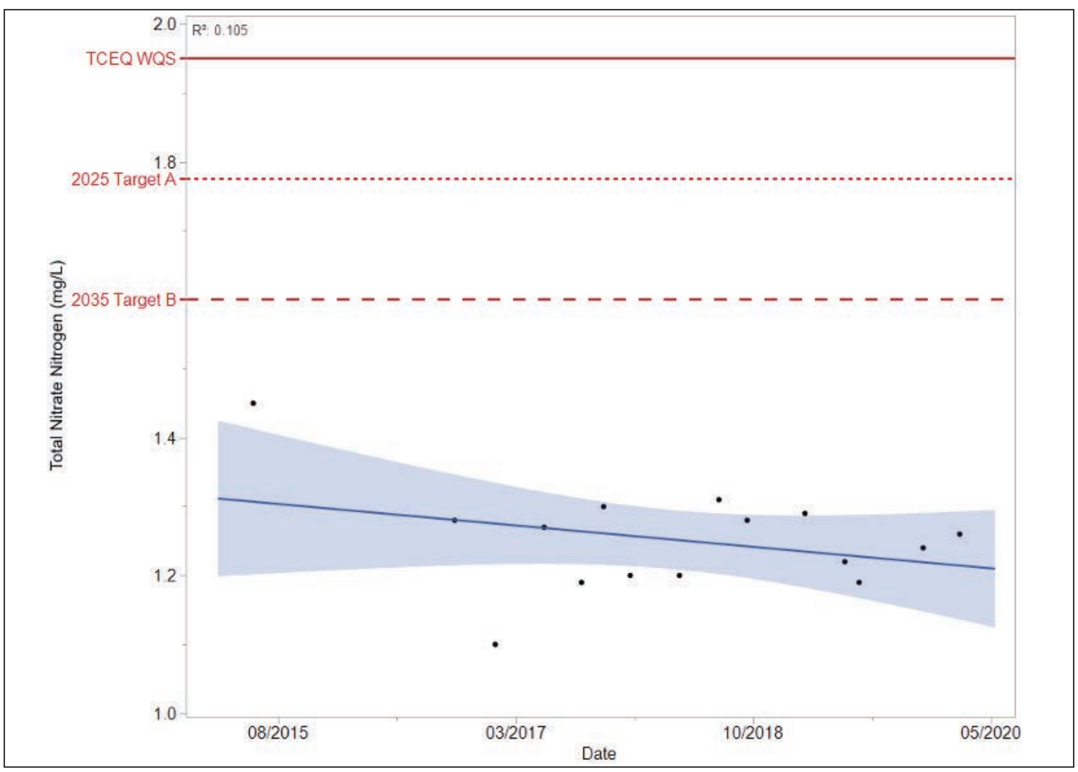


Figure 15. GBRA total nitrate nitrogen (mg/L) seven-year (2013-2020) trend analysis in Upper San Marcos River.

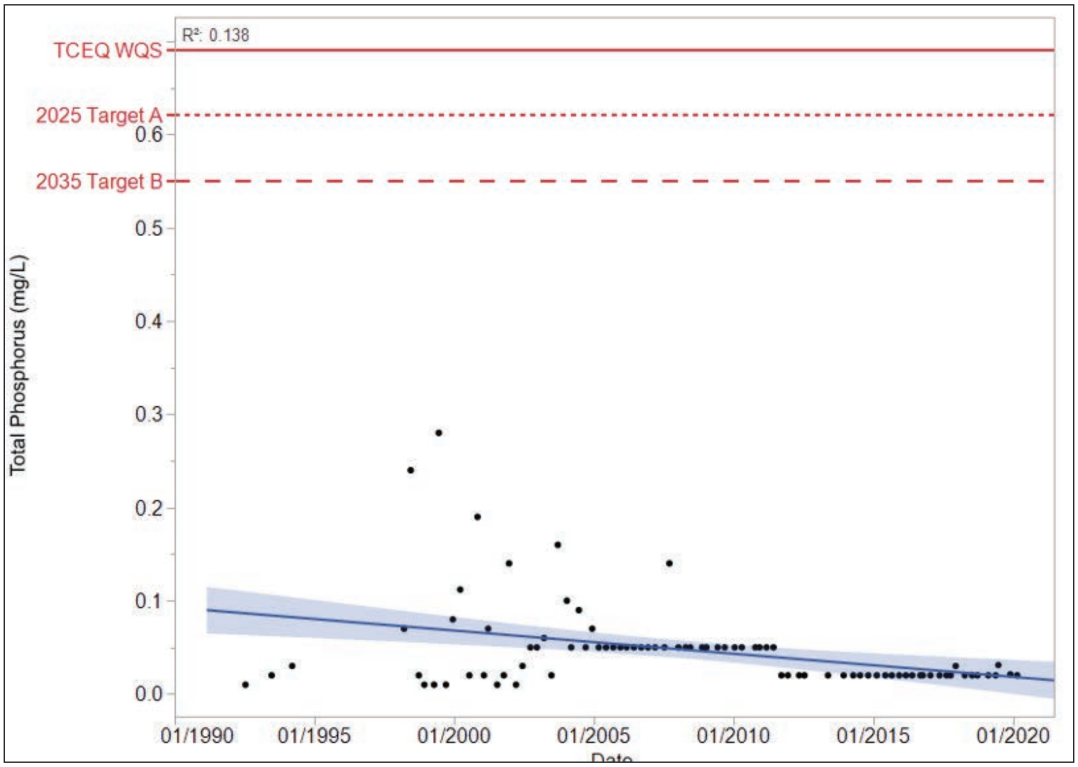


Figure 16. GBRA total phosphorus (mg/L) trend anaysis in Upper San Marcos River (1992-2020).

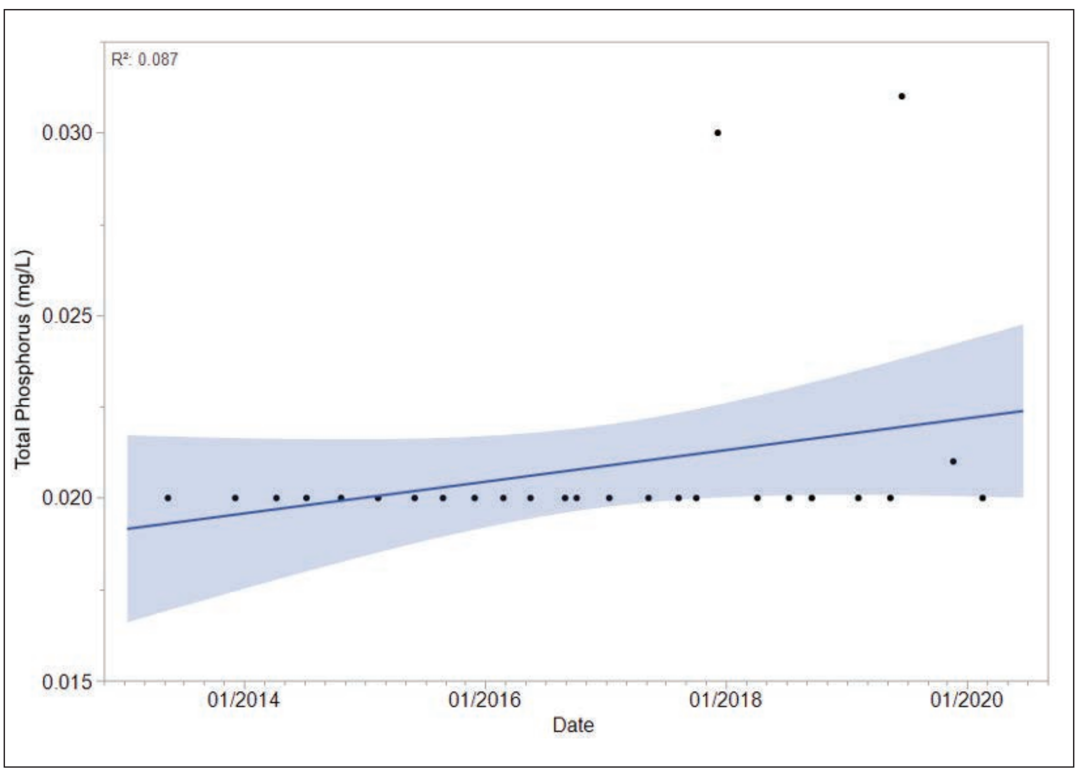


Figure 17. GBRA total phosphorus (mg/L) seven-year (2013-2020) trend analysis in Upper San Marcos River.

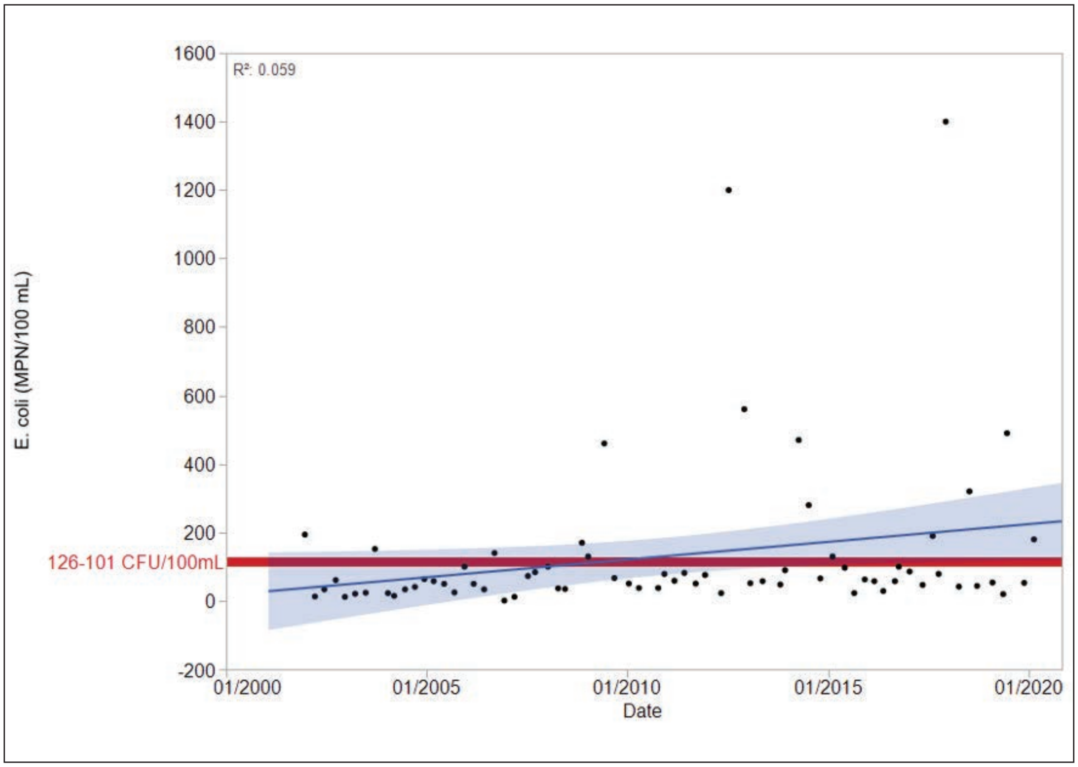


Figure 18. GBRA E. coli (MPN/100 mL) trend analysis in Upper San Marcos River (1992-2020).

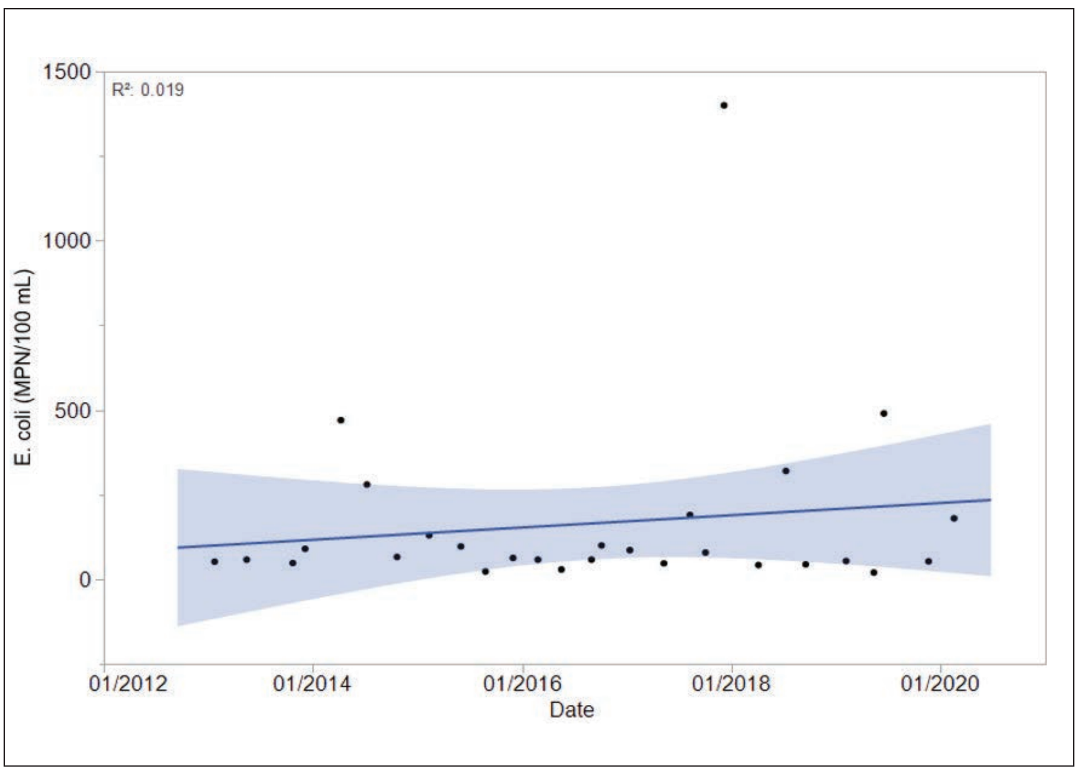


Figure 19. GBRA E. coli (MPN/100 mL) seven-year (2013-2020) trend analysis in Upper San Marcos River.

Texas Stream Team Surface Water Quality Monitoring Data

Parameter summary statistics for all Texas Stream Team data in the USMR are provided in Table 5. The core water quality monitoring parameters, air and water temperature, dissolved oxygen, pH and specific conductance/TDS, were the most numerous, while E. coli, an advanced water quality parameter, was the least sampled (n=16). All mean and geometric mean values met the corresponding water quality standards and targets except specific conductance/TDS. TDS is calculated from the measured specific conductance values. The mean specific conductance (616 µS/cm) and calculated TDS (400.4 µS/cm) values were slightly higher than the corresponding standards (615 and 400 µS/cm).

Tables 6, 7, and 8 contain station summary statistics for the groups of stations: Spring Lake Area (SLA), Below Spring Lake Area (BSLA), Northwest of IH35 (NW35), and Southeast of IH35 (SE35). The mean specific conductance/TDS values for all sites exceed the 2025 and 2035 WPP targets and most exceed the water quality standard.

Sixteen (16) data points were available for E. coli analysis in the USMR (Table 5). The geometric mean of the E. coli values (115.2 CFU/100 mL) at site 80646, the stormwater outfall across from Lion's Park, exceeded the 2035 water quality target established in the USMR WPP (Table 7).

Texas Stream Team citizen scientists measured air and water temperatures (°C) at 15 sites within 4 groups in the Upper San Marcos River (2005-2020) (Figures 20 and 21). Mean air temperature measurements and ranges were consistent among sites. Mean water temperatures at all sites met the TCEQ water quality standard (Figure 21), however individual temperature measurements from all sites exceeded the standard at some point during the period of record (2005-2020). There are two temperature criteria for the USMR, one (78°F/25.6°C) applies from the confluence with Sessom's Creek approximately 1.5 km (0.9 mi) upstream of Rio Vista Dam upstream to a point 0.7 km (0.4 mi) upstream of Loop 82 in San Marcos in Hays County (excludes the slough arm of Spring Lake), while the remaining portions of USMR have an 80°F/26.7°C criterion (TCEQ, 2018).

Mean dissolved oxygen values for 14 of 15 sites were at or above the TCEQ water quality standard during the period of record (2005-2020) (Figure 22). Among the SLA group, the mean dissolved oxygen value at Sink Creek (15496) was below the water quality standard and targets, while 3 of the remaining four sites in this group marginally met the TCEQ water quality standard (6.0 mg/L), but did not meet the WPP targets (6.6 and 7.2 mg/L). Only Spring Lake at the headwaters (80417) met both the TCEQ water quality standard and WPP targets.

All sites in the BSLA group met the TCEQ water quality standard for dissolved oxygen and exhibited a lower range of measurements than other groups (Figure 22). Three sites in the BSLA group did not meet the WPP targets. All of the sites in the NW35 and SE35 groups had means that met both the TCEQ water quality standard and WPP targets for dissolved oxygen, however all sites had individual measurements below at some point.

Mean pH values for all sites within all groups met the TCEQ water quality standards (Figure 23).

Mean specific conductance values at all sites within all groups consistently hovered immediately above, below, or at the TCEQ water quality standard (Figure 24).

Table 5. Texas Stream Team water quality monitoring data summary statistics in the Upper San Marcos River, Texas (December 2005 to May 2020).

Parameter	Number of Samples	Mean ± Standard Deviation	Min	Max
Air Temperature (°C)	1,800	22.8±7.1	-0.05	41.0
Water Temperature (°C)	1,819	21.8 ± 3.1	4.0	38.0
Dissolved Oxygen (mg/L)	1,786	7.25±1.8	0.81	15.4
pH (su)	1,808	7.3± 0.42	2.0	8.7
Specific Conductance (µS/cm)	1,736	616±41	160	1,120
*TDS (µS/cm)	1,736	400.4±26.7	104	728
**E. coli (CFU/100mL)	16	109.9±210.3	0	633.3

*TDS is calculated as follows: TDS = Specific conductance *0.65 (TCEQ, 2012)

**Geometric mean

Table 6. Texas Stream Team water quality monitoring data summary statistics at Spring Lake Area (SLA) sites in the Upper San Marcos River, Texas (December 2005 to May 2020).

Parameter	**Sink 15496** n=217 Mean±SD (Range)	**Spring Lake Boardwalk 81142** n=59 Mean±SD (Range)	**Spring Lake 80925** n=146 Mean±SD (Range)	**Spring Lake Headwaters 80417** n=53 Mean±SD (Range)	**Spring Lake near Saltgrass 15497** n=181 Mean±SD (Range)
Air Temperature (°C)	23.2±7 (37)	22.7±7.7 (34)	22.3±8.0 (34.5)	23.7±4.6 (18.5)	21.7±6.6 (31.5)
Water Temperature (°C)	21.1±4.0 (22)	22.3±4.3 (17.5)	22.1±2.9 (28)	22.7±2.6 (10.5)	21.6±1.7 (11)
Dissolved Oxygen (mg/L)	6.0±2.7 (12.4)	6.7±2.3 (10.6)	6.1±1.6 (8.7)	9.5±3.1 (9.4)	6.6±1.1 (8.6)
pH (su)	7.2±0.45 (4.7)	7.2±0.49 (2.7)	7.1±0.29 (2.2)	7.4±0.34 (1.3)	7.2±0.27 (2.0)
Specific Conductance (µS/cm)	615±61 (690)	597±39 (248)	608±26 (180)	616±28 (100)	622±37 (490)
*TDS (µS/cm)	399.8±39.7 (448.5)	388.3±25.4 (161.2)	395.4±16.9 (117)	397.8±18.2 (65)	404.3±24.1 (318.5)
***E. coli* (CFU/100mL)	-	-	56.7 (0)	-	-

*TDS is calculated as follows: TDS = Specific conductance *0.65 (TCEQ, 2012)

**Geometric mean

Table 7. Texas Stream Team water quality monitoring data summary statistics at sites below Spring Lake area (BSLA) in the Upper San Marcos River, Texas (December 2005 to May 2020).

Parameter	**Sessoms Creek 15498** n=183 Mean±SD (Range)	**Sewell Park 80119** n=53 Mean±SD (Range)	**City Park Bridge 81193** n=30 Mean±SD (Range)	**Stormwater Outfall across Lions 80646** n=36 Mean±SD (Range)
Air Temperature (°C)	23.0±6.3 (31)	23.5±7.2 (29)	22.1±6.7 (32)	26.6±5.3 (21)
Water Temperature (°C)	21.8±3.1 (26)	22.0±2.7 (13.2)	22.0±2.4 (9.5)	21.4±3.2 (14.1)
Dissolved Oxygen (mg/L)	7.3±1.0 (8.8)	7.3±1.1 (8.1)	7.0±0.82 (3.9)	7.1±0.98 (3.3)
pH (su)	7.4±0.38 (1.5)	7.1±0.31 (1.2)	7.2±0.28 (1.3)	7.0±0.31 (1.0)
Specific Conductance (µS/cm)	631±31 (270)	630±35 (160)	623±33 (160)	660±102 (550)
*TDS (µS/cm)	410.2±20.2 (175.5)	409.5±22.75 (104)	405±21.5 (104)	429±66.3 (357.5)
***E. coli* (CFU/100mL)	-	-	-	115.2±214.8 (633.3)

*TDS is calculated as follows: TDS = Specific conductance *0.65 (TCEQ, 2012)

**Geometric mean

Table 8. Texas Stream Team water quality monitoring data summary statistics at sites northwest (NW35) and southeast (SE35) of Interstate 35 in the Upper San Marcos River, Texas (December 2005 to May 2020).

Groups	Northwest of IH35 (NW35)			Southeast of IH35 (SE35)		
Parameter	**Purgatory Creek 15499** n=190 Mean±SD (Range)	**Rio Vista/ Cheatham 81022** n=39 Mean±SD (Range)	**R. Lucio Park 15500** n=257 Mean±SD (Range)	**IH35 E. Frontage Rd. 12672** n=161 Mean±SD (Range)	**Thompson's Island Mill Race 81021** n=26 Mean±SD (Range)	**Thomp-son Island 12671** n=210 Mean±SD (Range)
Air Temperature (°C)	22.8±7.4 (36.5)	24.3±7.1 (32.7)	22.7±7.3 (38)	22.6±7.8 (36)	25.5±7.9 (28)	22.8±6.4 (39.9)
Water Temperature (°C)	22.3±2.9 (16.5)	22.1±2.5 (10.1)	22.1±3.0 (18)	21.6±3.4 (23.5)	22.0±3.6 (11.9)	21.5±3.0 (23)
Dissolved Oxygen (mg/L)	7.8±1.8 (9.3)	7.9±0.86 (3.7)	7.9±1.1 (7.0)	7.9±1.4 (9.2)	7.5±1.1 (4.3)	7.6±0.87 (4.9)
pH (su)	7.3±0.34 (1.4)	7.3±0.30 (1.2)	7.4±0.35 (1.5)	7.4±0.41 (2.1)	7.4±0.39 (1.1)	7.6±0.52 (6.5)
Specific Conductance (µS/cm)	607±39 (390)	617±60 (360)	619±34 (310)	612±24 (172)	617±35 (145)	607±29 (190)
*TDS (µS/cm)	394.6±25.4 (253.5)	401.1±39 (234)	402.4±2.1 (201.5)	397.8±15.6 (111.8)	401.1±22.8 (94.3)	394.6±18.9 (123.5)
***E. coli* (CFU/100mL)	-	-	-	-	-	-

*TDS is calculated as follows: TDS = Specific conductance *0.65 (TCEQ, 2012)

**Geometric mean

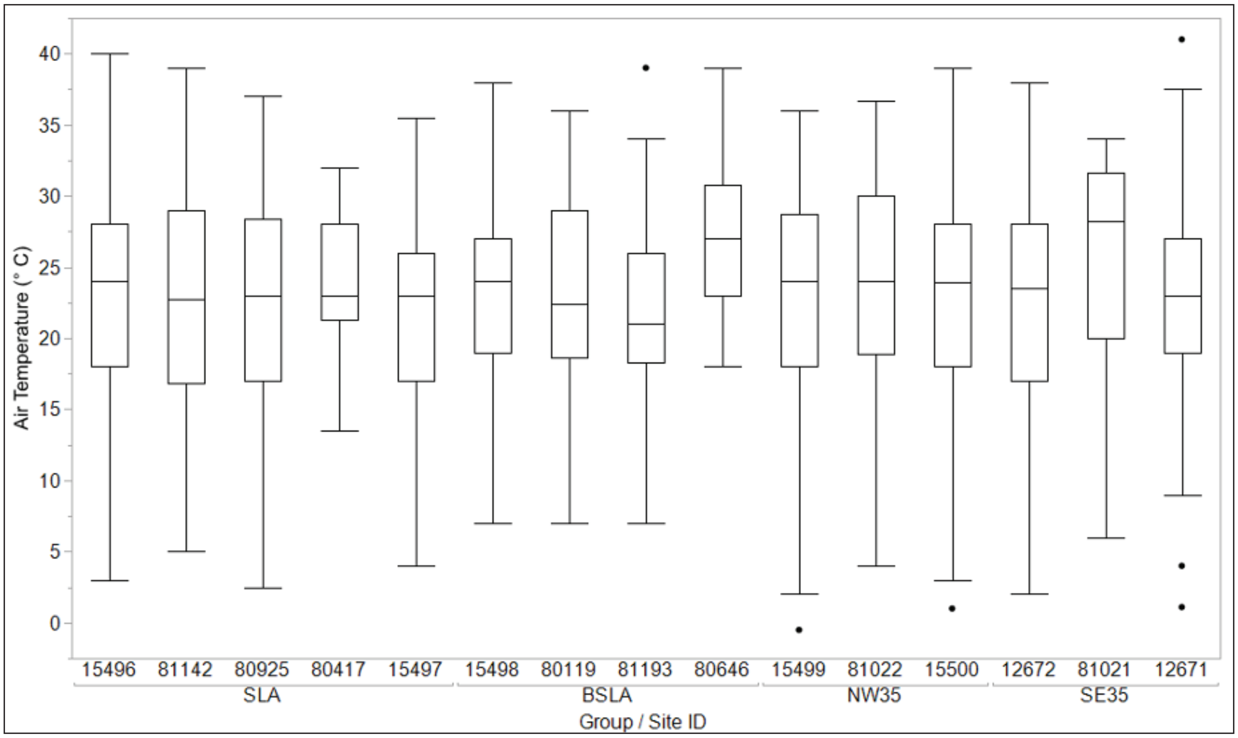


Figure 20. Texas Stream Team air temperature (°C) data by group and site in Upper San Marcos River (2005-2020).

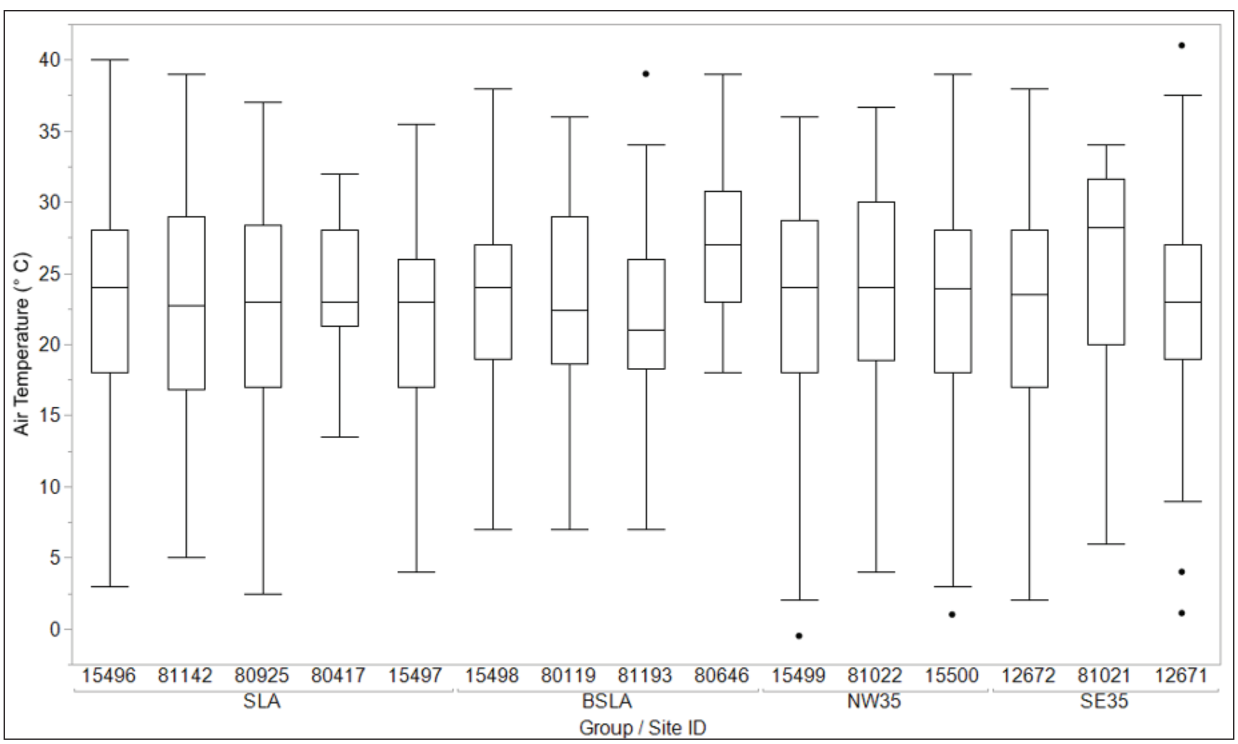


Figure 21. Texas Stream Team water temperature (°C) data by group and site in Upper San Marcos River (2005-2020).

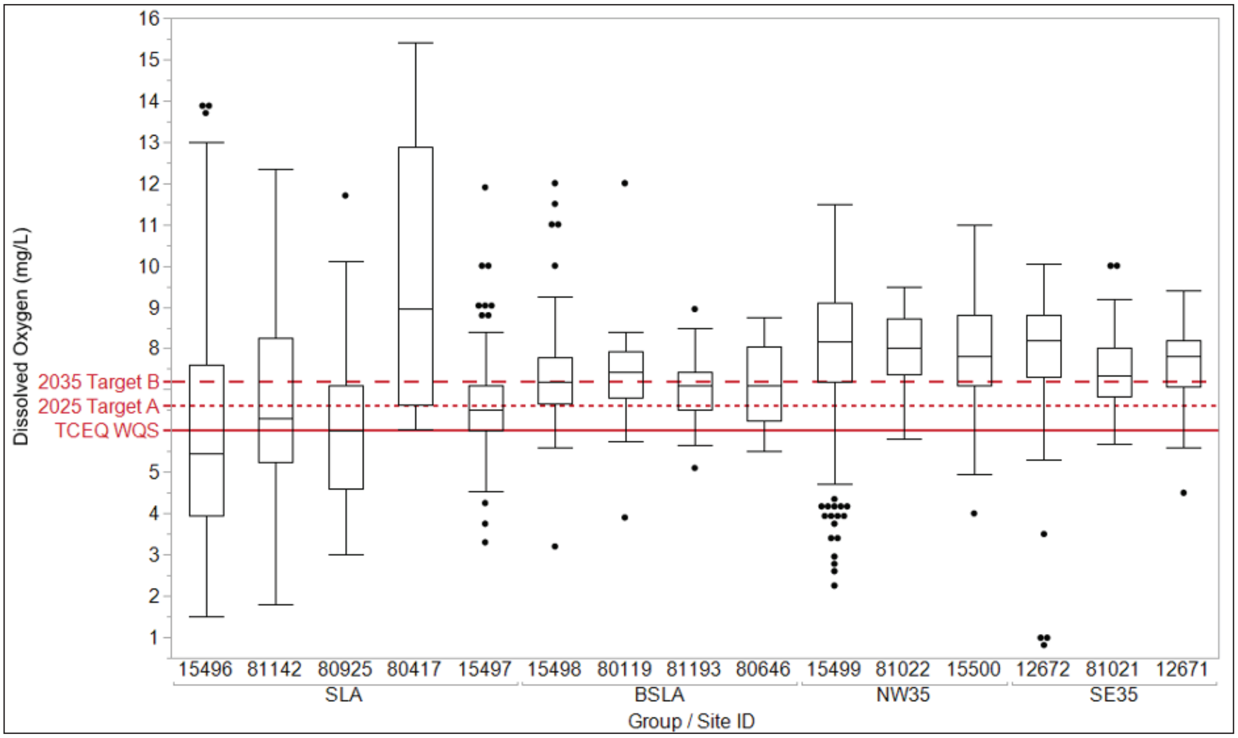


Figure 22. Texas Stream Team dissolved oxygen (mg/L) data by group and site in Upper San Marcos River (2005-2020).

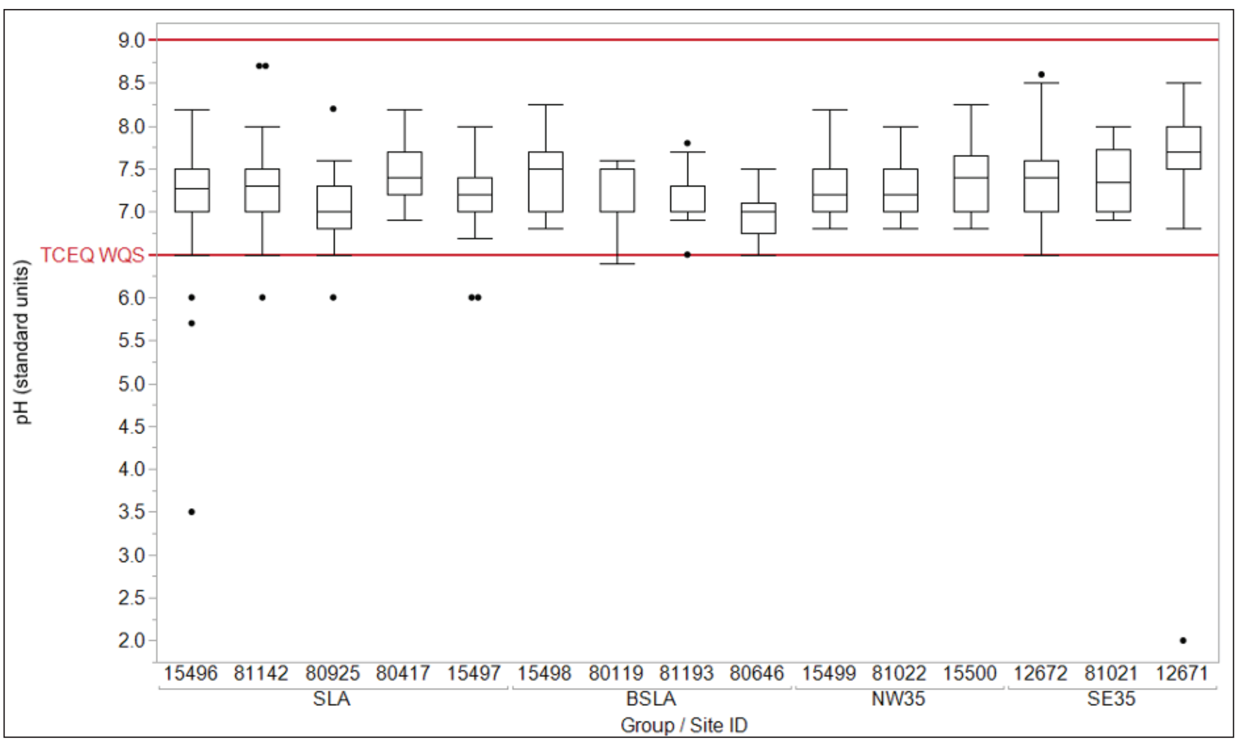


Figure 23. Texas Stream Team pH (s.u.) data by group and site in Upper San Marcos River (2005-2020).

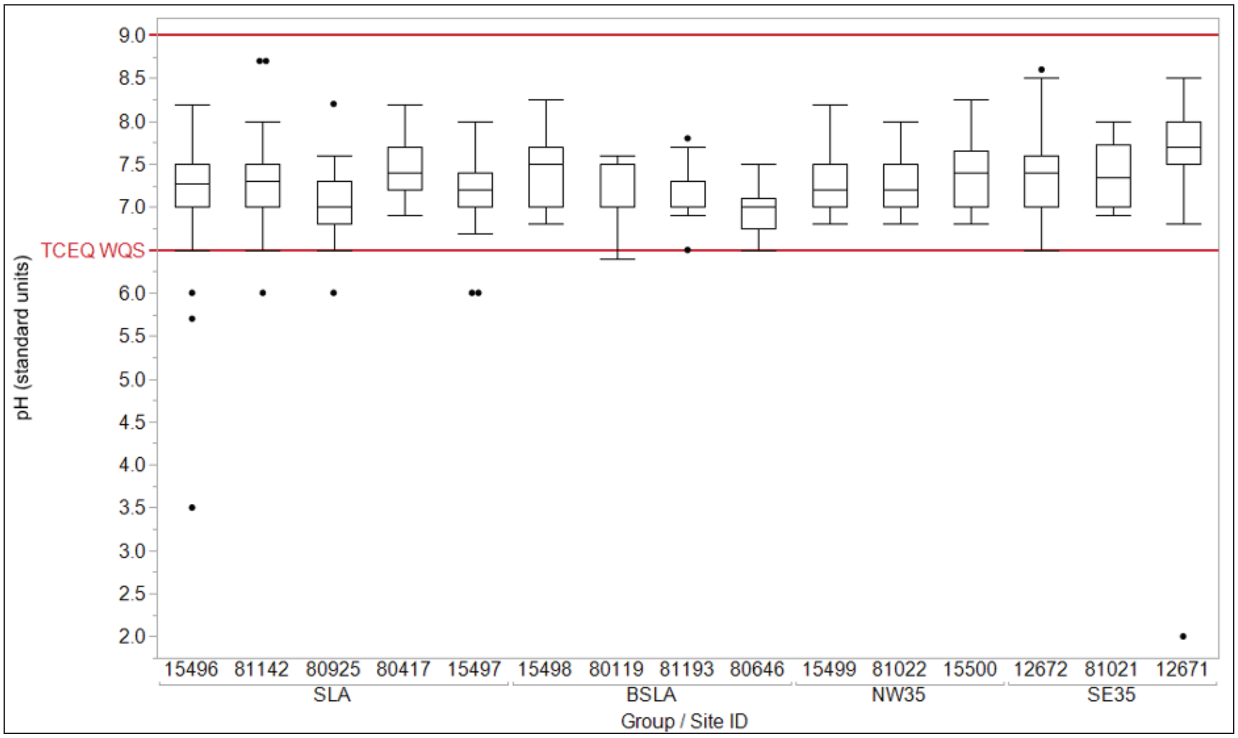


Figure 24. Texas Stream Team specific conductance (µS/cm) data by group and site in Upper San Marcos River (1992-2020).

City of San Marcos (COSM) Monitoring Data

Stormwater Monitoring Data

The COSM monitors E. coli bacteria at six sites along the USMR approximately weekly. Geometric means for the entire period of record (January 2015 – May 2020) were calculated for each site (Figure25). All sites met the water quality standard (126 CFU/100 mL) and the WPP Targets (2025 Target A=113.4 CFU/100 mL and 2035 Target B=101 CFU/100mL). Although trend analyses over time did not produce significant results, a gradual increase in geometric means was observed from the headwaters upstream to downstream (Figure 25).

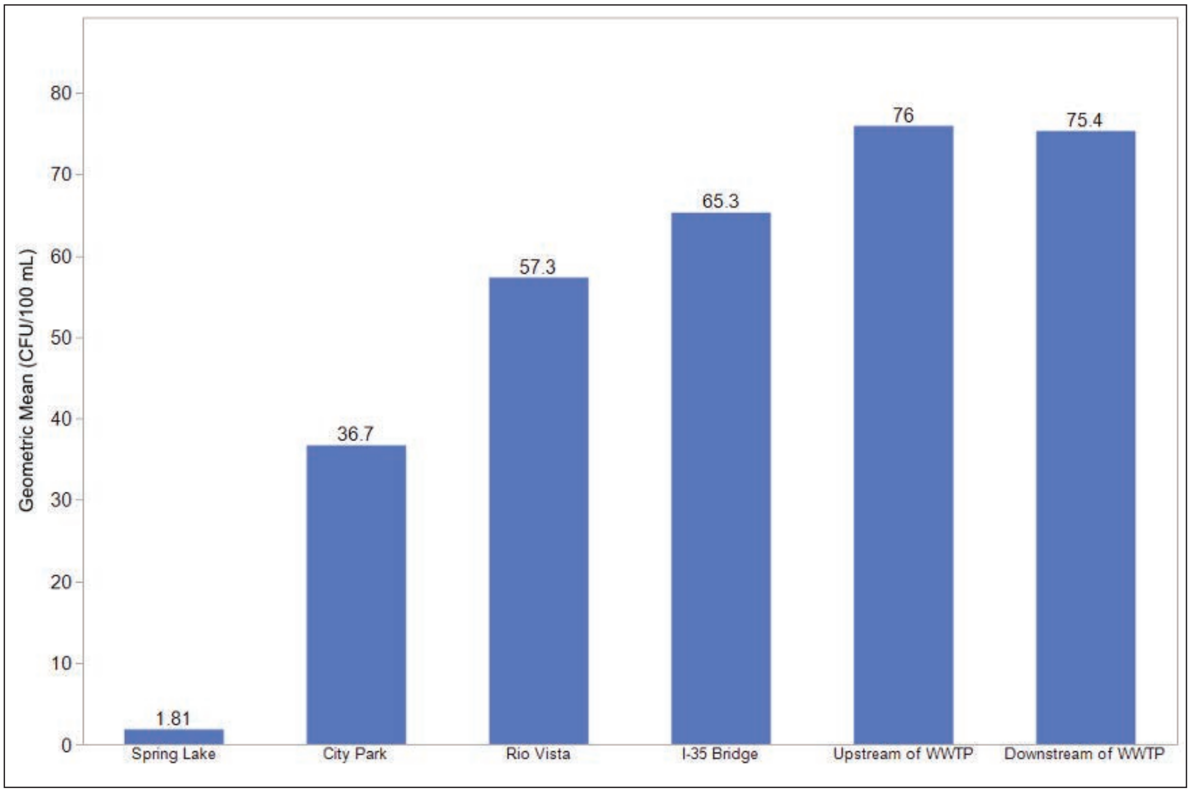


Figure 25. City of San Marcos stormwater monitoring E. coli bacteria data (January 2015 - May 2020).

Drinking Water Monitoring Data

The COSM drinking water quality data for 2016 thru 2018 are summarized in Table 9. Violations were identified in 2016 for Lead, Total Trihalomethanes (TTHM), and for the Public Notification Rule. No violations were identified in 2017 or 2018.

The COSM failed to provide TCEQ the Lead Consumer Notice Certification Form for the lead tap water monitoring conducted in September 2015 that resulted in one site exceeding the lead action level.

Drinking water sample analysis also resulted in levels of TTHM (81.5 ppb) that were above the maximum contaminant level (MCL) beginning January 1, 2016 through March 31, 2016. TTHMs are a biproduct of drinking water chlorination and individuals who consume water containing TTHMs in excess of the MCL over many years may experience health problems and may have increased risk of getting cancer.

The Public Notification Rule is designed to ensure consumers know if there is a problem with the drinking water and serve as an immediate notification to alert consumers of serious problems such as the need to boil water in the event of an emergency. In May 2016, the City failed to provide TCEQ the Certificate of Delivery of Public Notice within 10 days of providing the Public Notice to the consumers.

Table 9. City of San Marcos drinking water quality data summary (2016-2018). Bold values indicated a violation.

Contaminant (units)	Highest Level Detected (Range)			MCLG/MCL
	2016	2017	2018	
Fluoride (ppm)	0.2 (0.18-0.22)	0.23 (0.18-0.23)	0.22 (0.19-0.22)	4/4
Nitrate (ppm)	3.0 (1.13-2.58)	1.86 (1.15-1.86)	2.01 (1.09-2.01)	10/10
Barium (ppm)	0.0442 (0.0369-0.0442)	0.0489 (0.038-0.489)	0.0473 (0.3999-0.0473)	2/2
Arsenic (ppb)	-	2.2 (0-2.2)	-	0/10
Atrazine (ppb)	0.16 (0-0.16)	-	-	3/3
Di (2-ethylhexyl) phthalate (ppb)	0.87 (0-0.87)	-	-	0/6
Combined Radium 226/228 (pCi/L)	1 (1-1)	1.5 (1.5-1.5)	1.5 (1.5-1.5)	0/5
Turbidity (NTU)	0.13	0.09	0.07	-
TOC – Source Water (ppm)	-	1.21 (0.83-1.59)	-	-
TOC – Drinking Water (ppm)	-	0.99 (0.71-1.28)	-	-
Haloacetic Acids (ppb)	*29.3 (0.0-55.5)	*14.2 (0-14.2)	*13 (0-19.3)	NA/60
Total Trihalomethanes (TTHM) (ppb)	***81.5** (2.7-95.3)	*59.2 (0-59.2)	*54 (4.8-71)	NA/80
Disinfectant/Chlorine Residuals (ppm)	1.27 (0.37-3.66)	1.31 (0.27-2.20)	1.23 (0.03-6.10)	<4.0/4.0
Coliform Bacteria (presence/absence)	0% monthly positive samples	1.4%	0%	5% per mo.
Copper (ppm)	**0.26	**0.17	**0.18	1.3/1.3
Lead (ppb)	**3.4	**2.8	**2.1	0/15
Total Hardness (as CaCO3) (ppm)	16.8 (12.8-23.4)	16 (14.4-18)	15.2 (13.2-18.1)	NA
pH (su)	7.8 (7.8-7.8)	-	-	NA

*Highest average of all sample results at a location over a year

**90th percentile

USGS Stream Flow Monitoring Data

Average monthly stream discharge (cfs) measurements at the USGS flow gauge on the San Marcos River (#8170500) from September 2018 to May 2020 revealed a decreasing trend (R2=0.3375) (Figure 26).

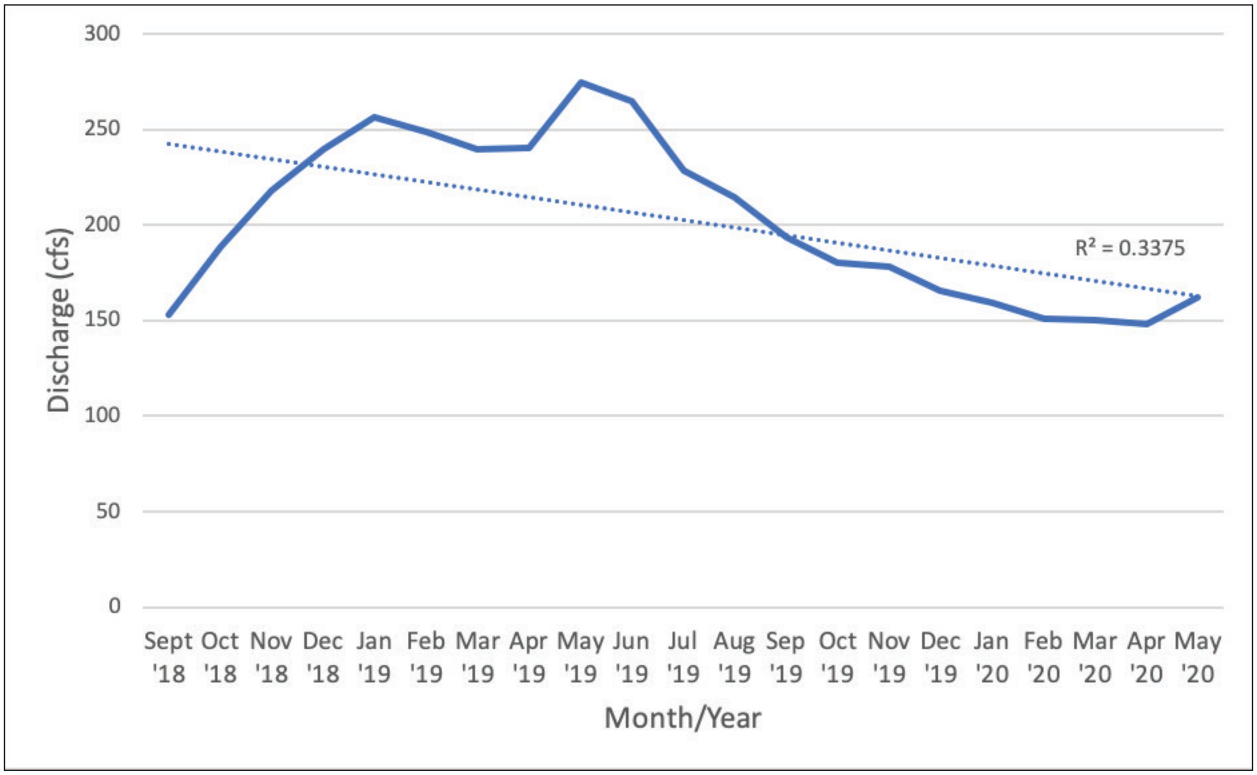


Figure 26. USGS stream discharge (cfs) at San Marcos River (#8170500) (September 2018-May 2020).

Texas Water Development Board Groundwater Monitoring Data

Groundwater wells in the USMR watershed were monitored irregularly over time (Table 3). The longest, continuously monitored well in the USMR watershed was the Summer Mountain Ranch well (#6808501) in the Trinity Aquifer. The SWT Farms EAA well (#6709110) in the Edwards Aquifer had the most data (N=773), however the monitoring was intermittent over time (Table 10). Two other wells, #6709101 and 6701403, in the Edwards Aquifer had 169 and 113 measurements (n) respectively, but were also monitored intermittently over time (Tables 2 and 10). Mean water levels (ft. below land surface) for all wells in the USMR watershed ranged from approximately 84 to 317 feet for the entire period of record. No discernable trends were observed in the resulting trend analysis for the groundwater well level data.

The mean water levels for the eight wells monitored fell into three broad groups. Mean water levels for four of the eight wells ranged from 83.93 to 119.32 feet, three of the wells ranged from 176.37 to 206.92 feet, while the remaining well had a mean water level of 317.08 feet (Figure 27). The four wells in the first group (83.93 to 119.32 feet) were shallower and closer in proximity to the headwaters of the USMR than the remaining four wells.

Table 10. Texas Water Development Board groundwater well water level monitoring data summary statistics.

Well No.	No. of Measurements (n)	Mean Water Level (ft. below land surface)	Standard Deviation	Range
6701403	113	83.93	14.95	58.59
6709101	169	104.62	3.02	17.06
6709106	14	119.32	3.42	9.74
6709110	773	99.51	3.09	25.25
6808501	194	206.92	8.33	52.87
6808902	17	188.11	15.01	46.53
6816601	10	176.37	4.03	13.23
6816303	10	317.08	7.13	24.84

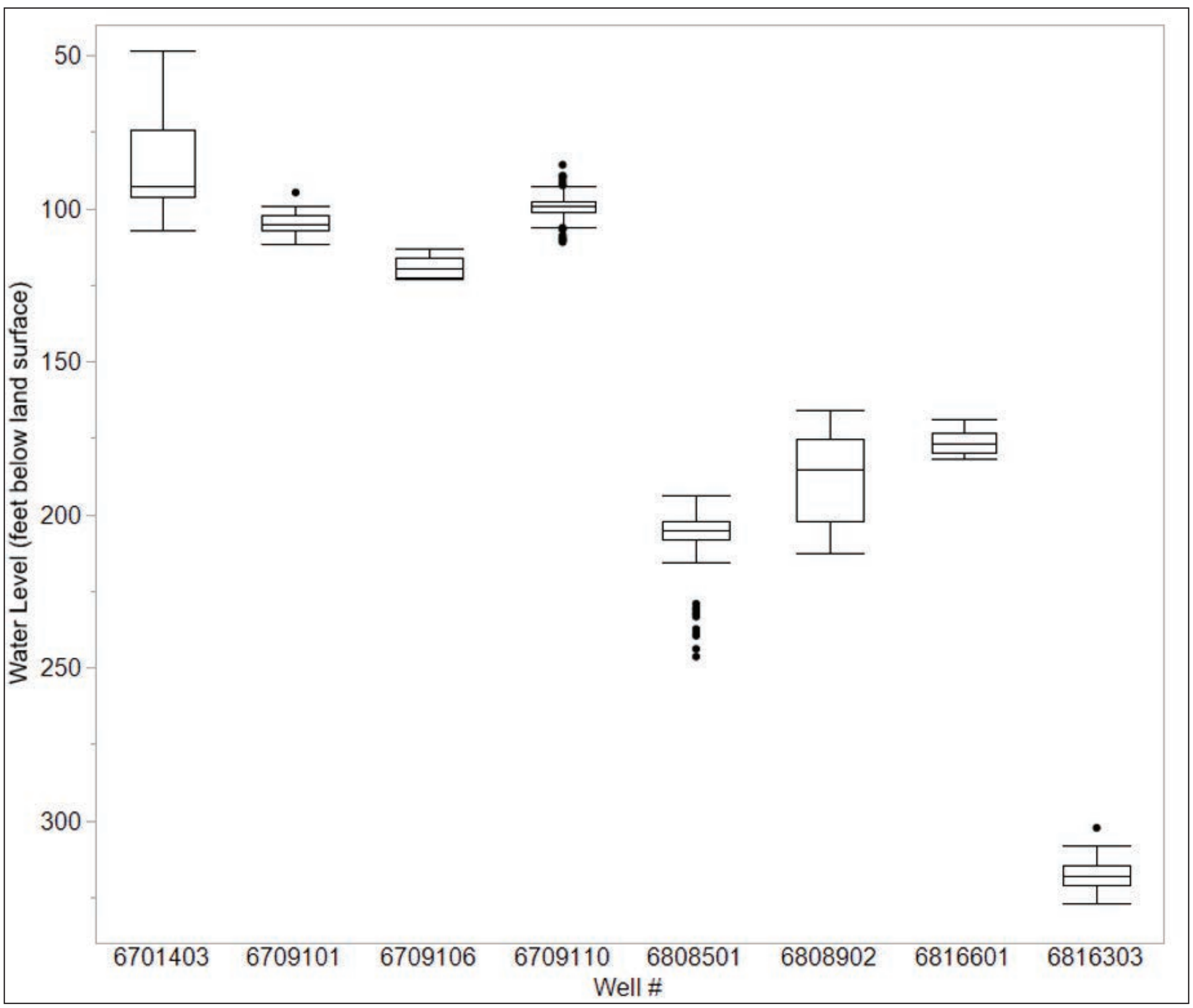


Figure 27. Texas Water Development Board groundwater level well data (ft. below land surface).

DISCUSSION

A multitude of management measures described in the USMR WPP have been and continue to be implemented. For example, various education and outreach activities were conducted in the USMR watershed during the project period associated with this contract including stakeholder meetings, workshops, ordinance, code and regulation reviews, StoryMap creation, utility bill stuffers, and interpretive signage. Two BMPs were also constructed by the WPP team, COSM, and Texas State University to address nonpoint source pollution. The purpose of this annual data summary report was to determine changes and trends in water quality over time as the management measures described in the WPP are implemented. Although the monitoring data for this report was collected and analyzed independent of the management measures implemented, it can be inferred that the results presented here are a result of the management measures implemented. For more information about the activities implemented for this project, go to The Upper San Marcos River Watershed Protection Plan: Implementation Phase I Final Report (Navarro and Schlandt, 2020).

The USMR is not listed on the TCEQ's 303(d) list of impaired waters, however, water quality monitoring data collected by the GBRA for the CRP at one site on the USMR and the Texas Stream Team citizen scientist data from 8 of 15 sites confirmed TDS concentrations are not supportive of the TCEQ water quality standard and USMR WPP targets. The GBRA CRP long-term and seven-year means for TDS exceeded the standard and targets. The TDS trend analysis conducted on the GBRA CRP data revealed an increasing long-term trend (1992-2020) and a decreasing seven-year trend (2013-2020), although both relationships were weak ($r2< 0.5$). Notably, all TDS means for the Texas Stream Sites in the BSLA, located along the centralized section of the USMR with more dense urbanization, exceeded the water quality standard. While only one site in the SLA group, two in the NW35 group, and one in the SE35 group exceeded the water quality standard, some of these occurrences are not unexpected given the USMR WPP modeled predictions for TDS (MCWE, 2018).

Chloride concentrations resulting from the GBRA CRP data met the TCEQ water quality standard and WPP targets. However, although the long-term trend analysis showed a decreasing trend, the seven-year trend analysis showed a strong ($r2=0.617$) increasing trend.

GBRA CRP sulfate concentrations analyzed met the TCEQ water quality standard and WPP targets, however both the long-term and seven-year trend analyses revealed increasing trends. The seven-year trend analysis showed a relatively strong ($r2=0.445$) relationship for sulfate concentrations over time, similar to that for chloride.

Mean GBRA CRP dissolved oxygen values met the 6.0 mg/L aquatic life use criteria and WPP targets. However, a rather weak ($r2<0.05$) decreasing trend in dissolved oxygen over time was observed. The Texas Stream Team citizen scientist data, however, revealed Sink Creek (15496) had the lowest mean dissolved oxygen value of all sites.

Nutrients, mean nitrate-nitrogen, and phosphorous values, met the TCEQ water quality standard and WPP targets. Trend analysis for nitrate-nitrogen revealed relatively strong ($r2>0.05$) values for both the long-term (increasing) and seven-year (decreasing) time frames. Similar results were observed for phosphorous, but the long-term trends were decreasing, while the seven-year trend was increasing.

The GBRA CRP E. coli geometric mean was well below the primary contact recreation use criterion and WPP targets. While the long-term trend analysis revealed a relatively strong correlation coefficient ($r2>0.05$), the seven-year trend was weak ($r2<0.05$). However, the seven-year geometric mean was greater than the long-term geometric mean. Only a few E. coli sampling events were documented in the Texas Stream Team Waterways Dataviewer (n=16), but the geometric mean for all samples fell just below the TCEQ water quality standard.

The COSM stormwater monitoring E. coli geometric means at all sites met the water quality standard and WPP targets, however there was a longitudinal increase in geometric means from the upstream to

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downstream sites. A report from the EAHCP, collected water samples from 12 storm events in 2018 and noted they contained very high concentrations of E. coli that exceeded the contact recreation limits (Schwartz et al. 2019). Perhaps the stormwater events sampled by the COSM and the EAHCP programs varied in type, size, and duration, resulting in different outcomes.

The USMR WPP established targets for oil and grease. However, no oil and grease monitoring data were identified in any of the partner monitoring programs. Therefore, no analysis of this type occurred.

USGS streamflow discharge data in the USMR resulted in a relatively strong decreasing trend in streamflow (r2=0.3375) for the project period. However other recent studies in the USMR resulted in predominantly above average spring flows in the San Marcos Spring system (EAHCP, 2019).

Groundwater level data was identified in the TWDB groundwater database (GWEB), however it was monitored irregularly. The groundwater quality data identified in the watershed was sporadic at best with only one event at one well taking place during the project period for this report.

Evidence of nonpoint source pollution in the USMR watershed is supported by results of the parameters analyzed in this study. TDS continues to exceed the water quality thresholds, while other parameters revealed mixed and/or strong increasing trends and have the potential for future exceedances of water quality criteria. Therefore, it is paramount for partners to continue monitoring and assessing the responses of this diverse and dynamic system given the explosive growth and subsequent development currently taking place in the watershed.

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