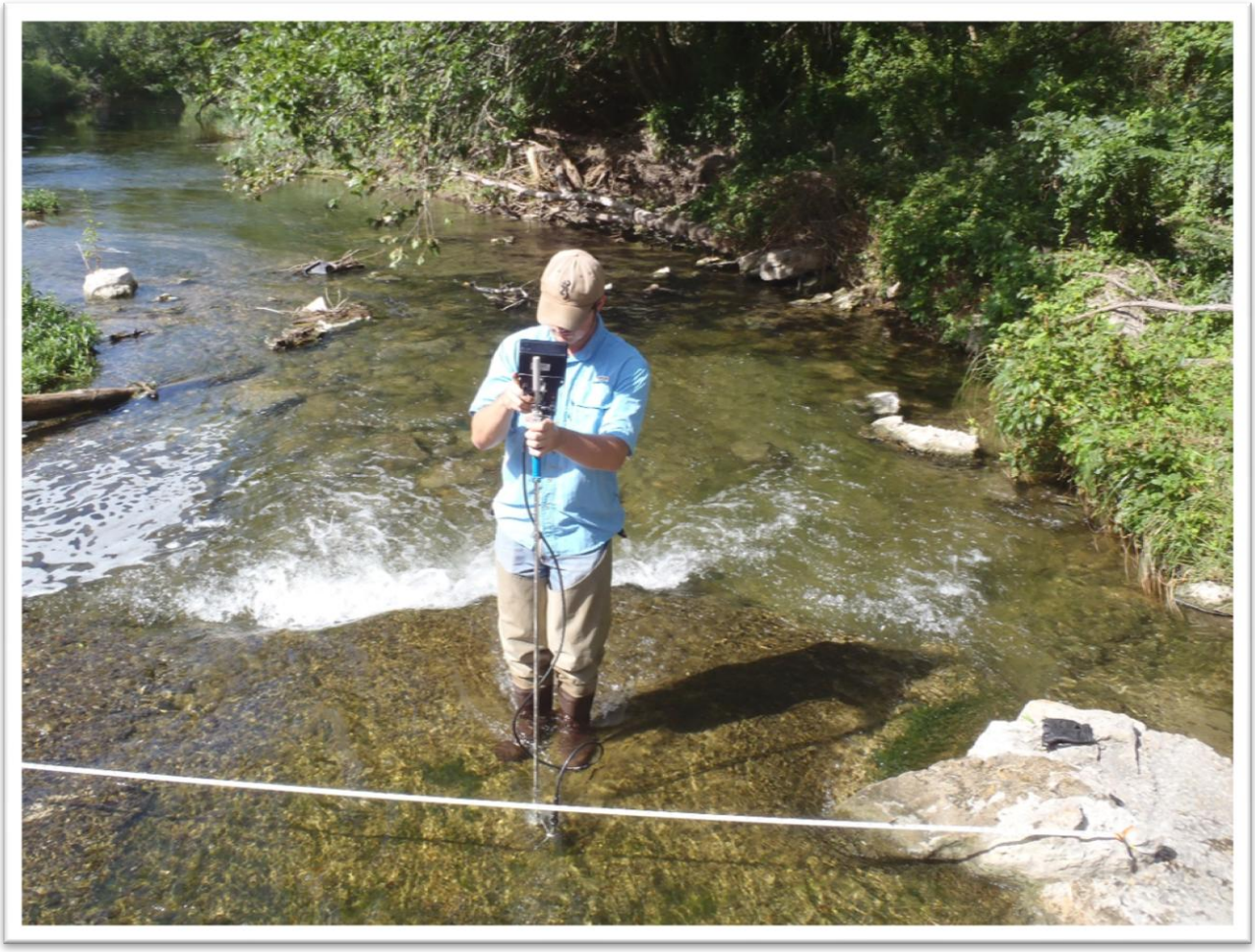

SURFACE WATER QUALITY MONITORING TO SUPPORT THE IMPLEMENTATION OF THE LAMPASAS RIVER WATERSHED PROTECTION PLAN

Final Report
TSSWCB Project # 13-09
Prepared by Texas A&M AgriLife Research

FUNDING PROVIDED THROUGH A CLEAN WATER ACT §319(H) NONPOINT SOURCE GRANT FROM THE TEXAS STATE SOIL AND WATER CONSERVATION BOARD AND THE U.S. ENVIRONMENTAL PROTECTION AGENCY

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ACRONYMS

AgriLife Research	Texas A&M AgriLife Research
BRA	Brazos River Authority
CFS	Cubic feet per second
cfu/100mL	colony forming units per 100 milliliters
CRP	Clean Rivers Program
mg/L	milligram per liter
Partnership	Lampasas River Watershed Partnership
QAPP	Quality Assurance Project Plan
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TIAER	Texas Institute of Applied Environmental Research
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSSWCB	Texas State Soil and Water Conservation Board
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plans

INTRODUCTION

The Lampasas River watershed lies within the Brazos River Basin in Central Texas (Figure 1), which drains to the Gulf of Mexico. The Lampasas River's headwaters are in eastern Mills County and flows southeast for 75 miles, passing through Hamilton, Lampasas, Burnet and Bell counties. In Bell County the river turns northeast and is dammed five miles southwest of Belton to form Stillhouse Hollow Lake. Stillhouse Hollow Lake is the primary drinking water supply for much of the surrounding area. The watershed encompasses 798,375 acres across Mills, Hamilton, Coryell, Lampasas, Burnet, Bell and Williamson Counties. The Lampasas River is primarily a rural watershed with few urban centers. The cities of Lampasas and Kempner are wholly within the watershed boundaries, while the cities of Copperas Cove and Killeen are only partially in the watershed.

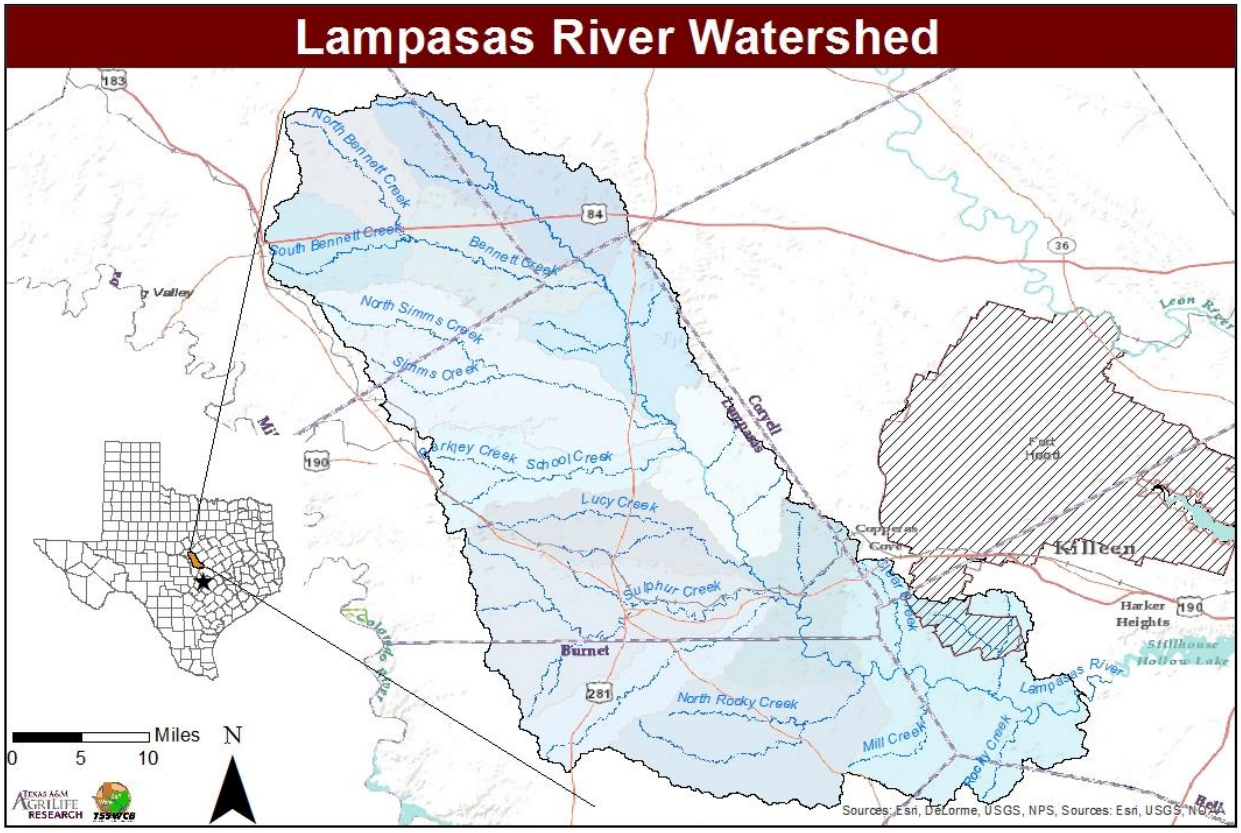

Figure 1 The Lampasas River watershed is a primarily rural watershed, located in Central Texas in the Brazos River basin.

The Lampasas River was originally listed on the 2002 303(d) List for elevated levels of bacteria and carried forward to subsequent lists in 2004, 2006 and 2008. Elevated bacteria levels are an indicator of fecal contamination from warm blooded animals and is a human health hazard. Texas A&M AgriLife Research (AgriLife Research) and Texas State Soil and Water Conservation Board (TSSWCB) established the Lampasas River Watershed Partnership (Partnership) in

November 2009 as part of TSSWCB project 07-11, "*Lampasas River Watershed Assessment and Protection Project"*. The project included an updated land use analysis, modeling of historical water quality data, and the development of a Watershed Protection Plan (WPP) to address the bacteria impairment.

The development of this WPP was a stakeholder driven process facilitated by AgriLife Research. With technical assistance from AgriLife Research and other state and federal partners, the Steering Committee identified water quality issues that are of particular importance to the surrounding communities. The Steering Committee also contributed information on land uses and activities that were utilized in identifying the potential sources of bacterial impairments and in guiding the development of the WPP. The WPP identified responsible parties, implementation milestones and estimated financial costs for individual management measures and outreach and education activities. The plan also described the estimated load reductions expected from full implementation of all management measures. In order to provide an accurate measure of the effectiveness of the WPP, the Partnership recommended an intensive water quality monitoring regime within the river and its tributaries.

Subsequent projects in the watershed have continued the implementation of the WPP, including TSSWCB project 12-09*, "Coordinating Implementation of the Lampasas River Watershed Protection Plan"*, and TSSWCB project 14-07, *"Continued Coordination of Implementation of the Lampasas River Watershed Protection Plan."* TSSWCB 14-06, "*Implementing Agricultural Nonpoint Source Components of the Lampasas River Watershed Protection Plan"* provides support for a watershed-wide District Technician to facilitate the development of Water Quality Management Plans (WQMPs) and implementation of nonpoint source BMP's with local landowners.

It is important to note that the Lampasas River was removed from the 2010 303(d) list. The delisting of the river occurred because additional data had not been collected for assessment between 2000 and 2009; existing historical data no longer met the Texas Commission on Environmental Quality (TCEQ) criteria to be included in assessment.

PROJECT OVERVIEW

AgriLife Research coordinated with Texas Institute of Applied Environmental Research (TIAER) to implement the recommended water quality monitoring regime which was outlined in the WPP. Historically surface water quality data was collected by the Brazos River Authority (BRA) and TCEQ through the Clean Rivers Program (CRP) on a quarterly basis. Additional data was collected through TSSWCB project 10-51 "*Bacterial Source Tracking to Support the Development and Implementation of WPPs for the Lampasas and Leon Rivers*."

The sampling sites were selected by the Partnership for long term sampling (Figure 2). The Partnership deemed these ten sites as "critical" for evaluating the effects of implementation. These sites were identified because they will yield a dataset that is all encompassing of areas where implementation will be focused and is spatially representative of the watershed. They felt that uninterrupted, routine, monthly monitoring would be key to providing accurate data to reflect changes within the watershed.

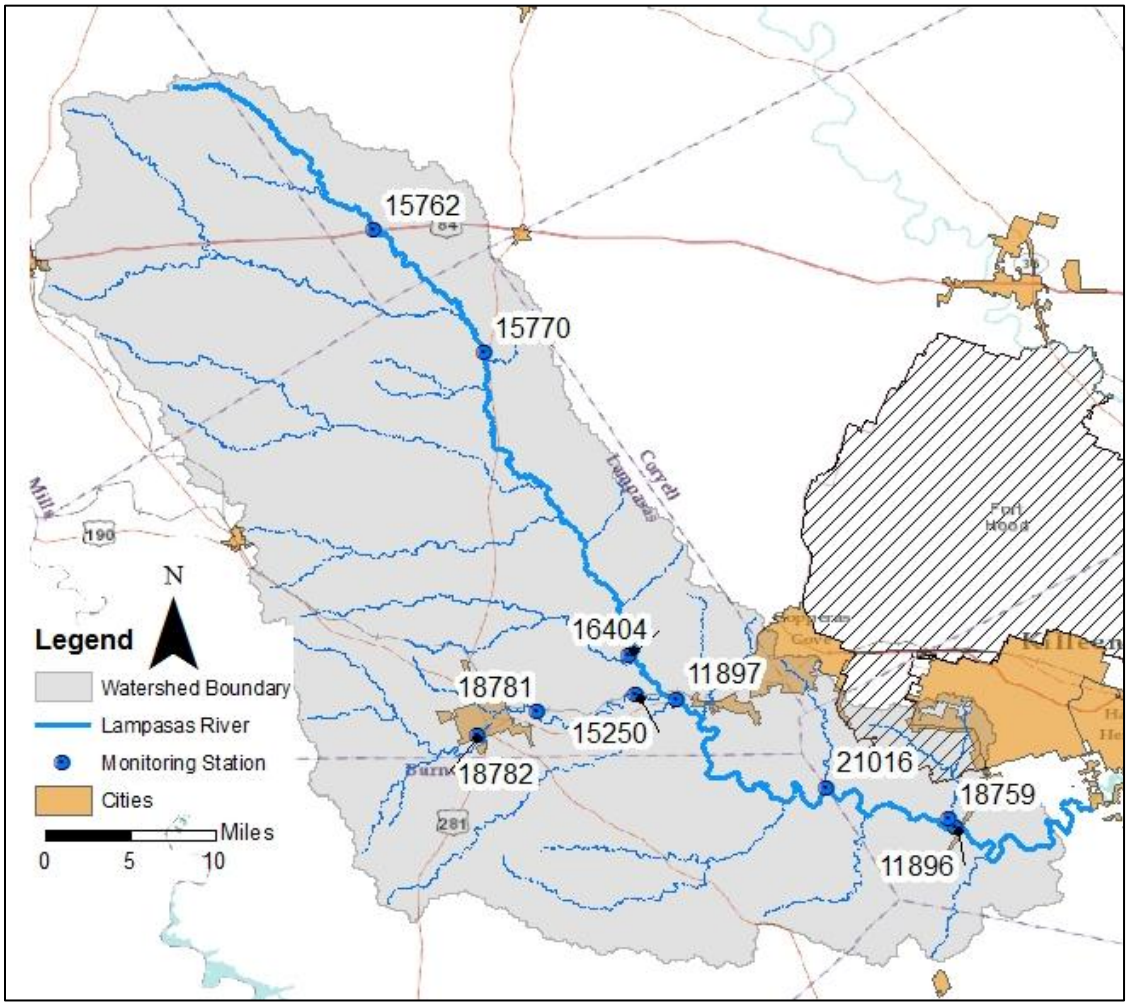

Figure 2 Ten monitoring sites were selected within the Lampasas River watershed.

TIAER conducted routine ambient monitoring at ten sites monthly collecting field, conventional, flow and bacteria parameter groups. TIAER collected monthly routine flow samples over a period of 24 months, from July 2014 through June 2016. Spatial and seasonal variations were captured across the sampling period (Table 1). The sites included 5 mainstem sites and 5 sites across 3 tributaries.

TIAER also planned to conduct biased flow monitoring at the 10 sites once per quarter/season under wet weather conditions, collecting field, conventional, flow, and bacteria parameter groups. If a routine sampling event happened to capture wet weather conditions, an additional wet weather sample was not collected that quarter.

Table 1 Samples were collected at 10 sites during routine and storm flow conditions over a 24 month period.

Segment ID	TCEQ Station ID	Site Description	Monitoring Type		
			Routine	Storm	Routine and Storm Combined[1]
1217	11896	Lampasas River at HWY 195	21	6	2
1217	11897	Lampasas River at US 190	21	6	2
1217B	15250	Sulphur Creek at FM 1715	21	6	2
1217	15762	Lampasas River at US 84	21	6	2
1217	15770	Lampasas River at Lampasas CR 2925	21	6	2
1217	16404	Lampasas River at FM 2313[2]	22	6	2
1217F	18759	Reese Creek at FM 2670	21	6	2
1217B	18781	Sulphur Creek at Lampasas CR 3010	21	6	2
1217B	18782	Sulphur Creek at Naruna Rd	21	6	2
Unclassified tributary to 1217	21016	Clear Creek at Oakalla Rd	21	6	2

[1]Routine sampling events that captured wet weather conditions.

[2]Additional bacteria only sample collected one day after routine collection due to broken sample container.

PROJECT HIGHLIGHTS

Data Collection and Submittal

Data collected through this project was collected under an approved Quality Assurance Project Plan (QAPP) that was updated annually. The objective of the quality assurance task was to develop and implement data quality objectives and quality assurance/control activities in order to ensure data of known and acceptable quality are generated through this project.

The data collected in this project was uploaded to the TCEQ Surface Water Quality Monitoring Information System (SWQMIS). A completed Data Summary was submitted with each data submittal. Corrective Action Reports were submitted by the TIAER staff if there was a problem or deficiency encountered. If a problem occurred during a sampling event, every attempt was made to recollect the sample if the flow conditions remained the same so there was no loss in data. Only three data sets were incomplete through June 2016 due to TIAER error, requiring a Corrective Action Report. The deficiencies are listed in Table 2.

Table 2 Deficiencies resulting in loss of data.

Date	Site Name	Deficiency	Explanation
November 6, 2014	All sites	TSS was not reported	Holding times for the TSS analysis was missed through lab error, thus no TSS was reported.
April 13, 2016	All Sites	*E. coli* not reported	The temperature of the water bath in the incubator slightly exceeded the maximum allowable temperature, so no *E. coli* analysis was reported.
May 11, 2016	All Sites	Chlorophyll-a and pheophytin were not available	The chlorophyll-a and pheophytin aliquot was spilled in the lab during final filtering, so no chlorophyll-a and pheophytin data are available for this sample

Highlights and Evaluation of Water Quality Monitoring Data

TIAER conducted routine ambient monitoring at 10 sites monthly, collecting field, conventional, flow and bacteria parameter groups. The objective of the routine monitoring was to provide sound water quality data to more accurately assess the current status of the Lampasas River by enhancing current routine ambient monitoring regimes. Analyzing this water quality data can show trends and the effectiveness of a WPP. TIAER and AgriLife Research coordinated with other entities, TCEQ and Brazos River Authority, to avoid overlapping of resources and sampling events when possible. TIAER's laboratory also conducted the sample analysis. Field parameters were pH, temperature, conductivity, and dissolved oxygen. Conventional parameters were total suspended solids, turbidity, nitrate + nitrite nitrogen, Total Kjeldahl Nitrogen (TKN), chlorophyll-a, pheophytin, and total phosphorus (TP). Flow parameters were collected by electric, mechanical or Doppler, including severity. Bacteria parameter is *E. coli*. A full list of parameters and field codes can be found in Table 3.

Beginning in July 2014 through June 2016, 24 routine sampling events were conducted. During the first year of sampling sites 15762 and 15770, the two most upstream sites, were continuously dry or pooled for the first nine sampling events. Site 15762 (Lampasas River at US HWY 84) only had pools sufficiently large enough to sample twice during this period. Site 15770 (Lampasas River at CR 2925) had 3 samples collected during this same period. The 3 remaining mainstem sites had routine flow, as did the 5 tributary sites.

Table 3 Measurement performance specifications of parameters collected.

PARAMETER	UNITS	MATRIX	METHOD	PARA-METER CODE	AWRL	LOQ	LOQ CHECK STD %Rec	PRECISION (RPD of LCS/LCS dup)	BIAS (%Rec. of LCS)	Lab
Field Parameters										
pH	pH/ units	water	SM 4500-H^+ B. and TCEQ SOP, V1	00400	NA	NA	NA	NA	NA	Field
DO	mg/L	water	SM 4500-O G. and TCEQ SOP, V1	00300	NA	NA	NA	NA	NA	Field
Specific Conductance	µS/cm	water	SM 2510 and TCEQ SOP, V1	00094	NA	NA	NA	NA	NA	Field
Temperature	°C	water	SM 2550 and TCEQ SOP, V1	00010	NA	NA	NA	NA	NA	Field
Flow	cfs	water	TCEQ SOP, V1	00061	NA	NA	NA	NA	NA	Field
Days since precipitation event	days	water	TCEQ SOP V1	72053	NA	NA	NA	NA	NA	Field
Flow measurement method	1-gage 2-electric 3-mechanical 4-weir/flume 5-doppler	water	TCEQ SOP, V1	89835	NA	NA	NA	NA	NA	Field
Flow severity	1-no flow 2-low 3-normal 4-flood 5-high 6-dry	water	TCEQ SOP, V1	01351	NA	NA	NA	NA	NA	Field
Flow Estimate	cfs	water	TCEQ SOP, V1	74069	NA	NA	NA	NA	NA	Field
Maximum pool width at time of study[1]	meters	other	TCEQ IGD	89864	NA	NA	NA	NA	NA	Field
Maximum pool depth at time of study[1]	meters	other	TCEQ IGD	89865	NA	NA	NA	NA	NA	Field
Pool length[1]	meters	other	TCEQ IGD	89869	NA	NA	NA	NA	NA	Field
% pool coverage in 500 meter reach[1]	meters	other	TCEQ IGD	89870	NA	NA	NA	NA	NA	Field
Conventional and Bacteriological Parameters										
TSS	mg/L	water	SM 2540 - D	00530	4	4	NA	NA	NA	TIAER
Chlorophyll-a, spectrophotometric method	µg/L	water	SM 10200 - H	32211	3	3	NA	NA	NA	TIAER
Pheophytin, spectrophotometric method	µg/L	water	SM 10200 - H	32218	3	3	NA	NA	NA	TIAER
E. coli, modified mTEC	CFU/100mL	water	EPA 1603[2]	31648	1	1	NA	0.5[3]	NA	TIAER
Total Kjeldahl Nitrogen	mg/L	water	SM 4500 – NH_3 G	00625	0.2	0.2	70-130	20	80-120	TIAER
Nitrate+Nitrite-N, total	mg/L	water	SM 4500 – NO_3 F	00630	0.05	0.05	70-130	20	80-120	TIAER
Total Phosphorus	mg/L	water	EPA 365.4	00665	0.06	0.06	70-130	20	80-120	TIAER

The following data tables compile the data collected to date at the routine sites. Table 4 compares the geometric mean of the *E. coli* data collected at each site during dry to normal conditions to the geometric mean of the data collected under high flow conditions.

Table 4 Concentrations of *E. coli* under low to normal and high flow conditions at all monitoring sites.

TCEQ Station Location	Low to Normal Flow					High Flow					Total Flow		[2] *E. coli* % Change
	[1]N	Mean Flow	*E. coli*			N	Mean Flow	*E. coli*			Mean Flow	*E. coli*	
			Geo-mean	Min	Max			Geo-mean	Min	Max		Geo-mean	
Lampasas River at HWY 195	15	39	28	4	220	14	1588	1736	26	28000	787	192	6006%
Lampasas River at US 190	17	38	21	3	210	12	917	1890	14	20000	402	145	8806%
Sulphur Creek at FM 1715	21	18	76	5	780	8	108	656	101	17000	43	140	769%
Lampasas River at US 84	18	5	106	35	470	11	51	2864	108	138000	22	894	2611%
Lampasas River at Lampasas CR 2925	16	7	73	23	150	13	319	1528	34	47000	147	655	2004%
Sulphur Creek at Lampasas CR 3010	20	14	56	7	300	9	111	595	150	16400	44	110	966%
Lampasas River at FM 2313	15	12	20	2	230	14	697	1993	17	19000	343	170	9841%
Reese Creek at FM 2670	16	2	56	4	2100	13	80	484	22	8000	37	152	767%
Sulphur Creek at Naruna Rd	20	1	27	5	230	9	31	346	34	5900	10	55	1204%
Clear Creek at Oakalla Rd	15	3	19	4	290	14	75	599	16	9180	38	107	3015%

[1]Number of samples collected.

[2]Percent change in pollutant between wet and dry flows. Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration

Table 5 shows the mean of the concentrations of total phosphorus at the routine sites. Although at no time, or under any flow conditions, did the mean exceed the screening concentration of 0.69 milligrams per liter there was an increase in total phosphorus during wet weather conditions at all but 3 sites, Lampasas River at US HWY 84, Sulphur Creek at CR 3010, and Clear Creek at Oakalla Rd., which showed a decrease in high flow.

Table 5 Concentrations of Total Phosphorus (TP) under low to normal and high flow conditions at all monitoring sites.

TCEQ Station Location	Low to Normal Flow					High Flow					Total Flow		[2] TP % Change
	[1] N	Mean Flow	TP			N	Mean Flow	TP			Mean Flow	TP	
			Mean	Min	Max			Mean	Min	Max		Mean	
Lampasas River at HWY 195	15	39	0.073	0.030	0.123	14	1588	0.162	0.030	0.467	787	0.116	123%
Lampasas River at US 190	17	38	0.082	0.030	0.142	12	917	0.138	0.030	0.279	402	0.105	69%
Sulphur Creek at FM 1715	21	18	0.134	0.030	0.247	8	108	0.156	0.066	0.281	43	0.140	16%
Lampasas River at US 84	18	5	0.160	0.030	0.803	11	51	0.114	0.030	0.221	22	0.132	-29%
Lampasas River at Lampasas CR 2925	16	7	0.133	0.030	0.344	13	319	0.163	0.030	0.439	147	0.154	22%
Sulphur Creek at Lampasas CR 3010	20	14	0.206	0.030	0.349	9	111	0.165	0.069	0.286	44	0.193	-20%
Lampasas River at FM 2313	15	12	0.059	0.030	0.123	14	697	0.120	0.030	0.257	343	0.088	102%
Reese Creek at FM 2670	16	2	0.056	0.030	0.161	13	80	0.097	0.030	0.330	37	0.075	72%
Sulphur Creek at Naruna Rd	20	1	0.048	0.030	0.106	9	31	0.103	0.030	0.195	10	0.065	113%
Clear Creek at Oakalla Rd	15	3	0.215	0.030	0.520	14	75	0.155	0.030	0.265	38	0.186	-28%

[1] Number of samples collected.

[2] Percent change in pollutant between wet and dry flows. Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration

Table 6 is the mean of the concentrations of Total Kjeldahl Nitrogen at the routine sites. There was an increase during high flow conditions at all but 2 sites, Lampasas River at US HWY 84 and Lampasas River at CR 2925, which showed a slight decrease in high flows.

Table 6 Concentrations of Total Kjeldahl Nitrogen (TKN) under low to normal and high flow conditions at all monitoring sites.

TCEQ Station Location	Low to Normal Flow					High Flow					Total Flow		
	[1]N	Mean Flow	TKN			N	Mean Flow	TKN			Mean Flow	TKN	[2]TKN % Change
			Mean	Min	Max			Mean	Min	Max		Geo-mean	
Lampasas River at HWY 195	15	39	0.37	0.10	0.83	14	1588	0.77	0.10	2.91	787	0.5586	110%
Lampasas River at US 190	17	38	0.32	0.10	0.89	12	917	0.69	0.10	1.53	402	0.4745	114%
Sulphur Creek at FM 1715	21	18	0.31	0.10	0.74	8	108	0.60	0.10	1.79	43	0.3921	91%
Lampasas River at US 84	18	5	0.87	0.10	3.84	11	51	0.71	0.10	1.91	22	0.7717	-18%
Lampasas River at Lampasas CR 2925	16	7	0.89	0.10	1.67	13	319	0.89	0.10	1.86	147	0.8884	-1%
Sulphur Creek at Lampasas CR 3010	20	14	0.25	0.10	0.99	9	111	0.47	0.10	1.07	44	0.3203	85%
Lampasas River at FM 2313	15	12	0.15	0.10	0.38	14	697	0.54	0.10	1.26	343	0.3362	261%
Reese Creek at FM 2670	16	2	0.28	0.10	0.65	13	80	0.43	0.10	1.30	37	0.3483	54%
Sulphur Creek at Naruna Rd	20	1	0.24	0.10	0.98	9	31	0.55	0.10	1.57	10	0.3345	135%
Clear Creek at Oakalla Rd	15	3	0.39	0.10	1.11	14	75	0.48	0.10	1.24	38	0.4341	21%

[1]Number of samples collected.

[2]Percent change in pollutant between wet and dry flows. Positive change indicates an increase in pollutant load with rainfall. Negative change indicates that rainfall is diluting the base flow pollutant concentration

ANALYSIS OF LAMPASAS RIVER MAINSTEM DATA FOR TRENDS

Each of the monitoring stations were analyzed for statistically significant correlations between concentrations for *E. coli,* total phosphorus, and total Kjeldahl nitrogen versus stream flow. Multiple t-tests were conducted to determine significance. If the absolute value of the t-statistic was greater than 2 and the p value was less than or equal to a 0.05 significance level, then the correlation between each of the dependent variables and stream flow was considered to be significant. The solid red lines on the accompanying charts represent contact recreation limits for *E. coli*, if applicable.

15762: Lampasas River at US 84

The Lampasas River at US Hwy 84 monitoring site, (Station 15762) is located in the northern portion of the watershed in western Hamilton County and is the most upstream sampling location. The upstream drainage area is primarily rangeland. This site was routinely dry or pooled insufficiently to sample in the early period of sampling. Several statistically significant correlations with flow were found at this location. While *E. coli* was not significantly correlated with flow, both total phosphorus; t(17)=3.92, p=0.001 (Figure 3) and total Kjeldahl nitrogen; t(17)=3.83, p=0.001 (Figure 4) decrease as flow increases.

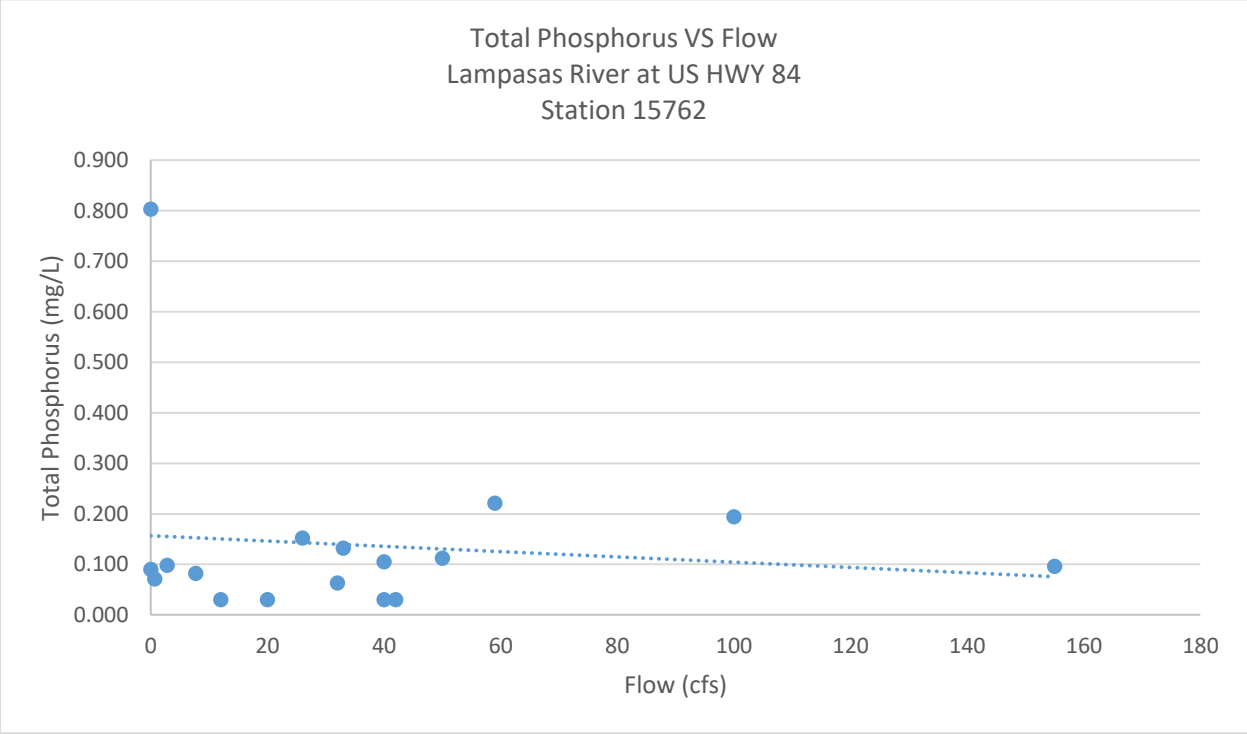

Figure 3 Total Phosphorus (mg/L) verses flow (cfs) at Station 15762, Lampasas River at US HWY 84.

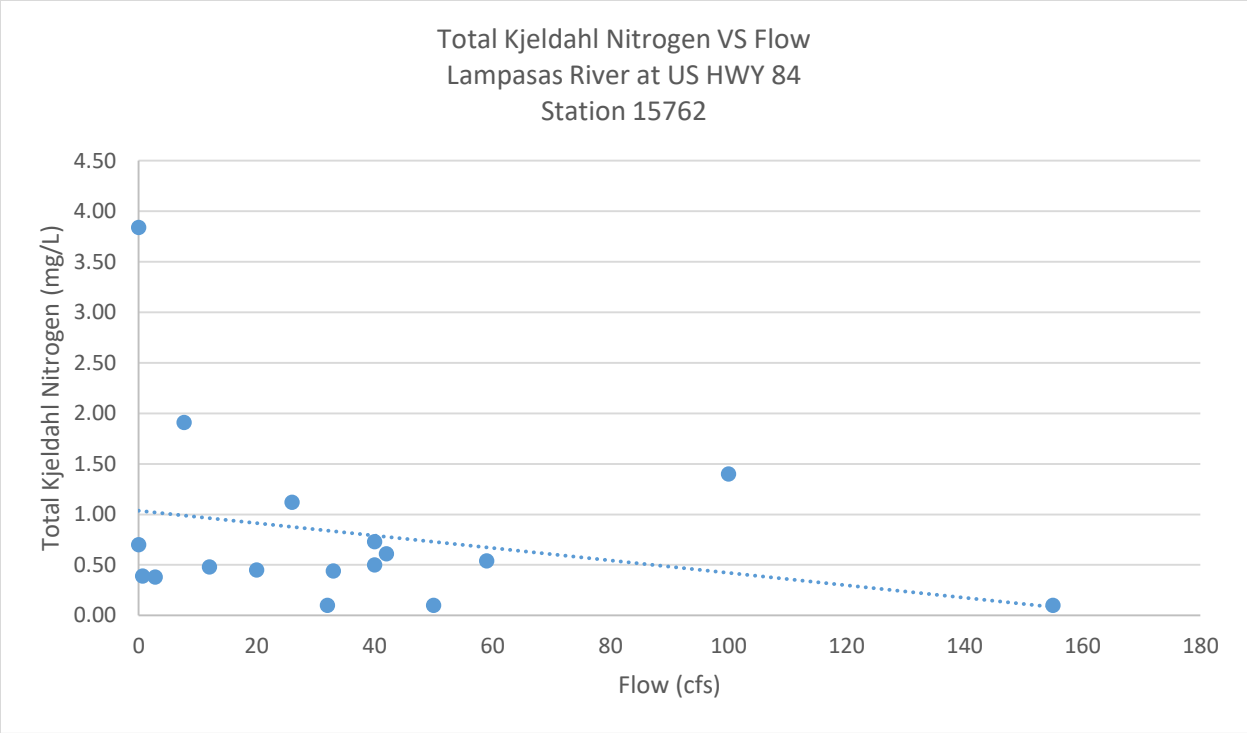

Figure 4 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at Station 15762, Lampasas River at US HWY 84.

15770: Lampasas River at CR 2925

The Lampasas River at Lampasas County Rd 2925 monitoring station, (Station 15770) is located in northern Lampasas County approximately 2.5 miles downstream of the Bennett Creek confluence. The upstream drainage area is primarily rangeland. Similar to the station upstream, this site was routinely dry or pooled insufficiently to sample in the early period of sampling. Several statistically significant correlations with flow were found at this location. While *E. coli* was not significantly correlated with flow, both total phosphorus; $t(18)=3.17$, $p=0.005$ (Figure 5) and total Kjeldahl nitrogen; $t(18)=3.16$, $p=0.005$ increase as flow increases (Figure 6).

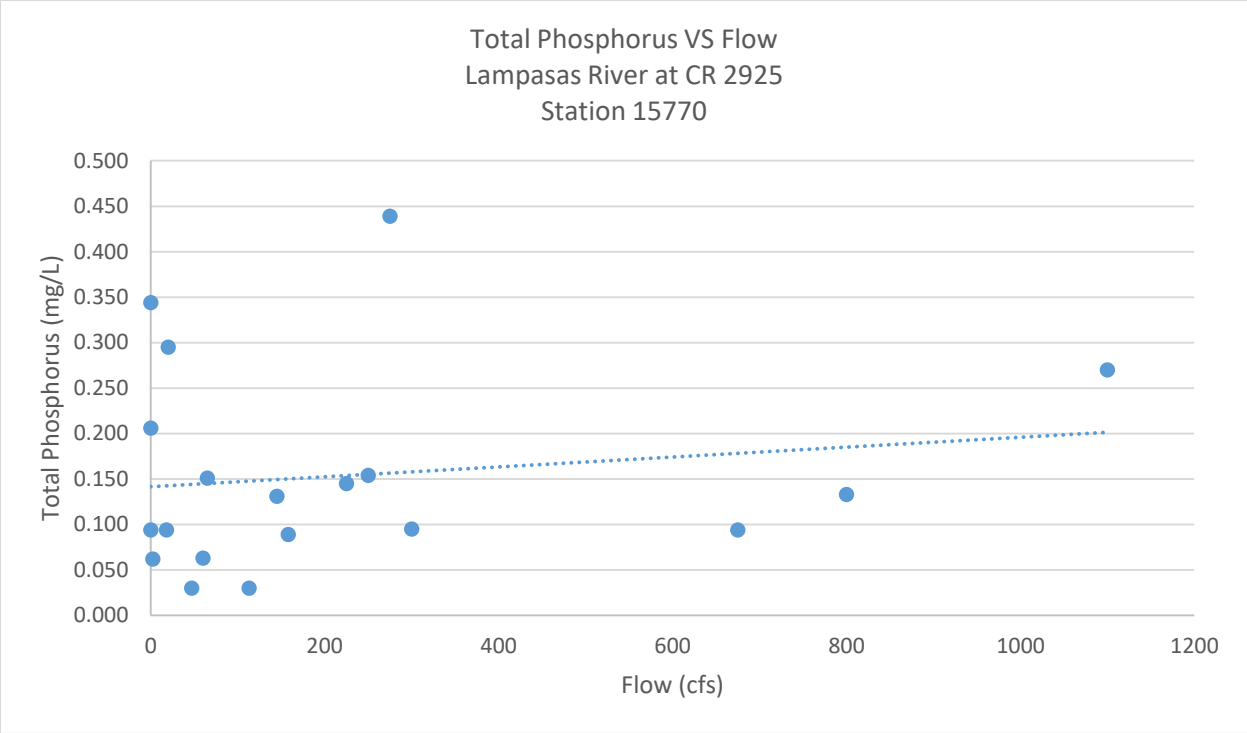

Figure 5 Total Phosphorus (mg/L) verses flow (cfs) at Station 15770, Lampasas River at CR 2925.

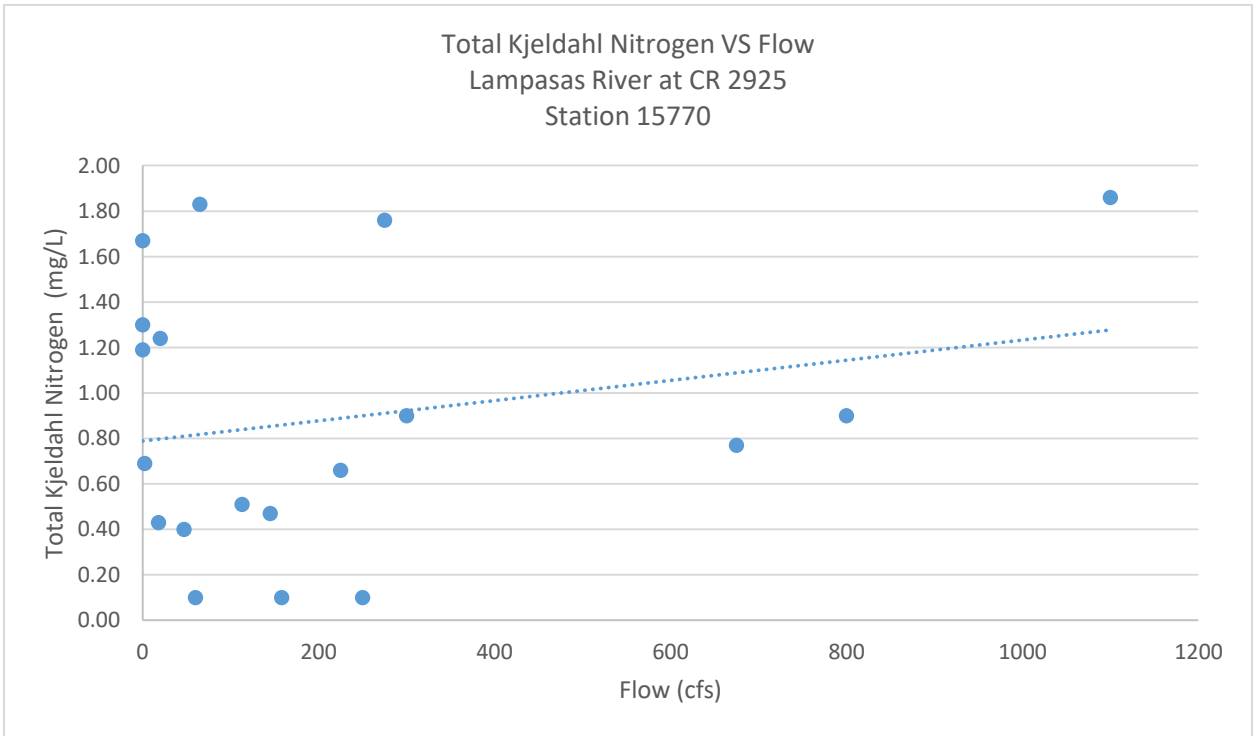

Figure 6 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at Station 15770, Lampasas River at CR 2925.

16404: Lampasas River at FM 2313

The Lampasas River at FM 2313 monitoring station (station 16404), is located in southern Lampasas County approximately 2.8 miles upstream of the Sulphur Creek confluence. The upstream drainage area is primarily rangeland. Statistically significant correlations with flow were found with 3 parameters at this location. *E. coli* was significantly correlated with flow, t(27)=-2.61, p=0.015 (Figure 7), along with both total phosphorus; t(28)=2.96, p=0.006 (Figure 5) and total Kjeldahl nitrogen; t(28)=2.96, p=0.006 (Figure 9) increase as flow increases.

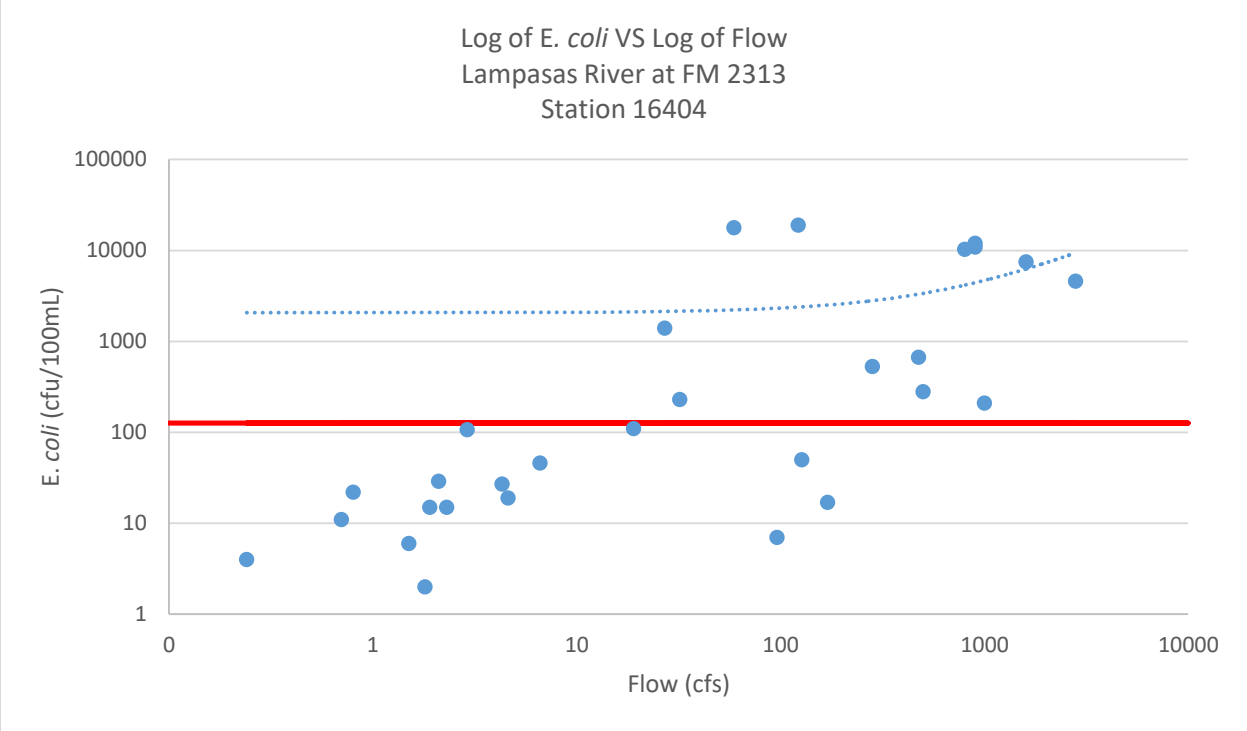

Figure 7 Log of *E. coli* (cfu/100mL) versus log of flow (cfs) at station 16404, Lampasas River at FM 2313.

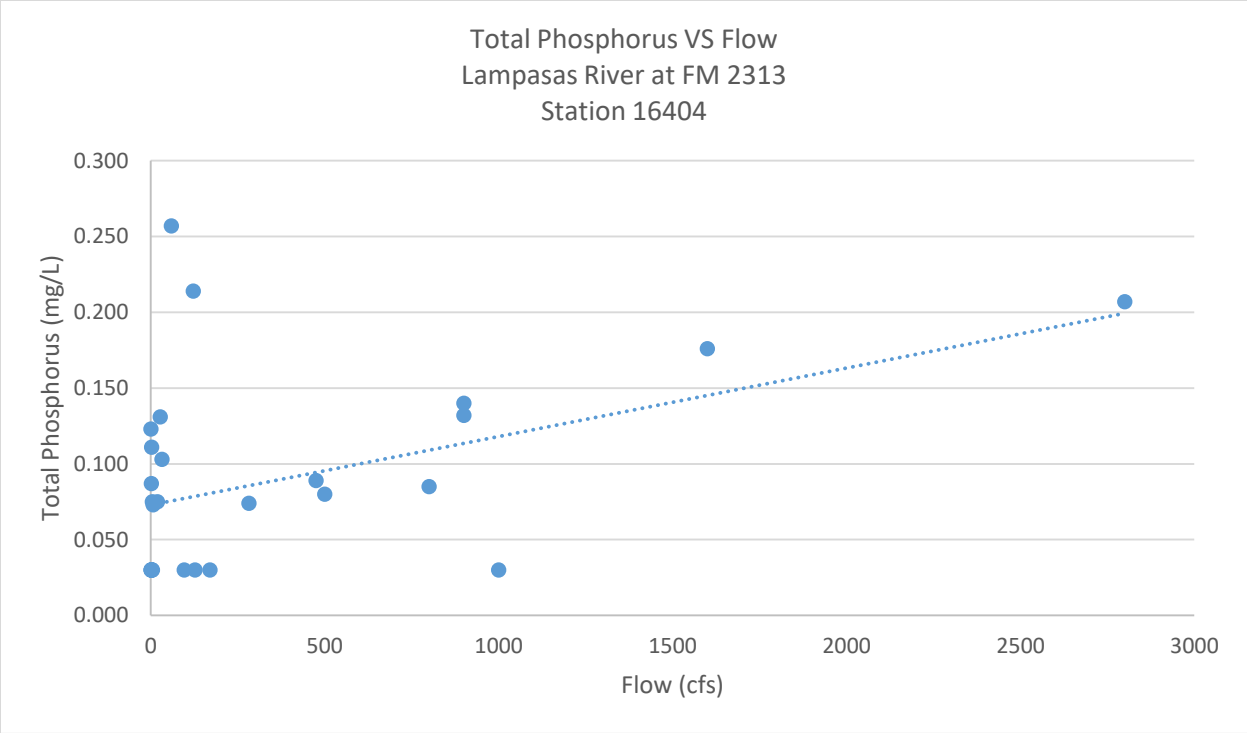

Figure 8 Total Phosphorus (mg/L) verses flow (cfs) at Station 16404, Lampasas River at FM 2313.

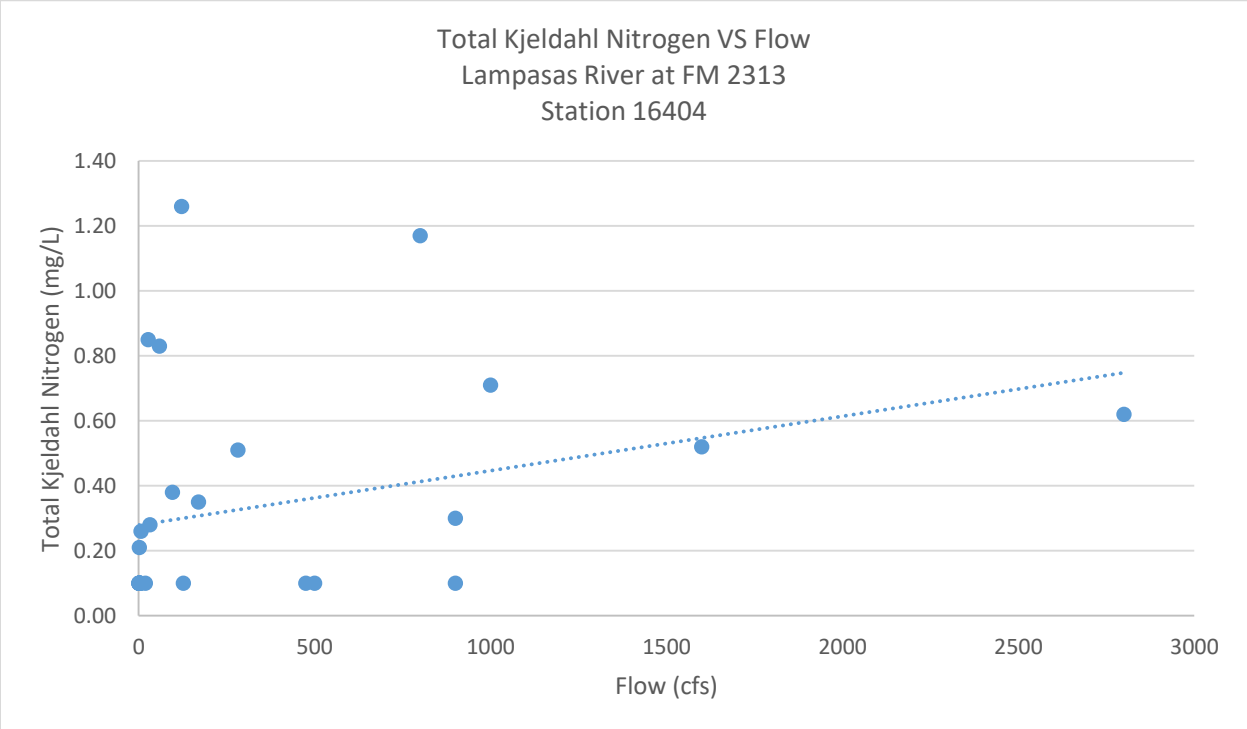

Figure 9 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at Station 16404, Lampasas River at FM 2313.

11897: Lampasas River at US 190

The Lampasas River at US HWY 190 monitoring station (station 11897) is located in southern Lampasas County approximately 0.8 miles downstream of its confluence with Sulphur Creek. The upstream drainage area is primarily rangeland although its summer flows are heavily influenced by Sulphur Creek, which includes the city of Lampasas. Statistically significant correlations with flow were found with 3 parameters at this location. *E. coli* was significantly correlated with flow, t(27)=-2.46, p=0.02 (Figure 10), along with both total phosphorus; t(28)=3.29, p=0.003 (Figure 11) and total Kjeldahl nitrogen; t(28)=3.28, p=0.003 (Figure 12). All three parameters were positively correlated with flows.

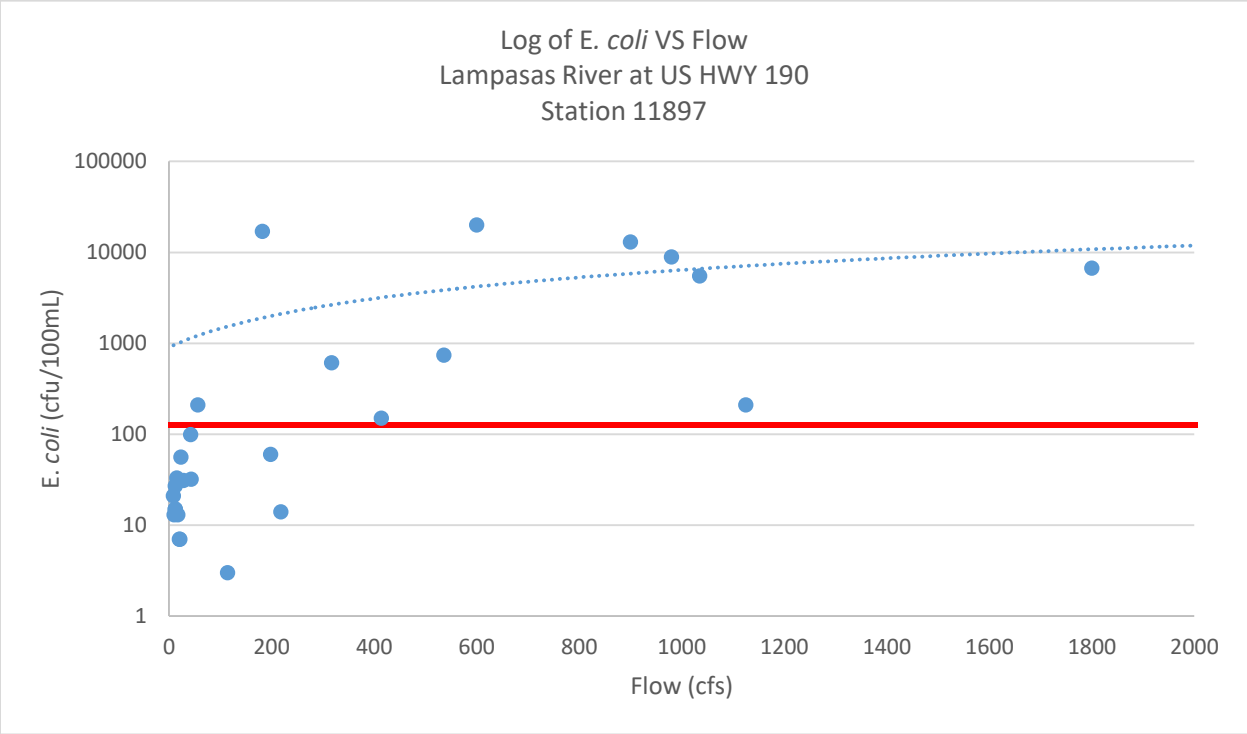

Figure 10 Log of *E. coli* (cfu/100mL) versus flow (cfs) at station 11897, Lampasas River at US HWY 190.

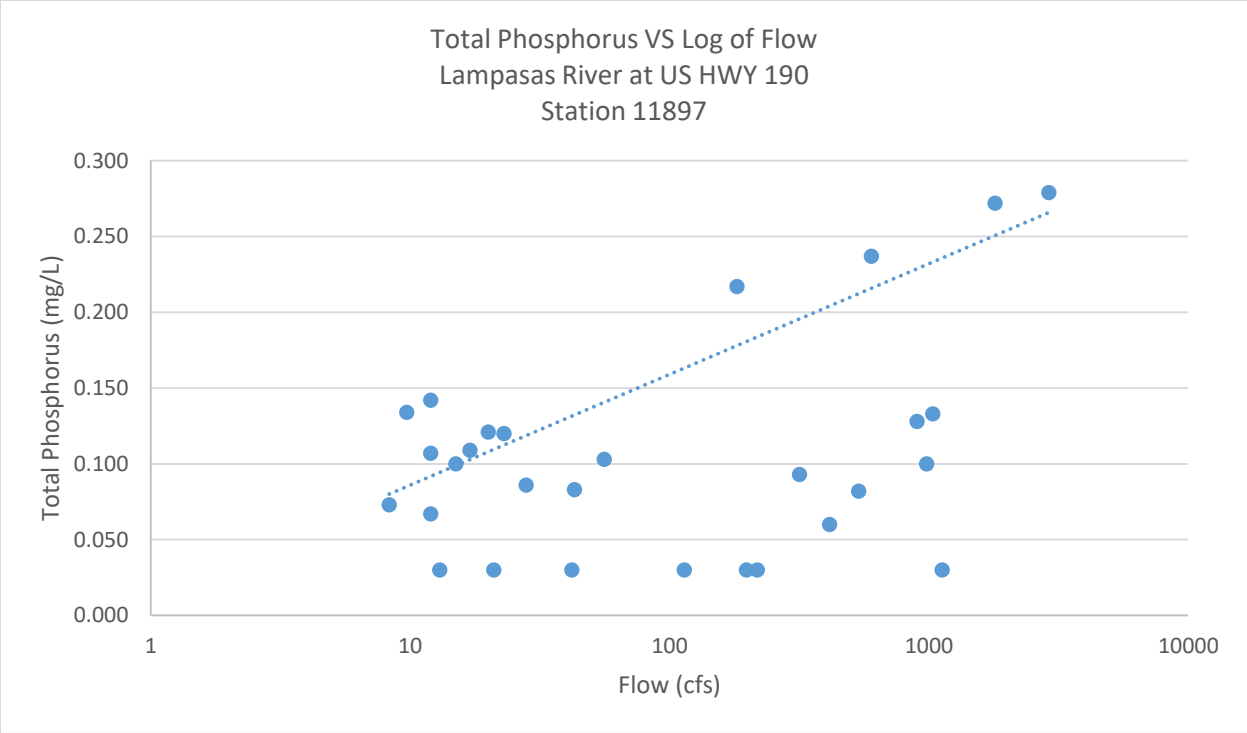

Figure 11 Total Phosphorus (mg/L) verses flow (cfs) at Station 11897, Lampasas River at US HWY 190.

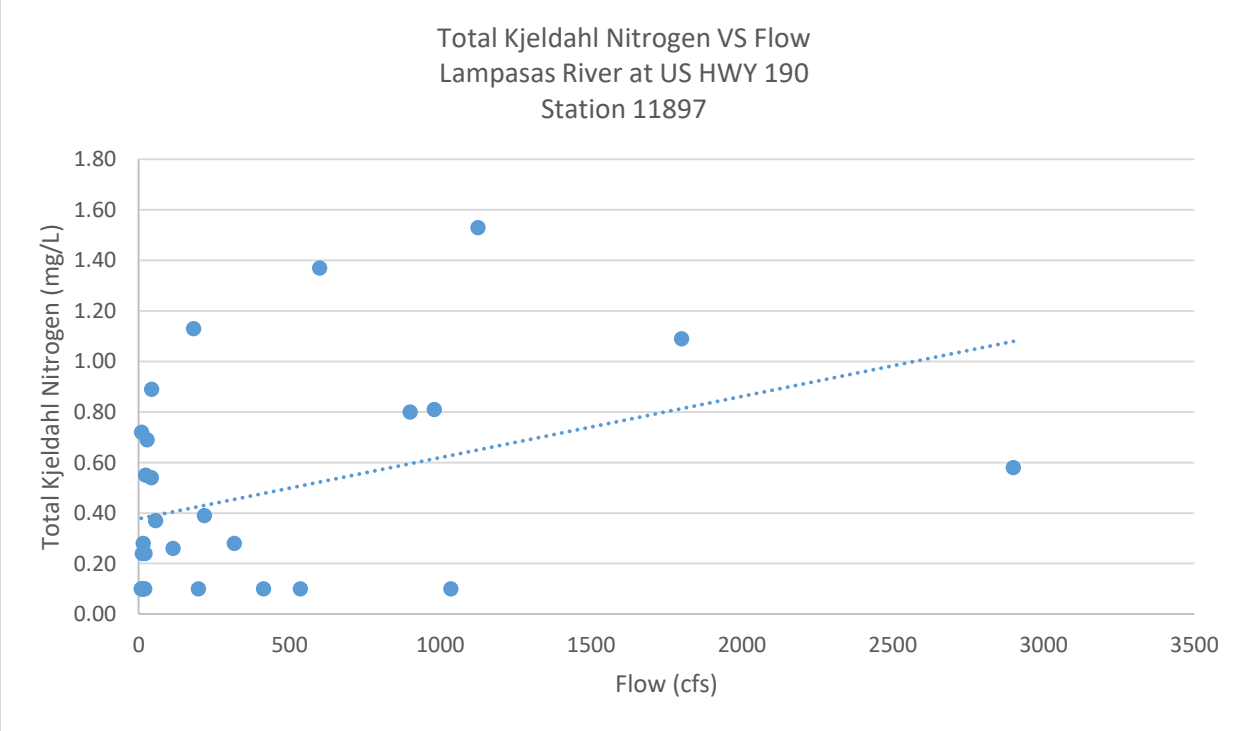

Figure 12 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at Station 11897, Lampasas River at US HWY 190.

11896: Lampasas River at HWY 195

The Lampasas River at State HWY monitoring station (station 11896) is located in eastern Bell County, approximately 7 miles upstream of its confluence with Stillhouse Hollow Lake. The upstream drainage area is primarily rangeland. This is the most downstream station for the Lampasas River. All monitored tributaries are also upstream from this location. Several statistically significant correlations with flow were found at this location. While *E. coli* was not significantly correlated with flow, both total phosphorus; t(28)=3.13, p=0.004 (Figure 13) and total Kjeldahl nitrogen; t(28)=3.13, p=0.004 (Figure 14) increase as flow increases.

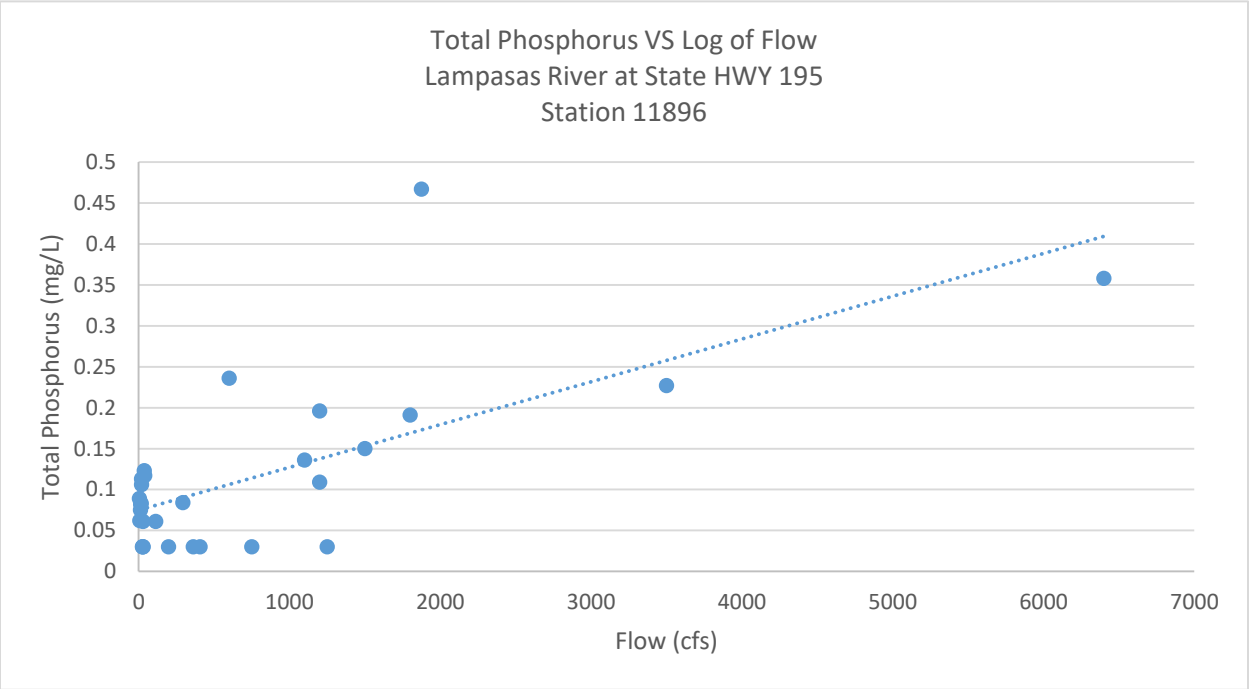

Figure 13 Total Phosphorus (mg/L) verses flow (cfs) at Station 11896, Lampasas River at State HWY 195.

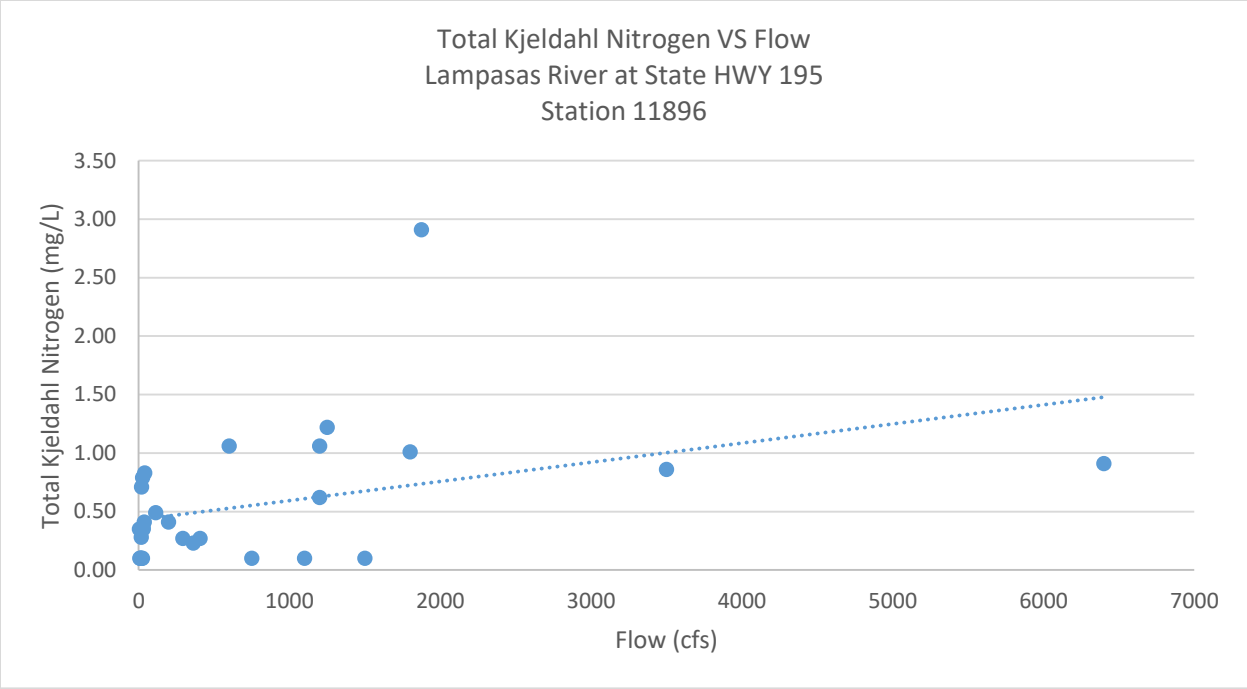

Figure 14 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at Station 11896, Lampasas River at State HWY 195.

ANALYSIS OF MAJOR TRIBUTARY DATA FOR TRENDS

18782: Sulphur Creek at Naruna Road

The Sulphur Creek at Naruna Rd monitoring station (station 18782) is located in southern Lampasas County. This station is upstream from the city of Lampasas, although the upstream drainage area is primarily rangeland. Several statistically significant correlations with flow were found at this location. While *E. coli* was not significantly correlated with flow, both total phosphorus; $t(28)=2.60$, $p=0.015$ (Figure 15) and total Kjeldahl nitrogen; $t(28)=2.55$, $p=0.017$ (Figure 16) increase as flow increases.

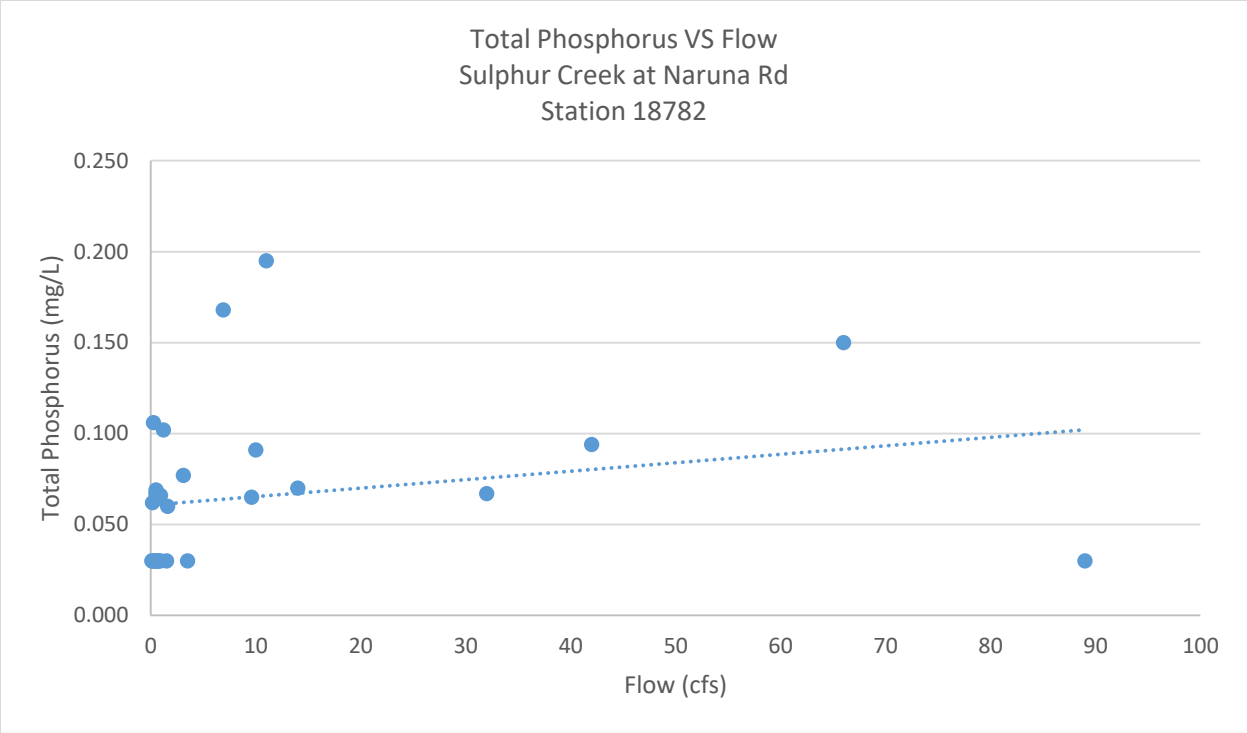

Figure 15 Total Phosphorus (mg/L) verses flow (cfs) at Station 18782, Sulphur Creek at Naruna Road.

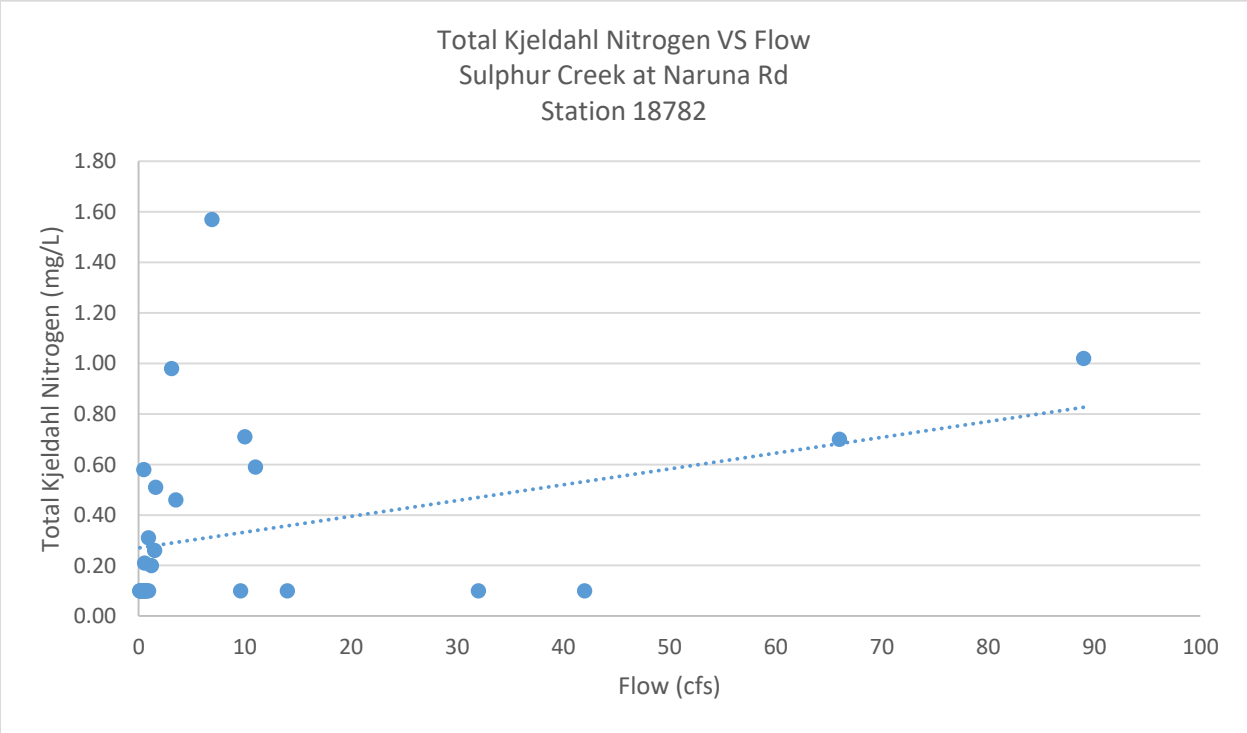

Figure 16 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at Station 18782, Sulphur Creek at Naruna Road.

18781: Sulphur Creek at CR 3010

The Sulphur Creek at Lampasas County Rd 3010 monitoring station (station 18781) is located in southern Lampasas County, several miles east of the city of Lampasas. Several statistically significant correlations with flow were found at this location. While *E. coli* was not significantly correlated with flow. Total phosphorus; t(28)=2.39, p=0.024 (Figure 17) was negatively correlated and decreased at flow increased while total Kjeldahl nitrogen; t(28)=2.38, p=0.024 (Figure 18) increased as flow increases.

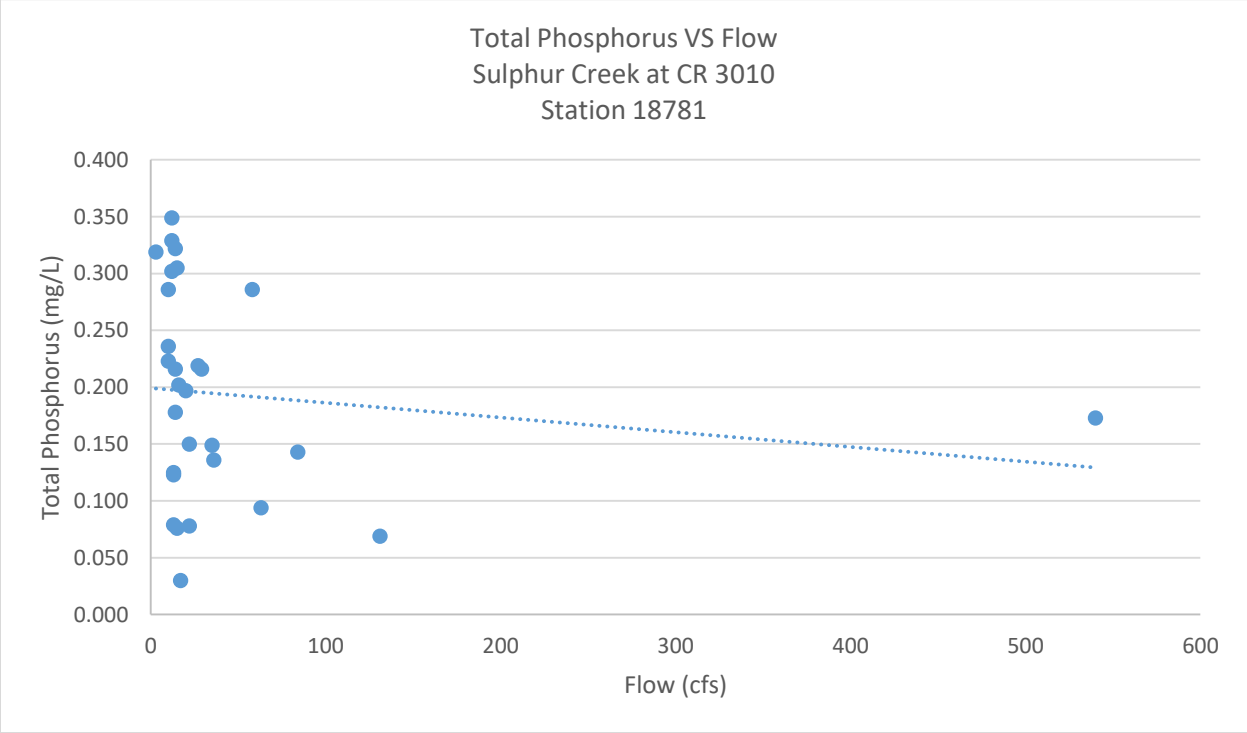

Figure 17 Total Phosphorus (mg/L) verses flow (cfs) at Station 18781, Sulphur Creek at County Road 3010.

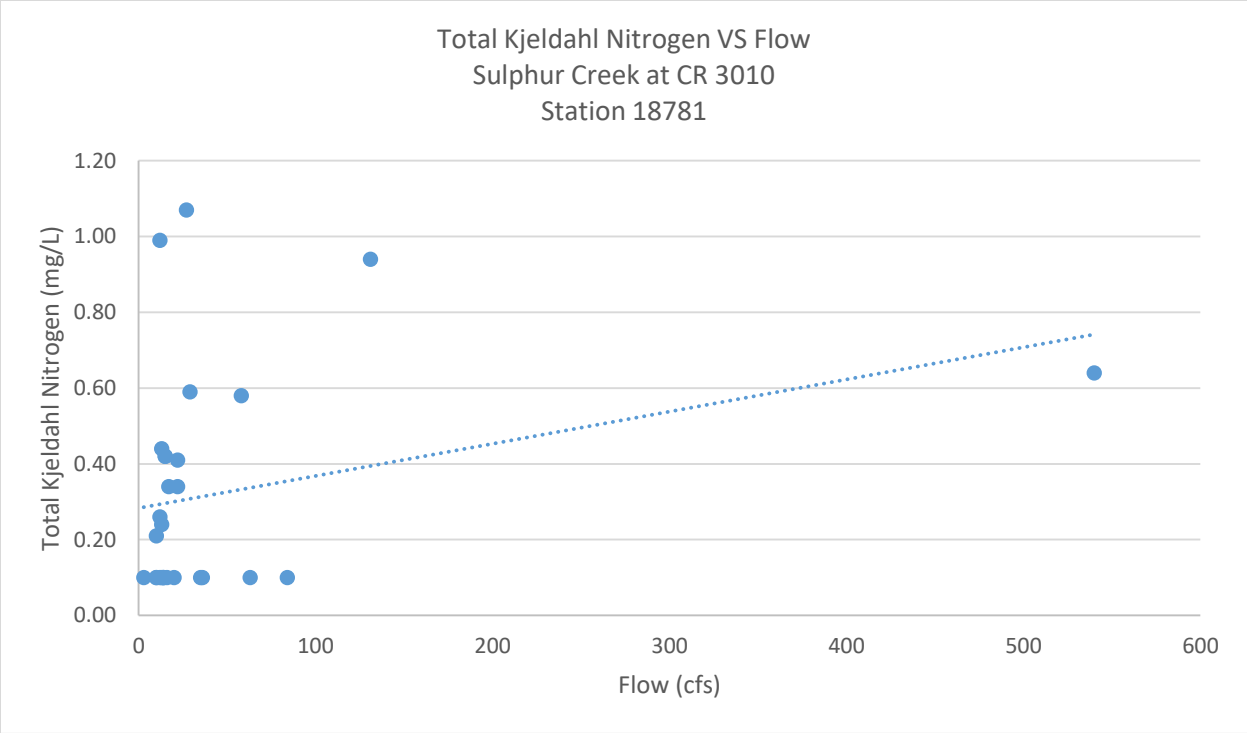

Figure 18 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at Station 18781, Sulphur Creek at County Road 3010.

15250: Sulphur Creek at FM 1715/CR 3050

The Sulphur Creek at FM 1715/CR 3050 monitoring station (station 15250) is located in southern Lampasas County, approximately 1.5 miles upstream from Sulphur Creek's confluence with the Lampasas River. Several statistically significant correlations with flow were found at this location. While *E. coli* was not significantly correlated with flow. Total phosphorus; $t(28)=4.23$, $p=0.000$ (Figure 19) and total Kjeldahl nitrogen; $t(28)=4.21$, $p=0.000$ (Figure 20) were both positively correlated with flow and increased as flow increases.

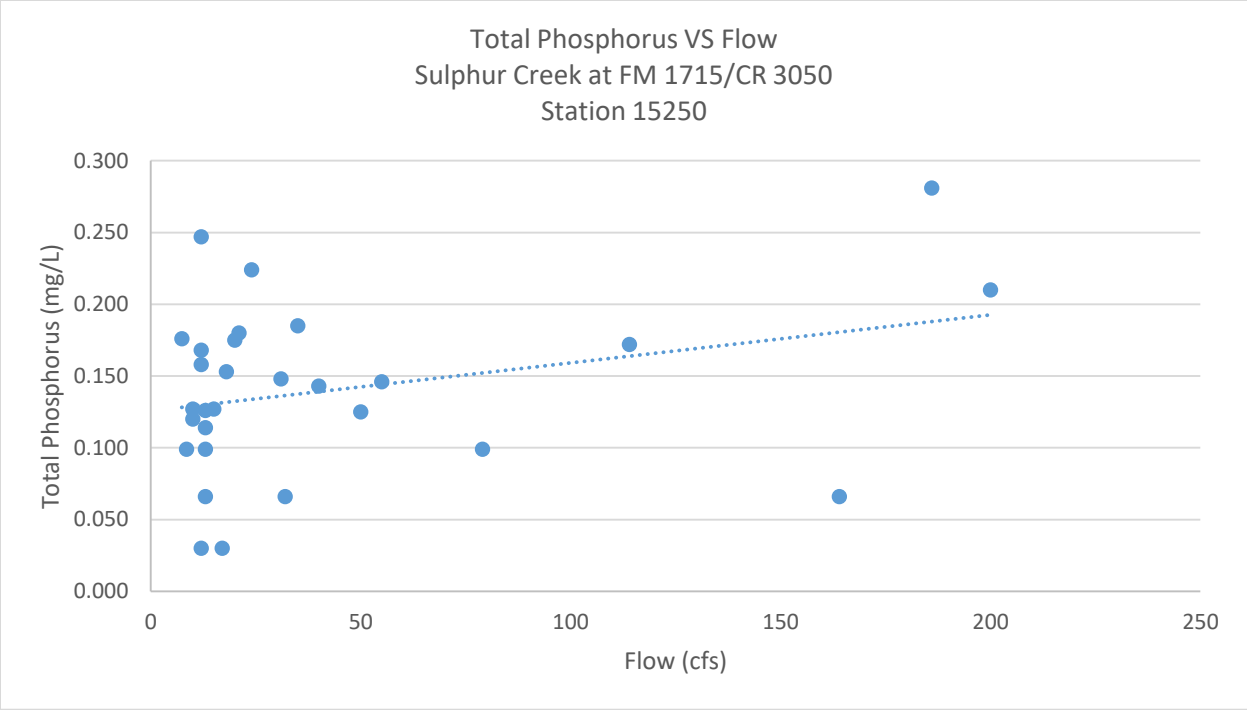

Figure 19 Total Phosphorus (mg/L) verses flow (cfs) at Station 15250, Sulphur Creek at FM 1715/CR 3050.

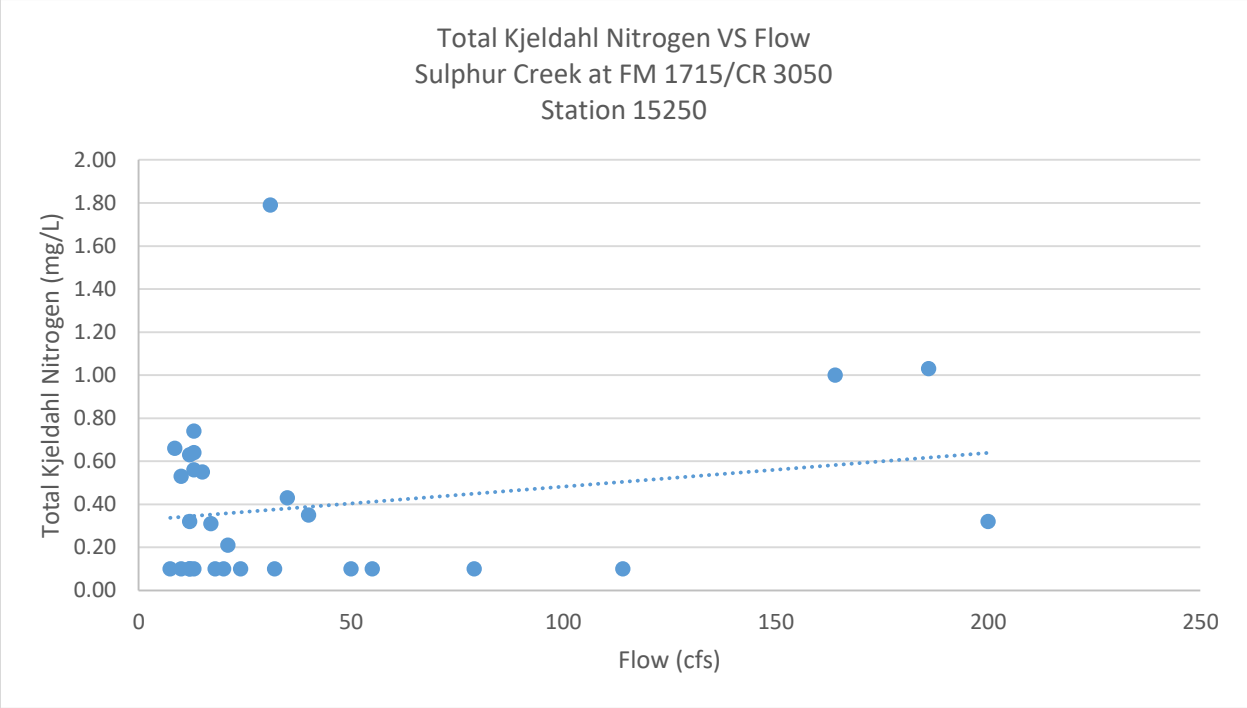

Figure 20 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at Station at Station 15250, Sulphur Creek at FM 1715/CR 3050.

21016: Clear Creek at Oakalla Road

The Clear Creek at Oakalla Road monitoring station (station 15250) is located in eastern Burnet County, approximately 0.5 miles upstream from its confluence with the Lampasas River. Clear Creek originates in southwestern area of the city of Copperas Cove and is partially residential/urban and partially rangeland land use. Statistically significant correlations with flow were found with 3 parameters at this location. *E. coli* was significantly correlated with flow, t(27)=-2.26, p=0.032 (Figure 21), along with both total phosphorus; t(28)=2.81, p=0.009 (Figure 22) and total Kjeldahl nitrogen; t(28)=2.79, p=0.009 (Figure 23). *E. coli* and total Kjeldahl nitrogen are positively correlated with flows, while total phosphorus was negatively correlated and decreased as flows increased.

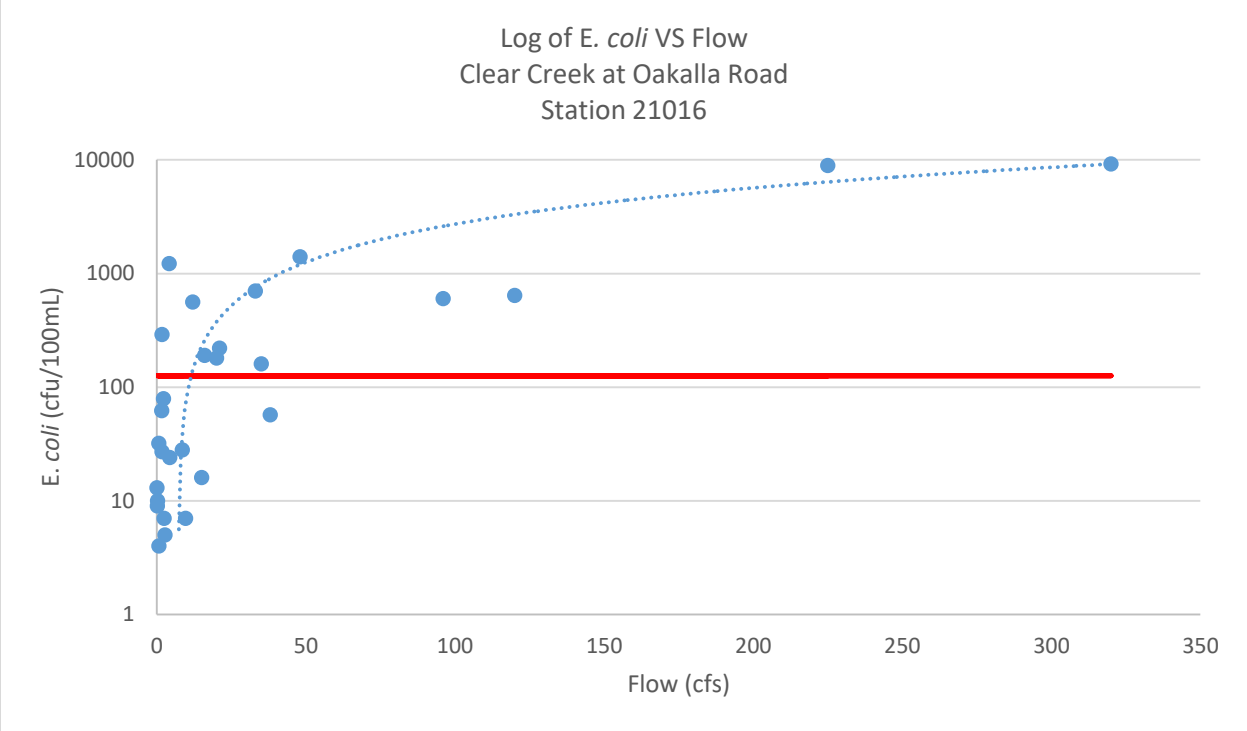

Figure 21 Log of *E. coli* (cfu/100mL) versus flow (cfs) at station 21016, Clear Creek at Oakalla Road.

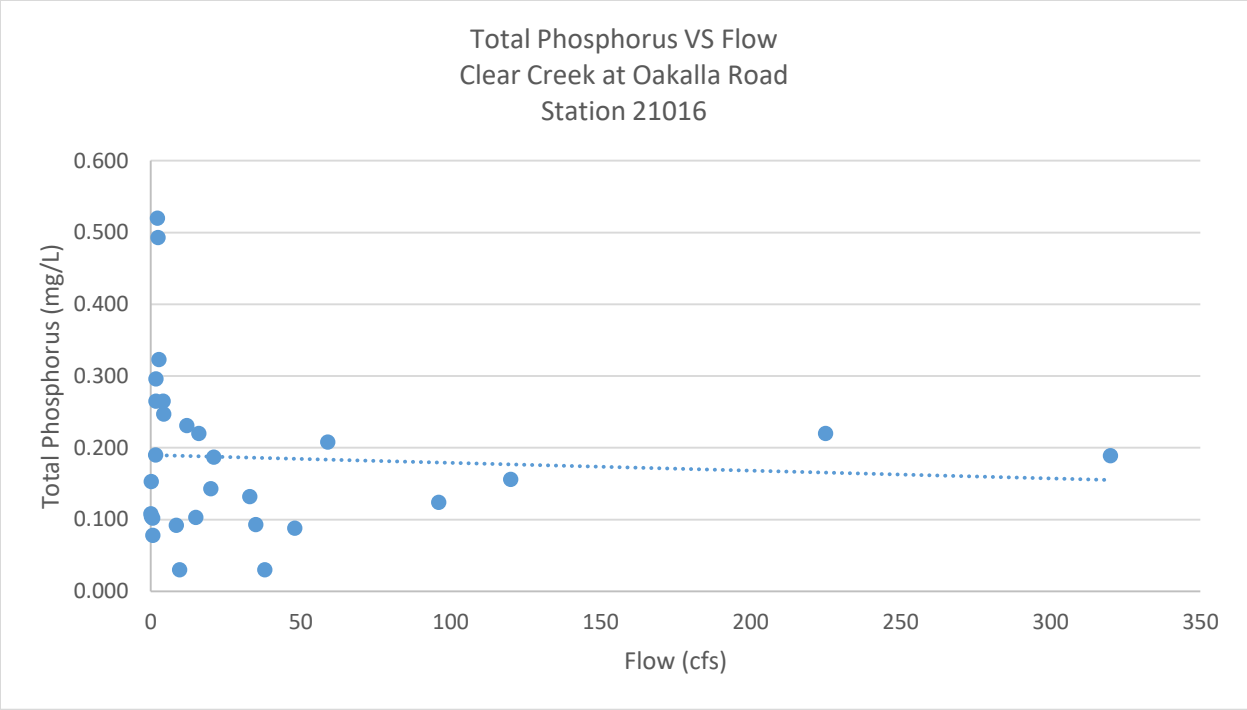

Figure 22 Total Phosphorus (mg/L) verses flow (cfs) at Station 21016, Clear Creek at Oakalla Road.

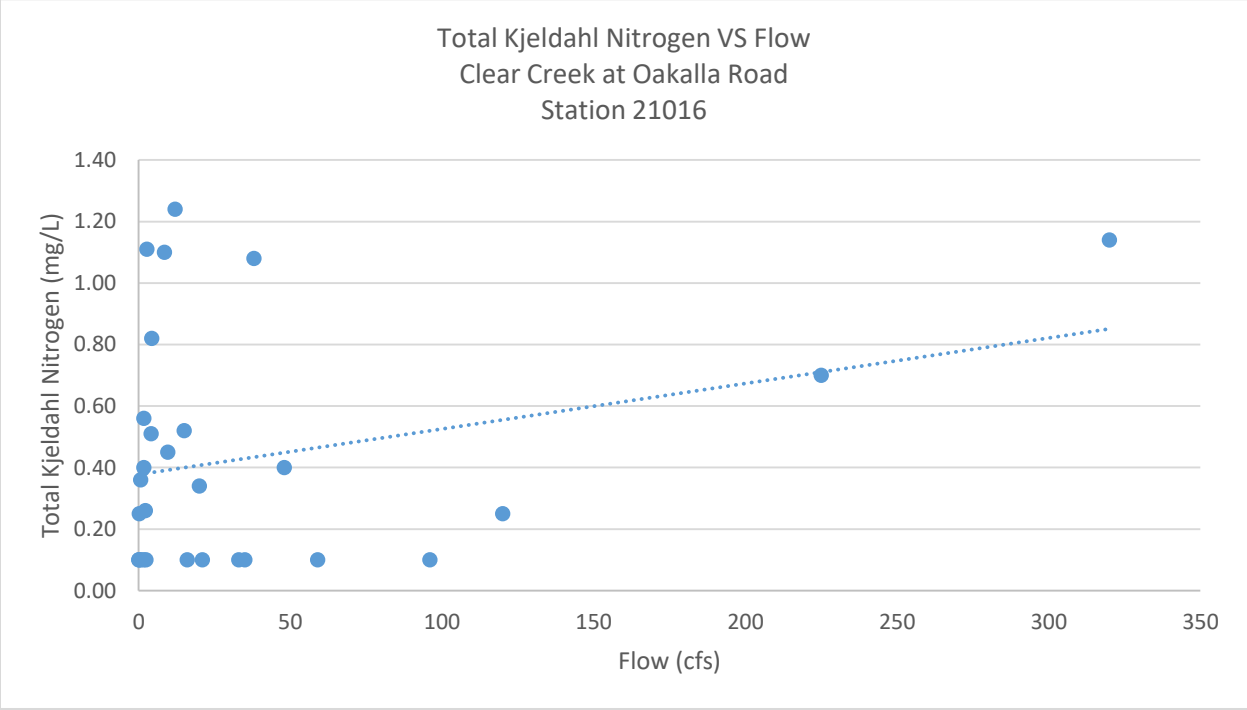

Figure 23 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at Station at Station 21016, Clear Creek at Oakalla Road.

18759: Reese Creek near FM 2670/BR985

The Reece Creek near FM 2670/CR 985 monitoring station (station 15250) is located in western Bell County, approximately 0.4 mile upstream from its confluence with the Lampasas River. Reese Creek originates in southwestern area of the city of Killeen and is partially residential/urban and partially rangeland land use. Statistically significant correlations with flow were found with 3 parameters at this location. *E. coli* was significantly correlated with flow, t(27)=-2.40, p=0.024 (Figure 24), along with both total phosphorus; t(28)=2.33, p=0.027 (Figure 25) and total Kjeldahl nitrogen; t(28)=2.32, p=0.028 (Figure 26). All three parameters were positively correlated with flow and increased as flow increased.

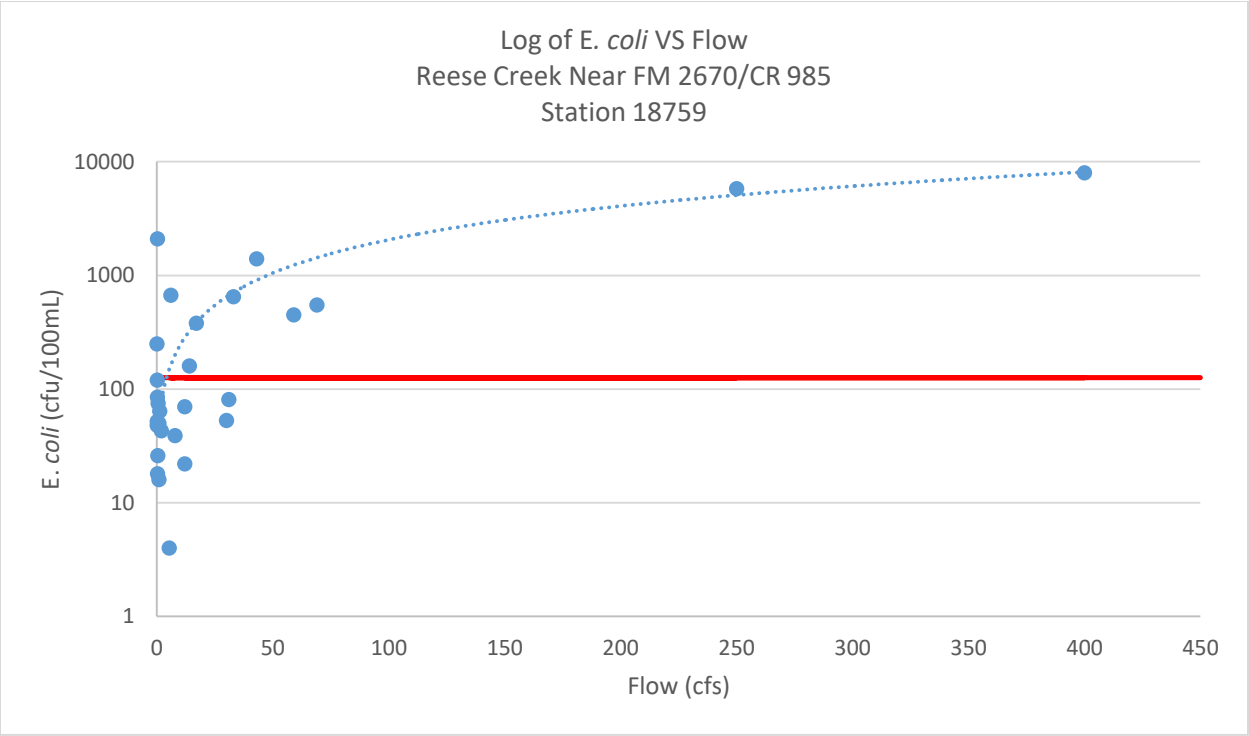

Figure 24 Log of *E. coli* (cfu/100mL) versus flow (cfs) at station 18759, Reese Creek near FM 2670/CR 985.

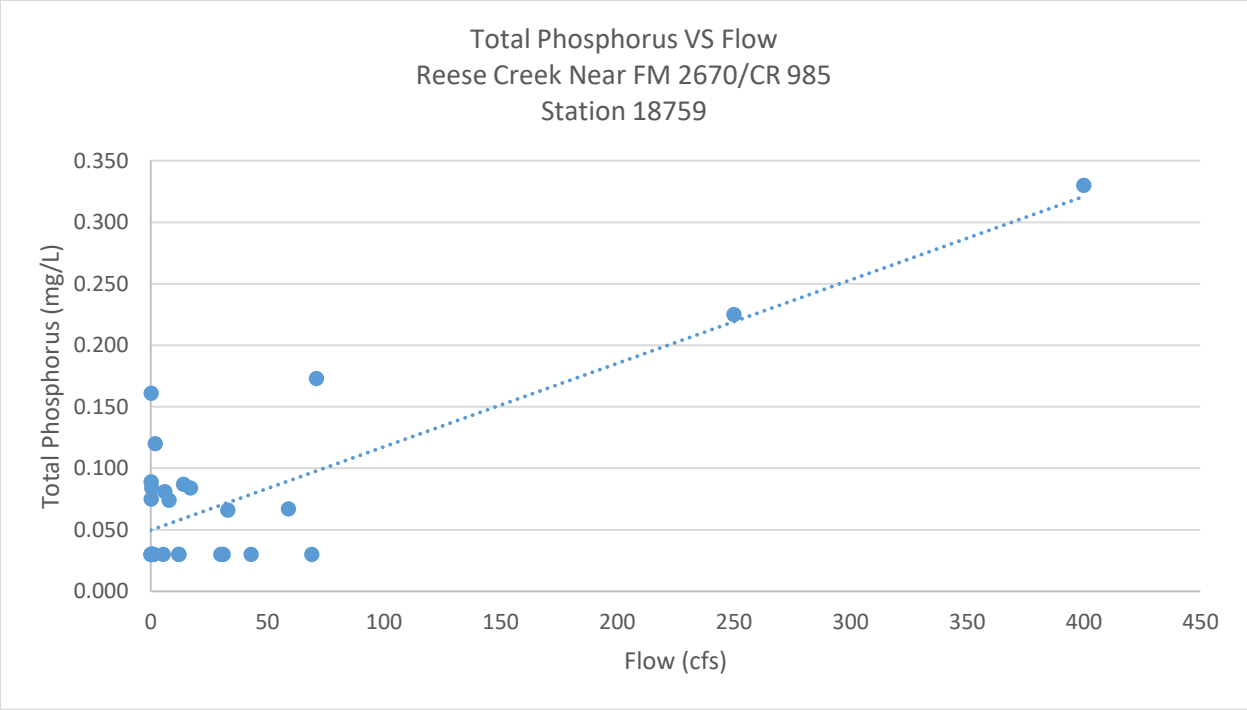

Figure 25 Total Phosphorus (mg/L) verses flow (cfs) at Station 18759, Reese Creek near FM 2670/CR 985.

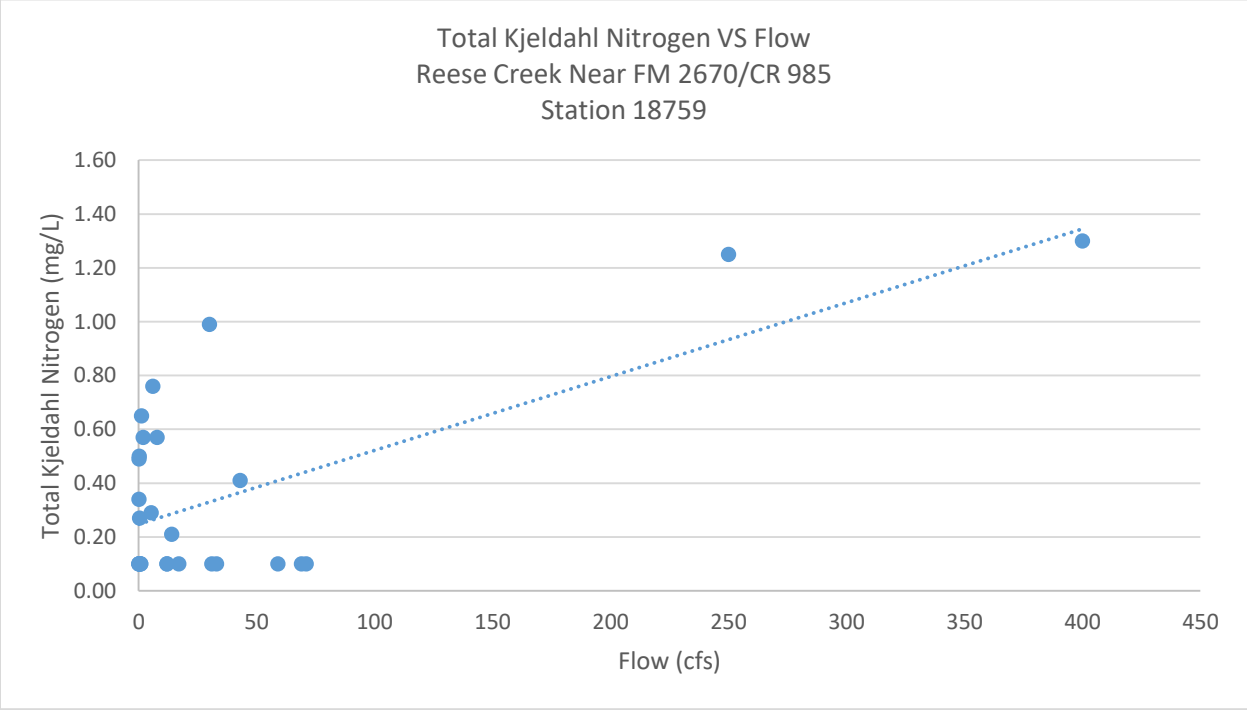

Figure 26 Total Kjeldahl Nitrogen (mg/L) verses flow (cfs) at Station at Station 18759, Reese Creek near FM 2670/CR 985.

CONCLUSION

Most stations saw an upward trend in pollutants with an increase in flow, which may occur in a watershed that is primarily rural, with few direct discharges to the system. There was some concern early in the project about lack of flow at stations 15762 (Lampasas River at US HWY 84) and 15770 (Lampasas River at CR 2925). After consulting with project partners the decision was made to not move any of the monitoring stations. Continued monitoring will create a robust dataset for these two sites.

An interesting observation was found on Sulphur Creek; the *E. coli* geomean increased moving downstream between the three stations on Sulphur Creek (upstream: 18782, middle: 18781, and downstream: 15250). Geomeans during dry to normal flow conditions were 27 cfu/100mL, 56 cfu/100mL, and 76 cfu/100mL, moving upstream to downstream. These geomeans are still well below the state standard at each station. *E. coli* geomeans increased moving down stream during high flow conditions as well, although they were significantly higher (346 cfu/100mL, 595 cfu/100mL, and 656 cfu/100mL, moving upstream to downstream). The land use between the upstream station and the middle station is predominantly residential and includes the city of Lampasas, while the land use between the middle station and the most downstream station is predominantly rural. The confluence of Sulphur Creek with the Lampasas River is in between two mainstem sites, Lampasas River at FM 2313 (16404, upstream of confluence) and Lampasas River at US HWY 190 (11897, downstream of confluence). There was not a significant difference in *E. coli* in dry to normal flows between the two sites (geomean was 20 cfu/100mL upstream and 21 cfu/100mL downstream) suggesting inflows from Sulphur Creek are diluted once assimilated with flows from the Lampasas River.

In summary, TSSWCB Project 13-09 has been completed and was essential to the continued water quality monitoring for the Lampasas River WPP. Early water quality data was presented to stakeholders. Final results will be communicated during the next Partnership meeting. While implementation of WQMPs did not start until mid-2015, this water quality monitoring provides the foundation for a robust dataset that can be analyzed for trends and changes in water quality as we move forward.

TSSWCB project 16-06, *Continuation of Surface Water Quality Monitoring to Support the Implementation of the Lampasas River Watershed Protection Plan*, began in late 2016. This project will provide additional water quality data.