Bacteria Study on the Tres Palacios River

Prepared by
David Bass and Alicia Reinmund
Lower Colorado River Authority
Austin, Texas
December 1999

For

The Texas Clean Rivers Program
Texas Natural Resource Conservation Commission

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ABSTRACT

The Tres Palacios River is located in south Central Texas in Wharton and Matagorda Counties. Over the past few years, the Texas Natural Resource Conservation Commission has listed the Tres Palacios River on the State of Texas' Clean Water Act 303(d) list as an impaired water body for elevated fecal coliform and dissolved oxygen standards violations. Occasionally, high bacteria levels in the river, especially after storm events, have resulted in oyster bed closings in Tres Palacios Bay. Ten sites were selected for this study, seven on the main stem of the river and one on each of its three largest tributaries. Samples were collected under two different flow conditions; dry weather and wet weather. High levels of bacteria occurred during storm runoff events. Fecal coliform and *E. coli* exhibited similar patterns and relationships with other parameters throughout the river during both wet and dry monitoring conditions. The percent of fecal coliform composed of *E. coli* was significantly different between monitoring conditions. Elevated fecal coliform and nutrients were found in the river immmediately below the City of El Campo during dry weather. Few (7%) violations of the fecal coliform grab sample criterion (400 cfu/dL) occurred when river flow was at or below the historical median of 23 cubic feet per second (cfs). Thirty-three percent (33%) of the dissolved oxygen measurements in the tidally influenced segment of the river were in violation of the 5.0 mg/L state criterion. This project was made possible by the contribution of many volunteers from several local, state, and federal agencies through the Texas Clean Rivers Program.

INTRODUCTION

The Tres Palacios River (stream segments 1501 and 1502) is located in south Central Texas in Wharton and Matagorda Counties. Its watershed includes the mouth of Tres Palacios Bay and ten tributaries. It encompasses an area of approximately 322 square miles and extends from the City of El Campo to the City of Palacios. Land use is predominantly agricultural (rice production and ranching). Population is densest at the headwaters and lower reaches of the river (El Campo, population 11000; and Palacios, pop. 4700, respectively), but there are several subdivisions along the length of the river.

The Tres Palacios River has two distinct utilizations. The headwaters of the river are used as a drainage way for the City of El Campo's stormwater and municipal wastewater treatment plant. Base flow in this area is intermittent and coincides with rain events. The city's treatment plant discharge also contributes to stream flow (permitted to release 2.6 MGD). In contrast, the lower portions of the river are used for contact recreation such as swimming, water-skiing and fishing.

The river discharges into Tres Palacios Bay, one of the larger secondary bays of Matagorda Bay. Tres Palacios Bay is an important nursery for fish and shellfish species and contains several oyster reefs. Many residents in the watershed make their living from the water. Occupations and businesses include shrimping, fishing and support industries such as marinas, boat repair, etc, and a growing tourist industry.

In 1996 and 1999, the Texas Natural Resource Conservation Commission (TNRCC) listed Segment 1502 (above tidal) of the Tres Palacios River on the State of Texas' Clean Water Act 303(d) list as an "impaired water body" for elevated levels of fecal coliform and total dissolved solids. The tidally influenced segment of the river (Segment 1501) is listed for dissolved oxygen violations. In the past, high bacteria levels in the river, especially after storm events, have resulted in oyster bed closings in the bay.

The purpose of the study was to analyze for bacteria indicators, nutrient and relevant field data (temperature, pH, dissolved oxygen and specific conductance) that can be used to determine: 1) where the levels of indicator bacteria are elevated in the river, 2) when these levels are elevated, 3) how long bacteria levels remain above contact recreation criterion after storm events, 4) provide information to the Tres Palacios watershed action team to make water resource management decisions, and 5) educate local residents about water quality issues in the watershed.

METHODS

Study design

Ten sites were selected for study: seven on the main stem of the river and three on its three largest tributaries. Figure 1 shows site locations, and appendix A presents rationale for site selection. Data were collected under dry and wet weather conditions. Differentiation between dry and wet weather conditions was based on flow conditions reported from USGS gauge 08162600 (Tres Palacios River at Midfield). For the purposes of this study, dry weather conditions were considered to exist when stream gauge height was = 5.5 ft, (the corresponding flow was approximately 110 cfs) for at least 72 hours. Flow conditions above110 cfs constituted wet weather conditions. The 110 cfs trigger level was determined by examining the previous three year's flow records to identify discharge values that coincided with rain events of a magnitude > 0.5 inches and a duration of one day. This prevented false sampling when flow increases could have resulted from irrigation releases. Precipitation data were provided by the Natural Resource Conservation Service's Bay City office.

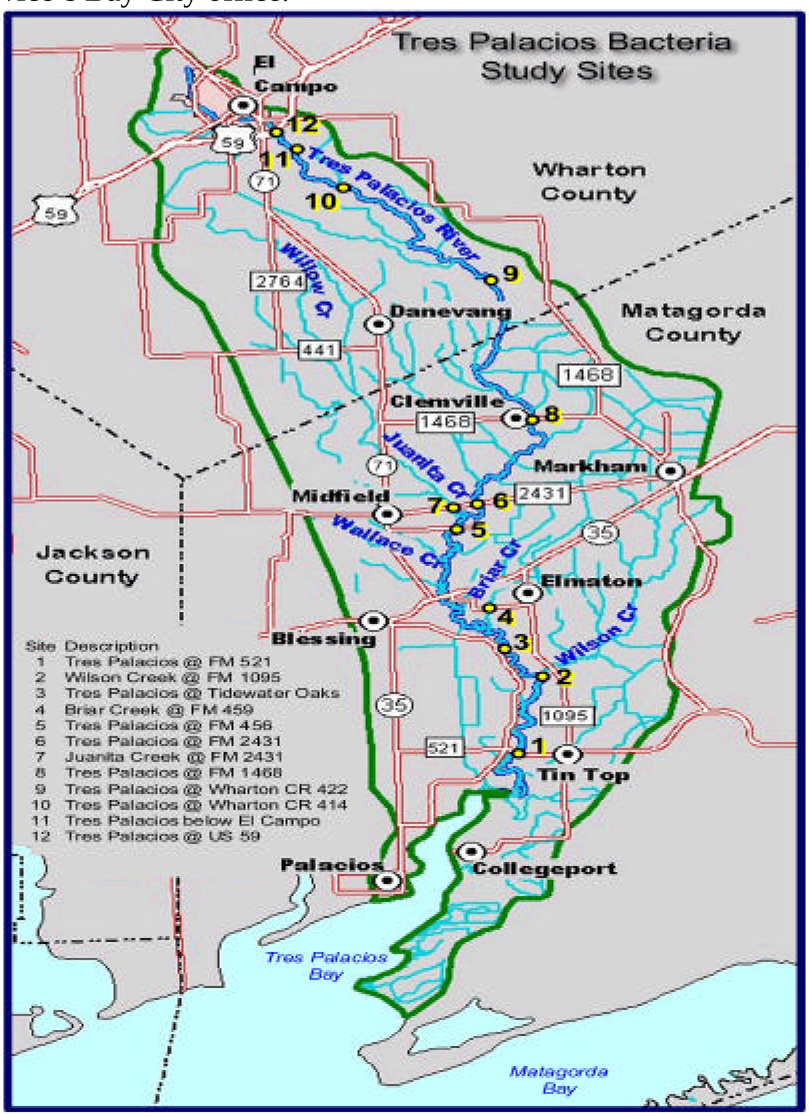

Figure 1. Map of the sampling locations used during the Tres Palacios Bacteria Study.

Sample collection and handling

In both dry and wet weather monitoring, samples were collected and analyzed for fecal coliform and *Escherichia coli*. At sites considered to be tidally influenced (sites 1-3), samples were also collected for analysis of Enterococci. Physical parameters (temperature and specific conductance) were also collected. Dry weather monitoring also included pH and dissolved oxygen measurements. At least once during each monitoring event, water samples were collected for nitrate + nitrite (NO_2+NO_3-N), ammonia (NH_3-N) and total phosphorus (TP) analysis. Nutrient data were collected to be used as possible indicators of leaking septic tanks. Where possible, sampling and measurements were taken mid-channel from bridges to minimize possible contamination from sediment introduced by bank-side sampling. Where mid-channel sampling was not possible (sites 1 and 3), grab samples were taken at least 1.5 feet from the bank.

During dry weather data collection, samples were preserved in the field and transported to LCRA's Environmental Laboratory Services lab for analysis within regulatory time limits (< 6 hours). Since transportation to the lab for analysis was not feasible, samples collected during wet weather conditions were delivered to the lab and analyzed within 30 hours after collection. Analysis for all constituents followed approved methods set forth by EPA (1983) and APHA (1998). Table 1 details the methodology for each parameter analyzed.

Table 1. Listing of methods used to analyze constituents in samples collected during the study.

Parameter	STORET	Method	Minimum Analytical Level
Nitrate+Nitrite Nitrogen	00630	EPA 353.2	0.02 mg/L
Ammonia Nitrogen	00610	EPA 350.1	0.02 mg/L
Total Phosphorus	00665	SM 4500 P E	0.02 mg/L
Fecal Coliform	31616	SM 9222D	1 cfu/dL
E coli	61648	SM 9213D	1 cfu/dL
Enterococci	31649	SM 9230 C	-
Temperature	00010	EPA 170.1	0.10 ºC
pH	00400	EPA 150.1	0.5 SU
Dissolved Oxygen	00300	EPA 360.1	0.03 mg/L
Specific Conductance	00094	EPA 120.1	1µS/cm

Other data collected

Field observations were recorded at each site, and daily rainfall data throughout the study area were obtained through the Natural Resource Conservation Service office in Bay City, TX. Precipitation data was available near four sites in the study – sites 1, 4, 5, and 8. The rainfall data was not collected at the monitoring site, but from the communities nearest the sites (Palacios, Elmaton, Midfield, and Markham). Flow data used in this study was provisional data from USGS stream flow monitoring station 08162600 (Tres Palacios River at Midfield). This gage location was also as a monitoring site (#5) during the study.

Uses of Data

When dry weather monitoring occurred, all 10 sites were sampled. The goal of each dry weather sampling event was to obtain enough data to calculate 30-day geometric means (5 data points per site per 30-day period) of bacteria indicators. When wet weather monitoring occurred, the goal of each event was to collect samples daily for 5-7 days after the hydrograph for each runoff event peaked. There were two sets of sites used for wet weather monitoring (wet weather I and II). The rationale for using two groups of wet weather monitoring sites was 1) to increase the coverage area of the study and 2) to examine watersheds without municipal or industrial discharges. The wet weather I group of sites include the downstream tributaries to the river. Wet weather II sites were located on the main stem of the river and included one upstream tributary. The groups of sites were alternated with each wet weather event. In order to allow comparisons, three sites were common between the groups of wet weather monitoring sites. Table 2 lists the sites used for each type of monitoring condition, and figure 2 details the timing and frequency for all monitoring.

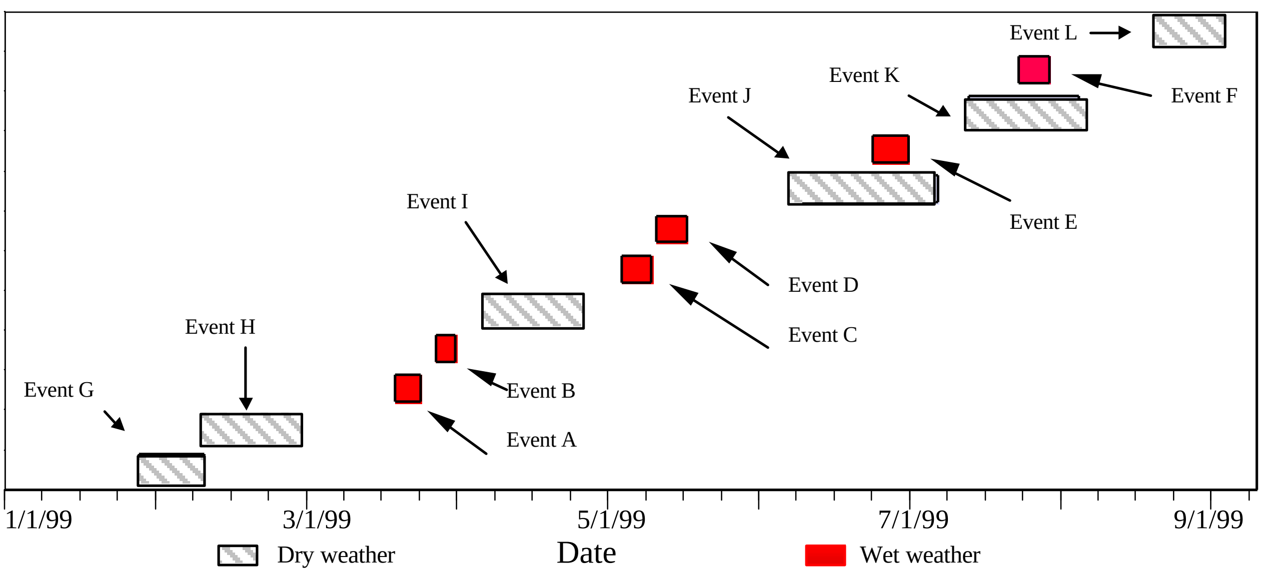

Figure 2. Dates and duration of each monitoring event. Overlapping events were discrete data sets. Some dry events were interrupted when wet weather conditions existed. Dry weather sampling resumed once flow returned to below 110 cfs for at least 72 hours.

Table 2. Tres Palacios Bacteria Study monitoring schedule. Values in parentheses are the number of times sampled.

Site	Dry Weather	Wet Weather I	Wet Weather II
Tres Palacios River @ FM 521	X (6)	X (3)	X (3)
Wilson Creek @ FM 1095	X (6)	X (3)	
Tres Palacios River @ Tidewater Oaks	X (6)		X (3)
Briar Creek @ FM 456	X (6)	X (3)	
Tres Palacios River @ FM 459	X(6)	X (3)	X (3)
Tres Palacios River @ FM 2431	X (6)		X (3)
Juanita Creek @ FM 2431	X (6)		X (3)
Tres Palacios River @ FM 1468	X (6)	X (3)	X (3)
Tres Palacios River @ Wharton CR 422	X (6)		
Tres Palacios River @ Wharton CR 415	X (6)		

Analysis of data

Relationships among bacteria, nutrient and physical data were identified and examined using regression/correlation analysis. Between-site differences were examined using the Student’s t test. Among- site and site/date relationships were examined using ANOVA/Tukey Honestly Significant Difference tests (Zar 1996, StatSoft 1998).

Since data have also been collected at Site 5 by TNRCC for several years, some comparisons were possible. The relationship between flow and fecal coliform concentrations were compared between data sets. The length of the TNRCC data set was June 1993 through December 1998.

RESULTS AND DISCUSSION

General

During the course of this study, chemical and physical data were collected in six 5-day dry weather and 6 wet weather monitoring events. All major rain events with runoff were sampled (Figure 3). The total numbers of sample events are listed in Table 3.

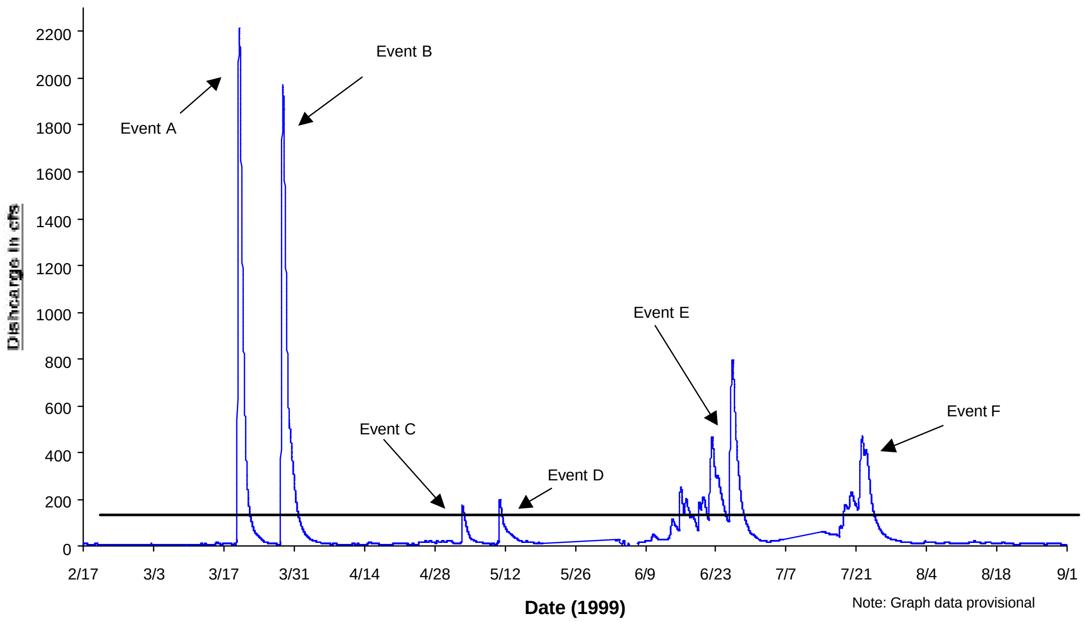

Figure 3. Hydrograph for the Tres Palacios River at Midfield (site 5) during the course of the study. The horizontal line is the 110 cfs trigger level.

Table 3. Summary of data collected and obtained for this report. Values represent the number of data collected. NO3 = nitrate + nitrite nitrogen, NH3 = ammonia nitrogen, TP = total phosphorus, SpC = specific conductance.

Site	Fecal Coliform	E coli	Enterococci	NO3	NH3	TP	Temp	pH	DO	SpC	Precip	Flow
1	68	68	68	19	19	19	65	30	29	65	X	
2	48	48	48	14	14	14	48	30	29	48		
3	49	49	49	15	15	15	46	30	29	46		
4	48	48	0	14	14	14	48	30	29	48	X	
5	68	68	0	19	19	19	65	30	29	65	X	16804
6	39	39	0	12	12	12	36	20	19	36		
7	36	36	0	10	10	10	36	20	19	36		
8	68	68	0	18	18	18	65	30	29	65	X	
9	30	30	0	11	11	11	30	30	29	30		
10	25	25	0	10	10	10	25	25	24	25		
Total	479	479	165	143	143	143	460	275	265	464	-	16804

The study area received an average of 20.40 inches of precipitation throughout the study, but it should be noted that the coverage of this rainfall was not uniform (Table 4). Because the middle portion of the basin received much more rainfall than either end of the watershed (based on NRCS data), it was possible that some of the wet weather events were not basin-wide occurrences.

Table 4. Rainfall totals associated with some sites in the study area. Measurements are in inches. Site 4 is a tributary to the Tres Palacios River.

Month	Site 1	Site 4	Site 5	Site 8	Mean
January	1.35	1.40	0.83	0.90	1.12
February	1.02	1.45	1.93	1.70	1.53
March	2.42	4.20	7.14	4.45	4.55
April	1.76	1.00	0.75	0.60	1.03
May	2.14	4.70	6.50	5.05	4.60
June	2.54	2.50	5.26	0.00	2.58
July	7.62	3.90	6.70	0.00	4.56
August	0.81	0.60	0.20	0.10	0.43
Total	19.66	19.75	29.31	12.80	20.40

All Data

Fecal coliform and E. coli

Overall, fecal coliform and *E. coli* correlated well with one another ($r^2 = 0.92$). However, the goodness of fit was due mostly to the influence of high values within the data set (Figure 4). When data pairs at or below the median fecal coliform value (134 cfu/dL) were analyzed alone, the coefficient of determination (r^2) fell to 0.42.

E. coli accounted for 69 ± 3 % (mean ± 95% CI) of fecal coliform for both wet and dry weather events combined. This value was well within the ranges reported by other authors in Francy et al (1993). Since this ratio was higher than the 0.63 used by EPA to set contact recreation criteria, more violations would be expected when using E. coli, rather than fecal coliform, data.

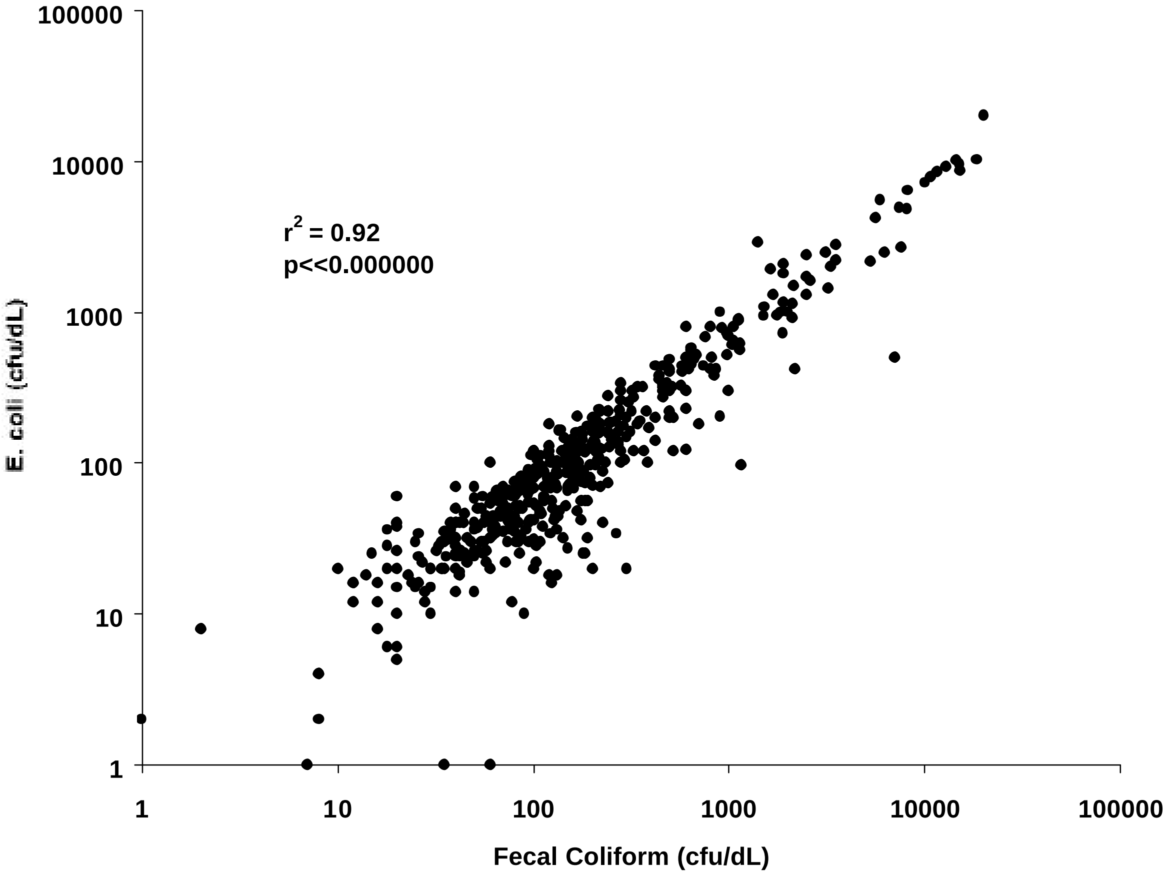

Figure 4. Relationship between fecal coliform and *E coli*, n = 479.

The *E. coli* to fecal coliform ratio (EC/FC) varied between weather conditions and among sites (Table 5). A Student's t-test proved mean wet and dry weather EC/FC to be significantly different from one another ($p = 0.00003$). The dry weather EC/FC ratio (0.74) was higher than the wet weather ratio (0.62). When sites were considered individually, only site 5 showed a significant difference between weather conditions ($p<0.0001$). The difference between wet and dry weather values could not be explained by the data collected in this study, but is apparently related to runoff.

For all data, the fecal coliform geometric mean was 163 cfu/dL and the E. coli geometric mean was 98 cfu/dL, both of which are less than the water quality standard for safe contact recreation. The EC/FC ratio of these numbers (.60) is similar to the wet weather ratio, but this masks the difference between wet and dry weather values.

Table 5. *E. coli* to fecal colifom (EC/FC) ratios by site and event. Values have been converted to percentages.

Event	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site10	Event Mean ± 95% CI
Dry 1	88.4	75.7	106.7	109.1	89.1	n/a	58.8	83.3	90.4	n/a	87.7 ± 16.0
Dry 2	65.9	64.8	64.4	44.3	58.5	n/a	n/a	55.3	92.3	69.6	64.4 ± 11.6
Dry 3	79.0	111.5	93.8	71.3	81.8	68.8	42.8	141.5	105.3	96.3	89.2 ± 14.2
Dry 4	66.5	61.9	57.7	115.8	83.5	70.3	60.4	60.0	66.6	62.9	70.6 ± 8.6
Dry 5	93.7	77.7	67.1	85.3	75.3	40.4	59.4	49.3	53.8	58.8	66.1 ± 9.4
Dry 6	115.0	58.6	65.7	69.9	67.2	43.0	n/a	31.3	83.1	61.2	66.1 ± 17.5
Site Mean -Dry	84.7	75.0	75.9	82.6	75.9	55.6	55.3	70.1	81.9	69.8	74.0 ± 5.3
95% CI	± 26.3	± 15.2	± 16.0	± 20.9	± 9.1	± 12.4	± 11.2	± 19.9	± 13.8	± 13.0	
Wet 1	68.9	n/a	71.9	n/a	57.8	74.8	n/a	55.5	n/a	n/a	65.8 ± 8.8
Wet 2	52.1	80.6	n/a	55.8	56.2	n/a	72.1	60.5	n/a	n/a	62.9 ± 10.5
Wet 3	74.5	n/a	74.0	n/a	59.5	66.4	n/a	64.4	n/a	n/a	67.8 ± 10.1
Wet 4	82.1	76.7	n/a	73.4	56.1	n/a	70.8	64.7	n/a	n/a	70.6 ± 5.7
Wet 5	59.8	57.5	n/a	77.3	63.9	n/a	60.9	59.8	n/a	n/a	63.0 ± 5.9
Wet 6	44.6	n/a	48.1	n/a	41.9	36.7	n/a	39.9	n/a	n/a	42.4 ± 6.9
Site Mean -Wet	64.0	71.4	63.9	69.8	55.8	57.7	67.5	57.5	n/a	n/a	62.1 ± 3.4
	± 8.7	± 9.5	± 16.4	± 10.4	± 5.4	± 12.6	± 9.7	± 8.8	n/a	n/a	
All Data	73.1	73.7	71.2	77.8	64.7	56.6	60.9	62.9	n/a	n/a	68.9
95% CI	± 12.2	± 9.6	± 11.1	± 13.1	± 8.6	± 8.2	± 7.4	± 9.6	n/a	n/a	± 3.4

Comparability of six hour and 24-hour bacteria results

For bacteria data to be used in making regulatory decisions, samples must be processed within a a six-hour period from time of collection. Since this was impractical during wet weather monitoring, there was concern that the two data sets were not comparable. In February 1999, sixteen samples were collected from Town Lake and Lake Austin for the purpose of comparing six and 24-hour holding times (Table 6). Both fecal coliform and *E. coli* were analyzed. Based on this small dataset, there was no significant difference in bacteria content between the two holding times using a Student’s t-test.

Table 6. Comparison of bacteria results from six and 24-hour holding times.

Site	STORET	6-hour	24-hour	% difference
12476 – Town Lake @ Dam	31616	69	9	-87
12487 – Barton Creek @ Pedestrian Bridge	31616	81	82	1
12294 – Lake Austin @ Dam	31616	5	4	-20
12486 – Town Lake @ Headwaters	31616	3	8	167
12215 – Bull Creek @ RR 2222	31616	15	10	-33
12300 – Lake Austin @ Headwaters	31616	7300	8800	21
12297 – Lake Austin at City Park	31616	15	21	28
Field duplicate	31616	7600	7100	-7
12476 – Town Lake @ Dam	61648	59	5	-92
12487 – Barton Creek @ Pedestrian Bridge	61648	73	80	10
12294 – Lake Austin @ Dam	61648	3	2	-33
12486 – Town Lake @ Headwaters	61648	2	4	100
12215 – Bull Creek @ RR 2222	61648	6	7	17
12300 – Lake Austin @ Headwaters	61648	6200	6000	-3
12297 – Lake Austin at City Park	61648	13	16	19
Field duplicate	61648	5800	5100	-14

Enterococci

Enterococci, collected only at tidally influenced sites, was not statistically related to any parameter. Changes in testing methodology led to inconsistent results in the first half of the study. The two approved protocols in Standard Methods (APHA, 1998) yield different results (Davis, 1999). The different results may be attributable to the laboratory staff's lack of experience with analyzing for enterococci.

Streamflow and fecal coliform

Although stream flow data were only available at site 5, river flow correlates well with fecal coliform ($r^2 = 0.67$, $p < 0.000001$) in both wet and dry weather monitoring (Figure 5). Solving the slope equation of the best-fit line, the single grab sample criterion of 400 cfu/dL would have been exceeded when flow reached 60.1 cfs.

During the course of this study, the flow at the Midfield gage was ≤ 60 cfs 78% of the time, and had a median discharge of 17 cfs. Over the life of the gage station (June 17, 1970 – present), 75% of the daily average discharge values were ≤ 60 cfs. The historical median discharge was 23 cfs.

A total of 68 sample collection events occurred at site 5 during the course of this study. Forty-two of the 68 fecal coliform samples were collected when flow was ≤ 60 cfs, and 7 (17%) of these violated the single grab criterion. TNRCC has collected a total of 27 fecal coliform samples at this location over the past 5 years. Twenty of these samples were collected when the daily average discharge was ≤ 60 cfs. Only 1 sample (5%) exceeded the 400 cfu/dL criterion.

Using all data available, for flows ≤ the historical median (23 cfs), only 7% of the fecal coliform samples violated the criterion. At flows ≤ 60 cfs the grab sample criterion was exceeded 13 % of the time. However, data collected under dry weather conditions (flow <110 cfs for at least 72 hours) is considered alone, 7% of the fecal coliform exceed the criteria.

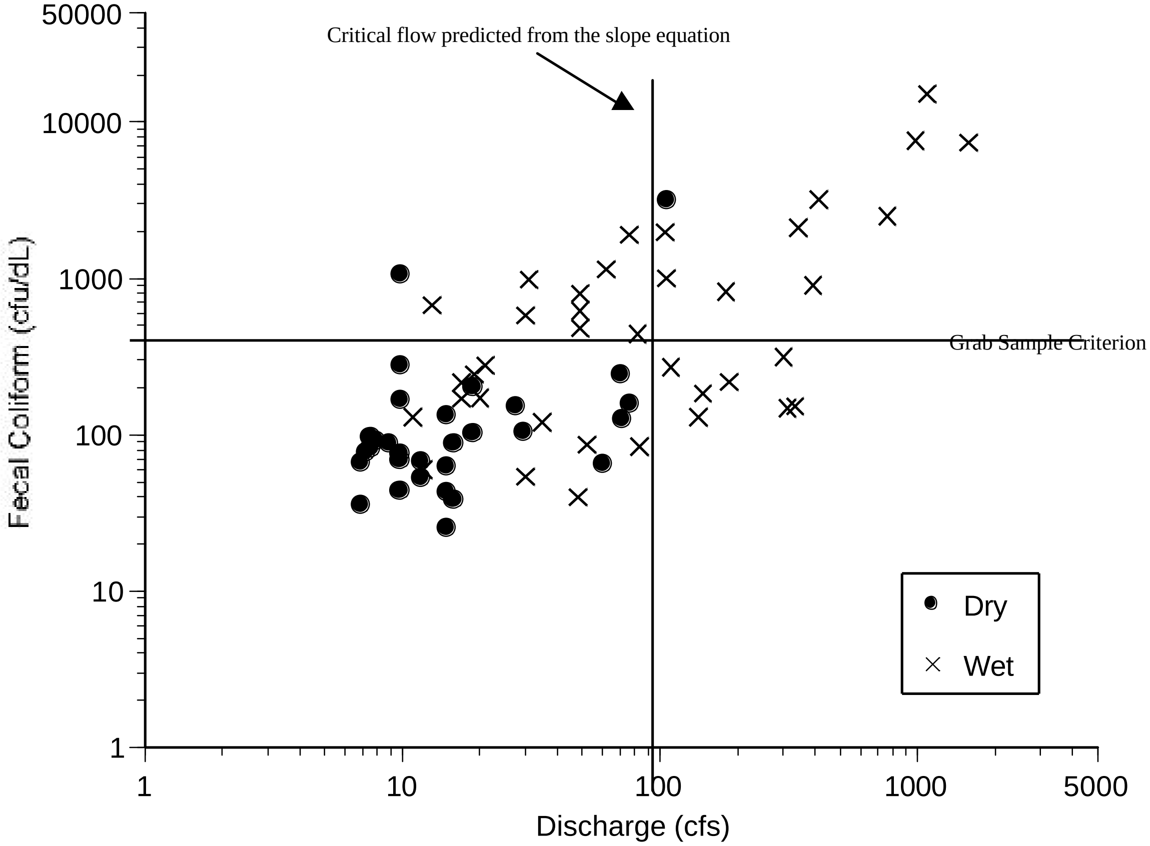

Figure 5. The relationship between discharge and fecal coliform for all data collected at site 5 during this study, n = 68.

Field parameters

There were correlations among field parameters (temperature, pH, dissolved oxygen, and specific conductance), nutrients and microbiological data, but these were driven by the uneven distribution of values caused by combining wet and dry weather data.

Nutrients

Nutrient data showed a pattern of higher concentrations upstream, lowest values in the middle portion of the study area and an increase toward the mouth of the river (Figure 6). Analysis of variance and consequent multiple comparisons testing showed total phosphorus means at sites 9 and 10 to be different than those of the remaining downstream sites. The mean

NO_2+NO_3-N concentration at site 10 was significantly different than the means of five of the remaining nine sites. Mean NH_3-N was not significantly different at any of the study sites.

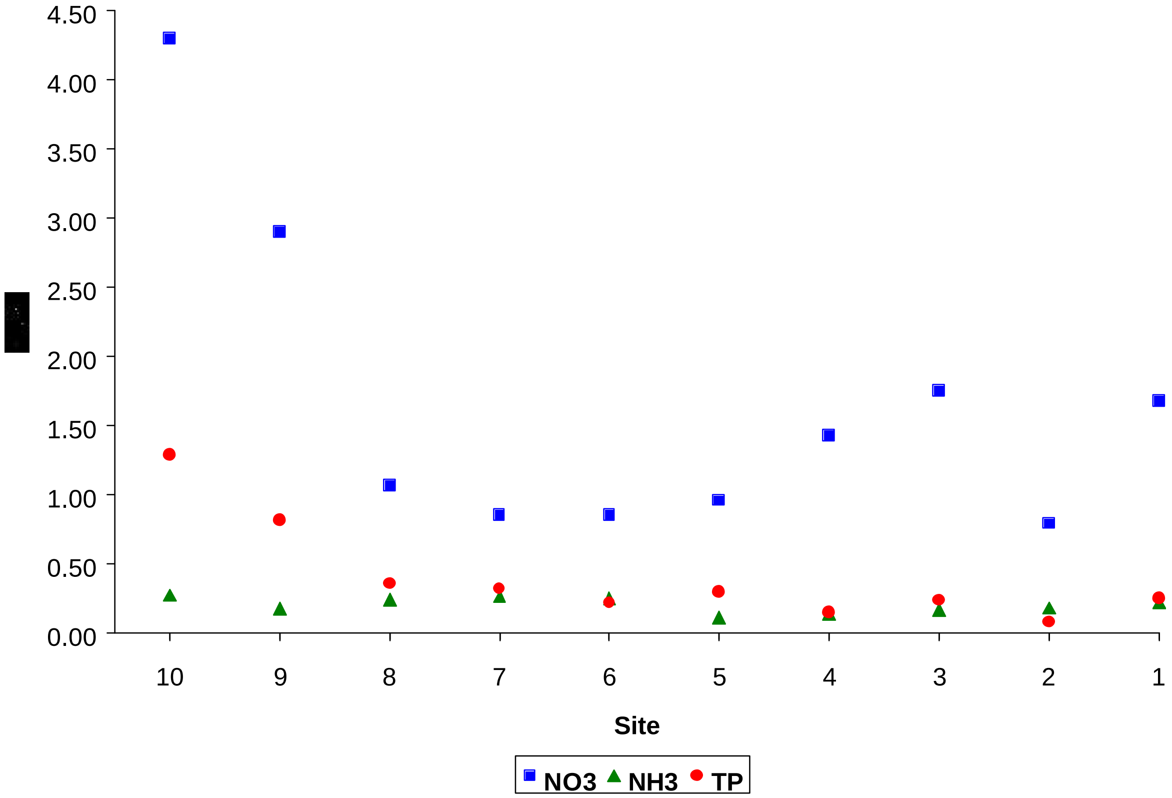

Figure 6. Mean nutrient concentrations for each site. NO3 = nitrate + nitrite nitrogen, TP = total phosphorus, NH3 = ammonia nitrogen. Data points represent the average of all values collected during the study. Sites 2, 4, and 7 are tributaries to the Tres Palacios. Although values are different, this pattern was also seen in dry weather conditions.

Dry Weather

Fecal coliform and E. coli

The average geometric means of fecal coliform and *E. coli* at sites located on the mainstem of the Tres Palacios River show high levels upstream and decrease steadily toward the mouth (Figure 7). Although the patterns seen in each sample set are different, the downstream decreasing trend is the general rule. This is probably due to the effects of changing channel morphology in the basin. The upper reaches of the system are more creek-like than the lower portions. Mean stream width at site 8 is approximately 10 feet, and the mean depth is approximately 6 inches. At site 3, these measurements are 100 feet wide by 12 feet deep. The narrow, shallow morphology upstream would tend to keep sediment, and any bacteria attached to it, suspended in the water column for a greater length of time than the deeper, more slowly moving downstream areas.

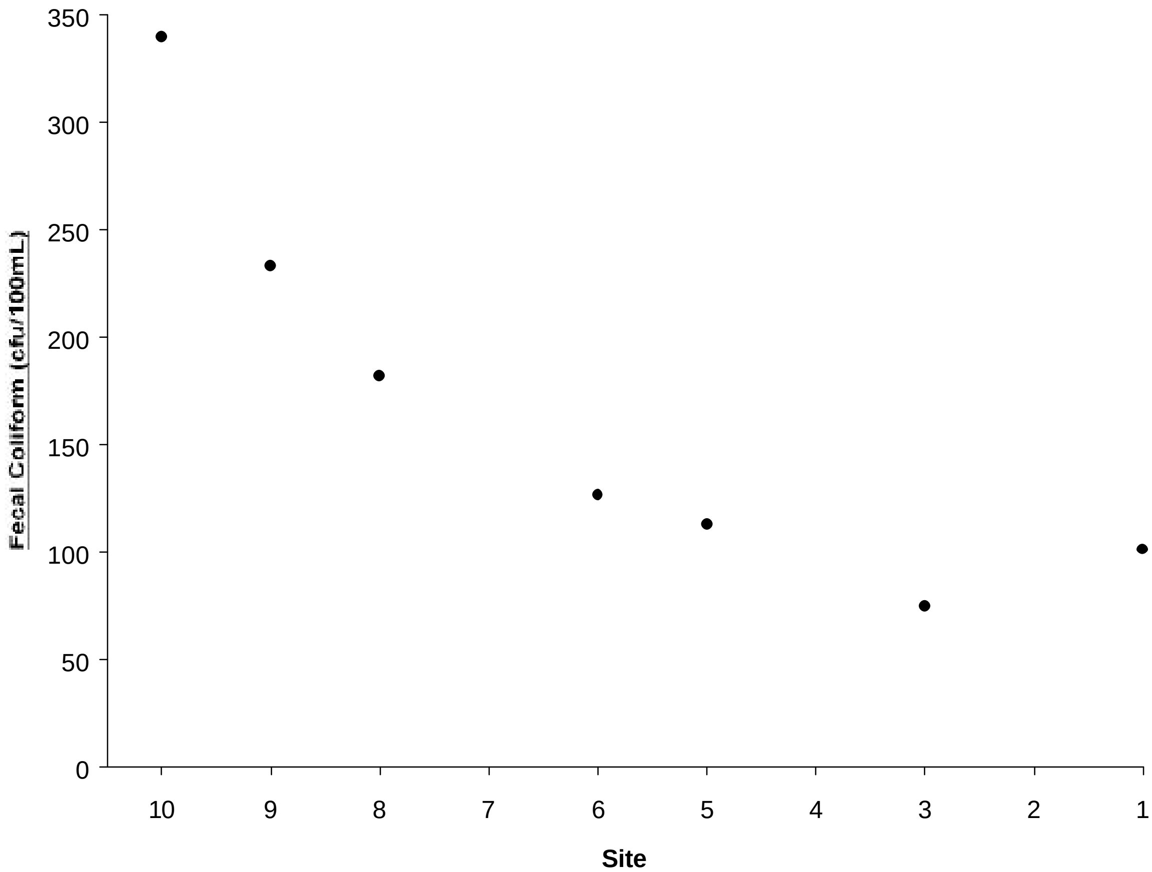

Figure 7. Composite dry weather fecal coliform geometric means for the mainstem sites on the Tres Palacios. Composites were used to show trends over the course of the study.

E coli displayed the same general patterns and fluctuations as fecal coliform and composed 74 ± 5% of the fecal coliform bacteria. There were ten violations of the proposed 30-day geometric mean *E. coli* criterion (126 cfu/dL) during dry weather as compared to six for fecal coliform (Tables 7 and 8). Most of these violations occurred in the upper end of the study area. When and wherever fecal coliform exceeded the criteria, *E. coli* did as well. Four of the 10 sites had >10% of their samples exceed their respective grab sample criteria (Table 9), and none of the ten sites has >25% of their samples exceed their respective grab sample criteria.

Table 7. Fecal coliform geometric means for all dry weather monitoring events and sites. Sites 2, 4, and 7 are tributaries to the Tres Palacios River. ▸ = value in exceedance of the geometric mean (200 cfu/dL) criterion.

		Segment 1501			Segment 1502						
Event	Mean Flow	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
1	8.0	56	109	65	50	99	N/A[1]	120	88	150	N/A[2]
2	10.7	▸ 302	60	52	57	163	N/A[1]	N/A[1]	173	155	▸ 392
3	12.7	108	32	179	173	78	39	61	36	40	63
4	50.4	108	177	102	187	195	▸ 260	106	▸ 437	▸ 808	▸ 1007
5	48.2	14	41	19	141	72	95	76	188	100	126
6	12.8	18	47	32	69	69	111	N/A[1]	170	145	110

N/A[1] = Unable to obtain clean samples due to construction in creek channel. N/A[2] = site dry (moved after this event).

Table 8. *E coli* geometric means for all dry weather monitoring events and sites. Sites 2, 4, and 7 are tributaries to the Tres Palacios River. ▸ = value in exceedance of the proposed 126 cfu/dL criterion.

		Segment 1501			Segment 1502						
Event	Mean Flow	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
1	8.0	47	78	62	27	88	N/A[1]	66	69	122	N/A[2]
2	10.7	▸ 192	29	21	21	75	N/A[1]	N/A[1]	85	▸ 140	▸ 268
3	12.7	82	32	▸ 159	119	62	25	16	44	36	55
4	50.4	67	104	58	▸ 202	▸ 155	▸ 169	52	▸ 245	▸ 530	▸ 596
5	48.2	9	30	11	115	52	37	43	92	52	70
6	12.8	10	25	18	42	44	39	N/A[1]	48	119	62

N/A[1] = Unable to obtain clean samples due to construction. N/A[2] = site dry (moved after this event).

Table 9. Percent of dry weather samples violating their single grab criteria.

		% samples in violation	
Site	n	Fecal Coliform	*E. coli*
1	30	10	7
2	30	3	3
3	30	7	7
4	30	7	3
5	30	7	3
6	20	5	10
7	20	5	4
8	30	17	20
9	30	10	15
10	25	20	20

Nutrients

Although the values were different, the nutrient data for the mainstem Tres Palacios sites show a pattern similar to that seen in figure 6; that is, decreasing from the upstream end to the near the middle of the study area and then increasing again toward the mouth of the river. Nutrients in the tributaries were usually lower than their adjacent mainstem sites.

Possible upstream sources

Elevated concentrations of bacteria and nutrients in the upstream reaches of the Tres Palacios prompted further investigation as to a potential source upstream of the study area. Two additional sites were established for short-term monitoring upstream of the original study area. One site (Site 12) was located at the US Hwy 59 bridge in El Campo. This site was approximately 200 yards downstream of the City of El Campo WWTP discharge. The other monitoring location (Site 11) was approximately one mile downstream of Site 12. This site was immediately downstream of a livestock auction facility. These new sites, as well as site 10, were sampled three times (9/15, 9/20, and 9/22) during dry weather conditions. The data collected show that bacteria concentration increased toward the El Campo (Table 10). There was no flow in the Tres Palacios river above El Campo during this data collection. There was a mean reduction of 93% of total phosphorus and 99.8% of NO_2+NO_3-N site 12 and the upstream end of the study area (site 10).

Table 10. Results of the 3 sampling dates of the City of El Campo. Units are cfu/dL for fecal coliform, mg/L for NH_3-N, NO_2+NO_3-N, and total phosphorus, and cfs for discharge. All samples were collected during dry weather conditions.

Monitoring Day/Parameter	Site 12	Site 11	Site 10
9/15/99			
Fecal Coliform	800	400	75
NH_3-N	0.040	0.040	0.083
NO_2+NO_3-N	20.0	20.0	< 0.020
Total Phosphorus	3.18	3.28	0.353
Discharge	0.45	0.41	0.09
9/20/99			
Fecal Coliform	700	500	101
NH_3-N	0.028	0.043	0.044
NO_2+NO_3-N	17.8	18.2	<0.020
Total Phosphorus	3.10	3.30	0.211
Discharge	0.56	0.33	0.02
9/22/99			
Fecal Coliform	800	136	52
NH_3-N	0.257	0.078	0.035
NO_2+NO_3-N	15.0	15.2	<0.020
Total Phosphorus	3.02	3.14	0.129
Discharge	0.53	0.48	0

Wet Weather

Bacteria and flow

As seen in dry weather monitoring, the bacteria concentrations during each wet weather monitoring event almost exactly follow discharge (Figure 8). The strength of this relationship, however, was stronger than that of the dry weather data.

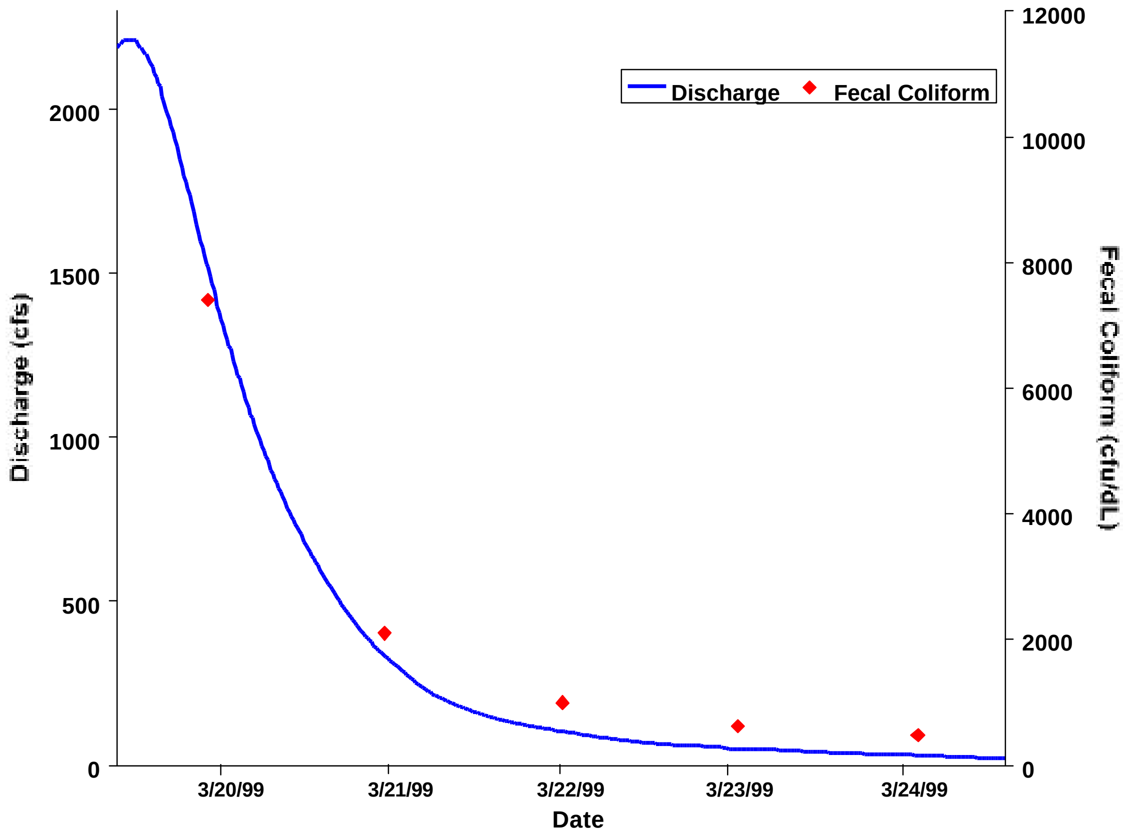

Figure 8. The relationship between flow and fecal coliform levels at site 5 during a wet weather monitoring event.

Wet weather monitoring events A and B showed a much higher elevation in fecal coliform concentrations than later events (Figure 9). The increased levels of fecal coliform during these events can be explained by the large increase in discharge of the river (peak flows of 2210 cfs for event A and 1960 cfs for event B). A possible contributing factor to the high numbers seen in event A could be that there had been very little rain in the watershed over the previous 6 months. Extended periods without runoff would allow an accumulation of animal wastes near the river, increasing the potential supply of bacteria to the river when runoff conditions occur.

The location of the rainfall within the watershed influenced the mean bacteria concentrations. For example, the rainfall associated with event A was mainly in the lower portion of the watershed, while precipitation for event B occurred mostly in the middle portion of the basin. Generally, the sites in the contributing watersheds experiencing the greatest rainfall produced the highest mean fecal coliform levels.

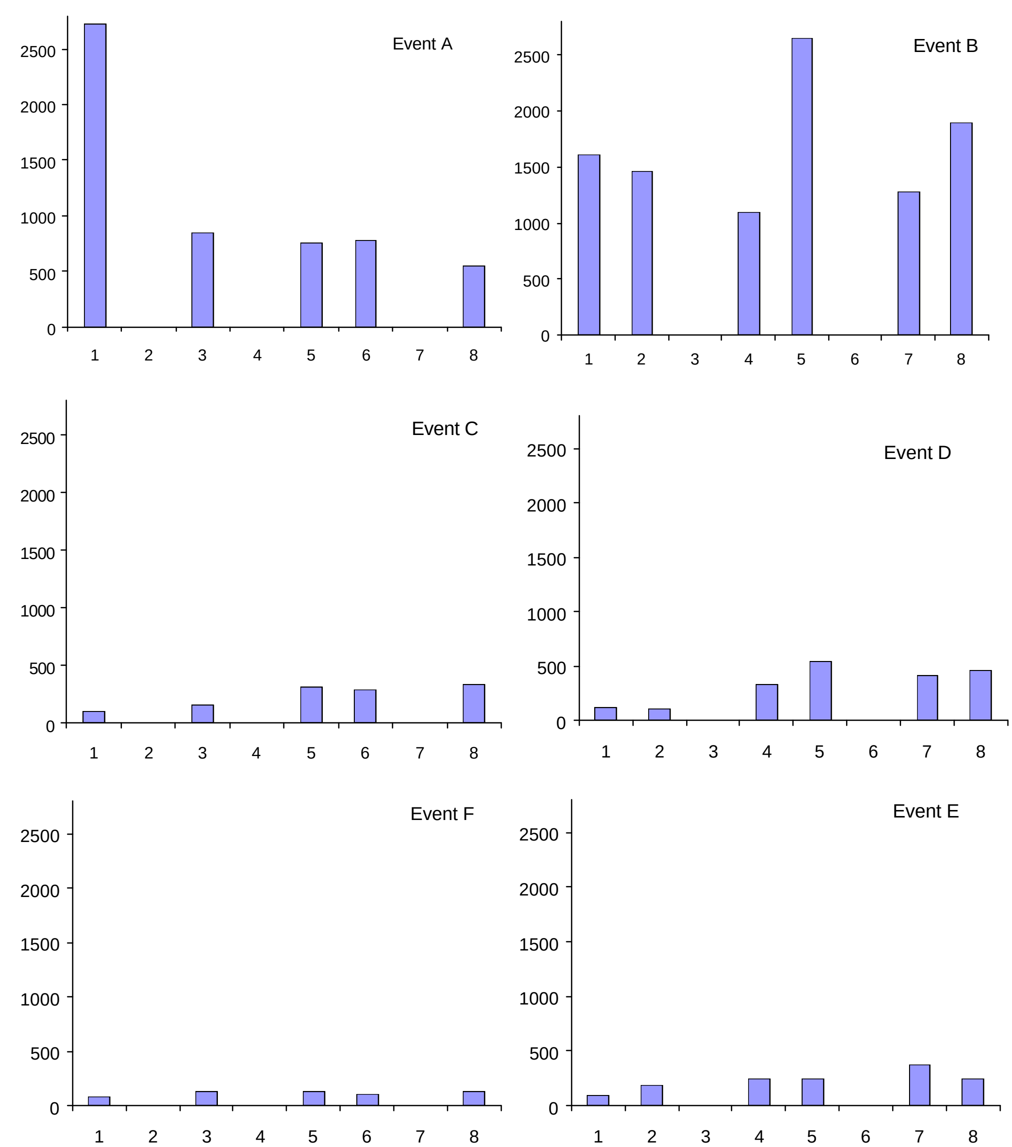

Figure 9. The geometric means of fecal coliform for each wet weather monitoring event for all sites. Values for x axes are site numbers, y axes values are in cfu/dL.

Nutrients

Generally, there was little fluctuation in the mean nutrient content of runoff waters in the watershed (Figure10). The exception is site 4. No reason is evident for the high NO_2+NO_3-N value. Nutrient values are similar to those seen at these sites when both wet and dry data are combined.

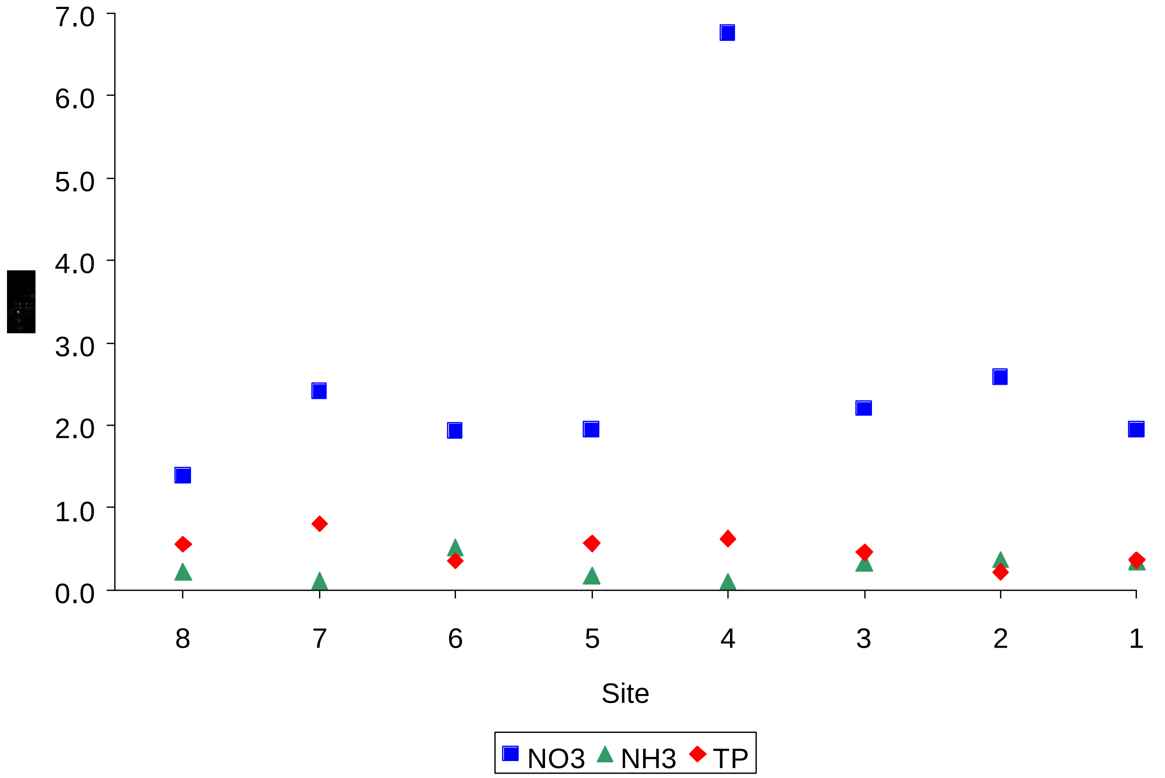

Figure 10. Wet weather condition mean nutrient concentrations for the all sites. NO3 = nitrate + nitrite nitrogen, TP = total phosphorus, NH3 = ammonia nitrogen. Data points represent the average of all values collected during wet weather monitoring.

Dissolved Oxygen in Segment 1501

Two sites in this study were located within the tidally influenced reach of the Tres Palacios River (Sites 1 and 3). Over the course of the study, 58 dissolved oxygen readings were collected, 39 (67%) of which were above the 5.0 mg/L state criterion. More violations of the criterion occur in the upper end of the segment.

CONCLUSIONS

- Bacteria concentrations and stream discharge were positively correlated in the Tres Palacios River.
- The Tres Palacios River appeared to be suitable for contact recreation when discharge was less that 60 cfs regardless of weather conditions.
- It typically takes at least 4 days after stormflows peak before bacteria concentrations return to background levels.
- Fecal coliform and *E. coli* were correlated well with each other, but this relationship was not as strong at lower bacteria concentrations (< 134 cfu/dL).
- Nutrient content during dry weather monitoring conditions appeared to be tied to populated areas. Higher nutrients were found at the upper (El Campo) and lower (subdivisions) ends of the watershed.
- Based on a limited set of data, the city of El Campo appeared to be a source of elevated nutrients and fecal coliform in the upstream areas of the river.
- In low flow conditions, the upper end of the watershed assimilates at least 90% of the nutrient content from the City of El Campo's.
- Channel morphology may contribute the elevated bacteria concentrations in the upstream reaches of the river.
- With respect to nutrients and bacteria, tributaries in the watershed displayed similar patterns as the river.
- Segment 1501 violated the state dissolved oxygen criterion in 33% of the measurements taken.
- The *E. coli* component of fecal coliform was higher during dry weather events. During runoff conditions the percent *E. coli* decrease by approximately ten percent.
- When compared to fecal coliform, *E. coli* was the more stringent indicator of microbiological content. On a sample by sample basis, *E. coli* produced more grab sample violations than did fecal coliform.

SUMMARY

The original purpose of this study was five-fold: to determine 1) where the levels of indicator bacteria are elevated in the river, 2) when these levels are elevated, 3) how long bacteria levels remain above contact recreation criterion after storm events, 4) provide information to the Tres Palacios watershed action team to make water resource management decisions, and 5) educate local residents about water quality issues in the watershed.

The results of the study have provided an adequate description of where and under what conditions bacteria concentrations are elevated. As to how long bacteria levels remain elevated after storm events, general conclusions can be drawn, but there are complicating factors (location and intensity of rainfall, time since the last runoff event, etc) that make exact determinations difficult. This study has produced a comprehensive look at water quality in the Tres Palacios River under a variety of weather conditions that may be used for education and resource management purposes.

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Appendix A. List of locations used in the Tres Palacios bacterial study.

Factors considered in site selection were 1) surrounding land use, 2) use for contact recreation, 3) spatial relationship to possible contamination sources, 4) even distribution of sites within the watershed, and 5) availability of flow and rainfall information

Site 1: Tres Palacios River at FM 521 N 28° 47' 10.91" W 96° 9' 0.81"

Data collected from this site can be compared to historical data collected by LCRA and TNRCC. This site is located downstream of the Tres Palacios Oaks subdivision, which has a number of failing septic systems (G&W Engineers, Inc 1993). This site is well within the zone of tidal influence.

Site 2: Wilson Creek at FM 1095 N 28° 50' 19.82" W 96° 7' 49.51"

Data collected from this site can be used to determine if the Wilson Creek watershed contributes to elevated bacteria levels in the River. The major land use in this watershed is rangeland and rice farms. Wilson Creek could be affected by the irrigation return flows from rice farms. Rainfall information is available for this site. This site is well within the zone of tidal influence.

Site 3: Tres Palacios River at Tidewater Oaks N 28° 50' 49.14" W 96° 8' 53.30"

This site is located in a major recreational area and downstream of the Tidewater Oaks subdivision. Data collected from this site can be used to determine if this portion of the Tres Palacios meets the criteria for contact recreation. This site is within the zone of tidal influence.

Site 4: Briar Creek at FM 459 N 28° 52' 38.31" W 96° 9' 30.76"

Data collected from this site can be used to determine if Briar Creek watershed contributes to the elevated bacteria levels in the River. The major land use in this watershed is rangeland and rice farms. Briar Creek could be affected by the irrigation return flows from rice farms. This site is on the edge of the zone of tidal influence

Site 5: Tres Palacios River at FM 456
N 28° 55’ 40.99”
W 96° 10’ 16.07”

This site is located downstream of the El Dorado subdivision which has been identified with septic system problems (G&W Engineers 1993). Also, data collected from this site can be compared to historical TNRCC data. Flow data will be obtained from the USGS Stream flow Monitoring Station # 08162600. TNRCC monitoring site 12517.

Site 6: Tres Palacios River @ FM 2431
N 28° 56’ 36.25”
W 96° 9’ 47.61”

Data collected from this site could be used to determine whether or not the water quality in this section of the river meets the criteria for contact recreation.

Site 7: Juanita Creek at FM 2431
N 28° 56’ 30.31”
W 96° 10’ 29.21”

Data collected from this site can be used to determine if Juanita Creek watershed contributes to the elevated bacteria levels in the River. The major land use in this watershed is rangeland and rice farms. Juanita Creek could be affected by the irrigation return flows from rice farms.

Site 8: Tres Palacios River at FM 1468 (Clemville)
N 28° 59’ 45.05”
W 96° 8’ 13.08”

This site will provide data to determine if the water quality in this area of the river meets the criteria for contact recreation.

Site 9: Tres Palacios River at County Road 422
N 29° 5’ 24.29”
W 96° 9’ 34.10”

This site will provide data to determine if the water quality in this area of the river meets the criteria for contact recreation.

Site 10: Tres Palacios River at County Road 415
N 29° 7’ 49.10”
W 96° 12’ 0.61”

Data collected from this site may be used determine if there are high bacteria levels from the City of El Campo.

APPENDIX B. SUMMARY STATISTICS FOR ALL WET EVENTS,

GM = geometric mean, AM = arithmetic mean.

Event	Site	NO_3 (mg/L)	NH_3 (mg/L)	TP (mg/L)	Temperature (°C)			Specific Conductance (μS/cm)			Fecal Coliform (cfu/dL)		E. coli (cfu/dL)		Enterococci (cfu/dL)	
					min	mean	max	min	mean	max	GM	AM	GM	AM	GM	AM
A	1	3.610	0.399	1.091	18.0	20.6	24.0	230	310	374	4140	7232	2722	6128	2813	4676
B	1	4.480	0.712	0.388	18.4	19.9	22.0	197	369	924	1612	2204	591	1431	1777	4480
C	1	0.980	1.410	0.040	22.7	25.2	26.6	7859	9286	10690	98	135	70	97	123	160
D	1	<1.000	0.149	0.051	24.2	26.8	28.4	1283	10250	13400	118	126	94	101	117	145
E	1	2.800	0.021	0.207	28.2	29.5	32.7	291	425	838	89	105	52	65	70	77
F	1				28.8	29.3	29.9	203	275	322	84	155	33	54	44	134
B	2	0.410	<0.050	0.118	17.0	20.1	22.7	128	275	354	1468	2008	1116	1296	5642	8176
D	2	4.260	0.796	<0.040	23.9	26.1	27.8	1246	4209	11650	108	145	83	111	148	192
E	2	1.250	0.223	0.040	19.0	27.3	30.0	157	469	543	192	1919	113	1367	187	2322
A	3	4.900	0.314	0.949	19	21.1	23.1	157	196	230	1212	3504	847	2576	985	3616
C	3	1.880	0.957	0.078	24	26.2	27.5	1988	4155	6705	162	1146	89	180	141	185
F	3				29.6	30.2	30.8	253	260	270	133	197	57	77	100	130
B	4	16.400	<0.050	0.778	16.3	19.9	23.2	248	386	478	1095	1800	589	1224		
D	4	0.300	0.091	0.377	23.5	25.6	27.2	496	634	719	333	372	239	287		
E	4	1.460	0.033	<0.040	19.7	27.3	30.3	170	421	469	242	1179	176	792		
A	5	5.700	0.314	0.712	19.7	21.6	24.9	170	284	490	1358	2320	751	1420		
B	5	2.700	<0.050	1.006	16.9	19.7	23.7	136	207	307	2657	5432	1435	2740		
C	5	1.840	0.806	0.606	23.0	26.0	27.4	595	934	1133	315	544	185	344		
D	5	1.320	0.126	0.781	26.2	27.1	28.4	291	617	958	546	789	304	422		
E	5	0.700	0.072	0.368	27.6	29.2	31.2	155	307	655	244	525	149	337		
F	5				29.1	29.8	30.3	253	438	660	135	217	51	68		
A	6	4.290	0.285	0.600	19.4	21.5	24.9	142	272	495	1099	2976	781	2096		
C	6	1.82	2.070	0.492	22.9	25.8	27.6	699	1034	1255	292	478	189	346		
F	6				28.8	29.6	29.9	284	496	704	112	133	35	48		
B	7	4.3	<0.05	1.178	17.1	19.6	23.2	105	188	271	1280	3656	836	2676		
D	7	1.39	0.112	1.070	25.8	26.8	28.5	270	473	691	416	685	291	472		
E	7	0.44	0.057	0.376	19.8	27.6	31.1	124	205	303	369	1425	223	859		
A	8	3.620	0.357	0.666	19.8	21.8	24.9	124	235	386	1089	2296	552	1304		
B	8	2.190	<0.050	0.821	17.2	19.8	23.2	123	178	233	1898	4816	1042	2696		
C	8	1.150	1.270	0.372	23.3	26.7	28.6	623	773	864	336	403	184	311		
D	8	1.030	0.164	0.841	26.5	27.6	28.9	246	533	752	463	774	285	511		
E	8	0.630	0.041	0.382	26.9	29.1	30.8	188	308	603	243	517	136	434		
F	8				29.4	30.5	31.1	228	417	619	129	173	49	66		

APPENDIX C. RAW DATA COLLECTED DURING WET WEATHER CONDITIONS.

SpC = specific conductance, FC = fecal coliform, EC = E. coli, ENT = Enterococci, NO3 = nitrate+nitrite nitrogen, NH3 = ammonia nitrogen, TP = total phosphorus.

Event	Site	Date	Time	Temp	SpC	Flow	FC	EC	ENT	NO3	NH3	TP
				°C	µS/cm	cfs	cfu/dL	cfu/dL	cfu/dL	mg/L	mg/L	mg/L
A	1	20-Mar	1030	18.0	334		10000	7200	10900	3.610	0.399	1.091
A	1	21-Mar	1100	19.8	230		3300	2000	2880			
A	1	22-Mar	1100	19.9	284		1880	720	960			
A	1	23-Mar	1100	21.3	374		980	720	7900			
A	1	24-Mar	1100	24.0	329		20000	20000	740			
B	1	28-Mar	935	20.4	924		1140	560	1540	4.480	0.712	0.388
B	1	29-Mar	932	18.5	243		5900	5500	17400			
B	1	30-Mar	950	18.4	197		2180	420	2200			
B	1	31-Mar	1011	20.4	239		1160	96	940			
B	1	1-Apr	1007	22.0	240		640	580	320			
C	1	4-May	1030				100	120	100	0.980	1.410	0.040
C	1	5-May	1015	25.9	9793		140	120	300			
C	1	6-May	1100	25.6	7945		68	44	106			
C	1	7-May	830	22.7	8766		72	46	132			
C	1	8-May	1030	26.2	7859		66	56	96			
C	1	9-May	1030	26.6	10660		42	18	30			
C	1	10-May	1010	24.1	10690		460	275	355	0.440	0.112	0.439
D	1	11-May	1330	28.4	1283		100	120	100	<1.000	0.149	0.051
D	1	12-May	1140	24.2	13400		120	120	240			
D	1	13-May	905	26.5	11700		160	80	160			
D	1	14-May	920	26.8	10800		140	100	100			
D	1	15-May	915	27.0	10830		158	144	280			
D	1	16-May	915	27.2	11290		154	108	110			
D	1	17-May	900	27.3	12450		50	36	26			
E	1	23-Jun	820	28.2	838		178	156	74	2.800	0.021	0.207
E	1	24-Jun	930	28.4	399		170	100	110			
E	1	25-Jun	800	28.3	466		124	56	78			
E	1	26-Jun	935	28.6	291		68	44	118			
E	1	27-Jun	1005	29.9	322		62	36	24			
E	1	28-Jun	1100	30.1	317		108	46	76			
E	1	30-Jun	1400	32.7	340		26	16	62	0.510	0.031	0.040
F	1	22-Jul	1315				500	200	140			
F	1	23-Jul	950				266	34	600			
F	1	24-Jul	1030	28.9	279		132	36	54			
F	1	25-Jul	1035	28.8	273		114	58	84			
F	1	26-Jul	930	28.9	203		28	14	20			
F	1	27-Jul	930	29.8	298		32	26	40			
F	1	28-Jul	940	29.9	322		16	8	1	0.200	0.049	0.284
B	2	28-Mar	1005	21.4	128		1520	1080	3680	0.410	<0.050	0.118
B	2	29-Mar	1020	19.5	236		5300	2160	16700			
B	2	30-Mar	1020	17.0	335		1640	1920	13600			
B	2	31-Mar	1029	19.7	320		1120	880	5700			
B	2	1-Apr	1024	22.7	354		460	440	1200			

Event	Site	Date	Time	Temp	SpC	Flow	FC	EC	ENT	NO3	NH3	TP
				°C	µS/cm	cfs	cfu/dL	cfu/dL	cfu/dL	mA/L	mA/L	mA/L
D	2	11-May	1400	27.8	1847		220	180	520	4.260	0.796	<0.040
D	2	12-May	1212	23.9	1989		200	180	300			
D	2	13-May	940	25.9	11650		240	160	160			
D	2	14-May	950	25.6	9280		220	160	100			
D	2	15-May	935	25.8	1246		36	24	100			
D	2	16-May	930	26.7	1639		34	30	64			
D	2	17-May	945	27.0	1812		62	44	98			
E	2	23-Jun	845	27.9	506		166	116	126	1.250	0.223	0.040
E	2	24-Jun	950	27.7	503		82	52	114			
E	2	25-Jun	915	28.0	517		114	60	100			
E	2	26-Jun	950	29.2	515		46	22	62			
E	2	27-Jun	1020	29.5	543		66	44	78			
E	2	28-Jun	1115	30.0	540		162	72	72			
A	3	20-Mar	1130	19.0	157		12800	9200	15700	4.900	0.314	0.949
A	3	21-Mar	1125	20.1	188		3500	2800	1280			
A	3	22-Mar	1130	20.7	189		580	440	480			
A	3	23-Mar	1126	22.4	214		360	320	320			
A	3	24-Mar	1115	23.1	230		280	120	300			
C	3	4-May	1010				60	20	200	1.880	0.957	0.078
C	3	5-May	1030	26.7	2355		160	120	160			
C	3	6-May	1130	26.0	1988		52	50	144			
C	3	7-May	900	24.0	3330		18	28	52			
C	3	8-May	1100	26.9	4240		7000	500	114			
C	3	9-May	1100	27.5	6313		70	54	74			
C	3	10-May	1040	25.9	6705		660	485	550	0.940	0.152	<0.040
F	3	22-Jul	1335				600	122	110			
F	3	23-Jul	1005				176	56	400			
F	3	24-Jul	1045	30.4	255		112	38	64			
F	3	25-Jul	1055	29.6	253		56	30	54			
F	3	26-Jul	945	29.6	256		60	54	60			
F	3	27-Jul	945	30.4	268		318	220	146			
F	3	28-Jul	950	30.8	270		58	22	76	0.300	0.116	0.346
B	4	28-Mar	1030	18.8	248		5600	4200		16.400	<0.05	0.778
B	4	29-Mar	1040	19.1	304		1500	940				
B	4	30-Mar	1040	16.3	467		1060	640				
B	4	31-Mar	1053	22.3	432		420	140				
B	4	1-Apr	1042	23.2	478		420	200				
D	4	11-May	1415	27.2	496		680	520		0.300	0.091	0.377
D	4	12-May	1230	23.9	609		460	300				
D	4	13-May	1000	23.5	632		420	440				
D	4	14-May	1000	25.5	633		440	380				
D	4	15-May	950	26.1	639		244	154				
D	4	16-May	940	26.4	707		152	94				
D	4	17-May	1000	26.8	719		210	118				
E	4	23-Jun	900	27.8	464		94	90		1.460	0.033	<0.040
E	4	24-Jun	1000	28.1	469		138	166				
E	4	25-Jun	930	27.3	467		132	68				

Event	Site	Date	Time	Temp	SpC	Flow	FC	EC	ENT	NO3	NH3	TP
E	4	26-Jun	1005	28.3	460		196	124				
				°C	µS/cm	cfs	cfu/dL	cfu/dL	cfu/dL	mA/L	mA/L	mA/L
E	4	27-Jun	1030	29.4	458		194	126				
E	4	28-Jun	1130	30.3	461		100	68				
A	5	20-Mar	1215	19.7	170	1580	7400	4900		5.700	0.314	0.712
A	5	21-Mar	1150	19.9	188	345	2100	1140				
A	5	22-Mar	1200	20.9	237	106	1000	300				
A	5	23-Mar	1150	22.7	333	49	620	420				
A	5	24-Mar	1140	24.9	490	49	480	340				
B	5	28-Mar	1100	17.8	165	1090	15100	8700		2.700	<0.050	1.006
B	5	29-Mar	1112	19.0	136	982	7600	2700				
B	5	30-Mar	1101	16.9	182	413	3200	1440				
B	5	31-Mar	1114	21.2	243	180	820	500				
B	5	1-Apr	1113	23.7	307	82	440	360				
C	5	4-May	940			76	1900	1160		1.840	0.806	0.606
C	5	5-May	1050	26.7	595	30	580	400				
C	5	6-May	1150	25.6	814	19	244	128				
C	5	7-May	930	23.0	950	17	216	108				
C	5	8-May	1120	27.0	1033	12	60	32				
C	5	9-May	1120	27.4	1133	11	130	72				
C	5	10-May	1100	26.0	1077	13	675	510		0.520	0.110	0.126
D	5	11-May	1435	26.7	291	105	1980	1000		1.320	0.126	0.781
D	5	12-May	1256	26.2	365	62	1140	620				
D	5	13-May	1020	26.4	495	49	800	420				
D	5	14-May	1015	27.3	598	31	980	520				
D	5	15-May	1010	27.2	739	20	172	94				
D	5	16-May	1000	28.4	870	21	278	208				
D	5	17-May	1015	27.8	958	17	170	90				
E	5	23-Jun	920	28.2	246	302	314	160		0.700	0.072	0.368
E	5	24-Jun	1015	28.2	278	185	218	126				
E	5	25-Jun	945	27.6	345	110	270	132				
E	5	26-Jun	1025	28.3	155	761	2500	1700				
E	5	27-Jun	1050	29.9	207	334	152	124				
E	5	28-Jun	1145	30.8	264	147	184	74				
E	5	30-Jun	1300	31.2	655	48	40	40		0.310	<0.020	0.251
F	5	22-Jul	1355			392	900	204				
F	5	23-Jul	1030			312	148	86				
F	5	24-Jul	1115	29.9	280	141	130	44				
F	5	25-Jul	1115	29.6	253	83	84	40				
F	5	26-Jul	1010	29.1	442	52	86	52				
F	5	27-Jul	1010	30.3	556	35	120	18				
F	5	28-Jul	1025	29.9	660	30	54	30		0.240	<0.040	0.209
A	6	20-Mar	1240	19.4	142		11600	8500		4.290	0.285	0.600
A	6	21-Mar	1150	19.9	188		1840	1000				
A	6	22-Mar	1215	21.0	219		840	380				
A	6	23-Mar	1206	22.3	316		320	300				
A	6	24-Mar	1155	24.9	495		280	300				
C	6	4-May	920				1680	1300		1.820	2.070	0.492

Event	Site	Date	Time	Temp	SpC	Flow	FC	EC	ENT	NO3	NH3	TP
				°C	µS/cm	cfs	cfu/dL	cfu/dL	cfu/dL	mA/L	mA/L	mA/L
C	6	5-May	1105	26.7	699		500	420				
C	6	6-May	1215	25.6	931		178	142				
C	6	7-May	945	22.9	947		224	124				
C	6	8-May	1135	26.5	1134		100	42				
C	6	9-May	1135	27.6	1255		96	66				
C	6	10-May	1125	25.7	1240		565	325		0.400	0.149	0.146
F	6	22-Jul	1405				300	148				
F	6	23-Jul	1045				168	48				
F	6	24-Jul	1140	29.9	284		124	16				
F	6	25-Jul	1130	29.5	371		84	30				
F	6	26-Jul	1030	28.8	495		136	48				
F	6	27-Jul	1025	29.9	626		78	12				
F	6	28-Jul	1050	29.8	704		40	32		0.150	<0.04	0.231
B	7	28-Mar	1145	17.6	105		14400	10100		4.300	<0.05	1.178
B	7	29-Mar	1125	19.3	152		1900	2080				
B	7	30-Mar	1122	17.1	183		1120	900				
B	7	31-Mar	1133	20.7	229		700	180				
B	7	1-Apr	1125	23.2	271		160	120				
D	7	11-May	1500	26.2	270		2140	1480		1.390	0.112	1.070
D	7	12-May	1320	25.8	371		460	320				
D	7	13-May	1030	26.1	433		500	300				
D	7	15-May	1035	27.2	598		134	84				
D	7	16-May	1015	28.5	691		190	176				
E	7	23-Jun	945	27.7	203		290	176		0.440	0.057	0.376
E	7	24-Jun	1030	28.3	256		132	84				
E	7	25-Jun	1005	28.1	303		94	62				
E	7	26-Jun	1035	28.2	134		1000	700				
E	7	27-Jun	1105	29.7	183		194	96				
E	7	28-Jun	1155	31.1	232		166	92				
A	8	20-Mar	1315	19.8	124		8100	4800		3.620	0.357	0.666
A	8	21-Mar	1235	20.6	163		1760	960				
A	8	22-Mar	1235	21.4	194		860	420				
A	8	23-Mar	1230	22.3	308		520	120				
A	8	24-Mar	1222	24.9	386		240	220				
B	8	28-Mar	1230	19.4	158		15000	9600		2.190	<0.050	0.821
B	8	29-Mar	1200	18.9	123		6200	2480				
B	8	30-Mar	1151	17.2	178		2120	920				
B	8	31-Mar	1158	20.4	197		520	200				
B	8	1-Apr	1147	23.2	233		240	280				
C	8	4-May	900				920	780		1.150	1.270	0.372
C	8	5-May	1125	27.7	623		280	260				
C	8	6-May	1242	26.6	749		228	88				
C	8	7-May	1015	23.3	845		280	100				
C	8	8-May	1210	28.6	864		600	800				
C	8	9-May	1210	27.7	864		126	50				
C	8	10-May	1150	26.5	690		385	100		0.250	0.104	0.207
D	8	11-May	1520	26.5	246		2500	1300		1.030	0.164	0.841

D	8	12-May	1342	26.5	383		1060	800				
Event	**Site**	**Date**	**Time**	**Temp**	**SpC**	**Flow**	**FC**	**EC**	**ENT**	**NO3**	**NH3**	**TP**
				°C	µS/cm	cfs	cfu/dL	cfu/dL	cfu/dL	mA/L	mA/L	mA/L
D	8	13-May	1045	27.2	397		640	560				
D	8	14-May	1040	28.3	515		760	680				
D	8	15-May	1055	27.5	691		164	106				
D	8	16-May	1030	28.6	744		168	86				
D	8	17-May	1045	28.9	752		128	42				
E	8	23-Jun	1010	26.9	264		308	252		0.630	0.041	0.382
E	8	24-Jun	1045	28.3	273		184	118				
E	8	25-Jun	1020	28.0	328		182	88				
E	8	26-Jun	1050	28.8	188		2500	2400				
E	8	27-Jun	1120	30.6	229		208	96				
E	8	28-Jun	1210	30.8	269		184	56				
E	8	30-Jun	1130	30.4	603		50	26		0.160	0.044	0.406
F	8	22-Jul	1420				390	172				
F	8	23-Jul	1105				78	60				
F	8	24-Jul	1210	30.4	228		108	30				
F	8	25-Jul	1150	30.6	304		142	32				
F	8	26-Jul	1050	29.4	405		82	30				
F	8	27-Jul	1045	31.0	528		370	120				
F	8	28-Jul	1125	31.1	619		42	18		0.370	<0.04	0.335

APPENDIX D. SUMMARY STATISTICS FOR ALL DRY EVENTS.

GM = Geometric mean, AM = arithmetic mean. NO3 = nitrate+nitrite nitrogen, NH3 = ammonia nitrogen, TP = total phosphorus. Nutrient information for events A and B are single data points, the remaining events are the average of first and last day results.

Event	Site	NO3 (mg/L)	NH3 (mg/L)	TP (mg/L)	Temperature (°C)			pH (SU)			Dissolved Oxygen (mg/L)			Specific Conductance (μS/cm)			Fecal Coliform (cfu/dL)		E. coli (cfu/dL)		Enterococci (cfu/dL)	
					min	mean	max	min	mean	max	min	mean	max	min	mean	max	GM	AM	GM	AM	GM	AM
G	1	2.29	0.419	0.273	18.82	20.05	21.53	7.49	7.83	8.27	7.77	8.21	8.71	1840	4454	6267	56	61	47	54	51	55
G	2	0.619	0.170	0.176	18.30	19.54	20.84	7.16	7.51	7.98	5.79	7.25	8.31	955	1157	1319	109	113	78	89	81	83
G	3	1.700	0.181	0.352	17.53	18.88	20.42	6.80	7.23	8.07	5.73	6.13	6.60	316	557	721	65	139	62	131	83	143
G	4	0.020	0.079	0.128	17.00	19.84	21.86	7.60	7.79	8.00	6.01	7.52	9.54	1421	1677	1832	50	68	27	60		
G	5	0.513	0.231	0.123	18.65	21.04	22.94	7.56	7.83	8.14	8.11	9.32	11.10	1047	1239	1362	99	117	88	101		
G	7	0.182	2.213	0.178	18.82	21.03	23.00	7.37	7.65	8.06	8.80	10.33	12.35	695	878	979	120	147	66	73		
G	8	1.670	0.543	0.390	19.46	21.36	23.12	7.17	7.62	8.00	7.81	8.86	10.90	737	915	982	88	119	69	97		
G	9	7.670	0.820	1.625	18.01	20.50	22.72	7.26	7.69	8.49	6.07	9.12	15.05	726	823	863	150	228	122	166		
H	1	2.880	0.204	0.289	18.45	20.19	21.50	7.09	7.78	8.13	5.47	7.61	8.54	338	11085	15632	302	382	192	221	295	365
H	2	0.520	0.077	0.102	17.88	19.70	20.72	7.19	7.42	7.66	3.65	4.97	7.06	478	5511	8965	60	77	29	38	90	116
H	3	2.405	0.217	0.260	18.81	20.15	21.39	7.02	7.54	7.88	4.17	6.66	8.53	270	5830	10195	52	94	21	22	61	87
H	4	0.445	0.559	0.122	13.72	19.09	21.97	7.33	7.52	7.76	4.51	5.88	8.34	642	1487	1833	57	76	21	21		
H	5	0.814	0.050	0.227	16.27	20.64	23.32	7.50	7.61	7.80	6.76	8.19	9.83	679	1058	1264	163	308	75	168		
H	8	1.280	0.088	0.308	16.49	20.50	23.15	7.16	7.52	7.74	6.63	8.19	10.73	537	745	858	173	254	85	157		
H	9	2.005	0.168	1.028	15.35	19.77	21.39	6.93	7.16	7.38	4.63	5.96	8.41	368	681	940	155	173	140	170		
H	10	3.975	0.192	1.434	16.73	20.30	21.90	7.28	7.49	7.98	5.84	7.54	10.98	471	733	901	392	611	268	508		
I	1	3.400	0.099	0.201	21.51	23.57	25.84	6.96	7.91	8.66	5.20	7.69	10.74	430	7089	11778	108	118	82	95	151	238
I	2	0.825	0.347	0.089	22.20	23.62	25.67	6.99	7.32	7.78	3.51	5.47	8.02	430	974	1101	32	35	32	34	720	1188
I	3	4.375	0.050	0.161	21.87	23.43	25.01	6.79	7.30	7.91	3.96	5.38	6.94	300	2301	3464	179	268	159	258	395	740
I	4	0.270	0.229	0.105	20.00	23.32	26.22	7.41	7.62	7.85	6.07	7.70	9.48	656	765	892	173	209	119	129		
I	5	1.150	0.050	0.170	23.20	24.88	26.95	7.56	7.87	8.16	7.57	10.15	12.21	899	1075	1273	78	83	62	71		
I	6	1.445	0.166	0.151	22.84	24.94	27.04	7.19	7.85	8.41	6.40	11.20	14.58	659	1013	1293	39	48	25	34		
I	7	0.695	0.050	0.100	22.06	24.41	26.87	7.46	7.52	7.61	6.47	8.03	10.07	809	965	1108	61	68	16	28		
I	8	2.095	0.817	0.246	24.12	25.45	27.86	7.49	7.95	8.58	6.82	10.67	14.77	726	813	934	36	84	44	80		
I	9	4.570	0.098	0.885	22.75	24.73	26.79	7.03	7.50	7.84	4.62	7.87	9.62	508	697	779	40	49	36	40		
I	10	8.065	0.054	1.543	22.16	24.54	26.29	7.31	7.71	8.00	6.12	7.99	9.56	705	802	925	63	80	55	62		
J	1	1.210	0.089	0.247	25.64	28.12	28.89	6.50	7.14	7.40	3.14	4.59	5.32	380	598	759	108	237	67	234	188	622
J	2	0.630	0.149	0.084	26.91	27.93	29.19	6.86	7.28	7.46	3.49	4.98	5.89	392	604	1060	177	306	104	202	513	729
J	3	0.990	0.058	0.193	28.04	29.14	30.01	6.53	7.05	7.34	1.95	3.31	5.27	284	390	504	102	148	58	96	309	781

Event	Site	NO3 (mg/L)	NH3 (mg/L)	TP (mg/L)	Temperature (°C)			pH (SU)			Dissolved Oxygen (mg/L)			Specific Conductance (µS/cm)			Fecal Coliform (cfu/dL)		E. coli (cfu/dL)		Enterococci (cfu/dL)	
					min	mean	max	min	mean	max	min	mean	max	min	mean	max	GM	AM	GM	AM	GM	AM
J	4	0.135	0.042	0.106	26.50	27.48	28.30	7.16	7.52	7.82	4.93	6.29	6.94	369	431	483	187	386	202	676		
J	5	0.080	0.050	0.166	27.46	28.19	29.60	7.35	7.71	8.04	6.04	6.94	7.52	403	656	863	195	723	155	580		
J	6	0.180	0.030	0.175	27.70	28.27	29.45	7.32	7.55	7.93	5.65	6.77	7.87	361	645	851	260	839	169	551		
J	7	0.275	0.030	0.063	27.03	28.23	29.27	6.93	7.32	7.57	4.92	5.83	6.43	599	667	732	106	178	52	119		
J	8	0.465	0.050	0.260	27.57	28.69	30.68	7.17	7.58	8.02	5.11	6.38	8.06	378	600	770	437	903	245	688		
J	9	2.620	0.212	0.870	26.53	27.39	28.38	7.02	7.14	7.41	5.05	5.44	5.98	296	395	418	808	4321	530	2446		
J	10	1.545	1.065	2.008	25.48	27.51	29.13	6.82	7.19	7.81	3.53	5.36	6.60	232	404	804	1007	3964	596	2928		
K	1	0.190	0.030	0.176	30.07	30.57	31.11	7.30	7.45	7.67	4.58	6.88	9.96	422	450	497	14	24	9	15	66	67
K	2	0.260	0.030	0.067	28.28	28.76	29.33	7.40	7.50	7.56	4.86	6.89	10.00	467	575	672	41	51	30	36	108	109
K	3	0.405	0.030	0.210	29.93	30.50	31.02	7.03	7.43	7.95	3.95	6.43	9.34	313	487	723	19	22	11	14	56	62
K	4	0.020	0.030	0.040	26.84	27.88	28.55	7.64	7.75	7.86	7.02	8.83	10.65	473	492	526	141	147	115	121		
K	5	0.135	0.030	0.087	28.92	29.49	30.05	7.68	7.76	7.83	6.50	9.50	13.41	398	647	906	72	84	52	57		
K	6	0.150	0.030	0.105	28.59	29.50	30.54	7.56	7.63	7.68	6.34	9.22	13.07	393	663	957	95	106	37	40		
K	7	0.130	0.030	0.040	29.00	29.96	30.91	7.32	7.54	7.70	6.38	8.05	10.16	500	602	660	76	84	43	52		
K	8	0.475	0.031	0.229	28.56	29.70	30.71	7.33	7.60	7.82	5.17	8.33	13.20	264	554	791	188	242	92	121		
K	9	2.080	0.052	0.597	27.94	28.74	29.38	7.52	7.59	7.66	6.10	8.13	10.73	408	516	655	100	128	52	72		
K	10	3.670	0.042	0.909	28.47	29.24	29.62	7.56	7.63	7.72	6.91	8.75	10.74	430	642	788	126	155	70	86		
L	1	0.110	0.020	0.710	29.1	30.13	30.72	7.77	7.84	7.90	4.12	5.11	5.87	2284	5712	8156	18	57	10	27	32	146
L	2	0.055	0.059	0.041	27.92	28.46	7.61	7.48	7.54	7.61	0.83	2.83	4.46	685	1020	2056	47	62	25	31	222	364
L	3	0.100	0.059	0.133	29.81	30.28	7.58	7.33	7.50	7.58	3.16	3.79	4.25	563	1755	4054	32	34	18	19	133	254
L	4	0.035	0.020	0.040	26.65	26.87	27.06	7.77	7.85	7.99	5.34	6.17	6.3	676	726	784	69	81	42	48		
L	5	0.020	0.020	0.083	27.81	28.78	29.74	7.77	7.94	8.21	5.66	6.82	8.72	873	975	1066	69	71	44	47		
L	6	0.020	0.012	0.158	27.58	28.65	29.54	7.66	7.86	8.22	5.34	6.79	8.75	871	981	1090	111	121	39	48		
L	8	0.270	0.024	0.160	27.66	28.91	30.23	7.69	7.89	8.32	5.33	7.13	11.31	685	818	920	170	188	48	55		
L	9	0.825	0.020	0.298	26.43	27.04	27.71	7.53	7.59	7.74	4.60	5.58	5.83	631	691	807	145	151	119	130		
L	10	4.240	0.013	0.563	27.00	27.80	28.85	7.52	7.74	7.96	4.34	6.23	7.64	752	834	908	110	123	62	68		

APPENDIX E. RAW DATA COLLECTED DURING DRY WEATHER CONDITIONS.

DO = dissolved oxygen, SpC = specific conductance, FC = fecal coliform, EC = E. coli, ENT = Enterococci, NO3 = nitrate+nitrite nitrogen, NH3 = ammonia nitrogen, TP = total phosphorus.

Event	Site	Date	Time	Temp	pH	DO	SpC	Flow	FC	EC	ENT	NO3	NH3	TP
				°C	SU	mg/L	µS/cm	cfs	cfu/dL	cfu/dL	cfu/dL	mg/L	mg/L	mg/L
G	**1**	28-Jan	835	18.82	7.49	8.34	1840		55	25	65	2.290	0.419	0.273
G	**1**	2-Feb	1255	18.88	8.02	7.79	3798		70	60	30			
G	**1**	4-Feb	1035	19.73	8.27	8.46	4313		105	105	90			
G	**1**	9-Feb	1055	21.31	7.64	7.77	6267		35	30	45			
G	**1**	10-Feb	1010	21.53	7.74	8.71	6050		40	50	45			
G	**2**	28-Jan	925	18.68	7.55	7.65	955		155	95	100	0.619	0.170	0.176
G	**2**	2-Feb	1310	18.30	7.59	7.75	1123		110	95	75			
G	**2**	4-Feb	1050	19.31	7.98	8.31	1150		80	40	55			
G	**2**	9-Feb	1105	20.59	7.16	6.73	1319		135	165	80			
G	**2**	10-Feb	1020	20.84	7.29	5.79	1237		85	50	105			
G	**3**	28-Jan	905	17.53	7.01	6.02	316		495	485	490	1.700	0.181	0.352
G	**3**	2-Feb	1340	18.12	7.30	6.60	498		85	65	60			
G	**3**	4-Feb	1025	18.43	8.07	6.30	506		50	25	70			
G	**3**	9-Feb	1045	19.89	6.80	5.73	721		10	20	30			
G	**3**	10-Feb	1000	20.42	6.97	5.98	744		55	60	65			
G	**4**	28-Jan	945	19.50	7.72	7.38	1421		95	90		0.020	0.079	0.128
G	**4**	2-Feb	1320	17.00	7.95	9.54	1626		20	60				
G	**4**	4-Feb	1100	19.01	8.00	8.14	1701		35	1				
G	**4**	9-Feb	1115	21.84	7.67	6.01	1832		160	130				
G	**4**	10-Feb	1025	21.86	7.60	6.51	1804		30	20				
G	**5**	28-Jan	1005	20.49	7.78	8.68	1047	10.0	275	225		0.513	0.231	0.123
G	**5**	2-Feb	1350	18.65	8.06	11.10	1221	8.0	90	75				
G	**5**	4-Feb	1110	20.64	8.14	10.30	1253	7.6	80	75				
G	**5**	9-Feb	1135	22.94	7.56	8.42	1362	7.3	75	65				
G	**5**	10-Feb	1035	22.50	7.59	8.11	1310	7.0	65	65				
G	**7**	28-Jan	830	20.17	7.54	8.80	885		150	90		0.182	2.213	0.178
G	**7**	2-Feb	1410	18.82	7.67	11.14	695		295	105				
G	**7**	4-Feb	1120	20.33	8.06	12.35	826		175	75				
G	**7**	9-Feb	1150	23.00	7.60	9.81	979		70	70				
G	**7**	10-Feb	1045	22.84	7.37	9.57	1007		45	25				
G	**8**	28-Jan	910	20.32	7.17	8.38	737		240	220		1.670	0.543	0.390
G	**8**	2-Feb	1430	19.46	8.00	10.90	982		50	70				
G	**8**	4-Feb	1150	21.15	7.98	9.39	940		205	140				
G	**8**	9-Feb	1215	23.12	7.51	7.81	965		70	35				
G	**8**	10-Feb	1055	22.73	7.43	7.82	949		30	20				
G	**9**	28-Jan	955	19.82	7.26	7.67	838		645	455		7.670	0.820	1.625
G	**9**	2-Feb	1445	18.01	8.49	15.05	791		40	70				
G	**9**	4-Feb	1205	19.73	8.06	9.69	726		95	55				
G	**9**	9-Feb	1235	22.72	7.38	7.10	863		145	145				
G	**9**	10-Feb	1120	22.24	7.27	6.07	895		215	105				
H	**1**	4-Mar	845	18.45	8.13	8.50	13892		105	85	90	0.400	0.050	0.141
H	**1**	10-Mar	845	20.81	7.95	7.79	12519		600	230	300			
H	**1**	11-Mar	825	21.50	7.78	7.73	13042		245	185	350			
H	**1**	18-Mar	830	19.25	7.96	8.54	15632		220	165	305			
H	**1**	25-Mar	1015	20.95	7.09	5.47	338		740	440	780	5.360	0.358	0.437

Event	Site	Date	Time	Temp	pH	DO	SpC	Flow	FC	EC	ENT	NO3	NH3	TP
				°C	SU	mg/L	µS/cm	cfs	cfu/dL	cfu/dL	cfu/dL	mg/L	mg/L	mg/L
H	**2**	4-Mar	900	17.88	7.66	7.06	5575		30	15	25	0.400	0.050	0.108
H	**2**	10-Mar	855	20.19	7.50	4.22	7164		185	25	70			
H	**2**	11-Mar	840	20.52	7.42	4.50	5375		80	35	90			
H	**2**	18-Mar	845	19.21	7.35	5.43	8965		30	15	155			
H	**2**	25-Mar	1030	20.72	7.19	3.65	478		60	100	240	0.640	0.103	0.095
H	**3**	4-Mar	830	18.81	7.88	8.53	5647		35	20	40	0.400	0.050	0.096
H	**3**	10-Mar	830	20.51	7.62	6.42	6661		95	30	35			
H	**3**	11-Mar	815	20.79	7.45	6.59	6379		15	25	60			
H	**3**	18-Mar	815	19.26	7.72	7.59	10195		25	15	40			
H	**3**	25-Mar	1000	21.39	7.02	4.17	270		300	20	260	4.410	0.384	0.423
H	**4**	4-Mar	915	13.72	7.76	8.34	1461		20	15		0.020	0.050	0.082
H	**4**	10-Mar	910	20.27	7.33	5.55	1745		180	25				
H	**4**	11-Mar	900	20.79	7.47	4.51	1755		40	25				
H	**4**	18-Mar	900	18.71	7.56	5.23	1833		40	20				
H	**4**	25-Mar	1050	21.97	7.47	5.77	642		100	20		0.870	1.068	0.161
H	**5**	4-Mar	930	16.27	7.80	9.83	1230	7.0	35	35		0.128	0.050	0.161
H	**5**	10-Mar	930	21.82	7.62	8.12	1264	7.6	95	40				
H	**5**	11-Mar	920	22.07	7.54	6.76	1128	10.0	1045	610				
H	**5**	18-Mar	915	19.74	7.50	8.24	987	10.0	165	135				
H	**5**	25-Mar	1120	23.32	7.58	8.01	679	19.0	200	20		1.500	0.050	0.292
H	**8**	4-Mar	1010	16.49	7.74	10.73	858		20	5		1.510	0.106	0.263
H	**8**	10-Mar	1005	21.64	7.64	8.58	773		220	220				
H	**8**	11-Mar	940	21.62	7.16	6.63	792		220	70				
H	**8**	18-Mar	945	19.62	7.48	7.68	764		350	190				
H	**8**	25-Mar	1150	23.15	7.57	7.31	537		460	300		1.050	0.069	0.352
H	**9**	4-Mar	1030	15.35	7.38	8.41	688		120	130		1.530	0.210	1.440
H	**9**	10-Mar	1030	21.24	7.16	5.70	940		150	110				
H	**9**	11-Mar	1000	21.18	7.16	4.63	909		75	50				
H	**9**	18-Mar	1030	19.71	6.93	5.08	501		280	340				
H	**9**	25-Mar	1230	21.39	7.19	5.98	368		240	220		2.480	0.125	0.615
H	**10**	4-Mar	1100	16.73	7.98	10.98	805		155	95		5.720	0.218	2.147
H	**10**	10-Mar	1050	21.46	7.52	7.21	747		1900	1800				
H	**10**	11-Mar	1030	21.36	7.34	5.84	901		460	330				
H	**10**	18-Mar	1100	20.06	7.28	7.09	743		200	135				
H	**10**	25-Mar	1250	21.90	7.33	6.56	471		340	180		2.230	0.166	0.721
I	**1**	7-Apr	900	23.11	6.96	5.20	430		160	80	460	5.190	0.121	0.313
I	**1**	12-Apr	1300	25.84	7.12	6.36	949		169	204	500			
I	**1**	19-Apr	1125	21.51	8.46	10.74	8472		50	40	36			
I	**1**	21-Apr	1130	21.96	8.66	9.49	11778		94	72	100			
I	**1**	26-Apr	1130	25.43	8.36	6.64	13816		118	80	96	1.610	0.077	0.089
I	**2**	7-Apr	935	22.56	6.99	4.85	430		20	20	2440	0.630	0.292	0.095
I	**2**	12-Apr	1315	25.35	7.44	5.30	1023		45	46	2200			
I	**2**	19-Apr	1135	22.31	7.28	5.68	1009		38	40	600			
I	**2**	21-Apr	1140	22.20	7.78	8.02	1101		52	26	600			
I	**2**	26-Apr	1145	25.67	7.10	3.51	1308		18	36	100	1.020	0.401	0.082
I	**3**	7-Apr	845	21.87	6.79	3.96	300		60	40	1760	6.730	0.050	0.242
I	**3**	12-Apr	1245	24.81	6.88	5.21	337		800	800	1400			

Event	Site	Date	Time	Temp	pH	DO	SpC	Flow	FC	EC	ENT	NO3	NH3	TP
				°C	SU	mg/L	µS/cm	cfs	cfu/dL	cfu/dL	cfu/dL	mg/L	mg/L	mg/L
I	**3**	19-Apr	1115	22.24	7.32	4.98	2202		120	182	300			
I	**3**	21-Apr	1120	23.20	7.61	5.80	3464		208	138	160			
I	**3**	26-Apr	1115	25.01	7.91	6.94	5203		152	128	81	2.020	0.050	0.079
I	**4**	7-Apr	1000	23.06	7.41	6.07	892		100	80		0.100	0.050	0.138
I	**4**	12-Apr	1330	26.22	7.85	9.48	718		166	159				
I	**4**	19-Apr	1145	20.00	7.60	8.36	846		500	220				
I	**4**	21-Apr	1150	22.39	7.78	8.31	713		164	98				
I	**4**	26-Apr	1200	24.91	7.45	6.28	656		114	88		0.440	0.408	0.072
I	**5**	7-Apr	1020	24.73	7.56	7.57	1027	19.0	100	120		1.040	0.050	0.156
I	**5**	12-Apr	1345	26.95	7.97	12.21	1082	9.9	43	26				
I	**5**	19-Apr	1155	23.20	7.86	10.52	1273	9.9	74	62				
I	**5**	21-Apr	1205	24.08	8.16	12.17	1095	9.9	68	46				
I	**5**	26-Apr	1215	25.44	7.78	8.27	899	15.0	132	102		1.260	0.050	0.183
I	**6**	7-Apr	1045	24.64	7.19	6.40	659		40	40		1.070	0.050	0.119
I	**6**	12-Apr	1400	27.04	7.95	12.80	1116		33	28				
I	**6**	19-Apr	1225	22.84	7.91	12.24	1293		20	6				
I	**6**	21-Apr	1240	24.76	8.41	14.58	1026		30	20				
I	**6**	26-Apr	1230	25.40	7.79	9.97	970		118	74		1.820	0.282	0.182
I	**7**	7-Apr	1100	24.52	7.46	7.02	1108		60	1		1.070	0.050	0.159
I	**7**	12-Apr	1415	26.87	7.47	10.07	809		77	37				
I	**7**	19-Apr	1210	22.06	7.55	8.38	941		104	52				
I	**7**	21-Apr	1230	23.63	7.61	8.19	973		24	16				
I	**7**	26-Apr	1240	24.98	7.53	6.47	996		76	36		0.320	0.050	0.040
I	**8**	7-Apr	1120	24.89	7.49	6.82	726		20	60		0.950	0.050	0.251
I	**8**	12-Apr	1430	27.86	8.02	11.73	767		18	20				
I	**8**	19-Apr	1240	24.12	7.91	11.00	934		12	16				
I	**8**	21-Apr	1305	25.63	8.58	14.77	744		40	32				
I	**8**	26-Apr	1300	24.77	7.75	9.04	894		328	272		3.240	1.583	0.240
I	**9**	7-Apr	1150	24.07	7.03	4.62	508		20	40		3.480	0.068	0.739
I	**9**	12-Apr	1545	26.79	7.48	9.62	779		42	19				
I	**9**	19-Apr	1300	22.75	7.52	9.44	605		38	34				
I	**9**	21-Apr	1330	25.42	7.84	8.80	707		118	72				
I	**9**	26-Apr	1330	24.61	7.61	6.87	888		26	34		5.660	0.127	1.030
I	**10**	7-Apr	1215	24.65	7.31	6.12	735		80	60		10.000	0.058	1.395
I	**10**	12-Apr	1600	26.29	8.00	8.95	925		80	44				
I	**10**	19-Apr	1330	22.16	7.72	9.56	705		20	38				
I	**10**	21-Apr	1400	25.28	7.98	9.06	813		44	40				
I	**10**	26-Apr	1400	24.31	7.56	6.25	831		178	126		6.130	0.050	1.690
J	**1**	9-Jun	940	28.60	7.13	4.96	759		124	80	230	1.870	0.146	0.242
J	**1**	14-Jun	1055	28.89	7.40	4.93	570		68	48	178			
J	**1**	15-Jun	1045	28.76	7.40	5.32	727		30	10	30			
J	**1**	6-Jul	1045	25.64	7.28		554		64	34	74			
J	**1**	7-Jul	930	28.71	6.50	3.14	380		900	1000	2600	0.550	0.031	0.252
J	**2**	9-Jun	950	27.78	7.24	5.89	496		254	142	1000	1.110	0.277	0.117
J	**2**	14-Jun	1045	29.19	7.46	3.49	1060		122	100	1300			
J	**2**	15-Jun	1100	27.80	7.40	5.73	512		100	30	360			
J	**2**	6-Jul	1055	27.95	7.46		558		56	40	84			

Event	Site	Date	Time	Temp	pH	DO	SpC	Flow	FC	EC	ENT	NO3	NH3	TP
				°C	SU	mg/L	µS/cm	cfs	cfu/dL	cfu/dL	cfu/dL	mg/L	mg/L	mg/L
J	**2**	7-Jul	940	26.91	6.86	4.80	392		1000	700	900	0.150	0.020	0.051
J	**3**	9-Jun	950	28.04	6.93	5.27	341		248	184	1400	1.380	0.050	0.229
J	**3**	14-Jun	1030	29.04	7.34	1.95	504		78	42	146			
J	**3**	15-Jun	1030	28.98	7.23	3.69	452		20	10	70			
J	**3**	6-Jul	1030	30.01	7.22		284		96	42	90			
J	**3**	7-Jul	915	29.64	6.53	2.31	371		300	200	2200	0.600	0.066	0.157
J	**4**	9-Jun	1000	26.50	7.37	6.92	369		200	200		0.230	0.058	0.172
J	**4**	14-Jun	1105	27.57	7.61	6.37	409		1400	2900				
J	**4**	15-Jun	1115	28.30	7.62	6.94	406		200	160				
J	**4**	6-Jul	1100	28.19	7.82		483		50	58				
J	**4**	7-Jul	950	26.86	7.16	4.93	490		82	62		0.040	0.025	0.040
J	**5**	9-Jun	1030	27.46	7.63	7.52	863	15.0	25	30		0.020	0.080	0.207
J	**5**	14-Jun	1120	27.67	7.54	6.04	403	108.0	3100	2500				
J	**5**	15-Jun	1130	28.69	7.99	6.66	462	71.0	240	220				
J	**5**	6-Jul	1120	29.60	8.04		784	28.0	150	66				
J	**5**	7-Jul	1020	27.52	7.35	7.52	767	30.0	102	83		0.140	0.020	0.124
J	**6**	9-Jun	1050	27.72	7.62	7.87	851		54	50		0.020	0.040	0.220
J	**6**	14-Jun	1150	27.70	7.49	5.65	361		3500	2200				
J	**6**	15-Jun	1145	28.76	7.40	6.42	445		340	320				
J	**6**	6-Jul	1130	29.45	7.93		783		218	158				
J	**6**	7-Jul	1030	27.73	7.32	7.15	786		85	25		0.340	0.020	0.130
J	**7**	9-Jun	1100	27.03	7.20	6.43	732		500	400		0.180	0.040	0.086
J	**7**	14-Jun	1140	29.23	7.56	5.78	605		218	124				
J	**7**	15-Jun	1200	29.27	7.57	6.18	599		90	10				
J	**7**	6-Jul	1145	28.44	7.35		694		58	44				
J	**7**	7-Jul	1040	27.18	6.93	4.92	707		23	18		0.370	0.020	0.040
J	**8**	9-Jun	1120	28.30	7.91	8.06	770		600	500		0.020	0.040	0.301
J	**8**	14-Jun	1210	27.89	7.17	5.11	378		3100	2500				
J	**8**	15-Jun	1215	29.02	7.40	6.05	496		510	320				
J	**8**	6-Jul	1230	30.68	8.02		676		234	100				
J	**8**	7-Jul	1100	27.57	7.39	6.31	679		72	22		0.910	0.060	0.219
J	**9**	9-Jun	1145	26.96	7.02	5.59	296		2600	1600		2.680	0.305	1.200
J	**9**	14-Jun	1230	28.16	7.02	5.13	401		270	162				
J	**9**	15-Jun	1245	28.38	7.41	5.98	418		200	180				
J	**9**	6-Jul	1245	26.90	7.17		330		18400	10200				
J	**9**	7-Jul	1120	26.53	7.10	5.05	531		133	88		2.560	0.118	0.539
J	**10**	9-Jun	1215	27.31	7.18	5.84	406		600	300		1.070	1.910	0.835
J	**10**	14-Jun	1245	29.13	7.15	6.60	343		82	68				
J	**10**	15-Jun	1300	25.48	6.97	5.45	235		8200	6400				
J	**10**	6-Jul	1300	28.88	7.81		804		240	74				
J	**10**	7-Jul	1145	26.73	6.82	3.53	232		10700	7800		2.020	0.220	3.180
K	**1**	12-Jul	1145	30.07	7.36	4.58	428		58	26	60	0.310	0.020	0.108
K	**1**	13-Jul	1145	30.22	7.51	4.74	475		40	28	86			
K	**1**	14-Jul	1025	30.48	7.67	5.44	497		14	18	74			
K	**1**	2-Aug	1015	31.11	7.30	9.70	422		8	2	52			
K	**1**	3-Aug	900	30.97	7.39	9.96	428		0	2	62	0.070	<0.04	0.244
K	**2**	12-Jul	1150	28.33	7.43	4.87	467		76	40	106	0.480	0.020	0.093

Event	Site	Date	Time	Temp	pH	DO	SpC	Flow	FC	EC	ENT	NO3	NH3	TP
				°C	SU	mg/L	µS/cm	cfs	cfu/dL	cfu/dL	cfu/dL	mg/L	mg/L	mg/L
K	**2**	13-Jul	1200	28.28	7.54	4.86	529		94	76	88			
K	**2**	14-Jul	1040	28.68	7.55	5.12	550		48	24	132			
K	**2**	2-Aug	1030	29.33	7.40	9.62	658		16	12	126			
K	**2**	3-Aug	915	29.16	7.56	10.00	672		20	26	94	0.040	<0.04	<0.04
K	**3**	12-Jul	1130	29.93	7.27	3.95	386		40	24	38	0.460	0.020	0.110
K	**3**	13-Jul	1130	30.50	7.84	5.20	723		18	6	56			
K	**3**	14-Jul	1015	30.20	7.95	5.24	697		34	20	32			
K	**3**	2-Aug	1000	31.02	7.03	9.34	313		12	16	102			
K	**3**	3-Aug	845	30.87	7.06	8.41	318		8	4	82	0.350	<0.04	0.309
K	**4**	12-Jul	1200	28.19	7.72	7.25	473		168	120		0.020	0.020	0.040
K	**4**	13-Jul	1220	28.55	7.84	7.02	473		150	70				
K	**4**	14-Jul	1055	28.36	7.86	8.88	473		108	112				
K	**4**	2-Aug	930	27.45	7.64	10.65	514		212	192				
K	**4**	3-Aug	1045	26.84	7.71	10.37	526		98	112		0.020	<0.04	<0.04
K	**5**	12-Jul	1215	29.23	7.77	7.21	535	72.0	124	100		0.200	0.020	0.133
K	**5**	13-Jul	1240	30.05	7.68	6.50	398	77.0	154	72				
K	**5**	14-Jul	1115	29.58	7.75	8.30	535	61.0	64	38				
K	**5**	2-Aug	1100	29.65	7.76	12.10	861	16.0	38	36				
K	**5**	3-Aug	945	28.92	7.83	13.41	906	15.0	42	40		0.070	<0.04	<0.04
K	**6**	12-Jul	1230	29.00	7.62	6.79	508		162	68		0.240	0.020	0.154
K	**6**	13-Jul	1315	30.54	7.56	6.34	393		146	52				
K	**6**	14-Jul	1205	29.77	7.68	7.82	537		104	28				
K	**6**	2-Aug	1115	29.60	7.65	12.08	920		42	24				
K	**6**	3-Aug	1000	28.59	7.66	13.07	957		74	30		0.060	<0.04	0.056
K	**7**	12-Jul	1240	29.56	7.61	6.38	653		120	110		0.05	0.020	0.040
K	**7**	13-Jul	1300	30.81	7.66	6.46	500		122	68				
K	**7**	14-Jul	1155	30.91	7.70	7.51	555		86	32				
K	**7**	2-Aug	1130	29.51	7.32	9.72	640		34	20				
K	**7**	3-Aug	1015	29.00	7.43	10.16	660		60	32		0.210	<0.04	<0.04
K	**8**	12-Jul	1300	28.56	7.33	5.17	264		600	300		0.290	0.021	0.268
K	**8**	13-Jul	1345	30.71	7.46	5.51	425		108	48				
K	**8**	14-Jul	1230	30.00	7.59	7.29	529		110	46				
K	**8**	2-Aug	1145	30.20	7.82	13.20	760		122	72				
K	**8**	3-Aug	1030	29.03	7.80	10.48	791		270	138		0.660	<0.04	0.190
K	**9**	12-Jul	1315	28.42	7.56	6.10	408		194	80		1.060	0.063	0.433
K	**9**	13-Jul	1410	29.35	7.60	6.22	415		264	188				
K	**9**	14-Jul	1250	29.38	7.66	7.79	457		92	36				
K	**9**	2-Aug	1200	28.63	7.52	10.73	644		46	22				
K	**9**	3-Aug	1045	27.94	7.59	9.80	655		46	32		3.100	<0.04	0.761
K	**10**	12-Jul	1330	29.41	7.56	6.91	430		62	60		1.790	0.063	0.548
K	**10**	13-Jul	1420	29.62	7.63	7.17	537		88	50				
K	**10**	14-Jul	1305	29.47	7.67	8.48	713		376	220				
K	**10**	2-Aug	1215	29.24	7.57	10.45	744		134	44				
K	**10**	3-Aug	1100	28.47	7.72	10.74	788		114	56		5.550	0.020	1.270
L	**1**	18-Aug	815	30.72	7.86	5.64	2284		7	1	49	0.200	<.020	<.040
L	**1**	24-Aug	830	29.10	7.77	4.64	5835		90	78	1			
L	**1**	25-Aug	815	29.72	7.85	5.87	5581		176	42	600			

Event	Site	Date	Time	Temp	pH	DO	SpC	Flow	FC	EC	ENT	NO3	NH3	TP
				°C	SU	mg/L	µS/cm	cfs	cfu/dL	cfu/dL	cfu/dL	mg/L	mg/L	mg/L
L	**1**	30-Aug	1020	30.54	7.90	5.27	6702		8	4	66			
L	**1**	1-Sep	1125	30.59	7.80	4.12	8156		2	8	16	<0.020	<0.020	0.137
L	**2**	18-Aug	840	28.81	7.61	4.46	685		74	42	126	0.050	0.035	<0.040
L	**2**	24-Aug	845	27.92	7.59	3.41	723		93	67	1000			
L	**2**	25-Aug	830	28.21	7.51	0.83	803		104	22	500			
L	**2**	30-Aug	1030	28.70	7.50	3.16	835		12	12	122			
L	**2**	1-Sep	1135	28.66	7.48	2.31	2056		28	12	70	0.060	0.082	0.041
L	**3**	18-Aug	800	30.96	7.33	3.16	563		50	14	53	0.150	0.079	<0.040
L	**3**	24-Aug	815	29.81	7.53	3.51	724		37	31	700			
L	**3**	25-Aug	800	30.00	7.56	3.55	762		27	22	400			
L	**3**	30-Aug	1010	30.03	7.58	4.25	2670		16	16	82			
L	**3**	1-Sep	1115	30.60	7.51	4.48	4054		40	14	34	0.050	0.039	0.133
L	**4**	18-Aug	850	27.06	7.80	6.00	676		96	79		<0.02	<0.02	<0.040
L	**4**	24-Aug	850	26.92	7.78	5.52	705		87	82				
L	**4**	25-Aug	845	26.80	7.77	5.34	731		150	27				
L	**4**	30-Aug	1045	26.93	7.89	6.30	784		48	30				
L	**4**	1-Sep	1145	26.65	7.99	7.68	733		26	24		0.050	<0.02	<0.040
L	**5**	18-Aug	910	28.80	7.77	6.23	1065	15	62	33		<0.02	<0.02	<0.040
L	**5**	24-Aug	900	27.81	7.85	6.54	931	12	52	37				
L	**5**	25-Aug	900	28.14	7.81	5.66	939	16	87	33				
L	**5**	30-Aug	1105	29.39	8.21	8.72	873	12	66	64				
L	**5**	1-Sep	1215	29.74	8.04	6.94	1066	9	86	66		<0.020	<0.020	0.161
L	**6**	18-Aug	925	28.62	7.66	5.34	1057		200	71		<0.020	0.022	0.055
L	**6**	24-Aug	920	27.58	7.71	5.89	946		123	34				
L	**6**	25-Aug	915	28.14	7.81	5.66	939		132	18				
L	**6**	30-Aug	1120	29.54	8.22	8.75	871		50	24				
L	**6**	1-Sep	1240	29.35	7.90	8.30	1090		102	92		<0.02	<0.02	0.262
L	**8**	18-Aug	1000	28.86	7.83	5.99	864		100	54		0.35	0.025	0.09
L	**8**	24-Aug	945	27.73	7.69	5.75	796		226	40				
L	**8**	25-Aug	930	27.66	7.74	5.33	685		100	31				
L	**8**	30-Aug	1142	30.23	8.32	11.31	823		190	32				
L	**8**	1-Sep	1300	30.05	7.88	7.27	920		326	120		0.190	0.023	0.229
L	**9**	18-Aug	1025	27.29	7.61	5.48	658		114	69		0.510	<0.020	0.135
L	**9**	24-Aug	1010	26.43	7.53	5.83	807		175	160				
L	**9**	25-Aug	945	26.54	7.54	5.33	685		146	113				
L	**9**	30-Aug	1215	27.24	7.55	4.60	631		102	84				
L	**9**	1-Sep	1330	27.71	7.74	6.65	674		218	226		1.140	<0.020	0.461
L	**10**	18-Aug	1040	27.40	7.77	5.39	840		44	40		4.870	0.023	0.258
L	**10**	24-Aug	1020	27.00	7.52	4.99	822		153	103				
L	**10**	25-Aug	1010	27.19	7.53	4.34	846		98	42				
L	**10**	30-Aug	1230	28.85	7.92	7.64	908		190	56				
L	**10**	1-Sep	1345	28.54	7.96	8.81	752		130	98		3.600	<0.02	0.867