Nutrient Effects in Small Brazos Basin Streams Historical Data Review

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List of Acronyms

Acronym	Definition
$CBOD_5$	Carbonaceous Biochemical Oxygen Demand (5-day incubation)
cfs	Cubic Feet Per Second
DO	Dissolved Oxygen
MTBE	Methyl-tert-butyl ether
PCS	Permit Compliance System
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TPDES	Texas Pollution Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSS	Total Suspended Solids
TSSWCB	Texas State Soil and Water Conservation Board
VSS	Volatile Suspended Solids

Introduction

Background

Increased pollutant loadings resulting from urban and agricultural development can lead to nutrient enrichment. Nutrient enrichment in streams may increase levels of dissolved nutrients in surface water, or algal, macrophyte, and bacterial communities can assimilate the added nutrients. Excessive growth of algae and aquatic macrophytes can cause swings in dissolved oxygen (DO) and pH to levels that are harmful to aquatic life. To address these issues, the United States Environmental Protection Agency (EPA) is requiring the states to establish numeric criteria for nutrient parameters. While considerable data is available for reservoirs, very little is known about nutrient effects in smaller streams.

The project will add to the body of data relating to the effects of nutrient enrichment in small streams. Similar studies have been conducted in East Texas and the Hill Country. No published data exist for the proposed study area. Data will be shared with the Texas Commission on Environmental Quality to assist the EPA-mandated process of developing numeric criteria for nutrient parameters that are protective of aquatic resources and water for wildlife. Data will also be shared with the Brazos River Authority (BRA) to assist in their management efforts.

A secondary objective is to increase knowledge about the distribution and status of freshwater mussels in the Brazos River Basin. Overall, mussel species are in decline and there are several species of concern in the Brazos Basin.

Approach

Water quality, fish, benthic invertebrates, mussels, and periphyton will be sampled at six sites in North Central Texas streams. Habitat and flow information will be collected to characterize sites and aid in interpreting the other data collected. The study is designed to sample wadeable streams where little data exist linking nutrient levels to dissolved oxygen and biological communities.

Six sampling sites were selected along small perennial North Central Texas streams (Figure 1). The streams are all in the Brazos River Basin, in ecoregions 32 (Texas Blackland Prairies) or 33 (East Central Texas Plains). Sites were chosen in coordination with TCEQ, Texas State Soil and Water Conservation Board (TSSWCB), Texas Institute for Applied Environmental Research (TIAER), Brazos River Authority (BRA), and TPWD Inland and Coastal Fisheries staff. Sites were selected based on estimated watershed size, presence of perennial flow, and encompassing a gradient of nutrient conditions. Some are potentially influenced by urban development and others by agricultural activities in the watershed. Sites of special interest were also considered,

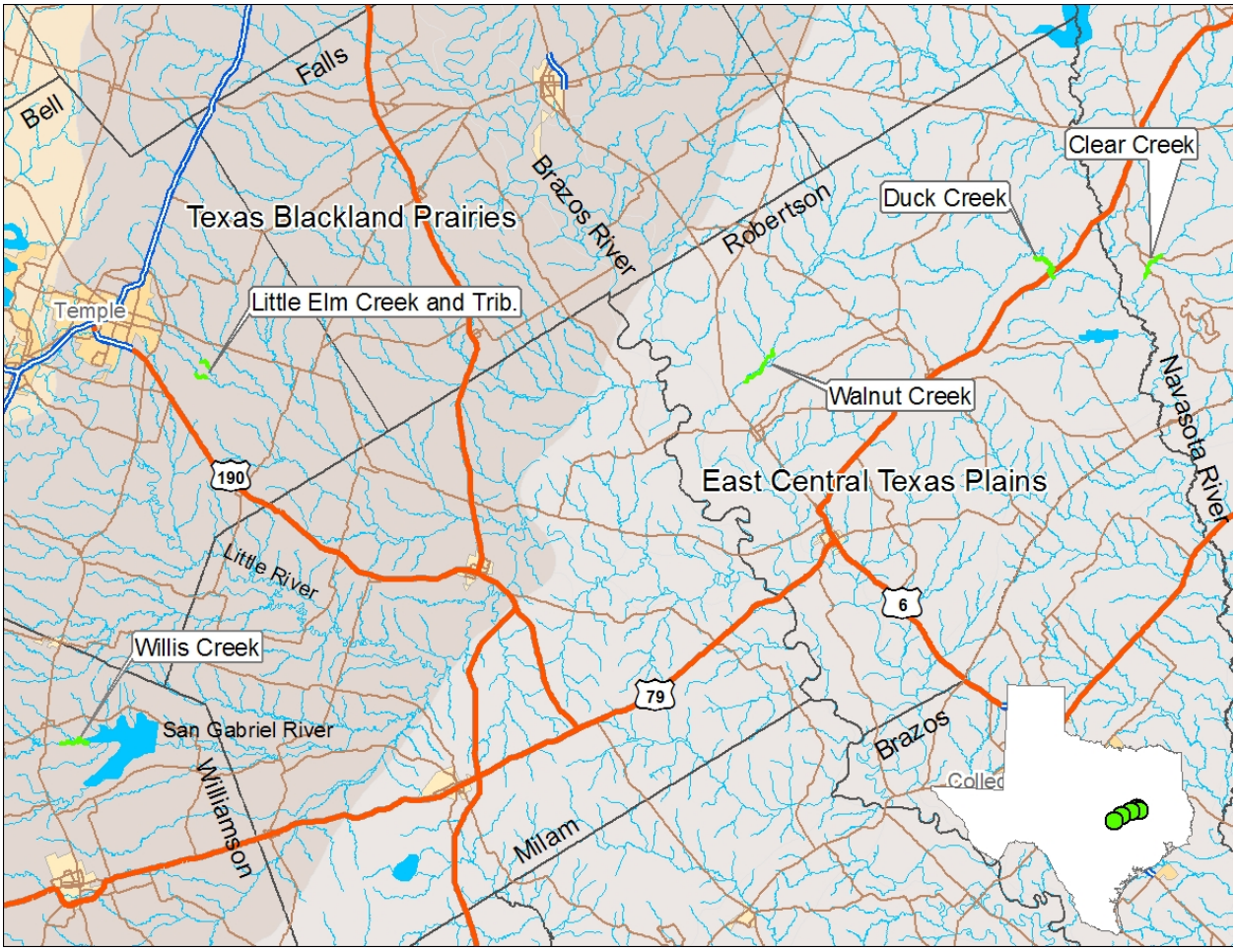

Figure 1.—Map showing relative locations of study streams.

including TPWD property. The overall purpose of this type of sampling is to select one site at each of the six streams that best represents conditions of the entire water body. The Navasota River at SH 7 was originally selected as one of the six sites. Due to heavy rainfall in the spring of 2007, this site was not wadeable and was dropped from the sampling schedule. Duck Creek at SH 79 replaced this site in the sampling schedule.

Water quality, algal, benthic, mussel, and fish community assessment will be conducted twice per year at each site for two consecutive years. One sampling trip each year will be undertaken in the index period (March 15 – October 15) and one in the critical period (July 1 – September 30).

Sampling trips will include the following data collection efforts:

- water samples collected for nutrient analysis
- instantaneous flow
- 24-hour (or longer) datasonde deployment for dissolved oxygen, temperature, pH, and conductivity
- fish

- benthic invertebrates
- periphyton
- mussels
- habitat

Review of Historical Water Quality Data

Surface water quality data were obtained from TCEQ via the agency's website using the application known as the Sampling Data Query (TCEQ 2006). Data for the entire Brazos Basin were obtained using this application in September 2006, and searched to identify all stations with data for the study areas. Available surface water quality data were downloaded separately for each station and are summarized here.

Duck Creek at SH 79 (Robertson County)

General Description

Duck Creek originates near the Limestone-Robertson county line four miles north of Petteway and runs southeast for thirty-two miles to its mouth on the Navasota River. It traverses nearly level terrain covered by sandy loams that support post oaks and grasses (Handbook of Texas Online 2007). The watershed is situated almost entirely within Robertson County and is almost entirely rural, with only two small communities, Franklin and New Baden, lying partially or completely within the watershed (TIAER 2002). Several miles upstream from the study reach, Duck Creek is impounded by Twin Oak Reservoir, a power plant cooling reservoir. The watershed lies within the East Central Texas Plains ecoregion.

Previous Studies

Brazos River Authority sampled habitat and fish and benthic invertebrate populations on Duck Creek at FM 979 (TCEQ station 16390) in May and August, 2001. Index of Biotic Integrity scores defined the fish community as high in May 2001 and intermediate in August 2001 (Table 12, Table 14). Benthic Index of Biotic Integrity scores defined the benthic invertebrate community as limited in both May and August 2001 (Table 13, Table 15).

TIAER examined land use, especially agricultural impacts, in a 2002 report (TIAER 2002). Based on Landsat imagery, land use in Duck Creek watershed was estimated to be 28 percent pasture, 9 percent hay, 45 percent range, 14 percent forest, 2 percent urban and other hard surfaces, and 1 percent water. An estimated 53 percent of hay fields and 19 percent of pastureland is assumed fertilized with poultry broiler litter. The study reported that the Duck

Creek watershed had one of the highest concentrations of producers and broiler houses in the region.

TIAER conducted a nutrient modeling study on the Duck Creek watershed, which has a high concentration of poultry production and poultry litter land application (TIAER 2002). At the time of the study there were 52 poultry houses in Robertson County. For each house, the authors estimated 200 tons of poultry litter produced per year. Modeling revealed a nitrogen input for the Duck Creek watershed of 1,165 tons, and a phosphorus input of 306 tons. Although comprising only 10 percent of the watershed land area, areas fertilized by chicken litter accounted for 19 percent of the nitrogen balance and 40 percent of the phosphorus balance, exclusive of atmospheric deposition. Altogether, anthropogenic activity on agricultural lands accounts for 71 and 87 percent, respectively, of watershed nitrogen and phosphorus balances. Atmospheric deposition, almost all of which is associated with rainfall, accounted for significant portions of watershed balances: 28 and 12 percent of nitrogen and phosphorus balances, respectively. Discharge from septic systems and contributions from urban areas accounted for less than one percent of total watershed balances for both nitrogen and phosphorus. An estimated 1,105 people reside within the watershed.

An earlier TIAER study reported typical poultry litter application rates are two tons/acre on pasture, applied once every three years, and three tons/acre on hay fields, applied every other year (TIAER 2001). The nutrient content of chicken litter was assumed to be 50 pounds of nitrogen and the equivalent 68 pounds of phosphate per ton of litter (TIAER 2001).

Wastewater Discharges

There are three industrial discharges, Sanderson Farms feed mill, Oak Grove Steam Electric Station, and Twin Oaks Lignite Mine. Sanderson Farms (TPDES permit number 03847) is permitted to discharge up to 0.029 MGD of boiler blowdown and truck wash water. Effluent limitations are 30 mg/L total suspended solids, 10 mg/L oil and grease, and a reporting requirement for total copper. Oak Grove Steam Electric Station (TPDES permit number 01986) has effluent limitations of 110 degrees F for temperature, 0.2 mg/L free available chlorine, and a daily maximum of 0.2 mg/L for total residual chlorine. The permit allows a maximum discharge of 1470 million gallons over a 24-hour period. Twin Oaks Lignite Mine (TPDES permit number 02699) has effluent limitations of 35 mg/L total suspended solids, 3.0 mg/L total iron, and a reporting requirement for total selenium. The City of Franklin's wastewater treatment plant discharges into an adjacent watershed, so Duck Creek receives no direct municipal discharges.

Data were obtained from the Permit Compliance System (PCS) from 2000 to the present (TCEQ 2006) for the Sanderson Farms feed mill. There were no exceedances of the effluent limitations for pH during this time period. There were two exceedances of the daily average limit and four of the daily maximum limit for total suspended solids. There was one exceedance of the total volume discharge for one 24-hour period. There were no permit compliance data for the other two industrial permittees in the Duck Creek watershed.

Water Quality Assessment Status

In the draft 2006 Water Quality Inventory, Duck Creek was assessed as two assessment units, 1209H_01 and 1209H_02 (TCEQ 2007). from station 16389, Duck Creek at SH 79, is used to assess 1209H_01. In this assessment unit, Duck Creek was listed as not supporting the contact recreation use due to the *E. coli* geometric mean. Assessment unit 1209H_02 is upstream from the study reach. This assessment unit was also listed as not supporting the contact recreation use due to the *E. coli* geometric mean. Also this assessment unit was listed as a concern for aquatic life use support based on DO grab samples.

TCEQ Water Quality Data

The nearest station to the study area is Station 16389, Duck Creek at SH 79 (Figure 2). This station is about 50 m downstream from the study reach. There were 65 sampling events yielding a total of 1386 individual measurements at this station. A summary of the routine water chemistry and field measurements appears in Table 1.

Instantaneous DO ranged from 1.6 to 14 mg/L. Only one of 60 observations fell below the 3.0 minimum DO criterion for Segment 1209, Navasota River Below Lake Limestone. Percent saturation ranged from 19.1 to 105.6%. pH ranged from 6.4 to 7.4, within the normal range for surface waters, and within the segment-specific criterion of 6.5 to 9.0. Specific conductance ranged from 130 to 672 umhos/cm. Temperature ranged from 3.7 to 28.9 degrees Celsius, under the segment-specific maximum of 34 degrees Celsius.

Site-specific criteria for Segment 1209 include a maximum annual average of 140 mg/L chloride and 100 mg/L sulfate. No chloride measurements exceeded the criterion. Five of 59 sulfate measurements exceeded the criterion. The geometric mean of all the samples exceeded the criterion of 126 colonies per 100 mL, and the grab sample criterion of 200 colonies per 100 mL was exceeded in 14 of 30 samples (47%). There were more fecal coliform data available since that was the method used to assess contact recreation historically until the recent shift in the water quality standards to *E. coli* as an indicator. For fecal coliform, 11 of 50 measurements (22%) exceeded the grab sample criterion of 400 colonies per 100 mL. However the geometric mean of all samples falls under the 200 colonies per 100 mL criterion.

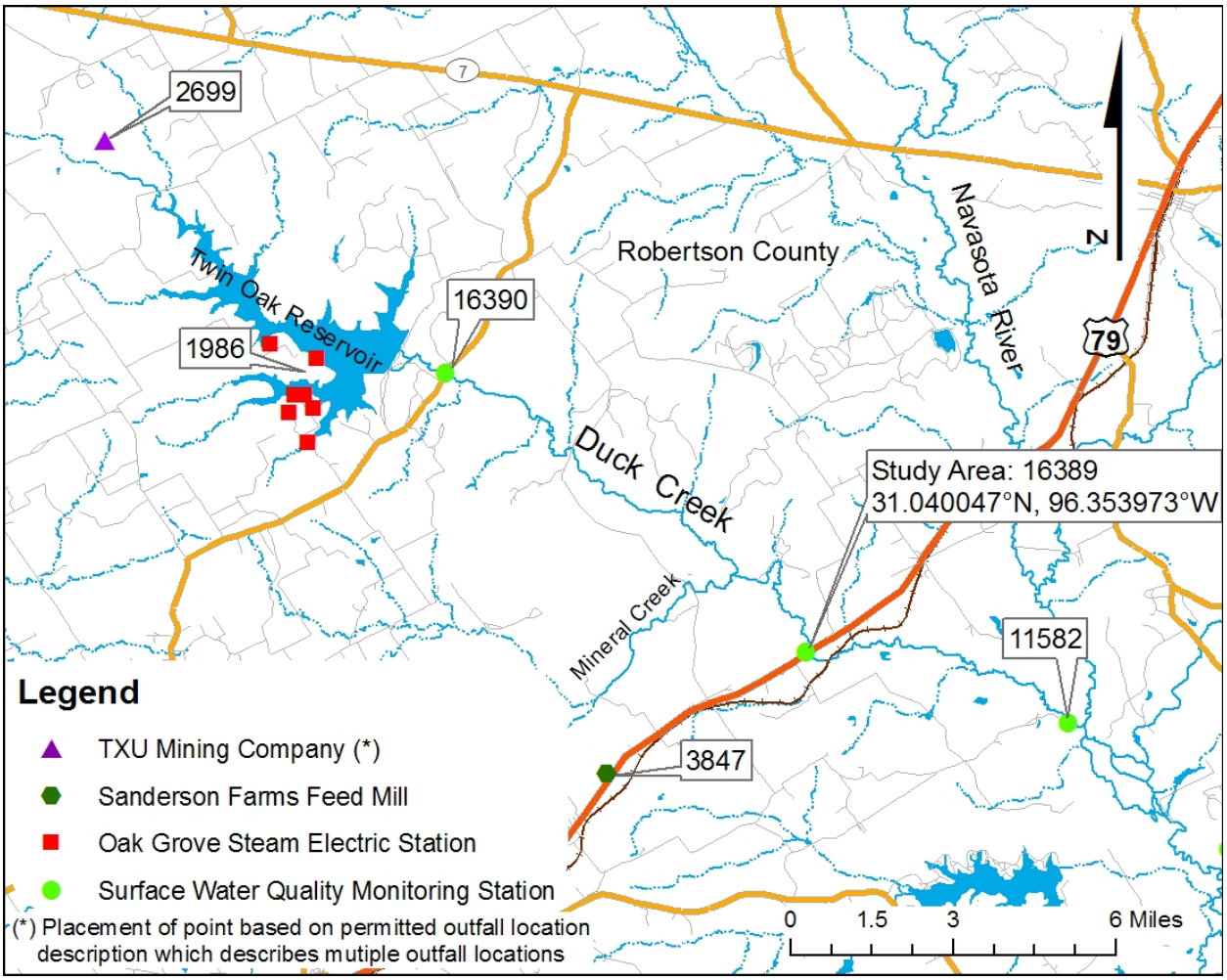

Figure 2.—Duck Creek in the vicinity of the study reach.

Nutrient measurements were compared with screening criteria used for freshwater streams in the biannual water quality assessment (TCEQ 2003). For chlorophyll a, the mean of 4.2 ug/L was below the 11.6 ug/L screening level, and only one of 31 measurements exceeded the screening level. Neither orthophosphorus nor total phosphorus exceeded the screening levels; in fact most orthophosphorus measurements were below the detection limit (0.04 or 0.05 mg/L). Nitrate and nitrite measurements were low and did not exceed the screening levels, with many of the measurements being below detection limits.

Table 1.—Routine water chemistry and field measurements for TCEQ station 16389, Duck Creek at SH 79 in the town of Easterley. Data collected from 12 Jan 1999 to 11 May 2006. All measurements in mg/L unless otherwise noted. Measurements are generally displayed to two decimal points for ease of formatting, not to assert number of significant digits. Median, not mean, reported for pH. Geometric mean reported for *E. coli* and fecal coliform.

Parameter Name	Mean	Minimum	Maximum	N
Average stream depth (meters)	0.48	0.10	3.00	25
Average stream width (meters)	4.59	0.67	15.00	53
Chloride	55.23	13.55	101.41	58
Chlorophyll *a*, fluorometric method (ug/L)	4.20	1.19	22.00	31
Depth of bottom of water body at sample site (meters)	0.66	0.25	1.50	14
E. coli (most probable number per 100 mL)	231.7	31.00	866.40	30
Fecal coliform (colonies per 100 mL)	180.5	24.00	820.00	50
Stream flow, instantaneous (cfs)	5.08	0.97	11.38	12
Stream flow estimate (cfs)	25.59	0.16	129.00	21
Stream velocity (feet per second)	1.59	0.25	4.00	29
Macrophyte bed at collection point (%)	5.52	0.00	85.00	62
Nitrate nitrogen, total	0.33	0.05	0.71	54
Nitrite nitrogen, total	0.04	0.02	0.05	58
Nitrogen, Kjeldahl, total	1.61	0.20	4.60	8
Orthophosphate phosphorus	0.05	0.04	0.17	46
DO	6.77	1.60	14.28	60
DO (percent of saturation)	68.46	19.10	105.60	60
pH (standard units)	7.00	6.42	7.43	60
Pheophytin *a* (ug/L)	3.00	3.00	3.00	1
Phosphorus, total	0.14	0.06	0.45	6
Specific conductance, (umhos/cm)	375.03	130.00	672.30	62
Sulfate	55.36	17.08	149.53	59
TSS	17.88	3.00	190.00	57
Temperature, water (degrees Celsius)	18.09	3.67	28.90	62
Transparency, secchi disc (meters)	0.52	0.04	1.05	10
Turbidity (nephelometric turbidity units)	22.90	22.90	22.90	1

A few measurements were available for metals and organics (Table 2). The majority of the analytes were not detected by the laboratory. Detections of metals or organics were compared, where possible, with criteria used in the state water quality assessment (TCEQ 2003). This comparison revealed no concern for aluminum, copper, lead, or selenium. Comparisons of

measurements with the United States Environmental Protection Agency (EPA) guidelines ("Gold Book"; USEPA 1986) showed no concern for barium or iron.

Table 2.—Metals and organics concentrations for TCEQ station station 16389, Duck Creek at SH 79 in the town of Easterley. Data collected from 7 Aug 2003 to 1 Aug 2005. All measurements in ug/L unless otherwise noted by parameter name. Measurements are generally displayed to two decimal points for ease of formatting, not to assert number of significant digits. Asterisk next to the parameter name (*) indicates the value(s) were reported less than some minimum value (probably laboratory detection limit).

Parameter Name	Mean	Minimum	Maximum	N
1,2-dichloroethane*	1.00	1.00	1.00	1
Aluminum, dissolved	109.24	36.77	181.70	2
Antimony, dissolved*	10.00	10.00	10.00	1
Arsenic, dissolved*	5.00	5.00	5.00	2
Barium, dissolved	113.95	82.46	145.40	3
Beryllium, dissolved*	1.00	1.00	1.00	1
Cadmium, dissolved*	0.30	0.30	0.30	3
Carbaryl, water, dissolved*	1.00	1.00	1.00	1
Chlorobenzene*	10.00	10.000	10.000	2
Chloroform, whole water*	10.00	10.00	10.00	1
Chromium, dissolved*	10.00	10.00	10.00	2
Cis-1,3-dichloropropene, total*	1.00	1.00	1.00	1
Cobalt, dissolved*	10.00	10.00	10.00	2
Copper, dissolved	1.26	0.30	2.50	3
Dibromochloromethane, whole water*	1.00	1.00	1.00	2
Iron, dissolved	320.13	218.70	421.56	2
Lead, dissolved	0.75	0.50	1.00	2
Manganese, dissolved	175.04	129.60	231.00	3
Nickel, dissolved*	10.00	10.00	10.00	3
Selenium, dissolved	1.15	1.00	1.30	2
Silver, dissolved*	0.30	0.30	0.30	3
Tetrachloroethylene, totw*	1.00	1.00	1.00	2
Thallium, dissolved*	1.00	1.00	1.00	1
Toluene*	1.00	1.00	1.00	2
Trichloroethylene, whole water sample*	1.00	1.00	1.00	2
Trihalomethane total, tthm, water*	50.00	50.00	50.00	1
Vanadium, dissolved*	10.00	10.00	10.00	3

Navasota River at SH 7 (Robertson and Leon Counties)

General Description

The Navasota River rises near Mount Calm (Hill County) and flows southeast for 125 miles to its confluence with the Brazos River near Navasota (Handbook of Texas Online 2006a). Reservoirs built on the Navasota include Lake Mexia, Springfield Lake (also known as Fort Parker State Park Lake), Joe Echols Lake, Lake Groesbeck, Lake Limestone, and Martin Lake. The river traverses flat to rolling terrain with local shallow depressions, surfaced by clay and sandy loams that support water-tolerant hardwoods, conifers, and grasses (Handbook of Texas 2006a). The upper portion, where the study reach is located, flows through the East Central Texas Plains ecoregion.

Previous Studies

Intensive surveys were conducted on Segment 1209 in 1987 and 1988 (TCEQ 1988; TCEQ 1989). One of the survey stations was located at SH 79, near the proposed study reach. The intensive surveys found that water quality standards and criteria were being met at that station. The only parameter that appeared slightly elevated was fecal coliform bacteria.

Studies of the entire Navasota River were conducted in the late 1960s and early 1970s by the Texas Water Resources Institute of Texas A&M University to look at the impacts of possible reservoir construction (Clark 1973). Water quality, flow, fish, algae, plankton, and benthic invertebrates were sampled at various locations on the mainstem of the Navasota River and some of its tributaries. Some of this sampling was done on a monthly basis over two years. This work produced extensive sets of data and lists of biota collected from various parts of the Navasota drainage (Clark 1973, Rozenburg et al. 1972).

Wastewater Discharges

The City of Marquez has a wastewater discharge in the watershed (Texas Pollution Discharge Elimination System (TPDES) permit number 13980-001), but the tributary to which it discharges is downstream of the study reach.

Water Quality Assessment Status

Segment 1209, the Navasota River below Lake Limestone, is divided into several assessment units for purposes of evaluating whether uses and criteria are being met. Station 11877, the Navasota River at US 79, is the closest station to the study reach (Figure 3). Data from this station are used to assess a section of the Navasota River extending from the confluence with

Camp Creek to a point 25 miles upstream (assessment unit 1209_05). The draft 2006 Texas Water Quality Inventory (TCEQ 2007) states the assessment unit is not supporting the contact recreation use because of the *E. coli* geometric mean. The assessment unit is also listed as a concern for near non-attainment due to fecal coliform single sample measurements.

TCEQ Water Quality Data

The nearest station to the study area is TCEQ station 11877, Navasota River at US 79 between Easterly and Marquez. Station 11877 is about ten miles downstream from the study reach. For station 11877 there were 132 sampling events yielding a total of 2,199 individual measurements. A summary of the routine water chemistry and field measurements appears in Table 3.

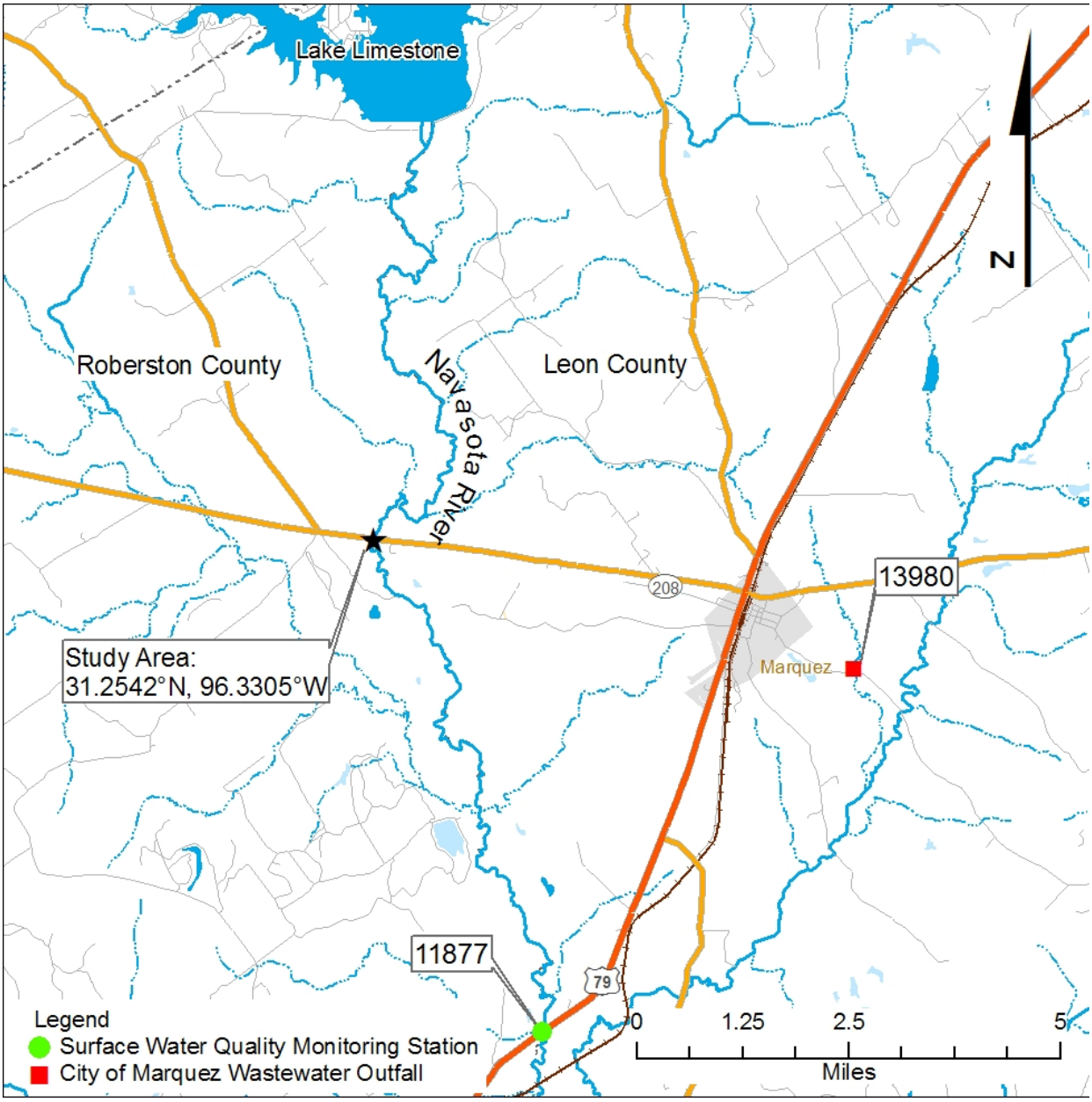

Figure 3. — Navasota River Below Lake Limestone in the vicinity of the study reach.

Table 3.—Routine water chemistry and field measurements for TCEQ station 11877, Navasota River at US 79. Data collected from 19 Oct 1981 to 11 May 2006. All measurements in mg/L unless otherwise noted by parameter name. Measurements are generally displayed to two decimal points for ease of formatting, not to assert number of significant digits. Median, not mean, reported for pH. Geometric mean reported for *E. coli* and fecal coliform.

Parameter Name	Mean	Minimum	Maximum	N
Alkalinity	58.84	16.00	80.00	44
CBOD-5	0.75	0.50	1.00	4
TOC	6.78	1.00	11.00	10
Chloride	47.22	11.63	118.39	106
Chlorophyll a (ug/L)	10.96	0.20	36.80	13
E. coli (most probable number of colonies per 100 mL)	169.9	16	>24,200	31
Fecal coliform (colonies per 100 mL)	178.2	16	>4,000	66
Fluoride	0.19	0.10	0.30	38
Nitrate	0.21	0.01	0.81	70
Nitrite	0.04	0.01	0.05	69
Ammonia	0.04	0.02	0.11	13
TKN	0.77	0.60	1.02	4
Orthophosphorus	0.05	0.01	0.20	63
DO	7.97	4.67	12.37	83
DO (percent saturation)	87.72	55.20	114.10	67
pH (standard units)	7.34	6.72	8.20	81
pheophytin a (ug/L)	4.41	0.00	15.70	13
Total phosphorus	0.11	0.07	0.25	13
TDS	204.00	138.00	286.00	3
TSS	45.23	5.00	460.00	74
VSS	11.69	2.00	56.00	13
Sp. cond. (umhos/cm)	318.97	113.20	644.20	85
Sulfate	47.29	11.89	130.00	107
Water temperature (degrees Celsius)	21.23	7.50	31.60	125
Secchi disk transparency (meters)	0.21	0.04	0.49	15

Instantaneous physiochemical parameters showed that DO ranged from 4.7 to 12.4 mg/L. Percent saturation ranged from 55.2 to 114.1, revealing a mild degree of supersaturation. None of the 83 measurements fell under 3.0 mg/L, the minimum DO criterion for this segment. The range of pH (6.7 to 8.2) was normal for surface waters and within the segment-specific criteria range of 6.5 to 9.0. Specific conductance ranged from 113 to 644 umhos/cm. Temperature

ranged from 7.5 to 31.6 degrees Celsius, which is below the site-specific maximum criterion of 34 degrees Celsius.

The study area lies in the watershed of Segment 1209, Navasota River below Lake Limestone. Site-specific criteria for Segment 1209 include a maximum annual average of 140 mg/L chloride, 100 mg/L sulfate, and 600 mg/L TDS. No chloride or TDS measurements exceeded the criterion. Only two of the 107 sulfate measurements exceeded the criterion. The site-specific criterion for *E. coli* is a geometric mean of 126 colonies per 100 mL, not to exceed 200 colonies per 100 mL in a grab sample. The geometric mean of all the samples exceeded the criterion, and the grab sample criterion was exceeded in 13 of 31 samples (42%). There were more fecal coliform data available since that was the method used to assess contact recreation historically until the recent shift in the water quality standards to *E. coli* as an indicator. For fecal coliform, 15 of 66 measurements (23%) exceeded the grab sample criterion of 400 colonies per 100 mL. However the geometric mean of all samples falls under the 200 colonies per 100 mL criterion.

Nutrient measurements were compared with screening criteria used for freshwater streams in the biannual water quality assessment (TCEQ 2003). For chlorophyll a, the mean of 11.0 ug/L was below the 11.6 ug/L screening level, although three of 13 measurements exceeded 11.6 ug/L. Neither orthophosphorus or total phosphorus exceeded the screening levels; in fact most orthophosphorus measurements were below the detection limit (0.04 or 0.05 mg/L). Ammonia concentrations did not exceed 0.11 mg/L (the screening level is 0.17 mg/L). Nitrate and nitrite measurements were very low and did not exceed the screening levels, with many of the measurements being below detection limits.

Most routine water chemistry parameters (alkalinity, $CBOD_5$, fluoride, TOC) were within normal expectations for unpolluted freshwater streams.

A few measurements were available for metals and organics (Table 4). The majority of the analytes were not detected by the laboratory. Detections of metals or organics were compared, where possible, with criteria used in the state water quality assessment (TCEQ 2003). This comparison revealed no concern for aluminum, copper, or selenium. Comparisons of measurements with the United States Environmental Protection Agency (EPA) guidelines (“Gold Book”; USEPA 1986) showed no concern for barium or iron.

Table 4. — Metals and organics concentrations for TCEQ station 11877, Navasota River at US 79. Data collected from 7 Aug 2003 to 1 Aug 2005. All measurements in ug/L unless otherwise noted by parameter name. Measurements are generally displayed to two decimal points for ease of formatting, not to assert number of significant digits. Asterisk next to the parameter name (*) indicates the value(s) were reported less than some minimum value (probably laboratory detection limit).

Parameter Name	Mean	Minimum	Maximum	N
1,2-Dichloroethane*	1.00	1.00	1.00	1
Aluminum, dissolved	126.26	77.22	175.30	2
Antimony, dissolved*	10.00	10.00	10.00	1
Arsenic, dissolved*	5.00	5.00	5.00	2
Barium, dissolved	98.87	73.12	123.60	3
Beryllium, dissolved*	1.00	1.00	1.00	1
Cadmium, dissolved*	0.30	0.30	0.30	3
Carbaryl, dissolved*	1.00	1.00	1.00	1
Chlorobenzene*	10.00	10.00	10.00	2
Chloroform*	10.00	10.00	10.00	1
Chromium, dissolved*	10.00	10.00	10.00	2
Cis-1,3-dichloropropene*	1.00	1.00	1.00	1
Cobalt, dissolved*	10.00	10.00	10.00	2
Copper, dissolved	1.85	1.35	2.60	3
Dibromochloromethane*	1.00	1.00	1.00	2
Iron, dissolved	127.84	88.50	167.18	2
Lead, dissolved*	0.65	0.30	1.00	2
Manganese, dissolved	122.33	66.00	169.90	3
Nickel, dissolved*	10.00	10.00	10.00	3
Selenium, dissolved	1.20	1.10	1.30	2
Silver, dissolved*	0.30	0.30	0.30	3
Tetrachloroethylene*	1.00	1.00	1.00	2
Thallium, dissolved*	1.00	1.00	1.00	1
Toluene*	1.00	1.00	1.00	2
Trichloroethylene*	1.00	1.00	1.00	2
Trihalomethane*	50.00	50.00	50.00	1
Vanadium, dissolved*	10.00	10.00	10.00	3

Clear Creek (Leon County)

General Description

Clear Creek, also known as Forky Deer Creek, rises 10 miles southwest of Centerville in southwestern Leon County and runs southwest for 14 miles to its mouth at the Navasota River. It drains into Segment 1209 and flows through the East Central Texas Plains ecoregion. It traverses nearly level terrain surfaced by sandy and loamy soils that support woods of pecan, elm, water oak, hackberry, post oak, and black hickory (Handbook of Texas Online 2006b).

There were no historical water quality data available on Clear Creek or its tributaries from the TCEQ Sampling Data Query application.

Clear Creek does not appear on the Texas Water Quality Inventory due to lack of information.

There are no permitted wastewater discharges to Clear Creek or its tributaries.

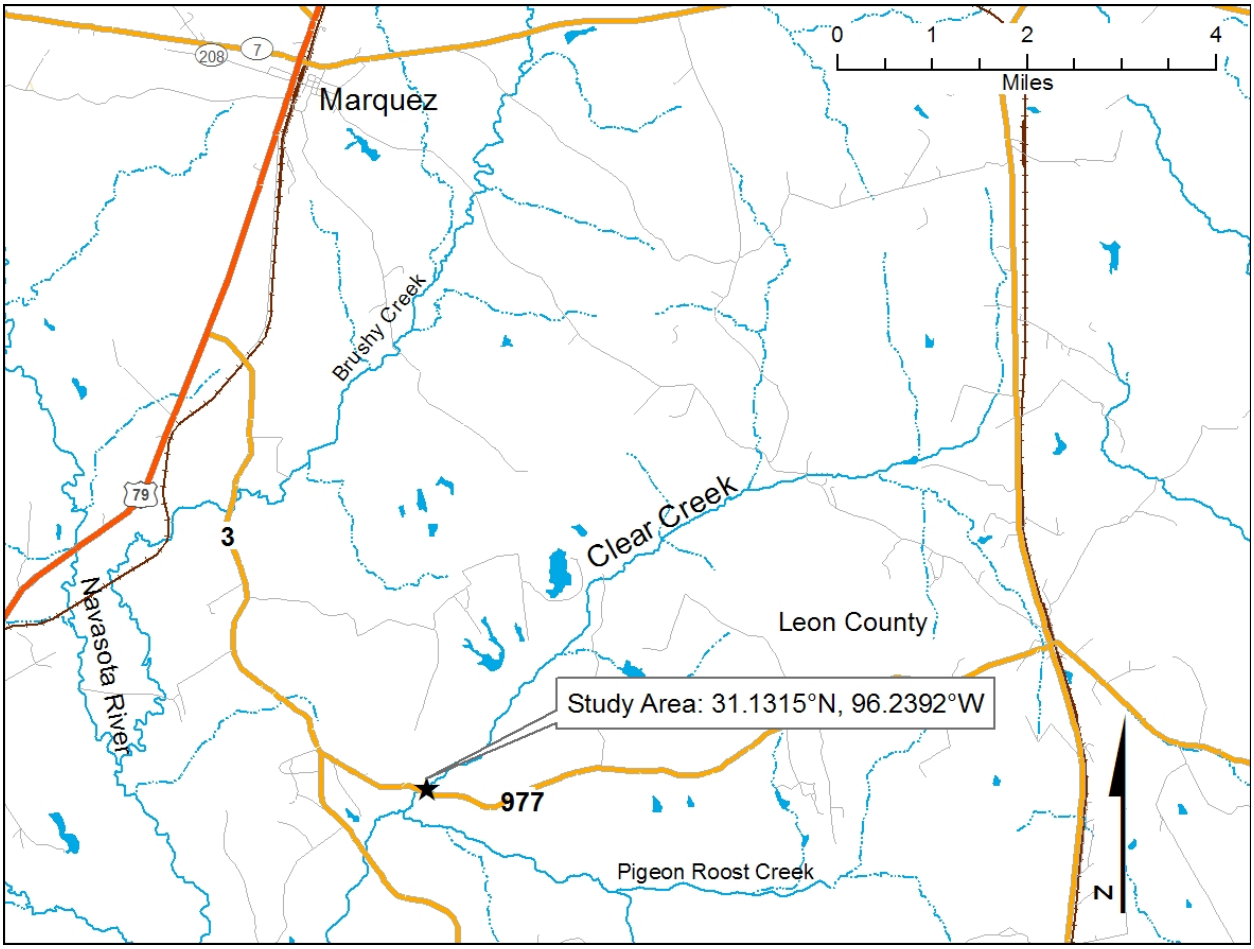

Figure 4. — Clear Creek in the vicinity of the study reach.

Little Elm Creek and unnamed tributary (Bell County)

General Description

Little Elm Creek originates near Pendleton in Bell County and runs southeast for 19 miles to its mouth at Big Elm Creek east of Temple. The unnamed tributary to Little Elm Creek originates near Temple and flows roughly parallel to Little Elm Creek for about five miles to its confluence with it. Little Elm Creek flows through nearly level to sloping terrain surfaced by clayey and loamy soils used predominantly for cotton production and other agriculture (Handbook of Texas Online 2006c). It flows through the Texas Blackland Prairies ecoregion.

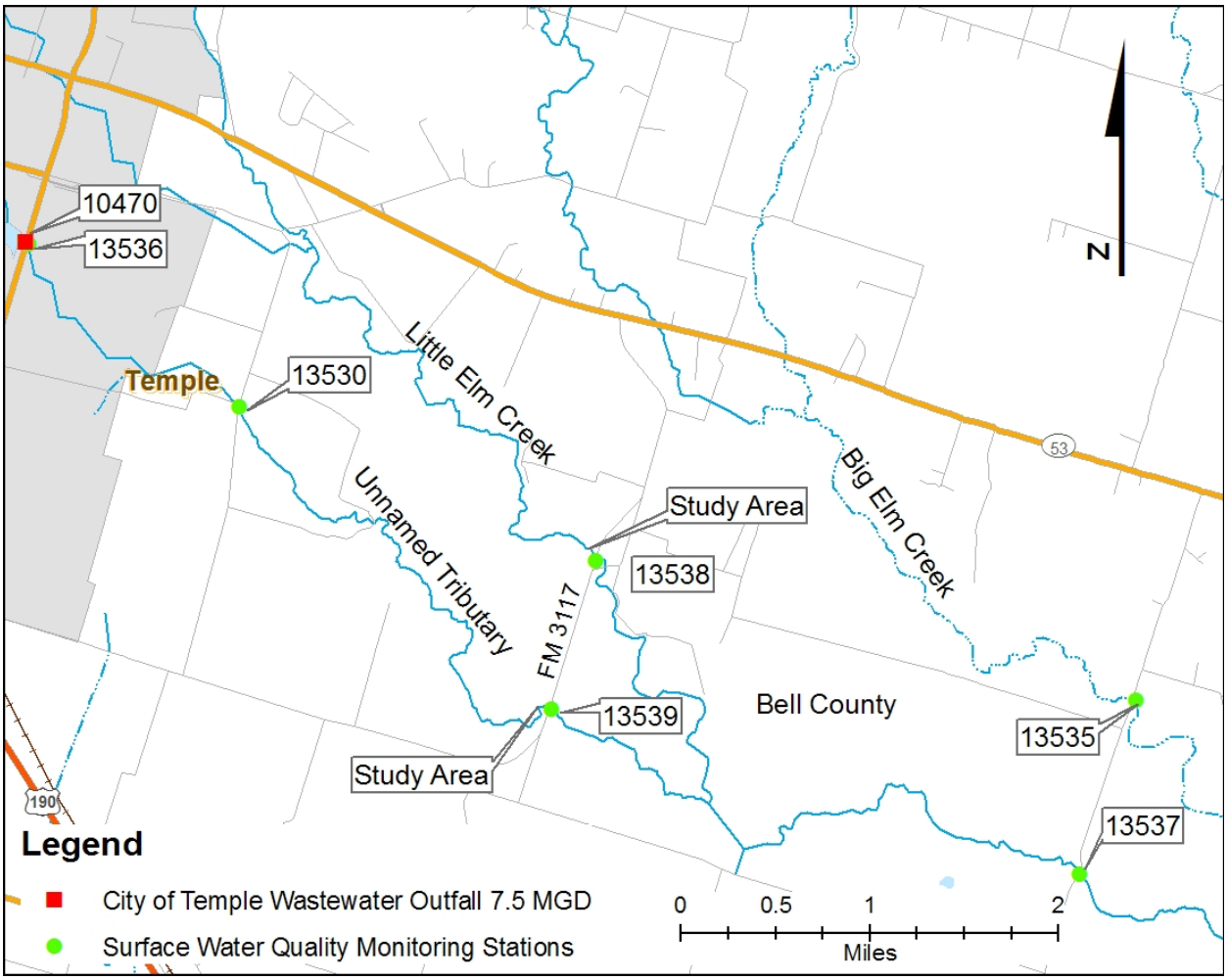

Figure 5. — Little Elm Creek and unnamed tributary to Little Elm Creek in the vicinity of the study reach.

Wastewater Discharges

The city of Temple discharges wastewater to an unnamed tributary of Little Elm Creek (TPDES permit number 10470-002). The permit authorizes an annual average flow of 7.5 million gallons per day (MGD) and effluent limitations include 10 mg/L $CBOD_5$, 15 mg/L TSS, 3 mg/L ammonia nitrogen, and 0.071 mg/L hexavalent chromium. This discharge must maintain a 4.0 mg/L minimum DO concentration, chlorine residual below 0.1 mg/L, and pH between 6.0 and 9.0 mg/L.

Data were obtained from the Permit Compliance System (PCS) from 2000 to the present (TCEQ 2006). Biomonitoring results showed no exceedances. There were no exceedances of DO or pH limits. There was one exceedance of the two-hour peak flow limit of 15,625 gallons per minute (gpm) (16,040 gpm). There was one exceedance of the daily average for $CBOD_5$ (18.6 mg/L) and one exceedance of the daily maximum for $CBOD_5$ (60.0 mg/L – daily maximum is not to exceed 25 mg/L).

There are no known permitted wastewater discharges directly to Little Elm Creek.

Water Quality Assessment Status

Neither Big Elm Creek or any of its tributaries have been assessed. However, Little Elm Creek flows into Big Elm Creek, which flows into the Little River, Segment 1213. According to the most recent draft water quality assessment (TCEQ 2007), Segment 1213 is identified with a concern due to screening level for atrazine in finished drinking water. Portions of the segment are also listed for exceeding the *E. coli* geometric mean.

TCEQ Water Quality Data

For TCEQ station 13538, Little Elm Creek at FM 3117 east of Temple, there were only two sampling events which produced 44 individual measurements (Table 5). There was no sampling on the unnamed tributary to Little Elm Creek. Some water quality data are available for Big Elm Creek, but they were not analyzed for this report.

Table 5. — Summary statistics for routine water chemistry and field measurements for TCEQ station 13538, Little Elm Creek at FM 3117. Data were collected on 19 Jan 1999 and 9 Feb 1999. All measurements in mg/L unless otherwise noted by parameter name. Measurements are generally displayed to two decimal points for ease of formatting, not to assert number of significant digits. Median, not mean, reported for pH. Geometric mean reported for fecal coliform.

Parameter Name	Mean	Minimum	Maximum	N
Chloride	20.58	20.31	20.85	2
Fecal coliform (colonies per 100 mL)	474.8	230.00	980.00	2
Nitrate	3.99	3.79	4.18	2
Nitrite	0.05	0.05	0.05	2
Orthophosphorus	0.05	0.05	0.05	2
DO	10.16	9.75	10.57	2
DO (percent saturation)	105.40	101.40	109.40	2
pH (standard units)	7.80	7.70	7.90	2
TSS	4.00	4.00	4.00	2
Specific conductance (umhos/cm)	585.00	572.00	598.00	2
Sulfate	31.32	31.28	31.35	2
Water temperature (degrees Celsius)	17.06	13.04	21.08	2

Instantaneous physiochemical parameters showed slight DO supersaturation during both sampling events (9.8 to 10.6 mg/L; 101 to 109%). Neither of the measurements were below the 3.0 mg/L minimum DO criterion for a stream with a presumed high aquatic life use. pH was normal for surface waters (7.7 and 7.9). Specific conductance was 572 and 598 umhos/cm, and temperature ranged from 13.0 to 21.1 degrees Celsius. Specific conductance can be multiplied by 2/3 to approximate TDS. This calculation results in values of 383 and 401 mg/L, which are close to the TDS criterion for Segment 1213 (400 mg/L).

Site-specific criteria for Segment 1213 include a maximum annual average of 75 mg/L chloride and 75 mg/L sulfate. No chloride or sulfate measurements exceeded the criteria. For fecal coliform, one of two measurements exceeded the grab sample criterion of 400 colonies per 100 mL, and the geometric mean of the two measurements also exceeded the criterion.

Nutrient measurements were compared with screening criteria used for freshwater streams in the biannual water quality assessment (TCEQ 2003). Both orthophosphorus and nitrite measurements were below the detection limits of 0.05 mg/L. Both nitrate measurements exceeded the screening level (2.76 mg/L). Elevated nitrate levels could be due to elevated nitrate in groundwater sources to the creek, an organic pollution source, or some other cause.

Walnut Creek at Sunnyside Road (Robertson County)

General Description

Walnut Creek originates east of Bremond and flows for 21 miles southwest to its mouth at the Little Brazos River near Calvert (Handbook of Texas Online 2006d). Tributaries include South Walnut Creek, Sandy Creek, Little Sandy Creek, and Big Willow Creek. The surrounding nearly level terrain is surfaced by loam that supports post oak and grass (Handbook of Texas Online 2006d). Walnut Creek lies in the East Central Texas Plains ecoregion.

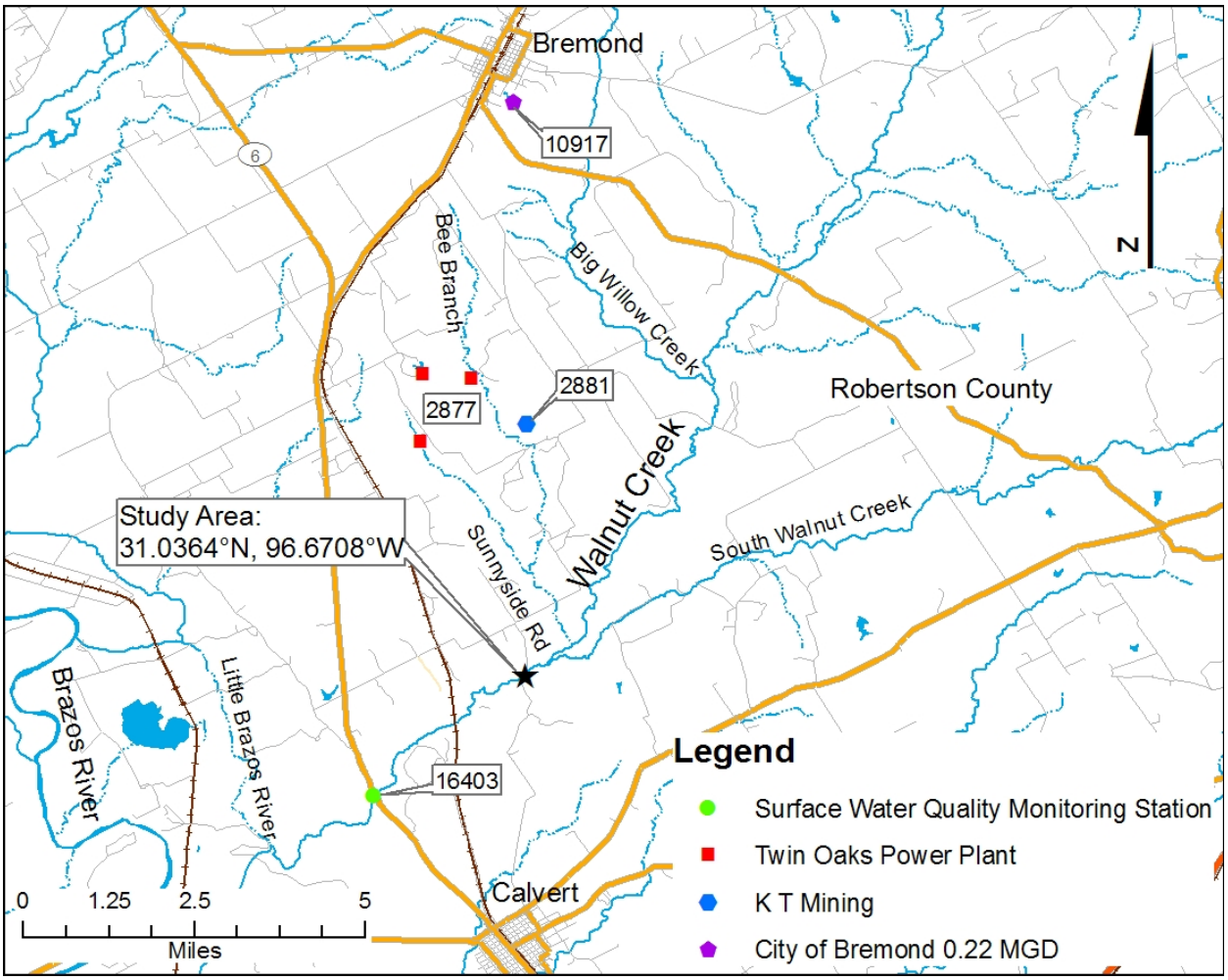

Figure 6. — Walnut Creek in the vicinity of the study reach.

Wastewater Discharges

There are two industrial discharges and one domestic discharge in the Walnut Creek watershed. The industrial discharges are KT Mining LP (TPDES permit number 02881) and Twin Oaks Power LP (permit number 02877). KT Mining LP is the operator of the Calvert Lignite Mine. The KT Mining permit authorizes several different discharges from the lignite mine, including intermittent and flow variable discharges from the active and post- mining areas, treated domestic wastewater, treated equipment wash waters, groundwater, and intermittent and flow variable mine pit water and storm water. Details about effluent limitations are summarized in Table 6. In addition, pH must remain between 6.0 and 9.0 standard units.

Self-report data for permit number 02881 revealed no exceedances of permitted effluent limits.

TPDES permit number 02877 authorizes discharges from Twin Oaks Power LP, a lignite fired steam electric generating station. The permit authorizes intermittent and flow variable coal pile runoff, low volume waste, cooling tower blowdown, and storm water runoff. A summary of the effluent limitations is given in Table 7. In addition, pH of the effluent must remain between 6.0 and 9.0 standard units.

Self-report data for this permit indicated that the daily average limit for TSS at Outfall 002 (30 mg/L) was exceeded three times (35, 46.5 and 46.5 mg/L). This occurred on 31 Jul 2006, 31 Aug 2006, and 30 Sep 2006, respectively.

TPDES permit number 10917-001 authorizes a discharge of domestic wastewater from the City of Bremond Wastewater Treatment Facility. The permit allows 0.22 MGD daily average flow, with effluent limitations of 30 mg/L $CBOD_5$, 90 mg/L TSS, 4 mg/L ammonia nitrogen, and 200 fecal coliform colonies per 100 mL. The effluent is required to maintain a 4.0 mg/L minimum DO concentration, and pH between 6.0 and 9.0 standard units.

Table 6.—Summary of effluent limits for TPDES permit number 02881, KT Mining LP. Units are mg/L unless otherwise specified. NA denotes not applicable. [a]million gallons discharged during any 24-hour period.

Outfall	Flow (daily avg. MGD)	TSS (daily avg./ daily max.)	Iron (daily avg./ daily max.)	Selenium (daily max.)	Settleable Solids	BOD (daily avg./ daily max.)	Oil and Grease
001	Report	35/70	3.0/6.0	0.1			
101	Report				0.5 mL/l		
004, 008, 010, 013, 014, 015 & 016	Report	35/70	3.0/6.0	0.1			
104, 108, 110, 113, 114, 115 & 116	Report				0.5 mL/l		
201	0.017	20/45				20/45	
301	0.0075						15/20
011 012 017	14.4[a] 4.32[a] 4.32[a]		NA/6.0	0.1			
009	Report	35/70	3.0/6.0	0.1			

Table 7.— Summary of effluent limits for TPDES permit number 02877, Twin Oaks Power LP. Units are mg/L unless otherwise specified. NA denotes not applicable. [a]Daily maximum dry weather flow limit.

Outfall	Flow (MGD)	Oil and Grease (daily avg./daily max.)	TSS (daily max.)	COD (daily avg./ daily max.)	TDS (daily avg./ daily max.)	Aluminum	Free Chlorine	Selenium (daily max.)
001	Report	NA/15	NA/50					
002	1.5[a]	15/20	30/100	NA/150	2,959/6,260	0.834/1.765	0.1/0.5	
003	Report	NA/15		NA/150				0.1

Violations of the minimum DO requirement occurred six times between 2001 and 2005, always in July or August. DO got as low as 1.3 mg/L. There were 19 exceedances of the pH requirement (pH elevated as high as 10.6). All the exceedances occurred in 2000 through 2003. The daily average for ammonia nitrogen was exceeded 24 times from January 2000 to July 2006. The highest value measured was 10.93 mg/L. The daily average fecal coliform limitation was exceeded 10 times. The highest value measured was 4,010 colonies per 100 mL on 30 Jun 2003. The single grab limit of 800 colonies per 100 mL was exceeded once (2000 colonies per 100 mL) on 31 Aug 2002. The daily average $CBOD_5$ limit of 30 mg/L was exceeded once, on 30 Apr 2001 (31.75 mg/L).

Because of frequent exceedances TCEQ initiated enforcement action for this permit in 2006. The most recent information available is that an agreed order was proposed in June 2006 which included penalties and the requirements that the permittee conduct a Supplemental Environmental Project (Wilson Snyder, personal communication).

Water Quality Assessment Status

In the draft 2006 Texas Water Quality Inventory, Walnut Creek was assessed as Segment 1242O (TCEQ 2007). Walnut Creek is listed as not supporting the contact recreation use due to exceedances of the *E. coli* and fecal coliform geometric means.

TCEQ Water Quality Data

The nearest station to the study area is TCEQ station 16403, Walnut Creek at SH 6 northwest of Calvert. For that station there were 72 sampling events yielding a total of 1,431 individual measurements. Routine water chemistry and field measurements are summarized in Table 8.

Table 8.— Routine water chemistry and field measurements for TCEQ station 16403,Walnut Creek at SH 6 northwest of Calvert. Data collected from 18 Jun 1998 to 25 May 2006. All measurements in mg/L unless otherwise noted by parameter name. Measurements are generally displayed to two decimal points for ease of formatting, not to assert number of significant digits. Median, not mean, reported for pH. Geometric mean reported for *E. coli* and fecal coliform.

Parameter Name	Mean	Minimum	Maximum	N
Chloride	78.57	8.20	145.03	66
E. coli (most probable number of colonies per 100 mL)	208.4	12.00	9,676.00	31
Fecal coliform (colonies per 100 mL)	198.0	20.00	700.00	56
Nitrate	0.23	0.02	0.57	60
Nitrite	0.04	0.02	0.05	64
Orthophosphorus	0.06	0.04	0.36	52
DO	8.23	3.40	12.12	68
DO (percent saturation)	91.07	40.50	123.20	68
pH (standard units)	7.82	6.90	8.60	68
TSS	29.87	4.00	192.00	67
TDS	415.33	392.00	432.00	3
Specific conductance (umhos/cm)	680.00	53.00	882.90	69
Sulfate	91.14	7.68	434.07	64
Water temperature (degrees Celsius)	20.62	8.70	27.95	69
Turbidity (nephelometric turbidity units)	10.70	10.70	10.70	1

Instantaneous physiochemical parameters showed that DO ranged from 3.4 to 12.1 mg/L. None of the measurements were below the 3.0 mg/L DO minimum criterion for a stream with a presumed high aquatic life use. Percent saturation ranged from 40.5% to 123.2%, evincing some supersaturation. The range of pH (6.9 to 8.6) was normal for surface waters. Specific conductance ranged from 53 to 883 umhos/cm, and temperature ranged from 8.7 to 28.0 degrees Celsius.

A few measurements were available for metals and organics (Table 9). The majority of the analytes were not detected by the laboratory. Detections of metals or organics were compared, where possible, with criteria used in the state water quality assessment (TCEQ 2003). This comparison revealed no concern for aluminum, copper, selenium, or zinc.

Table 9.— Metals and organics concentrations for TCEQ station 16403, Walnut Creek at SH 6. Data collected from 6 Aug 2003 to 15 Aug 2005. All measurements in ug/L unless otherwise noted by parameter name. Measurements are generally displayed to two decimal points for ease of formatting, not to assert number of significant digits. Asterisk next to the parameter name (*) indicates the value(s) were reported less than some minimum value (probably laboratory detection limit).

Parameter name	Mean	Minimum	Maximum	N
1,2-dichloroethane*	1.00	1.00	1.00	1
Aldicarb*	1.00	1.00	1.00	1
Aluminum, dissolved	128.38	17.15	239.60	2
Arsenic, dissolved*	5.00	5.00	5.00	1
Barium, dissolved	212.73	177.10	248.36	2
Benzene*	1.00	1.00	1.00	2
Cadmium, dissolved*	0.30	0.30	0.30	1
Carbaryl, water, dissolved*	1.00	1.00	1.00	1
Carbofuran, water, dissolved*	1.00	1.00	1.00	2
Carbon tetrachloride*	1.00	1.00	1.00	1
Chlorobenzene*	10.00	10.00	10.00	3
Chloroform*	10.00	10.00	10.00	1
Chromium, dissolved*	10.00	10.00	10.00	1
Cis-1,3-dichloropropene*	1.00	1.00	1.00	1
Cobalt, dissolved*	10.00	10.00	10.00	1
Copper, dissolved	1.10	1.10	1.10	1
Dibromochloromethane*	1.00	1.00	1.00	3
Iron, dissolved	343.20	343.20	343.20	1
Lead, dissolved*	0.30	0.30	0.30	1
Manganese, dissolved	150.60	55.80	245.40	2
Methomyl*	1.00	1.00	1.00	1
Methyl-tert-butyl ether (MTBE)*	1.00	1.00	1.00	1
Nickel, dissolved*	10.00	10.00	10.00	2
Selenium, dissolved	2.01	1.12	2.90	2
Silver, dissolved*	0.30	0.30	0.30	1
Tetrachloroethylene*	1.00	1.00	1.00	2
Toluene*	1.00	1.00	1.00	3
Trichloroethylene*	1.00	1.00	1.00	2
Trihalomethane*	50.00	50.00	50.00	2
Vanadium, dissolved*	10.00	10.00	10.00	1
Zinc, dissolved	8.82	8.54	9.10	2

The study area lies in the watershed of Segment 1242, Brazos River Above Navasota River. Site-specific criteria for Segment 1242 include a maximum annual average of 350 mg/L chloride, 200 mg/L sulfate, and 1000 mg/L TDS. No chloride or TDS measurements exceeded the criterion. Only two of 64 sulfate measurements exceeded the criterion. The site-specific criterion for *E. coli* is a geometric mean of 126 colonies per 100 mL, not to exceed 200 colonies per 100 mL in a grab sample. The grab sample criterion of 200 was exceeded in 14 of 31 samples (45%). There were more fecal coliform data available since that was the method used to assess contact recreation historically until the recent shift in the water quality standards to *E. coli* as an indicator. For fecal coliform, 12 of 56 measurements (21%) exceeded the grab sample criterion of 400 colonies per 100 mL.

Nutrient measurements were compared with screening criteria used for freshwater streams in the biannual water quality assessment (TCEQ 2003). No orthophosphorus measurements exceeded screening levels, in fact many of the orthophosphorus measurements were below the detection limit (0.04 or 0.05 mg/L). None of the nitrate measurements exceeded screening levels. Most of the nitrite measurements were below detection limits (usually 0.02 or 0.05 mg/L).

Willis Creek at FM 971 (Williamson County)

General Description

Willis Creek is located in Ecoregion 32 (Texas Blackland Prairies). The soils are alkaline clays. The upper end of the creek is influenced by the city of Granger (population 1190; Handbook of Texas Online 2006e). The creek runs through cotton farms and other agricultural land and the Willis Creek Wildlife Management Area before entering Granger Lake. The stream is characterized as sandy-bottomed with moderate bend development and flow in small shallow pools, glides, and riffles (Bayer et al. 1992).

Previous Studies

Willis Creek at FM 971 was sampled for the Texas Aquatic Ecoregion Project in 1989 (Bayer et al. 1992). On 19 Jul 1989, 772 benthic invertebrates, representing 62 species, were collected using a Surber sampler (Table 16). Summary statistics are presented for the benthic invertebrate data in Table 17. Fish were collected on 18 Jul 1989 using seines and backpack electrofishing. Species collected included central stoneroller, red shiner, blacktail shiner, bullhead minnow, yellow bullhead, western mosquitofish, green sunfish, longear sunfish, and orangethroat darter (Bayer et al. 1992).

Wastewater Discharges

The City of Granger is authorized to discharge domestic wastewater into a tributary of Willis Creek under TPDES permit number 10891-001 (Figure 7). The permit authorizes a daily average flow of 0.20 MGD, with limits of 10 mg/L BOD_5 and 15 mg/L TSS. DO in the effluent must be maintained at a minimum of 4.0 mg/L and the pH maintained between 6.0 and 9.0.

DO was noncompliant once on 30 Apr 2005 (3.95 mg/L). A pH excursion of 2.1 was reported on 30 Sep 2001, but that is almost certainly a transcription error. The daily average for TSS (15 mg/L) was exceeded on 31 Jan 2001 (18 mg/L) and 31 Mar 2002 (16 mg/L). Daily average flow slightly exceeded the permit limitation on seven occasions in 2002 through 2005.

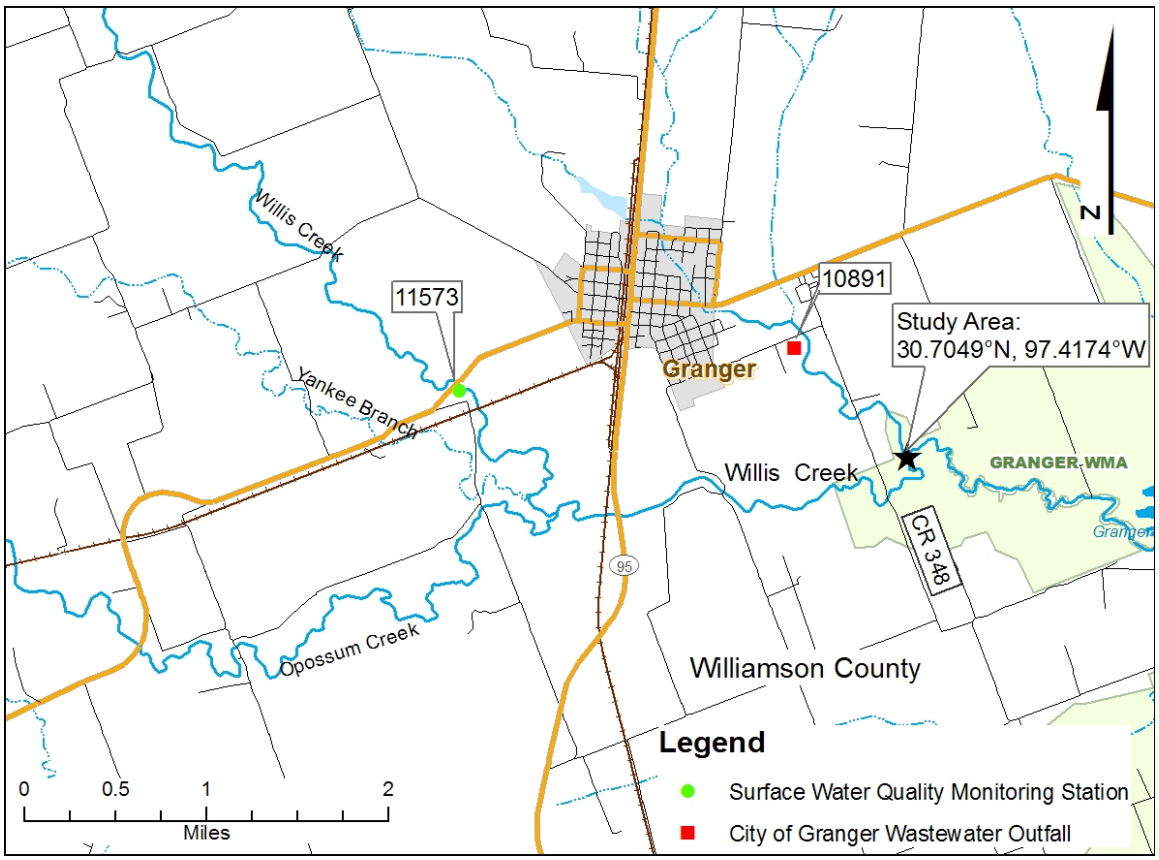

Figure 7.— Willis Creek in the vicinity of the study reach.

Water Quality Assessment Status

Willis Creek was assessed in the draft 2006 Texas Water Quality Inventory as Segment 1247A (TCEQ 2007). Willis Creek was listed as not supporting the contact recreation use to exceedances of the *E. coli* geometric mean and single sample criteria, and a concern for near non-attainment based on fecal coliform single sample measurements.

TCEQ Water Quality Data

There is a station in the study area, TCEQ station 11573, Willis Creek at FM 971 southwest of Granger. For that station there were 94 sampling events yielding a total of 1,397 individual measurements. Routine water chemistry and field measurements are summarized in Table 10.

Table 10.— Summary statistics for routine water chemistry and field measurements for TCEQ station 11573, Willis Creek at FM 971 southwest of Granger. Data collected from 18 Jul 1989 to 25 Apr 2006. All measurements in mg/L unless otherwise noted by parameter name. Measurements are generally displayed to two decimal points for ease of formatting, not to assert number of significant digits. Median, not mean, reported for pH. Geometric mean reported for *E. coli* and fecal coliform.

Parameter Name	Mean	Minimum	Maximum	N
Alkalinity	177.00	150.00	211.00	6
$CBOD_5$	0.50	0.50	0.50	1
TOC	1.25	1.00	2.00	4
Chloride	12.02	5.67	17.57	57
Chlorophyll a, (fluorometric, ug/L)	2.77	1.00	5.00	7
Chlorophyll a, (spectrophotometric, ug/L)	4.06	3.30	8.60	7
E. coli (colonies per 100 mL)	298.0	60.00	687.00	21
Fecal coliform (colonies per 100 mL)	253.9	1.00	900.00	45
Hardness	189.00	142.00	236.00	2
Nitrate	9.13	0.02	21.97	56
Nitrite	0.14	0.02	3.74	53
Nitrate + Nitrite	10.23	0.63	17.43	3
Ammonia	0.03	0.02	0.04	5
TKN	0.33	0.20	0.60	8
Orthophosphorus	0.06	0.01	0.40	47
DO	7.53	3.40	12.51	85
DO (percent saturation)	91.09	60.10	110.60	57
pH (standard units)	7.75	7.20	8.14	84
Pheophytin-a (ug/L)	1.86	0.00	3.00	7
Total phosphorus	0.05	0.01	0.16	14
TSS	10.91	3.00	160.00	57
VSS	1.40	1.00	2.00	5
TDS	312.00	312.00	312.00	1
Specific conductance (umhos/cm)	521.63	352.00	746.00	85
Sulfate	36.80	20.67	71.00	56
Water temperature (degrees Celsius)	21.75	7.61	30.24	85
Turbidity (nephelometric turbidity units)	3.80	3.80	3.80	1

Instantaneous physiochemical parameters showed that DO ranged from 3.4 to 12.5 mg/L. None of the measurements were below the 3.0 mg/L minimum DO criterion for a stream with a presumed high aquatic life use. Percent saturation ranged from 60.1% to 110.6%, revealing an occasional degree of supersaturation. The range of pH (7.2 to 8.1) was

normal for surface waters. Specific conductance ranged from 352 to 746 umhos/cm, and temperature ranged from 7.5 to 30.2 degrees Celsius.

The study area lies in the watershed of Segment 1247, Granger Lake. Site-specific criteria for Segment 1247 include a maximum annual average of 50 mg/L chloride, 50 mg/L sulfate, and 400 mg/L TDS. No chloride or TDS measurements exceeded the criterion. Only six of 56 sulfate measurements exceeded the criterion. The grab sample criterion for *E. coli* of 394 colonies per 100 mL was exceeded in nine of 21 samples (43%). The geometric mean criterion was also exceeded for *E. coli*. There were more fecal coliform data available since that was the method used to assess contact recreation historically until the recent shift in the water quality standards to *E. coli* as an indicator. For fecal coliform, 16 of 45 measurements (36%) exceeded the grab sample criterion of 400 colonies per 100 mL. The geometric mean criterion was also exceeded.

Nutrient measurements were compared with the screening criteria used for freshwater streams in the biannual water quality assessment (TCEQ 2003). For chlorophyll a, none of the 14 measurements exceeded the screening level of 11.6 ug/L. Neither orthophosphorus or total phosphorus exceeded screening levels, in fact most of the orthophosphorus measurements were below the detection limit (0.04 or 0.05 mg/L). None of the ammonia measurements exceeded the screening level of 0.17 mg/L. Nitrate measurements were elevated and many exceeded the screening level of 2.76 (for nitrate plus nitrite). Most of the nitrite measurements were very low or below detection limits, but one was elevated (3.74 mg/L). Elevated nitrate concentrations could be due to high levels in groundwater or organic pollution.

Aside from elevated nutrient levels, alkalinity was also unusually high compared to other freshwater streams (150-211 mg/L). However, hardness was also high (142 and 236 mg/L, N = 2), which could account for some or all of the alkalinity. Ambient values between 150 and 300 are classified as “hard water.” The high buffering capacity of alkaline water could help explain why the pH measurements were so stable (ranging only from 7.2 to 8.1 over 84 measurements).

$CBOD_5$ and TOC were within normal expectations for unpolluted freshwater streams.

A few measurements were available for metals and organics (Table 11). None of the analytes were detected by the laboratory.

Table 11.— Metals and organics concentrations for TCEQ station 11573, Willis Creek at FM 971. Data collected from 7 Jul 2004 to 14 Apr 2005. All measurements in ug/L unless otherwise noted by parameter name. Measurements are generally displayed to two decimal points for ease of formatting, not to assert number of significant digits. Asterisk next to the parameter name (*) indicates the value(s) were reported less than some minimum value (probably laboratory detection limit).

Parameter name	Mean	Minimum	Maximum	N
1,2-dichloroethane*	1.00	1.00	1.00	1
Aldicarb*	1.00	1.00	1.00	1
Anthracene*	1.00	1.00	1.00	1
Atrazine*	1.00	1.00	1.00	1
Benzene*	1.00	1.00	1.00	1
Carbaryl, dissolved*	1.00	1.00	1.00	3
Carbofuran, dissolved*	1.00	1.00	1.00	1
Carbon tetrachloride*	1.00	1.00	1.00	1
Chlorobenzene*	10.00	10.00	10.00	3
Chloroform*	10.00	10.00	10.00	1
Dibromochloromethane*	1.00	1.00	1.00	2
Methomyl*	1.00	1.00	1.00	1
Methyl-tert-butyl ether (MTBE)*	1.00	1.00	1.00	2
Phenanthrene*	15.00	15.00	15.00	1
Tetrachloroethylene*	1.00	1.00	1.00	2
Toluene*	1.00	1.00	1.00	2
Trichloroethylene*	1.00	1.00	1.00	1
Trihalomethane*	50.00	50.00	50.00	2

Biological Data

Data from two sampling trips on Willis Creek at FM 971 were found in the TCEQ water quality data set downloaded using Sample Query. In February 2002, a 15-foot seine was employed to catch two sunfish and five blacktail shiners. In April 2002 both the seine and a cast net were employed. The catch included red shiner, blacktail shiner, longear sunfish, bluegill, orangespotted sunfish, spotted sunfish, white crappie, channel catfish, fathead minnow, and blackspot shiner. Details are found in Table 18 in the appendix.

BRA conducted biological assessments on Willis Creek at FM 971 in 2004 (BRA, unpublished data). Habitat, benthic macroinvertebrates, fish, and 24-hour physicochemical parameters were sampled on 20 Apr 2004 and 13 Jul 2004. On both trips habitat scored high using the TCEQ Habitat Quality Index. The Qualitative

Benthic IBI score placed the site in the exceptional aquatic life use category for the April sampling and high for the July sampling (Table 19, Table 20). DO measurements from the 24-hour sampling rated the site in the exceptional category for both trips. Fish scored using the regionalized IBI (ecoregion 27/29/32) was high for the April trip and intermediate/high for the July trip (Table 21, Table 22).

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Appendix A. Biological Data Referenced in Text

Table 12.—Fish collected by the Brazos River Authority and Index of Biotic Integrity summary, Duck Creek at FM 979, 25 May 2001.

Common Name	Scientific Name	Trophic Group	Tolerance	Total Number	Number with Anomalies
Pirate Perch	*Aphredodenus sayanus*	IF	M	1	0
Longear Sunfish	*Lepomis megalotis*	IF	I	4	0
Lagemouth Bass	*Micropterus salmoides*	P	I	2	0
Green Sunfish	*Lepomis cyanellus*	P	T	4	0
Smallmouth Bass	*Micropterus dolomieu*	P	I	1	0
Blacktail Shiner	*Cyprinella venusta*	IF	M	24	0
Red Shiner	*Cyprinella lutrensis*	O	T	14	0
Blackspot Shiner	*Notropis atrocaudalis*	IF	M	2	0
Bullhead Minnow	*Pimephales vigilax*	IF	M	3	0
Blackstripe Topminnow	*Fundulus notatus*	IF	M	7	0
Brook Silverside	*Labidesthes sicculus*	IF	I	225	0
Flathead Catfish	*Pylodictus olivaris*	IF	M	8	0
Slough Darter	*Etheostoma gracile*	IF	M	3	0
Mosquito Fish	*Gambusia affinis*	IF	T	56	0
				354	

Nekton Bioassessment Results

Metric	Value	Score
Total # of species	14	5
Number of darter species	1	3
Number of Sunfish species (excluding bass)	2	5
Number of sucker species	0	1
Number of intolerant	4	5
Percentage of individuals as tolerant	21	1
Percentage Omnivores	4	5
Percentage Insectivore	94	5
Percentage Piscivores	2	3
Number of Individuals	354	5
Percentage Hybrids	0	5
Percentage Disease/Anomaly	0	5
	Total	48
	Aquatic Life Use	**High**
	Total	99
	Habitat Quality Index	**Marginal**

Table 13.— Benthic Index of Biotic Integrity summary for benthic macroinvertebrates collected by the Brazos River Authority, Duck Creek at FM 979, 25 May 2001.

Metric	Value	Score
Taxa Richness	5	1
EPT Taxa Abundance	0	1
Biotic Index (HBI)	6	1
% Chironimidae	0	1
% Dominant Taxon	33.3	2
% Dominant FFG	100	1
% Predators	100	1
Ratio Intolerant:Tolerant	0.5	1
% of total Tricoptera as Hydropsychidae	0	1
# of non-insect taxa	0	1
% Collector-Gatherers	0	1
% of total as Elmidae	0	1
	Total	13
	Aquatic Life Use	**Limited**
	Total	99
	Habitat Quality Index	**Moderate**

Table 14.— Fish collected by the Brazos River Authority and Index of Biotic Integrity summary, Duck Creek at FM 979, 2 Aug 2001.

Common Name	Scientific Name	Trophic Group	Tolerance	Total Number	Number with Anomalies
Texas Shiner	*Notropis amabilis*	IF	M	60	0
Smallmouth Buffalo	*Ictiobus bubalua*	O	M	10	0
White Crappie	*Pomoxis annularis*	P	M	2	0
Red Shiner	*Cyprinella lutrensis*	O	T	8	0
Blacktail Shiner	*Cyprinella venusta*	IF	M	15	0
Blackstripe Topminnow	*Fundulus notatus*	IF	M	6	0
Green Sunfish	*Lepomis cyanellus*	P	T	25	0
Brook Silverside	*Labidesthes sicculus*	IF	I	1	0
Mosquito Fish	*Gambusia affinis*	IF	T	22	0
Bluegill Sunfish	*Lepomis macrochirus*	IF	T	53	0
Longear Sunfish	*Lepomis megalotis*	IF	M	52	0
Spottail Shiner	*Notropis hudsonius*	IF	M	14	0
Largemouth Bass	*Micropterus salmoides*	P	M	5	0
Warmouth	*Lepomis gulosus*	P	T	4	0
Pirate Perch	*Aphredoderus sayanus*	IF	M	1	0
Fathead Minnow	*Pimephales promelas*	O	T	3	0
Tadpole Madtom	*Noturus gyrinus*	IF	I	1	0
				282	

Nekton Bioassessment Results

Metric	Value	Score
Total # of species	17	5
Number of darter species	0	1
Number of Sunfish species (excluding bass)	6	5
Number of sucker species	1	3
Number of intolerant	2	3
Percentage of individuals as tolerant	41	1
Percentage Omnivores	7	5
Percentage Insectivore	74	3
Percentage Piscivores	12	5
Number of Individuals	282	5
Percentage Hybrids	0	5
Percentage Disease/Anomaly	0	5
	Total	46
	Aquatic Life Use	**Intermediate**
	Total	116
	Habitat Quality Index	**Suboptimal**

Table 15.— Benthic Index of Biotic Integrity summary for benthic macroinvertebrates collected by the Brazos River Authority, Duck Creek at FM 979, 2 Aug 2001.

Metric	Value	Score
Taxa Richness	4	1
EPT Taxa Abundance	1	1
Biotic Index (HBI)	5	1
% Chironimidae	0	1
% Dominant Taxon	63	1
% Dominant FFG	63	1
% Predators	36	2
Ratio Intolerant:Tolerant	0.05	1
% of total Tricoptera as Hydropsychidae	0	1
# of non-insect taxa	0	1
% Collector-Gatherers	63	1
% of total as Elmidae	0	1
	Total	13
	Aquatic Life Use	**Limited**
	Total	116
	Habitat Quality Index	**Suboptimal**

Table 16—Invertebrate collection from Willis Creek at FM 971, collected 19 Jul 1989 comprised of 3 square foot Surber samples (Bayer et al. 1992).

STORET	Genus/species	No.	No. per m^2	No. per ft^2
90077	*Dugesia tigrina*	19	68	6.33
90196	Nematoda	1	4	0.33
90504	*Limnodrilus* sp.	79	283	26.33
90482	*Sparganophilus tamesis*	11	39	3.67
92890	*Biomphalaria obstructus*	2	7	0.67
92905	*Ferrissia rivularis*	3	11	1
93037	*Corbicula fluminea*	11	39	3.67
93031	*Pisidium casertanum*	3	11	1
91101	*Eucypris* sp.	1	4	0.33
92707	*Atractides* sp.	3	11	1
92692	*Hydrodroma despiciens*	2	7	0.67
92154	*Berosus* sp.	2	7	0.67
92242	*Microcylloepus pusillus*	5	18	1.67
92247	*Neoelmis caesa*	1	4	0.33
92213	*Psephenus texanus*	1	4	0.33
92254	*Stenelmis cheryl*	10	36	3.33
92259	*Stenelmis occidentalis*	3	11	1
92647	*Axarus* sp.	7	25	2.33
92645	*Cladotanytarsus* sp. gr. A	2	7	0.67
92502	*Conchapelopia* sp.	18	65	6
90999	*Cricotopus trifascia* gr.	2	7	0.67
92519	*Dicrotendipes neomodestus*	16	57	5.33
92628	*Hemerodromia* sp.	1	4	0.33
92678	*Larsia* sp.	9	32	3
92407	*Nilotanypus* nr. *dubius*	20	72	6.67
92484	*Palpomyia tibialis*	1	4	0.33
92680	*Paratendipes* nr. *nudisquama*	7	25	2.33
92501	*Pentaneura* sp.	32	115	10.67
93294	*Polypedilum convictum*	16	57	5.33
93289	*Polypedilum illinoense*	9	32	3
92401	*Polypedilum* nr.*scalaenum* sp.A	2	7	0.67
92486	*Probezzia* sp.	2	7	0.67
92566	*Rheocricotopus fuscipes* gr.	7	25	2.33
92419	*Rheotanytarsus exiguus* gr.	45	161	15
92596	*Simulium* sp.	1	4	0.33
92622	*Tabanus* sp.	1	4	0.33
92423	*Tanytarsus glabrescens* gr.	11	39	3.67
92426	*Tanytarsus guerlus* gr.	11	39	3.67
92588	*Thienemannie1la* sp.	2	7	0.67

STORET	Genus/species	No.	No. per m^2	No. per ft^2
91600	*Caenis* sp.	28	100	9.33
91555	*Choroterpes mexicanus*	127	456	42.33
91649	*Dactylobaetis mexicanus*	1	4	0.33
91651	*Fallceon quilleri*	71	255	23.67
91633	*Heptagenia* sp.	2	7	0.67
91597	*Leptohyphes packeri*	4	14	1.33
91620	*Stenonema* sp.	1	4	0.33
91595	*Tricorythodes albilineatus* gr.	31	111	10.33
92049	*Ambrysus circumcinctus*	1	4	0.33
92062	*Ambrysus pulchellus*	1	4	0.33
91919	*Microvelia* sp .	1	4	0.33
91923	*Rhagovelia* sp.	*2*	7	0.67
92667	*Parargyractis* sp.	2	7	0.67
91694	*Argia* sp. A	7	25	2.33
91692	*Argia* sp. B	6	22	2
91777	*Brechmorhoga mendax*	5	18	1.67
91669	*Hetaerina* sp.	2	7	0.67
92292	*Cheumatopsyche* sp.	81	291	27
92268	*Chimarra* sp.	1	4	0.33
92376	*Helicopsyche* sp.	11	39	3.67
92324	*Hydroptila* sp.	2	7	0.67
92307	*Nectopsyche gracilis*	2	7	0.67
92308	*Smicridea* sp.	4	14	1.33

Table 17.—Summary statistics for benthic invertebrate collection from Willis Creek on 19 Jul 1989.

STORET	Parameter	Value
90004	Number of Species	62
	Number of Individuals in Sample	772
90007	Number of Individuals per square meter	2,770
90003	Number of Individuals per square foot	257.33
90000	Diversity	4.59
90002	Redundancy	0.27
	Max. diversity	5.95
	Min. diversity	0.87
90001	Equitability	0.77
90008	EPT Index	14
90009	No. of Functional Feeding Groups	6
90010	Dominant Functional Feeding Group (% of Community)	25.45
90017	Cumulative Abundance of FPOM Feeders (% of Community)	63.73
90020	Grazers (% of Community)	18.05
90025	Gatherers (% of Community)	25.45
90030	Filterers (% of Community)	19.99
90034	Miners (% of Community)	18.29
90035	Shredders (% of Community)	1.86
90036	Predators (% of Community)	16.36
90037	Mean Point Score	3.33
90038	Ohio ICI Index Value	52

Table 18.—Biological data collected on Willis Creek, extracted from TCEQ water quality data download.

Date	Parameter name	Value
2/28/1992	*Cyprinella venustus* (#/sample)	5.00
2/28/1992	Ecoregion (Texas ecoregion code)	32.00
2/28/1992	Land develop impact (1=unimp,2=low,3=mod,4=high)	3.00
2/28/1992	*Lepomis macrochirus* (#/sample)	1.00
2/28/1992	*Lepomis megalotis* (#/sample)	1.00
2/28/1992	Net length (meters)	458.00
2/28/1992	Seining effort (# of seine hauls)	3.00
2/28/1992	Watershed sz sq.mi (1= <50,2=100 to 200,3= >300)	1.00
4/21/1992	Castnetting effort (# of casts)	2.00
4/21/1992	*Cyprinella lutrensis* (# sample)	15.00
4/21/1992	*Cyprinella venustus* (#/sample)	22.00
4/21/1992	Ecoregion (texas ecoregion code)	32.00
4/21/1992	*Ictalurus punctatus* (#/sample)	2.00
4/21/1992	Land develop impact (1=unimp,2=low,3=mod,4=high)	3.00
4/21/1992	*Lepomis humilis* (#/sample)	4.00
4/21/1992	*Lepomis macrochirus* (#/sample)	1.00
4/21/1992	*Lepomis megalotis* (#/sample)	3.00
4/21/1992	*Lepomis punctatus* (#/sample)	15.00
4/21/1992	Net length (meters)	4.58
4/21/1992	*Notropis atrocaudalis* (#/sample)	15.00
4/21/1992	*Pimephales promelas* (#/sample)	37.00
4/21/1992	*Pomoxis annularis* (#/sample)	1.00
4/21/1992	Seining effort (# of seine hauls)	5.00
4/21/1992	Watershed sz sq.mi (1= <50,2=100 to 200,3= >300)	1.00

Table 19.—Species and numbers of individuals for benthic macroinvertebrates collected with kicknet by the Brazos River Authority on 20 Apr 2004 in Willis Creek at FM 971.

STORET	Phylum	Class	Order	Family	*Genus*	No.
90382	Annelida	Oligochaeta				7
91183	Arthropoda	Crustacea	Isopoda			1
92748	Mollusca	Gastropoda	Limnophila	Lymnaeidae	*Fossaria*	1
93036	Mollusca	Pelecypoda	Heterodonta	Corbiculidae	*Corbicula*	2
92243	Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	1
92253	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	5
92154	Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Berosus*	3
92491	Arthropoda	Insecta	Diptera	Chironomidae		1
92596	Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	9
92622	Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	1
91645	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Acentrella*	8
91647	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Camelobaetidius (Dactylobaetis)*	1
91651	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	23
91600	Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	9
91557	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Neochoroterpes*	5
91562	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Thraulodes*	1
92054	Arthropoda	Insecta	Hemiptera	Naucoridae	*Ambrysus*	7
91713	Arthropoda	Insecta	Odonata	Gomphidae	*Erpetogomphus*	1
91776	Arthropoda	Insecta	Odonata	Libellulidae	*Brechmorhoga*	1
91883	Arthropoda	Insecta	Plecoptera	Perlidae	*Perlesta*	24
92292	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	4
92324	Arthropoda	Insecta	Trichoptera	Hydroptilidae	*Hydroptila*	1
92378	Arthropoda	Insecta	Trichoptera	Odontoceridae	*Marilia*	1

Table 20.— Species and numbers of individuals for benthic macroinvertebrates collected with kicknet by the Brazos River Authority on 13 Jul 2004 in Willis Creek at FM 971.

STORET	Phylum	Class	Order	Family	*Genus*	No.
90382	Annelida	Oligochaeta				1
92232	Arthropoda	Insecta	Coleoptera	Elmidae	*Elsianus (Macrelmis)*	1
92253	Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	1
92211	Arthropoda	Insecta	Coleoptera	Psephenidae	*Psephenus*	1
92491	Arthropoda	Insecta	Diptera	Chironomidae		10
92596	Arthropoda	Insecta	Diptera	Simuliidae	*Simulium*	1
92622	Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus*	5
92439	Arthropoda	Insecta	Diptera	Tipulidae	*Pseudolimnophila*	1
91647	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Camelobaetidius (Dactylobaetis)*	3
91651	Arthropoda	Insecta	Ephemeroptera	Baetidae	*Fallceon*	8
91590	Arthropoda	Insecta	Ephemeroptera	Isonychidae	*Isonychia*	1
91557	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Neochoroterpes*	68
91562	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Thraulodes*	4
91594	Arthropoda	Insecta	Ephemeroptera	Tricorythidae	*Tricorythodes*	1
92054	Arthropoda	Insecta	Hemiptera	Naucoridae	*Ambrysus*	5
91683	Arthropoda	Insecta	Odonata	Coenagrionidae	*Argia*	1
91776	Arthropoda	Insecta	Odonata	Libellulidae	*Brechmorhoga*	6
92292	Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	12
92268	Arthropoda	Insecta	Trichoptera	Philopotamidae	*Chimarra*	9

Table 21.—Species and numbers of individuals for fish collected with seine and electrofisher by the Brazos River Authority on 20 Apr 2004 in Willis Creek at FM 971.

STORET	Scientific Name	Common Name	No.	No.	No.	No.	No.	No.	No.
	Collection Method	(E=electrofisher, S=seine)	E	S	S	S	S	S	S
	Collection Effort	(for E, sec; for S, meters)	1278	10	10	20	20	20	10
98564	*Ameiurus natalis*	Yellow bullhead	17					2	
98502	*Campostoma anomalum*	Central stoneroller	53				51		
98474	*Cyprinella lutrensis*	Red shiner			1			2	
98487	*Cyprinella venusta*	Blacktail shiner	25				74		
99085	*Etheostoma spectabile*	Orangethroat darter	17	5					
98713	*Gambusia affinis*	Western mosquitofish				1			
99094	*Lepomis cyanellus*	Green sunfish	8			2			
99099	*Lepomis megalotis*	Longear sunfish	50		63				
98513	*Moxostoma congestum*	Gray redhorse	2						5
98498	*Pimephales vigilax*	Bullhead minnow	18						20

Table 22.— Species and numbers of individuals for fish collected with seine and electrofisher by the Brazos River Authority on 13 Jul 2004 in Willis Creek at FM 971.

STORET	Scientific Name	Common Name	No.	No.	No.	No.	No.	No.	No.
	Collection Method	(E=electro, S=seine)	E	S	S	S	S	S	S
	Collection Effort	(for E, sec; for S, meters)	1349	15	20	25	15	15	15
98563	*Ameiurus melas*	Black bullhead	3						
98564	*Ameiurus natalis*	Yellow bullhead	41						
98502	*Campostoma anomalum*	Central stoneroller	22	2		1			2
98474	*Cyprinella lutrensis*	Red shiner		1					
98487	*Cyprinella venusta*	Blacktail shiner	23	3	16	9	5	3	14
99085	*Etheostoma spectabile*	Orangethroat darter	8						
98713	*Gambusia affinis*	Western mosquitofish		13			6		
98561	*Ictalurus punctatus*	Channel catfish	2						
99094	*Lepomis cyanellus*	Green sunfish	6						
99099	*Lepomis megalotis*	Longear sunfish	87	7	2	3	6	14	3
99090	*Micropterus salmoides*	Largemouth bass	4					1	
98513	*Moxostoma congestum*	Gray redhorse	4						
98498	*Pimephales vigilax*	Bullhead minnow	5				1		1

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